1001 CELESTIAL WONDERS

BARNS

THIRD EDITION

BUILD me a book—
A Book of the welcoming Stars!
Nay, not a large book,
But rich in the essentials:
Compact with good tidings from afar,
A ready study-counselor by day,
My inspiration and guide
Under the beckoning blue.

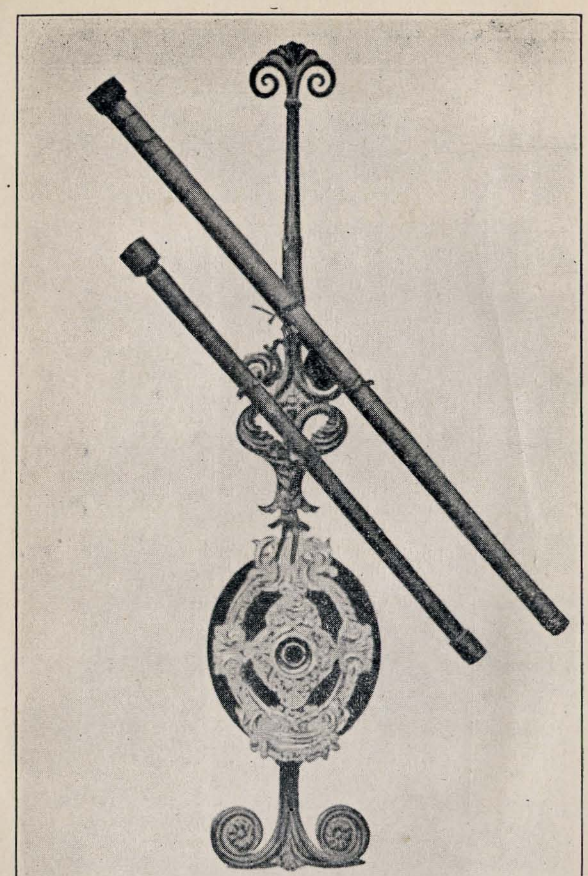
Of all these billion suns and riot forms
That brim the entrancing field,
Choose me a mere handful—
A thousand-and-one celestial wonders—
Many to be mere sight acquaintances,
Some few true, lifelong friends.

Let me learn all that is known of them,
Love them for the joy of loving.

For, as a traveller in far countries
Brings back only what he takes,
So shall the scope of my foreknowledge
Measure the depth of their profit
and charm to me.

Lo, the Star-lords are assembling,
And the banquet-board is set;
We approach with fear and trembling,
But we leave them with regret.

Haji-el-Nujum
Pilgrim of the Stars



GALILEO'S REFRACTING TELESCOPES

Built with his own hand. With these tiny "optick tubes" the Florentine master, in 1609-10, discovered Sun spots, Lunar mountains, Jupiter's satellites, Saturn's rings, the phases of Venus, double stars, etc. Note lens in center of standard. (Preserved in the Tribuna di Galileo, Florence, Italy).

(Title Page): Sir Isaac Newton's 6-in. home-built REFLECTING TELESCOPE, first exhibited before the Royal Society in 1672, the forerunner of all the giant Reflectors of the world. (Royal Society Archives).

1001 CELESTIAL WONDERS

AS OBSERVED WITH

HOME-BUILT INSTRUMENTS

Third Edition

SEVENTY-TWO CHARTS WITH FULL ANNOTATIONS

PRACTICAL CONSTRUCTION OF REFLECTING AND REFRACTING TELESCOPES AND ACCESSORIES

PROFUSELY ILLUSTRATED

By
CHARLES EDWARD BARNS

NEWTON'S FIRST REFLECTOR

1931

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CHARTER MEMBER AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS
MEMBER ASTRONOMICAL SOCIETY OF THE PACIFIC
AMERICAN ASTRONOMICAL SOCIETY
BRITISH ASTRONOMICAL ASSOCIATION
FELLOW ROYAL ASTRONOMICAL SOCIETY
FELLOW AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

FOREWORD

WHEN I behold a great city for the first time from some point of eminence, (said my friend, the Star Pilgrim), my impression is one of awe suffused with bewilderment, followed by a definite cumulative interest. It is so strange and new—so varied and complex in its charming intricacies that I wonder how even those who spend their lives within its alluring confines can find their way about and mentally chart its signal features. But soon I come to realize that through all these compact aggregations there runs one grand main thoroughfare—its Great White Way—from which chief artery all activities appear to radiate, from which plane all crossways seem to reach out even to great distances, and on which ground plan all major objects of interest may be located at will. Thus, with this comprehensive chart ever before me, I may wander down through its friendly highways and byways, knowing always that if I lose my way I can retrace my steps to the main thoroughfare. Also, (since I may not choose to spend a lifetime in these pleasant fields, my visit being brief and my interest thereby quickened), I soon learn to locate those cardinal units which have first claim on my time and energies, learning all that those whose careers have been dedicated to special research may vouchsafe me concerning them.

And so, as from some housetop or broad open space I review the richer, vaster City of the Stars, I am possessed of an even deeper sense of awe restrained by increasing bewilderment: it seems so humanly impossible that one mind in one lifetime could more than touch the hem of this great "garment of God," to say naught of exploring its resplendent warp and woof to the utterest space-deeps. But here too I soon perceive that whereever on the broad earth I chance to be, at whatever time of year, the heavens present a celestial Great White Way which is always before me—the meridian plane extending from the Pole Star southward to the horizon, cutting the starry vault in twain, from which all sidereal phenomena to eastward and westward are computed. But while the terrestrial city remains fixed and unchanging to my view, the celestial is ever moving westward; so that at each nightly observing-hour new stars, nebulae and clusters sweep across my meridian field till at last, without shifting one jot from my point of vantage, within the compass of a year I shall have reviewed all the glories of the firmament, as visible in my latitude.

Such is the meridian method of star-study, a source of the deepest pleasure and ever-increasing profit even when pursued with modest equipment, and best of all with instruments of one's own building. The labor is light and the rewards are many; and blest is he who pursues them with patience and understanding. For, as a great astrophysicist has observed, "While no one may hope to make a fortune in its pursuit, nevertheless astronomy provides that vision without which the people perish."

"Astronomy, the most ancient, most uncommercial, most unselfish of sciences, still allures the consecrated searcher for truth."—Chase.

CONTENTS

PART I.
CHART SECTION

"If the stars should appear one night in a thousand years, how men would believe and adore and preserve for many generations the remembrance of the City of God!"—Emerson.

"For those of every profession, occupation and station in life, astronomy offers an unbounded field for harvesting and gleaning that kind of knowledge which brings benefit, pleasure and satisfaction, drawing the human soul more and more into Universal harmony."—Chase.

"Nothing is more stimulating or more practically useful to the student than to regard every investigation, no matter how specialized, as an element in the great process that is steadily building up a general picture of the whole sweep of evolution. Beginning among the stars, this process finally leads up to the origin of man, his rise from savagery and the dawn of civilization."—Hale.

" 'Cui bone?'—to what practical end and advantage do your researches tend? This eternal query is one which the speculative philosopher who loves knowledge for its own sake, and enjoys the contemplation of harmonies and mutually dependent truths can seldom hear without a sense of humiliation. He feels that there is a lofty and disinterested pleasure in his speculations which ought to exempt them from such questioning, communicating as they do to his own mind the purest happiness of which human nature is susceptible."—Herschel.

PRELIMINARY

EACH hour of the twenty-four in Right Ascension requires three charts. Each chart is numbered, and lettered. If Charts A, B and C, of any series, were placed vertically, they would give the exact location of all objects listed between the Hrs., seen at the head of each Chart, from the Pole Star to Declination 30° South.

The Culmination Date signifies the month and day when the objects charted stand approximately on the observer's meridian at the hour of 9 P. M. It is also their Right Ascension. For each hour earlier, refer to the Charts preceding; for each hour later, the Charts following.

The star-places given in the Charts conform to the current epoch, and are standard for years to come. The planets, however, are changing their positions constantly, and so to chart them with the "fixed stars" would be a manifest impossibility. For locations and configurations, consult the Nautical Almanac, "Evening Sky Map," or other current authority listed in the Appendix. For full planetary data, see THE SOLAR SYSTEM, following the Chart Section.

According to established code, in the notes opposite each Chart, when giving the position of any celestial unit, the terms "Right Ascension" and "Declination", as well as all time and degree abbreviations, are discarded. This leaves only the essential six figures to point its place in the heavens. Thus, for instance, under Meridian Date, June 14, (Chart 15-B), ARCTURUS, R. A. 14h., 12m.; Decl., 19, becomes simply, 141219. Likewise, under Culmination Date, July 15, (Chart 17-C), we find ANTARES, R. A. 16h., 24m., Decl. —26°, here given as, *162426*, italic, (South). Secs. in R. A., and both mins. and secs. in Decl., are not necessary.

DETERMINING MERIDIAN: Laying down a meridian line and adjusting a telescope in the true north-and-south position is a problem of some importance in great observatories where the utmost precision is imperative. But for a lay-astronomer's practical purposes, a line may be struck with fair accuracy and marked permanently on the floor or platform supporting the instrument by an easy noon-and-night method, using each to check the other.

Fix firmly to the floor a sheet of cardboard, size about two feet by three, upon which has been marked and placed

in approximate position, by the aid of a pocket compass, a tentative north-and-south line. From a common center at the base of the line, with large dividers describe six wide semicircles an inch or two apart to northward. Suspend a plumb-line before this chart so that its shadow will cut the semicircles at right angles. Affix to the plummet a sliding bead or pith-ball that may be moved up or down at will.

For an hour or two before and after noon, as the shadow of the plumb-line moves over the face of this improvised sun-dial, shift the bead to better mark the intersection of the shadow with the semicircles, recording the exact locations with blue pencil. After several markings on both sides of the meridian line, with a straightedge draw accurate chords and bisect each separately, taking the mean as a correction to your trial north-and-south line. To this line set your telescope with care, proving on the stars.

Determining the meridian by observations of Polaris at upper or lower culmination, may be done with precision by consulting the Nautical Almanac (Tables I and VI), or by noting the instant when Mizar, (ζ Urs. Maj.), the fine naked-eye double in the handle of the Great Dipper, stands directly in line with δ Cass., either above or below the Pole, as seen on two plumb-lines adjusted a few feet apart, one behind the other, faintly illuminated. A line drawn between the two plummets will mark the true meridian.

LATITUDE calculations may be made at the same time; for, since the altitude of the true Pole indicates the observer's latitude, by adding 1° 6′ to the circle-readings in declination on Polaris, (the distance from the true Pole, southward along the plumb-line at lower culmination), the latitude is found with precision. This assumes that the instrument is in alignment; that the working parts are true, and that when trained on an equatorial star, (δ Orionis, ζ or η Virginis, or α Aquarii, allowing for the few mins. of arc deviation from the true Equator), the Decl. circle reads Zero.

Both the Latitude and Longitude of your observing station may be found approximately without observations or instruments other than a finely-divided steel rule and needle-point compasses. Geodetic Survey, and other official maps, of almost every region are extant, giving chart boundaries to a precision of a tenth-degree or less — a linear distance of less than seven miles. This may even be skillfully subdivided down to a few hundred feet. Choosing the nearest meridian, one computes the distance in miles

actually Polaris 20 min slower EST Clocks set on 75°
Dec = Nar on Son of Celestial Equator

and decimals to the observing station, adding if it lies west and subtracting if it lies east of the meridian, reducing to time units. A corresponding measurement may be made in latitude; but with this difference in the reduction: a degree of latitude is everywhere about sixty-nine miles in extent, while degrees in longitude diminish with increased distance from the Equator. A degree of longitude anywhere within the mid-latitudes of the United States may be fairly computed at fifty-four miles. Thus, 1′ long. equals 4752 ft.; 1″ equals 79.2 ft. For greater accuracy the calculations may be checked by ascertaining apparent local time by observations of the Sun, and Greenwich meridian time for that instant, longitude being the time interval of the mean Sun in traversing the arc between stations as seen from the Pole and measured along the Equator.

RIGHT ASCENSION AND DECLINATION:— The angular distance of any celestial object from the Vernal Equinox, as viewed from the Pole and measured eastward along the Celestial Equator, represents its Right Ascension. That object's position north or south of the Celestial Equator constitutes its Declination. The Celestial Pole is merely the projection of the terrestrial Pole into the star sphere; and the Celestial Equator corresponds to the earth's Equator as applied to the Great Circle.

Right Ascension is computed in hours, minutes and seconds; Declination in degrees, minutes and seconds. As a unit of time represents fifteen times that unit of arc, then 1hr. of time = 15° of arc; 1 min. = 15′; 1 sec. = 15″. Likewise, 1° of arc = 4 min. in time; 1′ = 4 sec.; 1″ = 0.066 sec.

To visualize the method of determining star-positions, imagine yourself at the north polar point at about the hour of nine, P. M., during the midweek of November. Polaris stands directly overhead. At a distance of 90° from the Pole Star describe a great circle in the heavens. This will represent the Celestial Equator. It will be found to cut many familiar constellations containing many bright stars, among them three almost on a direct north-and-south line: βCass., αAndrom., and γPeg., the last two bounding the Great Square of Pegasus on the east, and all three lying close along the Equinoctial Colure. Where this line intersect the Celestial Equator is fixed the Vernal Equinox: R. A. 0hr., 0min. 0sec.,; Decl. 0°, 0′ 0″. At this point the Sun crosses the line on Mar. 22, of each year, and from this station all Right Ascensions are computed eastward along the equatorial belt. Now, choose any bright star east or west

5T. Known to 12 noon it is RA 4 H

to be added 20 min to 12 to

Sid Time on 4/9/44 11 16 EST

Check 3 min Sec after approx

3/22/44 to 4/9/44 am = 17 days 16 hrs 4/18
17 days X 3′57″ = 67′9″
EST = 11:16 am
11:16 = 23 hr 16 m + 67 9″ =
24 hr - 23 min - 9 sec after noon 4/18

24 hr 23 mi 9 sec
+Pgh 20′
43 min 9 sec
(after 12 K)
Sidereal Time

At Pgh in computing Sidereal time use 3 m - 57 sec after 3/22 each day (not 4 mins)
also add 20 min to result as Pgh is 20 min + 5 sec west of 75°

of the Vernal Equinox—say, Aldebaran, the first-mag. star in Taurus—and from your point of vantage draw an imaginary line straight thru that star to the point of intersection with the Celestial Equator. The angular distance of that point from the Vernal Equinox, as measured eastward along the Celestial Equator, constitutes Aldebaran's Right Ascension: 4h., 31m., 25s.

Pgh. 79° 80° 5″

TO LOCATE ANY STAR E. OR W. OF YOUR MERIDIAN:— To compute the R. A. and Dec. of any unit not on the meridian requires: 1. Circles reading Hrs.-Mins., I to XXIV on polar axis; and Degs.-Mins., 0 to 90, reading both ways, on declination axis. 2. A timepiece set to sidereal time reduced from Mean Time, (See Tables, p. 166); or, by adding together two hrs. for each month and four mins. for each day that have elapsed since the preceding 22nd. of March, plus also the hrs. and mins. since noon of the current day, verifying on some culminating star as seen in these Charts.

1/3 of an hr + 5 Sec = 20 min

Example: Wanted, Sidereal Time, 9 p. m., October 25.
March 22 to October 22: 7 mos., × 2hrs. = 14hrs.
October 22 to 25: 3 ds. × 4 mins., = 12 mins.
Noon to 9 p. m., observing hour, October 25: 9hrs.
Total: 23 hrs., 12 mins., Sidereal Time, or Right Ascension of any objects on observer's true Meridian at that hour.

also, instead of actually 4 mins the lost time is 3 mins 57 sec

Chart 24C,, shows that Double-star, ψ Aquarii, *231109*, culminates within 1 min. of that time. Its transit thru the telescopic field affords a correction for your sidereal clock. (For accuracy to secs.. and decimals, see Nautical Almanac, p. 760).

With timepiece corrected and circles accurately set, you may locate any unit east or west of your meridian simply by subtracting its known R. A., or sidereal time, from that of your own as indicated by your clock. This gives the Hour Angle of that object; and swinging the telescope till the circle-readings correspond to the time-calculation, adjusting in declination, behold your star! If necessary, add 24hrs. to your clock-time in order to make the subtraction. Hrs. 0 to 12 indicate fields to westward of the meridian, and Hrs. 12 to 24 fields to eastward. Remember: Hour Angle equals Sidereal Time minus Right Ascension.

5T. *RA = 4H

To identify any celestial unit visible: read off its Hour Angle from the polar circle, also note its + or — position in declination. Subtract the Hour Angle reading from the Right Ascension, or sidereal time, of your meridian. This will give the object's apparent location, its identity made possible by reference to the corresponding chart.

Stars appear 20 min late at Pgh as it is 80° West at Pgh or 20 min in time, at mean noon it is 12 20 EST

See Page 310

See Bell's The Telescope - Pge 275 - use 1/4" on 1/5" eyepiece
4 1/4 Log 0.62839

STELLAR MAGNITUDES:

The absolute scale of stellar mags. adopts the fifth root of 100 — i. e., 2.512 — as the uniform light ratio; so that, approximately, a star of any given is mag. 2½ times brighter than one below it in the scale, and 2½ times fainter than one above it. This factor is assumed on the hypothesis that 100 stars of the sixth mag. equal one of the first; each magnitude being also divided into tenths on both ascending and descending scale. Thus Aldebaran, mag. **1.1**, is 2½ times fainter than Vega, mag. **0.1**; and 2½ times brighter than Polaris, mag. **2.1** After passing the zero mark, they take the negative sign. Thus, Sirius becomes mag. **−1.6**; Jupiter, at opposition, mag. **−2.0**; the Sun, mag. **−26.3.**

POWERS OF TELESCOPES of Various Apertures: —

Argelander's Scale: Multiply the log. of aperture in inches by **5**, then add **9.2**. The result approximates the lowest-magnitude star visible with that aperture. Example: Four-inch lens or mirror —

Log. $4 = 0.602 \times 5 = 3.01 + 9.2 = 12.21$: Mag. smallest Star.

Under favorable conditions, the following scale is fairly reliable: —

APERTURE	MAG.	APERTURE	MAG.	APERTURE	MAG.
2-Inch	10.07	5-Inch	12.69	8-Inch	13.71
3 "	11.58	6 "	13.09	9 "	13.97
4 "	12.21	7 "	13.42	10 "	14.20

4 1/4 - 12.34

RESOLVING DOUBLE STARS: —

Schuster's formula approximates the resolving power of lens or mirror of good figure, whereby a close pair of nearly equal magnitudes may be separated: Divide **5.03** by the aperture. Thus, a 2-in. objective should resolve the components of a binary system 2″.5 apart. A 4-in. should separate double-stars 1″.25 apart, etc., as per the following list: —

APERTURE in Inches:	SEPARATION in Secs of Arc:	APERTURE in Inches:	SEPARATION in Secs. of Arc:
2	2″.51	8	0″.63
3	1″.67	9	0″.56
4	1″.25	10	0″.50
5	1″.00	11	0″.46
6	0″.84	12	0″.42
7	0″.72	36 Lick Obs.	0″.14

Dawes 0.76
4 1/4 - 1".185

It is a curious physiological fact that low-magnitude stars and difficult doubles which defy direct vision may very often be glimpsed by an averted glance — that is, the direct gaze focused upon some spot a little to the right or left of the object sought, the star thus viewed obliquely at the same time. Experience will soon demonstrate that many factors enter into the art of observing — location, climatic and seasonal conditions, and above all the personal equation — for while the stars seldom appear precisely the same, so no two persons observe exactly alike: all of which calls for patience and concentration to attain proficiency.

Dawes limit for ... 4.56 / A
A = aperture in inches
4 1/4 = 1".14 sec of arc see Bell's The Telescope Pge 261

Ralph Wright Feckers
1/18 ... good as 1/20 here in dense atmosph...
1/8 to 1/10 wave

APPROXIMATE CENTER OF CONSTELLATIONS

Location Chart Number, and Date of Culmination, 9 P. M.

ANDROM.	004038	1-B	Nov. *13*	LACERTA	222543	23-B	Oct. *14*
AQUARIUS	*222015*	23-C	Oct. *14*	LEO	103015	11-B	Apr. *14*
AQUILA	193002	20-B	Aug. *29*	LEO Min.	102033	11-B	Apr. *14*
ARIES	023020	3-B	Dec. *14*	LEPUS	*052520*	6-C	Jan. *28*
AURIGA	060042	7-B	Feb. *12*	LIBRA	*151014*	16-C	June *29*
BOÖTES	143530	15-B	June *14*	LYNX	075045	8-B	Feb. *28*
CAMELOP.	054070	6-A	Jan. *28*	LYRA	184536	19-B	Aug. *14*
CANCER	083020	9-B	Mar. *15*	MONOC.	*070003*	8-C	Feb. *28*
CANES Ven.	130040	14-B	May *30*	OPHIUCHUS	*171004*	18-C	July *30*
CANIS Maj.	*064024*	7-C	Feb. *12*	ORION	052003	6-C	Jan. *28*
CANIS Min.	073006	8-C	Feb. *28*	PEGASUS	223017	23-B	Oct. *14*
CAPRICOR.	*205020*	21-C	Sept. *14*	PERSEUS	032042	4-B	Dec. *29*
CASSIOP.	010060	2-A	Nov. *29*	PISCES	002010	1-C	Nov. *13*
CEPHEUS	220070	23-A	Oct. *14*	PISCIS AUS.	*214032*	22-C	Oct. *14*
CETUS	*014512*	2-C	Nov. *29*	PUPPIS	*074032*	8-C	Feb. *28*
COMA BER.	124027	13-B	May *15*	SAGITTA	195018	20-B	Aug. *29*
COR. BOR.	154030	16-B	June *29*	SAGITTAR.	*190025*	20-C	Aug. *29*
CORVUS	*123018*	13-C	May *15*	SCORPIO	*162026*	17-C	July *15*
CRATER	*112015*	12-C	Apr. *30*	SCUT. SOB.	*183010*	19-C	Aug. *14*
CYGNUS	203040	21-B	Sept. *14*	SERPENS	153508	16-C	June *29*
DELPHIN.	203512	21-B	Sept. *14*	SEXTANS	*101001*	11-C	Apr. *14*
DRACO	160060	17-A	July *15*	TAURUS	043018	5-B	Dec. *29*
EQUULEUS	211006	22-C	Sept. *29*	TRIANG.	020032	3-B	Dec. *14*
ERIDANUS	*035030*	4-C	Dec. *29*	URSA Maj.	110058	12-A	Apr. *30*
GEMINI	070024	8-B	Feb. *28*	URSA Min.	154078	16-A	June *29*
HERCULES	171027	18-B	July *30*	VIRGO	*132002*	14-C	May *30*
HYDRA	*110012*	12-C	Apr. *30*	VULPEC.	201025	21-B	Sept. *14*

DEGREES in R. A. Converted into Hrs., and Mins.

	h. m.		h. m.		h. m.		h. m.
1°	= *0 4*	70°	= *4 40*	170°	= *11 20*	270°	= *18 00*
2°	*0 8*	80°	*5 20*	180°	*12 00*	280°	*18 40*
5°	*0 20*	90°	*6 00*	190°	*12 40*	290°	*19 20*
10°	*0 40*	100°	*6 40*	200°	*13 20*	300°	*20 00*
15°	*1 00*	110°	*7 20*	210°	*14 00*	310°	*20 40*
20°	*1 20*	120°	*8 00*	220°	*14 40*	320°	*21 20*
30°	*2 00*	130°	*8 40*	230°	*15 20*	330°	*22 00*
40°	*2 40*	140°	*9 20*	240°	*16 00*	340°	*22 40*
50°	*3 20*	150°	*10 00*	250°	*16 40*	350°	*23 20*
60°	*4 00*	160°	*10 40*	260°	*17 20*	360°	*24 00*

3" 4.56 (1.52
Stars must be of equal magnitude for this separation

MAIN DIVISIONS OF STELLAR SPECTRA.

A knowledge of spectral types leads to an appreciation of the vast diversity of celestial objects as to size, distance, motion and physical structure, without which the observer foregoes one of the chief charms of the science. See Brief Digests and chapter on the Spectroscope.

O Wolf-Rayet stars, along axis of Milky Way. White. Spectrum indicates gaseous nebulae, with bright bands of unknown origin. Planetary nebulae give similar spectra. Approximate Temp., 23000° C.

B Orion type. Blue-white helium stars. Small proper motions. Low density. Vast proportions. Very remote. No binaries of known orbits. Early stage of stellar evolution. Faintest units in excess of 3000 parsecs. Surface temperature, 16000° C.

A Sirian. Hydrogen type. Brilliant. Very numerous. Measurable parallax. Many binaries. Greater proper motions. Temp., 11000° C.

F Capellan. Sirian-Solar type. Large p. m. Measurable par. Binaries frequent. Calcium lines, H and K, and those due to metals, increase.

G Solar. Characterized by dark lines due to metallic vapors. Widely distributed. Swifter moving, more dense. H and K lines prominent. Chiefly dwarfs, 1800 times more numerous than B-type. Temp., 5600° C.

K Arcturian. Red-Solar type. Decreased intensity of continuous spectrum in the violet and blue. Bands due to hydrocarbons appear. Surface temperature, 3500°

M Antarean. Resembles solar type, but with broad bands or flutings. Ruby color. Rapid proper motions. Often variable, the long-period variables of this class having an angular diameter 100 to 200 times our Sun. M-giants youngest of all luminous stars. Temp. 2700° C.

N Similar to M-type, but further characterized by banded spectra due to carbon absorption. Deep red, indicating possible extinction.

Small letter, a-e, or No. 1-10, in text denotes Sub-group of Class.

Stellar temperatures are usually given Centigrade. To convert to Fahrenheit, approximately, multiply by nine-fifths. Ex.: Sun, 6000° C. equals 10800° F. Fahrenheit to Centigrade, multiply by five-ninths.

Absolute temperature, "K" is reckoned in degrees Cent., from Absolute Zero, which is 273° below Cent. Zero.

Radial Velocity, (r. v.) is usually given in kilometers: unit, 0.621 mi.

To determine Diam. of Field of Telescope: Watch in hand, count number of secs. required for an equatorial star to traverse diam. of field, multiplying by 15. Ex.: Time of transit of Delta Orionis, 50 secs. times 15 equals 750 secs., or 12½′, diam. of field.

Polaris and the Big Dipper offer a convenient year-round yardstick for approximating stellar distances. Polaris to Mizar 35°. To Delta Cass., 28°. Bowl of Dipper: Alpha to Beta, Urs. Maj., (pointing directly to North Star), 5°. Alpha to Delta, 10°. Delta to Gamma, 5°. Beta to Gamma, 8°. Handle of Dipper: Delta to Epsilon, 5°. Epsilon to Zeta (Mizar), 4°. Zeta to Eta, 7°.

Angular Diam. of Sun, (mean): 31′ 59″.3. Moon, 31′ 5″. Mercury, 4″ [illegible]. Venus, 9″.9 - 64″. Mars, 3″.5 - 25″.1. Jupiter, 30″.5 - [illegible] Saturn, 14″.7 - 20″.5. Uranus, 3″.4 - 4″.2. Neptune, 2″.2 - 2″.4.

ABBREVIATIONS.

D—Double star.
Sep.—Separation in ″ of arc.
Prim.—Primary of system.
Bin.—Binary. Vis.—visual.
Sp.—spectroscopic.
α = Mean separation of visual binary components.
Per.—Period of revolution of double star. Also, max. to min. brightness and return to max. of variable star.
Spc.—Spectral class.
Tr.—Triple system.
Mul.—Multiple.
Neb.—Nebula: diff., diffuse; pl., planetary; spl., spiral.
Cl.—Cluster: op., open, extended; glob., globular.
l. y.—Light years.
p. m.—Star's proper motion.
r. v.—Radial velocity. Approach, —; recession, +.
Par.—Parallax in ″ of arc.
A. u.—Astronomical units—dist. Earth ⊕ to Sun ⊙.
Parsec—1″ of arc = 3.26 l. y.
l. p.—Low power ocular.
h. p.—High power ocular.

DIRECTION OF OBJECT FROM KEY-STAR:— p signifies the object precedes star—i. e. its R. A. is *less* than the star as charted; f, object follows star—i. e. its R. A. is *greater* than the star; n p signifies north-preceding; n f, north following; s p south-preceding; and s f, south-following.

GREEK ALPHABET:—

α Alpha	ε Epsilon	ι Iota	ν Nu	ρ Rho	φ Phi
β Beta	ζ Zeta	κ Kappa	ξ Xi	σ Sigma	χ Chi
γ Gamma	η Eta	λ Lambda	ο Omicron	τ Tau	ψ Psi
δ Delta	θ Theta	μ Mu	π Pi	υ Upsilon	ω Omega

AUTHORITIES: Σ—F. Struve OΣ—O. Struve OOΣ—Pulkowa β—Burnham H—Wm. Herschel h—John Herschel M—Messier
Variable Stars: Harvard College Obs. Annals, Vol. 79, Part 3, (1928).

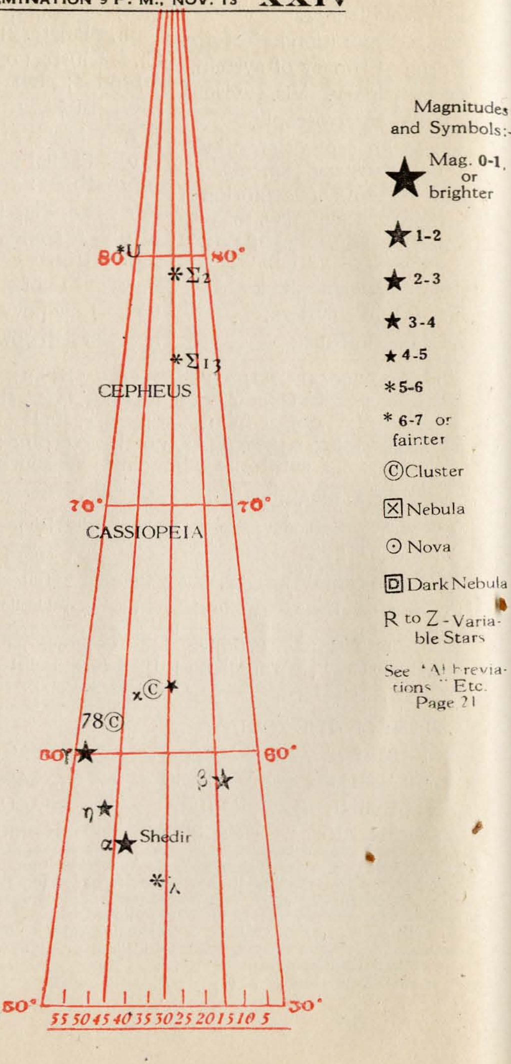
SIGNS OF THE ZODIAC:—

♈ ARIES	♌ LEO	♐ SAGITTARIUS
♉ TAURUS	♍ VIRGO	♑ CAPRICORNUS
♊ GEMINI	♎ LIBRA	♒ AQUARIUS
♋ CANCER	♏ SCORPIO	♓ PISCES

Color Scales.—Fa. Hagen's Scale for Stars, particularly Variables, is often employed, and runs from —1 for the blue-white stars to 10 for the dark red. The intermediate units of the scale give 0, for the white; 1, for the yellow-white; 2, white-yellow; 3, yellow; 4, orange-yellow; 5, yellow-orange; 6, orange; 7, red-orange; 8, orange-red; 9, red; and 10, as stated, for the deep-toned red carbon stars.

CHART 1-A

I CULMINATION 9 P. M., NOV. 13 XXIV



CEPHEUS: *Chart 1-A*

Region rather sparing of features to the unaided eye; but under patient scrutiny, even with small powers, the constellation of the mythological Ethiopian monarch discloses many gems.

U 005381 Var. 7.0-9.0. Per., 1d., 11.8h. Spc. Ao.

Σ2 000379 Vis. bin., 6.8-7.1. $a = 0''.55$. Spc. A3. Per. 166.2 yrs.

Σ13 001176 D: 6.6-7.1 Sep. 0″.5.

CASSIOPEIA:

The "starred Ethiop queen" is one of the most beautiful and familiar configurations of the northern heavens, being "always with us" as a low-lying **W** or a vaulting **M**, dervishing daily about the Pole Star directly opposite the Big Dipper, a line drawn from δ Cass., to ζ Ursae Majoris —Mizar—passing directly through the north polar point. Many striking diversities abound here—binaries, clusters, nebulae and vari-tinted units,—with a grand stellar highway from γ s w to α Cass., well worth traversing leisurely. Of the eighty-nine constellations in both hemispheres, not many offer richer fields for nightly exploration.

κ 002862 Cl. Set in gorgeous framing of varied forms.

78 003661 Notable cl., midway bet. κ and γ Cass.

γ 005160 Mag. 2.2. 11-mag. companion an easy test.

β 000458 Mag. 2.4, with faint *comites*. A noble star! Dist., 5.7 l. y. A mag. 7-8 Double, and also an 8-mag. Triangle in a scintillating field.

η 004457 Vis. bin. 3.6-7.9. Spc. F8. $a = 12''.21$. Per. 507.6 yrs. Orange and gold. Mass of pair, 0.9 × Sun. Sep., 61 ast. units.

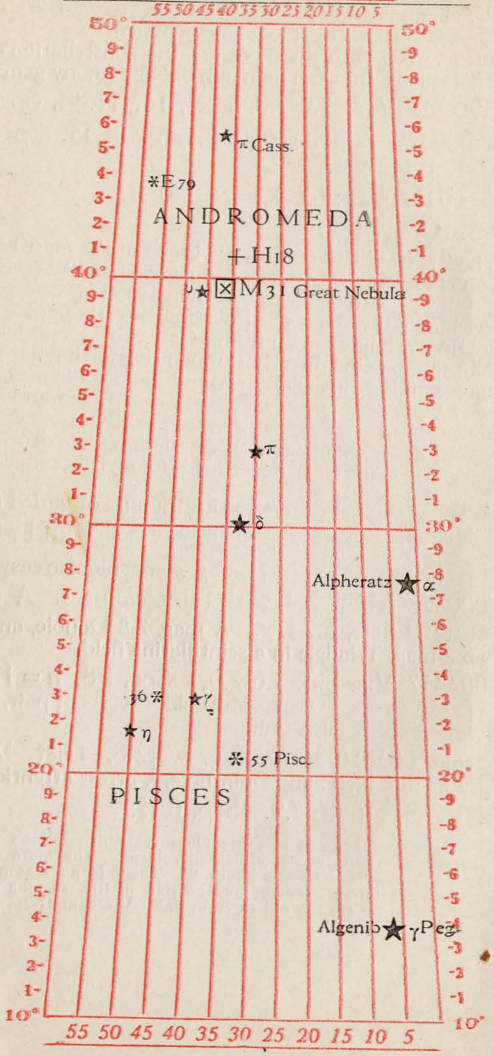
α Shedir 003656 Var. Mag, 2.2:2.8. Dist. 47 l. y. Large diff. Neb., and Quintuple, f, arrest attention.

λ 002754 D: 5.6-5.9. Sep. 0″.5.

"Astronomy offers one of those pleasures which follows the law of increasing rather than diminishing returns. The more you develop it, the more you know about it. There is no season in the year when the interest ceases; and no time of life, so long as sight remains, when we are too old to enjoy it."—Viscount Grey.

CHART I-B

I CULMINATION-9 P. M., NOV. 13 XXIV



π Cass. 003746 Mag. 5.02. Sp. bin. Per. 1.7 ds. Spc. A5. *Chart I-B*

ANDROMEDA:

No part of this exalted constellation is ever dull, even with low power and only fair seeing; and repeated explorations through its rich arcana of mysteries and surprises never fail of enlightenment and inspiration. The Great Nebula itself demands periodical observations under varying conditions to unfold the true glory of this celestial paragon, and will repay the observer for all his patience and skill, requiting him for any possible early disappointments.

Σ79 005544 D: 6-7. Sep. 7″.6.

H18 003641 Diff. neb., large, oval, pearl white.

υ 004440 Mag. 4.4. Sp. bin. Per. 4.28ds. Spc. B3.

M31 003840 Great Nebula. 6′ η And. Nearest of the Spirals,--900,000 l. y. Diam., 50,000 l. y. Fairly defined naked-eye spectacle; but in a telescope of low power and wide range, an object of increasing interest and wonder.*

π 003133 D: 4.4-8. Sep. 36″.0. Prim. Sp. bin. Per. 143.7 ds. Spc. B3. Fine Doublet, p, mag., 6-9.

δ 003530 Mag., 3.5. Faint 28″ dist.

α Alpheratz 000428 Mag. 2.2. Sp. bin. Per. 96.67d. Spc. A. N. E. star of Gt. Square of Pegasus.

ζ 004323 Sp. bin., mag. 4.3. Per. 17.76ds. Spc. K.

36 004923 2° η. Vis. bin., mag. 6.1-6.7. Spc. Ko. $a = 0.94$. Per. 109.07 yrs.

PISCES:

A few quite noteworthy features in this meridian area.

55 003521 D: 5-8.2. Sep. 6″.4.

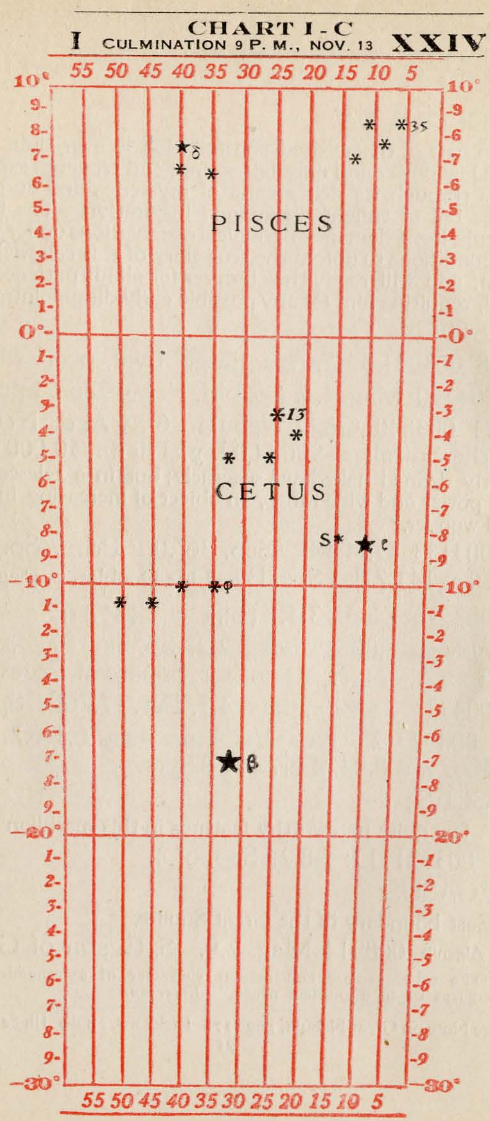
PEGASUS:

East boundary of the Great Square.

γ Algenib 000914 Mag. 2.9. S. E. star of Gt. Sq.

"The calm, remote and secular character of astronomical facts composes us to a sublime peace."—*Emerson.*

* See Note on Great Nebula, page 27. Lick Obs. photo, Ill. Sec.



PISCES:

35-41 001008 A region of splendors! *Chart I-C*

35 Pisc. D: mag. 6-7. Sep. 11″.5.

δ 004407 Mag. 4.6.
Superb sweeping, with 60 and 62 Pisc., mag. ±6, in field.

CETUS:

The "Whale" requires rather high power to disclose its many brilliants to advantage. A broad-ranged equatorial constellation finely placed for leisurely gem-hunting.

13 *003004* Vis. bin., mag, 5.2-6.4. $a = 0''.24$. Per. 6.88 yrs. Spc. F. Prim. Sp. bin. Per. 2.08 ds.
Interesting low-mag. double-doubles in field.

S *002009* Var. Mag. 8.2-13.9. Per., 320.2 ds.

φ 1-2-3-4 *004011* Royal procession of stellar nobles, mag. ±6, approx. E and W.

β *003918* Mag. 2.2. Vibrating, colorful star.

GREAT NEBULA OF ANDROMEDA. Most distinguished and apparently closest member of a countless and wholly mysterious class abounding in remote extra-galactic space-deeps, but save a few exceptions, like the Andromeda, beyond the reach of any save high-power instruments of research. Indeed, although the mammoth hundred-inch reflector at Mt. Wilson has disclosed the presence of hundreds of thousands of these objects at distances estimated at hundreds of millions of light years, science now looks forward to the completion of the two-hundred-inch super-giant telescope already in prospect, to assure us a better knowledge of these "Island Universes," of which our own galactic system is possibly a prototype. For, as Dr. Campbell points out, "while we do not know that our stellar system is now a spiral nebula, or that it is the developed product of a spiral of ages past, it does seem to have most of the known attributes of a spiral." Thus were we located at the million light-year distance of the Great Nebula, our Galaxy, with all its billions of suns, clusters and nebulae, might appear much as the Andromeda prodigy commands our awe today, with its total luminosity one billion and a half times that of our Sun, and a rotational period of seventeen million years!

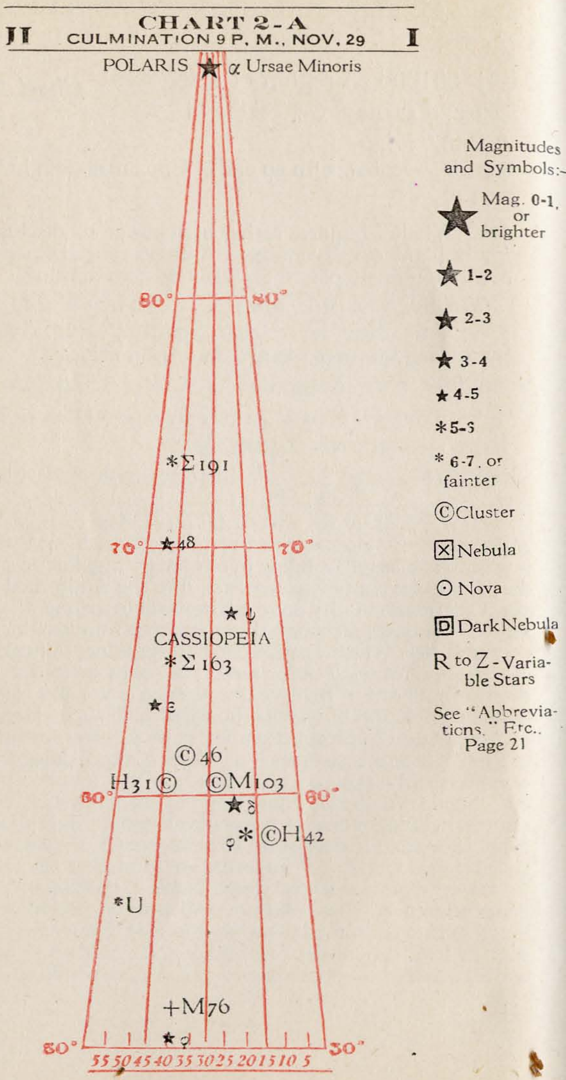


Chart 2-A

URSA MINOR:

A limited asterism receiving its chief dignity from the location here of the most observed of all the "fixed stars" of the northern heavens, dist., 1° 6′ from the true Pole, about which it revolves every twenty-four hours and toward which it gravitates so that about A. D. 2095 Polaris will be less than ½° dist., from that point. Thence it will draw away on its 25,600-year circuit about the pole of the Ecliptic; and 6000 years hence α Cephei, and 12,000 years hence Vega, in Lyra, will succced to that high historical office, as Thuban, in Draco, held it at the time of the building of the Pyramids of Egypt, B. C. 2170.

α Polaris 013488 Mag. 2.1. Cepheid var. Spc. F8. Par. 0″.017 = 190 l. y. Mag. 9 *come*, dist., 18″.3. Two spec. companions: per. 3.96 ds. and 11.9 yrs. Sep. 0″.13 and 0″.35. Luminosity of Polaris, 2570 × ☉.

CASSIOPEIA:

Almost every phase of celestial phenomena represented.

Σ191 015673 D: 6.2-8.5. Sep. 5″.6.

48 015370 Vis. bin., mag. 4.7-7.2. Per. 52.95 yrs. $a = 0''.61$. Sp. A2.

ψ 012067 Trip., 4.4-8.9-9.5. Sep. 32″.0 and 3″.0. A patience test, with good seeing.

Σ163 014564 D: 6.2-8. Sep. 35″.0. Colors contrasty.

ε 014963 Mag. 3.4. Entire region radiant.

H31 014060 and 46 n f. Two cls. Outlying doubles.

M103 012760 1° f δ. Vivid cl., in grand setting.

δ 012159 Mag. 2.8. A teeming expanse n.

H42 011457 Massed jewels! Topaz φ, mag. 5, close f.

PERSEUS:

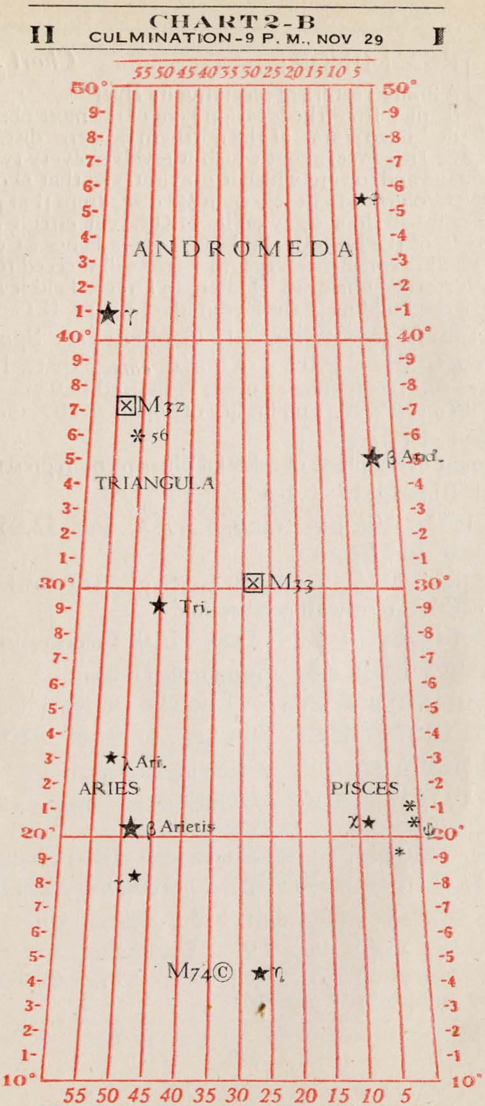
The "Champion" discloses here some stellar prodigies.

U 015354 Doub.-var., 7.5-11 : 8.0. Per. 320 ds.

M76 013751 Doub. spir. neb., joined, with ring.

φ 013950 Var. mag., 4.2. Doub. spec. bin. Per. 126.5 and 63.2 ds. Spc. Bp. "Presents puzzles and problems still unsolved!"

* Van Rhijn. Barton computes dist. of Polaris at 466 light years.



ANDROMEDA: *Chart 2-B*

Several absorbingly interesting features in this area, including a notable doublet.

φ 010446 D: 4.9-6.5. Sep. 0″.6. Two blazing suns!

γ 015941 D: 2.3-5.4. Sep. 10″.3. Companion a bin. system: Per. 55.0 yrs. $\alpha = 0''.346$. Spc. A. Gorgeous colorings—burnished gold and cerulean blue.

H32 015337 Nebulous unit. Curious groupings.

56 015136 D: 5.7-5.8. Sep. 181″.7. ½° s p H32. Σ179 D: 6.7-7.7 in field, making an imposing spectacle.

β 010535 Mag. 2.4. A lone monarch in rather isolated region, bold against a background of low-mag. stars.

TRIANGULA:

"The Triangle" begins here—a limited but well-placed asterism, with at least one feature of superlative interest

M33 012930 Faint spl. neb. Over ½° in extent, with crosses, rifts and nebulous condensations in a sea of glory! The recessional speed of this whirling mass through cosmic deeps is upwards of 400 mi. per sec.; and its period of revolution 160,000 yrs. Outlying regions disclose condensed swarms of stars — suns and systems in the making Dist., 900,000 light years.

α 014729 Mag. 3.5. Sp. bin. Per. 1.7 ds. Spc. F5.

ARIES:

"The Ram" begins between these hours—quite the most engaging portion of an otherwise indifferent constellation.

λ 01533 D: 4.7-6.7. Sep. 37″.9.

β 014920 Sp. bin. Mag. 2.7. Per. 107 ds. Spc. A5.

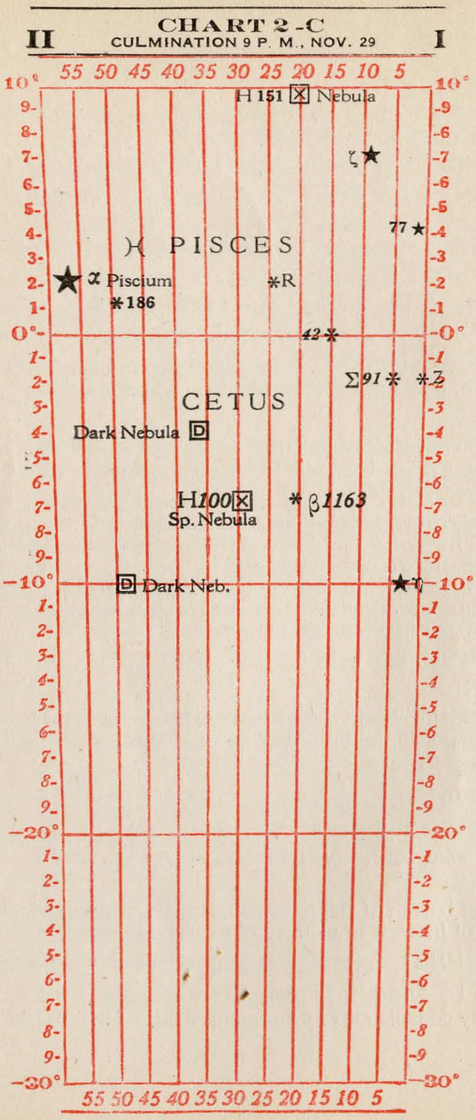
γ 014918 D: 4.2-4.4. Sep. 8″.6. Famous pair, disc by Hooke, 1664. Neb. H112, 1½°, worth while.

PISCES:

Rather barren of the more commanding phenomena, but fruitful of interest in vicinity of χ, and especially f η Pisc.

$\psi^{1\text{-}2\text{-}3}$ 010121 Amazing sequence, with χ in field.

η 012714 Mag. 3.7; Mag. 11 comes, dist., 1″.0. Chiefly conspicuous for luminous field, n f incl. Cl. M74.



H151 012009 Neb. Fairly bright, with central condensation, in isolated region. *Chart 2-C*

ζ 010907 D: 4.2-5.3. Sep. 23″.5. Colorful pair. Primary var.: 4.2:6. Astride the Ecliptic.

77 010104 D: 5.9-6.8. Sep. 32″.8. Fine prospect.

α 015702 D: 2.8-3.9. Sep. 3″.6. Weird coloring

Σ186 015001 Vis. bin. Mag. 7.0-7.0 $a = 1''.15$. Per. 136 yrs. Spc. Go.

CETUS:

42 *011500* D: 6.2-7.2. Sep. 1″.2.

Σ91 *010302* D: 6.7-7.5. Sep. 3″.9.

D *013704* Dark neb. Type of prevalent star barrier engrossing the minds of scientists from the time Herschel called these ink-black irregular blotches "holes in the sky", until the genius of Barnard, aided by photography, demonstrated them to be actual dark nebulae—vast opaque areas that obscure the stellar regions beyond like a curtain, proving Bessel's contention that "luminosity is not a necessary property of cosmical bodies."

Notwithstanding the cosmical cloud in interstellar space, there is ordinarily no appreciable absorption or scattering of the starlight on its way to us.

H100 *012707* Spl. neb. Bright nucleus. Chiefly of interest because of its stupendous space-velocity, notwithstanding its probable galactic size—1240 mi. per sec.—the record speed of any known celestial object! What supernal forces combined to give this vast aggregation its initial momentum, or what counter forces could halt or even swerve it from is course thru the ages, challenges all conjecture.

"Thirty years ago we did not know the radial motion of any star in the heavens; yet in this intervening period the radial velocities of more than a thousand stars have been determined. These velocities will enable us, both alone and in combination with proper motion and parallaxes, to solve many of the fundamental problems of stellar astronomy; not suddenly, but by rapid approximations to the truth."—Campbell.

β1163 *012007* D: 6-6.2. Sep. 0″.2. Excellent test

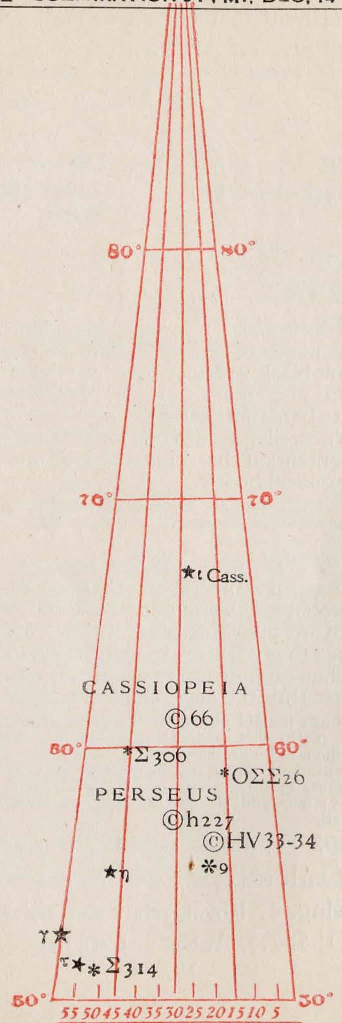
D *014810* Dark neb. ζ Ceti 1′ s p toward χ.

η *010410* Mag. 4. Royal arch of suns north-eastward.

χ *014511* D: 5.-7.5. Wide. ζ Ceti, mag. 3.9, 1° n f.

CHART 3-A

III CULMINATION 9 P. M., DEC. 14 II



Magnitudes and Symbols:-

Mag 0-1, or brighter

1-2

2-3

3-4

4-5

5-6

6-7, or fainter

© Cluster

☒ Nebula

⊙ Nova

◻ Dark Nebula

R to Z - Variable Stars

See "Abbreviations," Etc., Page 21

CASSIOPEIA: *Chart 3-A*

ι 022267 Tr: 4.2-7.1-8.1 Sep. 1″.9-7″.6. Not difficult; very fine.

Σ306 024460 D: 7.1-9. Sep. 2″.1. Cl. 66, ½° n p.

OΣΣ26 021359 D: 6.1-6.6. Sep. 63″.5. Gold-green.

PERSEUS:

A vast stellar revelation, especially inspiring vic. χ Pers.

h227 022757 Wide cl. Field shot with diamond-dust!

HVI33-34 021556 Two splendid naked-eye Cls. Midway bet. α Persei and γ Cass. Diam. of each Cluster about 100 l y., but overlapping so as to appear physically connected. Dist., 7500 l y. Stars blue-white and intense, with temp. from 15000 to 25000 C. Many exceed by a hundred times the brightness of our Sun. Rad. vel., —28 mi.-sec. Vivid ruby Var. in Cl. 34. (Trumpler).

9 021655 D: 5.5-12. Sep. 12″. Difficult; region rich.

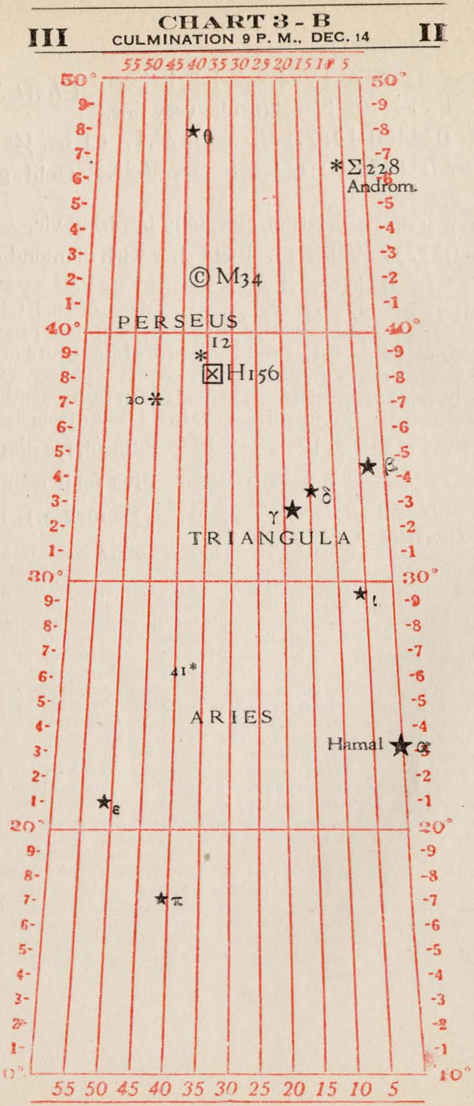
ε 024455 D: 4.-8.5 Sep. 28″. Five faint *comites*.

Σ314 024752 D: 6.9-7. Sep. 1.″5. γ mag. 3.1, 1° n f.

NO "EMPTINESS" IN SPACE.

An ordinary region, observes Eddington, where there is no observable nebulosity in the highest vacuum existing—within the limits of the stellar system, at least—there still remains about *one atom to every cubic inch.* It depends on our point of view whether we regard this as an amazing fullness or an amazing emptiness of space. Perhaps it is the fullness that impresses us most. The atom can find no place of real solitude within the system of the stars; wherever it goes it can nod to a colleague not more than an inch away. I think there can be no doubt that research demonstrates the existence of a cosmic cloud pervading the stellar system. The fullness of interstellar space becomes a fact of observation and no longer a theoretical conjecture. The system of the stars is floating in an ocean—not merely an ocean of space, not merely an ocean of ether—but an ocean that is so far material that one atom or thereabouts occurs in every cubic inch. According to the modern theory of gravitation, a globe of the size of Betelgeuze (almost contained in the orbit of Mars), and of the same mean density as our Sun, would have some remarkable properties. Owing to the intensity of its gravitation, light itself would be unable to escape, and any rays shot out would fall back again to the star by their own weight.

"Science has its competition as keen as that which is the life of commerce. But its rivalries are over the question, Who shall contribute the most and the best to the sum total of knowledge—who shall give, not who shall take, the most? and its animating spirit is the love of truth; its pride is to do the greatest good to the greatest number."—*Newcomb.*



ANDROMEDA:

Chart 3-B

θ 023948 Tr.: 4-10-10.

Σ228 020747 Vis. bin.: 6.4-7.3. *a*= 0".97 Per. 204.7 yrs. Spc. Fo.

PERSEUS:

M34 023642 Cl. 'A celestial aegis hung aloft in splendor!'

"Globular clusters range in distance from 7000 parsecs — over 20,000 light years — to values nearly ten times as great. Their diameters are of the order of a hundred parsecs; and their brightest stars are a thousand times as bright as our sun." – Shapley.

12 023739 Wide Tr.: 6-7.5-8.2. Guide-star to Cl. 156.

H 156 023538 Neb. Lenticular, bright, 5′ long, with nucleus. Object worth deep study. 1° s 12 Pers.

"Spirals have space velocities of the order of 1400 km. – over 800 miles – per second." – Slipher.

20 024737 Vis. bin.: 5.6-6.7. Per. 33.3 yrs. *a* = 0".16. Sp. Fo. 16 Pers., mag. 4, ½° p, very effective.

TRIANGULA:

β 020534 Mag. 3.1. Fruitful region s e toward δ and γ, Trian., mags. 5 and 4, presenting a dazzling outlook.

ι 020729 D: 5.6-6.4. Sep. 3".6. Sapphire and gold.

ARIES:

41 024326 Tr. 4-11-12. Small but bright. Use h p.

α Hamal 020223 Mag. 2.2. The shepherd's star.

ε 025421 D: 5.7-6. Sep. 1".2;

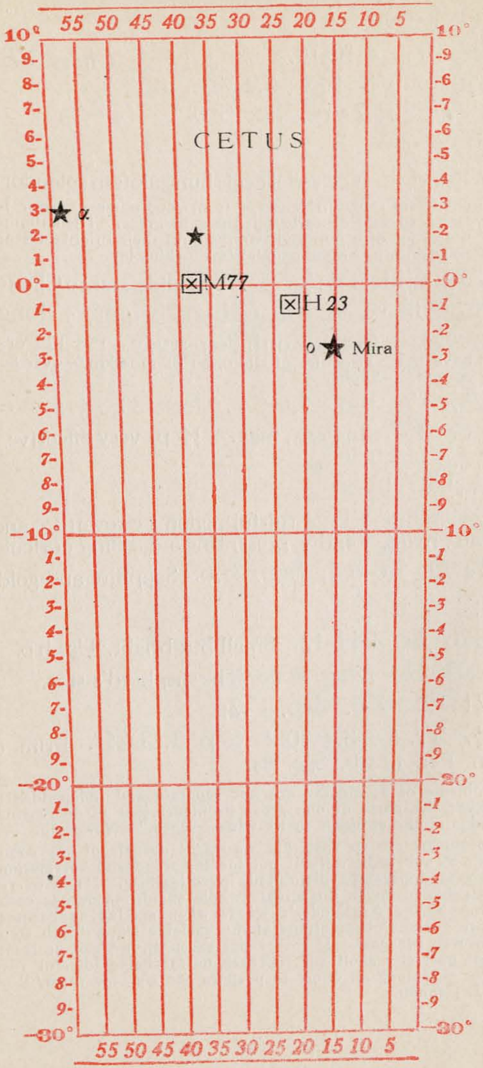
τ 024317 Tr. 5.3-8.4-10.2 Sep. 3."3-25". Prim. a Sp. bin. Per. 3.85ds. Spc. B5.

"The problems of astronomy are not separate and independent; but are rather the parts of one great problem: that of increasing our knowledge of the universe in its widest sense."—Newcomb.

"These problems are so vast that we might despair of any completed result of our tasks were it not for the wonderful correlation revealed among apparently disjointed investigations. That every fact is a valuable factor in the mighty whole should encourage each worker, remembering Argelander's words when making an earnest plea for more zealous observations of the variable stars, 'Each step brings us nearer the goal. If we cannot reach it, we can at least work so that posterity shall not reproach us for being idle, or say that we have not made an effort to prepare the way for them.' "—Dr. Annie J. Cannon.

CHART 3-C

III CULMINATION 9 P. M., DEC. 14 II



CETUS:

"The Whale" presents some fine though scattered gems aside from majestic Mira. *Chart 3- C*

α 025803 Mag. 2.8. Or.-red K-type. Fainter than β.

γ 023902 D: 3-6.8. Sep, 2".6. Colorful pair.

M77 ***023800*** Spl. neb. Faint, but interesting.

H23 ***022301*** Two faint diff. neb.

o ***021503*** Mira, the "Wonder Star."

Mag., variable: 1.7 to 9.6. Per., 332 ds. Par., 0".02. Dist., 163 l.y. Temp., 2400K to 1700K. Spc., M7c. Has a tenth-mag. *comes,* discovered spectroscopically by Joy, at Mt. Wilson, and verified visually by Aitken, at Lick. Ang. diam. determined by Pease with Michelson interferometer attached to 100-in. Hooker telescope: 0".056. Mira was recorded by Fabricius, 1596, but was doubtless known to the Chaldean shepherd-astronomers and others of ancient times who regarded changes in celestial phenomena with superstitious awe, as, witness, Algol, "the demon star."

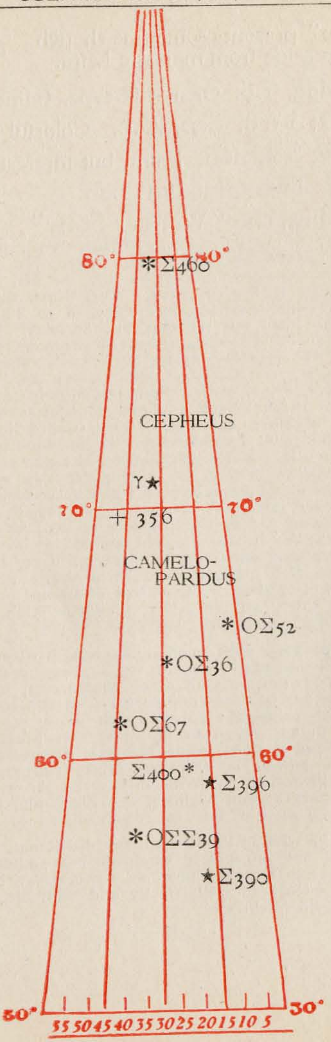
Diameter of Mira, 550 times our Sun, second only to Antares. If set in Sun's place in our system, Mira's boundaries would extend beyond the orbit of Mars, and Earth's orbit would lie about midway between center and circumference. If its mass were proportionate to our Sun's it would weigh 25,000,000 times as much; and, according to Einstein's theory, its own gravitation would be so great that its light would be unable to leave its surface, as thus to us would be forever invisible! However, its density is only one ten-thousandth that of our own atmosphere at sea-level—a vast aggregation of nothingness in whose torrid temperature of 2000° Cent. we might imagine a soul wandering for ages and never know he had arrived. The periodical pulsations of Mira—cause unknown—expand and contract its radius to the extent of twenty percent of its volume, or about thirty million miles, producing great changes in temperature and consequent light variation.

Any theory holds good until another, seemingly wiser and more in accord with the immutable laws of nature supercedes it. The nebular hypothesis, which, among other contentions, held that it was impossible for any subject body to move in any course except that in which its principal moved (such as a moon orbiting around a planet in any other motion than that provided by its parent unit), suffered a shock when Herschel discovered that the moons of Uranus moved in elliptical orbits retrograde to the planet's motion; Pickering, in 1898, discovered the same in the ninth satellite of Saturn; and Melotte, in 1908, and Nicholson, in 1914, discovered the same of the two remote moons of Jupiter.

"Science would be writing its own epitaph did it not, as occasion arises, review old and apparently established hypotheses with a readiness to relinquish them in favor of newcomers; but equally is it the duty of science to walk warily and with circumspection lest it leave the solid track."

CHART 4-A

IV CULMINATION 9 P. M., DEC. 29 III



Magnitudes and Symbols:-

★ Mag. 0-1 or brighter

★ 1-2

★ 2-3

★ 3-4

★ 4-5

* 5-6

* 6-7, or fainter

©Cluster

☒ Nebula

⊙ Nova

D Dark Nebula

R to Z - Variable Stars

See "Abbreviations," Etc., Page 21

CEPHEUS: *Chart 4-A*

Σ460 03560 D: 5.2-6.1. Sep. 0″.9. Strong pair in isolated glory.

CAMELOPARDUS:

Most inviting portion of this mammoth constellation.

γ 034271 Mag. 4.7. Bright beacon-star to neb., 2° s f.

356 035969 Diff. neb. Wide, bright, lace-like.

"Nebulosity seems to consist of clouds of matter, molecules, dust or perhaps even larger particles, not hot enough to be self-luminous, but visible because of light excited by or reflected from involved or neighboring stars." —Hubble.

OΣ52 031065 D: 6.4-7. Sep. 0″.5.

OΣΣ36 033863 D: 6.3-7.3. Sep. 45″.8.

OΣ67 035061 D: 5.-8.3. Sep. 1″.7. Green and gold

Σ385 032259 D: 4.7-9. Sep. 2″.4. A real gem-field!

Σ400 032859 D: 7-8. Sep. 1″.5

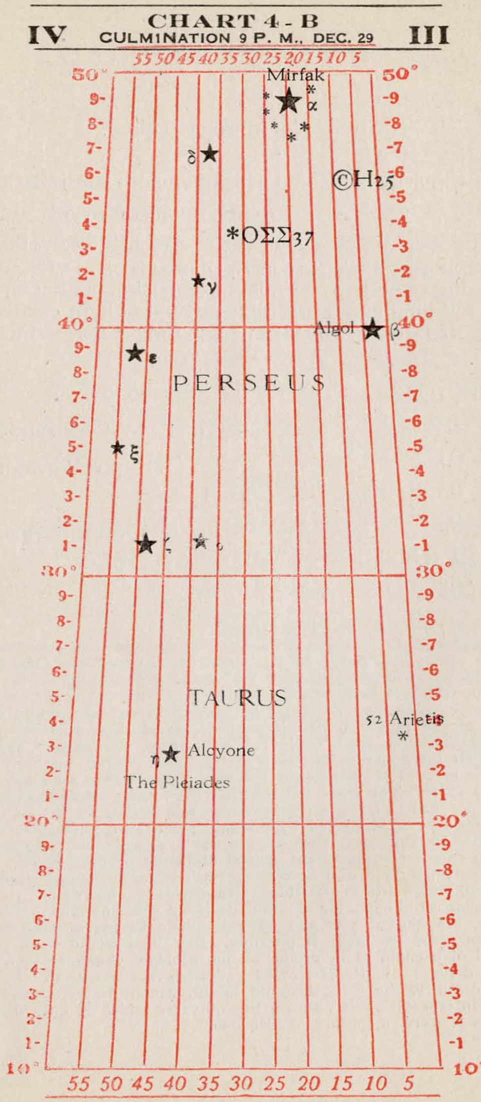
Σ396 032758 D: 6.3-8. Sep. 20″.4. Superb zone, n

OΣΣ 39 034256 D: 5.9-6.6. Sep. 58″.6.

Σ390 032355 D: 4.8-9.2. Sep. 15″.

PLANETS ALONE SUSTAIN LIFE.

According to Prof. Jeans, if the age of the earth be computed at seventy years, then humanity itself may be assumed as a babe three days old, by no means aware of the extent and meaning of the universe in which it finds itself. According to his argument, on any scheme of cosmogony, life must be limited to an exceedingly small corner of the universe. To this babe's wonderings whether other world-cradles and other babies exist in them, the answer appears to be that there can at best be very few such cradles, whether tenanted or not. The planets are the only places where we know that life can exist. The stars are too hot, even their atoms broken up by intense heat. Even if there were solid bodies in the nebulae, they would be so drenched with highly penetrating radiations as to make life in any form such as we could conceive it, impossible. Only in rare instances would special accidents produce bodies such as our earth, formed of a special cool ash which no longer produces radiation, where life is possible. From present observation it does not appear as though Nature had designed the universe primarily for life, the normal star and normal nebula having nothing to do with life except to make it possible. Life then would seem to be the end of a chain of by-products—the accident—and only the torrential deluges of life-destroying radiation the essential. In any case, humanity, the three-days-old infant, cannot be very confident of any interpretation it puts on the universe which it only discovered, as it were, a minute or two ago.



PERSEUS:

The heart of this imperial domain lies bet. hrs. III-IV, with princely Mirfak throned in the midst of a truly royal council of stars. *Chart 4-B*

α 031849 Mag. 1.9. Sp. bin. Per. 4.09d. Spc. F5.

H25 030946 Congeries of low-mag. stars.

ΟΣΣ 37 033244 D: 6.2-6.5. On direct line α s-e to ν

ν 034042 Mag. 4. 12-mag. *comes*. Rather difficult.

β ALGOL, the Ghoul, or Demon-Star 030340 Var: 2.2-3.2.

Once every 2 ds., 20.8 hrs., this remarkable star suffers partial eclipse by reason of a companion, mag. 5 2, revolving about a common center of gravity in the line of sight, losing five-sixths of its light thereby for about 20 min., and recovering normality in about 3½ hrs. Hence the leader of a type of Variable so named, of which there are nearly two hundred under observation to date. Algol also a Spec. bin. Per. 1.899 yrs. Spc. B8. Light of Algol, 160 times sun. Mass, ⅔ sun. "An enormously complex system, still only partially understood,"--Aitken.

Easily located when high in the heavens by drawing an imaginary letter F northward from the Pleiades thru Zeta and Xi, Per., to Epsilon, turning sharply thence westerly along 40° decl., to Beta—Algol.

ε 035239 D: 3.1-8.3. Sep. 8″.8. Not an easy double.

ξ 035435 Mag. 4.05. Sp. bin. Per. 6.9d. Spc. Oe5.

ο 033831 D: 3.9-8.5. Prim. sp. bin. Per. 4.4ds.

ζ 034931 Mag. 2.7. Three interesting comites.

ARIES:

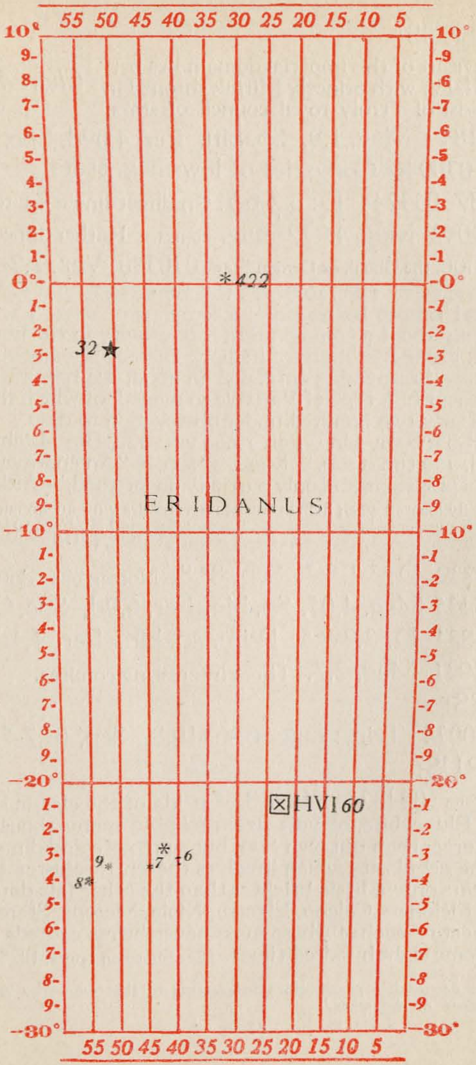
52 030024 Trip.: mag. 6.-6.-10.8. Sep. 0″.7-5″.2.

TAURUS:

η Alcyone 034323 Mag. 3. Lucida of the classic Pleiades. Blue-white, of vast size, probably many thousand times larger than our own Sun, but so remote and dimmed with the nebulosity which involves the entire cluster that it appears only a little brighter than the other fair daughters of Pleione—Caleno, Electra, Maia, Merope, Stereope and Tageta—each of whose mass nevertheless exceeds our Sun's some eight hundred times. (See photo and note, Ill. Sec.

"Every day of life grows more interesting to that man who reads the message of the stars."

IV CHART 4-C III
CULMINATION-9 P. M., DEC 29



ERIDANUS:

The sub-equatorial areas here not especially notable for wizardries, tho offering some broad sweepings in clear skies. The south-flowing constellation of the classic River Po reaches down to within 30½ of the Pole, beaconed by the flashing super-sun, Achernar. *Chart 4-C*

Σ422 033200 D: 6.-8.2. Sep. 6″.1.

32 *035003* D: 4.-6. Sep. 6″.7. Emerald and topaz gems—one of the redeeming features of this somber region. Low-mag. doubles and multiples far and wide.

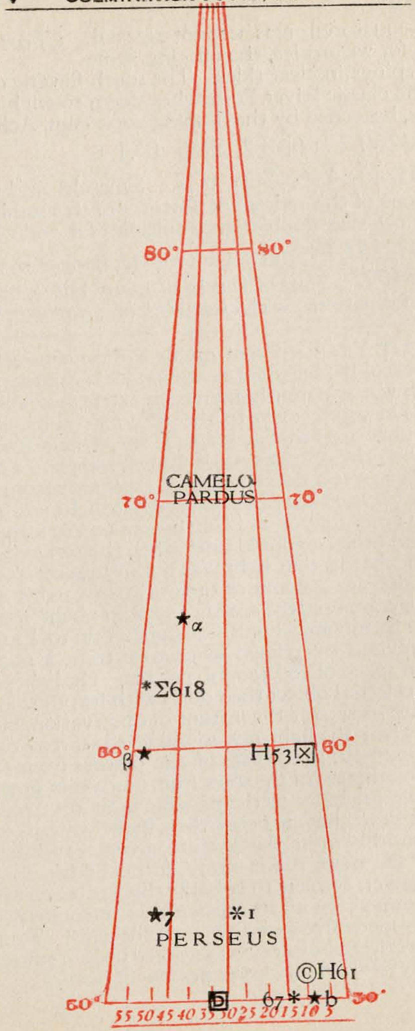
HIV60 *032221* Pl. neb. Quite vivid, flanked by stars.

τ 6-7-8-9 *034023* Zone of jewels of many hues and geometrical formations; with clear horizon a fine pageant.

THE LIGHT YEAR.—From man's earliest appreciation of the miracle of his existence he was under the illusion that light, which was apparently infinite in extent, was also instantaneous in speed, even to the uttermost space deeps. It was not until 1675 that a young Dane, Olaus Roemer, while studying the phenomena of Jupiter's moons. discovered that there was a discrepancy of some seventeen minutes in time between the observed eclipses of Jupiter's satellites when both Jupiter and Earth were on the same side of the sun, and the computed time when the sun stood between them: that is, that light was not instantaneous, but required a definite amount of time to span earth's orbit. Roemer thus computed the speed of light at about 500 seconds for one astronomical unit—distance Sun to Earth—or as since revised by refined laboratory tests, a positive speed-rate in space of 186,300 mi. per sec. The light equation of any celestial object then deals with its position and character, not as seen at the instant of observation, but at the instant when the light-ray so observed started on its hitherward journey: in the case of the planets from three minutes to four hours; of the stars from four years upward; of remote spiral nebulae to the possible limit of a million or more light years, having begun their space-voyages when Earth was possibly in its plastic state, aeons before the appearance of the most rudimentary forms of life on this planet. And yet, miracle to behold, this far beacon-light has never dimmed, for all its incalculable remoteness, nor faltered in its incredible speed thru all the ages! Thus in exploring the celestial we are ever engaged upon a survey of contemporary as well as the most ancient of history.

CHART 5-A

V CULMINATION 9 P. M., JAN. 13 IV



CAMELOPARDUS:

In the area bet. Decl. 50° and 60° will be found many dazzling gems. *Chart 5-A*

χ 044466 Sp. bin. Mag. 4.3. Spc. B. Per. 7.9 ds.

Σ618 045663 D: 7-7.3. Sep. 32″.0. Vivid 8-8 doub. *s.*

H53 040160 Pl. neb. Small, curious, with star center.

ξ 045660 Mag. 4.7. A monarch in lone splendor.

11-12 045858. Wide doub. Sep. 10″.3.

1 042553 D: 5.1-6.2. Sep. 10″.1. Varied region *s e.*

7 044953 D: 4.4-11.3. Sep. 25″.6. Prim. Sp. bin. Spc. A. Per. 3.8 ds.

PERSEUS:

H61 040951 Radiant Cl. Entire zone truly inspiring.

OΣΣ47 041450 D: 6.5-7.2. Sep. 74″.6. Each sun has a low-mag. *come.*. Striking expanse p.

b 041050 Sp. bin. Mag. 4.5. Spc. A2. Per. 1.5 ds.

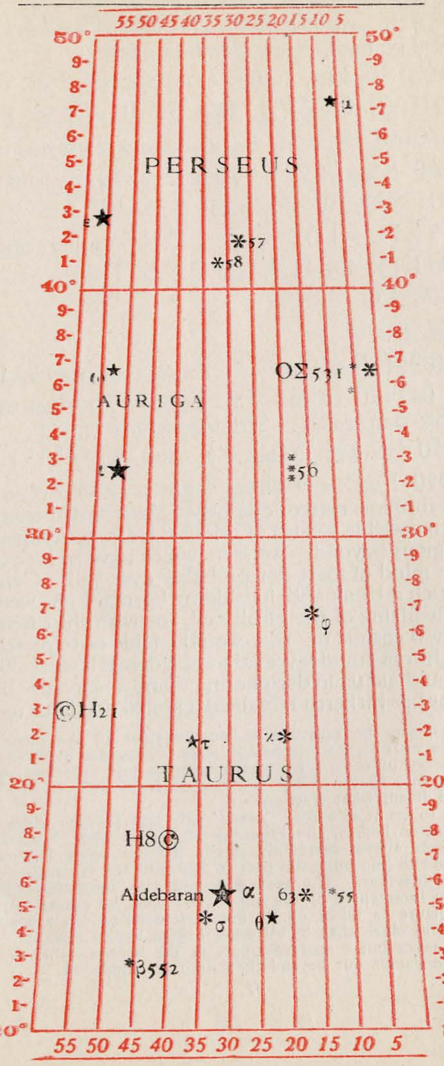
D 043050 Dark nebulous region. A vast obscuring sweep of formless meteoric or other absorbing media that obscures a possible wealth of celestial treasures lying in remoter regions beyond — wonders which have never yet entered the mind of man, nor probably ever will. Contemplating such a bleak and forbidding barrage, one wonders if with the lifting of the black veil, (or with the discovery of some new cosmic ray that would enable us to pierce it), there might not stand revealed some sidereal Rosetta Stone which would aid us in deciphering many a heavenly hieroglyph that has hitherto remained a sealed oracle to us.

The stars may be regarded as heat engines in the physicist's sense of the word—on an enormous scale. They are drawing upon internal energy of some sort, transforming it into heat and radiating it away into space. What becomes of the heat? Is any of it "used" and if so, what fraction?

If we are to count as energy "used," only that fraction which falls on other known bodies, the efficiency of a star—and in particular of the Sun—is almost incredibly small. Of the whole flux of radiation from the Sun only one part in 230 millions is caught by all the planets together. The rest goes out into interstellar space. The fraction intercepted by the other stars must be excessively minute. Far more is taken up by the dark nebulae—on account of their enormous size—than by all other known bodies together. But even these cover but a moderate part of the heavens, and most of the radiation passes out beyond them into the unknown.

CHART 5 - B

V CULMINATION - 9 P.M., JAN. 13 IV



PERSEUS:

μ 040748 D: 4.2-12. Sep. 15".1. *Chart 5-B*
Prim. Sp. bin. Spc. G. Per. 284 ds.
Interesting cluster, H60, 2° n p.

57 042742 Wide D: 5.2-6.2. Sep. 113".7

58 043141 Mag. 5.5. Two pretty pairs near by.

OΣ531 040237 D: 6.5-8-2. Sep. 4".5. Gems, s and p.

56 041933 D: 6-8.8. Sep. 4".5. Impressive environs.

AURIGA:

Begins abt. midway bet. hrs. IV and V. Fruitful fields ·

ε 045643 Conspicuous Var. 3:4.5.

ω 045337 D: 4-7.9. Sep. 6".5.

ι 045133 Mag. 2.9. Superb sun in lone grandure.

TAURUS:

The constellation of the Bull discloses here a treasure region. including that blazing V-shaped open Cluster—the Hyades—a hundred blue-white Class A suns, golden solar and red Antarean giants. Diam., 10 parsecs. Dist. 130 l y.

φ 041527 D: 5-8. Sep. 53".6.

H21 045923 Nebulous Cl. Entire zone appears enveloped in lambent clouds of cosmic dust.

τ 043622 Vivid D: 4.3-7.2. Sep. 62".5. Prim. Sp. bin. Spc. B5. Per. 1.5 ds.

χ^{1-2} 042022 D: 5-6. Sep. 5".5. Resplendent range s p.

H8 044118 Impressive Cl. About 2° n f Aldebaran.

α Aldebaran 043116 Mag. 1.6. Par. 0".057. Dist., 57 l y. Ang. diam., 40,000,000 miles! Spc. K5. Mag. 11 comes.

63 041716 Mag. 5.6. Sp. bin. Spc. A2. Per. 8.4ds.

55 041416 Vis. bin. 7.5-9.3. Go. 0".57. Per. 89ys.

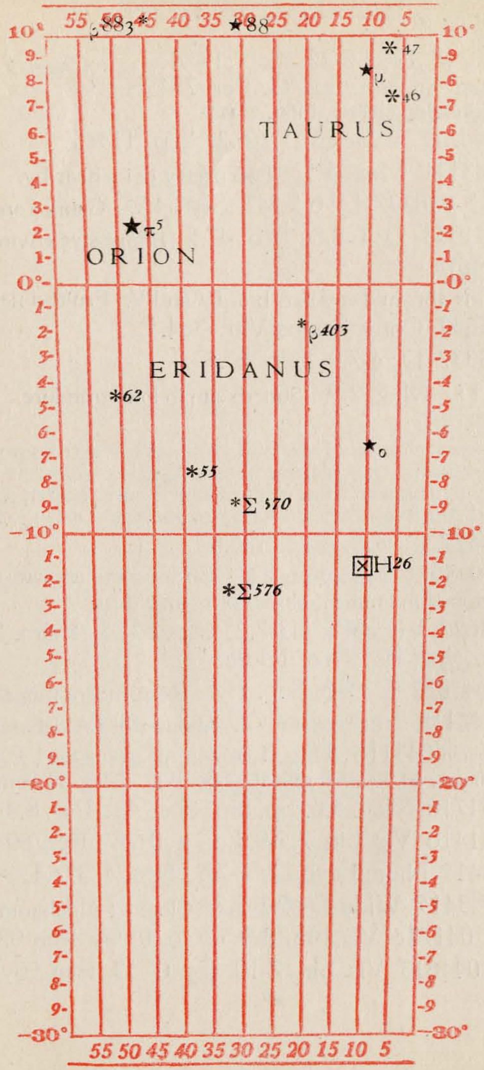
θ 042415 Naked-eye D: 4-7.5. Sep. 5' 37".4.

σ^{1-2} 043415 Wide D: 5.2-5.7. Close s f Aldebaran.

OΣ82 041714 Vis. bin. 8-9.5. Go. 0".94. Per. 98y.

β552 044613 Vis. bin. 7-10. F5. 0".53. Per. 56yrs.

VI CHART 5-C V
CULMINATION 9 P. M., JAN. 13



TAURUS: *Chart 5-C*

88 043110 D: 4-7.5. Sep. 69″.2.

47 040909 D: 5-8. Sep. 0″.9 Close n p μ Tauri. 9-mag. comes, dist. 31″.5.

46 040907 D: 5.8-6.1. Sep. 0″.1. 1° s p μ Tauri.

ORION:

West boundary of the imperial constellation of the firmament! For who would acquire a knowledge of the heavens in little, let him give up his days and nights to the marvels of Orion. Here may be found every conceivable variation of celestial phenomena: stars, giants and dwarfs; variables, doubles, triples, multiples; binaries visual and spectroscopic; clusters wide and condensed; mysterious rayless rifts and nebulae in boundless variety, with the supreme wonder of all supernal wonders at its heart — the Great Nebula—before which the learned and the laymen alike have stood silent in awe and reverence since the first lens unfolded to man's gaze its true vastness and intricacy; and which offers abundant field for all the geniuses of science, with their super-refinements of means and methods, for generations to come. To know Orion is to know astronomy!

**"When all the Temple is prepared within,
Why nods the drowsy worshipper outside."—Rubaiyat.**

β883 044510 Vis. bin. 7.9-7.9. Sep. 0″.19. Per. 16.61 yrs. Spc. F5.

π5 044902 Mag. 3.8. Spec. bin. B3. Per. 3.7 ds.

ERIDANUS:

Delta of the River Po which winds upward from sub-horizon regions as far as Rigel, in Orion; and tho low in our latitudes, with good seeing, offers some real surprises

β403 ***042102*** D: 7-8.5. Sep. 2″.0.

62 ***045205*** D: 6-8. Sep. 66″.0. Other D's in rare zone

ο2 ***041007*** D: 4-9.4. Sep. 82″.3. Com. Vis. bin. 9.4-10.8. α = 4″.79. Per. 180 y. Group apparently concrete

55 ***043908*** D: 6.2-6.7. Sep. 9″.1.

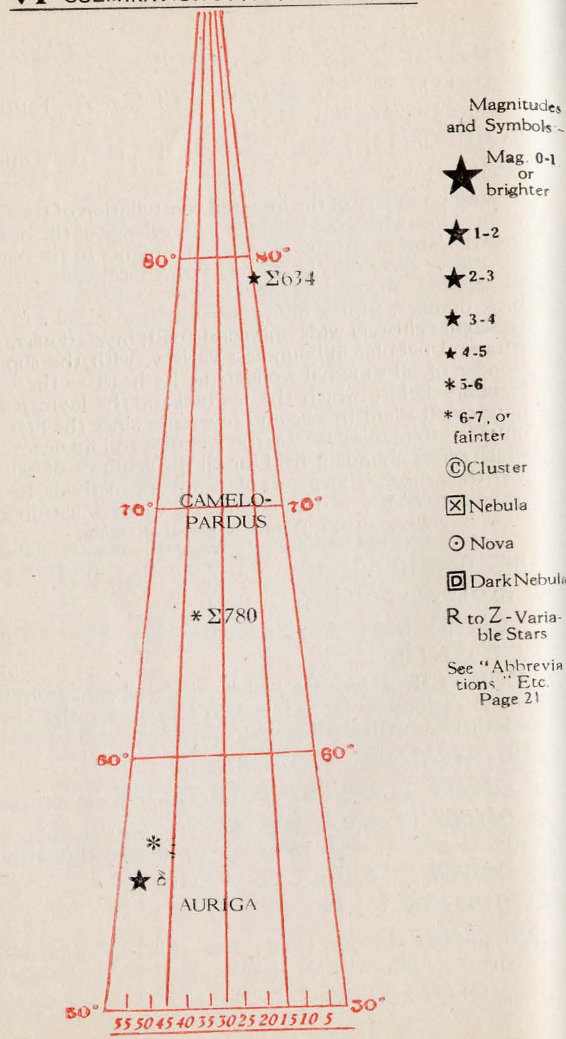
Σ570 ***043109*** D: 7-8. Sep. 12″.8.

H26 ***041012*** Bright plan. neb., with central star. Unique, visible with low powers Well worth the search

Σ576 ***043413*** D: 6.7-7.2. Sep. 12″.3.

CHART 6-A

VI CULMINATION 9 P. M., JAN. 28 V



CAMELOPARDUS: *Chart 6-A*

Σ634 050979 D: 4.5-8. Sep. 34″.

Σ780 054365 Trip.: 6.7-7.9-10.9. Colorful.

AURIGA:

Vast area, southern expanse a limitless exploration field.

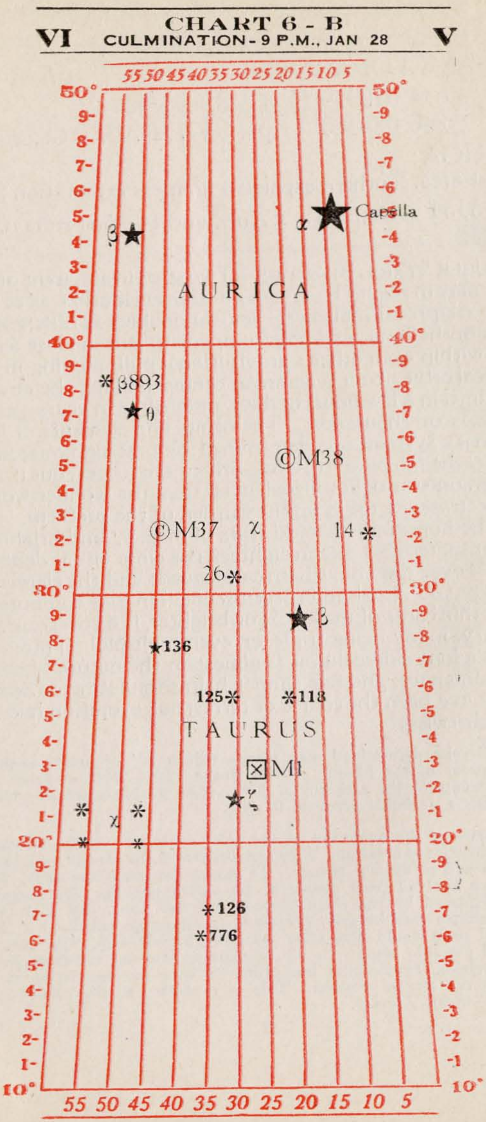
δ 055354 Mag. 2.1. ξ Aur., and two fine stars n.

DOUBLE STARS-BINARIES. – Two stars in apparent proximity may in reality be so remote from each other as to exert no reciprocal influence—optical doubles as differentiated from the binaries whose components are so close as to come within each other's gravitational pull, moving in an elliptical orbit about a common center, making the circuit sometimes in a few hours or days, more often in years—even hundreds or thousands. The orbits and elements of visual binary systems are determined by precision micrometers attached to powerful clock-driven telescopes; but if the companion-star defies visual detection, the wonder-working spectroscope takes up the burden of the problem.

Of the hundred thousand stars of mag. 9, and brighter, it is estimated that one in eighteen is a close visual double. Of these over 5000 have been catalogued: and the elements of nearly 300 visual and spectroscopic binaries computed. Every third star of mag. 5.5, or brighter, is a spectroscopic binary, many being triple or even multiple! Thus our Sun as a lone sidereal unit is almost in the nature of a celestial anomaly; and one cannot help speculating on what would have been the course of terrestrial evolution had it been otherwise!

The Greeks determined star places within 10′ of arc—one-third the diameter of the Moon. Tycho Brahe (1546-1601) reduced the measurements to the accuracy of 57″. Now double stars are measured with a probable error of 0″.001.

"Theories of the evolution of the solar system or of the universe are not theories of creation. They are theories of the eternal processes going on and of eternal change. To assert that stars are suns, that suns have evolved from clouds of gas called nebulae, that nebulae have originated by the close approach of two suns, and that in a spiral nebulae may be seen processes in operation which in a long period of time would give solar systems like our own, with central suns and possible planets, is not to offer a theory of creation, genesis, or original beginnings; but rather to state our conviction as to stages in the eternal process. This is evolution as the astronomer sees it."—*Prof. Linsley.*



AURIGA: *Chart 6-B*

α Capella 051145 Mag. 0.21. Spc. G. Par. 0".075. Dist. 43 l y. Sp.bin. Sep. 0".045. Per. 104ds. 33×Sun's brightness. Ang. diam. 10 million mi. Temp., 12,600°F. Abs. mag., —0.5. Rad. vel., +30.2. Abbot.

β 055444 Mag. 2.7. Var. Sp.bin. Per. 3.96d. Spc. Ap. Par. 0".34. Vel.—18.1. Comb. mass, 17 × Sun.

β893 055938 Mag. 5.3. Sp.bin. Per. 28.2d. Spc. A.

M38 052335 Open Cl. in form of an oblique cross. Commanding semicircle of Cls., units and multiples, s.

14 050832 Tr.: 5.1-7.2-11. Prim. Sp.bin. Per. 3.8d.

M37 054732 A diamond sunburst! 20,000 stars.

χ 052632 Mag. 4.8. Sp.bin. Per. 655.16ds. Spc. F

26 053330 D: 5.8-8. Sep. 12".3. Faint *comites*.

TAURUS:

Fairly bristles with phenomena of a rare order of interest.

β 052128 Mag. 1.8. Super-giant in kingly isolation.

136 054727 Mag. 4.5. Sp. bin. Per. 5.9 ds. Spc. A.

125 053325 Mag. 5. Sp. bin. Per. 27.8 ds. Spc. B_3.

118 052425 D: 5.8-6.6. Sep. 4".7. Blue-white.

M1 052922 Famous "Crab Nebula" of Lord Rosse (the analogy presupposed a strong Irish imagination), fairly defined tho pale, easily found 1° n p ζ Tauri. "Bears resemblance to planetary class in some respects, and to irregular gaseous nebulae in others, with central star of Wolf-Rayet type." Reynolds. First object to induce Messier, in 1758, to compile his immortal Catalog with a 2½-in. comet-sweeper!

"Far less power will reveal a celestial object that was required for its discovery. Far more depends upon the man behind the eye-piece than upon any instrument however perfect or efficient in practice."

ζ 052121 Mag. 3. Sp. bin. Per. 138 ds. Spc. B_3.

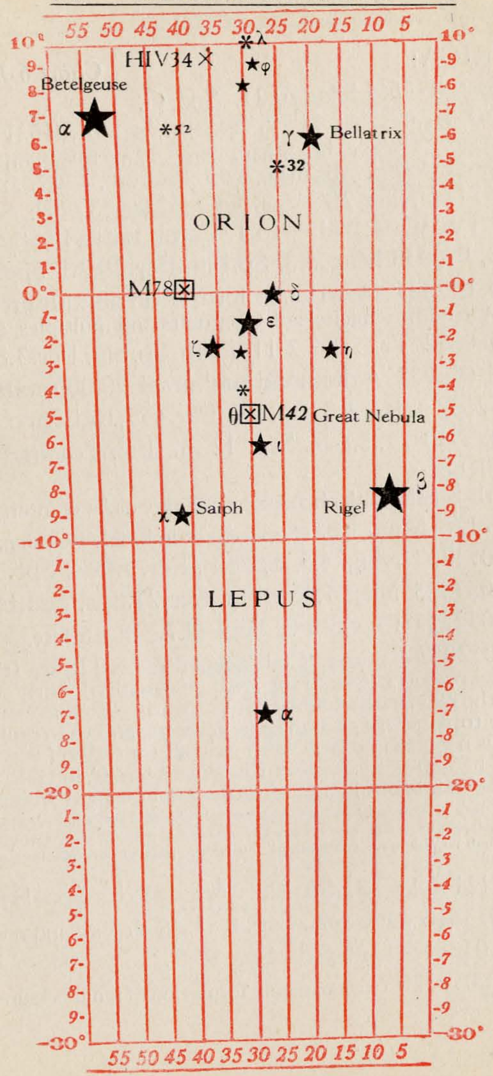
126 053616 D: 6-6.2. Sep. 0".3. Sweep s e and n w!

Σ776 053815 D: 6-8.8. Sep. 9".6.

$\chi^{1\text{-}2\text{-}3\text{-}4}_{\text{Orionis}}$ 055520 Curious geom. formation of mag. 5-9 suns.

VI **CHART 6-C** V

CULMINATION 9 P. M., JAN. 29



ORION: *Chart 6-C*

HIV34 053709 Pl. Neb. Clear, bluish.

λ 053009 D: 5-9. Sep. 4″.2. φ^{1-2} *s* and *s f* in field.

α Betelgeuse 055107 Mag. 0″.9. Sp. bin. Per. 6 yr. Aitken. Spc. Ma. Temp. 9000°F. Par. 0″.022 Yerkes. Dist. 1921 y. Brightness, 1000; vol., 50 million × Sun. Eddington. Density 1-1000 of air. Hale. First Michelson interferometer test: Ang. par., 0″.047: 250 million miles, or nearly 300 × diam. of Sun! R.v., +21.3 km-sec. Abbot. Irreg, Var., ½mg. Cannon.

52 054306 D: 6.2-6.2. Sep. 1″.7. 2° *s p* α Orionis.

γ Bellatrix—Female Warrior 052106 Mag. 1.7. B2. 0″.002.

32 052605 D: 5.2-6.7. Sep. 1″.0. Impressive pair!

M78 054200 Weird gas. neb. North edge clean-cut, south portion diffuse. Interesting! Sweep *e* from δ Ori.

δ 052800 D: 2-6.8. Sep. 52″.0. Par. 0″.006. Spc. B. Prim. Sp. bin. Per. 5.7 ds. Greenish; slightly variable.

ε ***053201*** Mag. 1.8. Spc. Bo. Central sun in O's belt.

ζ ***053702*** D: 2.-5.7 Sep. 2″. Spc. Bo. Par. 0″.008.

σ ***053402*** Quad. 4-10: 7.5-7. Thrilling neb. region!

η ***051902*** D: 3.4-5. Sep. 1″.0. Prim. Sp. bin. Per. 8 ds. Spc. B1. Helium stars involved in calcium clouds.

θ-M42 ***053105*** Great Nebula! Dist. 650 l y; diam. 5 to 61 y: 30 to 40 million million mi. Bailey. Surface area, + 500,000 ast. units; depth likewise. Enough matter to form a star cluster! Russell. (Cont'd, p. 59. See Lick Obs. photo, Ill Sec.)

ι ***053006*** Neb. D: 2.8-7.3. Sep. 11″. Prim. Sp. bin. Per. 29 ds. Spc. Oe5. Σ747 close *f*. D: 5.6-6.5. Sep. 36″.

β Rigel ***050908*** Mag. 0.3 Spc. B8. Par. 0.006. Dist. 543 l y. Blue-white. Temp. 16,000C. 13,000 × Sun's brightness. Ang. diam., 17 million mi. R.v., +22.6 km-sec. 8th.-mag. comes. dist., 9″. Arab., Rijl-el-Janza: Leg of the Giant.

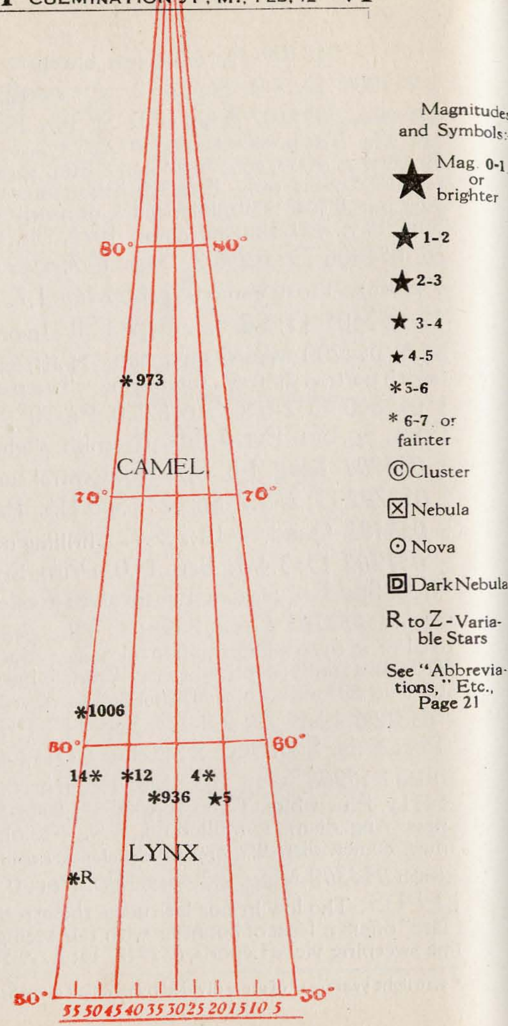
κ Saiph ***054309*** Mag. 2.2. Spc. Bo. Par. 0″.0069.*

LEPUS: Tho low in our latitudes, the asterism of "The Hare" offers a feast of bounties with fair seeing, especially fine sweeping vic. α Leporis, ***052917***, D: 2.7-9.5, Sep. 35″.4.

* 3.26 light years—1″ of arc—divided by parallax gives Star's distance.

CHART 7-A

VII CULMINATION 9 P. M., FEB. 12 VI



CAMELOPARDUS: *Chart 7-A*

Σ973 065375 D: 6.6-7.6. Sep. 12″.

Σ1006 065962. D: 7-8. Sep. 30″.6.

LYNX:

A scattering constellation with few conspicuous units but "the beauty of its pairs will reward perseverance."

14 064659 D: 5.7-9.1. Sep. 0″.9. Field inviting.

4 061559 D: 6.4-7.9. Sep. 0″.8.

12 063959 Superb Tr.: 5.2-6.1-7.4. Sep. 1″.5-8″.7.

5 062058 Mag. 5.5. A pendant ruby!

Σ936 063258 D: 7-8.7. Sep. 3″.4.

R 065555 Var. 8: 13.8. Per. 379.3d.

GREAT NEBULA OF ORION. (Cont'd from p. 57).

Disc. by Huygens, 1756. "Chiefly a superficial florescence of gaseous elements in a small region of an inconceivably great cloud of cosmic dust driven to and fro in never-ceasing currents." Hale. Most primitive form of matter known, as Aitken says, "in seething and well-nigh chaotic turmoil." Shapley records some hundred Variables associated with the Nebula as a whole. Delicate emerald. The famous Trapezium, comprising four involved giants—mag. 6, 7, 7.5 and 8, respectively—thrilling beyond words! Study this Nebula well during Orion's winter culminations.

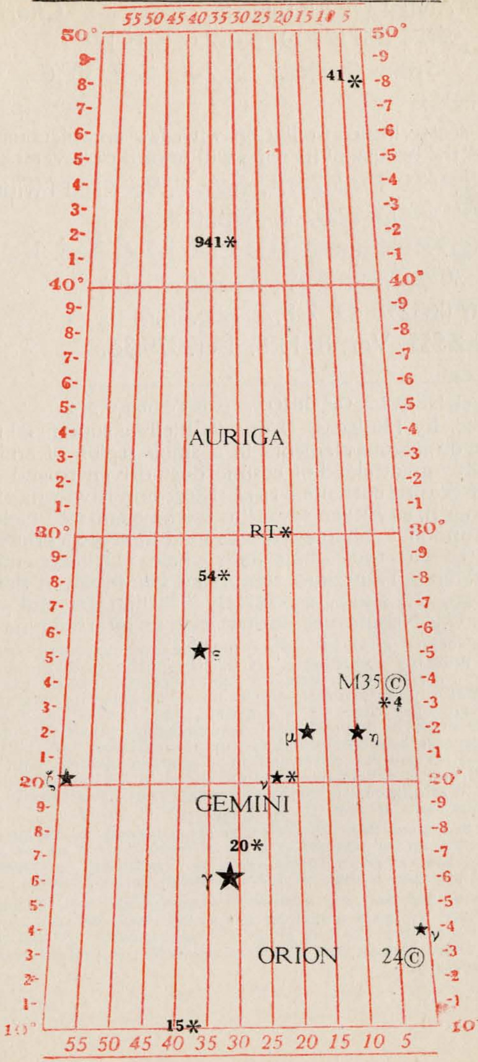
The surface areas of diffuse nebulae are enormous, and the depth probably accordingly. If but one-millionth of the density of our atmosphere, so vast are they that they would exert an appreciable gravitational effect upon neighboring stars; but since no such effect is discernible, the tenuity of nebulous masses must be beyond our comprehension, presenting one of the greatest unsolved problems in astrophysics. If the small residual air-content contained in a common electric light bulb—itself almost a vacuum—were expanded to the size of the capitol at Washington, it would scarcely express the tenuity of a nebulous mass as seen in the immensity of Orion.

The two green lines attributed to the nebuleum in the spectrum are not due to the presence of a gas to which there is no terrestrial analogy, but rather to known gases in "forbidden" combinations: ionized nitrogen, ionized oxygen and doubly ionized oxygen.

Gaseous nebulae are extremely tenuous, observes Eddington. When there is space enough to put a pin's head between adjacent atoms we can begin to talk about a "real vacuum." At the center of the Orion Nebula that degree of rarefaction is probably reached and surpassed.

VII CHART 7-B **VI**

CULMINATION 9 P. M., FEB. 12



AURIGA: *Chart 7-B*

41 060548 D: 5.2-6.4. Sep. 8″.

Σ941 063341 D: 7-8. Sep. 8″.

RT 062330 Algol type Var. 5:5.6. Per. 3.75d.

54 063428 D: 6-7.8. Sep. 2″. Environs enticing.

GEMINI:

The constellation of The Twins begins about the sixth hour, R. A.,—an embarrassment of riches in every quarter.

ε 063625 D: 3-9.5. Sep. 110″.6. Blue and white.

M35 060324 Cl. "Strikingly beautiful!" Sweep s-e.

4 060523 D: 6.3-6.4. Sep. 0″.4. Close n p η Gem.

η 061022 Var. 3.2:4. Per. 231 d. Mag. 10 comes.

μ 061822 D: 3-11. Sep. 73″. Difficult. Region rich.

15 062320 D: 6-8. Sep. 29″. 1′ n ν Gem.

ν 062420 D: 4.2-8. Sep. 112″.6. Double comites.

ζ 065820 Ceph. var. 3.7-4.5. Per. 10 15 d. Sp, G.

20 062717 D: 6-6.9. Sep. 20″.

γ Alhena, the Circlet 063316 Mag. 1.9. Sp. bin. Spc. A. Long per.: 2175 d. —6yrs.! Par. 0.″05. Framed in jewels

ORION:

ν 060114 Spec. bin. Mag. 4.4 Spc, B2. Per. 131d.

HVIII 24 060413 Cl. Triangular, with 6-mag. D, and other beautiful features. Worth study. Close s ν Orionis.

MONOCEROS:

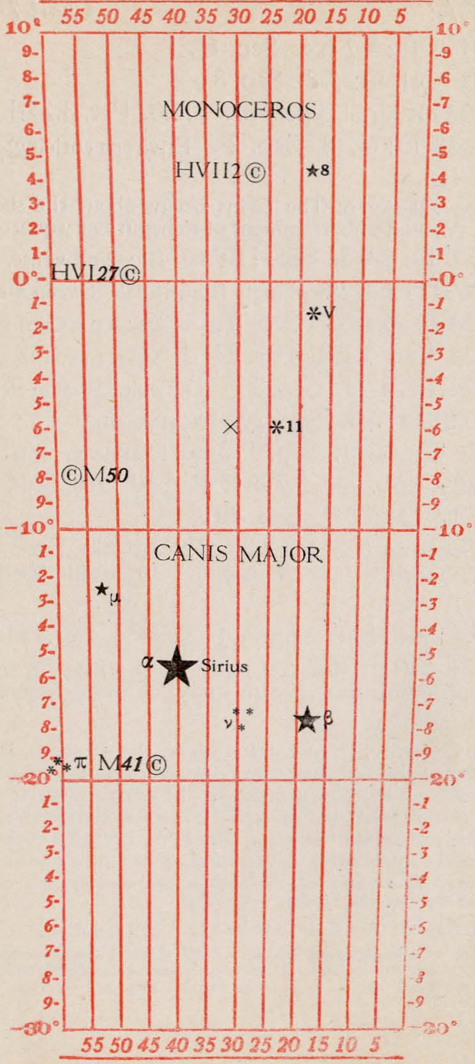
Unaided visually, the constellation of the Unicorn, beginning at this hr., appears unimpressive: but astronomically it holds an important place in the annals of galactic research, proving that the more famous constellations have no monopoly of stellar marvels. This one presents varied beauties and complexities. Even random sweeping charms.

"Unexpected by-products of observations are scarcely less important than the foreseen results."—Campbell.

15 063610 Striking Tr. 6-9-11. Very colorful.

"The work of a scientist is discovery. All research has discovery for its aim, if not for its end. Discovery is merely scientific work which has the good fortune to produce definite results."—Curtis.

VII **CHART 7-C** VI
CULMINATION 9 P.M.. FEB. 12



8 061904 D: 4-6.7. Sep. 14″. *Chart 7-C*

HVII2 062804 Pearl Cl. Mag.-6 star almost involved in naked-eye sunburst.

HVI27 064700 Cruciform Cl. Amazingly bright.

V ***061702*** Var. 7.2-13. Per. 334.7 d.

× ***063206*** Plaskett's monster Double! Mag. 6.6. Mass, 75.6 and 63.2 × Sun. Per. 14.4d. Spc. O8. Dist. 10,000 l y. "Most massive and absolutely the brightest star whose elements are known with fair certainty. Temp., 28,000° C. Every square centimeter of surface emits sufficient energy to run a locomotive at full speed for millions of years!" (Jeans)

11 ***062406*** D: 5-5.6. Sep. 7″. Herschel's wonder!

M50 ***065908*** Fine Cl. Blood-ruby star in center.

CANIS MAJOR:

The main features of The Greater Dog lie within these hours—a rather limited domain, nevertheless charming.

μ ***065213*** D: 4.7-8. Sep. 3″. Ruby-topaz. Cl. 1 4 1° f.

α Sirius, the Scorcher ***064016*** Vis. bin. —1 6-8.5. α = 7″.5. Per. 49.3 y. Par. 0″.37. Dist. 8.9 l y. Spc. Ao. Mass of Sirius, 2.56, and brightness, 30 × Sun. Weight, 1 ton per cubic inch! Eddington. Inconceivably high velocity in space, yet has moved only the Moon's breadth since the time of Ptolemy. Surface temp. 18,000° F. Were it as close to us as our Sun, it would consume the earth instantly!

But the "white dwarf" companion to Sirius presents the supreme celestial paradox. Only thrice Earth's diameter, its mass exceeds it 250,000 times; density, 4000 times lead, 50,000 times water; and surface gravity, 35000 Earth's. A man on this eighth-mag. star would weigh over 2600 tons! Sirius and its companion "presents facts which, as Campbell says, 'we are at present powerless to explain.'" Aitken

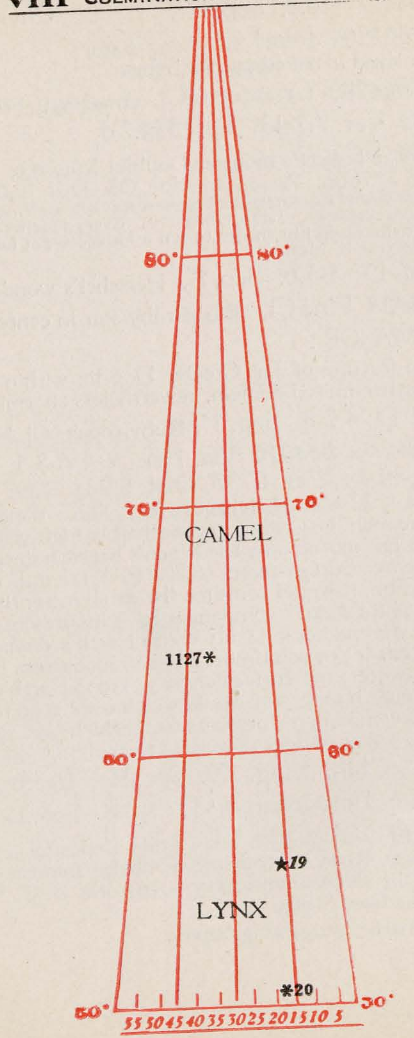
β ***061818*** Sp. bin. Mag. 1.9. Spc. B1. Per. 6 yrs.

ν^{1-2-3} ***063218*** Fine group. ν^1 D: 5.7-8. Sep. 17″.5.

M41 ***064320*** Naked-eye Cl. Truly imposing, even with low power. Ruby central star. Probably faintest object recorded in classical antiquity—Aristotle, B. C. 320. 4° almost due s from Sirius.

π^{1-2-3} 2° f, another gorgeous grouping.

VIII CHART 8-A **VII**
CULMINATION 9 P. M., FEB. 28



Magnitudes and Symbols:-

★ Mag 0-1 or brighter

★ 1-2

★ 2-3

★ 3-4

★ 4-5

* 6

* 6-7 or fainter

Ⓒ Cluster

☒ Nebula

⊙ Nova

D Dark Nebula

R to Z - Variable Stars

See "Abbreviations" Etc. Page 21

CAMELOPARDUS: *Chart 8-A*

Σ1127 073964 A pleasing Tr.: 6.2-8-9.2, Sep. 5″-11″.3.

LYNX:

19 071655 D: 5.3-6.6, Sep. 14″.7.

20 071650 D: 6.6-6.8, Sep. 15″. Most requiting region of this odd and rather featureless constellation.

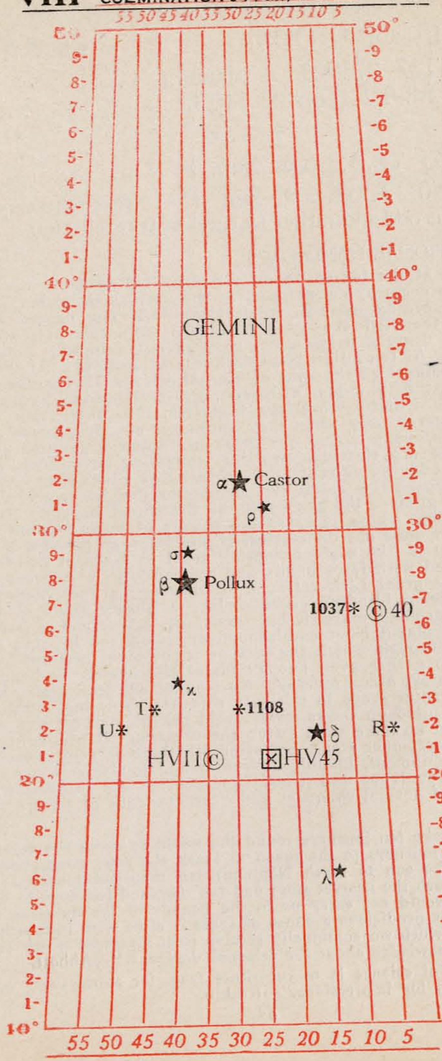
OBSERVATIONAL HANDICAPS.

We live at the bottom of an air-ocean 200 miles in depth—but only as deep, by comparison, as the varnish on a new golf-ball. Proceeding upward, temperature falls one degree with every 300 feet till the vast enclosing isothermal region is reached—60 degrees below zero, varying only slightly summer and winter. At ten miles, total darkness at noonday. At thirty miles is encountered the zone of eternal silence. Oxygen ceases to exist. At fifty miles, nitrogen; at two hundred, hydrogen and helium. Etheric vibrations transform into heat, light and electrical energy only when they encounter air, dust-motes and vapor in suspension. And yet these molecules of infinite variety and size are shifting, sworling, pulsating in swarms and clouds and eddying currents through all this enveloping ocean; and it is through this refractive complexity that we must strain our eyes to glimpse the glories of the firmament beyond! It is no wonder that as we increase the powers of magnification we likewise compound our difficulties. In my ten-inch reflector Mars at opposition is like a great floating pearl in a sea of cerulean glory, webbed with faint bands and nubbed with a snowcapped pole. In the great Lick refractor it looms up a vast, flaming, pulsing blurr of blinding crimson—like a bloody aegis of the Olympian war-gods, majestic but terrifying, a true god of battle with all his placid front emblazoned and distorted by this sea of troubles through which the human brain must perforce project itself to gather even enough material whereon to hang a theory and start a controversy. No wonder we seek high plateaus and remoter crags to mitigate this hardship; but a thousand Pelions piled on Ossas, even could mortal man survive the height, would no more than soften the sentence: it would in no wise set the prisoner free. So, after all, there is compensation in modest equipment, humble housetops and lowly open spaces, leaving to providence and a good imagination the fulfilment of our dreams of spacial conquest and "the evidence of things not seen."

"It would take ten journeys round the world to reach the moon; four hundred journeys to the moon to reach the sun; twenty-eight journeys to the sun to reach Neptune; ten thousand journeys to Neptune to reach the nearest star; and ten thousand journeys to the nearest star would not carry us to the bounds of the universe of stars. All this prodigious expanse of space is alive with interesting objects from which we continually receive light messages which tell a wealth of knowledge about the celestial denizens."—Abbott.

"The work of science is to substitute facts for appearances and demonstrations for impressions."—Ruskin.

VIII CHART 8-B VII
CULMINATION 9 P.M., FEB. 28



GEMINI: *Chart 8 - B*

Richest region of the zodiacal "Twins," a dazzling exploration field for the gem-hunter.

α Castor 072932 Vis. D: 2-2.8. Sep. 5″. Per. 346.8 y. Each a Spec. Bin. Pers. 2.92 and 9.21 ds Spc. A. Foremost of the Doubles in Herschel's list—"the one in which the fact of orbital motion was first demonstrated." Aitken. Each component six times more brilliant than our Sun would at a like distance—vastly larger tho inconceivably less dense. Rad. vel., 7.14 km.-sec. Par. 0″.86. A'den. Dist. 38 lt. yrs. Beautiful orange-blue pair for small glass.

ρ 072431 D: 4.2-12.5. Sep. 2″.8. 1° p Castor.

σ 073729 Sp. bin. Mag. 4.6. Sp. K. Per. 19.6d.

β Pollux 073928 Mag. 1.2. Spc. Ko. Par. 0.″095. Lundmark. Dist., 34 l y. Approx. diam., 14 million mi. Stetson.

Σ1037 070727 D: 7-7. Sep. 1″. Cl. 40 Gem. 1½° p.

χ 073924 D: 4-8.5. Sep. 6″. Impressive region!

T 074423 Var. 8:13. Per. 288d.

Σ1108 072823 D: 6.7-8.5. Sep. 11″.6.

R 070222 Var. 6.4:13. Per. 370d.

δ 071522 D: 3.2-8.2. Sep. 7″.

U 074922 Irreg. var. 8.9:14. "An enigmatic star!" Furness. Constantly watched for sharp and thrilling changes.

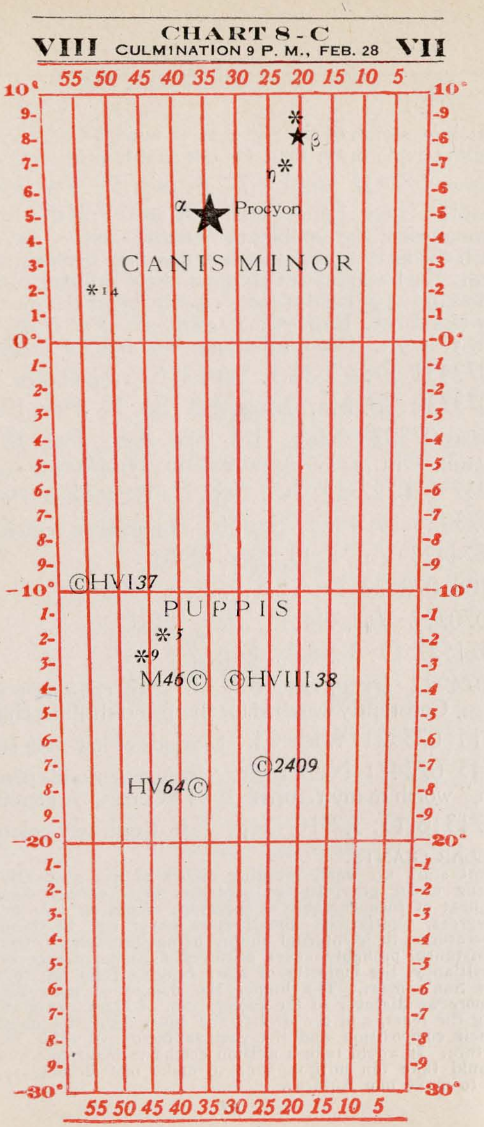
HVI1 073321 Wide Cl. Myriads of low-mag stars.

HV45 072421 Neb. unit. "Very remarkable phenomenon," worth many returns. 2° s f δ Gemin. A gem-field!

λ 071316 D: 3.2-10. Sep. 9″.6. Contrasty colors.

STELLAR GIANTS.

Giant stars are vast, seething globes of gas gradually contracting under gravitational pressure, their energy converted into heat of inconceivable temperature mounting into millions of degrees, Centigrade. Small stars never rise to these high temperatures, their internal energy being insufficient. Our Sun, for instance, probably never achieved a Sirian degree of heat or brilliancy, the majority of stars ranging from ten to thirty times Sun's mass. The higher the degree of incandescence, the more we discover of the composition of stars, the giants offering the least, and the dwarfs the most, difficult problems as to their composition and the various factors of their internal structure. It would take a million earths to make one sun; but it would take ten million suns to make one Betelgeuse, and forty to make one Antares.



CANIS MINOR: *Chart 8-C*

"The Lesser Dog" is a compact asterism, lying almost wholly between these Hrs., bounded on the south by the Celestial Equator. Many worthies to look up.

β 072208 Mag. 3.1. Prince of a resplendent court of suns of high and low degree, finely placed for leisurely study.

η 072307 D: 5.7-11. Sep. 4″. Ghostly nebulous!

α Procyon 073505 Bin.: 0.5-13.5. $a=13''.5$. Sp. F5. Par., of Procyon, 0″.315. Dist. 10.6 l y. Closest of high-mag. stars save Sirius. Luminosity, 7 × Sun. Surface temp., 8300° C. Rad. vel.,—3.5 km-sec. Pale topaz. Companion visible only in the larger telescopes—disc. at Lick Obs., '96.

"The interior temperature of a star is surprising—from two to twenty million degrees, Cent., at the center! Do not imagine that this degree of heat is so vast that ordinary conceptions of temperature have broken down. These temperatures are to be taken literally. Temperature is a mode of describing the speed of motion of the ultimate particles of matter."—Eddington.

14 075402 Notable Tr.: 6-8-9.

PUPPIS:

The poop of the good ship Argo is brilliantly beaconed in this quarter and on southward as far as your latitude insures fair seeing, high altitudes having great advantage.

HVI 37 075610 Colossal silvery star-cloud. Seen best with low power ocular. "Vicinity gorgeous!" Webb.

5 ***074412*** D: 5.3-7.4. Sep. 3″.3. Sapphire and gold.

9 (β 101) ***074713*** Vis. bin.: 5.8-6.4. $a=0''.69$. Sp. Go. Per. 23.34 y. Barely one in twenty of the visual binaries shows this stupendous speed about a common center.

M46 ***073814*** Annular star-cloud, 30′ in diam.

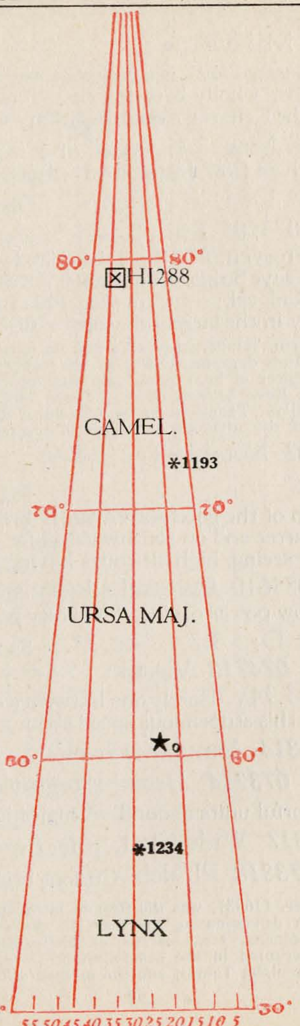
HVIII 38 ***073214*** Broad integration of mag. 5-9 suns. Colorful units abound. A majestic zone thruout.

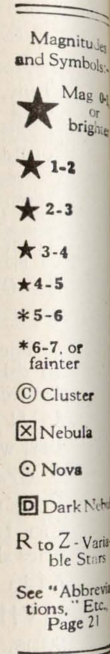
2409 ***072817*** Wide Cl. L. p. for these fine sweepings.

HIV64 ***073818*** Pl. Neb. Curious bright opal.

Johann Bayer, (1603), was the first to introduce the Greek alphabet system in denominating the stars in the order of magnitude, alpha, beta, gamma, etc., instead of distinguishing them by the places they occupied in the constellations, (Oculus Tauri, for instance, became alpha Tauri), and the method still obtains.

IX CHART 9 - A VIII
CULMINATION 9 P. M., MAR. 15





CAMELOPARDUS: *Chart 9 - A*

H I288 084478 Neb. Conspicuous in a dull expanse, with faint nucleus.

Σ1193 081272 D: 6-9. Sep. 44″.

URSA MAJOR:

Most familiar of the circumpolar constellations, enclosing within its spacious confines the Big Dipper which occupies nevertheless a mere tenth part of the Great Bear's extended domain. "Offers a large field to the persevering observer," Webb.

A circle of stars whose radius is about forty degrees, with the North Pole at its center, is always visible in our latitudes. A similar circle, with the South Pole at its center, is never visible here. The remainder of the celestial sphere is observable during rotational intervals.

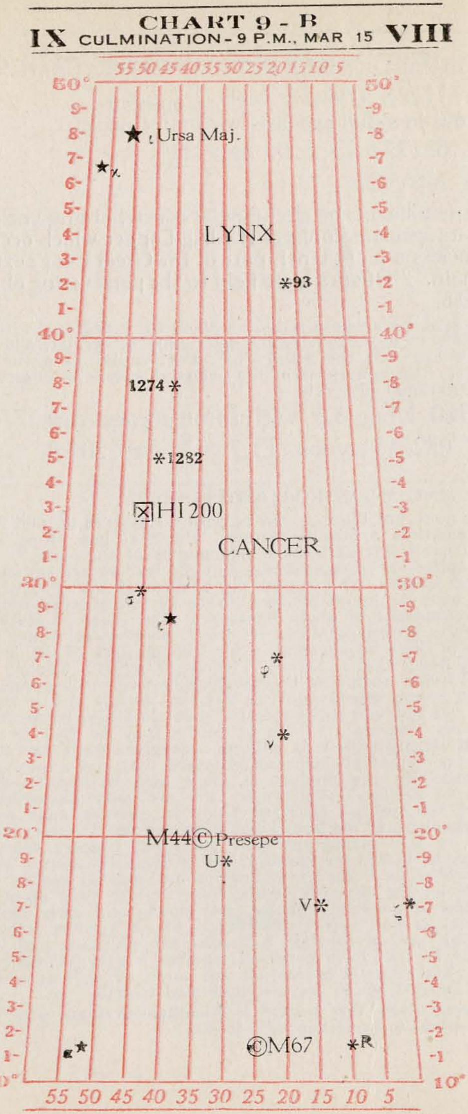
ο 082360 Mag. 3.5, with faint comes, dist. 7″.

Σ1234 082755 Lyncis D:7-8.3. Sep. 20″.8.

COLLECTING AN ASTRO-PHOTO LIBRARY.

"Since none but the rich can possess themselves of 'Old Masters'," remarked a famous painter, "the next best thing is to surround one's self with good photographs of the same." And his fine collection of reproductions of the leading schools of ancient and modern art attested the wisdom of his observation. So, too, with the lay-astronomer: since he cannot avail himself of the advantages of great telescopes, like those of Harvard, Yerkes, Mt. Wilson, or Lick, it is still possible to secure photographs of celestial phenomena by such masters of the art as Barnard, Bond, Curtis, Richey, Duncan, Ellerman, Keeler, and a host of others including the products of foreign observatories —striking enlargements showing intricate details and a thousand and one refinements of celestial splendors beyond the reach of ordinary instruments. These prints may be had at low cost; and although there is nothing that gives quite the thrill of some far-distant phenomenon glimpsed with one's own telescope—especially the product of one's own handicraft—these triumphs of celestial photography are not only beautiful as works of art but are constant helps in observational work. What is known as "the knowledge after the fact" is very valuable; for a fine photograph will point out obscure features which may be looked for visually, and perhaps discovered, since one is coached as to the exact location and general aspect. By all means let the observer secure from time to time excellent photographs of clusters, nebulae, star-clouds and other remote phenomena, as well as the closer units of our system, eclipses, occultations, auroral displays and cometary visitants, and in a short time he will have gathered together a very valuable library for his personal edification and profit as well as a rare source of entertainment for his interested friends.

"Men must know that science is beautiful—to those who will train themselves to appreciate it."—Bowley.



ι 085348 D:3-10. Sep. 8″.3. Difficult. *Chart 9-B*

κ 085847 D:4-4.2. Sep. 0″.2. Jewels!

LYNX:

OΣΣ93 081942 D:6-8. Sep. 76″.6. Azure and gold.

Σ1274 084438 D: 7-8.7. Sep. 8″.9.

Σ1282 084535 D:7-7. Sep. 3″.4.

LEO MINOR:

HI200 084733 Neb. mass. Quite interesting, but with abounding exploration fields to southward in Cancer.

CANCER:

Unaided, the Crab is not a stirring asterism, confined almost wholly within the bounds of this charted area; but aside from historic Presepe, offers many allurements.

σ² 084930 D:6-6.4. Sep. 1″.5. Like one elliptical star

ι 084129 D:4.4.6.5. Sep. 30″. Crocus and violet.

φ² 082227 D: 6.6-6.5. Sep. 4″.6.

ν 082124 D:6-7. Sep. 5.8.

M44 Presepe 083520 Wide Cl. Par. 0″.024. Dist. 70 light yrs. Area, 2.84 sq. deg. 363 suns—mag. 6 to 12—of which 173 belong to Cluster proper and have common motion in space—0″.0357 per annum. Wassink. Galileo counted 36 stars in the "Bee Hive" with his two-inch "optick-tube"! Noted by Aratus and Theophrastus (B. C. 300), as aiding weather prophecy, dimming at approach of storm. Many doubles, triples, multiples, stars of varied hues, etc.

U 083119 Var.: 9.4:13.8. Per. 304.5d.

ζ 080117 Vis. Bin.: 5.3:6.3. a=0″.856. Per. 60y. Spc. Go. A third star revolves with this binary in a much larger orbit, with an invisible companion, making it a quadruple system. Aitken. Disc. by Mayer, 1756. A test-object.

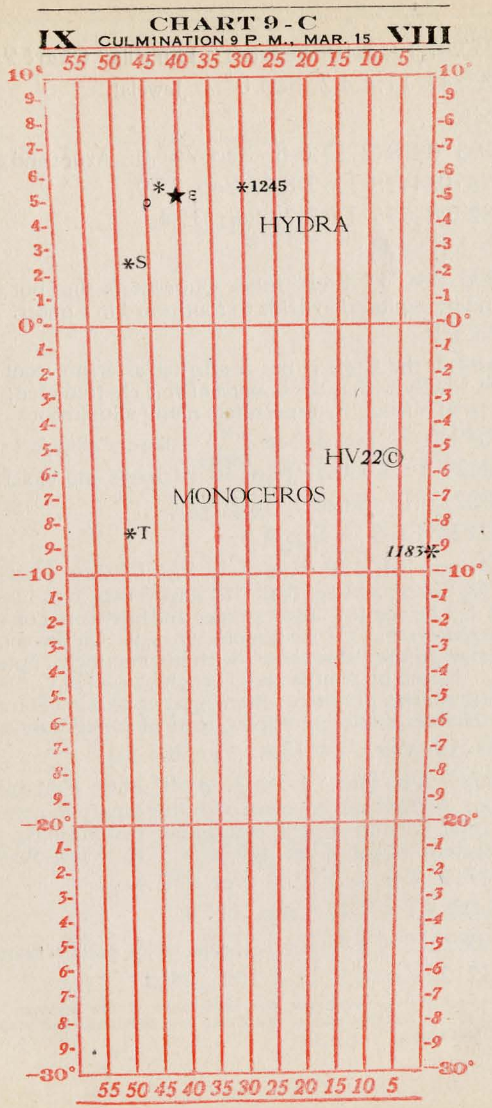
V 081717 Var. 7.7:12.7. Per. 252.4 d.

α 085412 D: 4.5-11. Sep. 11″.4.

M67 082612 Cl. Vivid, rich type of its exalted class.

R 081212 Var. 6.8:11.2. Per. 360d.

"The mind that comprehends the mechanism of the heavens has proved that it resembles that of the Being who fashioned and placed it there."—Cicero.



HYDRA: *Chart 9-C*

The limited pentagonal area comprised in the Chart is quite the most compelling section of the mythical monster which drags its dull length from this point south and eastward nearly a third of the distance around the celestial sphere. It would be strange indeed if so vast a precinct were not relieved here and there with some veritable highlights, available in our latitudes with fair seeing.

Σ1245 083106 D: 6-7. Sep. 10″.3. δ Hydrae 1° *s*.

ε 084106 Vis. Bin.: 3.7:5.2. *a*=0″.23. Per. 15.3 y. Spc. F8. Primary an unique l. p. Sp. Bin. Period, 5588 ds. —15 yrs.+ Par. 0″.025. Dist. 135 l y. Mass, 3½ × Sun.

ρ 084406 D: 5-12. Sep. 12″. ζ, ε, ρ, δ, σ and η Hydrae, in same field, with lesser lights, present a brilliant pageant.

S 084903 Var.: 7.9:12.8. Per. 256d.

MONOCEROS:

HVII 22 ***080905*** Cl. Isolated, but bright and curious.

T Hydrae ***085208*** Var.: 7.9:12.9. Per. 289.3 d.

Σ1183 ***080209*** D: 5.5-7.8. Sep. 31″.

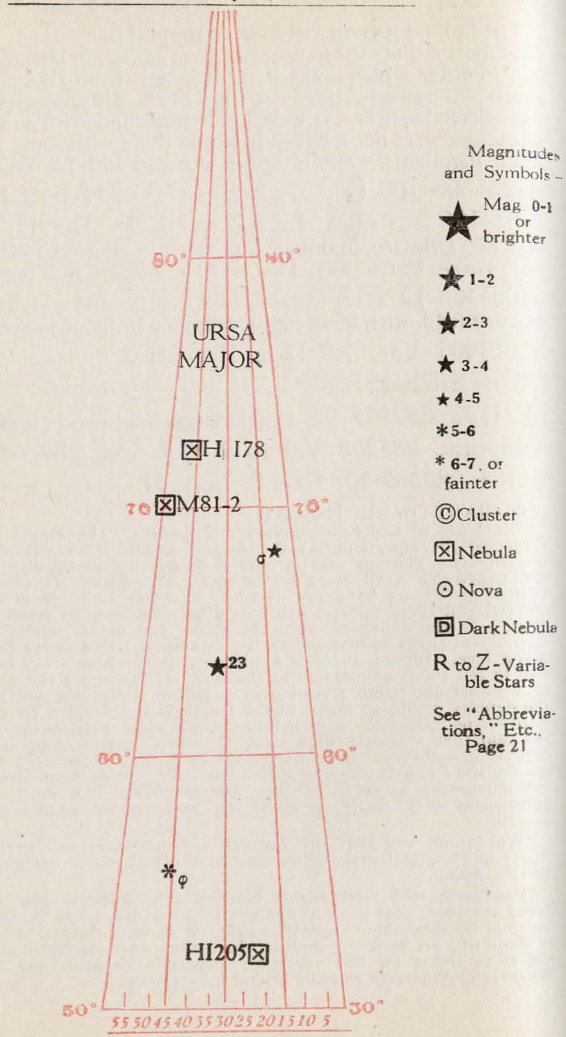
THE GIANT-DWARF THEORY.

"Stars are of two races—giants and dwarfs. The giants are large, bright and tenuous; the dwarfs small, faint and condensed. Our glorious Sun is only a dwarf; but practically all the naked-eye fixed stars are giants. The diameters of the largest giants are hundreds of times as great as those of the dwarfs, and their volumes are accordingly millions of times as great. If the densities were the same, the giants would be millions of times as massive as the dwarfs, but this is far from being true. Indeed, there is evidence that the giants are only two to ten times as massive as the Sun. If ten times the mass of a dwarf star were spread over a million times the volume, the density would go down to the fraction: ten divided by one million, or 1/100,000. A giant bears the same relationship to the Sun that a soap bubble six inches in diameter bears to a globule of gold one thirty-second of an inch in diameter; but its density is only one-hundredth, or even, in extreme cases, one-thousandth as great. To the question, What is a star? the astronomer might reply, A giant star is a red-hot vacuum!"—Merrill.

"We cannot say that the number of stars does not exceed thirty or forty billions, but we can certainly say it is not much less!"—Abbot.

"Familiarity with these mighty concepts most certainly does not breed contempt, does not dull our awe at the mightiness of the universe in which we play so small a part. It is very doubtful if any of those who are seriously studying the heavens ever lose their feeling of reverence for this supremely wonderful universe, and for Whoever or Whatever must be behind it."—Curtis.

X CHART 10-A IX
CULMINATION 9 P. M., MAR. 30



URSA MAJOR: *Chart 10-A*

HI78 094372 Neb. Bright.

M81,82 094969 Two Neb. Argent, 30′ apart. Unlike in size, structure and glow. Worth the search.

M81 was the first of the nebulae in which internal motions were detected and measured by a comparative study of photographs. Goodacre.

"Every effort of the pioneers, whether a success or a failure, is an index pointing the way of success to the observers who follow them."—Campbell.

σ2 090367 D: 5-8. Sep. 4″.6. Many brilliants in vic.

23 092563 D: 3.8-9. Sep. 22″.8. Neb. 260 close s.

φ 094554 Vis. bin.: 5-5.6. a=0″.32. Per. 99.7 y. A2.

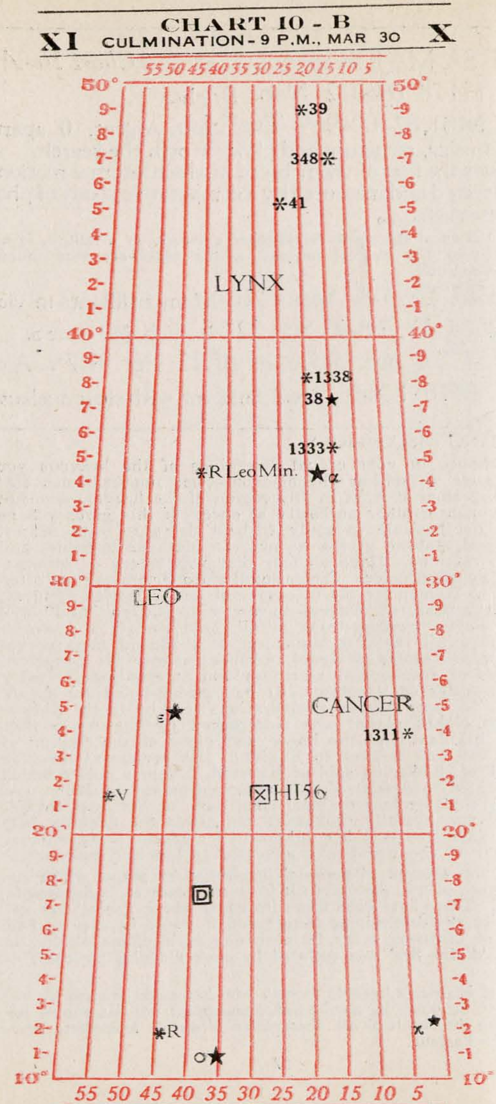
HI205 091651 Neb. Oval, lambent, with clear nucleus.

REPORTING DISCOVERIES.

If perchance in your casual sweepings of the heavens you glimpse some unfamiliar phenomenon—some unaccustomed star or puzzling atom of light in any region of the heavens—consult your star-map or other authority at once. If this gives you no clew, do not hesitate to apply without delay to your nearest astronomical station, giving as accurate data as possible, and await instructions. Have no fear that your query or information will go unregarded. Professional astronomers are too often beholden to laymen for the discovery of new celestial wonders; and while a score of chances to one your sudden "find" will prove to be no treasure-trove at all, gold medals and world-wide fame await the first announcer of a sudden nova or vagrom comet, as scores of signal instances attest. No danger in these days of intellectual alertness and international rivalry that your letter or telegram will be "pigeon-holed for future reference," as was Adams' computations leading to the discovery of an eighth planet was sidetracked by the Astronomer Royal of his day, and the honor and glory of the finding of Neptune was lost forever to England. Observatories now, as the late Prof. Pickering said of Harvard, "adopt a policy which may be stated to consist of advancing astronomy in every possible way, independent of local conditions or personal considerations;" and literally thousands can attest the friendly help which he gave freely to his unknown yet eager correspondents in all parts of the world who appealed to him for guidance.

"As to that element of personal inspiration or genius which enters into much of true discovery: it is by no means an indispensable ingredient. There have been many instances where 'genius' has appeared to be the determining factor; and it would be easy to find instances of discovery made by observers of mediocre ability, in which the 'divine fire' was replaced by mere plodding patience."—Curtis.

"Nothing is more agreeable to man who has made science his career than to increase the number of discoveries; but his cup of joy is full when the result of his observation is put to immediate practical use."—Pasteur.



LYNX: *Chart 10-B*

39 091749 D: 6.5-8.3. Sep. 6″.1

2484 [Boss] 091047 Sp. bin.: 5.7. Per. 15.98d. A2.

41 092345 D: 5.6-7.8. Sep. 82.5.

Σ1338 091638 D: 7-7.2. Sep. 1″.8.

38 091337 D: 4-6.7. Sep. 2″.7. Vivid stellar horseshoe.

Σ1333 091335 D: 6.6-6.9. Sep. 1″.4.

α 40 091634 Mag. 3.3. Low-mag. attendants.

R Leo Min. 094134 Var. 7: 12.8. Per. 371.8 d.

"If we really understood the causes of stellar variability, we should probably have advanced a long way toward the solution of the whole problem of stellar evolution, if not have solved it completely. But, in spite of the great number of variable stars, the variety of the phenomena which they represent, and the accuracy with which they can now be observed, the humiliating admission must be made that no even tolerably satisfactory theory of the causes of the variation exists, except for the eclipsing variables; and in this case it is based on the proposition that, except for the accident of eclipse, the components are not variable at all!"—Russell.

CANCER:

Σ1311 090223 D: 6.7-7. Sep. 7″.2.

χ 090211 Sp. bin. Mag. 5.1. Per. 6.39d. Spc. B8.

LEO:

ε 094124 Mag. 3.1. Alluring adventure field.

HI 56 092721 Neb. Elongated, faint, with double nuclei.

V 095521 Var.: 9:13.8. Per. 273.2d.

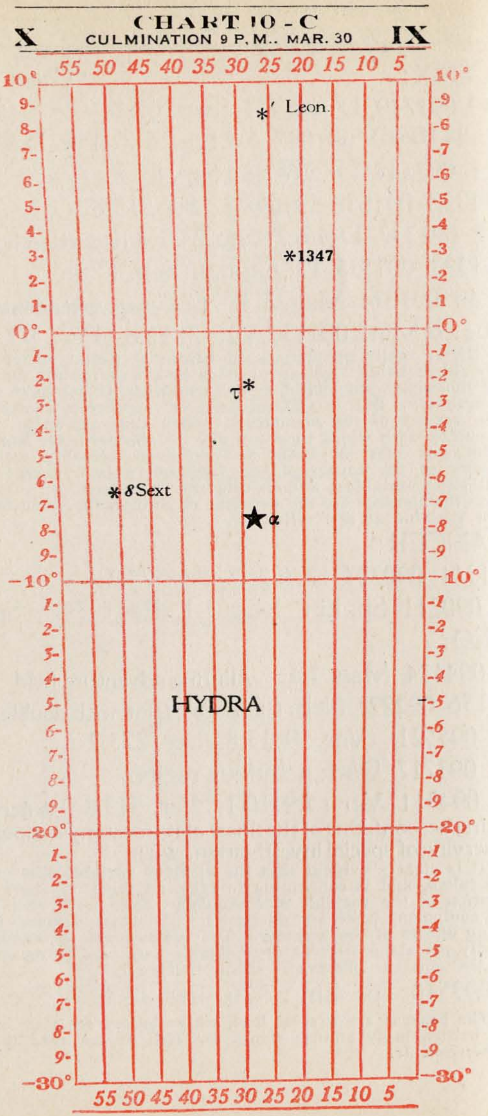
D 093717 Dark nebulous region.

R 094311 Var.: 5.9:10.1. Per. 313d. A fiery, pulsating beacon! One of the finest of its most mysterious class, deserving of special investigation. Webb.

"It is clearly evident that the amateur variable star observer has taken, and is continuing to take, an important part in the solution of the variable star problem. Even with very moderate equipment there are numerous stars which demand the untiring efforts of the amateur. The professional astronomer can hardly get along without the valuable data now being obtained by the amateur observer."—Leon Campbell.

o 093510 Spc. bin.: 3.76. Per. 14.49d. Spc. F5p.

"The heavens are a great book whose letters are stars wherein are written many strange things for such as can read them."—Democritus, Jr.



ω 092309 Vis. bin.: 5.9-6.7. Spc. *Chart 10-C*
Go. a=0″.844. Per. 116.74yrs.

Σ1347 091903Hyd. D: 6.7-8. Sep. 21″.3.

τ¹ ***092502*** D: 5.5-8.5. Sep. 3″.

8 (A.C.5) Sextantis ***094707*** Vis.bin.:5.8-6.1. a=0″.41. Per. 72.76yrs. Spc. A2.

α ***092308*** Mag.,2.2. Par.0″.014. Dist.2261y. K2.

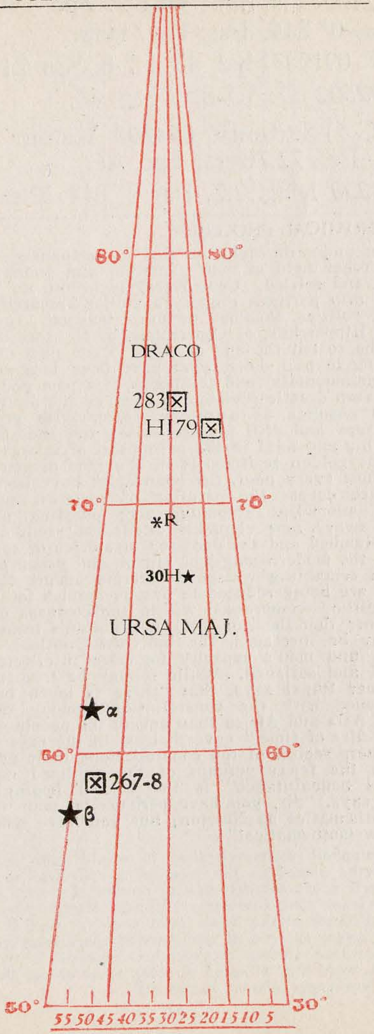
ASTRONOMICAL PROGRESS.

Be not under the delusion that in astronomy—any more than in any other field of man's interest and endeavor—everything is fixed and settled. Controversy is in the air and camps are divided into partisan groups in stellar research as in the domain of politics, theology or social science. It was so in the time of Hipparchus, of Copernicus, of Newton and Le Verrier: it will be so till the end of time. Even now there are groups conspiring to pull down what have been long regarded as the basic fundamentals; and textbooks of a past generation are receiving such drastic revision as to make the dictum of a decade gone as obsolete as astrology. Ever with greater problems solved, new and still greater arise; and the impossible, once written big and final in the palimpsest of science, fades utterly under the golden testimonies of the new dispensation. Every day, almost every hour, the boundaries have been pushed back into space deeps: the parallax of remotest suns re-revised; amazing anomalies accounted for; puzzling phenomena explained away; new elements cited, analyzed, classified; new depths plumbed and the deep-sea mysteries of space brought to book by the modern magic of mirror and prism and lens. And far from remaining whispered secrets among the elect, these wonders are being reduced to first principles for the edification of the million—compressed within the compass of the average intelligence that the sum-total of a nation's treasury of knowledge may be increased, the individual outlook immeasurably widened, and man's capacity for pure intellectual enjoyment deepened and satisfied. While it may be true, as the present Astronomer Royal says, that "there is much better practical acquaintance with the constellations among the uncivilized tribes of Asia and Africa than among the people who are in the foremost files of time," nevertheless, in the case of the former, with a mere recital of the constellations their education ends; but with the fewer perhaps of the civilized nations such a "practical acquaintance" is the veriest beginning. As Dr. Johnson says, "Sir, you have perhaps no man who knows as much mathematics as Newton; but you have many more men who know mathematics!"

Dr. Campbell estimates that it would take more than two billion earths placed in the form of a spherical shell around the Sun at Earth's present distance to receive the total output of light and heat from that luminary. Hence, Earth receives less than one two-billionth of the Sun's total energy. And if this enormous light-heat waste is true of our own comparatively cool Sun, what of others whose surface temperature exceeds it two to ten-fold, and which, were they situated as close to us as our Sun, would consume us into vapor almost instantly?

CHART II-A

X CULMINATION 9 P. M., APR. 14 IX



Magnitudes and Symbols:—

★ Mag 0-1 or brighter

★ 1-2

★ 2-3

★ 3-4

★ 4-5

* 5-6

* 6-7, or fainter

Ⓒ Cluster

☒ Nebula

⊙ Nova

D Dark Nebula

R to Z - Variable Stars

See "Abbreviations," Etc. Page 21

DRACO:

H I79 101073 Neb. Nucleus.
Neb. 283, $1\frac{1}{2}$° n f, also worth inspection.

URSA MAJOR:

R 103769 Var.: 7 : 13. Per. 302d.

30H 101966 Sp. bin. 4.9. Per. 11.58d. Spc. A.

α Dubhe 105862 Mag. 2. Par. 0".047. Dist. 70 l.y. Ko
11-mag. comes, dist. 0".9, difficult.

267-8 105758 Double Pl. neb. Close n p β Urs. Maj.
Diam., 3' of arc = 7 times Neptune's orbit! Disc. in 1781.

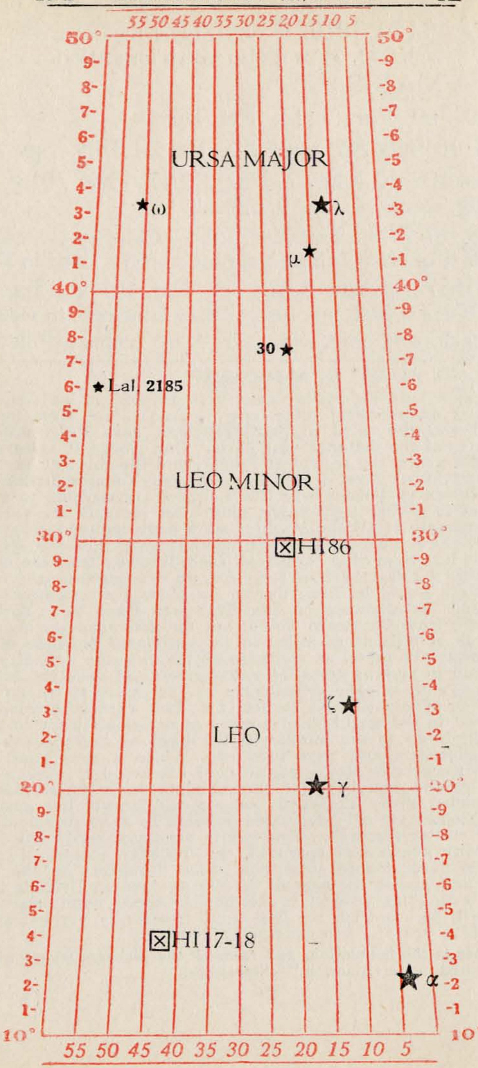
β 105657 Sp. bin. Mag. 2.4. Per. 0.31d. Spc. Ao.
Par. 0".054 = 60 lt yrs. dist. Three faint neb. in vicinity.
A line drawn from β thru α Urs. Maj., points to Pole Star.

NO "LAST WORD" IN ASTRONOMY.

Recently over the radio three distinguished authorities, during their astronomical talks, one in the Middle West, one in Boston and the third in San Francisco, gave three different estimates of the distance of Polaris. One placed it at seventy-five light-years, the second at ninety, and the third at one hundred and fifty. Now, I had long accepted Young's dictum that the parallax of Polaris was 0".074, which corresponds to a distance of forty-four light-years, plus. But recently the parallax measurements of all the brighter stars have undergone revision by ever-more intricate methods, so that with this one star we have no less than nine estimates, each differing from the others by sundry light-years from forty-four to two hundred and twenty! There would be little excuse for a corps of engineers who estimated the distance of San Francisco from New York as anywhere from Omaha to Tokio; but the discrepancies of many hundreds of billions of miles in the estimated distance of Polaris is merely taken as evidence of the extreme difficulty encountered in making celestial measurements of even the brighter stars, with all the refinements of instrumental means and perfection of method. No sooner is a "last word in astronomy" published to the world, than a corps of revisionists set to work bringing it up to the minute in the light of new discoveries, new deductions and new theories. While a generation ago earnest workers in this gigantic field numbered at most a few score, trained searchers for the absolute in celestial matters now number many thousand: some world-famous but most of them obscure, yet all "dedicated spirits" in some profound byway of stellar research. Thus while one may verify his facts from many avenues of approach, the ink may scarcely be dry upon the paper before some new voice "thunders in the oratories" and makes the current dictum as dead as Urban's bull. There is no "last word" in astronomy—there never was and never will be. Indeed, the first word is scarcely yet spoken in this golden era of its promising infancy.

"Science is the foundation, and research the ultimate means which have created our civilization."—Steinmetz.

XI **CHART 11-B** X
CULMINATION 9 P. M., APR. 14



λ 101243 Mag. 3.5. μ, 3.2, *s f.* *Chart 11-B*
ω 104843 Sp. bin. 4.8. Per. 15.8d. A.

LEO MINOR:

β 30 102337 D: 4.4-6.5. Sep. 0″.4. Neb. 164 5′ *f.*
Lalande 21185 105936 7.6. Par. 0″.41 = 7.9 lt yrs. Spc. Mb. Interesting, being the fourth nearest known star!
HI 86 102229 Neb. Bright, oval; starry nucleus.

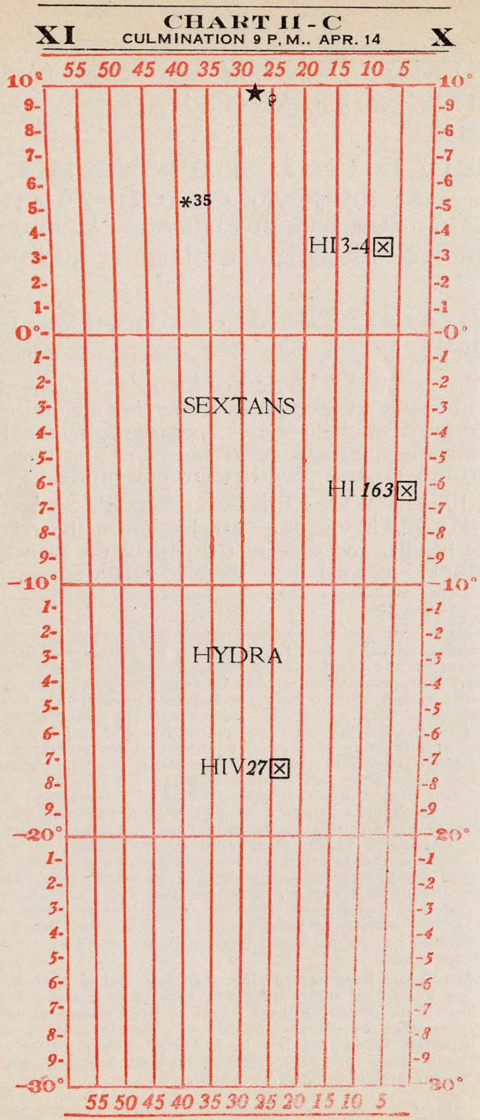
LEO:

ζ 101223 Wide D: 3.6-6. Sep. 5′. D: 5-11 in field s.
γ 101620 D: 2.6-3.5. Sep. 2″.5. Orange-pale yellow.
HI 17-18, etc. 104313 A nest of Nebulae! Two fairly bright, with starry centers, others fainter but interesting, in a region scarce of bright stars. Appear as spirals on the photographic plate, but are not so seen visually with ordinary apertures. Goodacre. Worth many adventures.
α Regulus 100412 Wide D: 1.3-8.4. Sep. 3′. Spc. B8. Par 0″.045 = 72.4 lt. yrs. dist. A noble sun, at the end of the Sickle handle, and close to the path of the planets. Approx. diam., 3 million miles—about 3.5 × Sun. Stetson.

SECULAR CHANGES.

If Hipparchus, "father of practical astronomy," should return to Nicea and review his familiar heavens, he would find only slight changes in the lapse of two thousand years. Even Arcturus, with its proper motion of nearly four hundred miles per second, would appear shifted only the length of a foot-rule seen at the distance of fifty miles. He would find the plane of the Ecliptic drawn toward that of the Equator by only one-quarter of a degree, and the day shortened by one two-hundredth of a second of time. He would note that the Moon moves slightly faster around the Earth, and Jupiter slightly faster in his orbit around the Sun, Saturn somewhat slower. Doubtless he would find other changes far more important; for the man who, without lens, mirror or prism, with only peep-sights on a yard-stick and a prodigious brain, discovered the precession of the equinoxes; divided the heavens into constellations and named their principal stars; determined planetary parallax; measured a degree on the earth's surface within a few feet; calculated the eclipses, and laid the foundations of trigonometry, could be confidently relied upon to enrich the science his name adorns, aided and abetted by the perfected modern instruments of penetration and precision.

"Thousands of years have passed since man first looked upon the stars. Yet we know that their order has apparently changed but little in all that time. Probably there would be little change of any kind among them that the sharpest naked eye observer could note, if, like the legendary Wandering Jew, he had lived from the time of Christ until now. Stars that were brightest then are brightest now, as we know on the best of grounds."—Abbot.



ρ 102709 Sp. bin.: 3.8. Per. 12.3d. Bp. ***Chart 11-C***

SEXTANS

35 103905 D: 6.1-7.2. Sep. 6″.7.

HI 3-4 100903 Neb. Faint. Neighborhood superb!

HI 163 ***100107*** Neb. Glowing center.

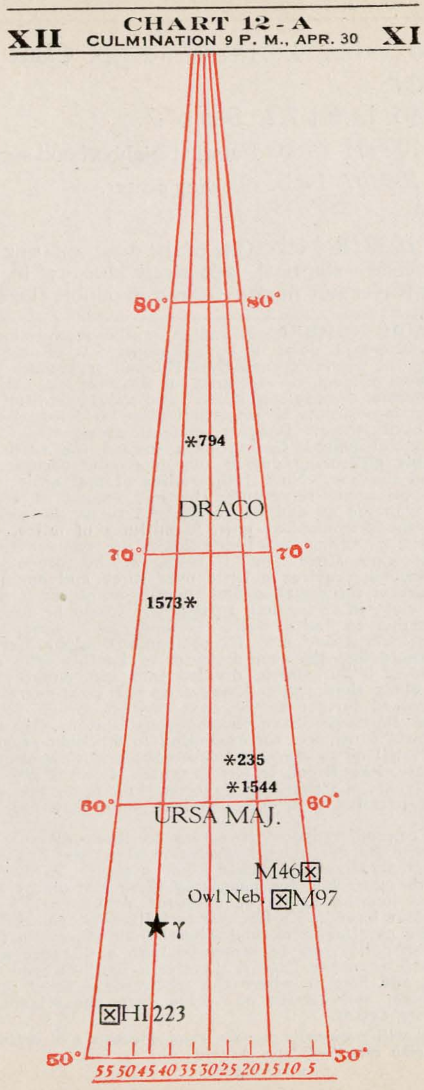
HYDRA:

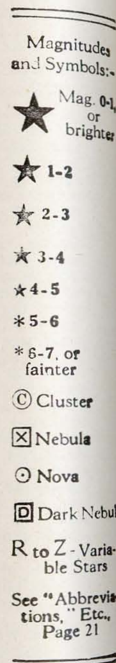
HIV 27 ***102018*** Neb. One of the most amazing of the planetary class—elliptical, pale steely blue, 45″ in diam., with Wolf-Rayet star-nucleus framed in double rings.

THE MAGIC NUMBER.—A radian is the semi-diameter of any circle measured along its circumference. It is determined by dividing the circumference by 2-Pi, and represents an arc equal to about 57 deg., or 3438 min., or 206,264.8 sec. This last is the astronomer's "Magic Number," and should be firmly fixed in mind, for it performs an important office in celestial computations. To illustrate: Imagine yourself transported to some distant celestial point. Gazing back toward the earth, with some suitable measuring device you determine accurately its orbit around the Sun. Now if the radius of that orbit is seen to subtend an angle represented by one second of arc, you know that you are at a distance 206,264.8 times the radius of that orbit—one astronomical unit, 92 millions of miles, or approximately six trillion miles—6 followed by twelve ciphers—or 3.26 light-years, since light, traveling at the rate of 186,400 miles per second, requires a little over three and one-quarter years to traverse the distance. But there is no object in sidereal space as close to us as that, so that you would be compelled to travel further to find a stellar foothold, as it were, say to your nearest star (save one, its companion), alpha Centauri. Here you would find the semi-diameter of Earth's orbit represents an arc of 0″.76; which, divided into 3.26, equalling one light-year, gives that star's distance as 4.3 light-years. But now you proceed further to the next nearest, which you discover to be Barnard's Star in the constellation Ophiuchus, which shows 0″.53 of arc, corresponding to 6.1 light-years distance. And still on to stars of hundredths and thousandths of seconds of arc, like Rigel, in Orion, which shows 0″.006, equal to 543 light-years distance, or Canopus, in Argus, the super-giant whose parallax is 0″.005, equal to more than 650 light-years!

Since we cannot transport ourselves to these distant ports and so compute Earth's annual revolution about the Sun to determine their parallax and hence their distance, astronomers accomplish the same end by measuring these star-places at intervals of six months, using the diameter of the Earth's orbit as a convenient base line. But wonderfully intricate and precise as is the parallactic method whereby an object no larger than a quarter-dollar can be measured from a distance as far as the Atlantic from the Pacific, there is a limit to even these refinements; and here is where the spectroscope takes up the exalted problem and carries on where even the wizard micrometer meets defeat.

"Astronomy will eventually be the chief educator and emancipator of the human race."—Edwin Arnold.





DRACO: *Chart 12-A*

β794 114874 Vis. bin.: 7-8.3. α=1″.345. Per. 42y. Spc. F8.

Σ1573 114467 D: 6.-7.6. Sep. 11″. 2½° s λ, mag. 4.

URSA MAJOR:

OΣ235 112661 Vis. bin.: 5.8-71. α=0″.78. Per. 71.9 yrs. Spc. F5. South and east, a veritable wonder-zone!

OΣ1544 112660 D: 7-8. Sep. 12.5.

HV46 110556 Neb. region in excelsis!

M97 111055 'Owl' Neb. Sweep 2° s e from β Ursa Maj. Largest of the planetaries: diam. 3′—7000 ast. units! Double formation. Gaseous. Five faint central stars. Region abounds in nebulae. See Lick photo, Ill Sec.

γ 114954 Mag. 2.5. Relative par., —0″.002. Spc. Ao.

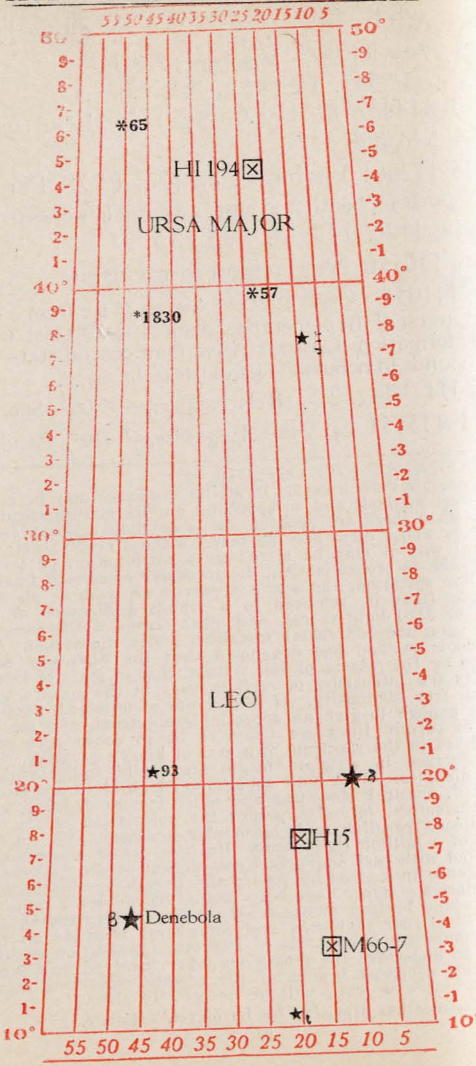
HI223 115551 Sp. Neb. Edgewise, 4′×20″. Peculiar.

ESTIMATING REMOTE OBJECTS.

Spectroscopic determination of stellar distances may be called the indirect method; and so appalling are its mathematical intricacies that there are perhaps not more than a dozen living authorities whose dicta may be taken without reservations. In a general way it may be stated as a combination of several factors, such as proper motion, the intensity of certain lines in the stellar spectrum, the star's apparent as well as absolute magnitude (that is, removed to a standard distance of ten parsecs, or 32.60 light-years), and other terms of the equation bearing upon the individual instances under discussion. The spectroscopic method has developed from the discovery some years ago by Dr. Adams, of Mt. Wilson, that in stars of known parallaxes the intensities of certain lines in the spectra vary with their true luminosity. If then a star of unknown parallax is bright enough to give an appreciable spectrum, and the intensity of certain lines are found to be in consonance with certain lines in the spectrum of a star of known parallax, then their difference in absolute magnitude would indicate their relative distance. With both apparent and absolute magnitude determined, spectral identities and other factors deduced, certain mathematical formulae permit the calculation of the remoter object's parallax with reasonable accuracy, even to the distance of a million light-years. But the varied complexities encountered with each individual computation places this branch of the science in a class by itself; and though by this method the boundaries of space have been pushed back toward infinity, and our whole horizon immeasurably widened (demanding the revision of all our textbooks and categorical treatises on the subject), there are few of this or any other generation willing and able to undertake the prodigious labor involved, and progress in this profound branch of the science, involving many kindred sciences as well, will be necessarily slow.

"Every science has prevision for its object."—Comte.

XII CHART 12-B XI
CULMINATION 9 P. M APR. 30



65 115146 Tr. 6-8.3-9. Sep. 3″.7-0″.3. *Chart 12-B*

HI 194 112144 Neb. Large, oblong.

57 112439 D.5.2-8.2. Sep. 5″.4. Neb. HI 219 s p.

1830 Groombridge 114738 Mag. 6.6. Par. 0.″15. Dist. 21.71 y. Space veloc., 138.2 mi. per sec. Speed of this "Runaway Star" equal to our moon's circuit of the earth in two minutes; yet at a distance of two million astronomical units, apparently moves a moon's breadth in 300 yrs.!

ξ 111532 D: 4.4-4.9. Sep. 2″.9. Per. 60 yrs. First binary star whose orbit was computed on gravitational principles. Ball.

LEO:

93 114220 D.: 4.5-8.4. Sep. 74″. Prim. a Sp. bin. Per. 71.7 d. Spc. F8. Field peppered with faint neb.

δ 110920 2.6. Double :9-9.3. Difficult.

HI 5 111817 Neb. Quite luminous.

β 114514 2.2. Par. 0″.13. Dist. 25 l y. Spc. A2.

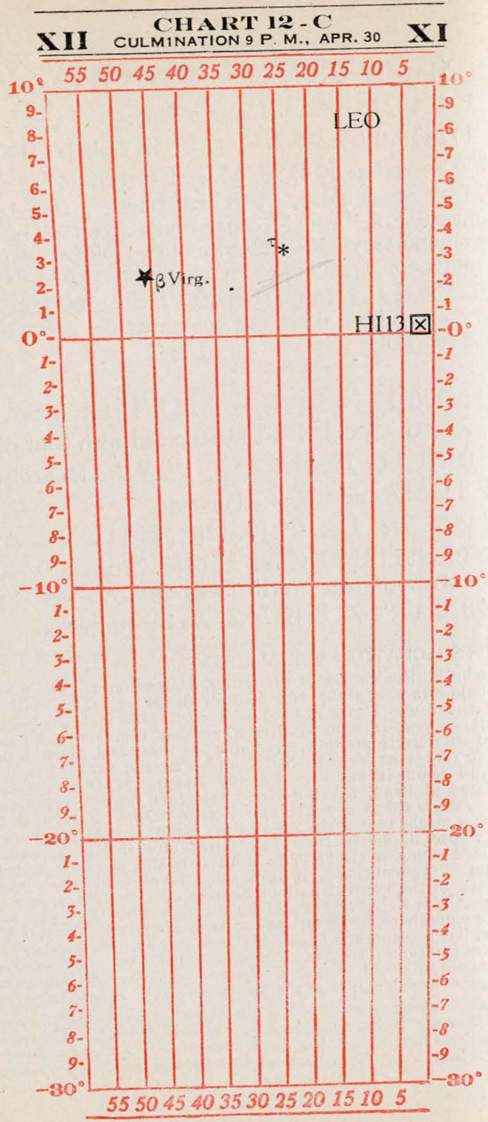
M66-67 and HI 29 Circa 111413 Sp. neb. Very curious and mystifying. Worth diligent study. 2° s θ Leo, 3.4.

ι 112010 D: 4-7. Sep. 2″.2. Amber-turquoise.

EARTH'S ISOLATION VISUALIZED.

Herschel's illustration of planetary dimensions: "On a wide, level field place a globe two feet in diameter. This will represent the Sun. Draw around it a circle 164 feet in diameter and place upon it a mustard-seed—which represents Mercury. Around this circle another, diameter 284 feet, and place upon it a pea to represent Venus. Still another circle, 430 feet in diameter, and upon it another pea—the Earth. Mars, represented by a large pinhead, takes a circle 654 feet; Jupiter, represented by an orange, takes a circle half a mile across; Saturn, a tiny orange, a circle four-fifths of a mile; Uranus, a large cherry, a circle whose diameter is a full mile; and lastly Neptune, a good-sized plum, a circle more than two and one-half miles in diameter." To continue, if this same level field were located anywhere in the central part of Kansas, the nearest star to our system—Alpha Centauri—would be located more than 8000 miles distant—somewhere, let us say, off the Australian coast. Now, if Alpha Centauri has a planetary family the smallest of whose members is of the size of Jupiter—itself over 1400 times Earth's volume—shining by reflected light, it would require a telescope of twenty-six feet aperture—over three times larger than the largest on earth—even to glimpse it!

The place which telescopes and observatories have taken in astronomical history is by no means proportional to their dimensions. Many a great instrument has been a mere toy in the hands of its owner. Many a small instrument has become famous.—*Newcomb*.



S 110506 Var. 10:13.9 Per. 189..5 *Chart 12-C*

τ 112403 D: 5.2-7. Sep. 94″.8.

HI 13 110100 Neb. Oval, 6′×45′, star center.

VIRGO:

The constellation of the Virgin, beginning here, holds more nebulae than any equal area in the northern heavens.

β 114602 3.8. A gem, almost on the Ecliptic.

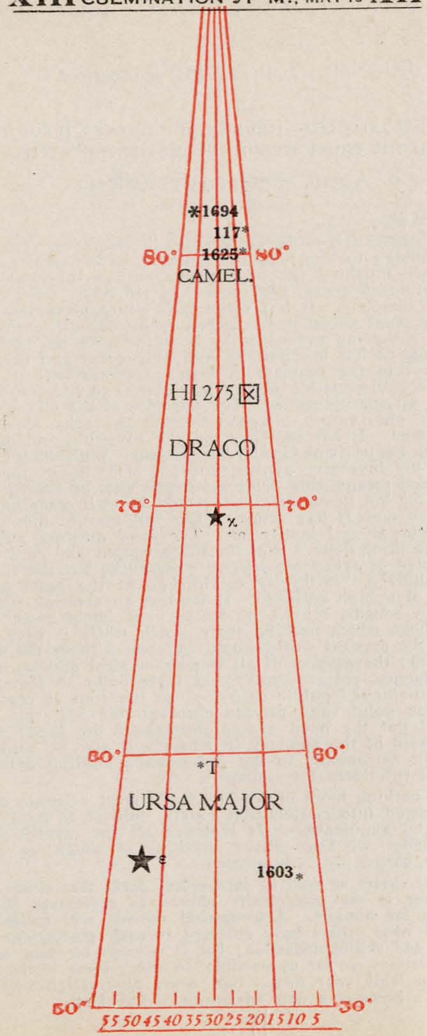
THE AMATEUR.

We in this generation no longer despise the amateur. We are too much beholden to him. To the amateur in art, music and science we are indebted far beyond our ability to repay for generations of indifference, hindrance and ridicule. Take photography, for instance. It has made portraiture perfection; it has made our great magazines possible, manifolding to infinity the output of the press and widening immeasurably the horizon of our learning; it has brought the infinitely great and the infinitely little into the compass of man's appreciation; it has made itself an indispensible ally of nine-tenths of our arts and sciences, and all our industries. The miracles of the clinic and of the modern observatory all pass through the ruby alchemy of the dark room. It has searched out the invisible and made it imperishable. Let us thank God for the amateur! Without his early enthusiasms, his inventive genius, and his often scant though wisely-expended means, this noble art would still be among the things hoped for but never attained—would be still creeping on all-fours where now it has attained the full stature and dignity of an international institution. The word amateur means "a lover of the thing done." Not the thing bought and paid for, borrowed, rented or taken on debt or sufferance; but the thing personally achieved, "faithfully established at the hand of a good servant of a high calling." It implies an emotion which nothing money-bought, rented, or stolen ever imparts—an enthusiasm without which nothing truly worth while is ever attained. As "the musical world would collapse without the successful amateur: the support of all worthy musical efforts; who by his intelligence, culture and sound taste helps to foster a sane and keen-spirited public opinion;" so the time is coming when a million public and private observatories will cap the housetops and dot the open spaces throughout the land; and what is now said of the amateur in music will also be said of the amateur in astronomy, to the individual's abiding delight and a nation's intellectual enrichment.

"Science is nothing more or less than the most accurate and best authenticated information that exists, subject to constant rectification and amplication. It includes all the careful and critical knowledge we have about anything of which we can come to know something."—Robinson.

"The chiefest charm as well as intellectual profit that comes to the star-searcher is the opportunity offered to rediscover great celestial truths for himself. Astronomical records will enlighten you concerning what others have achieved through generations of patient search and skilful deduction; but it remains for your own personal observations, so far as possible, to clinch these certitudes and make them truly your own. For, every observation with a definite purpose becomes a new adventure."—The Haji.

CHART 13-A
XIII CULMINATION 9 P M., MAY 15 **XII**



Magnitudes and Symbols:-

- ★ Mag. 0-1 or brighter
- ★ 1-2
- ★ 2-3
- ★ 3-4
- ★ 4-5
- ✱ 5-6
- ✱ 6-7, or fainter
- © Cluster
- ☒ Nebula
- ⊙ Nova
- D Dark Nebula
- R to Z - Variable Stars

See "Abbreviations," Etc., Page 21

CAMELOPARDUS: *Chart 13-A*

Σ1694 124883 D:5-6. Sep. 22″.

OΣΣ117 120782 D:6-8. Sep. 65″.1.

Σ1625 121280 D:6.5-7. Sep. 14″.3.

DRACO:

HI 275–8 121075 A wilderness of variform Neb.

χ 123070 3.9. Notable, 'mid glowing environs.

URSA MAJOR:

T 123160 Var.:8:12.8. Per. 256.7 d.

ε 125056 Mag. 1.68. Spc. Ao. Par. 0″.058. Dist. 561 y. Sp. bin. Per. 4.15 yrs. R. v. —19mi.-sec.

Σ1603 120455 D:6.9-7.3. Sep. 22″.4.

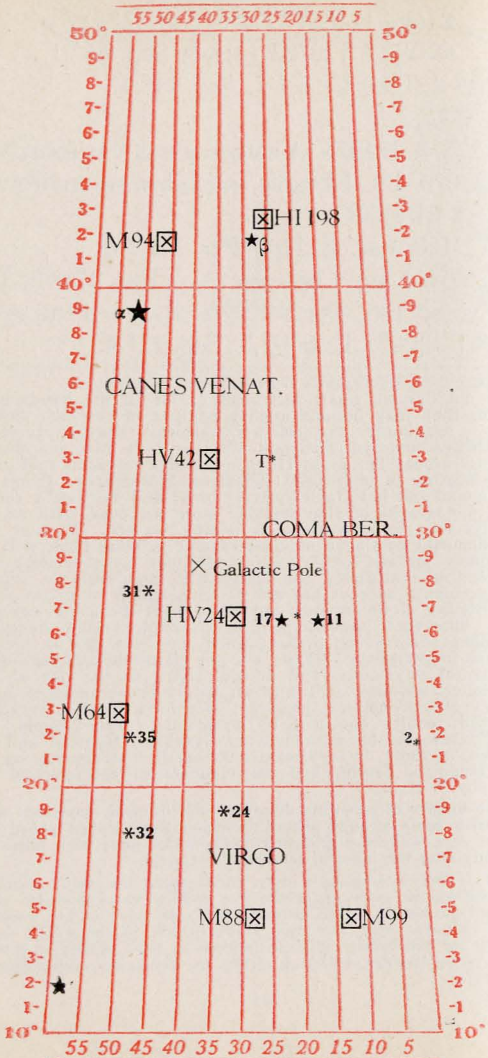
SMALL INSTRUMENTS IN MASTER HANDS.

Do not despise small instruments; for in the hands of the master they may become mighty engines of research and progress. Argelander mapped his immortal Durchmusterung of over three hundred thousand stars with a two and one-half inch telescope! The great Huygens used a refractor that gave a magnification of only 100! Pickering photographed Orion with a two and one-half inch portrait lens; and Barnard's remarkable photographs of that nebulae were achieved with an even smaller lens from a cheap projecting lantern. Messier made his immortal catalogue of clusters and nebulae (that will bear his name for all time), with a two-foot comet-seeker; while Tyche Brahe achieved the apparently impossible in celestial measurements without the aid of lens, mirror or prism at all! The history of the science is replete with the achievements of great observers handicapped with simple, often home-built equipment with which they attained eminence, and in some instances immortality. "If we are not all mathematicians or experimental physicists, and do not share in the use of large telescopes, we may still find an ample encouragement in the history of astronomical progress. We have only to recall the splendid results obtained by systematic observations with small telescopes by such men as Burnham, Barnard and Carrington, or those derived, also with small instruments, by men like Huggins, Secchi, and the pioneers in astronomical photography."—Hale.

"The history of scientific discovery affords many instances where men with some strange gift of intuition have looked ahead from meager data, and have glimpsed truths which have been fully verified only after the lapse of centuries."—Curtis.

"It is the astronomer's duty to discover the truth about his surroundings in space and make it a part of the knowledge of his day and generation. The ultimate and real value of his work lies in its influence upon the lives of the people of the world, in the changes for the better which it induces in their modes of thought, and in the impulse which it gives to advancing civilization."—*Campbell.*

XIII CHART 13-B **XII**
CULMINATION 9 P. M., MAY 15



CANES VENATICI: *Chart 13-B*

The "Hunting Dogs," beginning here, offer exceptional quarries for the adventurous.

HI 198 122642 Neb. Oval, finely placed n p β, mg. 4.3.

M94 124741 Sp. Neb. Small but bright—comet-like.

Σ1606 120640 D: 6.3-7. Sep. 1″.4.

α Cor Coroli 125138 D: 2.9-5.7. Sep. 19″.9. 2.9 a Sp. bin. Per. 5.5 d. Spc. Ap.

T 122532 Var. 9.3:12.3. Per. 290 d.

HV42 123832 Neb. Long, arrowy: possibly two joined.

COMA BERENICES:

31 124827 Mag. 5.1 Astronomically of interest since it lies within 8′ of the true N. Galactic Pole: 12 h. 40 m., + 28°.

17 122426 D: 4.8-6. Sep. 2½′. Prim. also double.

Σ1639 122026 D: 6.7-7.9. Sep. 1″.2.

HV24 123226 Sp. Neb. Seen edgewise, with bulbous center and long 20′ bifurcated luminous body. Unique!

11 121826 D: 4.5-8.5. Sep. 66″. Heart of constellation in the midst of a brilliant congress of stars.

M64 125222 Sp. Neb. One of the grandest in the heavens—like a colossal pendent abalone pearl in rayless void.

2 120221 D: 6-7.5. Sep. 3″.7.

35 124921 D: 5-7.8. Sep. 1″.4.

24 123118 D: 5.2-6.2. Sep. 20″.4. Fine! Or.-blue.

32 124817 D: 5.3-6.1. Sep. 3¼′.

VIRGO:

M99 121414 Sp. Neb. Bright, circular, nucleus uncondensed, bordering on Coma Ber. Holds attention

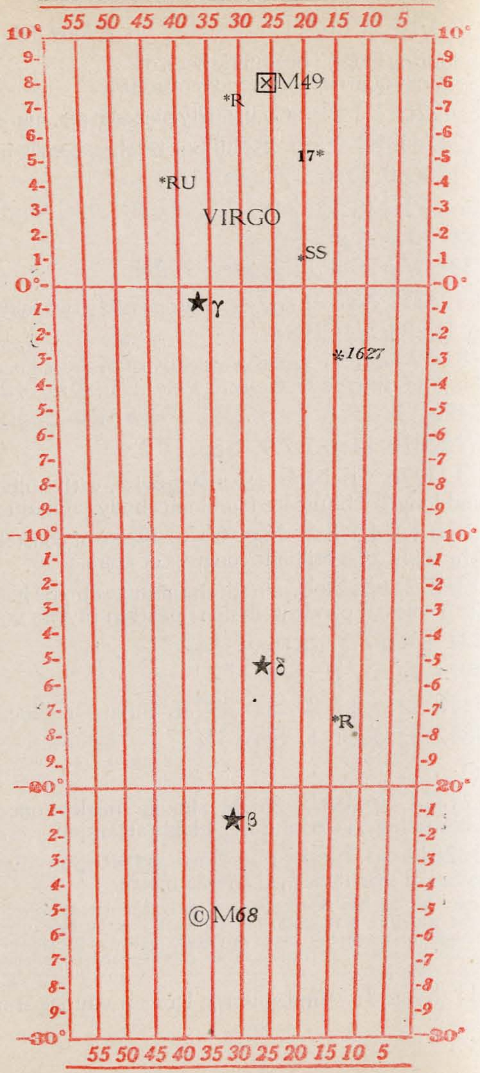
M88 122814 Sp. Neb. Foreshortened. Region a vast Sargosso Sea of star-illumined cosmic matter.

"Man may be, as has been claimed, only the latest development of the whirling star mist; but the fact that he has intelligence enough to trace his own evolution stands unexplained, except by the presence in Nature of an intelligence far superior to his own."—Bailey.

ε 125811 Mag. 3. Vindemiatrix, Roman vintage-star.

CHART 13 - C

XIII CULMINATION - 9 P.M., MAY 15 XII



M49 122508 Notable Neb., bet. *Chart 13-C*
two 6-mag. stars.

R 123307 Var.: 6.9:11.4 Per. 145.4d.

17 121805 D: 6.2-9. Sep. 19″.3. Contrasty. 2 Neb. s f.

RU 124204 Var.: 8.5:13. Per. 436d.

SS 122001 Var.: 8.3-12.5.

γ ***123601*** Vis. bin.: 3.6-3.7. *a*=0″.78. Per. 182.3 y.
Spc. F. One of the finest pairs visible! Disc., 1718.

Σ1627 ***121403*** D: 5.9-6.4. Sep. 20″.1.

CORVUS:

The "Raven" is a limited asterism: but for full measure of bounties, with clear skies, a real multum in parvu.

δ ***122516*** D: 3-8.5. Sep. 24″.3.

R ***121418*** Var. 7.4:13.0. Per. 317.4d. Neb. 65. 6′ f.

β ***123022*** 2.8. Dull-gold star. s e cor. of the quadrangle.

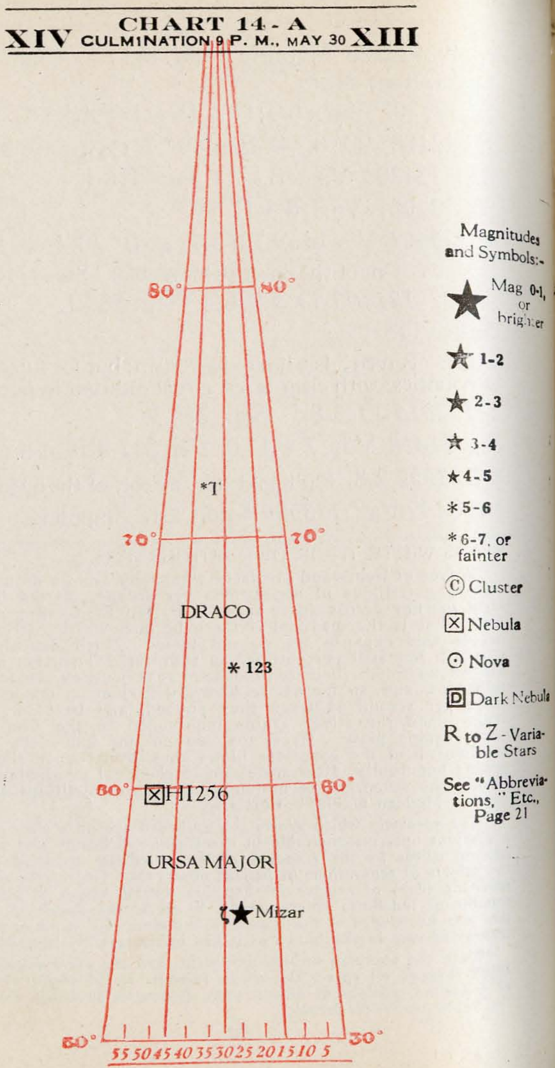
M68 Hydrae ***123526*** Glob. Cl. Imposing.

STARS WRITE THEIR OWN AUTOGRAPHS.

"Waves of light—and precisely what they are we do not know—making trillions of oscillations per second, started on their long journey across space towards us ten thousand years ago. Just what is the medium, if there be one, which carried them across this expanse we do not know. Much diminished in strength but still perceptible, an infinitesimal portion of these vibrations finish their ten-thousand-year journey, entering our telescope, and, so far as we know, with just as many oscillations per second as when they started, and beat for several hours upon the silver grains imprisoned in the film of our photographic plate. Here, too, we do not know the precise mechanism of the countless blows they inflict upon the silver grain; but finally, after some simple chemical manipulation, we obtain the autograph of unnumbered suns quadrillions of miles away. Modern magic!"—Curtis.

"The spectacle which greets the upturned eye on a clear night is a glorious one, incomparable in sheer physical beauty and enriched beyond words by the grandeur of the actualities revealed through the efforts of generations of patient observers. One of the most inspiriting ideas of science is that this mental vision is inherently capable of indefinite enlargement. It seems reasonable to believe that our knowledge of the nature of the stars will grow at an ever increasing rate in the future as it has in the past."—Merrill.

"Were the universe infinite in extent, and the stars equally scattered through all space, the whole heavens would blaze with light of countless millions of distant stars separately invisible even with the telescope."—*Newcomb.*



URSA MINOR: *Chart 14-A*

T 133273 Var. 9.1:13.4. 315d.

DRACO:

$O\Sigma\Sigma$123 132465 D:6.4-6.8. Sep.70″. Commanding!

URSA MAJOR:

HI256 134660 Neb. Bright: center of 3 in nw-se row.

ζ Mizar 132055 D: 2.1-4.2. Sep. 14″.4. Prim. a Sp. bin. Per. shortest known—20.23ds. Spc. A. Par. 0″.040=80 l y dist. Pioneer star: first double discovered, by Riccioli, 1662: first photographed, by Bond, 1857; first determined a spectroscopic binary, by Pickering, 1889.

Alcor, the mag.-5 companion of Mizar, 14′.5 dist., is no longer the eye-test of ancient days. The pair, so happily placed in the crook of the Big Dipper's handle, never fail to inspire awe, however frequently observed.

REDUCING ERROR PERCENTAGES.

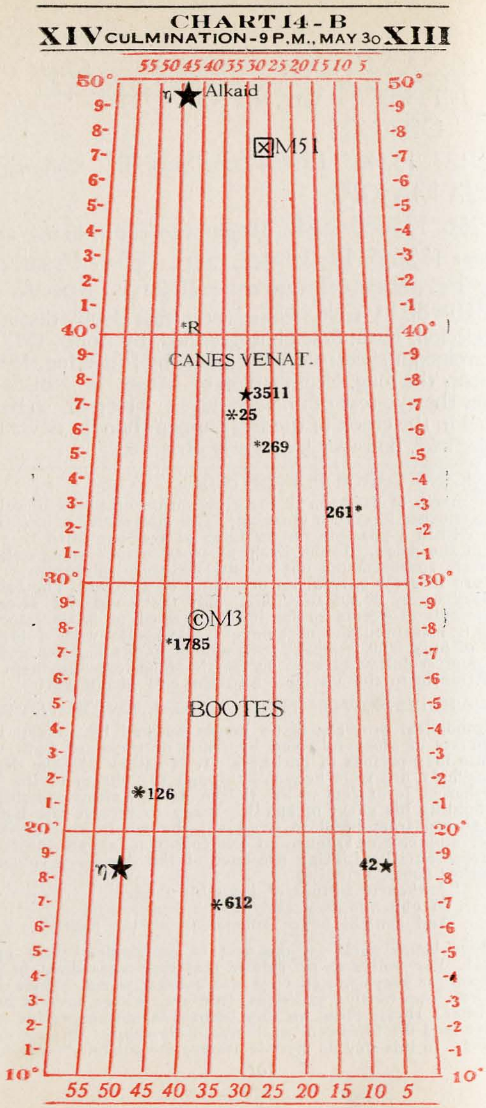
The march of progress in the elimination of errors in celestial measurements has been amazing. The star-places of the Greeks were within a possible ten minutes of arc—one-third the diameter of the moon. Tycho Brahe's errors in measuring neighboring stars approximated one minute. Modern micrometric measures are in error only about one-tenth of a second. Photographic parallax error, 0″.005 to 0″.010. But the wonderful Michelson interferometer seems to be the last word of human accuracy since it measured the components of Capella with a probable error of only 0″.001—which corresponds to the angular diameter of a quarter-dollar as seen across the American continent from the Atlantic to the Pacific. And the end is not yet!

DISCOVERIES NOW OF INSTANT WORLD-WIDE INTEREST.

Astronomical progress is no longer marked by sudden meteoric bursts of glory followed by trails of wayward light wasting into long periods of darkness. It is rather like the descent of the "holy fire from heaven" through the chapel of the Holy Sepulcher at Jerusalem to the thousands of waiting worshippers each holding his sheaf of candles ready to receive the light as it is passed from hand to hand till the whole vast edifice is ablaze, and carried thence to far countries as an inspiration and hope—an illuminating presence of the divine, a solace for the darker hours, bringing

> "Authentic tidings of invisible things
> Of ebb and flow and ever-during power,
> And central peace subsisting at the heart."

"Those happy souls — the first to contemplate these mighty themes! For well may we believe that they were lifted in spirit and truth far above human vices and a baser world. Their minds were free from wasting ambitions, void even of the envy of boundless riches. Honor them, for they brought far-distant worlds within our ken, and the firmament itself was made subject to their understanding. In this way do mortals achieve the sublime."—Ovid.



η 134449 1.9. Par.0″.03=108 l y. B3. *Chart 14-B*

CANES VENATICI:

M51 132647 Sp. Neb. Transcendent 'Whirlpool Nebula' of Lord Rosse, resembling more an eternal question-mark—a supernal celestial enigma which in very truth it is. Diam., probably twenty times orbit of Neptune; and tho whirling at incredible speed, requires 45,000 years to make a single revolution! Van Maanan. 3° s p η Ursae Maj. (See Mt Wilson Obs. photo, Ill. Seo

R 134440 Var. 6.1: 12.7. Per. 326d.

Boss3511 133037 Sp. bin. 4.9. Short per. 1.61 d. F.

25 133336 Vis. bin.: 5.-5.8. a=1″.12. Per. 220y Fo.

OΣ269 132835 Vis. bin.: 7.2-7.7 a=0″.325. Per. 48 yrs. Spc. A5.

OΣ261 130832 D: 6.9-7.4. Sep. 1″.6.

M3 133828 Glob. Cl. Pre-eminent in its class, visible unaided in a clear sky. Several hundred thousand suns, compact in center, scattering at circumference. Distance, 13,900 parsecs = 3000 million ast. units—60,000 lt. yrs. It requires light 65 years to span its angular diameter. Our Sun in its midst would be too faint even to photograph by two magnitudes. Shapley. Nearly 100 short-per. Cepheid variables found by Prof. Bailey. 30′ east of β Comae Ber.

"About 80 globular clusters are known, with distances ranging from 20,000 to 200,000 light years."

42 Comae Ber. 130518 Vis. bin.: 5.2-5.2. a=0″.674. Per. 25.33 y. Spc. F5. Plane of orbit in line of sight—inclination=90°—occultations thus occurring every 13 yrs.

BOÖTES:

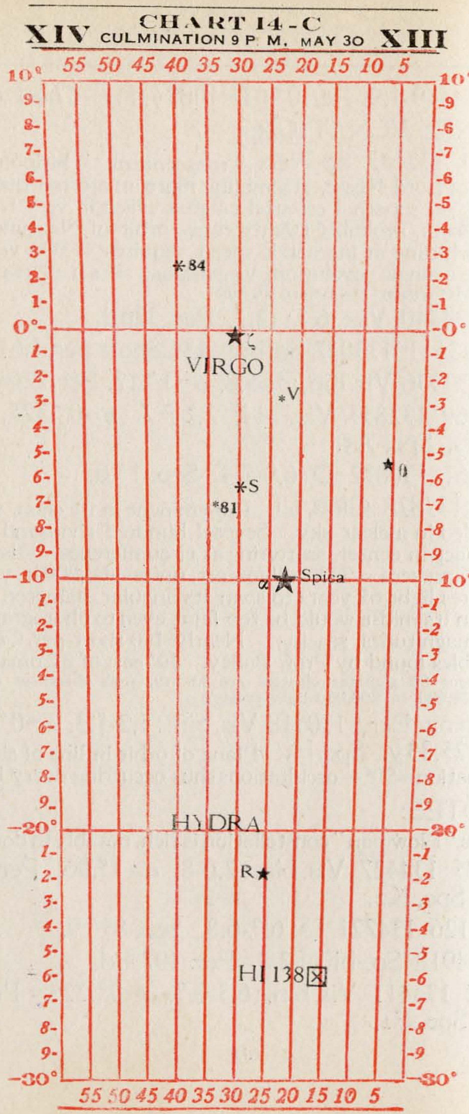
The "Plowman" constellation is rich, notably in doubles.

Σ1785 134427 Vis. bin.: 7.6-8. a=1″.06. Per. 199 yrs. Spc. K2.

O$\Sigma\Sigma$126 134721 D: 6.3-6.8. Sep. 85″.9.

η 134918 Sp. bin.: 2.8. Per. 497.1 d.

β612 133411 Vis. bin.: 6.3-6.3. a=0″.225. Per. 23 yrs. Spc. F2.



VIRGO: *Chart 14-C*

84 133903 D: 5,8-8.2, Sep. 3″.4.

ζ *133000* Mag. 3.4. 13′ south of Celestial Equator.

V *132202* Var. 8.6:13.9. Per. 250d.

θ *130505* D: 4-9. Sep. 7″.1.

S *132706* Var. 7: 12.3. Per. 376.3.

81 *133307* D: 7.5-7.5. Sep. 2″.7.

α Spica *132110* 1.2. Par. 0″.022. Dist. 150 ly. Spc. B2. Sp. bin. Sep. 12 million mi. Mass, 15½, and luminosity, 4000×Sun.

R Hydrae *132422* Var. 4.2:9.5. Per. 405d.

HI 138 *131326* Neb. Small but bright. High powers disclose nucleus.

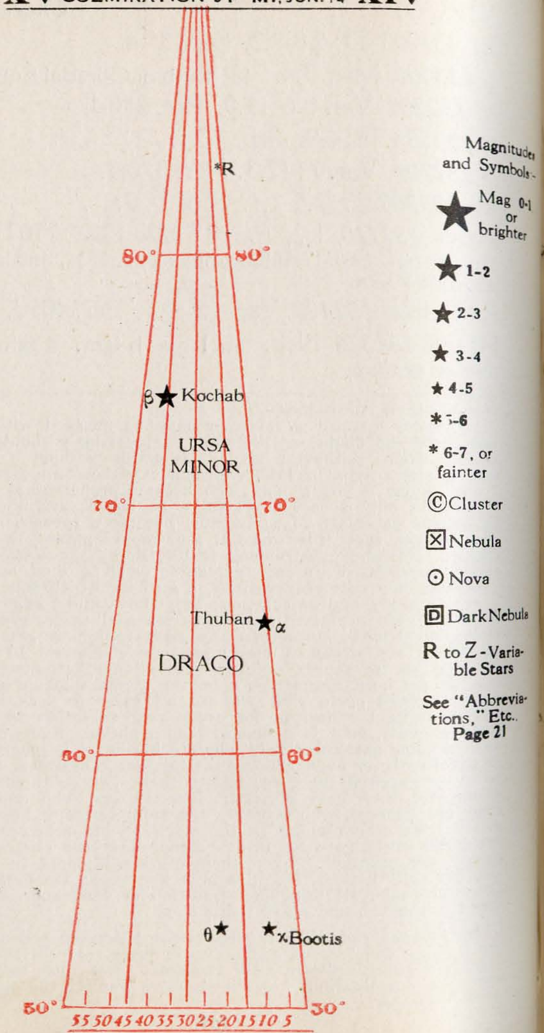
NAKED-EYE ASTRONOMY.

Astronomy without a telescope may be pursued with a certain profit, no doubt, as likewise, engineering without a transit, the drama without a stage, navigation without a sextant, art without crayon or brush, or music without an instrument. I once knew a young man who became proficient as a linotyper with only a card chart for a keyboard; and who, when he became possessed of a machine, became a speed-fiend. But who without these instrumental aids would pursue them from choice? Naked-eye astronomy is like doing the Vatican with spiked sandals, or in-door gardening with a seed catalogue. True, one may take observations in an hour which may call for a week's study and calculation; but who would forego the inspiration and incentive of the instrumental achievement save from compulsion? More than any other nation we are accused of taking our pleasures and often our education, by proxy; but that we so keenly enjoy a professional ball-game argues that we are born sportsmen; a boxing match that we are born fighers; grand opera that we are all more or less musical; and scanning the horizon for every new sensation in science because every man is a scientist in embryo. Everyone does well in some particular field wherein his heart is where a few do excellently or even achieve distinction. These few we look up to—protagonists of time, taking their dicta without reservations, for they have arrived. But the one who enjoys the game the keenest, who achieves the more intimate knowledge, who carries others along in the spirit of his progress is the first-hand investigator of things actual—the true observer, not merely the onlooker. Even though his equipment be modest and his skill limited, his pleasures and profit far outdistance those who take all things on tradition or sufferance. He has found a kingdom and made it his own.

"In the affairs of life how wide is the difference between having a thing done for us and doing it ourselves! In the latter case, how great is the interest awakened, how much more thorough the examination, how much more perfect the acquaintance!"—Draper.

CHART 15-A

XV CULMINATION 9 P. M., JUN. 14 **XIV**



CAMELOPARDUS *Chart 15-A*

R 142584 Var. 8.3: 13.1. Per. 271.2 d.

URSA MINOR:

β 145174 2.2. Par. 0".014=230 l y dist. Spc. K5 Ar. Kochab, 'Guardian of the Pole.' Pole Star, A.D. 140

DRACO:

α Thuban 140264 3.64. Sp. bin. Per. 51.38d. Spc. A.

"There is no doubt that Thuban was the Pole Star when the Great Pyramid of Egypt was built. The latter has an inclined gallery directed to a point 3° 42' below the Pole." Crommelin. As Thuban was approximately the Polaris of that day, it is only necessary to compute the time elapsed for the true Pole to describe the arc between them at the precessional rate of 50".2 per annum to ascertain the approximate age of the Great Pyramid: 2750 years, plus the span of the Christian era. I myself, some years ago, crept down into the sepulchral chambers deep in the bowels of solid masonry in this most ancient of tomb-observatories, and gazing obliquely up through the murky rift, beheld a rectangular patch of blue Egyptian sky where Thuban once reigned in solemn grandure—a thrilling moment! Well has the British savant further observed: "The early progress of astronomical knowledge is worthy of the minutest study on the part of all devotees of the science. Contempt for these pioneers is quite a misplaced sentiment. The great advance that has been made in modern times was rendered possible by the patient labors of our predecessors. The foundation is the most important part of the edifice; and the foundation stone of the lofty structure of astronomical science was well and truly laid in the distant past."

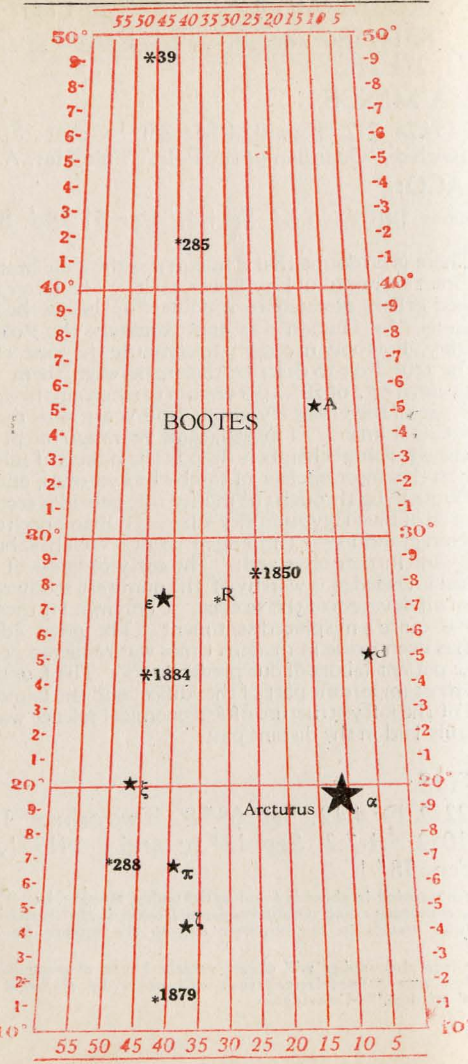
BOÖTIS:

θ 142252 D: 4-12. Sep. 68".8. Two others, 1½° *p.*
χ 141052 5.1-7.2, Sep. 12".6; and ι, 141351, 4.9-7.5. Sep. 38".1.

"Star observing is charming and enlightening always; but it is the serious, consecutive and definitely-planned outlook that really counts and brings results to the observer and to the science he would adorn."

"The true philosopher will always remain a man of sympathy with his fellow men. Speculative truth will never be alienated from practical wisdom."—Coleridge.

XV **CHART 15-B** XIV
CULMINATION 9 P.M., JUN. 14



39 144749 D: 5.8-6.5. Sep. 3″.7. *Chart 15-B*

OΣ285 144142 Vis. bin. 7.5-8.0. ***a***= 0″.34. Per. 97.93 yrs. Sp. F5.

A 141335 Sp. bin. 4.83 Per. 211.95 d. Spc. G5.

Σ1850 142528 D: 6.1-6,7, Sep, 25″.7,

R 143227 Var, 7,1: 12,3, Per, 223,2d.

ε 144127 D: 3-6.3. Sep, 2″,6. Gold and blue test-star.

d 150525 Sp. bin, 4,8 Per, 9,6 d. Sp, F5.

Σ1884 144424 D: 6,2-7.8. Sep. 1″.2,

ξ (1888) 144619 Vis. bin.: 4,8-6,4. Per. 159.54y. G5.

α Arcturus 141219 0.2, Par, 0″,105=31 ly dist, Spc. Ko. R. v., —3.9km.-sec. Linear diam., 21 mill. mi. Pease. 24½ × Sun! Density, 0.0002—(Water=1.) An. p. m., 2″.28=53mi.-sec, =2½ ×Moon's disc in 2000 yrs.! Von Humboldt. Continuing the curve in the handle of the Big Dipper 40° marks Arcturus. Gk. The Bearkeeper. Muller.

"It may now be said that within the first quarter of the twentieth century, a greater knowledge has been acquired of the distance, size, luminosity, mass, classification, composition, velocity, variability, magnitude and distribution of stars than has been acquired in all previous centuries!"—Dean.

"There is abundant room for the development of new and brilliant methods of attacking the larger astronomical problems. In general, however, it appears probable that future advances will depend upon the accumulation of many discoveries concerning the units of a class of objects, and upon careful and systematic analysis of these facts for the basic truths of stellar evolution."—Aitken.

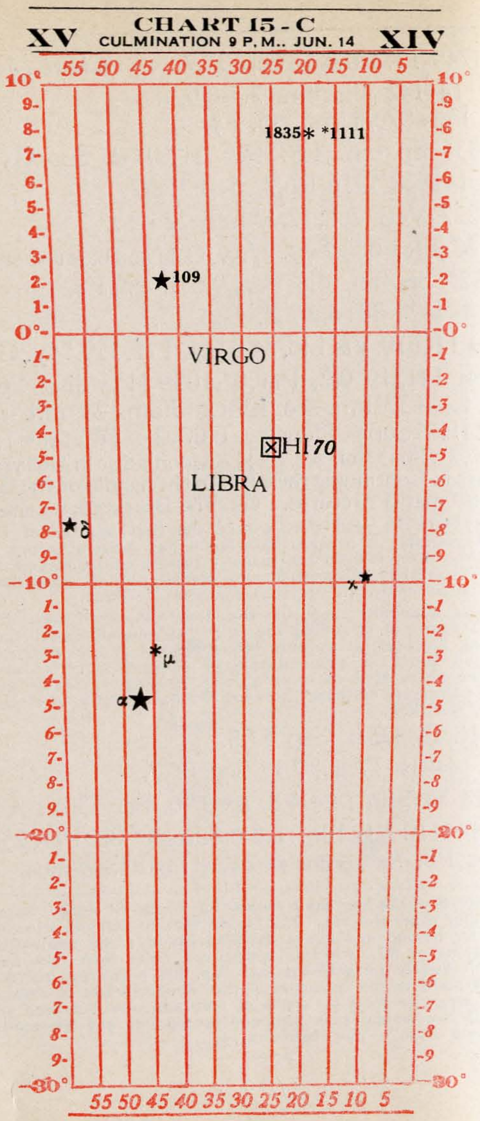
π 143716 D: 4.9-6. Sep. 5″.8.

OΣ288 144916 D: 6.4-7.1. Sep. 0″.7.

ζ 143614 Vis. bin.: 4.4-4.8. ***a***=0″.6. Per. 130y. A2.

Σ1879 144110 Vis. bin.: 7.8-8.8. ***a***=1″.06. Per. 238 yrs. Spc. F8. Sweep due westward from δ Serpentis.

"The majesty of the heavens I confess has under all circumstances a never-ending charm for me. The simple thought that the celestial units are far beyond and above anything earthly; the realization that everything of this world in comparison fades from view and man himself utterly insignificant—his fate, his pleasures, his desires. Engrossed in the splendors of this wonder-drama of nature, who could stray far from the paths of rectitude who had been accustomed to live amidst such profound conceptions and frequently to dwell upon them."—Von Humboldt.



Σ1835 141908 D:5.5-6.8. Sep. 6″.1. ***Chart 15-C***

β1111 141808 Vis. bin. 7.4-7.4. ***a***= 0″.26. Per. 44.3 yrs. Spc. Ao. In field with above.

VIRGO:

109 144202 3.8. Conspicuously fine Double field.

HI70 ***142505*** Neb. Beautiful lacery of nebulous stars.

κ ***140810*** 4.3. Blazing region to westward.

LIBRA:

δ ***145608*** Algol Var. 4.8-6.2. Per. 2.327 d Duration of eclipse, 13 hrs. Spc. A. A very notable object.

μ ***144413*** D:5.5-6.3. Sep. 1″.5.

144615 D:2.9-6. Wide, close to Ecliptic—Sun's path.

HYDRA:

54 ***144125*** D: 6-7.5. Sep. 9″. A legion of vari-tinted multiples, quite bewildering tho low in our latitudes.

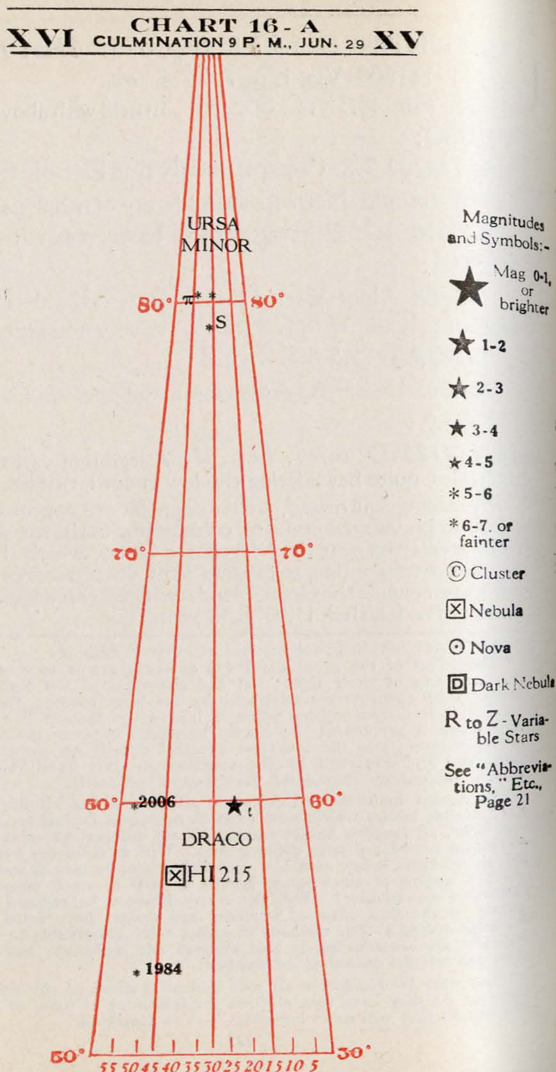
Proceeding southward, stellar aggregations appear to increase in prevalence and size, culminating in the five gigantic clusters lying near the Magellanic Cloud, which show a parallax corresponding to 110,000 light years distance from our system, while the Great Cloud itself gives an angular diameter of no less than 15,000 light years!

STARLIGHT'S UNCHANGEABLE CHARACTER.

"The effect of the great distances of the stars is to diminish the intensity of their light; but the character of the light appears to be absolutely unchanged by its long journey through space. If it is red or blue when it leaves the star, it is red or blue when it arrives at the Earth, hundreds or even thousands of years later; and the minutest spectral details are accurately preserved and analysed by the spectroscope just as if it came from a laboratory source ten feet away!"—Merrill.

"We cannot doubt that all the stars, all the nebulae, all the dark and invisible bodies which must exist in profusion throughout space —in brief, all tangible bodies making up our sidereal universe—are moving in accordance with definite laws. Will astronomers ever be able to tell their fellow men how each bright star in turn is moving, and how groups of stars—great groups as well as small ones—are related to one another? Will the starry heavens be reduced to a system, as the Sun, planets, satellites and comets have fitted into the solar system? The methods of today, truly remarkable in their accuracy, are contributing to this purpose and ambition; but time alone can tell the outcome."—Campbell.

"The stars bind together all men and all periods of the world's history. As they have seen all from the beginning of time, so shall they see all that will come hereafter."—Von Humboldt.



URSA MINOR: *Chart 16-A*

π 153380 D: 6.-7. Sep. 30″.

π^2 154580 Vis. bin.: 7-8. α=0″.42. Per. 115 y.

S 153378 Var. 8.3:11.5. Per. 322.5 d.

DRACO:

Σ2006 155859 Trip.: 7.5-7.7-9. Sep. 1″.6, 43″.5.

ι 152359 3.5. Index star to Neb. HI 215.

HI215 154056 Neb. Bright, 9′×30′. Two others, *n f.*

Σ1984 154953 D: 6.2-8.5. Sep. 6″.6.

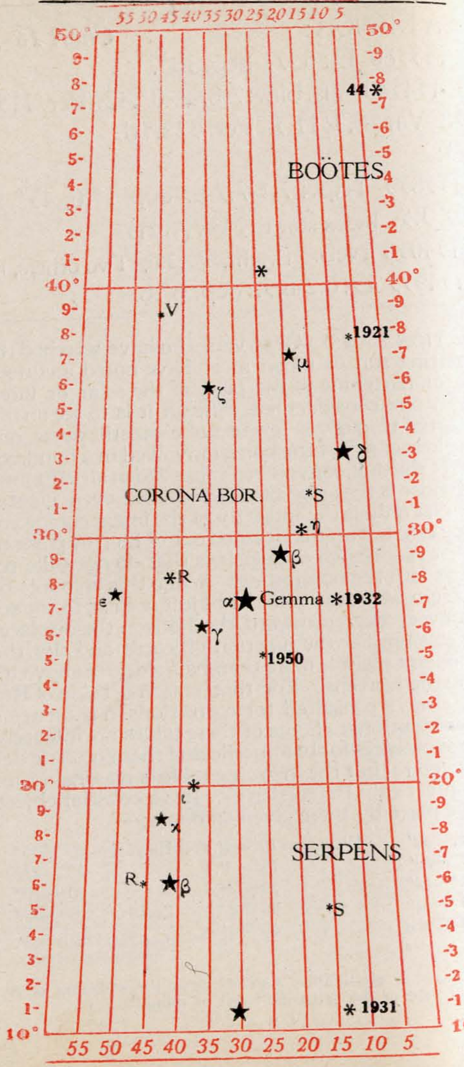
REFRACTION LAWS:—Observers who have watched the rising or setting sun or moon must have noted a curious oblateness or flattening of the poles of the solar or lunar disc. When one considers how difficult it is to see an image undistorted through a few feet of clear still water, one realizes the immensity of the barrier involved in a hundred-mile depth of shifting, convolving, vapor-laden air-currents, and the wonder is that the distortion is not even greater than it is. Not only is the integrity of the image compromised, but the celestial unit is elevated out of its true place to a degree that nullifies all calculations that do not take refraction laws into the accounting. While this amounts to practically zero when the celestial object is close to the zenith, with every degree toward the horizon the displacement increases until at the junction of earth and sky the object's apparent place is more than half a degree above its true place in the heavens. For that reason a Table of Refraction is always consulted for corrections in the matter of precise calculations. Some of these tables are infinitely exact, with allowances for barometric and thermometric deviations, et cetera; but the following table is reasonably accurate and practical. Refraction elevates a celestial object from its true place by these given amounts:—

On Horizon, *34′*	Elevation 10°—*5′.4*	Elevation 60°—*33″*
Elevation 1°—*24′*	15°—*3′.5*	70°—*21″*
2°—*18′*	20°—*2′.6*	80°—*10″*
3°—*14′*	30°—*1′.7*	Zenith, 90°—*00″*
5°—*9′.6*	40°—*1′.0*	Cold and high Bar. increase Refraction.
7°—[illegible]*′.3*	[illegible]*48″*	

"The future of our civilization depends upon the widening spread and deepening hold of the scientific habit of mind."

XVI **CHART 16-B** XV

CULMINATION 9 P. M. JUN. 29



BOÖTES: *Chart 16-B*

44 (Σ1909) 150048 Vis. bin.: 5.3-6.2. a=3″.58. Per. 204.74 yrs. Spc. Go.

ν² 152841 D: 5.5-5.5. Sep. 0″.1. With ν1 a fine duo.

OΣ298 153240 Vis. bin.: 7-7.3. a=0″.88. Per. 56.6 yrs. Spc. Ko.

V 154639 Var. 7.8: 11.3. Per. 357.5 d.

Σ1921 150938 D: 7-7.2. Sep. 30″.3. Central of 3 D's.

μ1-μ2 (Σ1938) 152137 Double D: 4-6.5; Sep. 108″5. and Vis. bin.: 7.2-7.8. a=0″.88. Per. 244.37 y. Ko. One of the pre-eminent quadruple systems.

δ 151233 D: 3.2-7.4. Sep. 105″.

CORONA BOREALIS:

ζ 153636 D: 4.1-5. Sep. 9″. Vivid pair. Another, s p.

S 151731 Var. 7.0: 12.8. Per. 361.2.

η 151930 Vis. bin.: 5.6-6. a=0″.9 Per. 41.5 y. Go.

β 152429 Sp. bin.: 3.70. Per. 40.9: 490.8 d. Fo.

R 154428 Var. 5.9: 15.0. Per. Irreg. Famous of its ever-surprising type. "Merits careful attention." Furness.

Σ1932 151427 D: 5.5-6.1. Sep. 1″.6.

α Gemma 153027 2.3. Sp. bin. Per. 17.36 d. Par. 0″.052=62 l y dist. Spc. Ao.

γ 153826 Vis. bin.: 4-7. a=0″.73. Per. 87.8y. Ao.

Σ1950 152625 D: 6.7: 8.1. Sep. 3″. Gold-turquoise.

SERPENS:

ι 153819 D: 5-5. Sep. 0″.2. A stellar Golconda south.

κ 154518 4.3. Center of vivid trapezium: serpent's head.

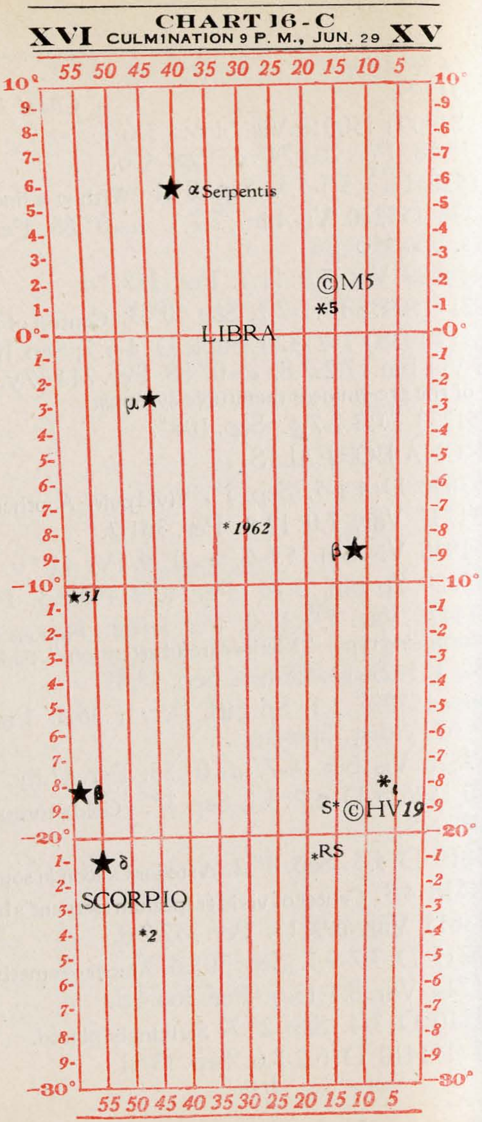
R 154615 Var. 6.9: 13. Per. 357.2 d.

β 154215 D: 3.7-9.1. Sep. 30″.6. Amber—amethyst.

S 151714 Var. 8.5: 13.6. Per. 366.4 d.

δ 153110 D: 3-4. Sep. 2″.7. Strikingly placed.

Σ1931 151410 D: 6.2-7.6. Sep. 13″.1.



α 154006 2.8. Par. 0″.038=861 y. ***Chart 16-C***

M5 (Librae) 151502 Cl. Close np 5 Serp., mg. 5. Glowing compress of 9-14 mag. stars. Contains many short-period Cephids. Dist., 40,000 lt. yrs.

μ ***154503*** 3.6. Bright unit in insular field. Mg. 6 comes.

LIBRA:

Σ1962 ***153408*** D: 6.3-6.4. Sep. 11″.8. Commanding!

β ***151209*** 2.5. Pale emerald unit, resembling Uranus.

ι ***150719*** D: 5-9. Sep. 57″. Wide guide-stars to Cl. 19.

HV19 ***151220*** Glob. Cl. A universe of remote suns.

"The period required for a single circuit of a star through a globular cluster is of the order of a million years; and the stars of which clusters are composed are several thousand million years of age."—Moulton.

S ***151520*** Var. 8.5:12.3. Per. 192.2.

SCORPIO:

The southeastward sweep of the zodiacal Scorpion begins here—the most commanding of the Summer constellations with burning Antares at its heart. The graceful cup-shaped curve of the tail dipping out of the horizon, ending in the scorpion's sting represented by two flashing stars, λ and υ, presents a prospect that, as Dr. Aitken observes, is "always striking."

The dark nebulae of Scorpio and Ophiuchus are distant from us about 100 to 150 parsecs—326 to 480 light-years. Those in Orion are further still: about 200 parsecs—640 light years. The mass, which is in the form of cosmic dust less than 0.1mm. in diameter, is nevertheless sufficient to form hundreds of stars of magnitudes visible from earth!

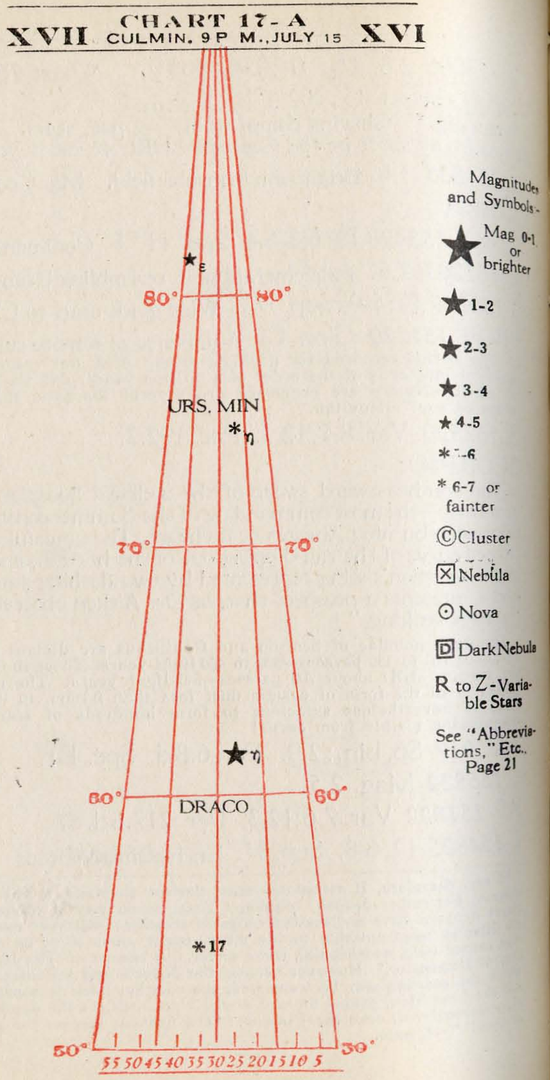
β ***155919*** Sp. bin.: 2.9. Per. 6.8 d. Spc. B1.

δ ***155522*** Mag. 2.5.

RS ***151822*** Var. 7.6:12.3. Per. 217.6d.

2 ***154825*** D: 6-8. Sep. 3″. Enchanting environs.

"I say, therefore, if astronomy must destroy theology, it will not destroy, but rather deepen, religion. There is no man in whom the starry heavens have not excited religious emotion; whatever may be the litanies most suitable to his mind, under some form or other man cannot help worshipping when under this canopy of 'The Cathedral of Immensity.' However various the dialects and formulas into which the emotion may be translated, the emotion itself is constant; and the Last Man, gazing upward at the stars, will, in the depths of his reverent soul, echo the Psalmist: 'The heavens declare the glory of God!' "—Comte.



URSA MINOR: *Chart 17-A*

ε 165682 4.4. Sp.bin. Per.39.5d.

η 161975 5.0. Makes pretty triangle with 19-20.

DRACO:

η 162261 D:2.9-8.1. Sep. 4″.7.

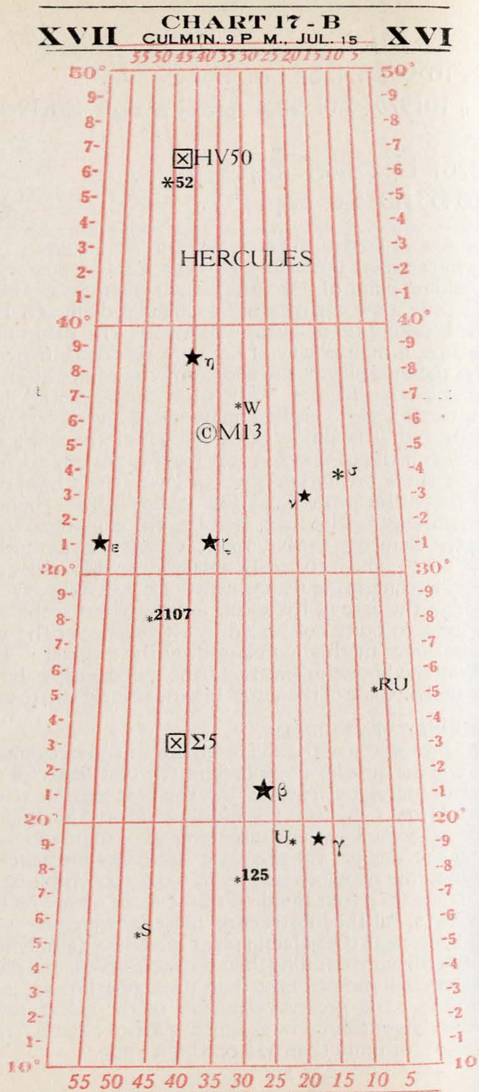
17 163453 D:5-6. Sep. 3″.7.

KNOWN ELEMENTS OF SPECTROSCOPIC BINARIES.

Even in the most powerful telescopes, a star appears only as a twinkling point of light, the planets alone presenting a disc of steady glow and measurable angular diameter. But with the breaking up of a star's beams by the prism of a spectroscope, a multiplicity of lines are disclosed, depending upon the intensity of the spectrum, the composition of the star and other factors. But when these spectral lines are seen to shift periodically, now toward the violet, now toward the red, it is almost certain proof of the star's duplicity, even if the companion star itself is invisible. The periods of these oscillations give a clew to the orbital motions of the visible primary and its unseen comes about a common gravitational center, enabling the computer to determine the elements—orbit, mass, velocity, magnitudes, distance, etc. Thus, curiously enough, the difficulties encountered in computing the elements of a visual binary are mitigated in the case of the spectroscopic binary—the science of the seen quite outranked by the science of the unseen—the direct method outclassed by the indirect. For this reason the known elements of the spectroscopic binaries outnumber those of the visual binaries nearly two to one

THE RICHEST STAR-FIELDS.

To the prospector with modest equipment, the regions in the galactic north polar areas present the best fields for the detection of individual features; but the vast expanse to the southward from Cygnus is the most impressive for leisurely sweeping, some locations disclosing sixty thousand suns to the square degree, till the lower latitudes are reached where obscuring nebulous masses thin out the visible star-swarm to less than four hundred to the same area. As Dr. Shapley says, "if the obstructing material were removed, we might see, near the galactic plane, clouds of faint Milky Way stars still more dazzling than those observed, and globular clusters still more distant than those now known, and hence find that the greatest diameter of the galactic system is even larger than now assigned—approximately 100,000 parsecs" or more than 326,000 light years!



HERCULES: *Chart 17-B*

"The Mighty One" discloses many rarities in radiant fields to the south and southeast.

HV50 164447 Pl. Neb. Sea-green in starry triangle.

52 164646 Tr.:5-9-9. Sep. 1″.8-0″.2. Difficult.

η 164039 3.6. Guide-star to great Cluster, 2° s toward ζ.

W 163137 Var. 8.2:13.5 Per. 279.5 d.

M13 163836 Glob. Cl. Conceded to be the finest of its class in the northern heavens. Forty-five thousand suns in a compact spheroidal mass, every unit of which exceeds our Sun by at least two magnitudes (and in whose midst our orb of day would be quite invisible), the majority of them from ten to hundreds of times more massive. Diam., 350, and distance 35,000, light years. And yet, according to Dr. Shapley, M13 is one of the nearest of the clusters! A naked-eye object on a clear moonless night, in a small glass a curious olivine blurr, often resolvable; but viewed with apertures of increased light-gathering power, a blazing panoply of suns of varied tints and staggering brilliancy. Good photographs of such majestic prodigies—of which there are all too few visible in our hemisphere—are always a great help. (See Lick photo, Ili Sec) Sweep 2° due s from η Herc.

σ Cor. Bor. 161234 D.:5-6.1. Sep. 5″.4.

ν Cor. Bor. 161933 D.:4.8-5.1. Wide. Sep. 371″.9.

ζ 163731 Vis. bin.:3-6.5. *a*=1″.35. Per. 34.46 yrs. Completed three revolutions since disc. by Herschel, 1782.

ε 165631 3.9. Sp. bin. Per. 4.0d. Spc. A.

Σ2107 164728 Vis. bin.:7-8.5. *a*=0″.85. Per. 221.95 yrs. Spc. F5.

RU 160625 Var. 7.9:13.7. Per. 478d.

Σ5 164123 Pl. neb. Bright. Diam. 8″. Blue-green.

β 162521 2.81. Sp. bin. Per. 410d. Spc. K.

γ 161819 D.:3.8-8.2. Sep. 40″.5.

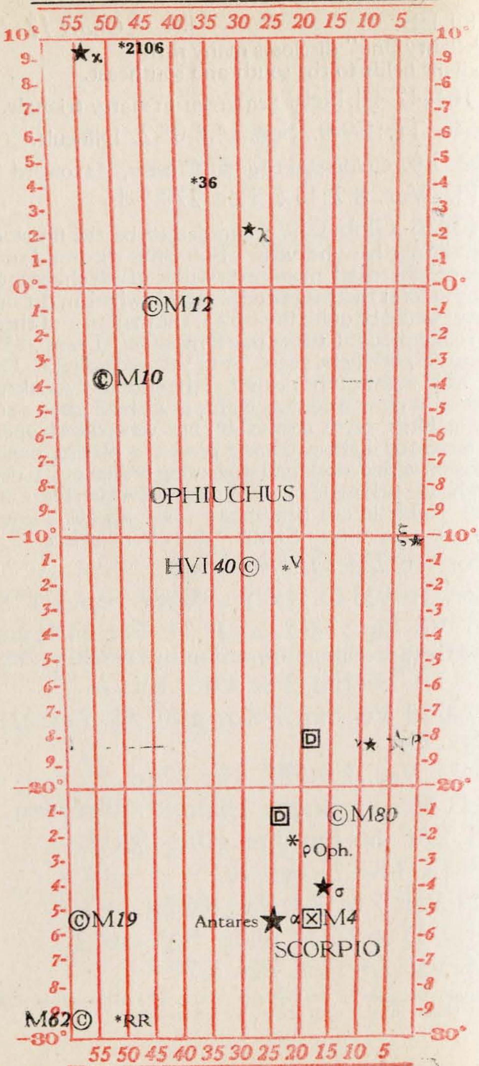
U 162119 Var. 7.6:12.3. Per. 406.2d.

125 163117 D.:6.2-7.5. Wide. Sep. 156″.2.

S 164715 Var. 7.5:12.2. Per. 307d.

The average distance of naked-eye stars is estimated at 320 light-years; those of the 12th mag., at about 1000.

CHART 17-C
XVII CULMIN.-9 P. M., JULY 15 XVI



OPHIUCHUS: *Chart 17-C*

The Snake Bearer begins at this meridian, and is unsurpassed for sweeping-fields and sensations.

Σ2106 164709 D:6.7-8.4, Sep. 1″.0. With Σ2114 D:6.2-7.4, finely placed e-w of χ Oph., 165409, 3.4.

36 163604 D.:6-7. Sep. 69″.7.

λ 162802 Vis. bin. 4-6.1. *a*=0″.99. Per. 134 y. Ao.

M12 ***164301*** Cl. "Intermediate between globular and diffuse galactic type." Distinguished surroundings.

M10 ***165204*** Cl. Silvery massed ±12-mg. suns.

ξ Scorp., 51 Lib. ***160011*** D:4.9-5.3. Sep. 1″.19. 45 y.

HVI 40 ***162812*** Cl. Pale but fine l. p. star-swarm.

V ***162112*** Var. 7.4:10.2. Per. 297 d. 11′ *p* ζ, 2.7.

ρ ***162123*** D:6-6. Sep. 4″.1. Region of dark neb.

M19 ***165726*** A bewilderment of loose Cls., accentuated by encompassing black rayless space-deeps.

SCORPIO:

ν ***160719*** D.:4.1-7. Sep. 48″.8. Both D's are doubles.

β ***160819*** D.:2-4. Sep. 13″.1. Intense, colorful.

M80 ***161222*** Noble Cl. Richest in the heavens. Herschel.

σ ***161525*** D.:3-8. Prim. Sp. bin. Per. 0.247 d. B1. Probably a Cepheid triple system—a case unique. Henroteau.

α Antares ***162426*** 1.2. "Rival of Mars." Par. 0″.017 = 1901 y dist. Spc. Ma. Ang. diam., 382 mill. mi., —nearly 500×Sun! Density, 0.00001—water=1.

This fire-bright prodigy not only has as a companion a vivid emerald comes emitting one-two hundredth of its own effulgency, but is so vast that six hundred million worlds like ours could crowd within its confines! If our Sun were at its center, the orbit of the Earth would lie buried deep within its circumference, and Mars itself scarcely more than skim the surface of this mammoth globe of incandescent gas.

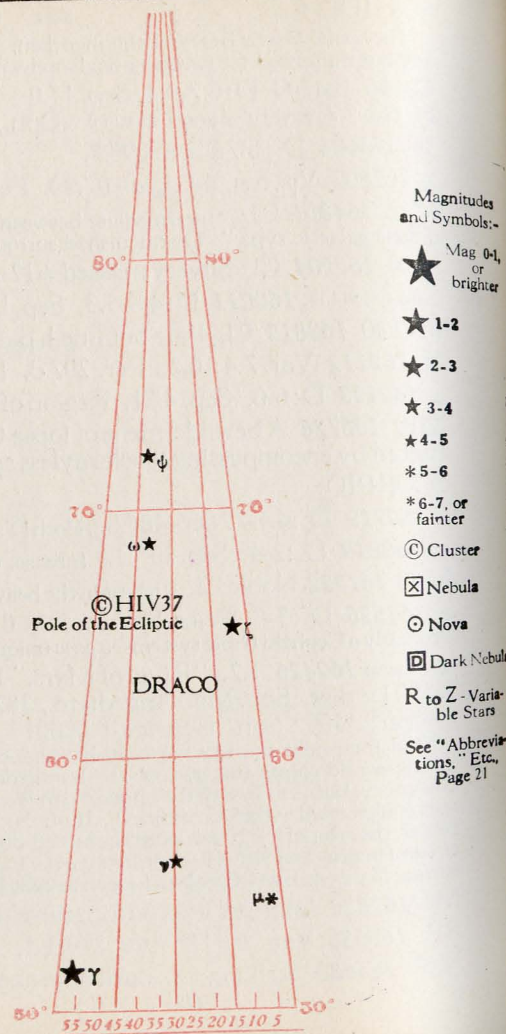
M4 ***161826*** Dim but interesting star-cloud.

RR ***165030*** Var. 6:11.5. Per. 279.3 d.

M62 ***165630*** Striking Cl., dark neb. abounding.

CHART 18-A

XVIII CULMIN. 9 P. M., JUL. 30 XVII



DRACO: *Chart 18-A*

ψ 174372 D:4-5.2. Sep. 30″.9.

ω 173768 4.87. Sp. bin. Per. 5.28d.

HIV37 175866 Pl. neb. Diam. 35″. Luminous blue.

Famous as being the first planetary nebula to reveal its gaseous nature to that master spectroscopist, Huggins, in 1864, leading up to many triumphs of research regarding these enigmatical bodies. Much smaller but brighter than the Owl Neb., in Ursa Major. Magnification discloses star center.

Planetary nebulae resemble somewhat the ball-and-ring aspect of the planet Saturn. They are ellipsoidal shells of gaseous content at high temperature, in composition similar to the diffuse, with helium disclosed in the central portions, hydrogen and nebulium—the element to which there is no terrestrial analogy—in the outer regions. They rotate at various rates of speed, increasing toward the central zones nucleated about a star of the Wolf-Rayet type, with a mass velocity in space of about twenty-four miles per second. Fewer than 200 planetaries have been catalogued to date, although they belong to our system, averaging about 1000 light years distance. "Planetary nebulae are probably wrecks of ancient collisions among stars, and may form into future solar systems similar to our own." Campbell.

About 11′s of HIV37, on the 18th. meridian, the Solsticial Colure, is located the Pole of the Ecliptic. No conspicuous celestial unit approximates its place to an observer such as Polaris at the Pole of the Equatorial system: but it is an important point in astronomical calculations and should be located for its bearing on many practical problems.

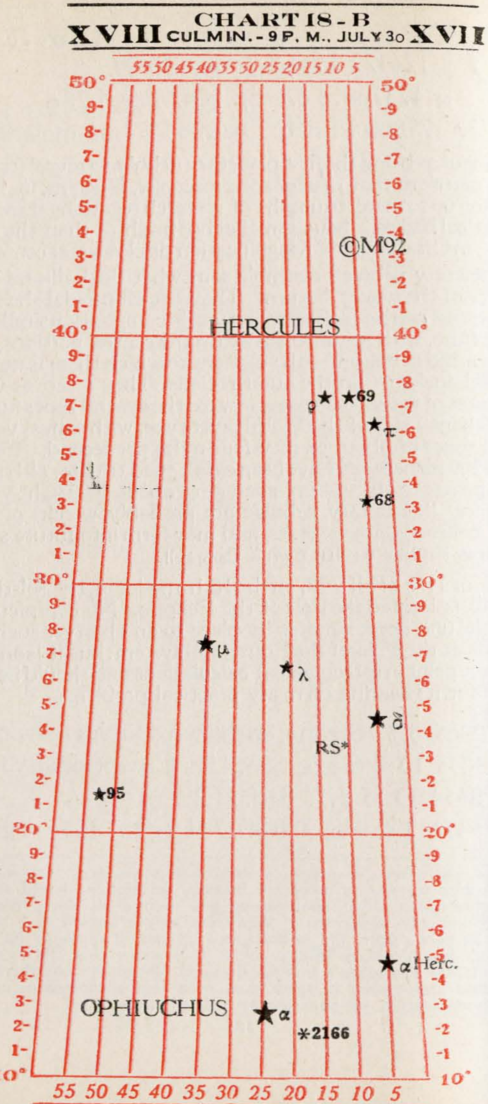
ζ 170865 3.2. Strong, with two doubles in field.

ν 173055 D:4.6-4.6. Sep. 1′+. Exceptionally fine.

μ 170354 D.:5-5.1. Sep. 3″.2.

γ 175451 2.4. Par. 0.044=741 y dist. K5. A gem!

Time was when, in order to determine star-speed, intervals of ten to fifty years were necessary between calculations based on direct observation. But photography has revised all that, reducing the time-interval necessary to determine proper motion to a single day. Barnard's Star, the swiftest moving sun in space so far discovered, has a proper motion of a little more than 10″ yearly, which means the Moon's breadth in about 180 years; but there are doubtless fleeter suns in space than even this phenomenon, as future determination by photography will disclose.



HERCULES: *Chart 18 - B*

M92 171443 Cl. Diam. 7'. Bright.

ρ 172037 D.: 4-5.1. Sep. 3".6. With π - 69 fine Tr.

68 171333 4.8 Var. Sp. bin. Per. 2.05 d. Spc. B3.

μ 174227 3.5-9.5. Vis. bin. $a = 1''.30$. Per. 43.23 y. Spc. Mb. Amber-blue. 9.5 also bin. "Most interesting system," according to Dr. Aitken, "showing that frequently it is the smaller or fainter star of a wide pair which is itself a close binary." Disc. by Alvan Clark, 1856.

λ 172726 4.5. Apex of Sun's way. Herschel.

If you describe an equilateral triangle from α Lyrae due south about 20° to 111 Herc., thence northwest a like distance to δ Herc., and so back to Vega, within these confines are located the various Apices of the Sun's Way as determined by distinguished authorities, from Herschel (1783) to Adams and Stromberg (1920), including Boss, Campbell and Kapteyn. The Sun with his planet-family is moving toward this region at the rate of about twelve miles per second, this star-drift having been determined by the apparent opening out of the star-fields as we advance, and their closing in as they recede, like forest-trees to a pursuing hunter. The motions of thousands of stars were computed to arrive at these approximations; and one can but marvel at the genius of Herschel whose conclusions were so brilliantly verified by time.

δ 171124 D : 3-8.1. Sep. 26".1. A study in color.

RS 171723 Var. 7.9:12.5. Per. 218.5 d.

95 175821 D.: 4.9-4.9 Sep. 6". Beryl - sardonyx.

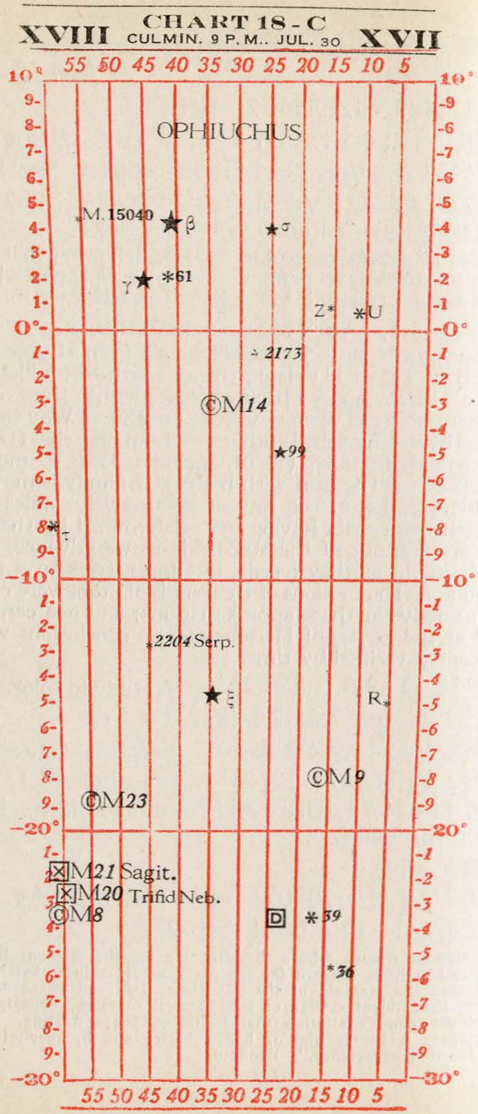
α 171114 D.: 3.1-6.1. Sep. 4".6. Prim. var.: 3.1 : 3.9. Par. 0".15 = 21.7 l y dist. Approximate diam., 185, 800,000 mi. Stetson.

OPHIUCHUS:

α 173012 2.1. Par. 0".052 = 60 l y dist. Spc. A5.

Σ2166 172411 D: 5.6-7.4. Sep. 27".5.

"The man or woman whose thoughts are for the moment lifted out of the humdrum concern for the petty sordid things that beset us, and into the marvels of that limitless time and space which constitute the subject matter of astronomical research, experiences an inspiration and exaltation that is in no sense fleeting. The effect abides; it leaves him or her a better and broader-minded citizen for that experience."—Benfield.



OPHIUCHUS: *Chart 18-C*

β 173904 2.9; σ, 4.4; and γ, 3.7, hold forth brilliantly, with 61 Oph., 174002 D.: 5.5-5.8 Sep. 20″.6, close *p* γ, noteworthy.

Munich 15040 175404 Mg. 9.4. Par. 0″.53 = 6.30 l y dist. Spc. Mb. Luminosity, 0.0005 × Sun. P. m., 10″.3 per annum. Next to α Centauri, our nearest star!

Z 171401 Var. 8.1 : 12.5 Per. 349 d.

Σ2173 *172501* Vis. bin.: 5.9-6.2. *a* = 1″.06. Per. 46 yrs. Spc. G.

M14 *173303* Cl. Extended—like blown star-dust.

99 *172105* Sp. bin. 4.6. Per. 26.27 d. Spc. F.

τ *175708* Vis. bin.: 5.3-6. *a* = 1″.3. Per. 223.82 y. F.

R *170215* Var. 7.6:13.8. Per. 302.2 d. Close p η.

M9 *171418* Cl. Small but scintillant and clear.

M23 *175219* Blazing wilderness of starry jewels!

39 *171324* D.: 5.5-6. Sep. 10″.6. Dark regions f.

36 *171026* D.: 6-6. Sep. 4″.2. Rapid p m—1″.27 an.

SERPENS:

Σ2204 *174113* D.: 7-7.2. Sep. 14.3.

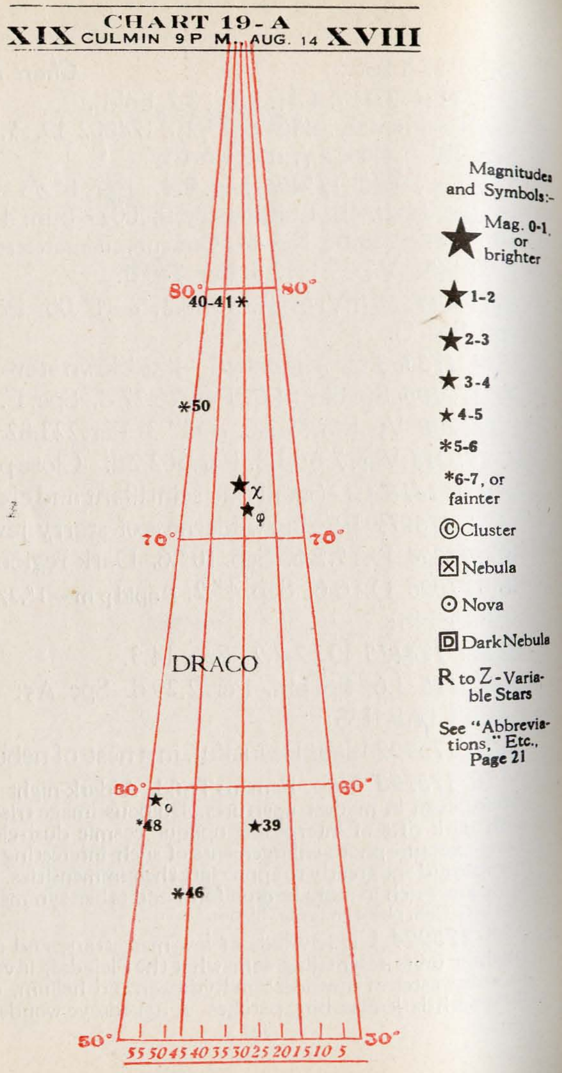
ξ *173115* 3.6. Sp. bin. Per. 2.29 d. Spc. A5.

SAGITTARIUS:

M21 *175922* Neb. Beautiful, in a nest of nebulae.

M20 *175723* Neb. Famous Trifid. A dark-night revelation, even in modest apertures. Bulbous image trisected with dark rifts of interposing opaque cosmic dust-clouds. Long-exposure photo-enlargements of such interesting phenomena aid one greatly to appreciate their immensities. Outlying areas rich in stars in cruciform and other symmetries. (See Lick Obs., photo and note, Ill, Sec.

M8 *175924* Cl. Myriads of low-mag. stars, and a few brighter units resembling somewhat the Pleiades, involved in wide wastes of incandescent hydrogen and helium, overflung with dark absorbing patches. A naked-eye wonder.



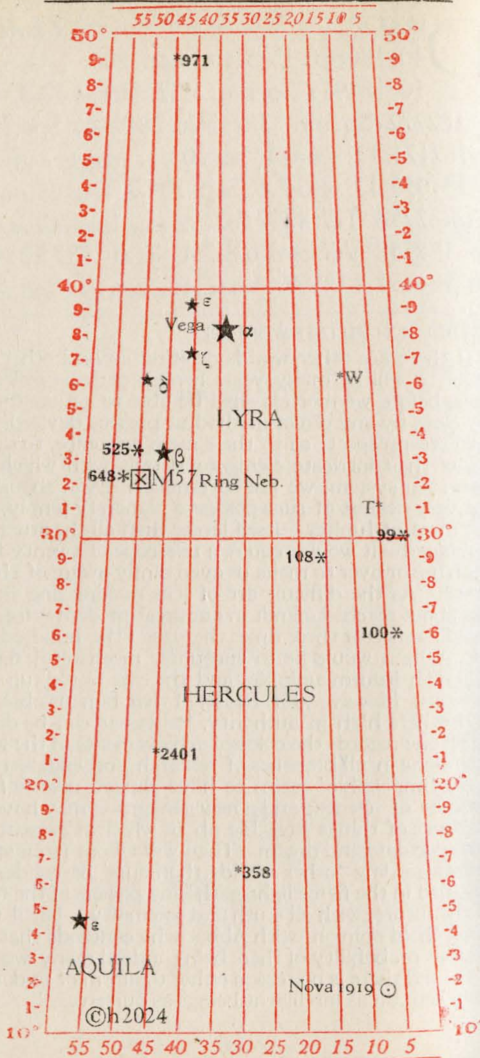
DRACO: *Chart 19-A*

40 180680 D: 5.4-6. Sep. 20″.
50 184975 Sp. bin. 5.37. Per. 4.12 d. Spc. A.
χ 182272 Sp. bin. 3.6. Per. 281.8 d. Spc. F8.
φ 182171 D: 4.8-6.5. Sep. 0″.5. In field with above.
o 185059 D.: 4.6-7.6. Sep. 30″.3. Nw-se trail of suns.
39 182258 Tr.: 4.7-7.7-7. Wide. Impressive, colorful.
48 185558 Vis. bin.: 6.8-7.4. $a = 0''.53$. 223 y. A2.
46 184155 D.: 5-9. Wide. Radiant blue and topas.

OTHER INHABITED WORLDS.

If there are other worlds orbiting around other suns in space, it will be many years hence, perhaps centuries, if ever, before we mortals shall be able to gather the slightest clew, by any direct method at present devised or in immediate prospect, as to their mere existence, to say nothing of their intricate elemental details with which, in our own solar system, we are so familiar. Even should one of the very nearest of suns possess a planetary family, each of the mass of Jupiter—itself larger than all the other planets combined—it would require a telescope of twenty-five feet aperture or over to make us even dimly aware of their existence. As the difficult art of lens-making and mounting has about reached a limit in our great modern refractors, to build a reflector three times the size of the hundred-inch at Mt. Wilson would be to encounter mechanical difficulties well nigh insurmountable, and the cost would run into the millions. However, Dr. Pease, of that famous observatory, and others high in authority, believe it can be done; and when one regards the colossal achievements in the last decade alone in all branches of research and engineering, the word 'impossible' seems to have slipped utterly from our lexicons of science; and a new generation may have ocular evidence of things invisible about which at present we can but speculate and dream. Then will all our fascinating theories regarding 'other worlds than ours' be condemned or justified in the fierce light-gathering powers of the telescope of the future, with all truth and solemnity. Until then we must 'hold opinion' with Abbot who contends that "there is great probability of there being indeed many worlds like ours; and there is no reason either to affirm or to doubt that they contain as intelligent beings as ourselves."

XIX **CHART 19-B** XVIII
CULMIN. 9 P. M. AUG. 14



β971 184549 D.:6.5-8.5. Sep. 0″.5. *Chart 19-B*

LYRA:

ε1-2 184139 Double D.: 4.6-6.3 : 4.9-5.2. Many low-mag. stars bet. —possibly one complex interrelated system.

α Vega 183438 0.1. Par. 0″.134 = 24 ly dist. Spc. A. Resembles an old-mine Brazilian brilliant of purest water intensified to infinity! 80 × Sun's luminosity. 1500 Vegas would give more starlight than all the stars in our heavens!

ζ 184137 Sp. bin.: 4.3. Per. 4.3 d. Spc. F.

δ 185036 D.: 4.5-6.5. Prim. a Sp. bin. Per. 245 d.

W 181136 Var. 7.7: 12.3. Per. 196.4 d.

OΣ525 185133 Tr.: 5-7-9.5. Sep. 1″.: 45″.5. Vari-col.

β 184633 D.: 3.6-7. Sep. 45″.8. Prim. Sp. bin. Per. 12.9 d. Spc. B2p.

β 648 185332 Vis. bin.: 5.2-8.7. ***a*** = 1″.04. Per. 45.8 yrs. Spc. Go. Probable Tr. system. Region thrilling!

M57 185132 Pl. Neb. Famous "Ring," 60″x80″. Finest of the annular type. With h. p., ring becomes a globe of luminous gas, receiving its effulgence from a central star. A cardinal unit, Easily sighted, s f βLyr. (See photo, Ill. Sec I)

HERCULES:

T 180531 Var.: 7.8:12.8. Per. 165 d.

99 180330 Vis. bin.: 5.2-10. ***a*** = 1″.1. Per. 53.5 y. F8.

108 181729 Sp. bin.: 5.5. Per. 5.5 d. Spc. A.

100 180426 D.: 5.9-5.9. Sep. 13″.8. Exquisite.

Σ2401 184521 D.: 7-8.6. Sep. 4″.1.

OΣ358 183216 D.: 6.8-7.2. Sep. 2″.

Nova Ophiu., 1919 180911 13.5. Test for a 6-in. glass.

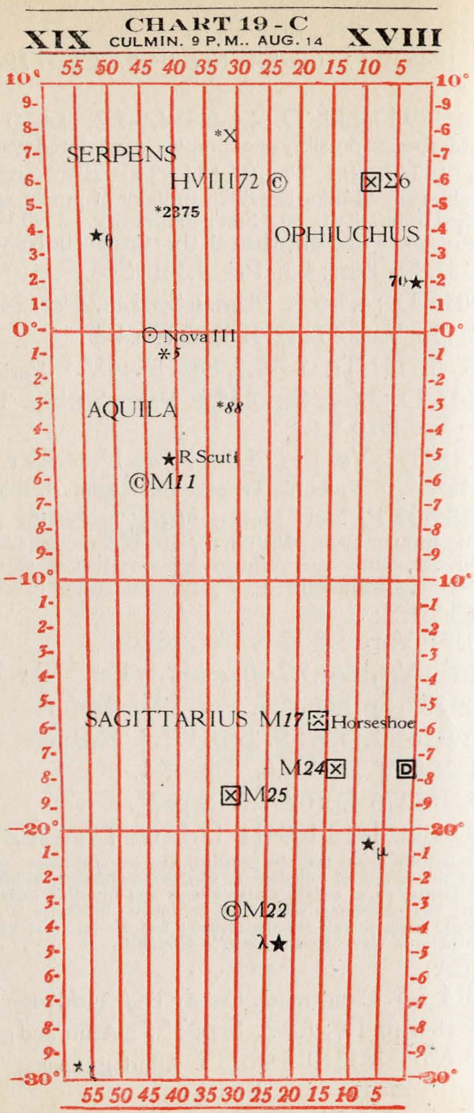
"There is little doubt that the principal new stars of recent years have been the results of collisions or of close approaches, either of two dark bodies, or of a dark massive body and invisible resisting materials. The suddenness with which the intense brilliancy is generated would seem to call for the former; but the latter is vastly more probable, in view of many facts."—Campbell.

AQUILA:

ε 185614 3.5. Clear amber. Dainty Tr. *f*. Field supreme.

Σ2404 184710 D.: 5.8-7. Sep. 3″.7 Azure and gold.

h2024 - 6709 185310 Two Cls. Alluring expanse f.



OPHIUCHUS: *Chart 19-C*

X 183308 Var.:6.6:8.8. Per. 335.4d.

Σ6 180806 Neb. A curious, bright, gaseous unit. Makes isos. tri. with two 8-mg. stars. Diam. 6″. Bluish.

70 180102 Vis.bin.:4.1-6. *a*=4″.56, Per. 87.8y. K. Presents puzzles and problems still unsolved, offering the best opportunities for discoveries which may advance our knowledge of the forces at work in the stellar systems. If it were not for these, our interest in the systems themselves would flag; but there is always a new problem to spur us on. Aitken.

SERPENS:

HVIII72 182406 Cl. Superlative! Grand star-clouds f.

Σ2375 184105 D. 6.2-6. Sep. 2″.2.

θ 185204 D.:4-4.2. Imperial pair in regal setting!

AQUILA:

Nova III, 1918 184300 Mag. var., bet. 10.5 and 11.5. Easily glimpsed. (See Mt. Wilson photo, with note Ill. Sec.

5 ***184201*** D.: 5.6-7.4. Sep. 13″.

A88 ***183303*** Vis. bin.: 7.2-7.2. *a*=0″.176. Per. 12. 12yrs. Spc. F8.

R Scuti ***184205*** Var.: 4.5:9. Per. 146d.(?) Irreg.

M11 ***184606*** Cl. Fan-shaped, bright star at apex.

SAGITTARIUS:

M17 ***181616*** Neb. "Horseshoe." In brightest portion of Milky Way. Curiously arched. Interesting with l. p., but with increased magnification an exquisite object. Legions of neb. south, with M24 ***181318***, giant Cl. Dark region p.

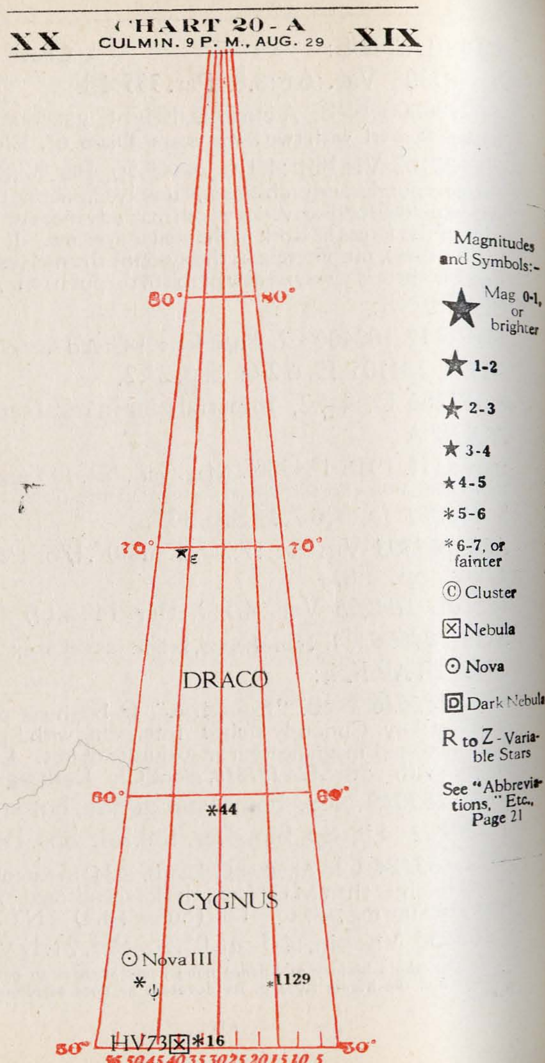
M25 ***183019*** Neb. Somewhat diffuse, but strong.

μ ***180721*** 4.0. Sp. bin. Per. 180.2 d. Spc. B8p.

M22 ***183124*** Cl. Another Colossus, ±½° in extent larger and brighter than M13 Herc., tho less condensed. 70,000 suns, absolute mg., +5 to —1.8. (Sun=+4.9). N f λ Sag.

ζ ***185630*** Vis. bin.:4-5. *a*=0″.56. Per. 21.17y. A2.

"In the whole history of science none bears witness to pathos of struggle and the heroic lives of its devotees as does astronomy."—Brasch.



DRACO: *Chart 20-A*

ε 194870 D.: 4-7.6 Sep. 2″.8.

Σ I44 193159 D.: 5-7. Sep. 76″.6. Gold - blue.

CYGNUS:

The graceful star-imagery of the Swan, with its six high-magnitude brilliants slanting a cross athwart the northern heavens, is the very ganglion of the Galaxy, making the search for reputed features rather difficult, since on every hand there is such a bewilderment of stellar riches.

Nova III, 1920 195553 ±11.5. Burst from mag. 15 to mag. 1.9 within ten days, passing thence thru characteristic spectral stages. (See photo and note, p. 190).

There are only three or four more of these wondrous objects to be reached with modest instrumental equipment, notably Nova Persei, 1901, 032443, mag. 12-14; Nova Oph., 1919, 180911, mg. 13.5; and Nova Aquil. III, 184300, mg. 10.2 to 10.9, any one of which may be glimpsed with a telescope of three inch aperture. It is well to study these amazing paradoxes of the spheres not only because they have been known to recover a portion of their brightness after a period of years, but to the discoverers of novae there is the reward of sundry gold medals and world-wide fame; and curiously enough, the honor in almost every instance has gone to some hitherto "mute and inglorious" amateur rather than some trained professional in one of the world's great observatories.

"The term new star, or nova, is actually a misnomer. There is no evidence that the birth of a new star has ever been witnessed. Even the term 'temporary star' often used, is not exact, for novae appear to be permanent. They are really stars which are temporarily bright. In several cases photographs show the previous existence of a faint star in the very same position occupied by the nova. And furthermore, the nova always fades and becomes an inconspicuous star again after a few years."—Cannon.

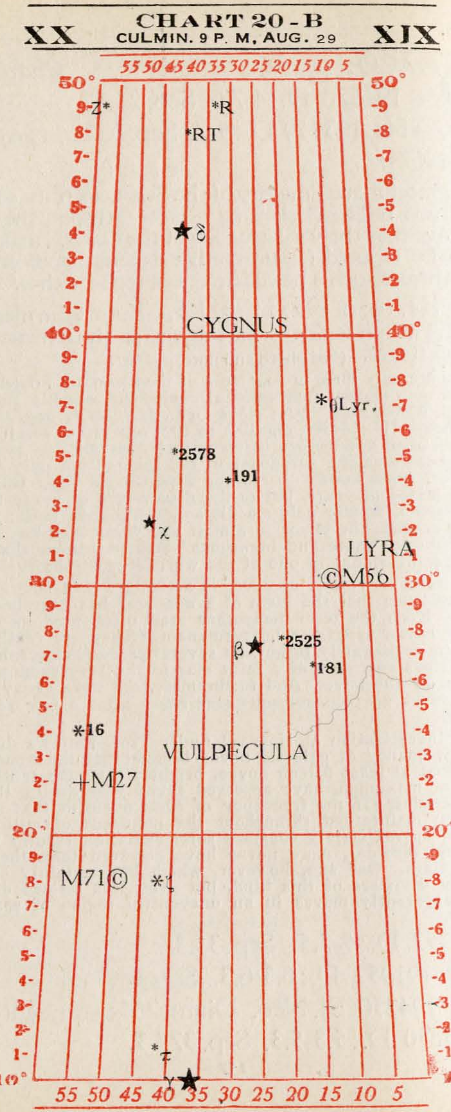
"The investigation at Harvard under Prof. Bailey's direction of the frequency of galactic novae brought out the remarkable result that at least fifteen novae, brighter than the tenth magnitude at maximum, have appeared every year during the last three decades. If the frequency of even one-fifth that amount has been maintained throughout the hundreds of millions of years of approximately constant solar radiation (shown by the geological records), more novae have occurred than there are known stars. Our sun, however, which has certainly escaped not only disasters of this kind, but even less serious disturbances, apparently moves in an uneventful region of space."—Shapley.

ψ 195352 D.: 5-7.5. Sep. 3″.3.

β 1129 191952 D.: 6.3-6.3. Sep. 0″.3.

HV73 194250 Pl. Neb. Diam. 20″; star center.

16 193850 D.: 5.3-5.3. Sep. 37″.3.



Z 195849 Var. 8.8:13.3 Per. 262.4d. *Chart 20-B*

R 193449 Var. 7.4:13.9. Per. 425.5d

RT 194048 Var. 7.3:11.8 Per. 190.4.

δ 194244 D.: 3-7.9. Sep. 1″.9. Faint ruby comes.

Σ2578 194235 D.: 6-7.4. Sep. 14″.8.

OΣΣ 191 194234 D.: 6-8. Sep. 38″.1. Exceptional.

χ 194632 Var. 5.1-13.3. Per. 406.6d. "These variables of long period are red stars, generally of class M in spectrum, having also glowing lines of hydrogen at maximum and of iron at minimum—young giants at the beginning of the sequence of star life. χ Cygni is predicted to be larger than than Mira, ο Ceti, itself over 250 million miles in diameter! Its variation of nearly ten magnitudes corresponds to a ten thousand-fold change in light." Cannon.

β Albireo 192727 D.: 3-5.3. Sep. 34″.5 Thrilling pair!

Σ2525 192327 Vis. bin.: 8.2-8.2. $a = 0''.95$. Per. 243.9 yrs. Spc. F8. Interesting. Sweep due west from β.

LYRA:

θ 191237 Wide D.: 5-8. A fascinating field.

M56 191330 Semi-glob. Cl. Neighborhood radiant.

VULPECULA:

OΣΣ 181 191626 D.: 6.2-6.3. Sep. 54″.6. Charming.

16 195824 D.: 5.8-6.2. Sep. 0″.6. Guide-stars to Neb.

M27 195622 Pl. Neb. Giant "Dumb-bell," so called on account of its resemblance with low powers; but with higher magnification the likeness vanishes, as in the case of most celestial analogies to terrestrial commonplaces. Largest of the planetaries—major axis about 11′ of arc. Faint nucleus, many stars enmeshed like pearls caught in swirls of lace. Planetary stage of nova of remote ages. (See photo, p. 199).

SAGITTA:

ζ 194418 Vis. bin.: 5.4-6.4. $a = 0''.3$. Per. 25.2y. A2.

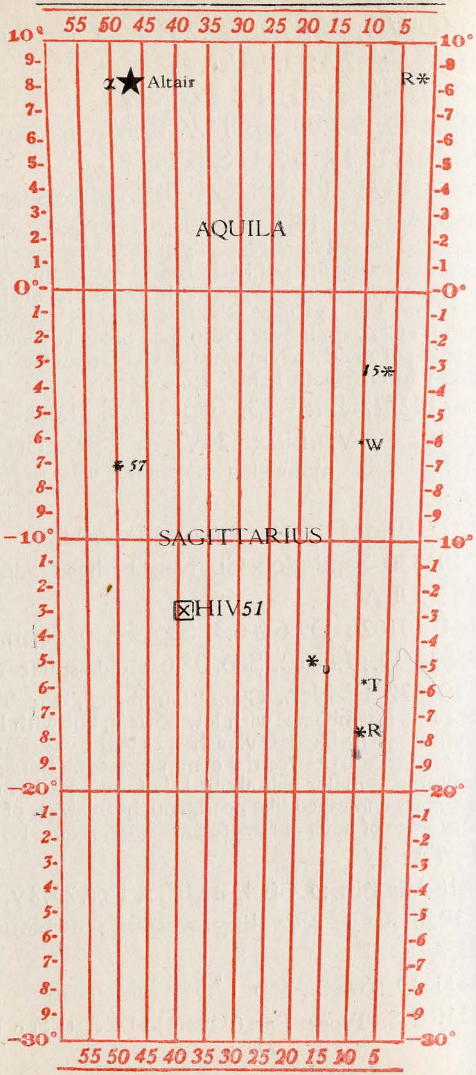
M71 195018 Cl. Dazzling sweep of star-clouds!

AQUILA:

π 194411 D.: 6-6.8. Sep. 1″.5. Color-test.

γ 194110 2.8. Topaz. Par. 0″29=112 l y dist. Spc. K2.

XX CHART 20-C XIX
CULMIN. 9 P. M., AUG. 29



AQUILA: *Chart 20-C*

R 190108 Var. 6:11.4. Per. 329.3d

α Altair 194608 0.9. Par. 0″.214=15.41y dist. Spc. A5. R. v., —27mi.-sec. Mg. 10 comes. White 9×Sun's brightness. Central of three stars representing an eagle in flight—one of the few skiey similitudes that seems to be even remotely justified.

"Much less than one per cent. of the starlight is scattered while traveling for one thousand years through space. Blue and yellow light travel with the same velocity with an uncertainty of less than one part in ten thousand million years."—Shapley.

15 *190704* D.:6-7. Sep. 37″. Gems in a royal crown.

W *191007* Var. 8.4:14. Per. 493 d.

57 *195008* D.:5.1-6 Sep. 35″.6. A color variant.

SAGITTARIUS:

HIV 51 *194014* Pl. neb. Like a monster fish-eye.

"With the exception of some difficult and doubtful cases, each galactic nebula has associated with it one or more stars of a type comformable to its own spectral type. This definite relation between the spectra of the nebulae and of the associated stars suggests that the source of luminosity of the nebulae is the radiation from those stars. According to this view, the nebulosity has no intrinsic luminosity, but either is excited to emission by light from a star of earlier type, or merely reflects light from a star of later type. From a demonstration of the nebulosity around Rigel, it appears that this luminosity may be excited at a distance of twenty light-years."—Hubble.

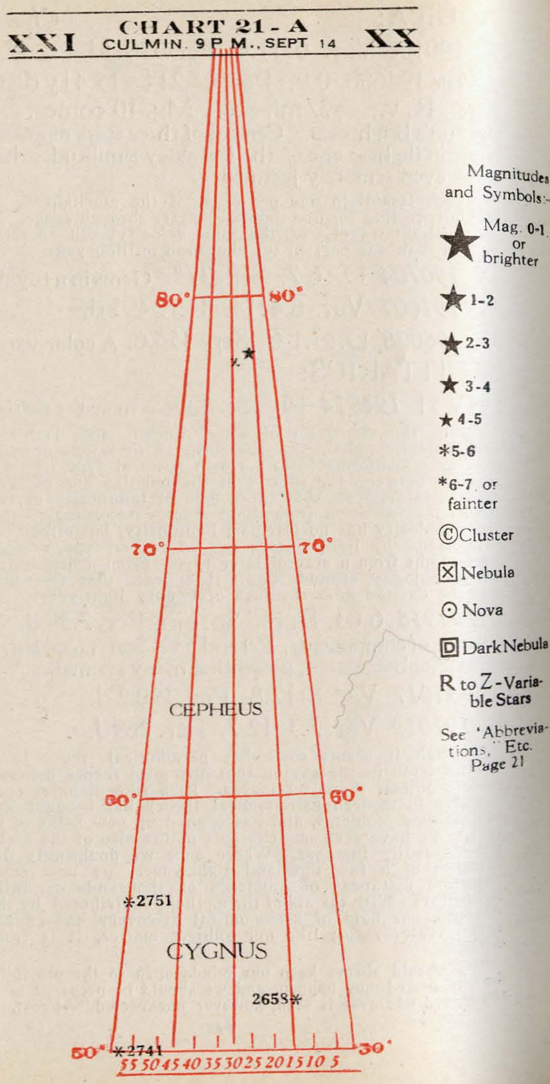
υ *191916* 6.03. Rapid Sp. bin. Per. 7.39 d. Spc. A. Masses of components, 260 and 54×Sun. Ludendorf. Under constant observation, presenting many anomalies.

T *191017* Var. 8:12.8. Per. 390.2 d.

R *191019* Var. 7.3:12.7. Per. 269d.

"Though it seems somewhat paradoxical, there is a great deal of truth in the saying that any good theory brings with it more problems than it removes. In a like manner, each great advance in modern astronomical theory has brought with it a host of new problems, and has opened up new fields of vast extent. We have seen our concepts of the size of the stellar universe steadily increase. Where once we doubtingly discussed distance of a few thousand light-years, we now confidently postulate distances of hundreds of thousands or millions of light-years. With the aid of the methods contributed by the allied sciences, our field of astronomical discovery has expanded in even greater ratio; like our subject matter, it is infinite."—Aitken.

"We should always keep our minds open to the possibility that the unexpected may happen, and we should be prepared to observe and record whatever is seen, however unexpected."—Frost.



CEPHEUS: *Chart 21-A*

ϰ 201178 D.:4.8. Sep. 7″.4.

Σ2751 205956 D.:6-7. Sep. 1″.9.

CYGNUS:

Σ2658 201152 Tr.:7-9-10.1. Sep. 5″.5-32″.1.

Σ2741 205550 D.:6-7.3. Sep. 1″.9.

ASTRONOMY AND MATHEMATICS.

When, some years ago a traveler in Egypt, I climbed the Great Pyramid, says my friend, the Hadji, a giant sheik had hold of my right hand, another gripped my left, and a diminutive imp, all brawn and sinew, closed in at the rear to boost. As each ledge of ancient masonry just met my chin, and to climb this skyward steep would have been impossible for me without assistance, I was willing to pay the price; and the way I went aviating upward, dragged and boosted with such skill and agility that I only touched the high spots, was epical of old Egypt; and before I realized it I stood on the rectangular open space at the top, quite triumphant, and settled down to survey the historic scene—

"the blear white stretch of sand
With a palm at either hand,"

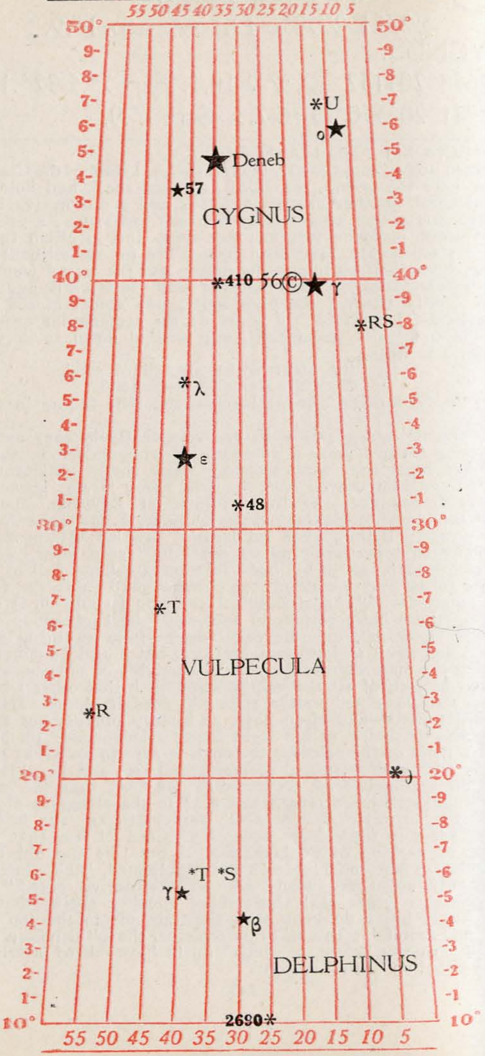
and the far-flowing silver ribbon of the Nile fading in the distance.

About the time of my swift and comparatively easy ascension, a young Oxford man—a powerful athlete—undertook the same journey hand over foot, scorning these costly assistants; and we passed him quarter-way up, still going strong, game to the last. Poring over my little volume of Egyptian history on that remote pinnacle for nearly an hour, I had quite forgotten the doughty Briton, when suddenly I saw his blazing face and dishevelled torso straining up over the last parapet, with just enough breath left in his body to utter a college yell of victory as he rolled over beside me too exhausted to enjoy the fruits of his enterprise. "There! Didn't I tell you I could do it without any of these bally rotters to help me?" he exclaimed.

This experience may be very remote from anything astronomical and more so from mathematics; but I could not help comparing the man who would scale the heights of science, and who avails himself of all the help at hand with that other who, with all his courage and native strength, goes it alone. The latter may get there—and often does, as history proves; but the man who has geometry at his right hand, trigonometry on his left and a little of the calculus to boost, is sure to arrive at the pinnacle with swiftness and comparative ease, and be able to enjoy the spectacle from the summits far more than the one who has exhausted his strength and zeal in the struggles of an unassisted journey. A venerable mathematician who had spent forty years in the science once said to me, "I fear that I know little or nothing of mathematics. I am like the old German philologist who, on his death-bed, exclaimed, 'Ach, Gott! If I had only spent my whole life on the dative case.'" Now, there was a great deal about those doughty sheiks that I did not know, but I do know that they got me to the top strong, safe and grateful, with ample time to gather the full significance of the mighty prospect before me which I might have missed utterly had I too insisted on "going it alone."

XXI **CHART 21-B** XX

CULMIN. 9 P. M., SEPT. 14



U 201647 Var. 7:10.6. Per. 464d. *Chart 21-B*

ο 201146 Tr.:3.7-5-6.5. Wide.

α Deneb 203845 D.:1.3-12. Sep. 75″.4. Par. 0″.012 =272 l y. R. v., —4mi.-sec. Spc. A2. A super sun!

57 204744 Sp. bin. 4.7. Per. 2.8 d. Spc. B3.

OΣ410 203740 Tr.:6.4-6.7-7.7. Sep. 0″.7-69″.

HVIII56 202040 Open Cl. A pageant of splendors!

γ 201940 2.3 Par. 0″.006=540 l y dist. Spc. F8p.

RS 200938 Var. 7.2:8.9. Per. 413 d.

λ 204436 D.: 5-6.3. Sep. 0″.7.

ε 204333 2.6. Marks eastern arm of "Northern Cross."

48 203431 Wide D.: 6-6.1. Sep. 3′. Regal domain!

T Vulpec. 204727 Var. Sp. bin. Per. 4.4 d. Spc. F.

R Vulpec. 205923 Var. 8-12.6. Per. 136.8 d.

θ Sagittae 200620 Tr.: 6-7.1-83. Sep. 11″.4-70″.7.

DELPHINUS:

The constellation of the Dolphin—sometimes called Job's Coffin, tho like sundry other celestial facetiae, without logical explanation—is a dainty asterism to the eastward a little north of Aquila; and for all its limitation in size, will be found quite a varied treasury, particularly for the ambitious estimator of variables. The Eagle and Arrow form with it a conveniently located triangle of fairly bright naked-eye stars

T 204016 Var. 9.4:14.8. Per. 332 d.

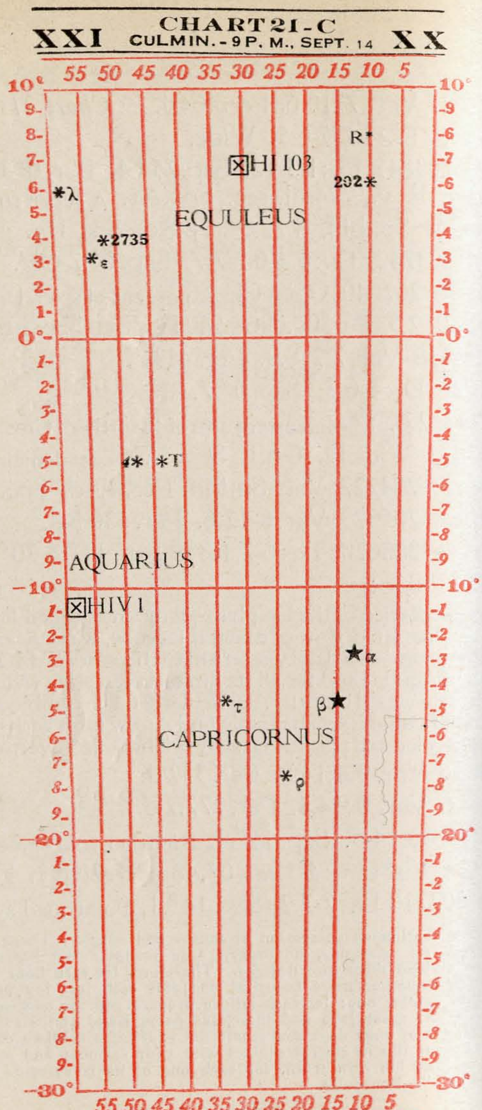
S 203816 Var. 9:14.4. Per. 277.2 d.

γ 204315 D.: 4-5. Sep. 11″.9. Rich duo, gold - green.

β 203314 Vis. bin.: 4-5. *a*=0″.48. Per. 26.8 y. F5.

Σ2690 202710 D.: 7-7.2. Sep. 14″.1. Faint quad. sys.

"Life is a continuous succession of causes and effects. There is no tomorrow, no yesterday, no today. Life is one. We humans alone have divided them into degrees. Therefore, let each hour be a step toward another more beautiful one; let each lost joy prepare another greater one; let each failure prepare you for new successes. Let the great joys and the great pains make you strong. Test the course of your days and create for yourself a sublime destiny. Live your life in closest contact with your science; and may each of you find his own truth, for each one of us is carrying it within himself."—Bourdelle.



R Del. 201008 Var. 8 4-13.4 284d. *Chart 21-C*

H I 103 203007 Neb. Vast, lustrous.

EQUULEUS:

The Colt is another limited depository of stellar curios to the southeast of the Dolphin, not quite so conspicuous for features, but a lively region for random sweeping.

λ 205806 D.: 7.-7.1. Sep. 2″.6. Exceptional.

Σ2735 205104 D.: 6.7-7.7. Sep. 2″.1. Crocus - lilac.

ε 205403 Vis. bin.: 5.8-6.3. *a*=0″.61. 97.4 y. F5.

OΣΣ 202 Aquilae 201006 D.: 6.9-7.3. Sep. 43″.4.

AQUARIUS.

The Water Bearer, the eleventh zodiacal sign, is a vast region with a few scattered objects of moment, and these are well worth consideration. Good prospecting to eastward.

T ***204405*** Var.: 7.6: 12.9. Per. 202.5 d.

4 ***204705*** Vis. bin.: 6.3-7.6. *a*=0″.64. 135.6 y. F.

H IV 1 ***205911*** Pl. neb. Prodigious! Ang. diam. 25″ × 17″—about equal to orbit of Uranus. Huggins found it gaseous. Elliptical, pale blue, said to resemble planet Venus. Disc. by Herschel who assigned to it a class unique.

CAPRICORNUS:

The Sea-goat, tenth zodiacal sign, the ancients' Southern Gateway of the Sun, opens widely here; and while somewhat richer than Aquarius in this meridional area, offers few high lights aside from its two superb doubles, recorded in ancient writ, and at least one surpassing cluster, M 30, to eastward.

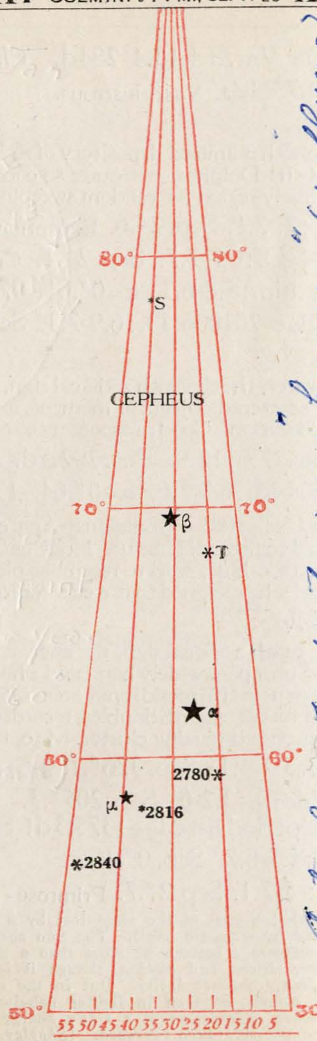
α ***201313*** D.: 3.2-4.1. Sep. 376″.1. Magnificent!

β ***201515*** Wide D.: 3.2-6. Sep. 205″.3. Prim. Sp. bin. of longest period listed—1375.3 d! Spc. Gp.

τ ***203415*** D.: 5.5-6.7. Sep. 0″.1.

ρ ***202418*** D.: 5-7.1. Sep. 2″.7. Primrose - plum.

It seems likely that a part of the mass lost by a star through radiation is replaced by meteoric infall. The Sun absorbs at least a million million meteors a second, or more than a thousand tons of iron, magnesium, silicon and oxygen, though it is situated in regions of space free from nebulosity. But in the case of stars on dark nebulous clouds, or even in lighter nebulosity like the Pleiades, the radiative degradation of a star's energy may be retarded, balanced, or possibly even reversed. (*Shapley*.)



"Astrology predictions and horoscopes" (influence) based on position of the background of stars at least 2000 BC, so that such reckoning is entirely out of line in 1960.

CEPHEUS: *Chart 22-A*

S 213678 V.:8.1:11.3. 485.8d.

β 212770 3-7. Prim. Sp. bin. Per. 0.19d. B1.

T 210868 Var. 6.1 : 10.1. Per. 387d.

α 211662 2.6 Par. 0″.091=361 y dist. Spc. A5.

Σ2780 210959 D.:6.1-7.1. Sep. 1″.1.

μ 214158 Var. 4:5. Irreg. H's curious "garnet sidus."

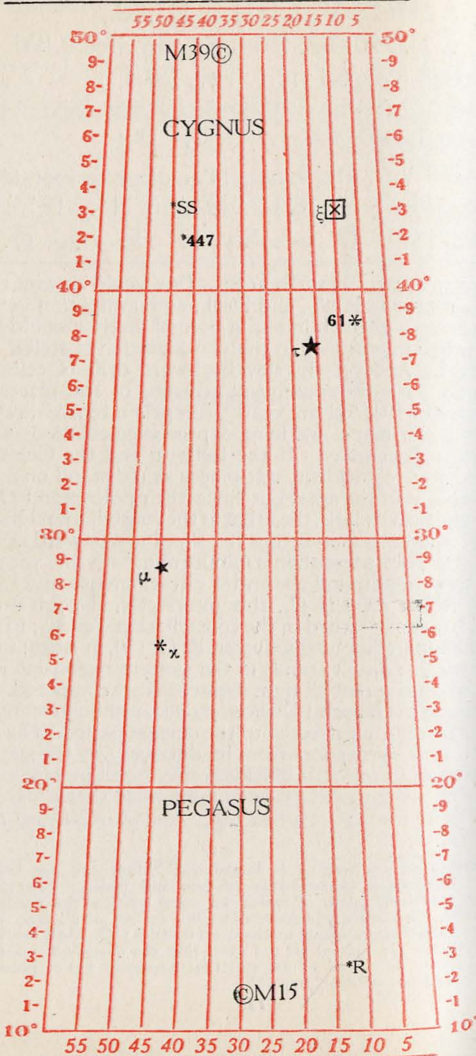
Σ2816 213657 Tr.:6.3-7.9-8. Sep. 11″.7-19″.

Σ2840 214955 D.:6-7. Sep. 19″. Very fine. Cl. s f.

PRECESSION AND STAR-PLACES.—One would imagine that a shift of stars in R. A., and Decl., amounting to no more than a moon's breadth in half a normal lifetime would not be of prime importance in the consideration of stellar adjustments. And yet this slow backward drift of celestial longitude, with the consequent advance of star-places to the extent of 50¼″ of arc yearly, compels a ten-year revision of our star-maps, and in more precise calculations, with even greater accuracy. If the Ecliptic and the Celestial Equator were coincident, star-places would stand unalterable throughout the ages; but since their poles stand 23½° apart, one near Polaris, the other in the constellation Draco, this gyroscopic motion causes the slipping westward of the equinoctial points less than a minute of arc a year, yet sufficient to swing around the entire circumference in 25,900 years. About 2000 B. C., this intersectional point—the Vernal Equinox—stood in the constellation Taurus; in the time of Hipparchus, its discoverer, B. C. 150, in Aries; until at the present day it stands in the western regions of Pisces, from which point all right ascensions are computed. In these charts the Epoch 1920 is employed, although many of the star-places are corrected to the current period. The entire history of Precession, from its discovery by the amazing Bithynian to its masterly elucidation by Newton, reads like one of the romances of celestial mechanics that challenge the world for interest. See Book List. Also Polaris, p 29, and Thuban, p 107.

"Depend upon it, nothing is haphazard, things are not left to chance. Everything is amenable to law and order. Everything points to a rational plan, of which we know neither the beginning nor the end, but toward which we can help. In face of all that, shall we allow ourselves to squabble about trivialities! Or shall we realize that we are the heir of all the ages, that the destiny of mankind is being partly entrusted to us, and that humanity has a potential future beyond our wildest dreams!"

XXII CHART 22-B CULMIN.-9 P.M., SEPT. 14 XXI



CYGNUS: *Chart 22-B*

M39 212949 Cl. Grand open type.

SS 213843 Var. 8.1-12. Very irregular. Sp. peculiar. Most popular star with Variable observers. Disc. at Harvard, 1896. Fairly faint star which at intervals from twenty to ninety days suddenly brightens up a hundred fold, almost reaching the eighth mag. Its rise to maximum is almost unpredictable, and also the speed with which it increases in light intensity is variable. To-night it may be barely visible in a four-inch telescope, tomorrow night it may be at full brightness—the brightest in the field. At other times it may consume a week or more in attaining its maximum. Is it any wonder that scores of amateurs vie with one another to be the first to catch SS Cygni on its rise to maximum?—Leon Campbell.

ξ 210243 Neb. Vast, very curious, sharp so. area.

OΣ 447 213641 Tr. 7-7.9-11. Sep. 30″-15″.

61 210338 D.:5.3-5.9. Sep. 15″.3. Par. of primary, 0″.30=10.91y. Lum., .06 Sun. P.m., 527″. Spc. K5. One of the four nearest stars in the northern heavens, the other three being: Munich 15040, Oph., 6.2 light years distant; Lalande 21185, Leo Minor., 7.9; and Procyon, Canis Minor., 10.9. In the southern hemisphere there are seven stars as near to our solar system as 61 Cygni, or nearer.

Our nearest object among the stars is the small companion to the visual binary, Alpha Centauri, itself 4 1-3 light-years distant. This 11-mag. star is called Proxima Centauri, with a proper motion of 3″.90, which value leads to a parallax of 0″.80—4.075 light-years (Luyten). Proxima is thus computed to be one-sixteenth nearer our system than Alpha, with a period of revolution about its primary measured in hundreds of thousands of years! (Aitken's 'Binary Stars.') Proxima's color index denotes extreme redness; and, intrinsically, is by far the faintest star of which we have any definite knowledge.

τ 211037 Vis. bin.: 3.8-8. *a*=0″.91. Per. 47 y. Fo.

μ 214028 D.: 4-5. Sep. 1″.4. Bin. Red gold-purple.

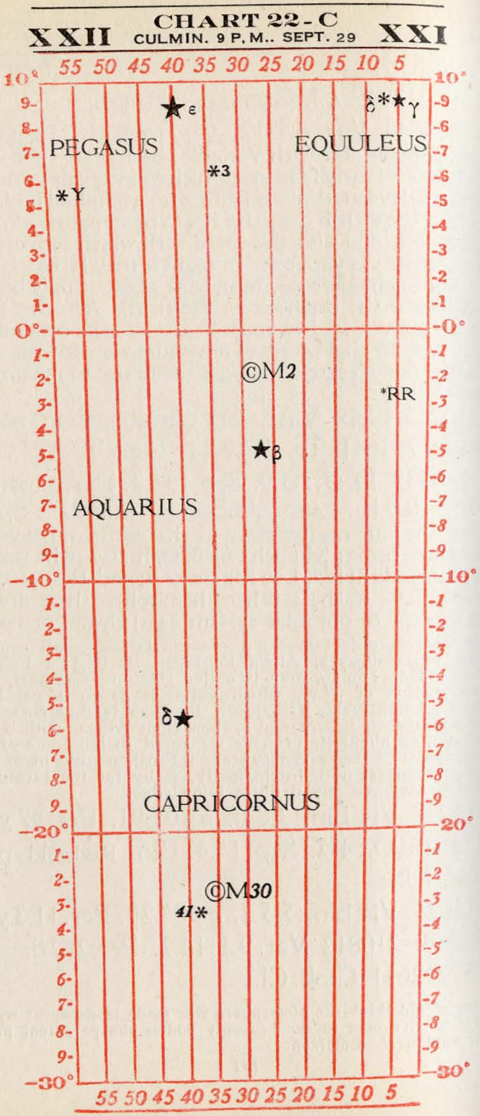
PEGASUS:

κ 214025 Vis. bin.: 5-5.1. *a*=0″.29. Per. 11.3 y. F5.

R Equul. 210812 Var. 9.1:14.2. Per. 262d.

M15 212611 Glob. Cl.

"One would think the atmosphere was made transparent with this design: to give man in the heavenly bodies the perpetual presence of the sublime."—Emerson.



ε Peg. 214009 Tr.: 2.5-8.8-11.5. Sep. *Chart 22-C*
81″.4-140″.3. Contrasty colors.

3 213306 D.: 6-7.4. Sep. 39.1. Others in field.

EQUULEUS:

γ 210609 Tr.: 4.1-5.7-11. Sep. 2″.1. Attractive.

δ 210909 Vis. bin.: 5.3-5.4. *a*=0″.27. Per. 5.7 y. F5.

AQUARIUS:

M2 ***212902*** Glob. Cl. Diam. 6′+. Thousands of suns compressed into a glowing opalescent mass.

β ***212705*** 3.0. Test mag. 9.9 comes, dist. 35″.

δ ***214116*** 3.0. Par. 0″.110=29.61 y dist. Spc. A5.

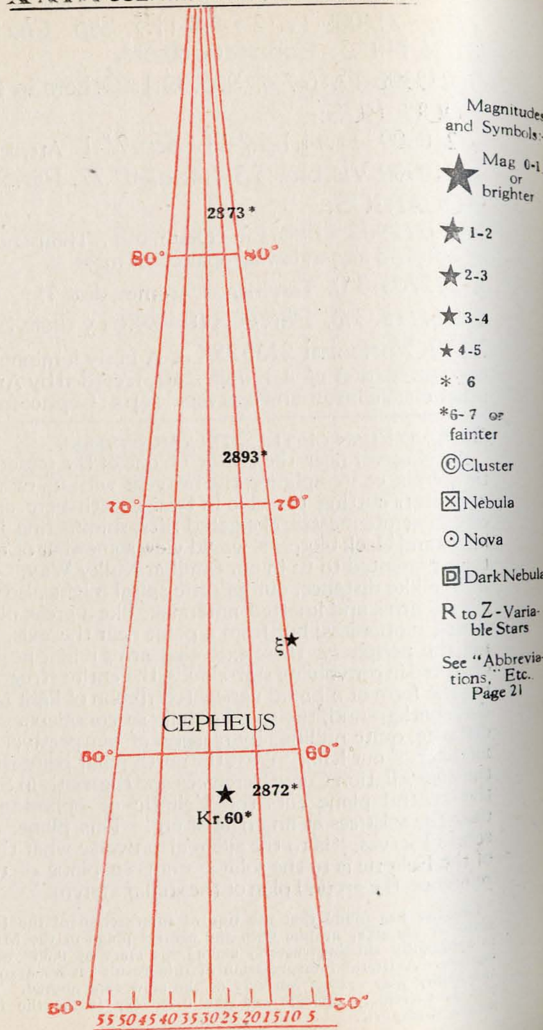
M 30 Capricorni ***213523*** Cl. A fairly luminous naked-eye aggregation of ±12-mg. stars, recorded by Aratus and other classic historian-observers. N p 41 Capricorni, mag. 5.

GROUND PLAN OF THE STELLAR SYSTEM.

An observer near the center of one of the remote gigantic spirals, contemplating the heavens with its radiant river of stars cutting the blue in twain, with here and there conglomerate masses, elongated rifts, shimmering irregular knots and black blotches, would view somewhat of the spectacle presented to us in our familiar Milky Way. As seen from a like distance, our galactic spiral might also disclose curved arms and knotted antennae, like a great pin-wheel struck motionless; but from a point near the axis, surveying the periphery, these extended arms might possibly be obscured in convolving star-clouds, the entire structure taking the form of a broad variegated ribbon of light against a dark background, the spiral detail, so conspicuous from a distance, quite nullified by reasons of perspective. In the instance of our Milky Way, the north polar point situate in the constellation Coma Berenices and the south in Sculptor, the central plane cuts the Ecliptic at opposing points near the solstices at an angle of 60°. This plane, as Herschel observes, "is to the sidereal universe what the plane of the Ecliptic is to the solar system—a plane of ultimate reference, the ground plan of the stellar system."

Charlier has found that the line of intersection of the invariable plane of the solar system with the central plane of the Milky Way is apparently shifting easterly among the stars by 0.35″ of arc per century. A literal interpretation of this result favors a rotation of the Milky Way system westerly at the slow rate quoted. The subject is extremely difficult and the discovery is for the future to make.—*Campbell.*

CHART 23 - A
XXIII CULMIN. 9 P.M., OCT 14 XXII



CEPHEUS: *Chart 23-A*

2873 220182 D:6.2-7. 14 .

Σ2893 221172 D:5.5-6.2. Sep. 29″.

ξ 220164 D.: 4.7-6.5. Sep. 5″.6. Fine sequence s.

Σ2872 220558 Tr.: 7.1-8-8. Richly diverse region f.

δ 222658 Prototype of the Cepheid class of short-period Variables—mag., 3.6:4.3. Per. 5^{d}-8^{h}-48^{m}. Sp. bin. Spc. G. Two lambent Cls. in field.

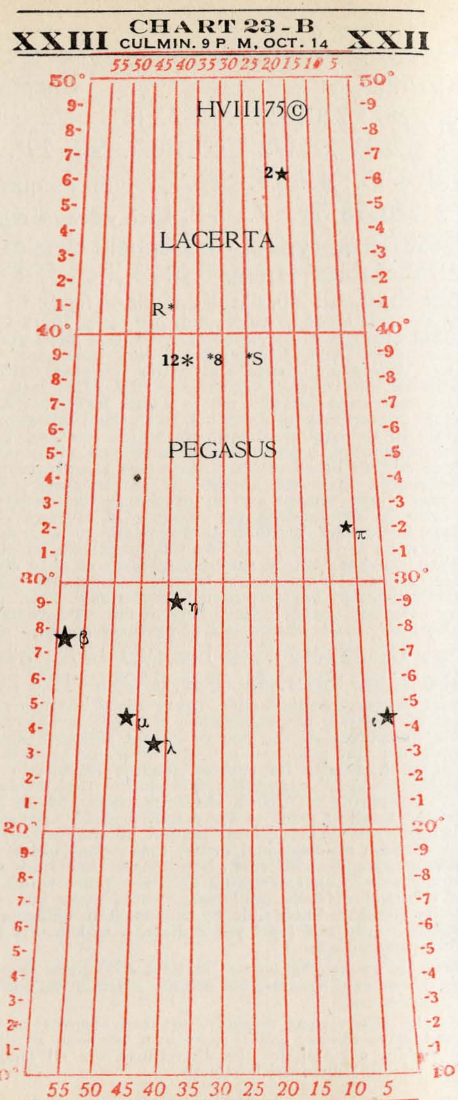
What the first violin is to the full orchestra, Delta Cephei is to the full complement of variables. While of short period, the Cepheids, which Miss Cannon calls "the timekeepers of the heavens," widely distributed and vastly numerous, differ from the eclipsing short-period variables of the Algol type in that the light fluctuations are due not to a dark body passing before a brighter in the line of sight, but to internal pulsations—vast upheavals in the stellar atmosphere which rise and fall with amazing regularity, a maximum to minimum often occupying but three or four hours of time. Cepheids are of giant dimensions—probably from one hundred to ten thousand times our Sun's mass—very remote and of exceeding luminosity; hence their value in determining the distance of clusters in which they may be located, for there is discovered to be a direct relation between periodicity and absolute magnitude, so that having found the parallax of the nearer stars of this class, the distance of remoter members become computable. By this method Dr. Shapley has determined the distance of far globular clusters in which Cepheids have been found, thus revising and broadening our whole theory regarding these outposts of space.

Krueger 60 222457 Vis. bin.:9.3-10.8. *a*=2″.86. Per. 54.9 yrs. Spc. Ma. Par. 0″.256=12.5 l y.

A faint but remarkable double, being one of the nearest to us in point of location, in consequence of which we have a more intimate knowledge of the two reciprocal masses. Both units are small, one but one-third and the other one-seventh of our Sun; but with density far greater, leading Russell to contend that both stars are "nearing the very end of their evolutionary period." According to Aitken, the faint companion of Kreuger 60 is of the smallest mass so far established for any star; and the phenomenally rapid orbital motion of the two tiny suns about a common gravitational center make them objects of exceptional astronomical interest. Ninth-magnitude stars are usually at a distance approximating 400 light years which, in the case of a binary of such small mass, would make the computation of its elements impossible by any modern methods. Kreuger 60, being only 12.5 light years distant, makes this possible and altogether unique.

"Adams has shown that matter at least 2000 times denser than platinum is not only possible, but actually exists in the stellar universe."—*Eddington.*

"To make observations carefully, to keep accurate records, to leave nothing to chance, and to pass over no point of difference without seeking a reason for the discrepancy, are all fundamental factors in scientific discovery."—Curtis.



LACERTA: *Chart 23-B*

The constellation of the Lizard is a conspicuously placed modern asterism, being banked on the n, e, s, and w, by Ceph., Andr., Pegas., and Cyg., almost wholly within the confines of the accompanying chart, and first recorded by Hevelius,in 1790. Though it displays no special units brighter than the fourth magnitude, as an aggregation half enclosed in the Milky Way, it offers a noble field for explorations.

HVIII 75 221249 Cl. Massed star-jewels.

2 221646 4.6. Sp. bin. Per. 2.6d. Spc. B5.

R 223841 Var.: 8.3 : 14.6 Per. 299.4 d.

12 223739 5.1. Sp. bin. Per. 0.193 d. Spc. B2.

8 223239 Double-D.: 6.5-6.5 : 8.5-10. Superb!

S 222439 Var. 8.2:12.9. Per. 240 d.

"Scattered through all our galactic space there are not only visible stars and nebulae, bright and dark, but there is also diffuse matter, which, in the aggregate mass, has been estimated to be greater than is contained in all the stars. There are also supposed to be more dark, invisible stars than luminous ones."—Dean.

PEGASUS:

π^{1-2} 220632 4.4-5.1. Fine wide pair.

η 223829 3.1. L. p. Sp. bin. Per. 818 d. Spc. G.

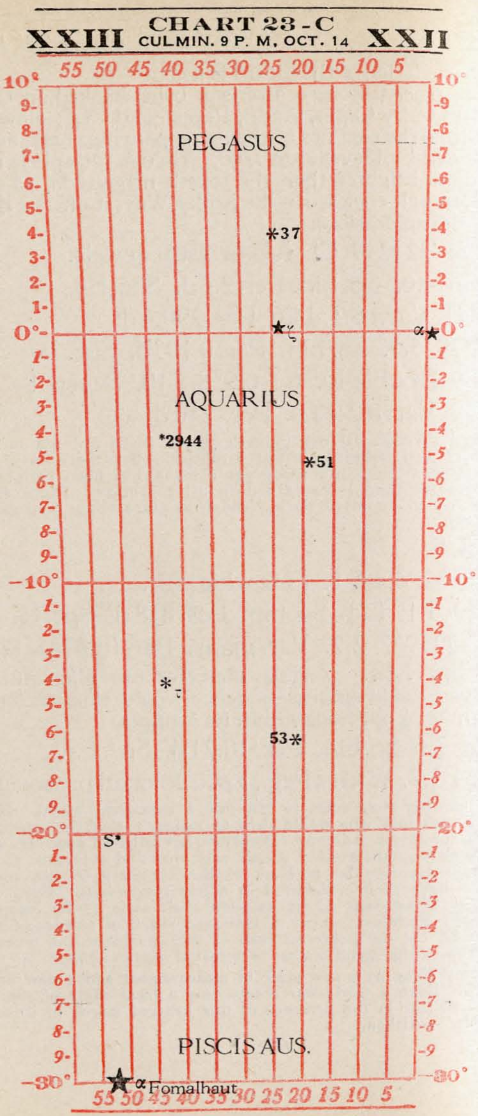
β Scheat 225927 2.2. Var. giant. Par. 0″.026 = 125 l y dist. Spc. Mb. Angular diameter, 81 million miles. Scheat's vast luminous circumference would thus enclose more than 94 of our Suns within its confines.

ι 220224 3.6 Sp. bin. Per. 10.21 d. Spc. F5.

μ 224624 3.7. With λ Peg., *s p*, a colorful prospect.

Most of our big facts seem to fall into a consistent whole. He would be a rash fool who would dare to maintain that the scheme of things is surely the true one. Discovery has followed discovery at such a pace of late that another decade may well find evidences of a very different tenor. The problem of the evolution of the universe is too large to be exhausted in a few generations. Even if at length the foundations of its solution shall seem to be established, it will doubtless occupy a thousand years of astronomical research to fill out the noble outlines of the structure, and reveal in its full beauty the grand system of celestial hosts.—*Abbot.*

"Astronomy gives us a new scale of measurement and a new order of ideas. Even a world-war seems only a local affair of some ill-governed asylum in the presence of this ordered march of illimitable worlds."—Aitken.



37 *222504* D.:5.8-7.2. Sep. 1″.2. *Chart 23-C*

AQUARIUS:

α *220100* Mag. 3.2.

ζ *222400* D.:4-4.1. Sep. 2″.5. In center of cross.

Σ2944 *224304* Tr.:*7*-7.5-8. Sep. 4″.1-55″.8.

51 *221905* D.:5.6-5.7. Sep. 0″.7.

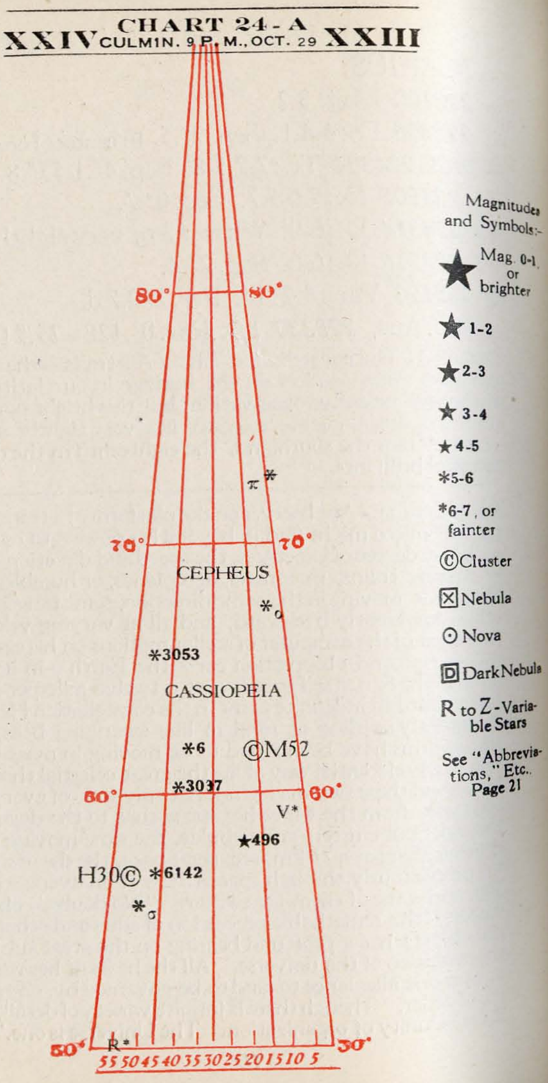
τ2 *224314* D.:6-9. With τ1 *s p*, very sightly.

53 *222216* D.:6-6. Sep. 7″.4.

S *225120* Var.:8.2:14. Per. 279.7 d.

α Pisc. Aus. *225330* 1.3. Par. 0″.128=25.5 l y dist. Spc. A3. The constellation Piscis Australis—the Southern Fish—lies too low on the horizon in our latitudes to encourage extensive observation: but this bright particular unit (Fom-al-hut, the Fish's mouth), is a very sightly autumn visitant from the southland, the eighteenth in the order of celestial brilliants.

STAR SPEED.—An observer on the platform of a trans-continental limited might find it beyond his powers to estimate, with any degree of exactness, the speed and direction of other passing trains, motorcars, aeroplanes, or humbler vehicles, some moving in the same direction, some tangent, and others apparently backward, and all at varying velocities. But what of the computer of stellar motions on his eighteen-mile-per-second observation car—the Earth—in its orbit around the Sun, itself speeding at a twelve-mile-per-second rate toward an indefinite point in the constellation Hercules! Apparently swirling at random like swarming bees, these star-swarms have been found to be moving in mass formation in a preferential way along the great celestial thoroughfare. And these swarms include not only stars of every spectral type, from the white-hot super-suns to the dwarf carbon stars, but clusters and nebulae, the slow-moving giants drifting along at a 21 km.-sec. snail-pace, the dwarfs plunging precipitously through space-deeps at an average rate of 100, and some of them far swifter. "No doubt," observes Abbot, "this remarkable procession of stars and other celestial objects has a profound bearing on the great subject of the evolution of the universe. All the hosts of heaven seem to bear one allegiance to, and to be governed by, one principle of order. Though there is infinite variety of detail, there is entire unity of organization. The Universe is one."



CEPHEUS: *Chart 24-A*

π 230573 D.:5-7.5. Sep. 1″.1.

γ Cephei, mag. 3.4, holding forth brilliantly 1° to the northeast, completes the classic configuration of the 'starred Ethiopian monarch' comprised in α, β, δ, ι, and π Ceph.

ο 231567 D.:5.1-7.7 Sep. 2″.6. Their primrose and lilac tints seem to appear stronger with relatively poor seeing, or thru a faint aurora, as is the case with circumpolar stars in particular. The sharpest skies are not always the best for comparative observation.

CASSIOPEIA:

One of the richest constellations of the northern galactic area, beginning at this hour and extending majestically toward the northeast, comprising some of the noblest objects to lure the explorer: famous groups, clusters and vari-colored units of great brilliancy in the clear blue of the polar skies, with a Variable-field scarcely surpassed in any constellation of equal area, there being more than a score of both the long and short period under close observation and annotation by zealous observers in various parts of the world. This constellation alone is worthy of years of intensive research.

Σ3053 235865 D.:6-7.3. Sep. 15″.1.

6 234461 D.:5.7-7.9. Sep. 1″.7. Orange - gold.

M52 232061 Cl. Extended center, fairly clear.

Σ3037 234160 Tr.:7-8.5-9. Sep. 3″-29″. Contrasty.

V 230759 Var. 7.8:12.4. Per. 228.8d.

OΣ496 232558 Mult.:4.8-10:7.4-8.9. Prim. a Sp. bin. Per. 6d. Spc. B3. Neighborhood truly dazzling.

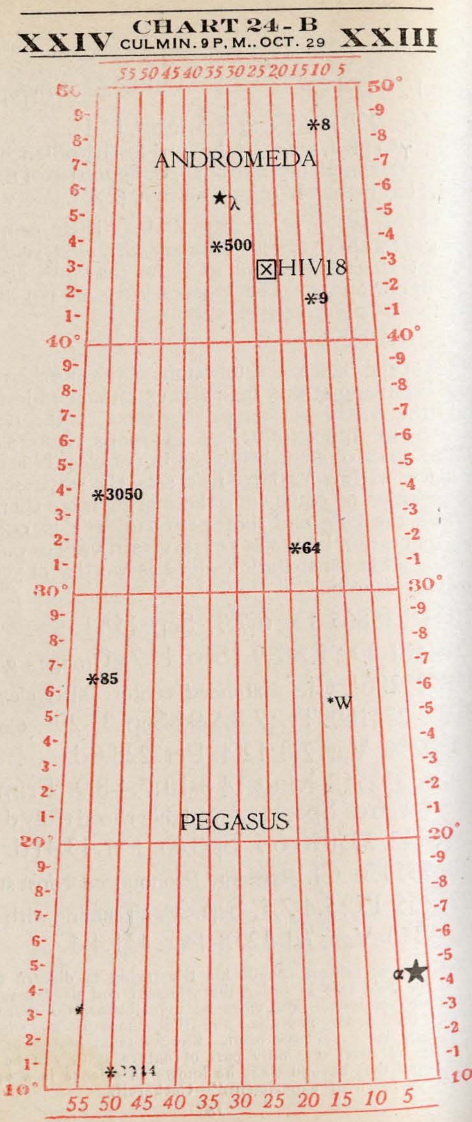
Boss6142 235056 6.5. Sp.bin. Per. 13.41d. ρ 11′n.

H30 235356 Cl. Radiant. Pronounced 'Most superb!'

σ 235455 D.:5.4-7.5. Sep. 3″. Teeming with jewels.

R 235350 Var. 7.1-12.9. Per. 431.4d.

"The man of science spends his life trying to discern the workings of nature's law in order that thought and deed may conform to nature's harmony. The more he investigates, the more sure he becomes that order prevails, and that there is no supernatural phenomena, nor ever have been. But we must hasten to add that he knows full well that only part of nature is or can be revealed to him; and that beyond what he knows as science is a vast realm beyond the reach of experiment."—Cockerell.



ANDROMEDA: *Chart 24-B*

8 231248 5.0. Rose-jewel, ***comes***.

λ 233245 4.0. Sp. bin. Per. 20.54 d. Spc. K.

OΣ500 233343 D :6.1-7. Sep. 0″.5. 3′ *p* χ And.

HIV18 232242 Pl. neb. Bright, bluish green, elliptical. Diam., 20″. Var. nucleus and two oval rings.

9 231341 5.9. Sp. bin. Per. 3 22 d. Spc. A2.

Σ3050 235533 D.:6-6. Sep. 2″.0.

PEGASUS:

64 231831 D.:5.5-7.5. Sep. 0″.5.

85 235526 Vis. bin. 5.8-11. *a*=0″.82. Per. 26.4 y. G.

W 231425 Var. 8.1:12.7. Per. 342.7 d.

α Markab 230114 2.6. Dist., 272 l y. S w cor. of Great □.
Great Square of Pegasus: From Alpha (Markab) n 12° to Beta (Scheat); thence e 13° to Alpha And., (Alpheratz), on the Equinoctial Colure; thence s 12° to Gamma Peg., (Algenib); and back 15° to Markab.

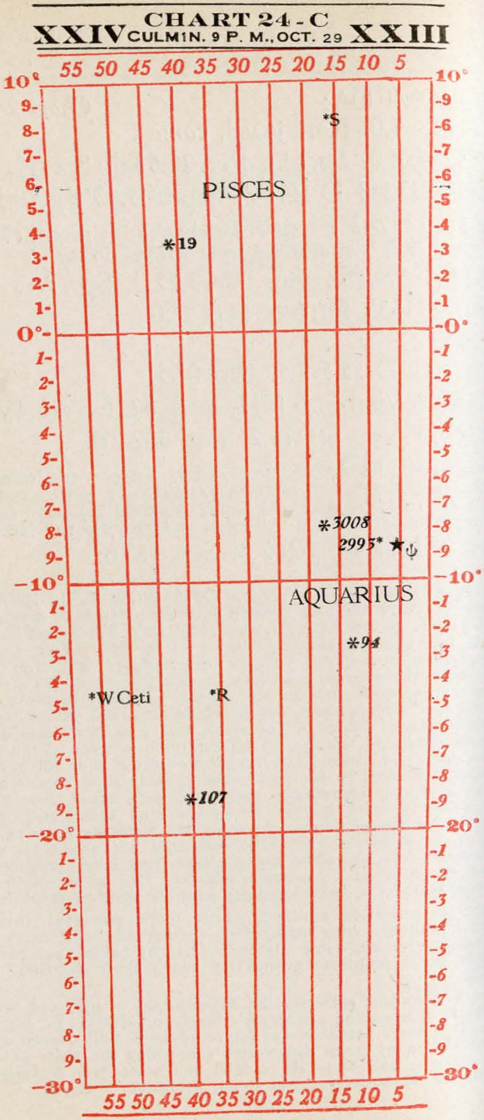
Σ3044 234811 D.:6.9-7.3. Sep. 18″.6.

THE GREATEST OF ALL TELESCOPES NOW BUILDING.

Seldom has the world been thrilled with the prospect of a new engine of science as by the announcement that a 200-in. reflector—twice the size and four times the power of the Mt. Wilson giant—is to be, within the next few years, an accomplished fact. The models are made, the necessary millions in money pledged, the staff of constructors, foremost men in their various specialty in the world, organized, and a proper site now being sought. The mirror, 16 ft. in diameter (about 240 sq. ft. of area), will penetrate space deeps beyond all imagining, picking up billions of new stars of the 25th mag., and less, and "Island Universes" at a distance of 400,000,000 light years, revealing to us the secrets of their size, velocities in space, composition, temperature and other facts wrung from these outpost celestial units by the wonder-working spectrograph and astro-camera in master hands. In solar and planetary research the benefits to be conferred cannot be estimated nor predicted, with many present problems solved and doubtless new ones encountered. Fortunate are we of this generation who may live to see the fruits of this new miracle of man's ingenuity in the eternal quest of truth.

"Future astronomers equipped with more powerful instruments and probably with more effective methods, will carry on with stars fainter and more distant. It is by taking successive steps that great problems eventually reach their solution." — Campbell.

"There is abundant room for the development of new and brilliant methods of attacking astronomy's larger problems. In general, however, it appears probable that future advances will depend upon the accumulation of many discoveries concerning the units of any class of objects, and upon the careful and systematic analysis of these facts for the basic truths of stellar evolution."—Curtis.



S 231508 Var.: 8 : 13.3. Per. 318.8d. *Chart 24-C*
AQUARIUS:
Σ3008 *231908* D.: 7-8. Sep. 7″.5.
Σ2993 *230909* D.: 7-8. Sep. 25″.6. Field diverse.
ψ2 *231109* D.: 4-8.5 Sep. 46″.6. Pairs abound.
94 *231413* D.: 5.2-7.2. Sep. 13″.4. Colorful.
R *233815* Var. 6.4 : 10.3. Per. 386.8 d.
W Ceti *235715* Var. 7.4 : 14.5. Per. 351.2d.
107 *234119* D.: 5.3-6.5. Sep. 5″.6.

THE ETERNAL MYSTERY OF SPACE.

To catalogue and classify with exactness the faunas of the Five Seas and yet to confess only a vague theory as to the nature of the medium in which they live, would be a serious challenge to science. Yet, while of various celestial units we have reasonably exact knowledge, of space itself we have only vague hypotheses. Whole libraries have been written upon its mysteries, many abandoning three-dimensional reasoning entirely, employing metageometrical methods of attack—a fourth, fifth or sixth-dimensional argument, bearing the same relation to Euclidean geometry that metaphysics bears to pure physics—vague and imponderable. Still, a few facts are quite within our grasp: namely, that interstellar space is finite, as Einstein proves; that its temperature is absolute zero; that it is not "empty," as Eddington shows, supporting at least one material atom to every cubic centimeter of its content; that, according to Lodge, its functions are gravitation, cohesion, light, radiation and electro-dynamics—"a vast storehouse of energy in a rotational ether which only, or mainly, manifests itself in localized portions apprehended by us as particles or waves." The term "ether," as Prof. Born points out, is only a compromise, "no longer denoting a substance with its traditional attributes;" and Michelson recently contended that the actual existence of an ether appears to be "inconsistent with the theory of relativity; yet without a medium of some sort, how can the propagation of light-waves be explained?" Truly, as Newcomb remarked years ago, "Progress is slow in the solution of the greatest problems when measured by *what we want to know.* Some questions may require centuries, others thousands of years for their answer."

"The fundamental basis on which science rests is the orderliness of the universe. That it is not a chaos has been confirmed by an enormous amount of experience, and the principle that it is orderly is now universally accepted. This principle is completed in a fundamental respect by the doctrine of evolution. According to the fundamental principle of science the universe was orderly yesterday, is orderly today, and will be orderly tomorrow. According to the doctrine of evolution, the order of yesterday changed into that of today in a continuous and lawful manner; and the order of today will go over into that of tomorrow continuously and systematically. That is, the universe is not only systematic and orderly in space, but also in time."—*Moulton.*

Special Chart Index

SELECTED LIST OF LEADING CELESTIAL FEATURES

Index to Constellations, page 19.

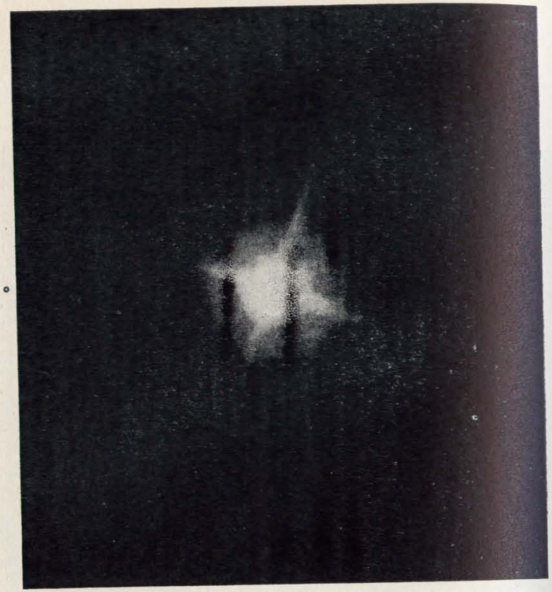
General Chart Index

ILLUSTRATION SECTION

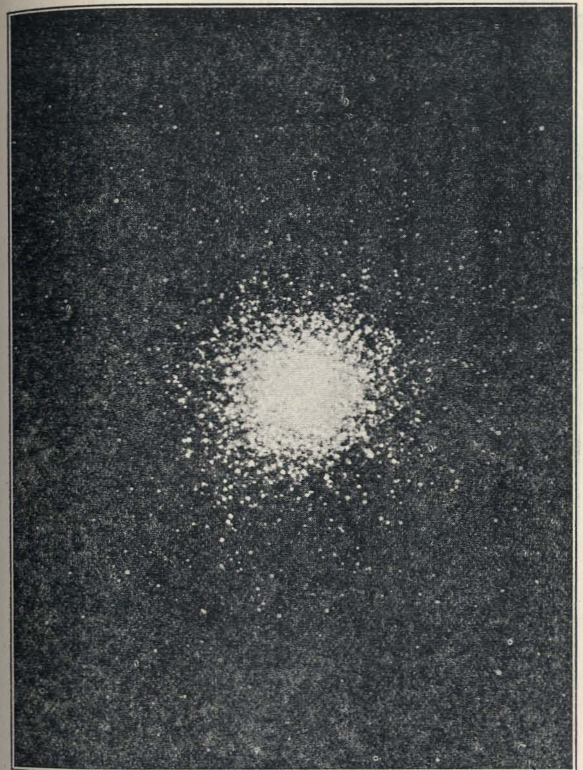
TYPES OF

CELESTIAL PHENOMENA

THE GREAT NEBULA OF ORION — Messier 42 — Most impressive of the diffuse type, enveloping the rare multiple star, Theta Orionis. Photo reveals much of the nebula's internal structure and the location of the gorgeous Trapezium, easily seen with a 3", or over. Receding as a whole at the rate of 17.5km.-sec., with a probable revolutionary period of 300,000 years. The unknown green spectral lines of "nebuleum" are now believed to be known elements under double and triple ionization in a medium inconceivably rare — one millionth of a billionth of our atmosphere — at which rate of proportion one-tenth of our earth's mass would fill a globe as large as the orbit of Neptune! Nevertheless, the Great Orion Nebula contains enough matter to form a cluster of 10,000 suns rivalling our own. See Chart [illegible] ps. 57 and 59. (Lick Obs. photo).



NOVA AQUILAE III, 1918. About the middle of the eighth century, A. D.. (seven hundred and thirty-odd years before the discovery of America by Columbus), a mighty catastrophy took place in the heart of the constellation of Aquila, the Eagle. A star of the 11th. magnitude (a hundred times fainter than visible with the naked eye, tho fairly comparable with our own Sun in actual size), either exploded utterly or else encountered another, perhaps a massive burned-out sun, or a vagrant nebula, in its swift space-flight. Within a few hours it flamed up to a maximum rivalled by Sirius alone, 400,000 times the luminosity of our Sun! Now, of the millions of people abroad on the earth in that far day 1160 years ago, not one made note of it, nor even beheld it, for the reason that the tidings of that celestial cataclysm, travelling earthward at the constant rate of 186,300 miles per second, did not reach us till the night of the seventh of June, 1918, Here a new world, a new generation of investigators and a new astronomy greeted it with tools of research of which they of that dark era had not the vaguest conception. Slowly then this flaming aegis of the sky paled to the lusterless proportions of a planetary nebula, after the manner of its class, resuming its original magnitude, with occasional brightening variations. At present Nova Aquilae III is of mag. 10.5, surrounded by a nebulous sheath 18″ in diameter Easily glimpsed with moderate powers, 10° west and 8° south of Altair, mag. 0.9. The tiny circle on the upper margin of the photo represents the comparative size of the Nova a few days before the explosion, which, if that distant sun had a system of planets like our own, must have destroyed them all almost instantly! See Chart 19-C, page 135. (Photo by Dr. Hubble, Mt. Wilson. Exposure 45 min.)



GLOBULAR CLUSTER, Messier 13, in Hercules. Most notable example of its type. Forty-five thousand suns whose light-journey hitherward began before the dawn of civilization on earth over a hundred thousand years ago. Diam., 10 parsecs:32 light years. A ball, not a disc, of blazing suns: red super giants rivaling Betelgeuse and Antares, blue-white units and myriads of fainter yellow like our own Sun which would be utterly lost in its brilliant mazes. Total luminosity, 50,000 times Sun's. Center appears densely massed, but nuclear stars doubtless are separated from one another by more than 50,000 astronomical units. No internal motion discovered, tho Clusters as a class have a radial velocity of 100 mi-sec., plus. See Chart 17-B, p 121. (Lick photo).

Partially condensed type of SPIRAL NEBULA, M 81, in Ursa Major, some of the peripheral condensations appearing of stellar character, the spectrum being of the solar type. Inclination of 30° discloses the presence of dark obscuring matter. Mean residual radial velocity (recessional), about 400 miles per sec. Estimated distance, two million light years! For location, see Chart 10-A, page 77. (Photo, Mt. Wilson Obs. 60" reflector; exposure 4¼ hrs.)

"We must think of our Galaxy as a companion of the spirals seen in the telescope; and that we are probably as near to our nearest spirals as they are to one another."—Dean.

TRIFID NEBULA, Messier 20, in Sagittarius. A conspicuous naked-eyed phenomenon in the densest central areas of the Milky Way. Dark lanes of obscuring cosmic matter lie between us and the flare of luminous dust-clouds that veil the massive suns inciting the radiation, since a star of even the first magnitude will illumine an area over twenty light years in radius, and there must be many far brighter, of various spectral types from O, (blue-white) to K, (red-solar). Whole mass probably in a high state of expansive turbulence that has required millions of years to attain its present size and aspect. Messier 20 and its rich environs are worthy of long and patient study. For location, etc., see Chart 18-C, p 129. (Lick Obs. photo. Exposure, 3 hrs.)

DIFFUSE NEBULA, Messier 8, in Sagittarius. Irregular type, lying in the galactic equatorial region, the densest areas of the Milky Way system. Dimensions, several square degrees, merging into others of its class which abound in this bewildering domain, notably the wonderful Trifid Nebula and M. 21, on the north. Distance, probably exceeding 100,000 parsecs (326.000 light years). Small proper motion. Stars involved, from mags. 1 to 13, radiating energy which gives the illusion of self-luminous incandescence in the cosmic cloud which would otherwise be as dark as its blackest rifts that doubtless obscure myriads of giant suns in remoter space deeps, never yet seen by man and never will be. Very impressive with clear seeing and low power ocular. For location, etc., see Chart 18-C, p. 129. (Lick Obs, photo. Exposure, 4 hrs.)

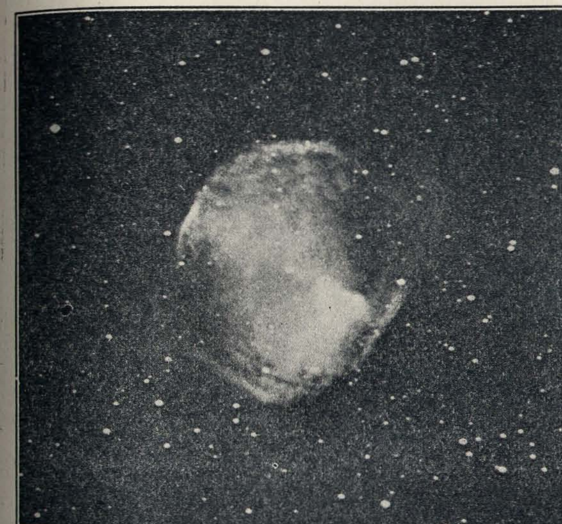
THE WHIRLPOOL NEBULA, Messier 81, in Canes Venatici. First nebula that determined Spirals to be of a distinct class. On account of their vast distance, (Curtis finds by comparison of galactic Novae with those in Spirals that the latter objects lie at a distance approximating ten million light years!) these extra-galactic wonders are disclosed in all but large apertures as misty blotches in dark sparse fields. But higher magnification reveals them in their true splendor as seen above—colossal sun and world-building prodigies in vorticose motion that requires upwards of a hundred thousand years to complete one revolution! Recessional velocity: 620 km.-sec. Prof. Jeans observes in such spirals as the Whirlpool Nebula a slow development from the globular type under increased urge of motion until it becomes lenticular, at which critical stage the arms begin to condense at the periphery, finally separating from the parent body under tidal action from outside sources.
(Mt. Wilson Obs. photo. Exposure, 10 hr., 45 min.)

GREAT NEBULA OF ANDROMEDA—Messier 31. Inclined 15° to line of sight. Length, 3°. Diam., 14,000 parsecs (nearly 50,000 light years. Nuclear mass equal to seventy million Suns like our own! Solar type spectrum. Outer regions thick with giant stars. Neighboring nebulae belong to the parent system, being of like recessional radial velocity: 286 miles per second.

About fifty variable stars, thirty-six of which are Cepheids, and eighty Novae, have been observed by Hubble in the study of the Andromeda Nebula, reports Dr. Adams, of Mt. Wilson. These Cepheids establish a good period-luminosity curve for periods between ten and seventy days. At the distance of the Nebula indicated by the Cepheids (nearly a million light years), the mean absolute magnitude of the Novae is −5,2, beside which our own Sun would shine like a candle amid a blaze of arc-lights! See Chart 1-B, ps. 25-27.

DARK NEBULA in Orion. Rara illustration of occulting clouds of cosmic matter which abound in the galactic regions, obscuring, according to Prof. Bailey, upwards of 10,000 suns to every square degree! Indeed, the entire Milky Way is apparently divided into two star-streams by a vast longitudinal sweep of opaque material, 120° from Cygnus to Centaurus, which, if torn aside, would reveal one unbroken band of light from millions of suns now eternally curtained, many perhaps far more brilliant than those now seen hemming the silvery garment of the Galaxy. See ps. 33,47 (Photo by Duncan, Mt. Wilson. Exp, 3 hrs.)

THE PLEIADES, in Taurus, renowned in classical and Holy Writ, as observed with moderate powers. Finest of the open cluster type: 500 suns and photographically (tho probably remoter and thus unrelated), 2000 more. Cluster, according to Dr. Hale, comprises "a definite physical group of common origin and movement in space" at the rate of 6″ per century — a Moon's breadth in 5400 years. B-type giants, blue-white, gold and violet, (in whose midst our own Sun would shine as an eighth-magnitude unit only), involved in far-reaching nebulosity, the mass of each of the five brightest exceeding our luminary eight hundred fold. Alcyone, the super-giant lucida of the group, has a surface temperature of 12,000° to 15,000°C., (Sun: 6000°C), as determined by Dr. Trumpler, "causing light emission of great intensity." Diameter of the Pleiades group, 10 l. y., and distance, 325 l. y. — five times more remote than the Hyades. See Chart 4-B, p. 43. (Photo by Barnard, Yerkes Obs.)



"DUMB-BELL" NEBULA, M27, Vulpec. A vast pearl-white ellipsoidal unit of great interest, several stars of low magnitude illumining an exceedingly tenuous globe of gas comparable in content to a cubic foot of air expanded to a cubic mile. Probably in rotation with a period of several thousand years. Diameter, about 9000 astronomical units. Parallax, .002. Over 1600 light years distant. Notwithstanding extreme tenuity contains enough substance to ultimately form a star cluster. See location, Chart 20 B, p. 139.

SPIRAL NEBULA, HV24, Comae Ber. Typical of its lenticular form, bulging midway and fading along the extending arms, a rift of dark obscuring matter slashing the nuclear section, with a faint star at center. A test object for a six-inch. Spirals are incalculable in number, scattered throughout the regions of the poles of the Milky Way. Perhaps originally globular, they assume their present forms under the stress of gravitation and high-speed rotation. Inconceivably remote and vast in size. "Possible reservoirs of future galaxies, if not indeed already composing systems of innumerable stars too far distant to discriminate." See Chart 13, p. 97.

The central, unresolved parts of spirals are something like white dwarfs of enormous size, where the atoms are as closely packed as in the interior of the companion of Sirius, whose surface gravity is 35,000 times greater than that on the Earth. The motions in the spiral arms of these vast island universes still remain unexplained on the basis of Newton's law. (*Jeans.*)

OWL NEBULA, M97, Urs, Maj. One of the most remarkable of the planetary type. Mag. 12 central star quite discernible with good seeing, and two others fainter involved in gaseous envelope, with apparently totally encircling outer ring. Diameter, 200" of arc, probably ten times the orbit of Neptune. Perhaps a giant solar system in the making. For location, see Chart 12 A, p. 89.

Planetary nebulae are so called because each presents a disc instead of a point of light, like a star, although they are of stellar structure at their centers. Sometimes the starry nucleus is quite absent, but in the case of the Owl Nebula it is quite bright in contrast with the silvery lustre of the surprising configuration in which it appears involved. The central star is of Type O, denoting a very high temperature, probably thirty thousand degrees, Cent. Though there is apparent density, nevertheless more distant stars are sometimes seen through more than a hundred billion miles of the nebular content surrounding the nucleus, giving evidence of its extreme tenuity. These objects are extremely remote, with high velocity in space for all their size calculated to be from five to eight hundred times the diameter of the earth's orbit.

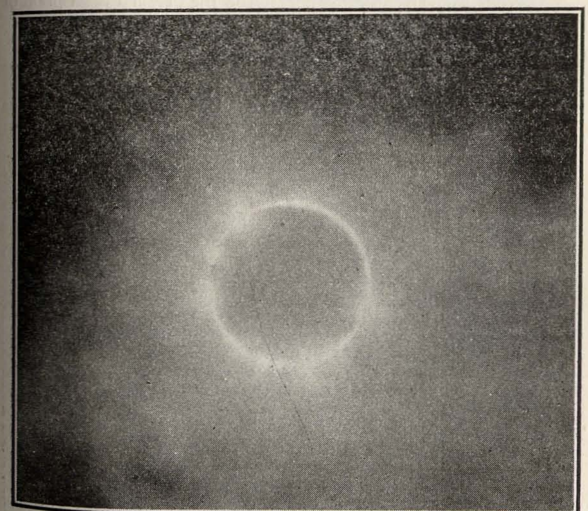
RING NEBULA, M57, in Constellation Lyra. One of the most beautiful and unique of the planetaries, easily sighted and strong enough in outline to be examined. Only annular type glimpsed with ordinary telescopes. The nuclear star, about mag. 12.5, seems brighter because of its spectacular framing, and with good seeing, even the fainter star, s f, may be glimpsed. A vast and very remote globe of gas whose central star might enclose our Sun and entire solar system. Elliptical, 83" by 59". The planetaries, of which there are fewer than one hundred and fifty, tend to congregate in the Milky Way where stars are found in greatest numbers. Apparently revolving on their axes, and of exceedingly complicated structure, they are complex forms and show certain motions not accounted for by gravitational laws, but due perhaps to radiation pressure or other forces as yet unknown to us. Curtis contends that the planetaries, owing to their high space velocity, their rarity and other factors, do not indicate stellar evolution in early stages, but are sporadic cases of collisions or celestial cataclysms. "A very puzzling class." See Chart 19 B, p. 133.

NUBECULAR MINOR, Small Magellanic Cloud, .004873 Tucanae. Area about ten square degrees. Distance, over 100,000 light years. High recessional speed. Over a quarter of a million stars in this Cloud are each a hundred times brighter than our Sun, which, in their midst, would be an object of about mag. 23, invisible in our greatest telescopes. Whole region surpassingly rich, particularly in Cepheid variables by which the distance of the Cloud was determined by shapely, super-giant stars, globular and open clusters, diffuse nebulae, etc. Globular Clusters, 47 Tucanae, lies in field as photographed at Harvard Arequipa station, and is itself a stupendous object, milk white with ruddy center.

THE SOUTHERN CROSS in the Constellation of the Centaur, about 30° from the South Pole, (indicated by white lines, turning page sidewise), with vast sweep of diffuse Neb. at extreme right, the famous "Coal Sack" in center, and Alpha Cent., our nearest star, (dist., 4¼ lt. yrs.), at extreme left. The So. Cross is small but exceptionally brilliant. Harvard Obs. photo, Arequipa Station.

THE SOLAR SYSTEM

While the stars and other "fixed" celestial units lend themselves to the arts of the cartographer, to map the positions of the Moon and planets (save day by day and even hour by hour), would be manifestly impossible. Current positions and configurations are given in the several monthly publications listed in the Appendix, and with exact notation for every day in the American, British and other Nautical Almanacs.

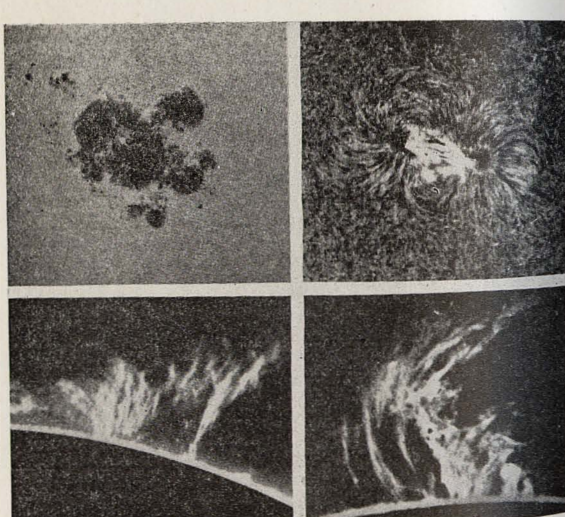


Annular Eclipse, April 28, 1930. Photo by Ansel Easton Adams, at Camptonville, California.

THE SUN

SYMBOL ⊙

SUN-SPOT Maxima Periods, about a decade apart, may be called the Jubilee Years of Apollo when, from an astronomer's standpoint, he holds forth most brilliantly. Still, there is seldom an interval between when one or more of these stupendous outbursts in the Sun's photosphere are not visible, and even the thrill-proof celestial campaigner is often awed and spellbound before some sudden solar cataclysm that merits world-wide record. For the amateur a systematic survey of the Sun, while never-failing in impressiveness, frequently brings important scientific results. Particularly is this true if the telescope is supplemented with a camera for making permanent record. (See chapters on Astrophotography and The Spectroscope. Also the detailed description of Dr Hale's Spectroheliöscope for Amateurs).



SUNSPOTS — Direct Photograph and Hydrogen Spectroheliograph.
SOLAR PROMINENCES, Mt. Wilson Obs.

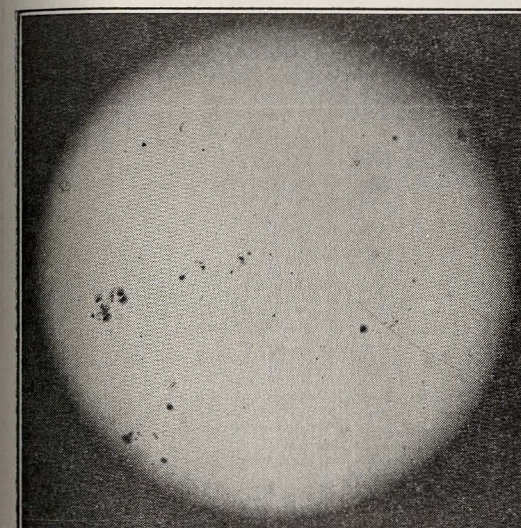
Dist. from Earth: Mean, 92,900,000 miles.

Diam.: Mean apparent, 32′ 4″. In miles, 866,500. **Surface Area:** 12,000 times Earth's.

Mass: 333,000 times Earth's. **Volume:** 1,300,000 times Earth's.

Density: 0.255—about one-quarter of Earth's density, one and one-half times the density of water. **Surface Gravity:** 27.6. A 200-pound man would weigh over two and three-quarter tons on the Sun.

Axial Rotation: 27.25 days, synodic; 25.35 days, sidereal.

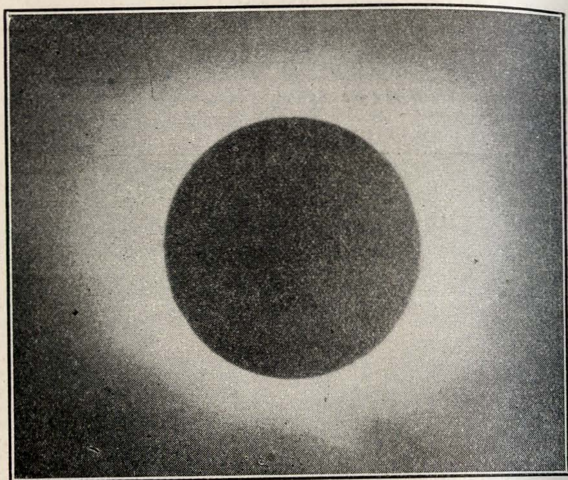


SUNSPOTS. Photo by Wm. Henry, Brooklyn, N. Y.

Temperature: Surface, 7000° C., or 12,000° F. Interior temperature estimated in millions.

Sun's Gravitational Pull: Equal to a steel rod 3000 miles in diameter, extending from Earth to Sun. **Light:** Equals six hundred thousand Moons, or fifty billion first-magnitude stars. **Heat:** If equally distributed, would in one year melt a shell of ice one hundred and fourteen feet thick surrounding the entire Earth. Perpendicular energy represents three horsepower per square yard of space on Earth's surface.

Principal Solar Features: Photosphere, chromosphere and corona. Photosphere is the source of light and heat, where sunspots and faculae abound. Above is the reversing layer, composed of incandescent gases, somewhat cooler, about a thous-



TOTAL ECLIPSE OF THE SUN. Photo by Wm Henry, Brooklyn, N. Y

and miles in depth, in which the spectroscope discloses many of the elements found on Earth. Enclosing all is the chromosphere, possibly ten thousand miles in depth, composed of glowing gases, chiefly hydrogen; and lastly the vast outer sheath of the corona which extends outward into space many millions of miles, seen only on the occasion of a total eclipse when the intenser photosphere is blotted out by the Moon, and the other solar features may be examined photographically, and more important still, spectroscopically.

Light, Sun to Earth, 500 seconds—8m., 20s. Sound would require fourteen years; an aeroplane, one hundred; and relay runners seven hundred to cover a like distance.

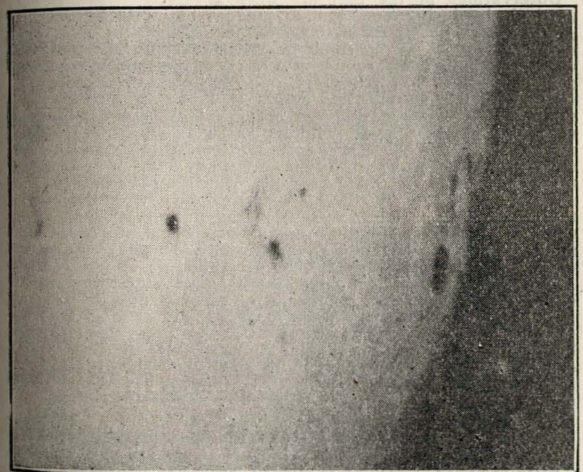
If Sun were a hollow sphere, with Earth at its center, the Moon would describe a circle half way between the center and Sun's circumference.

Sunspots: Colossal storm-centers of solar and magnetic energy, ranging from a few hundred to many thousands of miles in diameter, at various levels, some deep in the photosphere, some at higher elevations, with a dark umbra (only by comparison), and converging filaments of photospheric cloud — sources of magnetic energy sufficient to reach and encircle the

Earth and account for many disturbing phenomena. General distribution of sunspots between Lat. 5° and 40°, N. or S., few near the Equator and none at the Poles. No true theory of sunspots established: whether causes or effects, of external or internal origin.

We do not believe that the magnetic fields in sunspots can directly affect the earth. The best existing evidence points to the view that auroras and terrestrial magnetic storms are caused by electrified particles shot out from eruptive regions which usually surround active spots. Thus very large quiet spots, with intense magnetic fields, may cross the disc without producing magnetic storms on the earth. Such eruptions can easily be seen with the spectrohelioscope.—*Dr. Hale.*

"Hale's measurements of the flow of hydrogen in the vicinity of sunspot vortices have afforded new evidence in support of his previous conclusions that the law of gyratory storms in the solar atmosphere is the same as the terrestrial law of cyclonic storms."—*Adams.*



Remarkable Spots seen edge-on at Sun's limb. Photo by Wm. Henry.

Earth's diameter as viewed from Sun, 17".6 of an arc. All the planets together receive but one hundred millionths of Sun's total energy. The remainder is lost in space. Each square foot of Sun's surface radiates energy of 10,000 horsepower per minute. If Earth fell into the Sun, it would supply heat for ninety-five years, and the whole planetary system for 46,000 years. If

Sun were fed only by cosmic bodies drawn into it, the Earth too would receive meteoric matter to the weight of fifty tons annually per square mile, its axis changed and day lengthened—a manifest absurdity. If Sun's internal combustion is kept up by consuming itself, even if it were pure coal, it would not last 5000 years—a mere instant in the star's life-history. If by convection—the outer components falling into and feeding the internal furnace—since from the size of Neptune's orbit the Sun has shrunken to its present proportions, it would have burned out in a mere fifteen million years. The whole question then, What keeps up the Sun's mighty forces? is as much a complex mystery as ever; but the answer at last seems dimly foreshadowed in the progressive discoveries of radioactive elements whose disintegrations yield a maximum amount of energy to a minimum loss, or transmutation, of these elements—the breaking up of atoms into electrons under inconceivable pressure and of heat millions of degrees beyond anything producible by laboratory methods. Here is a problem we would all love to live to see solved.

Observations of the Sun are always replete with interest, particularly during a sunspot maximum; but it is seldom that there is not to be found at least one sunspot on the solar disc, either elongated at the limb or sharply facing the observer, with dark umbra and round, ragged-edged penumbra very well defined even in a small glass. The presence of sunspots, as well as their approximate location in longitude, is best seen preliminarily by focussing the entire image of the Sun on a sheet of white cardboard held a foot or two behind the low-power ocular, and the relative position of the spots noted. Another sheet of cardboard through which the upper end of the telescope extends will aid in taking the glare from the lower sheet. As for viewing the spots individually with the eye at the ocular, it is needless to caution the observer that this concentrated glare is more than any human eye could stand, and might be a very dangerous experiment. A densely dark screen is necessary, preferably of blue or green glass; but the observer may make his own by smoking a strip of thin lantern-slide glass and affixing another strip of glass over it, separating them by a thin sheet of cardboard. Even then, if held before the ocular too long in one spot, the glass may crack; so the best method is to make a regular Herschel solar diagonal, which can be done very effectively with small expense by following instructions given in the instrument-building section. This makes observation very easy, eliminates danger to eyesight and prolongs the pleasure of solar study. The early morning hours are best for viewing sunspots, the heat and glare being less intense and the images sharper.

Solar radiation, according to Russell, converted into power at the low rate of 1c per kilowatt hour, represents a dire wastage of $478,000,000.00 per second! Appalling as this loss appears, it represents merely one part in over two thousand millions of the Sun's total energy radiating prodigally into space deeps. If the Sun were encased in a shell of ice forty feet thick, the interior heat would melt it in one minute; and a column of ice two miles in diameter extending from Earth to Sun would melt in the total solar radiation in one second, and disappear in vapor in eight seconds more!

The stupendous radiative energy of our own star—the Sun—we have fairly well computed; but what of the thirty billion other suns in the firmament, some smaller, but millions a hundred or even a thousand-fold larger: what becomes of their aggregate radiation continually pouring into space from these vast storehouses of energy? Whither it goes, or is destined to go in a possible finite space, as Lodge says, no one has yet been able to hazard a plausible guess. Indeed, Prof Jeans contends that space itself is so vast in comparison with the matter it contains, for all the inconceivable energy of its masses, that to discuss the ultimate fate of stellar radiation is like discussing the fate of a few grains of sugar dropped into the Atlantic!

THE ZODIACAL LIGHT.—This beautiful solar phenomenon is best seen in the Springtime twilight when the Pleiades ride high in the heavens, marking the apex of a weird, cone-shaped effulgence that spreads upward from the sunset horizon in soft amber gradations to the zenith. This is not of terrestrial, but of solar origin, due to the fact that the Sun is the center of a vast lens-shaped cloud of meteoric dust which sweeps beyond the boundaries of Venus's orbit, and visible only at these opportune times, or in the eastern heavens before sunrise in autumn. Instead of dimming the stars seen thru it, the Zodiacal Light seems rather to enhance their color effects, imparting a sort of ghostly glow, as in the case of an aurora. The spectrum is continuous.

The nature and origin of the Zodiacal Light is regarded as more or less a mystery.—*Elihu Thompson.*

Albedo.—Lat.: whiteness. The amount of sunlight which a planet or satellite reflects as compared with the amount which it receives. Thus, the Moon reflects a little more than one-sixth of the light it receives from the Sun; Mercury about one-eighth; Venus, one-half; Mars, one-quarter; Jupiter, three-fifths; Saturn, one-half; Uranus, three-fifths; Neptune, less than one-half; and the planetoid Vesta, the highest of all—nearly three-quarters. By comparison, the coefficient of reflection of magnesium carbonate is nearly ninety per cent.; of sodium chloride, eighty-two; snow, seventy-eight (Zollner); cloud, sixty-five (Abbot). The high albedo of some planets has suggested the possibility of their being partially self-luminous—Jupiter, for instance—but there is no proof of internal heat sufficient to augment its natural albedo.

Apex of Sun's Way. Approximate point of the heavens toward which our Sun and attendant planets are moving at the rate of 12 mi. per sec. (127)

Apsis. A point in an elliptical orbit furthest from or nearest to the Sun—aphelion or perihelion—the **Line of Apsides** joining the three. (Gk. **hapsis,** wheel).

Anomaly. Angular distance of a planet from its perihelion as calculated from the Sun's center.

Aphelion. A planet's furthest orbital position from Sun. (**Ap**—away from; opposed to **peri**—close to).

Conjunction. Two celestial bodies having the same long., or R.A. (**Jugare,** to yoke). **Inferior C.,** when Venus or Mercury stands in line with the Sun on the near side, and **Superior C.,** when on the far side, as seen from Earth.

Opposition. An outer planet's position 180 in longitude from Sun, with Earth between.

Equinox. Equal night and day. The Sun's position at the intersection of the plane of the Equator with that of the Ecliptic.

Forces. Centrifugal: direction away from center. (**Fugio,** the flee from). **Centripetal:** tendency toward the center. (**Peto,** to seek).

THE MOON

SYMBOL: ☾

OUR knowledge of selenology has widened greatly in recent years with the work of astrophysicists who have met the lunar problem from new points of attack and greatly spirited our scientific interest in our nearest celestial neighbor. Refinements of research methods tend to disprove many theories long held inviolate, to the conclusion that our satellite is not such a dead, airless, vaporless and eternally changeless body as we supposed, but yielding evidences of recent eruptive disturbances and even of a low form of vegetable life in its spacious ravines, presupposing air and moisture fed from the interior. At any rate, lunar study is evolving out of its long period of neglect, and is now commanding the skill and genius of some of the world's leading investigators whose dicta merit profound respect.

Dist. from Earth: Mean, 238,840 miles—60.3 times Earth's equatorial radius.

Diam.: 2163 miles—31′ 7″ of arc—0.273 of Earth's diam.

Surface Area: One-fourteenth of Earth's; **Volume;** one forty-ninth.

Mass: One eighty-one and five-tenths that of the Earth. **Density:** 0.61 compared with Earth; 3.4 the density of water. (Earth's density, 5.53.) **Gravity:** One-sixth of Earth's. A 200-pound man would weigh 33.31 pounds on the Moon.

Orbital Velocity: 2287 miles per hour; 3350 feet per sec. **Angular Velocity:** 33′ per hour—about Moon's breadth—13° 11′ per day. Complete circuit twenty-seven and one-third days—one sidereal month. **Synodic Period:** 29d. 12h. 44m. 2.86s. (new Moon to new Moon), varying about two per cent.

Libration in Long., enables us to see alternately nearly eight degrees more of eastern and western limbs; and **Libration in Lat.**, to glimpse over six degrees more of both polar regions.

Atmosphere: Not more than one one-thousanth of our atmosphere, if any. **Temperature:** Lunar night, minus 200° F. The fourteen days of constant sunlight must raise this temperature very considerably, but it is soon lost.

Albedo: 0.0174—surface reflects only one-sixth of Sun's light.

Not only does the Moon's nearness vouchsafe us a more intimate knowledge of its topography than that of any other celestial body, but the absence of enveloping vapors, even of a refracting atmosphere, makes the work of selenographers easier than the surface of Earth's to our own geodetic survey. The vast and waterless Dead Seas of the Moon have been measured as with transit and leveling-rod. The craters, some large enough to enclose a municipality, others no bigger than a suburban handkerchief-garden, have been reduced to exact dimensions. Likewise the mountains enclosing them, often rising to the height of the Catskills or Coast Range, with central cones lifting from the depths to pinnacles taller than a dozen Washington Monuments piled end on end—all yielding to the refinements of triangulation; and mountains—the lunar Alps, Apennines, Pyrenees and Caucasus, challenging their terrestrial originals for towering peaks and rugged splendor, to say naught of the dread duplicates of Grand Canyons, mimic Death Valleys and Libyan deserts. Everywhere is the evidences of primeval volcanic convulsion whose relics no storm nor quake nor disintegrating agency has leveled or perhaps even disturbed its inchoate aspect. It is the same today as it was ten million years before the first star-watchers of Chaldea, save perhaps the soft reddish-grey mantle of dust that overspreads it from the meteoric barage of ages.

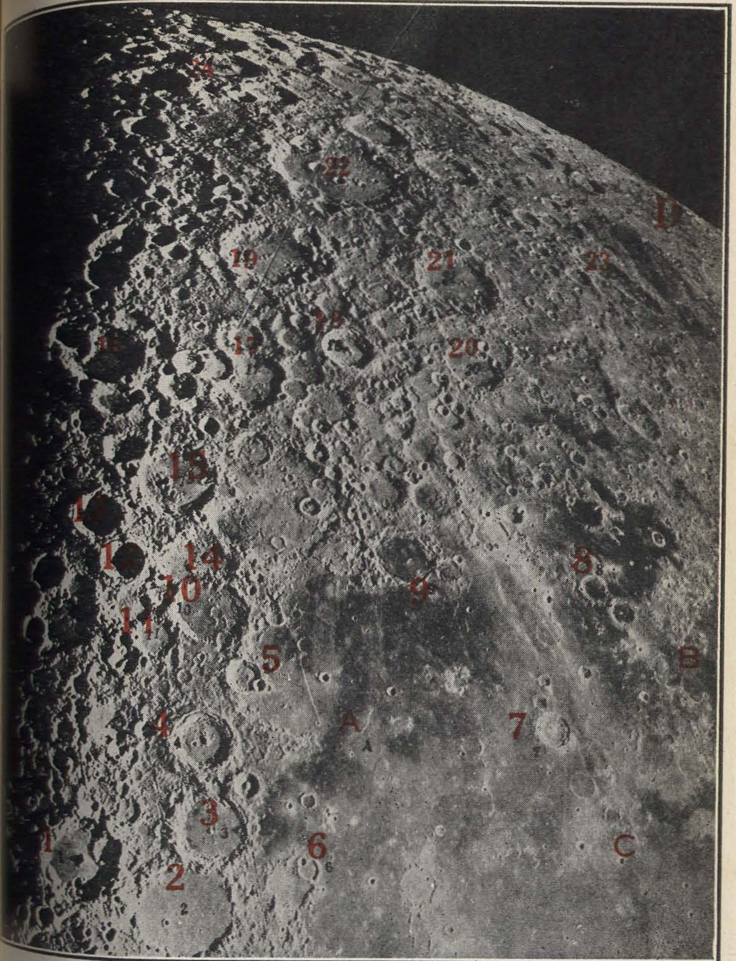
Comparatively low power will give the moon-student all the detail he will require for making succeeding observations as the thin crescent widens to full moon, and the elongated shadows of the lunar mountain ranges flatten out to apparent level of a burnished disc. A good lunar map, with the principal objects designated, may be had very reasonably; and the following of these spectacular features in the lunar landscape in the ever-changeful light, and familiarity with the major units, will be found a charming and worth-while adventure. For those who wish to delve deeper into lunar lore, let there be no illusions that our satellite's problems are all unsealed oracles. As Goodacre says, "Our present knowedge of the Moon is only fairly complete, the result of so much strenuous and persistent work spread over the last hundred years, in which the work of amateurs forms the larger part. But there still remain many enigmas, which we can only hope will be solved by the continued efforts of lunar observers of the present and future generations."

OCCULTATIONS.—One of the most interesting phenomena, occurring periodically, which the star-student seldom misses if conditions are favorable, is the occultation of the fixed stars and planets by the passage of the moon before them in the more or less direct line of sight. Sooner or later every star of the zodiacal constellations is eclipsed by the moon, stars of the third, fourth and fifth magnitude at the rate of a hundred or more per month (quite within the detection of small apertures), and occasionally one of the first or second, like Aldebaran, Spica, or of the Pleiades. But the most impressive of all is the rarer occultation of a planet like Jupiter, Saturn or Mars in a clear sky when the planet seems to hover an instant at the dark eastern limb of the moon, then plunge instantly into obscurity, to emerge as suddenly on the western limb a few minutes or even an hour or more later, depending upon the chord of the arc which it cuts behind the moon's disc. Stop-watch records of these phenomena are valuable. The **Ephemeris** gives the elements for the prediction of occultations of the planets and stars down to the sixth magnitude for every day in the year. Occultations have played an important part in the profoundly difficult construction of Lunar Tables, problems of navigation, parallax, etc.; and the instantaneous immersion and emersion of a star behind its disc, without the slightest sign of halo or appreciable refraction, proves that the moon is utterly devoid of any atmosphere or trace of water-vapor at its surface.

Recently Dr. Brown, of Yale, world authority on lunar motions and compiler of Lunar Tables, has sent out a call to all observers, amateur as well as professional, to send in their records of occultations for reduction and permanent tabulation to the better understanding of the moon's complex variations and the laws which govern them. Here is a definite program for the layman, eminently worth while.

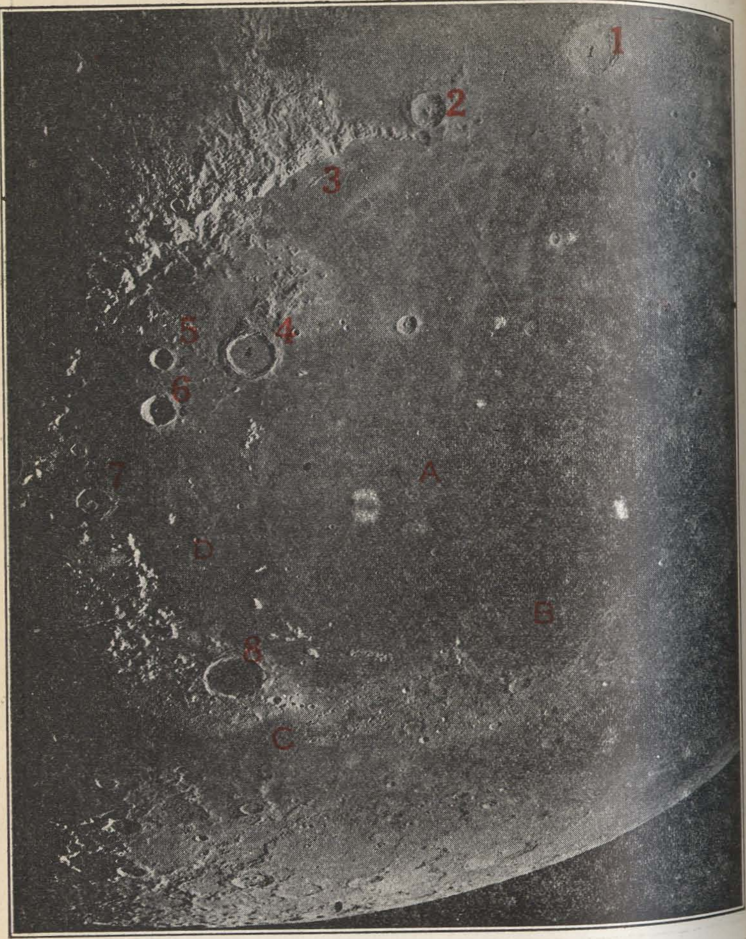
(D—Diameter. Alt.—From depth of Crater or Walled Plain to highest peak).
A—Mare Crisium, 281x355 mi. **B**—Mare Serenitatis, 433x424 mi. **C**—Mare Imbriur, 50,000 sq. mi. **D**—Oceanus Procellarum. **E**—Mare Humorum, d. 280 mi. **F**—Mare Nubium. **G**—Mare Fecunditatis. **1**—Tycho, d. 54 mi., alt. 17,000 ft. **2**—Grimaldi, d. 147 mi. **3**—Plato, d. 60 mi., alt. 7000. **4**—Aristillus, d. 34 mi. **5**—Posidonius, d. 62 mi. **6**—Copernicus, d. 56 mi., alt., 24,000 ft. **7**—Kepler, d. 22 mi.

Lick Obs. Photo.

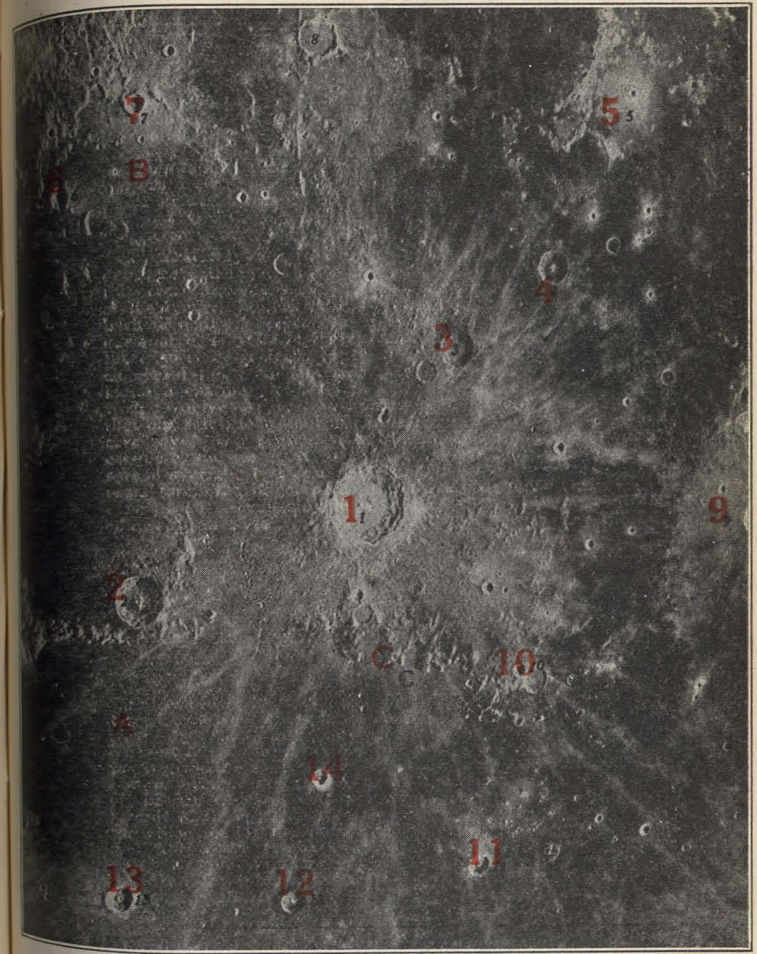


—Mare Nubium. **B**—Mare Humorum, 280 mi. wide. **C**—Oceanus Procellarum. **D**—Dor-
Mts, alt. 26,000 ft. **1**—Albategnius, d. 71 mi., alt. 9000 ft. **2**—Ptolemaeus, d. 102 mi.,
9400 ft. **3**—Alphonsus, d. 75 mi., alt. 3900 ft. **4**—Arzachel, d. 65 mi., alt. 13,600 ft.
—Thebit, d. 30 mi., 9000 ft. deep. **6**—Davy, d. 23 mi., alt. 4100 ft. **7**—Bullialdus, d. 38
alt. 9000 ft. **8**—Campanus, d. 30 mi., alt. 5500 ft. **9**—Pilatus and Hesoid. **10**—Purbach,
7000 ft. **11**—Delaunay. **12**—Werner, d. 45 mi., alt. 16,500 ft. **13**—Aliacensis. **14**—
omontanus, **15**—Walter, d. 93 mi., alt. 9200 ft. **16**—Stoefler, d. 90 mi., alt. 11,400 ft.,
—Tycho, d. 54 mi., alt. 17,000 ft. **19**—Maginus, d. 133 mi., alt. 8000 ft. **20**—Heinsius,
34 mi., alt. 9100 ft. **21**—Longomontanus, d. 90 mi., alt. 13,700 ft. **22**—Clavius, d. 142
alt. 14,940 ft. **23**—Schiller, d. 131 mi., alt. 8400 ft. **24**—Moretus, d. 78 mi., alt. 15,000 ft.

Mt. Wilson Obs. Photo.



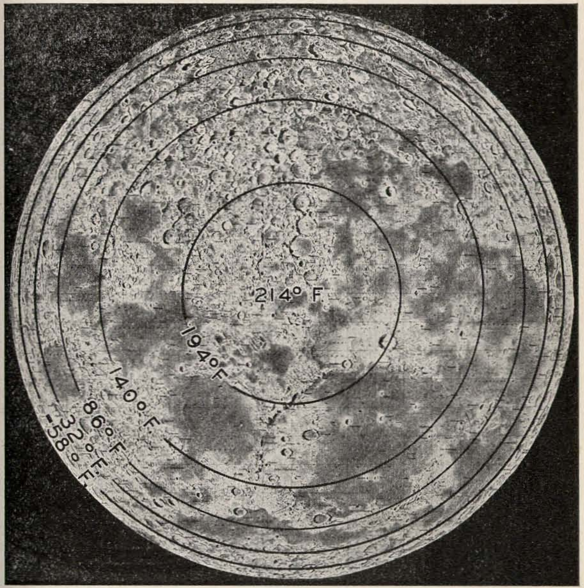
(D—Diameter. Alt.—From depth of Crater or Walled Plain to highest peak). A—Mare Imbrium, 50,000 sq. mi. B—Sinus Iridum. C—Mare Frigoris. D—Alps, ht. 14,000 ft. 1—Copernicus, d. 56 mi., alt. 24,000 ft. 2—Eratosthenes, d. 37 mi., alt. 10,600 ft. 3—The Apennines, alt. 18,000 ft. 4—Archimedes, d. 50 mi., alt. 6500 ft. 5—Autolycus, d. 33 mi., alt. 8,800 ft. 6—Aristillus, d. 34 mi., 11,000 ft. deep. 7—Cassini, d. 36 mi., alt. 3000 ft. 8—Plato, d. 59 mi., alt. 4880 ft. Mt. Wilson Obs. Photo.



A—Mare Imbrium, 50,000 sq. mi. B—Mare Nubium. C—Carpathian Mts. 1—Copernicus, d. 56 mi., alt. 24,000 ft. 2—Eratosthenes, d. 37 mi., alt. 10,600 ft. 3—Reinhold, d. 28 mi., alt. 2135 ft. 4—Lansburg, d. 28 mi., alt. 9700 ft. 5—Flamsteed, d. 16 mi., alt. 1400 ft. 6—Ptolemaeus, d. 102 mi., alt. 9400 ft. 7—Alphonsus, d. 75 mi., alt. 3900 ft. 8—Nicollet. 9—Kepler, d. 21 mi., 10,000 ft. deep. 10—Tobias Mayer, 9700 ft. deep. 11—Euler, d. 19 mi., alt. 6200 ft. 12—Lambert, d. 19 mi., alt. 2000 ft. 13—Timocharis, d. 19 mi., alt. 3200 ft. 14—Pytheas, d. 12 mi., alt. 4400 ft. Mt. Wilson Obs. Photo.

(D—Diameter. Alt.—From depth of Crater or Walled Plain to highest peak). (Hold sidewise). 1—Copernicus, d. 56 mi., alt. 24,000 ft. 2—Kepler, d. 21 mi., alt. 10,000 ft. 3—Aristarchus, d. 27 mi., alt. 6400 ft. 4—Eratosthenes, d. 37 mi., alt. 10,600 ft. 5—Flamsteed, d. 15 mi., alt. 1370 ft. 6—Reiner, d. 21 mi., alt. 6400 ft. 7—Riccioli, d. 100 mi., alt. 10,300 ft.

Mt. Wilson Obs. Photo.



The above Relief Map, by Dr. Edison Pettit, of Mt. Wilson Obs., shows the circles of equal temperatures on the Moon, with the Sun in the zenith. It is based on calculations made with the aid of the Hooker hundred-inch telescope combined with the most delicate of precision instruments, the thermocouple, so sensitive that it could record the heat from a candle at a distance of one hundred miles, if there were no atmosphere to interfere.

Only thirteen percent of the Sun's radiation is reflected by the Moon, the balance being absorbed and raising the temperature of that body to about that of boiling water when the Sun is directly overhead, falling to lower points, as seen on the chart, as the Sun sinks below the Moon's horizon. Lunar nights are therefore excessively cold, approaching the temperature of the Moon's dark side which is about —214 degrees F. As the lunar nights are fourteen days long, the constant temperature during that period must be about that of liquid air! The changes of such wide range are due to the fact that, unlike the situation on the Earth, there is no water-vapor present to pass through, but retaining all but a small percentage, as is the case on our planet.

A S. of P.

MERCURY

SYMBOL: ☿

BEING "Inferior Planets," and thus never orbiting far afield from the parental fireside of the Sun, Mercury and Venus are no objects for night-long vigils as in the case of the "Superior," being on display to best advantage just after sunset as evening, and just before sunrise as morning, stars: and then, in the case of Mercury, for only a few precious minutes, and for Venus at best an hour or two, both at crescent stage, like the Moon at quadrature. But even in small telescopes they afford a thrill that is certain to lead one to a deeper study of their classic mysteries.

Dist. from Sun: At aphelion, 43 million miles; at perihelion, 28 million; mean, 36 million.

Dist. from Earth: At inferior conjunction (between Earth and Sun), 57 million miles; at superior conjunction (Sun between Earth and Mercury), 129 million; mean, 93 million.

Diam.: 3000 miles—only 900 miles larger than our Moon. **Surface Area:** one-seventh of Earth's—about equalling that of Asia and Africa combined.

Mass: One-eighteenth of Earth's; density, two-thirds; gravity, one-quarter.

Orbital Velocity: At perihelion, 35 miles per sec.; at aphelion, 23.

Eccentricity: .20560. **Inclination to Ecliptic:** 7° plus.

Year: 88ds., 23 hrs. **Axial Rotation:** Unknown. Probably same as mercurial year—that is, keeps same face toward Sun as our Moon towards Earth. Owing to libration, one-eighth of Mercury's surface is alternately in sunlight and darkness.

Temperature: On side toward Sun, 300° C.; on dark side, absolute zero, i.e., —275° C., or —449.4° F. Mercury receives seven times as much light and heat from the Sun as Earth, and six thousand times more than Neptune.

Light: Sun to Mercury, 4 min.

Mercury's Exception to other Planets: Nearest the Sun; most light and heat; swiftest orbital motion; most eccentric orbit; greatest inclination to Ecliptic; lowest albedo; smallest diameter and least mass, the planetoids excepted.

Sun's corona, elliptical in shape and filled with highly resistant media, extends outward as far as Mercury's orbit, retarding the planet's speed and accounting for its extreme eccentricity. (Moreaux.)

Even in full daylight Mercury is sometimes visible in a small glass or mirror of good definition, and the faint dusky markings descried. But observers who have glimpsed them are by no means of one accord with regard to these outlines, and a map of Mercury's surface areas is a desideratum which only the far future may vouchsafe us. Here is some great work for the planetarian enthusiast.

Transits of Mercury across the face of the Sun are quite frequent compared with the transits of Venus; the next one occurring on Nov. 8, 1927, and one following ten years later—May 10, 1937. Watching the progress of the little black dot across the blazing disc is a memorable event.

Albedo: Only 0.13—lowest of the planets, owing presumably to dark rock formation.

Mercury is best seen when he reaches his greatest apparent elongation east or west of the Sun, rising or setting about two hours before or after. Spring is best for viewing him as an evening star, autumn as a morning star, his declination north at these times being an advantage. Owing to low horizon and twilight, scintillation often makes him difficult to differentiate from a star. There are only a dozen or more times in the year when he is on observation, even for so short a time; and it is said that many astronomers, even the great Copernicus, never glimpsed him at all. Calculating the times of Mercury's most favorable appearance from the Ephemeris, (or as noted in the various bulletins), he is an object of great beauty and interest; and even a small glass will show his phases very distinctly, atmospheric conditions being reasonably favorable.

First recorded observations of Mercury, B. C. 264.

"Mercury may not be, in himself, one of the more splendid objects in nature, but he often forms one of the chief brilliants in real sky pictures of charming character. There is here a very valuable piece of observational work awaiting some capable student. It is chiefly amateurs who investigate the physical aspect of the planets, and they should especially direct their attention to Mercury and the determination of his rotational period. A marking which would aid the solution of the problem might present itself at any time. It should be carefully watched." (Denning.)

Authorities agree that daylight observations of Mercury as well as of Venus are the best for essaying the rather difficult but charming task of glimpsing and perhaps making a drawing of its surface markings. Dazzling brilliancies against a dark sky appear to bewilder the optic nerves and quickly fatigue them, even giving rise to phantom objects which subsequent observations prove illusory. Many an enthusiast whose ardor overbalanced discretion has announced and staggered the world with "discoveries" which were later proved to be the fictions of an overwrought brain, strained nerves, faulty equipment, or all three combined. Witness the glimpsing of an intra-Mercurial planet; of mountains on Venus twice the height of Mt. Everest, and a bursting volcano at the heart of Mercury during a transit! Still, that is no argument against the imminent possibility of still greater actual features being discovered by reason of more perfect equipment and superior intelligence and deeper knowledge. The planetary branch of astronomy is greatly neglected; and while the terrestrial planets do not offer as brilliant a field for sustained study as do the major, nevertheless, one who has achieved all there is to be known of these nearer planetary neighbors cannot but be accounted a man of learning and enterprise.

"The noblest and most exalted consideration of infinite space is that of Newton, who calls it 'the sensorium of the Godhead.' For infinite space gives room to infinite knowledge, and is, as it were, an organ of omniscience."—Addison.

VENUS

SYMBOL: ♀

OUR lovely twin-planet typifies an eternal question-mark "hung aloft the night," being our nearest member and closest paradigm in the Sun's family, and yet the one whose very fundamental elements still defy our profoundest research. However, here are a few facts of which, until a greater light dawns, we may be reasonably certain.

Dist. from Sun: Mean, 67.2 million miles.

Dist. from Earth: At inferior conjunction, 26, and at superior, 160 million miles.

Diam.: 7700 miles, to Earth's 7918. **Surface Area:** 0.91 Earth's.

Mass: 0.82 Earth's. **Density:** 0.94. **Gravity:** 0.90.

Orbital Velocity: 22 miles per sec. Orbit almost circular.

Eccentricity: 0.007—smallest in system. **Inclination:** 3° 5'.

Year: 224.7ds. **Axial Rotation:** Unknown. Probably same as the Venusian year, although some recent determinations by English observers, as well as Pettit and Nicholson, of Mt. Wilson, would lead to the conclusion that Venus has a short-day period of rotation.

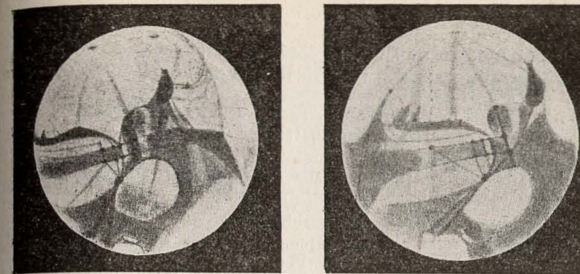
Temperature: Receives about twice as much heat from the Sun as Earth.

Albedo: 0.76—highest of the planets owing to cloud-sheath which surrounds it to the depth of many miles, obscuring its surface. It is this highly-reflecting vaprous envelope that makes Venus at its brightest no less than twenty times brighter than Aldebaran, nine times brighter than Sirius, and five times brighter than Jupiter at opposition.

Two noteworthy facts in the student observation of both Mercury and Venus are, first, that the best drawings of the surface markings by various astronomers have been made during daylight; and, second, that these have invariably been accomplished with telescopes of small aperture.

As for daylight observation, if the telescope is not provided with circles so that the planet's position may be computed from the Ephemeris at any hour, when Venus is at western elongation as a morning star, it may be located very easily in a clear sky a little before sunrise, the instrument set upon it and moved in right ascension from time to time so that even in the full morning sunlight it is still visible and may be followed and studied thence for hours.

The combined mass of all the Asteroids must be far less than that of our Moon, having no disturbing effect upon the nearest neighboring planets. Their courses are exceedingly erratic, like schools of salmon in a sea of whales. Some of their orbits are circular, some elliptical; and some sweep out of the confines of the Zodiac by as much as fifty degrees.



MARS, drawn by G. H. Hamilton: showing surface changes within five days.

MARS

SYMBOL: ♂

CONTROVERSY which agitated the scientific world for a generation following the discovery and mapping of the so-called martian "canals"—which engineering feat appeared to offer us the first visual proof of extra-mundane intelligence of human or superhuman order—has settled back into a "plausible but not proven" attitude of mind in which all parties are satisfied to retain their convictions, since subsequent and very favorable oppositions have neither substantiated nor nullified them. Nevertheless, every advance in enlightenment concerning our brother-planet whose physical aspects much resemble the Earth's should be given the deepest consideration; for the piling up of facts and theories year by year may lead to superlative results within the next generation, and the observant amateur may be one to receive the highest honors.

Dist. from Sun: Mean, 141,500,000 miles. **On account of extreme** eccentricity, radius vector varies more than 26 million miles.

Dist. from Earth: Mean, 48,600,000 miles. Nearest approach, 35 million; at superior conjunction, 234,000,000 miles.

Diam.: 4200 miles. **Surface Area:** Two-sevenths, and **Volume** one-seventh Earth's.

Mass: One-ninth Earth's. **Density:** 0.73, and **Gravity,** 0.38 compared with Earth, so that a man weighing two hundred pounds here, and a quarter of a ton on Jupiter, would weigh only seventy-six pounds on Mars.

Orbital Velocity: 15 miles per sec.

Eccentricity: Large—0.93. **Inclination:** Small—1° 51'.

Year: 687 terrestrial, and 669 Martian, days. Seasons double our own.

Axial Rotation: 24h., 37m., 22.65 sec.—Martian sidereal day.

Temperature: Mean, 48° F. Boiling point of water on Mars, 111° F. (Lowell).

Light: Sun to Mars, 12min., plus.

Albedo: Low—0.26—owing to tenuous, cloudless atmosphere and dark surface areas.

Mars receives only four-ninths of the Sun's light and heat that Earth does, and theoretically should be much colder than science has proven it to be. Whence this heat, external or internal, still an unsolved problem.

Moons: Two—Mag. 12.0—Deimos, the outer satellite, being only ten miles in diam., and Phobos, the inner, only thirty-six miles. (Lowell.) The latter, only 6000 miles distant, has a period of revolution one-third of the planet's own day; hence, Phobos rises in the west and sets in the east, making this retrograde revolution about every seven and one-half hours.

Mean Opposition Magnitude: 2.25, over three times brightness of a first-magnitude star.

Water-vapor has been found in traces on Mars by Slipher, at Flagstaff; but Campbell, on Mt. Whitney, found not even the faintest water-vapor bands in the planet's spectrum. (Jacoby). Dr. Stoney has shown that water-vapor cannot be held by a body whose mass is less than one-quarter the mass of the Earth—Mars' mass being only one-ninth. (Espin). Poor contends that "the spectroscope fails to establish anything definite with regard to **atmosphere on Mars."**

As Earth in its orbit around the Sun overtakes and passes relatively close to Mars every two years and two months, the times of most favorable observation of the planet which in all physical aspects most resembles our own, makes it possible for the enthusiast of Martian phenomena to keep up his interest both visually and statistically. For, although there are whole libraries on Martian discoveries and controversies, no near approach of the planet goes by without some new and often startling revelations leading to new theories, either refuting or substantiating the dicta of a whole army of Martian authorities. Even modest equipment, with good seeing at opposition, will disclose many of its surface configurations, polar snowcaps, et cetera; and the constant changes over its surface keep the observer ever alert for new surprises during this biennial period. You, too, as Prof. Waterfield says, may "leave Mars with the memory of some things seen certainly: mists and clouds, snow, water, vegetation and deserts. But there is something else that we cannot forget—a something seen as through a glass darkly. For, outlined upon the sand of the desert and stretching away into the regions of fertility we have found strange tracks—the footprints, may be, of an unknown intelligence."

"Knowing as we do how on the earth life exists under the most diverse conditions, it would appear that on a planet where the surface conditions are so similar to our own, the presence of intelligent life involves no improbability whatever."—W. H. Pickering.

The first telescopes increased human vision by barely eighty times; the latest by no less than two hundred thousand!

THE ASTEROIDS

SEARCHING for a missing planet and ultimately discovering a thousand, more or less: this is one of the surprises of a science whose perennial charm is this very element of the unexpected. When Titius, in 1772, deduced a mathematical sequence for all the known planets from the Sun outward, leaving only the open space between Mars and Jupiter unaccounted for, remembering the honors and emoluments accruing to Herschel for his discovery of Uranus, all the astronomers of Europe combined in 1789 in a systematic hunt for the hypothetical planet in agreement with this, known as, Bode's empirical law. It was not until the first night of the new century that 'pay dirt' was struck, to use a gold-prospector's phrase, in the locating of an eighth-magnitude planetoid, afterwards named Ceres, by Piazzi, in Sicily. Thereafter "they came not single spies, but in battalias,"—a vagrom swarm of interweaving worlds, some a hundred or more miles in diameter, myriads of them mere boulders. Aside from being mathematical test-objects, as well as illustrating Newton's majestic law of universal attraction, planetoid-hunting is a very worth while branch of a science that never palls, where earnest effort may lead to new theories and advanced conclusions.

Here is the mathematical sequence of Titius—Bode's Law—that amazed Europe at the close of the 18th. century, and is quite as unexplainable today as it ever was:—

To each of the following Numbers—

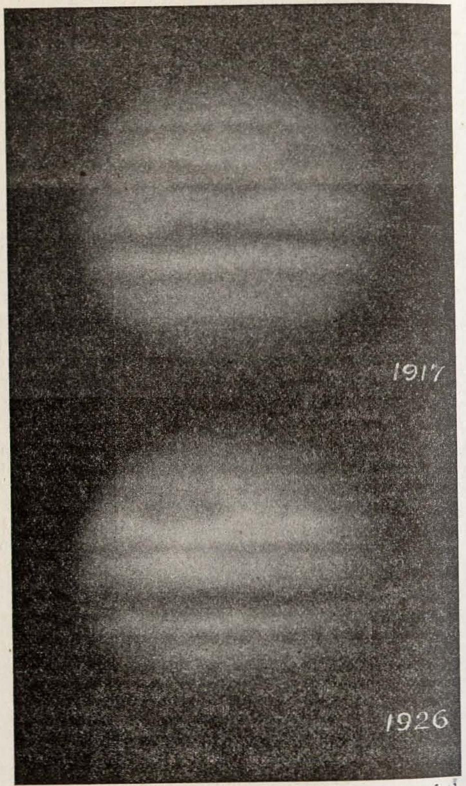
	0	3	6	12	24	48	96	192	348
Add 4, giving—	4	7	10	16	28	52	100	196	352
	☿	♀	⊖	♂	(?)	♃	♄	⛢	♆
True Ratio.—	3.9	7.2	10	15.2	27.7	52	95.4	191.8	300.5

The Titius ratios of distance from the Sun are truly remarkable in their approximations, falling down most decisively in the instance of Neptune. But it is no wonder that the great celestial interrogation-point, in the fifth place of the series, quickened the imaginations of the scientists of that day as nothing short of a miracle could do.

The Asteroids were probably bodies thrown off by the Sun in the form of a ring, somewhat like those of Saturn, which, owing to the perturbations of the giant Jupiter, never coalesced into one homogeneous mass—in other words, a single planetary unit. The result is a swarm of probably many millions of these orbited particles, only the largest of which have ever been detected. Ceres is the leader, though less than five hundred miles in diameter; with Pallas three hundred, Vesta two hundred and fifty, Juno about a hundred, down to Eros, the most interesting of them all, barely twenty miles across. Owing to its extreme eccentricity and inclination, Eros periodically swirls into the confines of the orbit of Mars, coming between us and that planet at a distance of about fourteen million miles!

JUPITER

SYMBOL: ♃



Photographs of Jupiter showing two different views of the Great Red Spot which, since its discovery in 1878, has appeared as the only permanent marking on the disk. At discovery it was described as a brick red spot, but more recently it has been gray, until 1926 when it appeared as a pinkish spot 19,500 by 6,300 miles in size. (Photograph by E. C. Slipher. Courtesy A. S. of P.)

EVEN the symbol representing Zeus is evidence of the exalted rank bestowed by the ancients on this chief of the planetary clan. For, while the origin of some of the symbols is in doubt, this one seems justified, since even the lensless observers of old must have gauged Jupiter's apparent preeminence over any other 'wanderer' of the zodiacal highway; and his perceptible flatness at the poles might have given them a clew to his inordinate speed of rotation. Indeed, those keen-visioned shepherd-starmen of Chaldea might even have glimpsed Io and Europa if not all four major satellites —a feat claimed in more than one modern instance—though it was reserved for Galileo to see them in their true relation to their primary, and deduce the epochal truths which required centuries for an inflexible intelligence to accept. And while to this day our knowledge of the Jovian mystery is at best tentative and abridged for lack of evidence, the movements of the moons, their vivid transits and occultations as well as the deep-dyed floating archipelago of spots along Jupiter's noble expanse, make repeated and prolonged vigils a delight and a source of profit always.

Dist. from Sun: Mean, 483 million miles.

Dist. from Earth: At opposition (near side of Sun), 390 million; at conjunction (far side), 576 million; mean, 483 million miles.

Diam.: Polar, 84,000; equatorial, 90,000; mean, 87,000, miles.

Mass: 317 times Earth's. **Surface Area:** 122 times Earth's.

Volume: Nearly 1400 times that of the Earth—greater than all the other planets combined. **Density:** 0.23—that is, less than one-quarter of Earth's! Interior probably solid; exterior, semi-liquid, with gases and metallic vapors under octuple layers of dense cloud 1000 miles in depth, each with a different rate of rotation. **Specific Gravity:** 2.64 times Earth's, so that a man weighing two hundred pounds here would weigh a quarter of a ton on Jupiter.

Orbital Velocity: 8 miles per sec.

Eccentricity: 0.048. **Inclination to Ecliptic:** 1° 19′.

Year: 11.86 terrestrial years. **Day: 9hr., 53m., shortest in solar** system.

Temperature: Probably 200° F., but internal heat immense, though insufficient to make planet self-luminous.

Albedo: 0.62 (Zollner), owing to its enveloping cloud-sheath which gives back more than one-half the light it receives from the Sun.

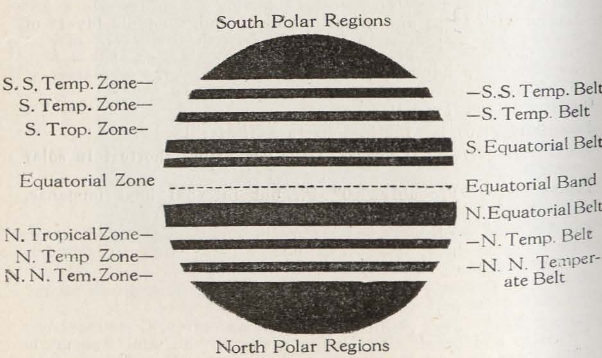
Objects at Jupiter's equator move at the rate of eight miles per second—28,000 miles per **hour!**

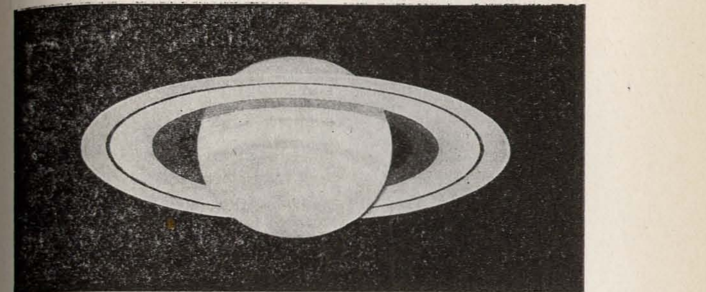
Moons: Nine. Four visible with small apertures, their recurrent transits and occultations being given in the **Am. Ephemeris** and **Evening Sky Map** so that these interesting objects may be studied nightly whenever the planet is visible. Satellite **Io** is about the size of our Moon; **Europa**, slightly smaller; **Ganymede** challenges Venus, and **Callisto** almost matches Mercury. These four were discovered by Galileo. The others are ineffectual as objects of interest, ranging from about forty to a few hundred miles in diameter. All moons probably keep same face to planet. Motions of 8th and 9th moons retrograde.

Surface markings, including the famous Great Red Spot (at one time 30,000 miles long and 7000 wide), shifting and changeful, proving that the planet itself has never yet been visible. Owing to Jupiter's terrific orbital velocity, his surface areas must be in constant and stupendous turmoil, spots having been seen to drift by one another at the rate of hundreds of miles per hour through oceans of metallic vapors! Enormous gravitational power must hold down elements lighter than those on Earth and unknown to us; and the spectroscope reveals unidentified constituents, besides the spectrum of ordinary reflected sunlight.

Light: Sun to Jupiter, 43min. Earth receives seventy-five per cent more light and heat from the Sun than Jupiter. Light travels from planet to Earth in from 33 to 53min., depending on positions in respective orbits.

In order that observers making notes of the changing phenomena seen almost hourly along the various zones of the Jovian planet, the diagram below, (adapted from the Jupiter Sec., Brit. Ast. Assn.), will aid in systematic study of the forms, colors and other features. Also will aid in an investigation of the drift in longitude of the spots and other definite markings to ascertain the rotational velocities in different latitudes, et cetera. Drawings should be made, (preferably in color), within an ellipse to represent the planet's disc, the ratio of the polar to the equatorial diameter being about 15 to 16. Reflecting telescopes give the best color values, and good seeing conditions are more essential than high powers. It will be found interesting and highly instructive work.





SATURN

SYMBOL: ♄

BEHOLD, the supreme appeal in all the solar symphony —"the most purely beautiful object in all inanimate nature!" Whatever his position in the visible heavens, or the aspect of the rings: broadened out like a cardinal's hat or flattened to a dagger-edge, Saturn never fails to quicken the admiration and pique the curiosity of the novitiate or to fire the speculative zeal of the veteran observer.

Dist. from Sun: Mean, 887 million miles—twice Jupiter's and ten times Earth's, distance.

Distance from Earth: Mean, 900 million miles.

Mean Diam.: 75,000 miles—about nine times Earth's. Most oblate of the planets, the equatorial being about 7000 miles greater than the polar diameter. **Surface Area:** 86, and **Volume** 800 times Earth's.

Mass: 95 times that of Earth. **Density:** One-eighth of Earth's, or only two-thirds that of water; so that, as has often been said and pictured, if only there were an ocean big enough, Saturn would float! **Gravity:** 1.2 times Earth's.

Orbital Velocity: 6 miles per sec. **Eccentricity:** 0.056. **Inclination to Ecliptic:** 2° 30′.

Year: 29.46 of our years. **Axial Rotation:** 10h., 15m. Saturn's seasons are of seven years' duration.

Temperature: About —300° F. Saturn receives but one-ninetieth of the light and heat of the Sun that Earth does, light requiring 1hr. 20m. to make the journey. **Albedo:** 0.52—about that of Venus.

Surface of planet probably liquid in a less turbulent state than on Jupiter, superimposed by cloud-masses of metallic vapors. Spectrum discloses bands of unknown origin, elements to which there is no terrestrial analogy. Disc is belted like Jupiter, with shifting tinted areas and local bright or dark spots, which have given a clew to Saturn's rotational period.

It is Saturn's **Ring System**, however, that makes him the most spectacular and unique of the Sun's august family. These three flat, concentric rings in the plane of the planet's equator, probably not more than fifty miles in thickness, extend outward from a distance of eight thousand miles from the planet circumference to a radius of 86,000 miles. Being neither liquid, gaseous nor solid, it is as if in remote ages a moon had been crushed to powder and hurled into space, each infinitesimal particle taking up an independent orbit around its principal, which motion it has ever since maintained.

If these rings were homogeneous, the outer rims would move faster than the inner; but Keeler proved spectroscopically that the reverse is the case. When seen edge-on, as is the case every fifteen years when the plan of the planet's equator coincides with our point of view, the rings become a thin line, all but invisible. At all other times, whether viewed from below the plane or above it, it is one of the most bewilderingly beautiful objects in the heaven.

Moons: Ten. The largest, Titan, is easily picked up with a small glass, being about the size of our own Moon. Two others, Rhea and Iapetus, are each about 1000 miles in diameter; five others ranging from 800 down to 200 miles; and two so small as to be beyond visual range, being photographic objects only. All proceed in regular orbital order save one of the latter, which moves retrograde—a celestial inconsistency which science is powerless to explain.

THEORIES OF WORLD-BUILDING

During the latter part of the eighteenth century, Swedenborg and Kant, philosophically, and Laplace, mathematically, offered the nebular hypothesis: briefly, that tens of millions of years ago the masses of all the solar-system components were in the form of one vast moving cloud of gas and cosmic dust. This, under the stress of gravitation, contraction and cooling, gradually resolved itself into a concrete unit, which, under swift rotation, finally separated portions of its surface mass by centrifugal force, forming rings like those of Saturn. These finally condensed into individual planetary forms, the giant of them all, the Sun, at its center. This theory held for several generations until the progress of astrophysics made the hypothesis untenable. A practical reverse of this process is contained in the Chamberlin-Moulton theory of "planetesmals." This conception assumes the planet-building procedure as having resulted from nothing more or less than the near approach of a wandering star to our Sun—an accident which may occur to any star once in several million years. The force of this gigantic impact dragged the surface Sun-substance into space in the form of planetesmals, or tiny planets, which assumed elliptical orbits about their primary, thence coalescing into solid bodies (Mercury, Venus, Earth and Mars) in the nearer confines, and the liquid and gaseous (Jupiter, Saturn, Uranus and Neptune), in the outer regions. More recently Prof. Jeans, revising the theory of "dynamic encounter," attributes to tidal forces the elongation of the liquid parent mass till that critical state is reached when vast portions become detached in isolated units, later condensing into planetary configurations and given rotational courses about the Sun. The subject is of profoundest interest to all students of the stars ***(See works by Chamberlin, Moulton, Jeans and others in Book List.)***

URANUS

SYMBOL: ♅

SAVE for the reward of patience in having located conclusively this tiny emerald gem in the solar circlet, and coaching up on its very romantic history for so modest a member of so brilliant a family, the seventh planet of the system does not enthuse one to sustained interest. Nevertheless, what little is known of "the 'star' that set the intellectual world a-flame" in Herschel's time is worthy of serious consideration, and an occasional greeting is a delight.

As Phillips remarks, what the discovery of America was to old-world Europe, such was the discovery of Uranus to celestial science, quadrupling the area of the Sun's planetary dominions.

Dist. from Sun: One and three-quarter billion miles, plus.

Diam.: 31,000 miles. **Volume:** Forty-seven times Earth's.

Mass: 14.6 times Earth's. Density, 0.31 of the Earth; and **Gravity,** 1.11.

Orbital Velocity: Slowest save Neptune—4.2 miles per sec.

Eccentricity: About same as Jupiter's—0.048—Sun being 83,000,000 miles out of center of orbit. **Inclination to Ecliptic:** 0° 46′ 20″ smallest of the planets.

Year: 84 yrs., 7 ds. **Axial Rotation:** 10hr., 45min. (?). **Temperature:** Unknown, but probably close to absolute zero—minus 449.4° F.—as there is no evidence of internal heat, and planet receives only one-three hundred and sixtieth of the Sun's light and heat that we receive.

Albedo: High by comparison—0.62—about equal to Jupiter's, else planet would be invisible. As it is, Uranus is seen even in small telescopes to be a slightly flattened sea-green disc, about four seconds of arc in diameter, with (under higher magnification) a white streak through the center between two dusky belts almost perpendicular to the line of vision.

Moons: Four—Ariel, Umbriel, Titania and Oberon, in order outward from planet, all small (200 to 500 miles in diam.), comparatively close to their principal; and, as their orbits are inclined to the Ecliptic at more than a right angle—97°.8—their motion is retrograde.

"Calculating inconceivable things, testing conclusions by ever new observations, astronomers gather data for those who shall come after. With their eyes on celestial objects unimaginable millions of miles away, they may meet disappointments today and tomorrow; but they go on building for futures a score or a hundred centuries to come, almost daily uncovering facts which illumine our knowledge not of the heavens alone, but of the planet upon which we live. Their hopes may often suffer eclipse; but their work is founded upon something more than chance; and they press on, content if what they do endures and proves a safe foundation for the builders who follow."

NEPTUNE

SYMBOL: ♆

WHILE Uranus, once located, may be espied without optical aid by keen vision aided by favorable conditions—being only a little below the sixth mag., the accepted limit of naked-eye visibility—the outpost planet, Neptune, is a telescopic object only, being less than mag. eight. However, as Neptune occupies each of the zodiacal constellations for a year or more in succession, once located his march amongst the stars may be followed with interest.

Dist. from Sun: Mean, two and three-quarter million miles, plus.

Diam.: 33,000 miles—2″.2 of arc—visual mag., 8.5, visible in telescopes of modest aperture, but more difficult than Uranus, having less albedo as well as being a billion miles more distant, though slightly larger.

Mass: Seventeen times Earth's. **Volume,** fifty-three times. **Density,** 0.34, and **Surface Gravity,** one and one-fourth times Earth's.

Orbital Velocity: Lowest of the planets—3.4 miles per sec.

Eccentricity: Only 0.0009—orbit almost circular. **Inclination:** 1° 45′.

Year: 164.9 terrestrial years. **Axial Rotation:** Doubtful—about 7h., 55m.

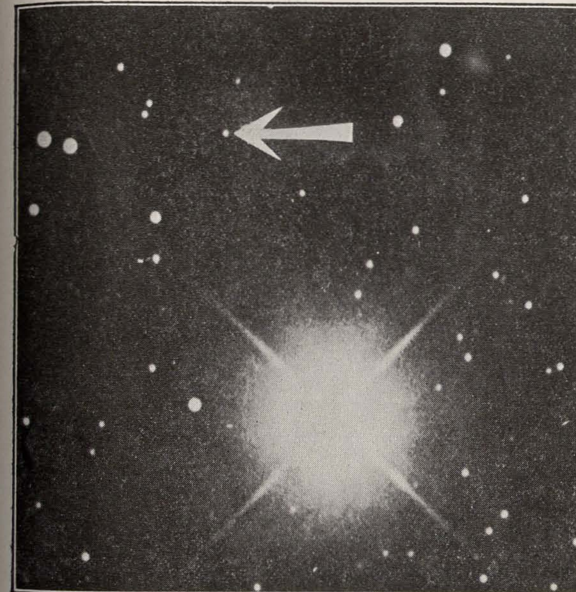
Albedo: 0.46 (Zollner)—slightly less than Saturn.

Sun's Light and Heat: Only one nine-hundredth of that which Earth receives, still equal to about seven hundred full moons; and requires over four hours to make the journey.

Moon: Only one, so far as known, about the size of our Moon and approximately the same distance from the planet, but with a period of less than six days, and motion retrograde.

No fiction could match the story of the triumph of mind over Nature's most secret and stubborn laws as was exemplified in the simultaneous, though independent, discovery of Neptune by mathematical deductions leading to a visual verification in the mid 'forties of the last century. It fairly electrified Europe, and incidentally led up to one of the bitterest wars of the intellectual giants that the world has ever known, whose distant rumbles are echoing still. The perturbations of Uranus, believed due to an outer planet, had long been known; but only two living men had the courage and skill to attempt to locate it—Adams, of England, and Le Verrier, of France, both young men, unknown to each other. After months of most exacting labors, Adams sent his calculations to the Astronomer Royal, who promptly pigeonholed them, afterwards passing them over to an incompetent for visual verification, without success. Meanwhile the young Frenchman presented his calculations to the French Academy, then wrote to the eminent Dr. Galle, of the Berlin Observatory, asking him to direct his telescope to a certain point in the constellation Aquarius, where he would find a new and uncharted planet. Within less than a degree of the calculated place, Neptune was found!

PLUTO



Arrow points to Planet. Bright star below, Delta Gemini (Flagstaff Obs photo. Courtesy Evening Sky Map).

Ninth (first trans-Neptunian) planet of our Solar System.

Discovered March, 1930, at Lowell Obs., Flagstaff, Arizona, on photographic plates of regions calculated by the late Percival Lowell as the possible location of this and perhaps other more distant members of the Sun's family.

Distance from Sun, nearly 40 ast. units, or approximately three billion, seven hundred million miles.

Mag., 14—barely visible with ten-inch telescope.

Plutonian year, two and one-half centuries. Moves only three apparent Moon-breadths in a year.

Mass, probably approximating that of Mars.

Orbit, more elliptical than any other major planet, inclined 17° to the plane of the ecliptic, all others lying within 7°. Center of orbit, just outside that of Saturn; hence, apparently, at perihelion, Pluto's orbit lies slightly within that of Neptune.

Probable surface temperature, Absolute Zero (—273 Cent.)

Mass, about three-quarters Earth's.

Color, yellow, resembling inner planets. (Uranus and Neptune are blueish).

Albedo, about two-fifths that of the Moon, resembling somewhat the Moon's darker areas.

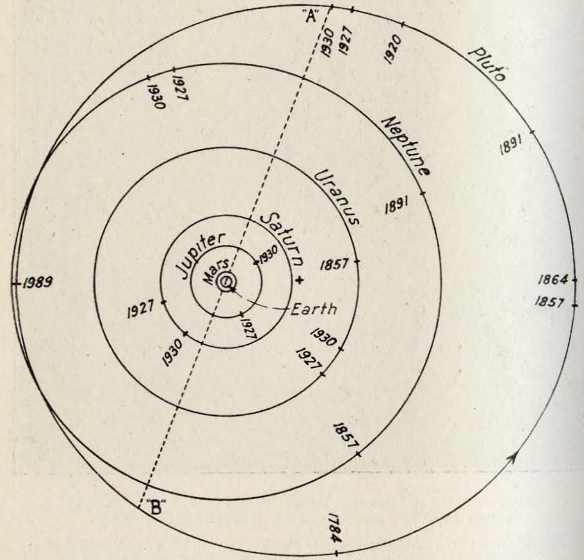


Illustration adapted from a diagram prepared by Mr. F. L. Whipple, showing the orbits of the planets Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto. The innermost circle depicts the orbit of the Earth, 1 "astronomical unit," or 93,000,000 miles in radius. The planets all revolve around the Sun from west to east—that is, in a counter-clockwise direction. To make the representation of Pluto's orbit more realistic, the plane in which it is drawn should be rotated from left to right about the dotted line AB, through an angle of 17 degrees to the plane of the printed page. 2The orbits of all the other planets shown, lie nearly in a common plane, represented by that of the paper. The positions of the planets on various dates from 1784 to 1989 are marked. The center of Pluto's orbit is indicated by a cross, lying just to the right of the circle representing the orbit of Saturn, which is 9.5 "astronomical units" in radius.

A. S. of P

COMETS AND METEORS

Comet-Sweeping is a branch of practical astronomy that has occupied the attention of some of the ablest observers; and many, like Messier himself, beginning as humble comet-hunters, have developed into professionals whose work has displayed skill and patience amounting to genius. Many great names are among those who have served cometary apprenticeship, and there are corporate societies whose members make a specialty of adding to our treasury of comet-lore. These gigantic and vagrom objects, so terrifying to behold, yet many of whose actual contents you could gather up in a pint-cup, generally belong to one of the planetary "families" of comets, Jupiter's mostly, since he has dragged the greater number of them out of space-deeps and sent them bowling periodically about the Sun, though all the planets have from two to thirty captures to their credit. The return of these comets is predicted with fair accuracy, usually picked up by the great telescopes and announced in the astronomical periodicals (and also the general press), long before the observer with modest equipment could hope to glimpse them. But as the comet approaches, by setting the instrument in the proper position, and by a careful sidewise and slow upward movement across the field a few degrees in extent (using a low-power ocular), the approaching visitant may be glimpsed, and its onward march toward perihelion calculated and watched night by night until lost in the sun's obliterating blaze. After its half turn around the Sun (having possibly lost a portion of its element, or at least suffered a change in form, if not utterly torn to shreds by its violent proximity), the comet may be picked up again and watched on its swift passing into spacial infinitudes till it becomes the merest dot of vanishing light. If a small cloud of vapor passed before a star, it would dim or even blot out its light entirely; but through the whole length of a comet, nucleus to tail-tip, a star may be seen with undiminished brightness as through a mere aurora, showing that a comet's most solid content must be in the form of dust of inconceivable fineness, with hydrogen and carbon, and a trace of other elements, in a high state of incandescence. Nevertheless they are very beautiful and interesting celestial phenomena; and whenever one is announced within the range of the observer's glass, it is worth all time and patience required to locate it and watch its progress through the constellations.

Meteor-hunting is another department of the science which has been found so appealing to the sense of the miraculous and beautiful that societies have been formed for the exchange of visual data and of prints of these elusive visitants, for of course photography now plays an important role in stalking meteors. The photographic instruments employed are usually small cameras with wide-angled lenses, shielded by dew-caps, fixed on the sky in the approximate locations of the radiant—the point of radiation named after the constellation in which the shower is predicted. Thus the Leonids emanate from the constellation Leo, about the middle of November; the Lyrids from Lyra, in April; the Aquariids, in May; and the Orionids, in October. Sometimes the patient watcher will be rewarded with one or two bright streaks across his photographic plate; sometimes for hours there will be none. Still again the plate will be slashed with lines of various degrees of sharpness and directional variation; and it is the work of the observer to record as nearly as possible the altitude of the visitor, its line of progress among the stars, and seconds of time of flight. These records are often of great value. As Denning says, "Only those who have occupied themselves considerably in this work can realize the attractiveness of meteor observation. Others who are fresh to the study and lacking experience can hardly appreciate the pleasure which the habitual observer feels in its pursuit."

Meteor swarms, being the remains of disintegrated comets, preserve their original orbits around the Sun, the Earth cutting throuhg them at the orbital intersections. Here is a fine field for the visual or photographic investigator; and for full instructions in the work, maps and blanks, interested observers are advised to address The American Meteor Society, C. P. Olivier, Pres., Flower Obs., Univ. of Penna., Upper Darby, Pa.

TABLE OF DATES OF METEOR SHOWERS, (Denning).

Quadrantids	Jan. 3	230°+52°	Slow, long paths
Lyrids	April 21	270°+33°	Swift, streaks.
η Aquarids	May 2-6	338°— 2°	Swift, very long.
Draconids	June 28	228°+54°	Very slow, short.
Aquarids	Jul. 28-30	339°—12°	Slow, long paths.
αCapric'nids	July 25	303°—10°	Slow, bright, long.
Perseids	Aug. 11	45°+57°	Swift, streaks.
Orionids	Oct. 19	92°+15°	Ditto
Leonids	Nov. 14	151°+23°	Very swift, streaks.
Andr'medids	Nov. 17	25°+44°	Slow, short, train.
Geminids	Dec. 11	110°+33°	Short, swift, white.

The rocky material of meteorites is mixed with metalic iron, pure or in compounds, a small per cent almost pure iron mixed with nickle. Thirty of the known elements have been found in meteorites, but none new to science. The very perfect crystalization, as well as their fractures and re-cementations, says Dr. Moulton, indicate that these fragments came from masses of world-like dimensions. If they were ejected from the Sun, or from volcanoes on Earth or Moon, they would cool quickly and be glassy instead of crystalline. Chamberlain suggests that they may be fragments of planets of a pre-solar system period; but at any rate they are proven to be of extra-terrestrial origin.

If the earth-structure was built up of large and small accretions of meteoric matter through countless ages, as the planetesmal hypothesis assumes, it may be said that the process is still going on, for upwards of twenty million foreign bodies collide with our planet daily. If these aggregations were massed, they would break through the barrier of atmosphere and bring a frequent toll of destruction; but being scattered, under a speed of perhaps forty miles per second, friction in Earth's atmosphere turns the greater portion of them to vapor and ashes, though the evidence of some of truly mountainous size (notably in Arizona and Siberia), as well as others weighing a few pounds or many tons, convinces us that the skiey bombardment still goes on, and Earth is slowly growing larger thereby. Only a beneficent atmosphere saves us from many a tragedy.

"Handling a meteorite, we can be sure that it is something akin to the material the nucleus of a comet is built up of, if not actually a piece of a disintegrated comet."—*Bobrovnikoff*.

PART II.

INSTRUMENT BUILDING

THE REFLECTOR — THE REFRACTOR MOUNTINGS — OCULARS — PRISMS SPECTROSCOPES — ASTRO-PHOTOGRAPHY — THE SUN DIAL DRIVING CLOCKS — THE OBSERVATORY, ET CETERA

"Of all tools the observatory is the most sublime."—*Emerson*.

"Without the telescope, astronomy could have advanced but little beyond the pre-Galilean epoch. Science, like civilization itself, is a matter of tools."—Curtis.

"The pupil of the human eye is about one-fifth of an inch in diameter. It brings to a focus on the retina only so many rays of light as fall within such an area. If it were an inch in diameter and could bring to a focus all the rays entering it, our vision would be twenty-five times as strong. If six inches, we could see an object nine hundred times as faint as those visible with the unaided eye. We cannot regulate the pupils of our eyes at will, but we can build an artificial pupil that serves the same purpose,—namely, the telescope."—Showalter.

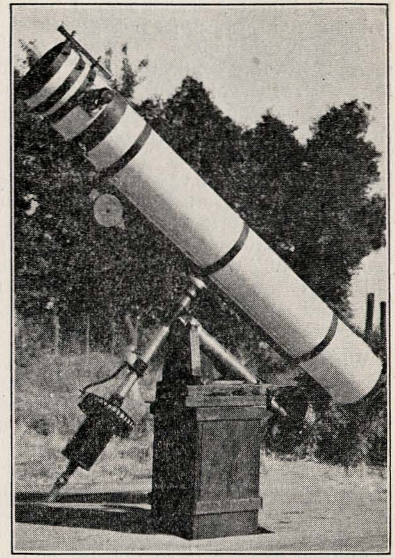
"The character of the true philosopher is to hope all things not unreasonable. He who has seen obscurities which appeared impenetrable in mathematical and physical science dispelled, and the most barren and unpromising fields of inquiry converted as if by inspiration into rich and inexhaustible springs of knowledge and power will surely be the last to yield to any dispiriting prospects of either the present or the future destinies of mankind. On the other hand, the boundless views of intellectual and moral relations which open to him on every hand in the course of these pursuits, the knowledge of the trivial place he occupies in the scale of creation and the sense continually pressed upon him of his own weakness and incapacity to suspend or even modify the slightest movement of the vast machinery he sees in action around him, must effectually convince him that humility of pretension, no less than confidence of hope, is what best becomes his character."—Sir John Herschel.

OURS is the golden age of self-help—the lone-hand era. We enjoy most that which gives us a chance to play our part—if not a first violin, at least the humble "traps;" and the best game is the one in which we are both observer and participant. Every hour beholds its own miracle of unheralded genius in unexpected places. A new discovery in science falls to the honor of an unfamiliar name; a great book bursts the barriers of a remote wilderness; a new record is established by a hitherto unknown contestant; and gold medals of honor cross the seas to discoverers of novae or comets who never saw the inside of a great observatory. Truly, in these times, perhaps even more than in ages remote, "the race is not to the swift, nor favor to men of skill; but time and chance happeneth to them all."

That which affords the keenest thrill as well as the most lasting advantange is the product of one's own ingenious handicraft—the expression of one's own constructive individuality. A purchased instrument inspires at best a subjective interest; but one's own finished product is an objective experience which gives a deeper insight into values and relations than is otherwise possible. Let him buy then who has neither time nor skill, patience nor assiduity to achieve this personal triumph; but his knowledge and enthusiasm—without which nothing worth while was ever mastered—will never match his whose labor of love is both a problem and a pastime; whose workshop is his classroom and his playground. Not that the great masters will be equalled or rivalled (though miracles still abound); but at least the earnest worker may achieve an instrument that will be as open windows into new realms boundless as beautiful, and one of which the giants of Copernican and Galilean days might well have been proud.

THE REFLECTOR

IT is fortunate, in a way, that a reflecting telescope is cheaper from the standpoint of initial outlay, as well easier to construct, than a refractor. But while the point of economy is well taken, let there be no illusions concerning the production of a good glass—the only kind that will requite your labor and insure permanent satisfaction. Any one can produce a mirror; but the accomplishment of a speculum of fine figure and perfect definition is nothing short of a personal triumph.



TEN-INCH HOME-BUILT REFLECTOR.
Focal length, 90 in. Tube, 11″ galvanized iron irrigation pipe. Axes, 1½″ machine-threaded pipe. Four ball-bearings from discarded motor-cars. Circles on 8″x2″ weighted pulley-wheels. Base, sunken box filled with stone and concrete. Ocular, Huyghenian, 1½″ e. f., in rack-and-pinion cell. Definition brilliant. Total cost of materials, $26.80.

As Byron said of Italian—"the most beautiful and easiest of languages to learn, the most difficult to master." Be not satisfied, therefore, with half measures, short cuts and partial success. Nothing but your best will bring the reward that your labors entitle you to—riches beyond price.

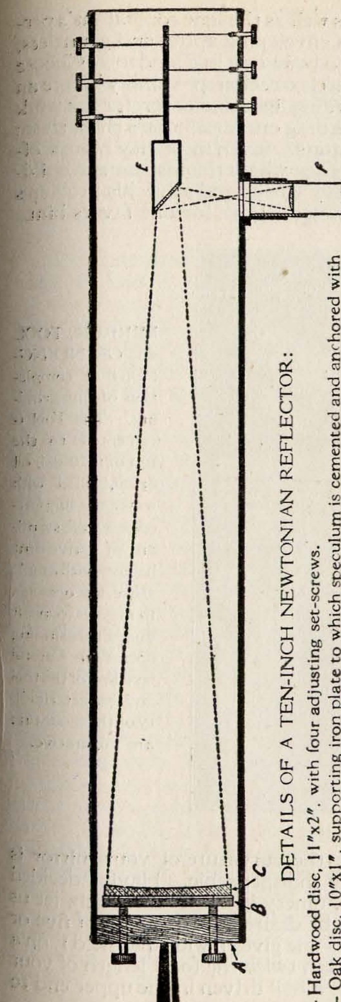
Unless handicapped by difficulties in securing good glass or a suitable mounting for the larger sizes, anything smaller than an eight-inch speculum is rarely advisable, and a ten-inch is better still. Beyond that size difficulties increase in a ratio that discourages even the trained professional at times; but a six-inch glass requires almost as much time and labor as a larger mirror which gives far greater satisfaction from the standpoint of light-gathering power, a ten-inch giving not twice but four times the observing value of a five-inch glass. The ideal combination, it would seem, is a ten-inch reflector and a four-inch refractor auxiliary, both of the observer's own construction.

Another preliminary recommendation concerns the attack on the mounting problems simultaneously with the work on the speculum. This may seem a little premature; but the reason is the very human one that as the mirror approaches completion, though other tests are important, nothing gives quite the thrill of satisfaction as when one slips the unsilvered speculum into the tube and gives it a real "try out" with a low-power ocular on the moon. Besides this, the leisurely construction of the mounting will be found a grateful change from the rather monotonous labor over the grinding-post.

With the relative merits of reflectors and refractors and the laws which govern their optical principles, as well as the variations of the Newtonian type of reflector—Cassegrainian, Gregorian, Herschelian, etc.,—we need not deal with here, but concern ourselves only with the practical construction of the simple Newtonian. This form was devised by Sir Isaac Newton, about 1668, the first model built by his own hand, and of less than two-inch aperture, being still preserved.

Having decided upon the size of your instrument, the first step is the procuring of your speculum-blank and the glass "tool" of the same diameter but relatively thinner. (See Appendix: Where to Buy) As only the surface reflection is required, and no rays pass through the glass as in the case of a lens, glass of optical fineness is not necessary, though it should be of high-grade commercial plate, free from cracks and surface flaws, perfectly circular, ground at the edges and as thick a disc as possible for your particular requirements—at least an inch for every six of aperture. Thus a 1¾-inch disc will suffice for a ten-inch speculum, but nothing lighter is recommended.

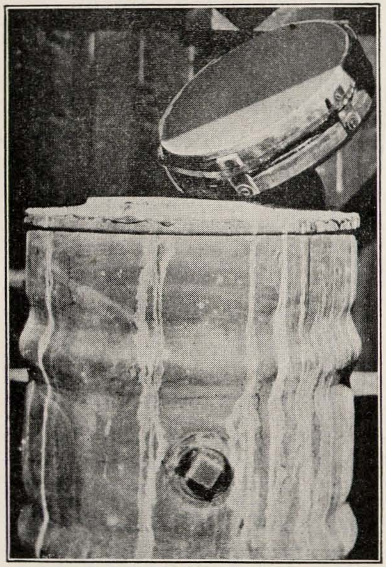
As you value peace in the family, do not attempt speculum-grinding in your well groomed apartments; for, with the drippings of carborundum and emery and the penetrative pervasion of red oxide, the immediate region of the con-



DETAILS OF A TEN-INCH NEWTONIAN REFLECTOR:

A—Hardwood disc, 11"x2", with four adjusting set-screws.
B—Oak disc, 10"x1", supporting iron plate to which speculum is cemented and anchored with side-clamps.
C—Concave speculum, 10"x2", parabolized and silvered on face.
E—Silvered diagonal (oval plate-glass flat), affixed to block cut to 45°, from which extends an iron bar passing thru a tube, itself supported by six adjustable steel wires thru barrel, with thumb-screws for accurate centering. A right-angled prism is often employed in place of a flat.
F—Ocular in rack-and-pinion cell, centered on silvered flat or prism.
Telescope tube made of galvanized iron pipe, 11"x90", seamed inside, including revolving sleeve holding ocular system, not shown in diagram, but seen in photographic reproduction and fully explained in text.

quest of idea over form, as well as the lone combatant's personal presence, for all his enveloping apron and gauntlets, will resemble the close of a busy day in Flanders. Choose rather a shed, outhouse, attic or cellar, preferably before an open window or door affording light and cheer, for the work grows tedious as the hours drag on, for all one's enthusiasm and delight in visible progress. Even most city homes offer at least one solitary refuge where the instrument builder may hold forth in grimy glory, and solve his problems without criticism or hindrance. If so, fortune favors him.



MIRROR, TOOL and GRINDING-POST at completion of fine-grinding. The Tool is cemented to the top of a 20-gal. oil drum, filled with water and supported on a solid standard of convenient height, with ample space for optician to move around it during the grinding operation. Careful levelling of the tool and perfect rigidity of the mounting are imperative.

A template for testing the curvature of your mirror is easily made, and is quite indispensable. Having decided on a ten-inch speculum of ninety inches focal length, let us say (a deeper curve may be desired, a ratio, say, of five or six-to-one, though nine-to-one gives a wide, flat field), on a bare floor lay down a batten twice the focal length of your mirror: i, e., 180 in. from a nail driven in the upper end to

serve as a fulcrum, to another sharp nail, or awl, driven thru the lower end of the battan to serve as a scriber. Underneath this scriber tack a flat sheet of zinc, carefully marking thereon the line of curvature, cutting it out with tinner's shears and filing true. As your mirror-grinding proceeds, by standing this gauge across its center, your progress may be noted; and when you have reached the point where the template fits the concavity of the mirror, rough-grinding may cease, and fine-grinding and polishing proceed.

Another method of determining your progress is by covering the face of your mirror with tepid water and projecting the image of the sun upon a wall or sheet of white paper at the exact focal distance. As grinding proceeds the image will be seen to grow smaller and smaller until at last it becomes a burning bright disc about the size of a quarter-dollar, at which point the optician proceeds to polish and parabolize.

In the matter of abrasives, corborundum will usually be found best for rough grinding, emery for the fine. Both come in various degrees of fineness, from Grade 40 to 300 and even finer, for the corborundum, and Grades M301 to M303½ for the Wellsworth emery which is standard for excellence. Two hours' grinding with each of four or five grades of corborundum, mixed to a thin paste with distilled water, ought to bring the mirror to proper curvature --- perhaps in even less time than that --- using just enough abrasive to cover the disc scantily, and working from tweny minutes to a half-hour at each session --- rarely more. At each change of grade be sure to sponge off every trace of the preceding grade, both on mirror, tool, and everywhere about the grinding-post, shaking out apron and gauntlets, for a single rougher grain may drive you back to a previous grade of grinding, quite discouraging but easily avoided.

Most novices complain that while they find bringing the mirror to acceptable curve, with a fine velvety texture of surface, is comparatively easy, the polishing process is slow and laborious beyond all reason. This should not be; and the reason usually is because fine-grinding is not carried far enough. The finest grades of Wellsworth emery ought to produce a surface that makes polishing easy and sure. This emery is used by leading lens-workers, washed free of grit and foreign particles, and not used in suspension unless the worker so desires, in which case a quantity is placed in a clean glass jar half filled with distilled water, well shaken and allowed to settle a half-hour, only the water with the minutest particles thus in suspension being used. This affords so fine a surface that lens-makers often bring the glass to a brilliant polish with only broadcloth and rouge.

It is curious to note how quickly the ingenious workman will acquire his own individual way of doing things, once he has mastered first principles and got possession of the main idea. It is due partly perhaps to man's natural rebellion against set rules, but still more to the urge of feeling his way along and working out his salvation on his own lines. In the matter of grinding and polishing, for instance, he may be advised to use three half-diameter circular strokes to the right to one three-quarter stroke straight across, twirling the mirror slightly by the handle between strokes, meanwhile moving leftward step by step around the post, making the complete circuit every twenty or thirty strokes, no two strokes over exactly the same area. While this procedure is in a general way trustworthy, the operator is sure to adopt variations of his own as conditions arise—which is one of the fascinations of glass-working in that it affords such latitude for original methods. Grubb, who produced many wonderful mirrors and lenses in his day, affirmed that each attack on a blank of glass was a new problem and a distinct adventure.

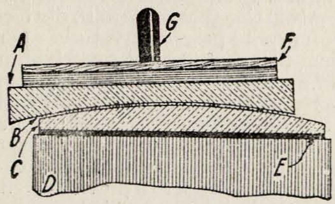


DIAGRAM OF GRINDING POST.
A – The glass speculum. (Curve greatly exaggerated to show effect of abrasion).
B – Abrasive.
C – The glass "tool".
D – Grinding post.
E – Cement. **F** – Wooden disc. **G** Handle.

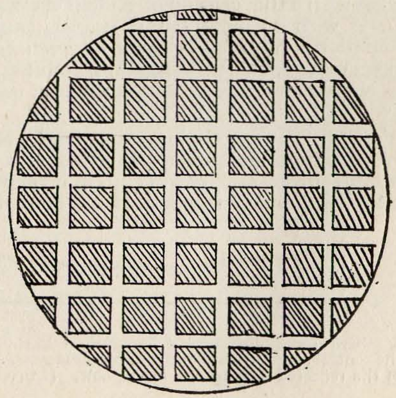
The puzzling phenomenon of increased concavity as the two flat glass surfaces are abraded is explained when it is observed that while with each circular stroke some part of the speculum is off the rim of the tool, the grinding of the central areas "goes on forever." This is illustrated in the above cross-section, though the degree of curvature as illustrated represents an impracticably short focus. The depth of curvature of a normal ten-inch speculum is only about two millimeters—an amount so small as to be easily overdone without repeated tests with the template.

Having achieved as good a surface as care and patience

in the fine-grinding should reward you, the polishing process is next in order; and therein you have the experience of many notable instrument-builders to profit by, so that mastery of this interesting branch of the art is only a question of following rules. Various polishers have been tried—paper, tin and lead foil, cloth of all grades and textures, silk, graphite, starch, resin, shellac and paraffin—and whereas some of these are recommended in special cases for lenses, flats or prisms, the good old standby, Archangel, Wilmington, or any other good grade of commercial p i t c h, fulfills the most exacting requirements, whatever shorter-cut expedients may be recommended. Snow's grafting-wax, a California product, which has much the same base, while no faster than pitch, is highly refined, of even texture and the right consistency without tempering, holding up well at the tool-edge. I have used and recommended it with confidence for years.

Whatever medium is used, it should be melted and twice strained through cheesecloth as a safeguard; and, if necessary, tempered with turpentine so that when cold it can be easily dented with the thumbnail. While warm enough to flow, but not too hot, the pitch may be poured evenly over the tool to the depth of a quarter-inch, and the mirror, well wet with soapy distilled water, pressed firmly down upon it and moved around to afford a perfect union. Before the pitch is quite cold, lay a straight-edge across the tool, and with a knife dipped in soapy water, cut V-shaped

THE NORMAL POLISHING TOOL.
This is the regular Grinding Tool covered with a quarter-inch layer of pitch cut into squares and overlaid with rouge to impart a brilliant polish to the speculum, preparatory to parabolizing and silvering.



grooves clean across the face of the tool about an inch apart, then another series crosswise, making a series of squares the middle one of which falls a little off the true center. Brush clean and cover with soapy water, replacing mirror under moderate weight till pitch hardens. You are now ready for the polishing process which should be done as far removed from the region of the grinding-post as possible—even another room or a draftless basement; for one grain of emery or corborundum dust on your pitch tool will mar if not ruin your speculum, and drive you back to fine-grinding again.

Even the best of rouge [chem,, iron sesquioxide], needs "washing" so that only the finest of the fine particles touch the glass. Place a half-pound of the "red oxide" in a clean glass jar, fill with distilled water, shake well and let stand over night. Pour off water, leaving about an inch to cover. Spoon out the top portion, spreading it evenly and thinly over the pitch squares. Place speculum on the rouged tool and proceed to polish with a straight stroke, varying it occasionally with the circular, twirling the handle between strokes, meanwhile moving about the post as in the grinding process. Within a very few minutes a change will be seen, the central areas will brighten, and little by little, depending on how far the previous fine-grinding was carried, the entire disc will take on a brilliant polish. If the operator experiences any difficulty in attaining his ideal of a perfect reflective surface, he might finish polishing and parabolizing with a thin coating of melted beeswax laid over the squares with a camel's hair or surgical gauze brush. The foundation-comb used by apiarists is refined and free from foreign matter, but straining through muslin while very hot is a simple and wise precaution before using any kind of wax.

You have now a speculum ground and polished to perfect spherical curvature, perhaps, but this is far from producing a perfect image, as Newton and his contemporary mirror-makers saw and demonstrated mathematically. All the

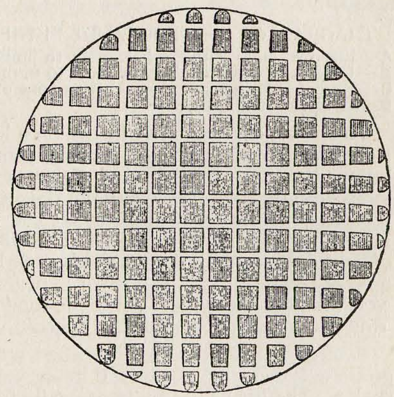
A spherical speculum with dotted line indicating a deepening of the central areas in the form of a parabola in order to bring all of the reflected rays to one focal point. (Curves exaggerated).

rays which strike a spherical mirror in straight lines are reflected back, distributing themselves along the focal plane. These rays must all be brought to a single point, as near as possible, at the eyepiece; hence the parabola which approximates this desideratum.

In order to accomplish this it is only necessary to alter the pitch-pad on the tool by paring down the outer squares and leaving the central areas intact; which, on resuming the polishing function once more, will naturally wear down the central regions of the speculum, altering it from the spherical to the parabolic form. When you realize that the difference between the curves is computed in hundred-thousandths of an inch—an amount so minute that no micrometer can register it, and only repeated laboratory tests on an artificial star can prove it—the danger of over-parabolizing becomes apparent, Usually twelve to fifteen minutes' parabolizing will bring the mirror to a point of readiness for a first test, if not to complete parabolic curvature. It is much easier and safer to approach this condition slowly than to over-parabolize and be compelled to alter the pitch-pad in a reverse form to bring the mirror back to normal curve again.

PARABOLIZING TOOL.

Being the normal Polishing Tool cut down at the periphery to alter the form of the mirror from the spherical to the parabolic, bringing all the rays to one focal point.



There have been innumerable lens and mirror tests, with now and then an original one—or at least a modification of one long tried and found reasonably true in all the optical laboratories of the world since the time of its inventor, Leon Foucault, about the middle of the last century. Tho it calls for no elaborate or expensive apparatus, the Foucault "knife-edge" test will be found as much a test of patience and skill as of the product of your handicraft; but let not that discourage you, for it is above all a very beautiful experiment.

In a curtained but not too dark a chamber set up your mirror vertically on a standard or low shelf against a wall, anchoring it there securely. Directly opposite, at the center of curvature, as when scribing the template, place a small table upon which stands a small tin coffee-can with an inch-hole in the side toward the mirror. Over this hole glue a piece of black darkroom paper in whose center you have thrust a cambric needle, making a clean round hole. Directly behind it in the can suspend a frosted electric globe, or place a small oil-lamp, which thus makes of the pin-hole your artificial "test star."

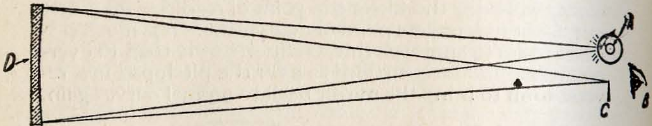


DIAGRAM OF THE FOUCAULT "KNIFE-EDGE" TEST.
A—Enclosed lamp with pin-hole sight to imitate a star.
B—Observer's eye brought very close to upright knife-edge.
C—Razor-blade in focal plane, cutting cone of rays from mirror.
D—Speculum under test.

To the left of this point of light, on a level with it, set upright on a moveable standard a safety-razor blade, or other knife-edge. Bend close and bring your eye to the left of the lamp, and by cautiously moving the latter, you will find a position in the focal plane where the light of the artificial star will illumine the entire mirror with a brilliant sheen of light. Now, with due care move the knife-edge along to a point where it cuts the cone of light from the mirror, and you will note the typical parabolic shadow—a faint smoke-ring effect: one proof of a good speculum. See Appendix, p 291.

If, now, in place of the knife-edge we substitute a low-power eyepiece, likewise placed in the exact focal plane, we shall see the image of the "star" reflected back as a small burning bright disc; and wherever carried across the field of the speculum, remains the same—clean and sharp of contour, like a bright new dime—clear to the mirror's edge.

But this is an ideal condition; and ten chances to one, considerable labor still will be exacted of the operator before

such perfection is reached. There may be certain zones where faintly darkening shadows show slight elevations, or others that denote slight depressions; or still again, inequalities near the periphery—all of which must be noted and the mirror returned to the polishing-tool, slightly altered to meet the requirements, for correction. While this may appear to be difficult, it is surprising how soon the remedy for these faults will suggest themselves, and how amazingly the glass responds to the lightest chastening, even with rouged ball of the thumb or finger-tips. Figuring a mirror to perfect paraboloid form is a very delicate if fascinating art; and its chief feature is that it is so easily overdone. Volumes have been written on this intricate subject; but the ablest mentor of all is patient persistence in the test-room.

As you will doubtless avail yourself of the first opportunity to test the merits of your optical handiwork on the stars, you will be grateful for the suggestion that you provide in advance a mounting, however simple, for your precious mirror, much as a proud mother has the cradle in waiting for the new-born child. Any loose makeshifts may lead to disappointment and the illusion that you have not succeeded so well in your undertaking at all, when in reality the imperfect performance of your mirror is wholly due to faulty alignment of the optical train, improper focussing or ocular of too high power. But well mounted, you will be surprised at its unsilvered light-gathering power on some object like the moon, though it is only the silvered and polished surface, giving eighty to ninety per cent reflection, that brings out the stars in their true beauty and majesty. This silvering process—all honor to Baron Leibig!—is not difficult; and is one of the prettiest experiments in applied chemistry.

Anyone who has had even slight experience in darkroom work—and who among this generation of experimenters has not?—will welcome this silvering episode as something after his own heart, being somewhat in the nature of developing a rare negative or print, save that in case of failure to attain the highest results in the case of a silvered surface, he can sponge off with nitric acid, wash well and begin again—and doubtless often will. But while no darkroom is necessary, the same rules with regard to exact measurements, chemically pure ingredients, regulations of temperature and above all cleanliness, obtain; and there should be neither haste nor guesswork. The formulae are standard; and as given here and in the Appendix, offer quite a field for experimentation with view to attaining the best results.

TEN-INCH SPECULUM

Banded with a wide strip of paraffined paper to hold the silver nitrate solution during the silvering process — one of the most interesting experiments in the art of Reflecting Telescope building.

(Other Silvering Formulae are given in the Appendix).

Clean four quart-bottles thoroughly, and label: A, B, C, and D, as seen in the above cut.

Solution A — Nitrate of Silver, 175 gr. Distilled water, 10 oz.

Solution B — Ammonium Nitrate, 262 gr. Distilled water, 10 oz.

Solution C — Granulated sugar, ½ oz., distilled water, 5 oz. Dissolve and add Tartaric Acid, 50 gr. Boil in glazed dish ten minutes. Add pure grain Alcohol, 1 oz., and water to make 10 oz.

Solution D — Caustic Potash, purified by alcohol, 1 oz. Distilled water, 10 oz.

Lay speculum in large graniteware dish, face up. Cut a three-foot strip of stout paper, about three inches wide, and run it thru a shallow pan of melted paraffin, coating it well on both sides. Wrap this strip tightly around the rim of the speculum, securing it with several turns of strong cord. This will serve as a container for the solution during the silvering process.

With rubber gloves to protect the hands as well as the mirror, with a wad of surgical gause dipped in pure nitric acid, go over every square inch of the glass surface several times with thoroughness and considerable pressure to insure absolute cleanliness, rinsing with distilled water between scrubbings. A saturated solution of stannous chloride, diluted one-half with distilled water, as a finishing cleanser, is advised; but all traces of this scouring agent must also be eliminated. The insistence upon a perfectly receptive surface to the silvering agent cannot be too strongly emphasized. After the final rinsing, cover the glass with distilled water and let stand in the same temperature as the chemicals for several hours. At a temperature of 60° to 70° F., the silver deposits best. If warmer, the action is too rapid and the metal deposit too soft to stand the polishing process afterward. If too cold, the mirror coats slowly.

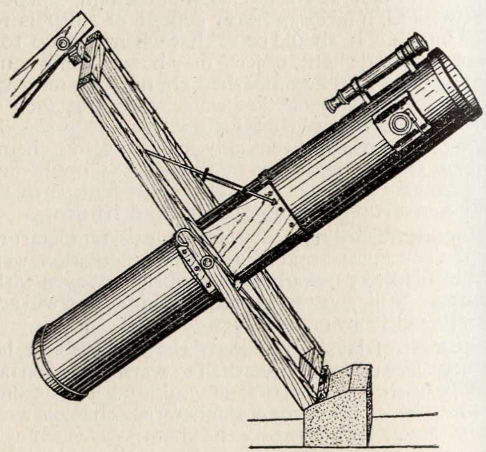
Place two measuring glasses side by side, Into one of them pour an ounce of Solution A, adding an ounce of Solution B. In the other glass mix likewise one ounce of Solution C, and one of Solution D. You are now ready to silver.

Pour off the water covering the face of the speculum, replacing the latter in the graniteware dish. Pour contents of one measuring glass into the other. The mixture will instantly turn straw-color, soon deepening to inky blackness. At this instant flow the solution over the speculum, rocking the dish vigorously. Soon the metallic deposit will be seen to film over the entire disc, while muddy granules will form thru the solution. Before these floating particles settle too thickly over the silver film, pour off the solution and dash over the mirror enough distilled water to cover, Mix Solutions A, B, C, and D, exactly as before, pour water from the speculum and flow over with the silvering mixture a second time. This doubles the thickness of the film, Repeat a third time; and, if an extra heavy deposit of silver is required, a fourth. It should be so that when held up to a window or an electric light, objects may be seen dimly outlined through it. This accomplished, the mirror is returned to the dish, flowed with distilled water, and every inch of the surface gone over very cautiously with a tuft of absorbent cotton to clear away the muddy settlings of the chemical. Repeat two or three times till the silver is bright and clean, taking care not to damage the tender film; then set up on edge in a sunny window to dry and harden.

If instructions regarding purity of chemicals, temperature, and above all cleanliness and caution in manipulation, were observed, your mirror is doubtless very brilliant, even without polishing. Still, this process is quite simple and will add greatly to its efficiency on the stars.

After a couple of days' hardening of the silver deposit, lay the speculum face up on a stove-shelf to warm. Spoon out a little of the washed rouge on a saucer, allowing it to become bone-dry over heat. In a piece of soft new face-chamois wrap the lump of rouge, working into the chamois as much as it will take up, discarding the rest. Place the mirror before a window, wrap the rouged chamois around a wad of cotton and begin polishing at the center, lightly, with circular motion, slowly advancing toward the circumference. A full hour may be well spent in this occupation, for the results will fully justify the painstaking, and your speculum will resemble a polished block of finest ebony.

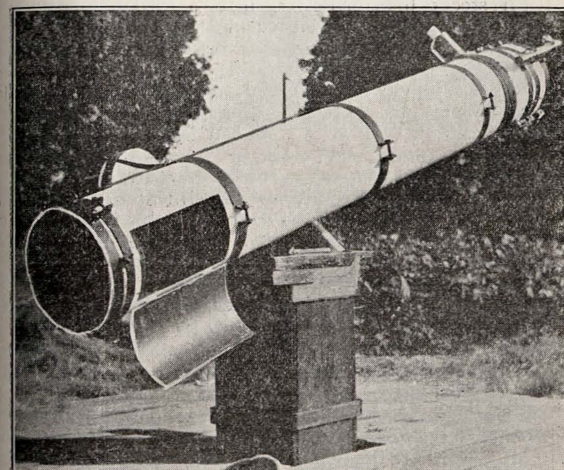
Doubtless by this time the ambitious optician will be so pleased with his handicraft and thrilled with the prospect of giving the results of so much labor a real try-out on the stars that he will be thankful he had the foresight to carry on the building of the mounting simultaneously with work on the speculum, and now has it in readiness for this interesting event. However, many affairs may have intervened to make this impossible, however desirable. In that case he is recommended to construct a temporary mounting, as designed after the English model by Prof. Fullan, which may be easily made, having all the merits of serviceability, rigidity and low cost. The lower bearing may be set in concrete, the wooden frame, properly oriented, in perfect balance, permitting a full sweep of the telescope in Right Ascension and Declination for all the visible heavens save, of course, the extreme circumpolar regions. But remember, some of the greatest reflectors suffer that handicap as well.



"English Equatorial" type of Reflector mounting.

The plain "parallactic ladder" form of mounting pictured on the preceding page may be elaborated into a more permanent device with ingenuity and a little more expense, as will recommend itself to the builder. But whether it be of this model or the equatorial form illustrated elsewhere in this chapter, four things are paramount: rigidity, perfect alignment, smooth working parts and balance.

The reflector may be set up in any open space which commands a wide view, particularly of the southern heavens. A domed or sliding-roof housing for a reflector is not imperative in our latitudes, though many have so provided, since by fitting a tight felt-lined cap over the mirror, (reached through a door at the lower end of the tube, as shown in the reproduc-



TUBE OF TELESCOPE, showing door for capping and uncapping the mirror, or for adjustments as occasion requires.

tion), and covering the optical end during inclement weather, the instrument will retain fair adjustment for years. As a further precaution against tarnishing, the speculum may be flowed over with lacquer diluted six to one with amyl acetate and dried an edge. It is so transparent as not to impair the reflective values of the mirror to any appreciable degree.

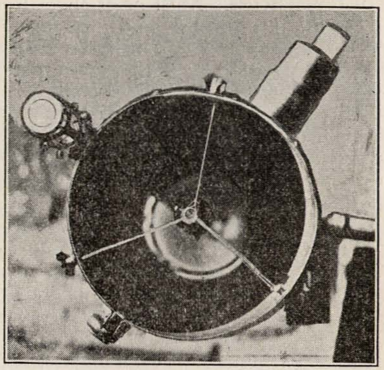
Having chosen a spot with at least a free north and south view of the heavens, set solidly in the ground an upright four by four post about two feet above an eight-foot square platform. Around this post set a box of twelve-by-one inch lumber, squared with the points of the compass, and filled in with crushed stone and concrete, topped with a heavy oak platform for the telescope mounting, oriented, levelled and made secure. A heavy hardwood wedge, sawed to an angle equal to the latitude of this observing station, supports the polar axis, which, on looking through it, should show Polaris in its exact fixed center.

Ordinary inch and one-half and two-inch galvanized iron piping, machine-threaded for accuracy, serves very acceptably for polar and declination axes, the bearings being tight-fitting steel collars, or better still, discarded motor-car ball-bearings which are inexpensive and afford ease and smoothness of motion. Right ascension and declination circles may be marked off accurately on the flat faces of eight-inch pulley wheels, previously painted dead black, the former with the Hrs, and Mins., I to XXIV, and the latter in Degs. and Mins., running both ways from 1° to 180°, the readings depending upon which side of the pier the telescope is swung. Old clock-hands clamped to the tubing will serve very well for indicators. In the matter of adjustment for observation, when the declination axis is horizontal, the right ascension circle should be set at 0, or XXIV hrs.; and the declination circle should read 0° 0′ when telescope points to a star on or near the celestial equator, -- δ Orionis, ζ Virginis, θ Aquilae, or α Aquarii, for instance, -- or 90° when fixed on the North Star.

The construction of the main tube will probably be delegated to the practical metal-worker, tho here again perhaps the valiant experimeter will decide to "go it alone." Galvanized iron irrigation pipe comes in various sizes, tho a neater job may be done by building it specially, seaming it inside. Its diameter should be at least an inch larger than that of the mirror, four or five inches longer than its focal length, a revolving sleeve carrying the optical parts, as seen in the illustrations. Reflectors up to six-inch aperture may revolve in their cradle supports, tube, mirror, optical parts and all; but for larger sizes a fixed tube with a revolving sleeve that carries diagonal mechanism, eyepiece mounting and finder, will be found a great convenience, making observational adjustments quick, smooth and easy. This sleeve should be large enough to support two quarter-inch iron rings on the inside which fit snugly against two

other rings affixed to the outside of the tube, the sleeve clamped firmly with bands and revolving true.

REVOLVING SLEEVE holding the diagonal flat, ocular-tube and finder for quick and easy adjustment on either side of pillar, showing steel wires which support tube containing a sliding bar to whose further end is affixed the diagonal flat.



The sleeve thus removable makes it easy to arrange all the details of the optical train: lengthening or shortening the tube so that the focal point falls within the ocular system after right-angled reflection from the diagonal. The centering and anchoring of the flat is also made easy, for no true image is possible without perfect alignment.

The diagonal may be cut out of a piece of good plate glass, elliptical in shape, large enough to receive the image at its proper station, and bevelled at both ends. It should be silvered as carefully and polished as brightly as the mirror itself, and offers a good subject for preliminary experimental work along these lines before attacking the major problem of the mirror. A perfect diagonal is an achievement in itself.

While the great reflectors employ the diagonal flat, smaller ones may use the right-angled prism with increased advantage, since a silvered flat gives from eighty to ninety per cent reflection while a prism gives practically one hundred, and moreover needs no after care save to keep clean. Still, prisms are rather expensive to buy, unless the worker decides to undertake grinding and polishing his own according to instructions given later on, in which effort he will find another opportunity to prove his skill in the instructive arts of glass working.

It is scarcely necessary to call attention to the fact that counterweighing of both polar and declination axes is essential to insure smooth movement on the bearings during observational hours. Most print-shops have "hell-boxes" for discarded type-metal, and a quantity of this may be had at a reasonable outlay, melted and moulded into discs that fit the iron piping of your axes, counterbalancing to a nicety, without appearing cumbersome.

Another detail concerns the blackening of the inside walls of the entire telescope tube to insure against cross-reflections. Vegetable black in lacquer thinned with wood alcohol will be found efficient and fairly permanent.

The important matter of eyepieces and their construction will be found elswehere, if the experimenter wishes to pursue an interesting byway in optics instead of purchasing the finished product from a dealer. Sooner or later he will probably take up this branch of the art anyway, and so have a full battery of oculars for the price of one or two of the professional kind.

A finder being merely a wide-angle field-lens with a positive Ramsden eyepiece with cross-hairs, the glass-worker may also undertake one of these, in the meantime contenting himself with an ordinary field-glass from which he has removed the erecting train. Even with a good finder, just plain sighting along the tube-length gives fair accuracy.

A convenient notebook at hand is recommended; for, whatever operations are repeated at a later date — and there are certain to be many — it is a source of satisfaction to be able to turn back to dates, hours given to each successive function, materials used, etc.; and particular data regarding every phase of the parabolizing, silvering and polishing processes. This information may save much time and avert many an error in subsequent operations.

As a passing admonition: do not suffer your passion for instrument-building — and I have known it to become a positive obsession in more than one instance — to blind you to the prime object in view: that of observing the heavens. It is well sometimes to try to improve upon yourself, but this commendable enterprise may be overdone. I have in mind several who started out with the genuine ambition to become astronomers who were so enamored of the fine-art of mirror and lens-making that they have done nothing else since; and the glories of the heavens are still a sealed oracle to them. Perhaps a perusal of Part I, of this book, will stir them to a realization of what they are missing by too much devotion to the grinding-tool, and profit accordingly.

Remember that the best traveller is not he who makes undue haste to reach his destination, but rather the one who derives the utmost pleasure and profit from each day's unhurried progress. In this work one may delve as deeply into mathematics, optics and chemistry as one may wish, for the field is vast and the rewards are great; but if each day's advance yields its own intellectual profit, ultimate triumph is assured, even to those unskilled in the higher sciences.

As to the respective merits of reflectors and refractors, it would seem that those who own them should be the most competent to judge; tho, as Pope said of our consciences and our watches, each is most inclined to "believe his own." Nevertheless, there are a few facts relative to each that are worth consideration by the prospective telescope-builder.

As to initial cost, the reflector has an immense advantage. A ten-inch speculum-blank and "tool" cost about eight dollars; the crown and flint optical discs of the same size for a refractor, upwards of two hundred. The mounting of the former may be a very inexpensive home-built affair, while that of a large refractor is intricate and costly.

A ten-inch mirror may be ground and figured in ten to fifteen hours; an achromatic lens of equal size would require months of most exacting labor to bring to equal perfection.

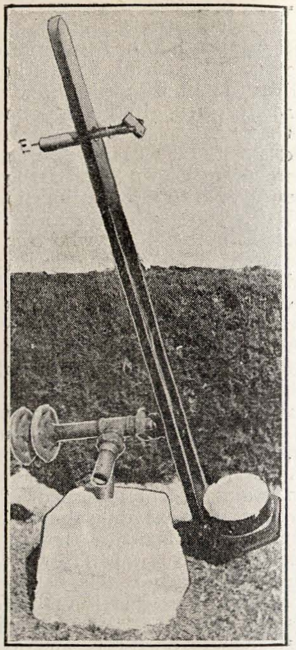
Aperture for aperture, the ratio of power is about eight and one-half to ten, in favor of the refractor. The latter is rarely truly achromatic, being more or less afflicted with color aberration, while the reflector gives clean, sharp images, tho liable to spherical distortion by reason of temperatural changes, open-tube air currents and flexture. A refractor's tube being closed avoids these very largely.

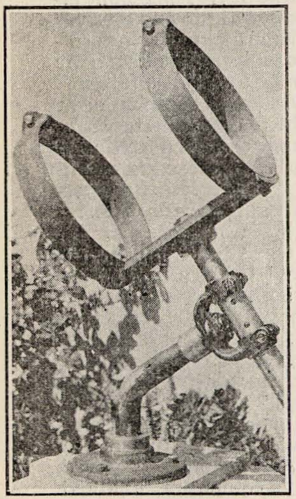
Observations with the reflector are easy, even of objects at high altitudes quite inconvenient to reach with a refractor and star-diagonal, especially tiring for long sessions.

In astrophotography, and in some phases of spectoscopic work, the reflector stands supreme; but in the field of visual observation the refractor has never been supplanted.

Refractors of small aperture are handiest for quick service and short sessions, portable, easily adjusted, never deteriating, and requiring no special care. Moreover, some epochal work has been achieved with such instruments in the hands of masters. Vide p. 95. As previously observed then, the most efficient star-layman's equipment, it would seem, is a ten-inch reflector with a refractor of small aperture as a most valuable adjunct, both the products of his own constructive genius.

While the methods employed in mirror-making do not admit of much latitude for such individual variations as may present themselves, with mountings the case is different. Here the ingenious craftsman may choose from various designs that which is best suited to his requirements, his skill with tools, his equipment, and more than all, perhaps, his purse. Even if he does elect to follow some particular design, the chances are that he will depart more or less from the original pattern



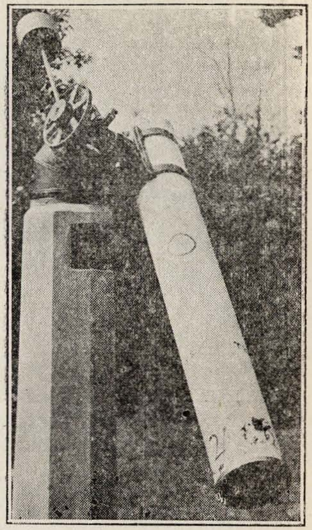


Gas-pipe mounting for 8½″ mirror. Coupling on oak shaft permits removal of optical parts. E: Eyepiece. (V. M. Massey, S. Pasadena, Calif.)

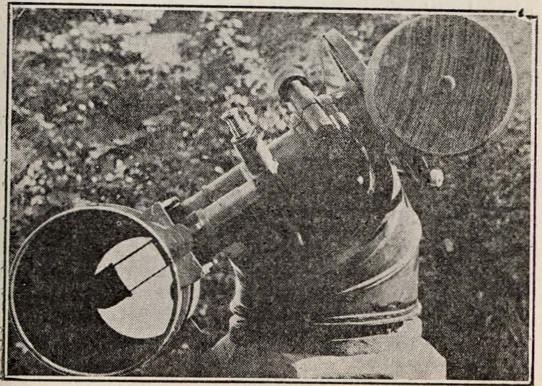
(Left) "Auto" mounting, using a discarded driving shaft. For mirrors up to 10″. (F. M. Hicks).

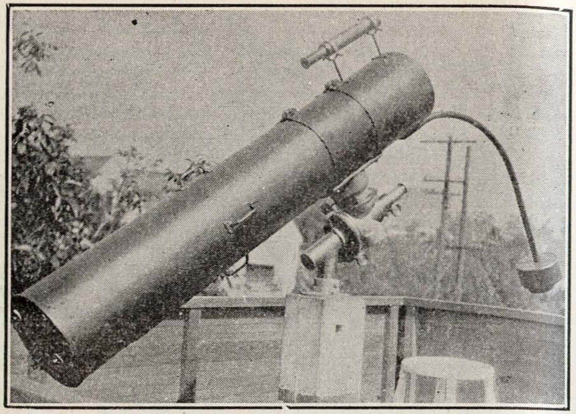
as work progresses, so many variations suggest themselves to the better solution of the mounting problem as he sees it. Few mountings work out as originally planned from the photos and specifications.

Next to optical perfection is facility and ease in observation. Any innovation that mitigates the fatigue of long sessions at the eyepiece makes for efficiency and pleasure in the work at hand. In a stationary ocular mounting, while involving two reflections of the image—one at the diagonal flat, the other at the encased prism in the polar axis—the incident loss of light is negligible, while the advantage of surveying the entire heavens from one position is obvious. This particular mounting demands some considerable skill on the part of the builder; but aided by the fine blueprints (which may be had at mere cost from the designers), the task should not be so very difficult.



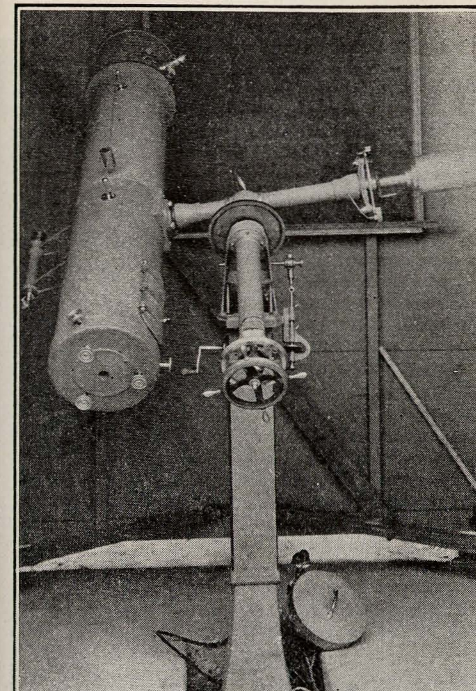
Fixed Eyepiece mounting, with double prism system. Built by O. S. Marshall, Springfield, Vt. (Below: close view).





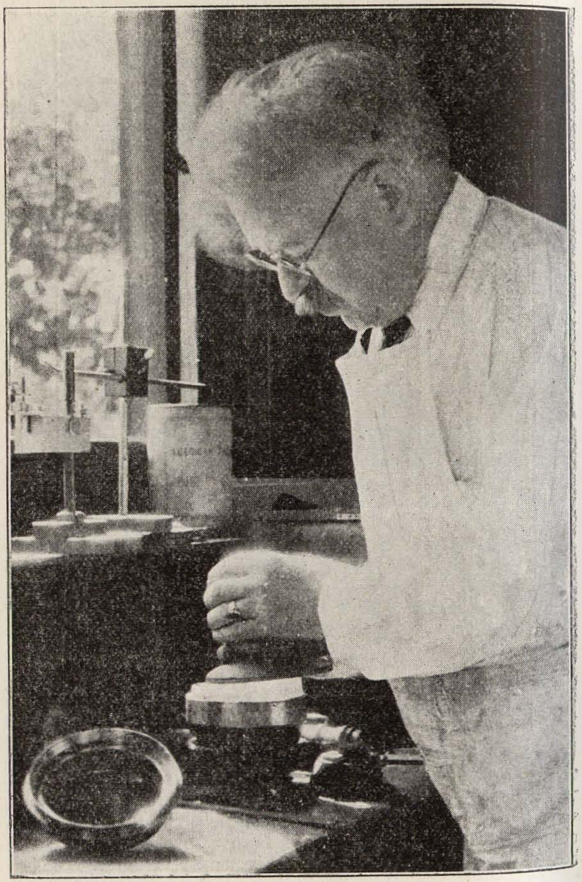
"Pasadena Mounting." stationary eyepiece, for mirrors up to 12". Designed by F. M. Hicks, Pasadena, Calif. (Blue prints at cost).

Aside from the physical comfort of remaining seated at the eyepiece during an entire observing session, there are other features of the fixed-eyepiece reflector that challenges the refractor for readiness and adaptability. While a finder has always been regarded as a prime necessity, whatever the type of instrument, it is probably less frequently employed with a mounting of this pattern, and some discard it altogether. Sighting along the tube with the aid of ring-sights affords fair approximation, when with a low-power ocular, giving a field of half a degree or more, the object sought may be quickly centered, and a higher power substituted, if desired. Again, graduated circles in right ascension and declination in the fixed-eyepiece form are easy to install, with the very distinct advantage of being always within instant range of vision, and you are spared the necessity of leaving your post to go gunning in the dark with a flashlamp to secure your bearings—always a loss of valuable time and sometimes dampening to enthusiasm. In the case of variable star work, when it is desirable to make as many magnitude estimates at a single session as possible, often in widely separated celestial areas, the practical value of circles right under your ocular, as it were, is obvious.

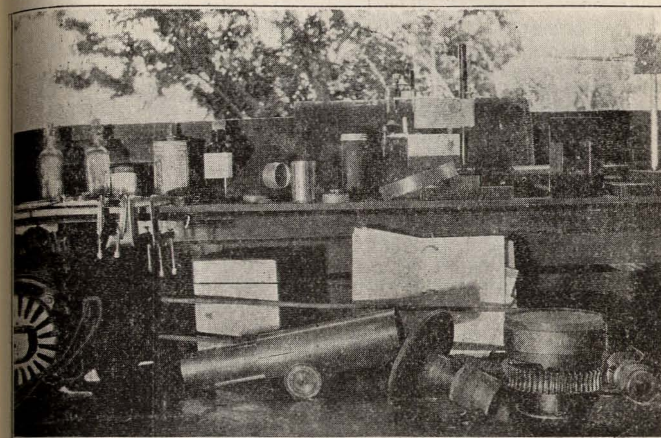


Equatorial Mounting for 10" Reflector, by J. A. Johnson, Fresno, California. (See also Driving Clock, in Appendix).

Thus the ambitious telescope-builder will decide upon the mounting best suited to his needs, his dexterity with tools, and of course his means. But whether it is of the simplest and most inexpensive design, or like some one of those reproduced here and displaying rare craftsmanship, be assured that the expenditure is amply justified. No enthusiast in star study will cavil at his bargain, whatever it be: and if he is over-critical of his handiwork, it will be in view of better, if not always bigger, results next time.



THE LENS GRINDER AT WORK



LENS-GRINDER'S BENCH, showing (left to right) Motor, rack-and-pinion Ocular-tube, Notebooks, iron Grinding Tool, and vertical Lathe-head with four-inch optical Blank in process of fine-grinding. Full working instructions in text.

THE REFRACTOR

WHILE differing from each other in optical principles and construction, between the reflector and refractor there are many factors in common from the practical optician's standpoint. Though in the refracting system there are four surfaces to be ground and figured as against one in the reflector, the methods of attack are very similar save that, owing to the smaller areas to be worked, hand power may be largely superceded by machine power, to the great saving of time and gain in accuracy. Two glass discs ground together by hand, as in the case of mirror-working, would eventually bring them to curve; but iron "tools," previously worked to form in a lathe, do the work in less than half the time, and may be used repeatedly, even on blanks of various sizes, with proper corrections.

Likewise in lens-work a system of templates is employed for gauging curvatures as in mirror-making; the abrasives are the same; the squared-surface pitch-pads are similar, as are the strokes and general methods in practice, so that to this point the successful speculum-worker will graduate into the refractor class by easy stages, nor feel far from home in any one of them. But here the similarity in appliances and treatment ceases, for the figuring and testing methods employed in lens-work are of a far more intricate and exacting kind, though not beyond the skill of the average master of the common tools applied to glass-working—perhaps the simplest of home-built equipments in all the arts.

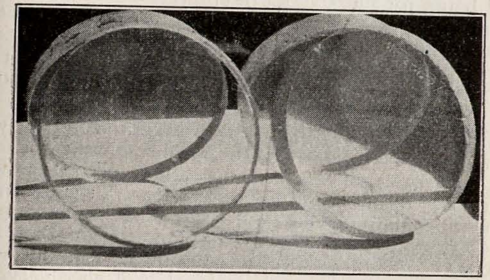
Given the requisite tools, the mere mechanical labor involved in producing two crown and two flint surfaces of proper curvature to combine in an achromatic system is surprisingly easy, calling for no involved mathematics nor phenomenal manipulative skill. Indeed, some of the finest objectives have been achieved by masters of the craft who relied almost wholly upon an intuitive sense of mechanical fitness, as many build houses, or radios, or play instruments, or write clever books who were never schooled in the subtilties of their craft—and were not accounted geniuses either. By all means, bring all the mathematics you have, or have time to acquire, to your lens work, to a better understanding of what you do and why; but without an intuitive sense of cause and effect—of optical values and proportions as well as limitations—you will miss the ideal you set out to realize, just as with this fine enquiring sense unaided you may attain it to your lasting satisfaction.

While a foot-power vertical lathe-head, (used by lens-workers for a hundred years or more), is not to be despised even now, electrical power is available in remotest places, and simplifies grinding problems immensely. The bench seen on the previous page displays a quarter-horsepower motor, geared to slow speed, driving a wormscrew engaging a cogwheel attached to an upright steel shaft. This shaft passes thru ball-bearings set flush with the bench-top, and rests on ball-bearings set in concrete in perfect alignment below. In a rigid metal cup-device, furnished with set-screws for accurate centering, a four-inch optical blank is cemented in a bed of shellac tempered with oil of cloves, the disc levelled and otherwise made ready while the shellac is still warm.

Economy in many particulars may be commendable, but in the matter of glass suitable for a telescope objective anything but the highest optical grade spells failure. In point of fact, considering the difficulties and intricacies involved in producing a flawless, homogeneous disc of crown or flint, free from bubbles, striae and other imperfections, meeting all the requirements of the exacting optician, the wonder

is that it can be produced commercially at so reasonable a price. Considering, too, the time, thought and labor which must be spent upon it to bring it to its highest usefulness as a telescope objective, even the novice at the bench could afford to take no chances with glass of inferior grade, or with any not guaranteed by reputable makers. If there be any shortcomings in the finished product, let not the lens-worker reproach himself that he used inferior glass.

Properly matched crown and flint discs come from the makers with their characteristics diamond-scratched upon their edges: Size, No., Melt, Type, value of D-line in spectrum, i. e., the index of refraction; the ν-sign, or relative amount of refraction to a given amount of dispersion, etc., being also oversize to give plenty of latitude in working.



OBJECTIVE BLANKS—Four-Inch, Clear Aperture.

CROWN:	FLINT:
Type, C. Melt No 593	Type, FM3. Melt No. 1637
Index for D-Line, 1.51823	Index for D-Line, 1.62071
$\nu = 59.8$	$\nu = 36.2$

Many will wonder at the outset why it is that while a single crown lens may give a good terrestrial image under test, a flint lens of reciprocal figuring to supplement it is so essential on the stars. The answer is to be found in the familiar phenomenon known as chromatic aberration whereby the star-image through a single lens is seen to be surrounded by a series of beautiful but embarassing rainbows of color, impeding observational work very seriously. Because of this difficulty, with no known methods of correction, Newton and his colleagues temporarily abandoned the refractor in favor of the reflector which presented no such color problems. It was in 1758 that a practical optician, John Dollond, demonstrated that by placing a plano-concave flint lens, possessing a different characteristic of dispersion, in conjunction with a double-convex crown, chromatic aberration was partially if not wholly neutralized; and thus was the so-called achromatic combination standardized for all time.

The novitiate's first reaction upon attacking an optical blank is one of misgiving—even self-doubting reluctance. But once launched upon the enterprise, deeply absorbed in the fascinating work, doubt and hesitancy disappear; and thereupon arises an delusion of quite an opposite character: that is the easiest task imaginable, with an uncontrollable impulse to hurry on to the end, forgetting that lens-work admits of no short cuts, no rash advances nor prolonged sessions at the grinding table. The best method is to have fixed hours for slipping on the apron and gauntlets, resting a quarter-hour between half-hour seances, limiting the total working-time to two hours daily. This may be exceeded during the process of rough grinding; but you will soon reach a pass where you will choose to proceed with due caution and reserve.

Opticians of many lands have experimented for years with view to approximating the ideal conditions for a lens that shall meet all requirements, visual, photographic, et cetera; but for all-round observational work there seems to be nothing more reliable than the familiar combination of the double-convex crown with the plano-concave flint, focal ratio of the system about fifteen to one. Naturally as the refractive and dispersive characteristics of glass vary, and even melts differ one with another, the maker's data will be found the safest criterion; and his advice, always cheerfully given, the best guide in questions of doubt or expediency.

Of course, if one adopts the simple double-convex crown (of equal curvature), and plano-concave system, there are but two iron tools to be roughed up to reverse template form, whereas with four surfaces to work, (as in the combination diagrammed to scale on a succeeding page), there are four tools to be prepared and kept true to form throughout the entire grinding process.*

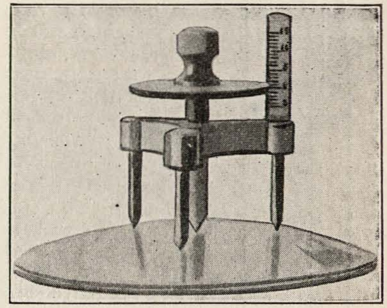
*To illustrate: Below are given two five-inch objective systems as adopted by the famous Mantois, of Paris:—

Radius:		Radius:	
Outside Crown, Plus,	20¾"	Outside Crown, Plus,	18"
Inside " "	17⅛"	Inside " "	27"
" Flint, Min.,	17¼"	" Flint, Min.,	25⅛"
Outside " "	69"	Outside " "	68⅜"
Length of Focus	78"	Short Focus.	

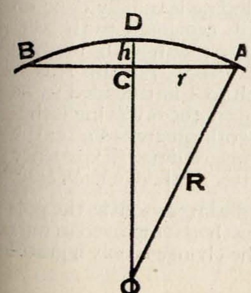
(For Sharp's system for calculating radii, see Appendix).

It is sometimes a privilege accorded the novice in the art to be allowed to take the curves of some good objective of the size decided upon, and whose capable performance he would endeavor to duplicate. This simplifies matters somewhat, insuring greater accuracy and offering a criterion of excellence for the final test. Taking the lenses from their cell with due care, the curves may be measured and computed by the aid of a spherometer, which the clever worker

OPTICIAN'S SPHEROMETER for determining the radius of curvature of a lens to the accuracy of 1-100th of a millimeter, and with convex and concave range of 15mm. latitude above and below plane.



may construct with his own hands—an implement in constant use around the optician's bench. It consists of a solid metal table supported on three equi-spaced needle-point steel legs. A central screw, threaded fifty to the inch, is surmounted by a milled twirling nob, and provided with a metal disc accurately graduated at the circumference, 1 to 100. A millimeter-scale attached to the standard at the side runs to 15mm. above plano—convex; and 5mm. below—concave.

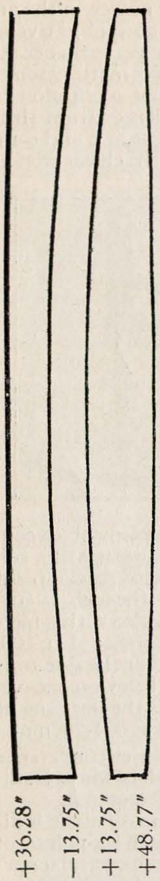


In skilled hands the instrument attains a precision of 1-200mm.

ADB represents circumference of a spherical surface whose Radius, OD or OA, is required.

Let AB = Diam. of circle indicated by the three leg-points of spherometer whose central screw-point is at C, whose Radius AC is expressed by r, and whose versed sine, by h. Hence, the formula:

$$\text{Radius} = \frac{r^2 + h^2}{2h}$$



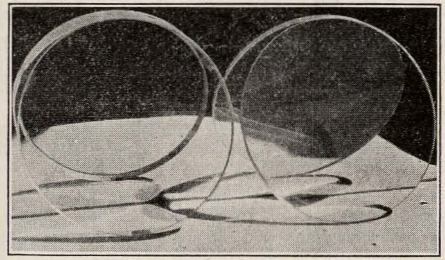
Placed upon a perfectly flat surface, with the central screw carefully adjusted, the spherometer-reading should be zero. Transferred to lens-surfaces, the plus and minus readings should be taken several times and averaged for precision. The next important step is to determine the value of '*r*,' the radius of the circle drawn thru the three outer leg-points of the spherometer. This is best done by making micrometric measurements of the distance between the central screw-leg point and that of each outer leg, taking the mean and recording it for permanent reference. The values of the curves in the four-inch system diagrammed on this page were calculated from a standard objective, and the templates cut accordingly.

For each unlike surface to be manipulated separate tool is required. A flat-faced hardwood model may be turned in a lathe, supplied with a boss, or handle. This pattern-tool, which is of the same diameter as the optical blank to be worked, must be cast in iron in quadruplicate, each boss threaded in a lathe, and the surface of each turned to fit its particular template. This is quite a job in itself; but when one remembers that these tools may be used for years, with occasional corrections, they are worth doing well.

While the grinding is usually done on the optical blank cemented to the vertical lathe-head, in polishing the method is sometimes reversed. For this reason the boss on each tool is threaded so as to fit a coupling on the revolving lathe-head, and the work progresses after the manner of mirror-grinding. Experience suggests the better method in each case.

The processes of rough and fine grinding as well as the polishing are so far duplicates of the methods employed in mirror-work, (See p. 207, et seq.,) that the change is only a grate-

ful one of substituting a motor-driven lathe-head for a stationary grinding-post. The vertical shaft should be provided with ball-bearings, running perfectly true, and so geared down that you can make ten or twelve hand-turns counterwise with the tool, thus no two strokes passing over the same area. It is surprising how quickly a curvature is reached; and your template should always be at hand for testing to guard against over-grinding. A variation of a hundredth of a millimeter from your calculated curves will make a vast difference in the focal length and working capacity of your achromatic, so it pays to proceed with patience and caution.



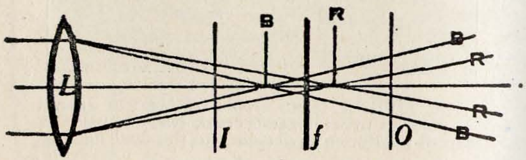
OBJECTIVE BLANKS, shown on page 229, ground and polished to achromatic curves, ready to place in the cell for testing preliminary to the final figuring.

Having brought the surfaces of the crown and flint to perfect spherical curves and given them high polish, you are ready to seat them in their cell and proceed to test for correction in chromatic and spherical aberration, definition, etc.

Lens-testing is a fine-art in itself—the most exacting with which the optician has to deal as well as the most fascinating to the enquiring student of the mysterious laws of light. Every maker has his own peculiar, often secret, methods, jealously guarded perhaps; but the main principles have become more and more the property of him who has the interest and zeal to dig for them, and like as not he will develop a few "secret" processes of his own. I never knew a lens-worker who wasn't proudly mysterious about something or other—probably an unconscious survival of the spirit of ancient times when it meant death to disclose the secrets of the craft. But while volumes have been written on the subject, some of them involved in fairly Einsteinian mathematics, great work has been done by men who never delved into these intricacies, but who pursued the common methods with common sense and the determination to make a good lens.

A moderately darkened chamber makes a good test-room, in an open window of which is set a solid screen. A hole is cut in this screen just the size of the lens under test, and the latter set upright before it. At about the focal distance a low-power ocular is mounted on a skeleton tripod in the exact focal plane.

Some fifty feet or more in the open beyond the window is set up your artificial star in the sunlight, preferably against a dark background. This "star" may be a steel ball, silvered bottle-stopper, or best of all a discarded electric-light globe silvered on the inside, lined up accurately in the optical train. Now, if the artificial star is first viewed thru the crown lens alone with the carefully adjusted eyepiece, blue and red rainbows will be seen to encircle the image. If the ocular is pushed forward a little, the blue rings will fade and the red flare up more brilliantly. Likewise when the eye-

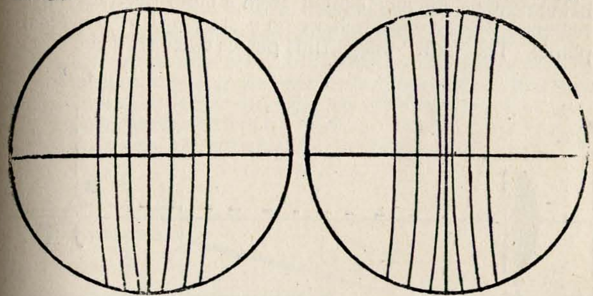


L Lens under test. *f* True focus. *I* Inside. *O* Outside true focus.

piece is drawn back of the true focal point, the red rings will be seen to soften down and the blue to intensify. It is because a lens is an aggregation of prisms; and each color has a distinctive deviation constant, distributing along the focal plane, the blue nearest and the red rays furthest from the lens. By placing the flint lens behind the crown and again examining the artificial star at the true focus, it will be seen that the so-called chromatic aberration is mitigated if not wholly neutralized by the different refractive values of the two lenses and a clear image results. But this ideal condition is seldom attained—only approximated by even experienced workers; but it is by a close study of these spectral rings, both inside and outside the focal point, that the optician determines the degree of under or over-correction of his lens and takes measures accordingly.

Spherical aberration reveals itself under various tests.

As a preliminary, in place of the artificial star, as suggested in the foregoing, suspend a series of equi-spaced plumb-lines against a dark background at a suitable distance. If the lines show straight and sharp clean to the rims of the field, the lens tests well; but the chances are that they will appear slightly bowed one way or another, as seen (much exaggerated) in the diagram below. Such a condition sug-



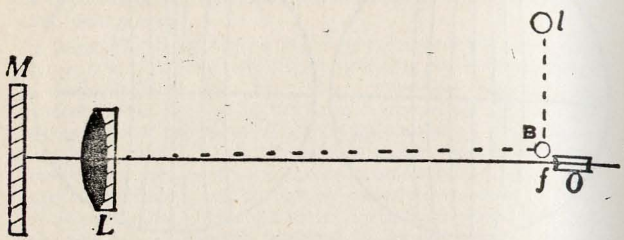
Spherical aberration in lens-system as disclosed by bowed plumb-lines

gests a return to the polishing table, repeated trials alone indicating the afflicted areas and dictating the kind and amount of correction necessary. A spherical surface is extremely sensitive to chastening which can be easily overdone; for a few minutes' manipulation with a rouged ball of the thumb is sufficient to change the direction of a light-ray and make or mar a good objective. Here is where the wizardry of lens-figuring begins, and where practical experience is more informing than many a learned treatise

The artificial star serves well in testing for spherical as well as chromatic aberration. In a perfectly centered system, viewed inside or outside the true focal point, a good lens will show a series of quite sharply defined diffraction rings, the outer one somewhat fringed, but all of them symmetrical, with no over-lapping, ellipticity or flare. All corrections should be directed toward attaining this desideratum, a trustworthy ocular being used lest any faults observed be accountable to the eye-piece and not to the lens under test at all. Precise centering is another important factor to avoid attributing to your objective shortcomings of which it is entirely innocent.

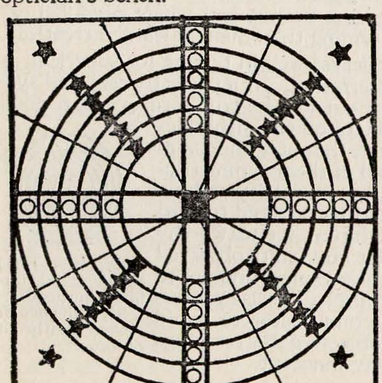
Diffraction rings surrounding star-image in a good objective, the ocular racked slightly out of focus.

An auto-collimation method of test for spherical aberration gives a refinement of results that is gratifying; but demands an accurately planed flat—not a simple achievement in itself, by any means—of the test-lens diameter, or larger, and silvered on face. This resembles the Foucault pin-hole speculum test somewhat, the source of light being next to the eye, caught from a lamp overhead and reflected from a steel ball set on a standard in the focal plane. The "star"-image thus passes twice thru the test-



M -- Silvered optical flat. L -- Lens under test. l -- Lamp whose rays directed on steel ball (B) afford an artificial test-star. O -- Ramsden ocular.

achromatic set up before the silvered flat, doubling any aberrational factors that may be disclosed. It is a highly recommended test, and makes full returns for labor involved in making a silvered optical flat, (see instructions under a later head), and which is a very valuable accessory to any optician's bench.



There are many photographic tests, some of them simple enough for the non-professional to undertake, others highly technical, requiring special apparatus. Familiar geometrical or other designs, (like the illustration on this page), may be enlarged and set up at a distance for photographing thru the system to discover any possible aber-

rational defects and so determine the rational remedies

Perhaps the long-established Hartmann test has received more modifications under procedure than any other, every optician using it in some individual way to suit his precise needs, for it is above all a precise test method. Basically it consists of making two comparison negatives, one inside and one outside the rational focal point, of a series of holes

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about 1 mm. in diameter, in a screen set upright behind the lens system, crossing the field at its true center. Thru these tiny holes the lens-system projects the incident light upon the plates in the form of black discs, which, taken from the two positions, are subjected to precise measurements. The

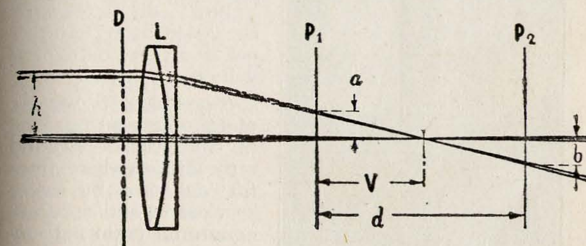
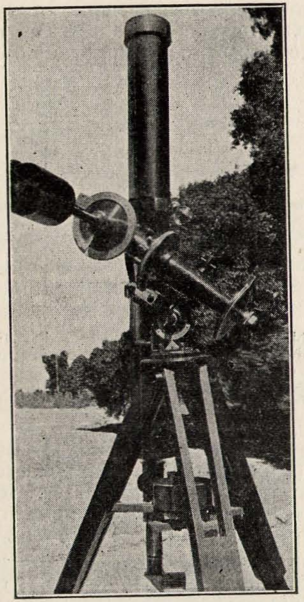


DIAGRAM OF HARTMANN TEST. h -- Light source. D -- Diaphragm with series of holes, either equispaced across diameter of lens or placed arbitrarily in zones. L -- Lens under test. P1 -- Photographic plate inside true focus. P2 -- Same, outside. d -- Distance between the two exposures. V -- Distance from the plate to intersection of marginal beam with optical axis.

amount of deviation from true correspondence of the pattern on the two plates determines the amount of spherical aberration present. If they coincide it is reasonable proof that all rays striking the objective at equal distances from its center are equally refracted, and the lens tests well.

It is worth while to remember that the human eye itself functions very imperfectly at times, and achromatically the judgment of some otherwise good observers is entirely untrustworthy. It is therefore unwise to accept any one person's dictum on the merits or demerits of your handicraft—even your own; for many a good lens has gone into the discard thru imperfect methods of test, false alignment, unreliable ocular or personal equation when it was in reality a work of real promise and a credit to its maker.

As for lens-cells, I have turned and polished some very satisfactory ones in hard maple and burl-redwood; but afterward used them for models for casting in brass, lathed true and threaded, at moderate cost. As the centering of an achromatic is of prime importance, side-screws in the flange-coupling on the telescope tube is recommended tho not imperative if the seating of the lens is true. Neither is the cementing of crown and flint discs with Canada balsam, (as is often done with camera and other small systems), at all necessary. If the inner surfaces are truly reciprocal the separation afforded by tiny strips of postage stamps affixed to the rim will suffice. If a "ghost" interferes with the vision, owing to internal reflections, balsaming will obviate it.



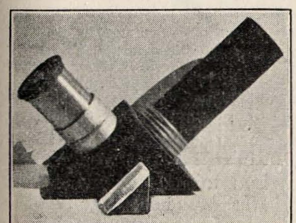
EQUATORIAL, Tripod Mount, set on Zenith star in true Meridian and observed with Star-diagonal.

A good lens is worthy of a good mounting. One of the professional kind may cost anywhere from fifty dollars up; but a very serviceable and accurate equatorial mounting may be constructed for a third of that figure by using an oak standard (bevelled to the meridian), surmounting a concrete pillar, the polar and declination axes made of hand-threaded wrought-iron pipe and automobile shafting, ball-bearings, et cetera, after the reflector method explained on p. 217. Brass protractors of suitable size serve excellently for circles, and clock-hands for pointers, giving readings to a few minutes of arc. I worked almost nightly for three years with such an equipment, with marked success and with only occasional readjustments. Only those who strive can know the possibilities of simple tools and modest means—plus ingenuity.

A rigid and serviceable alt-azimuth mounting is one of my home products, seen in the cut, with its ninety-two millimeter refractor set for meridional observations. It is an all-iron tripod, the inch-piping legs seating into the standard, interchangeable with shorter ones when so desired. The vertical and crossbars are of solid steel, clamping firmly; and the triangular reinforcing table serves as a convenient shelf for a battery of eyepieces. The sliding counterweight and crossbar are quickly removable, and the optical parts taken indoors while the standard may remain in the open, carefully levelled and anchored. A protractor declination-circle may easily be installed to facilitate meridian observation.

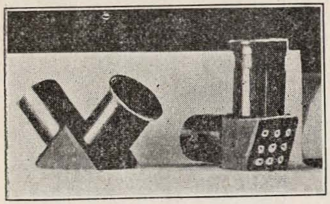
IRON TRIPOD MOUNT, Home-built, for 92 mm. Telescope.

The value of a star-diagonal is best realized by those who have endured long hours of observing in all sorts of cramped positions and then found relie in one of these prism accessories that make high-altitude observing so easy and delightful. Perhaps the high cost of so slight a mechanism deters many, (the professional kind are priced from twelve to forty dollars); but when one like that shown in the illustration may be put to-



STAR DIAGONAL AND PRISM.

gether for less than a dollar, this aid to vision may easily be added to any equipment. One-inch boro-silicate crown prism-blanks cost about seventy-five cents; and after grinding and polishing to true 90° angle, may be mounted against two hardwood blocks set at right angles to each other, one-inch holes opposite the faces of the prism, the whole boxed in with polished hard rubber. While there is an incident loss of light—barely ten per cent—the offsetting advantages in observing zenith stars horizontally and those at high altitudes obliquely downward are such as to justify its adoption. The reflection being total, silvering the surfaces is unnecessary.



STAR AND SOLAR DIAGONALS

For those who observe sunspots and other solar phenomena directly, the Herschelian solar diagonal is indispensable and quite as easily constructed. The prism unit, however, instead of being right-angled, is merely a wedge-shaped slab of glass set in the mounting at an angle of 45° to the telescopic axis. Thus while only a low percentage of light reflects into the ocular (which is carefully covered with a disc of dark glass to avoid injury to the eye), it is all-sufficient; the balance of the intense radiation escaping thru the holes cut in the cap at the end of the axis tube. Violet, blue or neutral-tinted glass discs on the ocular may be tried out to find the most suitable for clear-seeing and safety. The wedge-flat may be made of commercial plate, ground to about a 10° angle. This deviation from the two-flat surface form averts the objectionable double image.

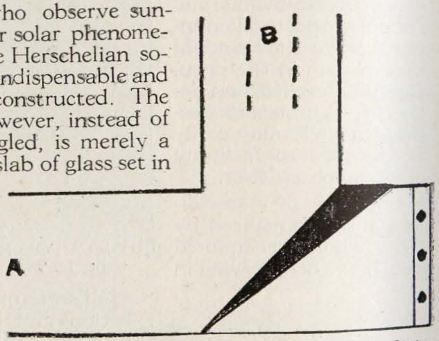
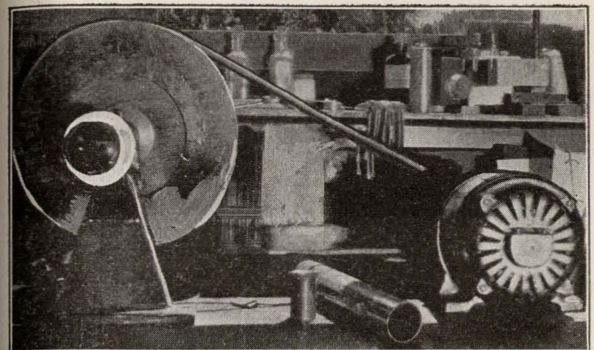


Diagram of Herschel Solar Diagonal: A—Tube fitting into Telescope. B—Slit Tube for capped eyepiece.



A SERVICEABLE GRINDING HEAD FOR SMALL LENSES

THE EYEPIECE

JUST why the successful objective and mirror-maker should pass up the daintier art of ocular construction and thereby miss one of the most fascinating branches of optical bench work is a mystery. It cannot be that he regards it as beneath his consideration, for it is quite as exacting in its way as work of a more pretentious order. Neither can it be charged to economy, for oculars which ordinarily cost from six to twenty dollars may be built for a fifth of this outlay, once the tools are in hand; and one may grind and mount a whole battery of eyepieces in the time required to grind and figure a speculum or objective of size. Besides, the field for experimentation in this enchanting realm of optics is limitless, and leads to the production of lenses for other uses: the spectroscope, microscope, astro-photographic camera and projection devices. In fact, the field is as wide-ranged as it is inviting to the student explorer in the mysteries of light.

To be sure, if one elects to make a real professional job of it, constructing the mountings of brass or other metal, the advantage of a good threading lathe is obvious. But in these halcyon days of the experimenter when almost every crossroad garage is so equipped, assistance in this particular is not hard to find if one must forego the pleasures and profit of having one's own at convenient hand. But mountings of seasoned and well-turned hardwood are by no means to be despised if the lenses are perfectly seated at their calculated distances apart; and I have seen many that might do very exacting professional duty if so required.

Of course, a grinding head, as shown in the illustration on the previous page, (quite inexpensive and interchangeable for many glass, metal and wood-working utilities), is essential, foot-driven, or better still, powered by a small motor geared down to slow speed. A chuck on the end of the spindle holds the tool for shaping to curve, and later the block whereon the lens-blank is cemented, (as also seen in the illustration), for grinding to template form and imparting a brilliant polish.

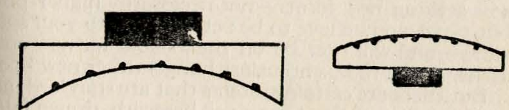
If the optical mechanism of the human eye gave seeing values corresponding to an inch or more instead of a mere fifth of an inch, and very imperfect at that, we might not need enlarging aids to vision at all. For all an ocular does is to magnify the image as seen at the focal point. Therefore, the matter of oculars is one of personal equation; and while some demand complicated and high-power systems —always at the expense of light—others may be content with a single-lens ocular, as in the case of the great Herschel who held in contempt those observers who would sacrifice sharp definition to increased magnification, claiming that objects seen indifferently or not at all with high-power oculars often came clearly to view with a single lens.

Whatever else is true, high powers magnify faults as well as virtues: lens-astigmatism, atmospheric disturbances and personal defects of vision; and while the ambitious lens-worker will likely try his hand at various complex systems, for steady observational work he will revert to first principles and consistent combinations. No photographer would think of trying to cover an eight-by-ten plate with a four-by-five lens; and yet some there are who would expect an objective or mirror to do the like impossible.

The method of grinding and polishing eyepieces is practically the same as that employed in objective work save that the horizontal grinding-head spindle is substituted for the vertical shaft; and the motion being swifter, the abrasives and polishing agents work faster. Templates are as much in evidence in this work, too, to avoid errors of curvature; but faults and even breakage are not so serious as the cost of the working material is negligible by comparison, and one may make a dozen discards in experimenting without much monetary loss. Indeed, the chances are

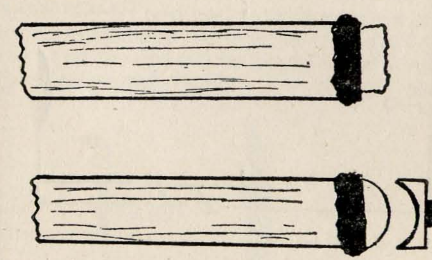
that the optical bench will be pretty well littered up with wreckage before the novice attains his precise desires; and yet he may achieve success at his very first venture. Glass-working is one of the world's oldest and most absorbing games of chance.

There is such latitude in the methods of bringing tools to template form that probably every available implement will be tried out to find the quickest means of accomplishing this rougher part of the job. Old files, rounded on the end against a grindstone, are as good as anything, both for preliminary work on the iron and later on glass. The convex and concave tools (of various sizes depending on your template curves), will take the forms seen in the drawings below; and, to make more efficient, may be finely grooved



TYPICAL GRINDING TOOLS FOR LARGER EYEPIECES.

across the face with a circular saw to afford more even distribution of abrasive in the case of the larger surfaces. In the instance of the smaller lenses, the tools may be cut in drawn brass, ungrooved, the rough blank under treatment cemented to a spindle held true in the grinding-head chuck.



SMALL LENS WORK: (Above) The rough Disc cemented on a spindle. (Below) Lense and Tool in process of grinding.

The polishing process with all small lenses is also much the same as with larger units, as previously explained in detail in instructions on polishing objectives, every optician having his favorite medium: cartridge paper, broadcloth or whatnot; but well-washed rouge, moist or dry, is common to them all, and the novice is given free rein to his passion for exeprimentation along these lines.

If the operator does not wish to risk his purchased optical blanks at once, he can usually pick up a handful of suitable trial-bits from some optician's discard-drawer with which to get his hand in; and likely as not his very first effort will be creditable as well as instructive. Even fragments of high-grade commercial plate have been known to furnish material for some excellent oculars; but small bits of high optical grade are cheap, and much good labor on poor material will afford only half results at best.

Whatever ocular you succeed in producing, you will always be seeking new forms—not necessarily higher powers, but types you believe to be better suited to your special needs—and will ever be on the lookout for new combinations, as the radio enthusiast hungers after new hookups. But there are certain systems that are standard; and the most familiar of these are given herewith, drawn fairly close to scale. These forms are susceptible of many modifications, as experience will dictate; but while each has its advantages, it has its limitations too, so do not expect any one of them to work a miracle.

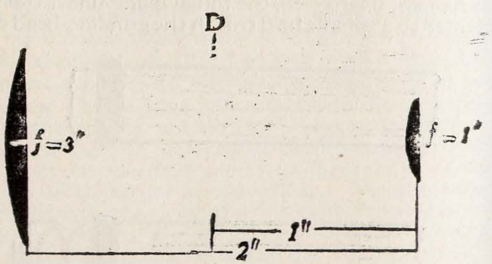
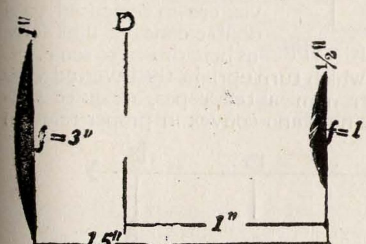


DIAGRAM OF HUYGHENIAN TYPE OF EYEPIECE.

The HUYGHENS type of ocular is probably the most popular with telescopists, giving a fairly large angular field—about 60°—free from distortion, but not altogether from color. Components: two plano-convex lenses, planes toward the eye. Relative focal lengths: 3 to 1. Distance, plane to plane, equal to one-half the sum of their focal lengths. Thus is applied the rule:—

TO FIND THE FOCAL LENGTH OF THE EQUIVALENT LENS: Multiply the focal length of the field-lens by the focal length of the eye-lens. Divide the product by the distance between the planes—i. e., half the sum of their focal lengths. The quotient will represent the equivalent focus of the system.

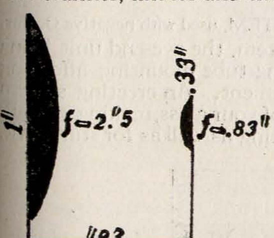
Thus the equivalent focus of the Huyghenian system is found to be one and one-half inches. When applied to a ten-inch reflector of, say, ninety inches focal length, using the formula: $M = F \div f$—that is to say, Magnifying Power equals Focal Length of Mirror divided by Equivalent Focus of Eyepiece—we have $90 \div 1\frac{1}{2} = 60$, the power of the telescope with this equipment.

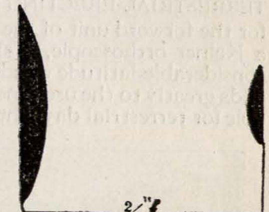


MODIFIED HUYGHENIAN FORM

One of the many variations of this Huyghenian (negative) system is diagrammed here. The field-lens is seen to be an inch shorter of focus, the eye-lens being the same as in the common type. This system affords an angular field of about 60°.

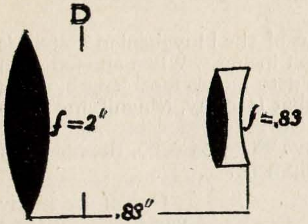
The RAMSDEN, (positive) type of eyepiece is chiefly adaptable to micrometric or other precision work using cross-wires or spider-web reticles placed in the focal plane, for transits, finders and the like. The system consists of





ORIGINAL RAMSDEN FORM. MODIFIED RAMSDEN.

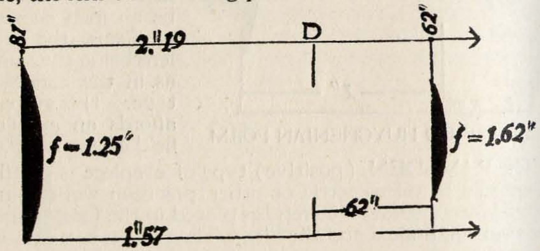
two plano-convex lenses of equal focal length, the eye-lens usually one-half the diameter of the field-lens and proportionally thinner. The plane sides are placed outward and at a mutual distance represented by two-thirds the focal length of either lens. Sometimes both field and eye-lenses are of equal size, giving an angular field of 90°, or thereabouts—very desirable in comet or meteor observations.



The Kelner orthoscopic ocular, computed to afford even greater freedom from distortion, fulfills more exacting conditions It is an achromatic combination, consisting of a double-convex field-lens in series with an eye-lens of double-convex crown cemented to a double-concave flint lens, as here drawn to scale.

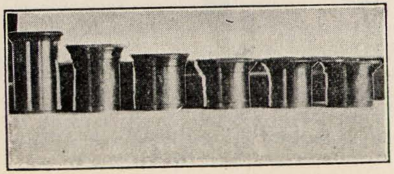
KELNER ORTHOSCOPIC TYPE.

Erecting eyepieces, which turn upright the inverted view charateristic of all astronomical telescopes, are quite simple, the lens-curves being plano-convex in proper relation

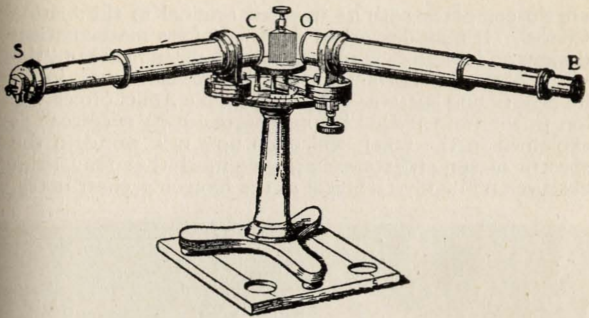


TERRESTRIAL ERECTING SYSTEM, used with negative Ocular.

for the forword unit of the system, the eye-end unit being a Kelner orthoscopic, a sliding-tube mounting affording considerable latitude of adjustment. An erecting system adds greatly to the usefulness of your glass, making it available for terrestrial daylight seeing as well as for star-work.



A Battery of Eye-Pieces: Powers, 60 to 280

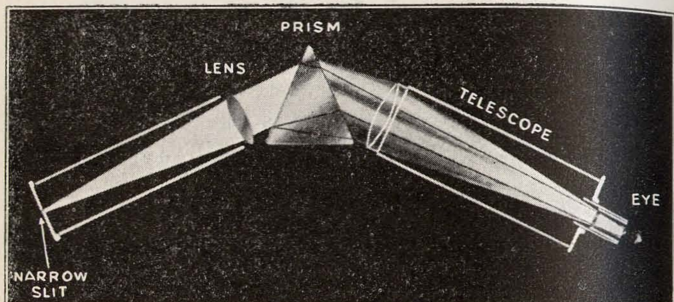


Laboratory SPECTROSCOPE, (Newall). S--Slit. C--Collimator lens. O--Objective of Telescope. E--Eyepiece. Crown glass prism supported on revolving table, and optical parts adjustable to prism-train.

THE SPECTROSCOPE

WHILE spectroscopy would seem to be a distinct and wholly justified science in itself, quite apart from astronomy, yet during the past few decades star-study has made such amazing advances thru its aid, playing so brilliant a role in all branches of celestial research, that a working knowledge of the rudiments—even so much as may be glimpsed with simple equipment of one's own construction—is quite essential to an unfoldment of the mysteries of space, as well as an appreciation of what the master intellects of our time are achieving along these lines.

One observation may be stated as a truism: once a spectroscope-fan, always. The charm of constant surprise stimulates to ever deeper enquiry. It is as if the firmament itself had issued through the blazing spectrum an eternal challenge written in rainbows of promise. Whoever has once climbed this dazzling Jacob's Ladder into the empyrean will ever remember the glorious adventure, nor once regret the time and labor involved in constructing his own outfit, however modest the beginnings; and it is safe to predict that he will be urged to pursue his researches to the limit of his means and intelligence, so great is the lure of the spectral art once its fascinations take hold. For in truth the printed reproductions of a stellar or solar spectrum are to thing seen thru the wizardry of the prism as the photograph of a masterpiece by Raphael or Michelangelo compares with its inspired original in the Sistine Chapel. It may disclose in sharp relief its mathematical designs and give a clew to their hidden meanings; but "the vision of the master mind" only the real can reveal in all its beauty and austerity. Even a simple Amici direct-vision prism train placed before the telescope eyepiece (as explained in the text), will open up a new world in the spectra of sun and stars, clarifying much that may seem obscure and highly technical in the foregoing chart notes.



PRINCIPLE OF THE SPECTROSCOPE. (Steavenson). Schematic view showing how the incident ray, entering the Collimator at the focal point of the Lens, is projected into the Prism and emerges in a spectral band, passing thru the telescope to the eye, or is caught on the photographic plate for permanent record.

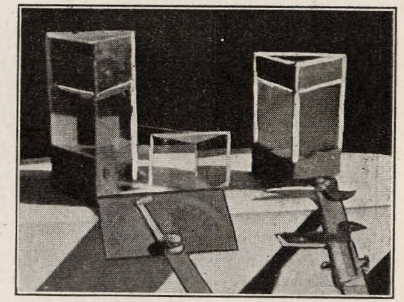
The benefits to research by reason of this "sesame" of the stars are incalculable; yet as a mine of great riches its possibilities have scarcely been surface-panned. Nevertheless by its aid we discover the physical elements in suns far and near, of which our own Sun is one of thirty billion; and that these elements are fairly identical with those on this earth—that the universe is a unit. Moreover, it has discovered unseen bodies orbiting around seen suns, and weighed them as in a balance. It has determined the velocity and direction of suns in space, our own among them. It is contributing to the solution of the intricate problems of stellar temperatures; of the pulsations of the Cepheids and the mystery of the long-period variables; the paradox of the ether; and with each recurrent eclipse a deeper understanding of solar phenomena by which we may formulate laws which govern other suns in space. The merest index of spectroscopic achievements at the hands of the

masters of all the great observo-laboratories of the world would fill pages, and their full commentaries already comprise libraries, aside from purely local research in every branch of applied chemistry and the arts.

But it is only with the introductory glimpses into this promised land of research that we have to deal here, describing only the simplest home-built forms of the spectroscope for the novitiate in the art, recommending the brilliant authorities (listed in the Appendix), for the deeper enlightenment he is certain sooner or later to crave.

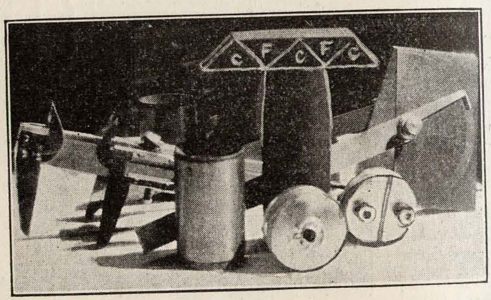
As the prism is the prime factor in the equipment, the experimenter will at once undertake the grinding and polishing of a suitable block of glass—crown, flint, or good commercial plate—unless he elects to purchase his prism-blanks, which come in various grades and angles, making work at the bench easier and insuring greater accuracy.

But it may be that the novice will wish to experiment with even a simpler form, in which case he will construct a sixty-degree prism of three strips of thin negative-glass, perfectly cemented at seams and bottom, and filled with distilled water, carbon disulphide, or other liquid, as shown in the illustration. In laboratory research such liquid prisms are of great survice, giving brilliant results with solar light reflected into the optical train, or the bright-line spectra of various chemical salts vaporized in an alcohol or other hot flame: lithium, sodium, barium, strontium, potassium, and the like. Carbon disulphide gives magnificent dispersion; but it must be carefully contained in a capped prism, being volatile, highly inflammable and malodorous; but it affords full requiting compensations.



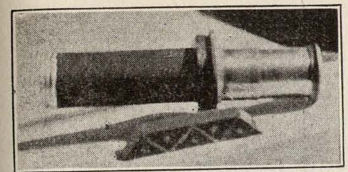
HOME-BUILT PRISMS: Left, hollow glass, filled with distilled water. Right, same, filled with carbon disulphide. Center, boro-silicate crown, angle, 90°. Tools, goniometer for measuring angles, and vernier precision caliper.

The grinding and polishing of prisms to angular precision is not so difficult a job as it is a particular one. If purchased blanks of boro-silicate and flint are used, they are already fairly accurate of angle, and need only the finishing process for whatever use they are intended. Blocks of glass may be quickly worked down to prism form on a power corborundum or emery wheel, afterwards transferred to the upright grinding table whose tools must be absolutely plane and frequently tested to keep them so. Prisms may be worked singly or in gangs four-on, each supported by a brass or typemetal block sawed to the complementary angle, and the entire series seated firmly in the holder with hot shellac as in grinding an objective. In fact, the process from now on is a duplication of lens work save that a plane instead of a spherical surface is the goal, calling for some pretty nice workmanship. Still, all things are possible with patience, plus a little experience; and the rewards are mighty well worth the effort.



Parts of a portable DIRECT VISION SPECTROSCOPE: Amici Five-prism Train and Collimator; Eye-piece and adjustable razor-blade Slit, for general observation.

Anyone who achieves a good prism may be proud of a precise job well done; but a five-prism Amici train, three crown and two flint, so accurate of angle that they may be balsamed side to side in perfect series—this is a real triumph. Still, a combination of this order justifies the labor since it affords such a range of dispersion, revealing a bewilderment of Fraunhofer lines, and available for laboratory experiment or for spectral observation of the celestial units. In the latter case a dazzling shaft of spectral hues cuts the sky several times the width of the telescopic field from crimson to violet, with dark beads strung along its



Amici five-prism Direct Vision Spectroscope adapted to the Telescope.

span, representing the Fraunhofer indices, which characteristic dots, by the use of a cylindrical lens eyepiece, may be elongated into definite lines.

If the enthusiast wishes to undertake a larger prism—40 mm. or more, for instance, from base to apex, preferably dense flint—he may mount it at the proper angle in front of his refractor objective, making what is known as an "objective prism," used very largely in spectral photography. No slit is required, one or more spectra in the telescopic field being displayed at once—often a truly beautiful spectacle. The Pleiades, for instance, thru my 46 mm. objective prism disclose at least a dozen spectra, entirely filling the field like a flock of birds of paradise in flight, four or five of them especially brilliant and well defined. This arrangement is a little tedious of adjustment, but not so difficult as the Amici slit-train at the eyepiece, which latter of course gives far greater dispersion, tho only a single unit is under examination at a time.

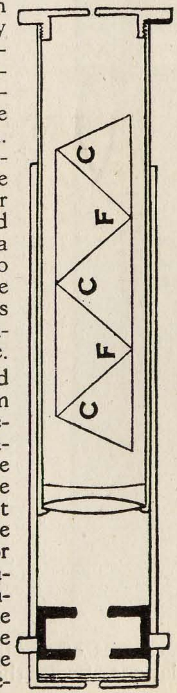
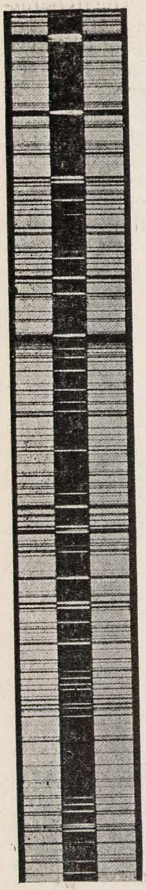


Diagram of a sliding-tube Direct Vision Spectroscope for general analysis.

In viewing the spectrum of reflected sunlight in the sky thru your five-prism portable spectroscope, you will soon become familiar with the principal features, notably the vivid double D-line of sodium conspicuously placed a little out of center toward the red where it merges into the orange. This may be called the weather-prophet's line; for if the atmosphere be charged with vapor even in a slight degree, fuzzy rainbands will be seen alongside the D-line toward the red, the heavier the charge of moisture the more pronounced the telltale rain-bands, making storm predictions possible, sometimes hours before the actual event. This is but one of the practical uses of this brilliant device.



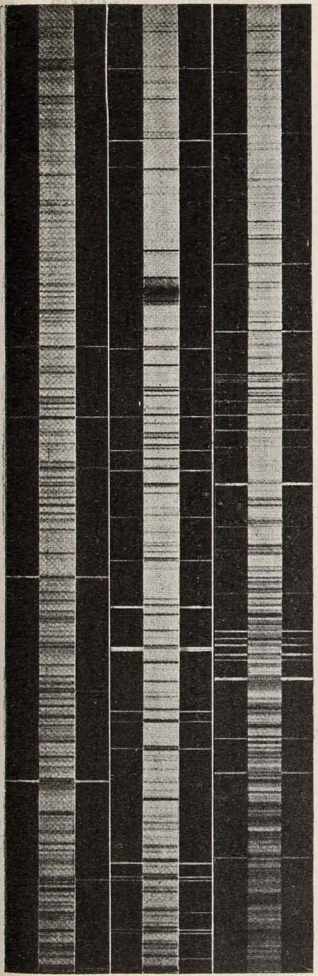
Dark-line SOLAR SPECTRUM, (Violet Region), coincident with bright-line Spectrum of Iron, center. To the left are the Ultra-Violet (invisible) regions, analyzed only by photography; to the right the Indigo, Blue, Green, Yellow, Orange and Red, (visible), and the invisible Infra-Red, manifest by heat.

Extremely simple, but with results surpassingly interesting and beautiful, is this cryptographer of the cosmos. It is merely an analyzer light from whatsoever source: "the heavens above, the earth beneath or the waters under the earth," for nothing can resist heat; and as heat gives light, the prism literally tears its beams apart like a royal garment and reveals the origin and composition of each individual thread. It is only necessary to pass the incident ray from whatsoever source—Sun, star, candle-flame or volatilized element—thru a narrow slit and condensing lens, viewing it with an enlarging telescope, and its secrets stand revealed! This amazing discovery gives rise to a few formulated facts which serve as a basis for all spectroscopic investigation:—

(a) A glowing transparent gas gives a spectrum of isolated bright lines.

(b) A solid element, or combination of elements, heated to incandescence, gives a continuous visible spectrum.

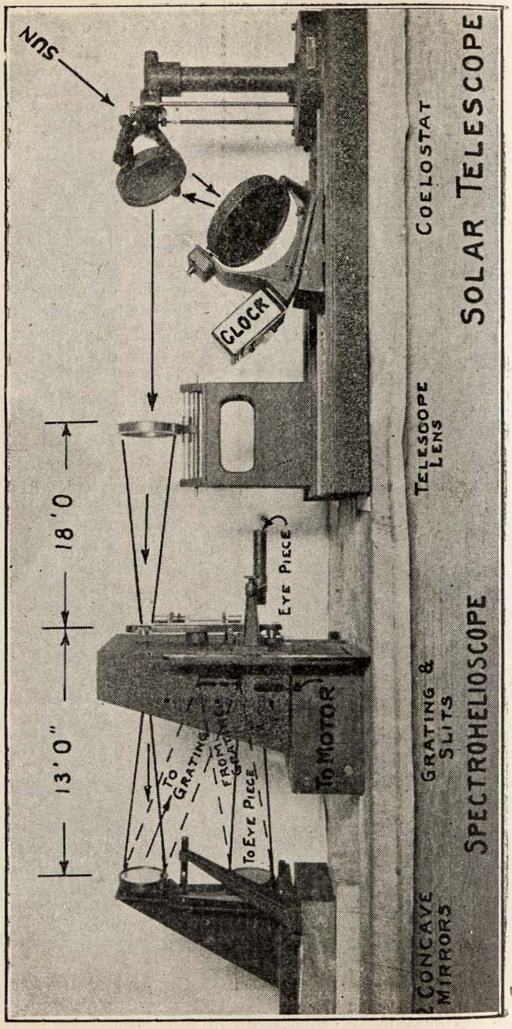
(c) If a cooler gas of any element is interposed, dark absorption lines appear, giving direct evidence of the nature of that element, whether seen in a laboratory flame or electric furnace, in the photosphere of the Sun or that of the most distant star. Thus in the solar spectrum here reproduced are disclosed the presence of more than thirty known elements, with many more yet to be revealed. This amazing phenomenon is the ground plan of all branches of spectroscopy as pertaining to terrestrial analysis, and also justifies the more intricate system of classification of stellar spectra as given on page 20. Plain black and white reproductions of these messages of the Infinite give no hint of the dazzling gradations of color that fascinate the beholder; but they draw



TYPICAL STELLAR SPECTRA. (Top) Polaris, Class F8. (Center) Canopus, F. (Bottom) Arcturus, K. (Mills).

a vivid picture of the teeming complexity of elemental forces at war in the high temperature photosphere of the neighboring Sun or distant star.

Of the discoveries of Newton, Fraunhofer, Kirchhoff, Huggins, Rutherford, Doppler, Draper and others, and of the conditions and laws which govern variation of spectral types—continuous, bright-line, banded, fluted, absorption, etc., as applied to celestial or purely laboratory research, the ambitious are referred to the excellent authorities listed in the Book section, ps. 280-1. The merest survey of the Golconda of unmined wealth disclosed to the prospecting spectro-analyst would fill pages. It is the chief function of this chapter to encourage the novice to build his own spectroscope, and, as Newall says, "See for himself!" He too may yield to its intellectual fascinations, and understand why men have given, and are now giving, their entire lives to this noble branch of research, accounting themselves rich in the privilege to do so. From such will come the greater spectroscopic revelations of the future.



The simplified SPECTROHELIOSCOPE, designed especially for amateurs, by Dr. George E. Hale, Hon. Director, Mt. Wilson Observatory, California, easy of construction and brilliant in results. (Diagram by Mr. F. M. Hicks).

DR. HALE'S SPECTROHELIOSCOPE.

Next to the thrill of making great discoveries is the joy of imparting them to others; also, if possible, to bring the means of making more discoveries within the province of the amateur by simplifying the methods of the great research institutions so that any ambitious layman may "see for himself," and perchance add his bit to the sum total of astronomical research. Dr. George E. Hale, founder of observatories and master-mind in astrophysics, has thus embodied the principle of the Spectroheliоscope, one of many of his epochal inventions, in an instrument which any experimenter may build (excepting the grating) and so behold the wonders of the Sun's activities—flames of gas shooting half a million miles in height at a speed of two hundred miles a second, the shifting sunspots and swirling solar whirlpools—almost as if he were working with the giant instrument on Mt. Wilson itself. It is Dr. Hale's desire to see these spectrohelioscopes established by amateurs and professionals alike in all parts of the world so that a constant watch on solar variations may be noted and placed on record. Here then is another brilliant opportunity for the thrill-searching experimenter.

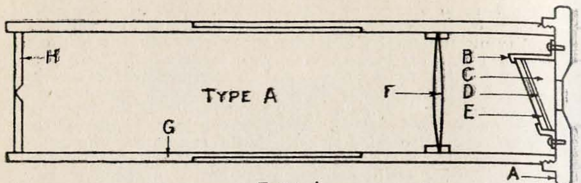
Briefly, the photographic reproduction on the opposite page tells the story. The instrument consists of two parts: the Solar Telescope and the Spectrohelioscope itself. The rays of the sun fall upon the lower plane mirror, 5½ in. in diameter, silvered on the face, which is set parallel to the earth's axis, and rotated by an ordinary clock movement at the rate of one complete revolution in forty-eight hours. The rays are thus sent upward to the second 4½ in. plane mirror which is held in a fork so that it may be rotated at will, bringing various parts of the sun into view for investigation by the spectrohelioscope. Between the two instruments is mounted a four-inch plano-convex lens of 18' focus. This forms a solar image on the upper slit of the Spectrohelioscope. The narrow divergent beam then passes to a concave mirror of 13 feet focal length, which returns it as a parallel beam to a diffraction grating, mounted near the slit.

The grating itself is so mounted as to be turned on its vertical axis to any angle corresponding to the various regions of the spectrum. The lower concave mirror, to the left, receives the spectral image and projects it back through a second slit to the eyepiece. The upper and lower slits are so mounted as to oscillate and synchronize the spectral line under observation, this motion (a small fraction of an inch) being imparted by a small motor.

If the instrument is set up in a darkened chamber and the sunlight projected from the coelostat through a convenient hole in the wall, the gorgeous solar spectrum will be seen in all its glory, from extreme red to violet, crossed by myriads of lines of varying degrees of intensity, and solar prominences and the moving flow of flaming hydrogen rounding sunspots may be examined. So enthusiastic has Dr. Hale become over the prospect of amateurs building spectrohelioscopes and undertaking serious observational work that he has provided that complete working blueprints may be obtained at the nominal cost of production by addressing the Mt. Wilson Observatory, Pasadena, Calif. Unfortunately no grating replica suitable for use with this instrument are yet obtainable, but good speculum metal gratings can be purchased from certain dealers in optical instruments.

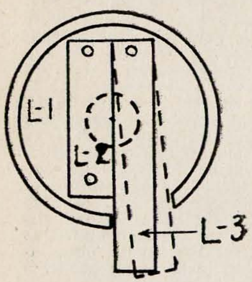
REPLICA GRATING SPECTROSCOPES

By F. M. HICKS

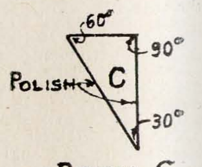


Type A

A—Knurled end piece with 5/16″ diameter opening.
B—Metal holder (2 wanted).
C—Prism 30° — 60° — 90° (optical glass preferred).
D—Replica grating ½″ square (ruling set horizontally). Ruled side toward slit.
E—Glass to hold replica grating, use microscope cover glass.
F—Lens with 3 or 4″ focus.
G—Brass tubing 1¼″ outside diameter to fit eye-piece holder of telescope.
H—Stationary slit, jaw set about 100th of an inch apart (may be made from a safety razor blade, non-rusting metal preferable). Inside of tube and slit to be finished dead black.



ADJUSTABLE SLIT L



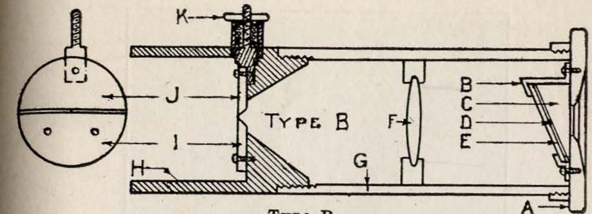
PRISM C

L.1 shows simplified form of adjustable slit. C is angle prism which should be of optical glass; angles made perfect as possible and surfaces true.

Zollner Type Ocular Star Spectroscope

This type may be constructed by taking the knurled end-piece A with the prism and grating attached; add to the prism side 1″ of fitting or tube threaded so it will fit on one of the eye-pieces of your telescope. Select a low power eye-piece (not over 10 diameters for each inch of your objective).

To use this type of spectroscope first bring the star to the center of the field, then screw on the above described end-piece A. (No slit is required.)



Type B

Direct Vision Spectroscope with adjustable slit and magnifying lens. A B C D and E the same as in Type A. F magnifying lens with one and one-half inch focus (this can be obtained at small expense from a discarded camera). G brass tubing one and one-quarter inch outside diameter. H end-piece to hold adjustable slit. I and J adjustable slit (I being stationary). Sketch on left shows threaded holder by which slit J is moved and closed by spring tension. K loose knurled nut. All metal inside of tube to be finished dead black. By reducing diameter of Type B it will make a very handy pocket spectroscope for spectrum analysis in the laboratory. Try it on the new type of Neon or Mercury vacuum tube signs and you will see a beautiful example of spectrum analysis.

The above designs of direct vision spectroscope have been worked out from suggestions made by Dr. J. A. Anderson of Mount Wilson Observatory. Blue prints of the same may be obtained from F. M. Hicks, 1315 South Oakland Avenue, Pasadena, at 35 cents each.

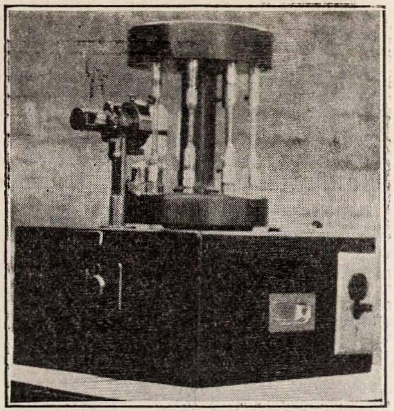
Replica Gratings: Messrs. Howell & Sherburne, Pasadena, Calif.

Wallace Replica Diffraction Gratings, ruled 14,438 lines to the inch, ($2.00), to 25,000 lines per inch, ($9.00 to $15.00 each): Central Scientific Company, 460 E. Ohio st., Chicago, Ill. (Bulletin 22).

The amateur will do well to begin his observation with the Sun, our nearest star. Study his chromosphere and prominences. With telescope of over four inch aperture, the aperture should be reduced to prevent possible injury to the eye. Betelgeuse and Antares are good types of red stars, while Sirius and Vega are good types of blue-white stars. The planets, first magnitude stars and some of the nebulae will be found most interesting.

When using the spectroscope on the stars it is easier to operate without a slit, unless you have a good clock or motor drive. With the stars it is better to observe with the slit wide open while with the sun and planets a narrow slit is needed. In order to show the spectrum lines well, except in case of prominences where it is better if the slit is somewhat widened. It is preferable to have a telescope with not less than 8″ mirror if the spectroscope is used on the stars whose spectra will appear quite narrow but may be widened by the use of a cylindrical lens placed in front of the replica grating.

With the spectroscope the image of the star will be transformed from a point of light into a color band crossed at intervals by the distinctive lines that constitute the signature of that particular star.



THE HICKS SPECTRA DEMONSTRATOR

The Spectra Demonstrator shown in the above cut contains 4 vacuum tubes, three incandescent lamps, iron and copper electrodes, which when excited by an electric current give off light which varies in wave length (i.e. color) according to the element excited.

Examine this light with a spectroscope and you will see it dispersed into a band called a spectrum, the visible part of which shows violet (short waves, about two hundred thousandths of an inch in length), green, yellow and dark red (the dark red being produced by waves about twice the length of those producing the visible violet.) Beyond these visible rays are the invisible rays that range from infinitesimally short penetrating Milliken cosmic rays about two-trillionths of an inch in length on through the gamma rays, X-rays, ultra violet, red heat rays to Hertzian waves (used in radio), the longest of which are many miles in length. These rays all have a speed of 186,300 miles per second, the same as light. From the study of the spectrum, which is the study of luminous bodies by the light they emit, is discovered what the stars are made of, their density, pressure, temperature and direction of motion.

The visible part of the spectrum (only about one-sixtieth of the whole) reveal the fact that each element has its own distinctive lines and spacings, colored according to the region in which they occur, not duplicated in any other element. In this connection it is interesting to note that helium, now commercially valuable, was discovered in the sun many years before it was found on the earth. Some spectra such as mercury show the movement of electrons in masses, while the spectra of others such as nitrogen show the movement of masses of molecules, a very noticeable difference in effect, thus demonstrating certain phases of the atomic theory.

It is into this most interesting and fascinating world, that reaches into physics and chemistry as well as astronomy, that the amateur is invited with his home-made spectroscope. While the Hicks Spectra Demonstrator shown above was designed especially for schools, colleges and the interested public for educational purposes, the amateur may assemble an inexpensive demonstrator that will reveal nature in one of her most fascinating moods.

Amateur Spectrum Demonstrator

Vacuum Tubes ½" diameter, about 6" long, the middle 1/3 of the tube (where the spectroscope is used) reduced by the glass blower to ¼" diameter. Fill tubes with gas to about 10 MM pressure; copper electrodes and terminal wires same as those used for Neon signs. Tubes of mercury, neon, helium and nitrogen are recommended. These you should be able to get from your nearest neon electric sign builder.

Transformer. Preferably 4000 volts .02 amps. built to suit your house current; secure from neon sign builder or manufacturer of transformers (cost about $5.00).

Condenser. Material wanted: 4 pieces selected single thickness glass 5½x7½; 4 pieces pure tinfoil 4"x6"; 2-stranded wire terminals. Fasten in the center of each side of two pieces of glass the sheets of tinfoil, and held in place by heating glass and applying hot beeswax. This will leave a border ¾" wide around the tinfoil. Paint this border with asphalt paint. The other two glasses are protection cover plates (outside). Bind the whole together with electric tape.

The two terminals should be of stranded copper wire. Strands spread out fan-shaped, laid between double thickness of tinfoil, then one terminal placed between the two middle pieces of tinfoil plates and the other terminal prepared in the same way, divided into two parts and contacted with the other two sheets of tinfoil. The condenser is wired in series between the transformer and the spark electrodes. The size and capacity of the condenser may be increased if desired. The condenser is used only with "Sparks" not connected with vacuum tubes.

Iron Spark, a round fat spark is required, use 3/16" diameter iron rods for electrodes, space them about ⅛" apart, wire up same as the vacuum tubes, with condenser added.

Incandescent Frosted Lamps are used to show continuous spectra (same as the sun spectra) use lamp having the light concentrated at one point in the light bulb, it is at this point you direct the spectroscope (there is a 1" round 15 watt lamp fills this requirement). **Absorption Spectrum** effects are shown by placing in front of the lamp colored gelatin paper or glass screens such as used with moving picture lanterns. By selecting the proper colors you can cut out or absorb any one or all of the four primary colors.

Wiring, leading from the house current to the primary terminal of the transformer, and to the incandescent lamps, use ordinary house electric light cord; all other wiring should be of the heavy insulated stranded copper cable type such as is used on ignition system of automobiles. In general wire up same as for the neon signs.

Caution. Insulate thoroughly and handle carefully as you are handling dangerous high frequency electric current. The vacuum tubes should last a long time if the current is on only when looking through the spectroscope. The slit of the spectroscope should be close up to the vacuum tube.

The Hicks Spectra Demonstrator together with its companion instrument, the Color Absorption Demonstrator, both designed and built by F. M. Hicks, have been installed in the National Academy of Science at Washington, California Institute of Technology and Mount Wilson Observatory at Pasadena, as permanent exhibits to illustrate the principles of spectrum analysis.

Newton decomposed light in 1672. Wollaston used a narrow slit and detected the principal dark lines in the solar spectrum in 1803. Fraunhofer perfected the method, and in 1820 measured six hundred of these lines which now bear his illustrious name; but they were not interpreted until 1852 by Stokes (who recognized the D-line as due to sodium vapor), and Kirchhoff and Bunsen, who, in 1859, identified many terrestrial elements in the sun and so founded stellar spectroscopy.

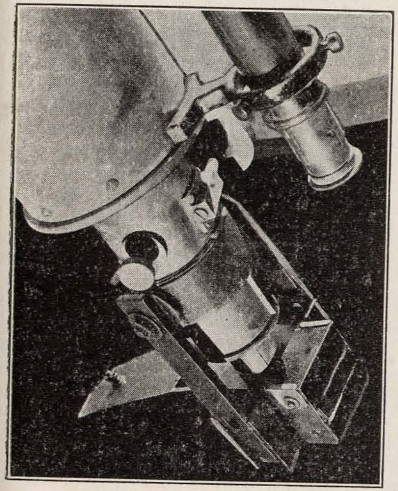
A single photograph of a spectrum, says Dr. Adams, will yield a value of the intrinsic brightness and distance of a star, and it is applicable to stars whose distances are so great that the usual direct method of measurement cannot be used. The nearest star to us is at a distance of twenty-five million million miles, and most of even the brightest stars are from ten to one hundred times further away. As seen from these greater distances the earth's orbit becomes almost vanishingly small. In the spectroscopic method, however, the intrinsic brightness of a star can be determined equally well whatever the distance. This method has nearly tripled the number of stars of which we now know the distance.

From a star's light we can measure its position, its slow movement across the sky, its brightness and its distance, but we can do a great deal more. By analyzing its light we can study its individuality, which is defined almost as uniquely by the faint rays of light which reach us as is the personality of a friend by the actions of his daily life.

"We have every reason to believe that there are no great differences in the composition of the heavenly bodies. Why then do we not see in their spectra the lines of all these elements? The answer is a very simple one. The Sun and the stars are too hot or too cold, too rare or too dense, to show all the lines at the same time. It takes more energy to rob some elements of their electrons than it does others. A sun-spot and the red stars are comparatively cool, and the temperature is high enough to bring out strongly only those lines of the elements which require little energy for their excitation. So the low-temperature lines are strong and the lines of ionized elements are weak. At the higher temperature of the general surface of the Sun the ionized lines become stronger. When we come to the hottest stars the elements become completely ionized, the lines due to the normal atom disappear, and we have a spectrum consisting solely of lines due to very highly excited atoms. The spectra of the hottest stars, accordingly, are very simple, consisting of lines of ionized helium, doubly or triply ionized oxygen, nitrogen, and one or two other elements. It would be quite possible, therefore, to conceive of a star so hot that it had no lines at all—at least, in the part of the spectrum we can observe."—*Adams.*

ASTRO-PHOTOGRAPHY

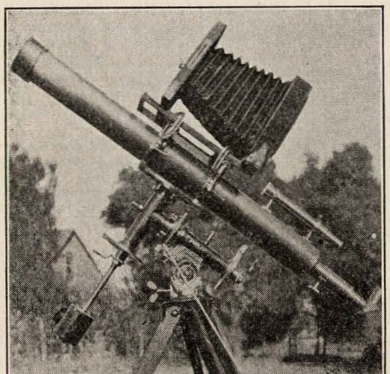
SUCCESS in visual observation leads sooner or later to an enquiry into the methods of stellar photography as practiced by aspiring amateurs ever seeking new angles on celestial problems. And, excepting work with the spectroscope, there is nothing more interesting in process nor gratifying in results. In star-work the unexpected is constantly happening; and instances are by no means rare wherein some obscure astro-photographer has been "on the job" at some critical moment and given to the world an imperishable record of some celestial event, becoming, as it were, internationally famous over night.



Improvised CELESTIAL CAMERA, attached to a four-inch Refractor, showing Holder for a No. 500 Film-pack, sliding Slit-shutter, and reticled Finder for hand-guiding when necessary.

Visual observation is at best a fleeting, and at times, a wholly unreliable impression; a photograph is a definite and lasting memorial. The human eye sees imperfectly after a few tense moments; the sensitized plate never tires: its effect is cumulative. If astronomy were still dependent upon the "drawings" of celestial phenomena that passed credence in the elder Herschel's time, how limited would be the scope and preposterous our concepts of the familiar gems as revealed to us by the modern witchery of the sky-camera! In truth, it has revolutionized the science.

It is not to be expected that with simple home-built apparatus one can compete in long-distance contests with the great observatories with their colossal power-driven telescopes that hold their far-seeing eyes on remotest objects for twenty to thirty hours in five-hour nightly shifts. Nevertheless, a genuine thrill of accomplishment rewards the investigator who makes his first excursion in celestial snapshotting; and the chances are that his very first evening's returns will prove gratifying, perhaps even valuable as a record of some unique celestial happening



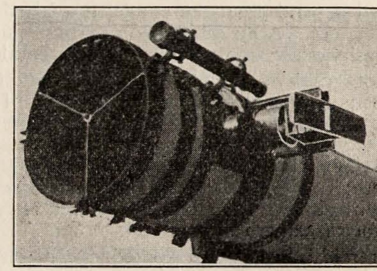
An 8x10 View Camera, equipped with old-style Portrait Lens, mounted on an equatorial Refractor for long-exposure guiding in R, A. -- a very fair substitute for the costly driving-clock.

If, among the relics of an old-time photo-gallery, the treasure-trover discovers a portrait lens (preferably of English manufacture), such as did service in the slow pre-dry plate days, he may consider himself very fortunate. Speed is no object in star-photography, so in these days of the miracle-lens the old-school portrait type is salvaged for celestial uses.

Whatever size plate the lens may cover, it may be installed in a view-camera mounted securely on an equatorial placed in the meridian, a central star of the field being followed at the eyepiece during an exposure of six to thirty minutes, depending upon the lens, the plate, atmospheric conditions, and the sky-region sought. Longer exposures are very fatiguing, and the brighter units suffer by halation in an effort to grasp the fainter star-clouds, clusters or nebulae that abound so generously in almost every constellation, notably in or near the Milky Way. If the mounting is altazimuth instead of equatorial, a meridian star-field is preferable since at culmination there is the least concurrent motion in declination, and following a key-star in right ascension is not so difficult to insure clean, sharp star-images.

In photographing single units, such as the members of our solar system, an improvised camera, capable of holding a small film-pack and provided with a slit-shutter, takes the place of the eyepiece of either refractor or reflector, receiving the image at the focal point without ocular magnification, leaving to darkroom treatment the enlarging of the negative print to any size that the grain of the emulsion will stand. The image of the Moon, for instance, at the primary focus of a ten-inch reflector is eight-tenths of an inch, plus.* This seems very small: but a good sharp negative of even smaller size, (preferably one taken thru a light yellow ray-filter), will stand enlargement up to six or eight times its size, particularly if an enlarged negative, (three or four times the size), is first made from the original, and the Velox or bromide enlargement made from the latter.

Another method involving the use of a regular Huyghens ocular, or a Barlow (double concave) lens to enlarge the image on the plate or film-pack, using a common hand-camera secured to the ocular-tube, produces some fine results in skillful hands. However, the incident loss of light and the necessarily increased time of exposure present difficulties that only considerable practice successfully overcomes. The reflector image is practically self-corrected for photographic rays; but in the refractor the chemical and the visual rays differ, making a shorter focus for photography imperative to insure sharp details. Magnification of the image also demands an increase in exposure-time in regular ratio: twice the diameter, four times the exposure; thrice the magnification, nine times the ex-



Film-pack Camera attached to a 10″ Reflector, (reversed in the cut to show slit in Slide), very practical for lunar and solar photography.

*RULE: To find size of image of Sun or Moon (angular diam., 31′) on ground glass of camera at primary focus: Divide focal length of telescope by .111. Ex.: Focal length of 10-in. reflector, 90 in. Divided by .111 gives .81, or a little more than four-fifths of an inch.

posure, etc. This calls for an equatorial mount and careful guiding, as well as quite perfect atmospheric conditions. Of course, during a lunar eclipse, the occultation of a major planet or a first-magnitude star, p. e., Aldebaran, or like interesting event, (fully worth while taking all kinds of pains), a slightly prolonged exposure is desirable.

Snapshotting sunspots at the primary focus is fascinating work, and the results, (during a sunspot maximum, for instance), are sometimes very valuable. If plates are used, they should be the slowest obtainable, and the shutter the fastest you can devise; and even then the mirror or lens must be "stopped down" by placing over the field-end of the telescope a blackened cardboard or aluminum hood in whose exact center is sharply cut a round hole whose diameter is not greater than one-sixth of the diameter of the lens or mirror. Even this may admit an over-abundance of light and a smaller superimposed diaphragm found necessary. It will all depend upon the emulsion used, the speed of the shutter, etc. Adjustable diaphragms of various apertures are easily made, and experiment is the guide to perfection.

Photography of the planets is the most difficult and least compensating of all, for even the products of the great telescopes leave much to be desired, since the limited areas under reflected light and atmospheric obstacles planetary and terrestrial give the images the appearance of flash-shots at sea-bottom: interesting but inconclusive as regards details. The experiment is worth the trial, nevertheless, preferably with a refractor-camera and a Barlow amplifying-lens ocular.

Asteroid-hunting with a portrait-lens camera mounted on an equatorial refractor is often fruitful of a rich results. By "focussing for infinity" on the zodiac, (the path of all the planets, major and minor), and following the stars for a half-hour or more with due care, the latter will show themselves as small round dots; whereas the planetoids, if any may be present, will disclose themselves by distinct trails, owing to their motion in space. Many observers reverse the process, swinging the camera counterwise in right ascension at the speed-rate of the little "wanderers," in which case the stars will describe elongated streaks, while the asteroids will punctuate the field with perceptible round dots. Report should be made of the detection of any planetoid, (or any other uncharted celestial visitant, for that matter), with full data, to the nearest professional observatory where it will receive due consideration, and doubtless elicit some very valuable advice. (See p. 77).

The darkroom work in conjunction with stellar photography is so simple and interesting that few will choose to pass it on to the commercial professional, once they have known its charms. There are professionals who so delight in producing something new and beautiful that they will give your precious exposures the time and care necessary to attain the best results; but I have seldom tried to save time and labor that way without undue expense, and then done the work all over again to completer satisfaction.

Instructions in the art of enlarging on any of the standard sensitized papers may be had for the asking, and elaborate apparatus is not necessary. A small bellows-camera with a good lens, backed up against a hole in the darkroom wall will throw on a screen an enlarged image of any negative placed between glass plates in the plateholder's groove. A sheet of ground glass will diffuse the sunlight thru the orifice by day, or the light of a hundred-watt lamp suspended behind it for enlarging by night. Sharp-focussing with a hand-magnifier, and test-slips to gauge the timing to best advantage will secure the utmost that the plate can give; and as experiment along these lines is inexpensive, one can afford to be satisfied only with the best prints obtainable.

In developing the original plate or film, it is unwise to indulge in any of the intensification or reduction methods so dear to the victim of mistaken exposure—mercuric chloride, red prussiate, etc.—which usually fall down in celestial work. Of course in the case of an eclipse or some event not soon to be duplicated, when it is a matter of risk something or lose all, any corrective might be justified; but any celestial exposure that has been so treated usually shows it to its detriment.

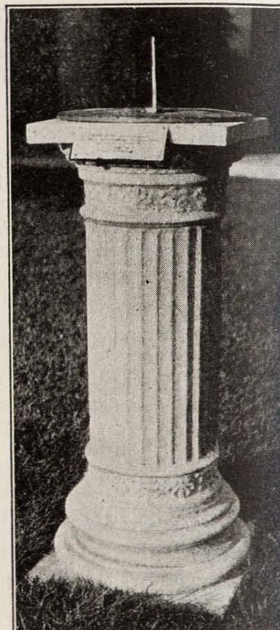
If the product of your skill is of timely interest, such as a comet, fireball or an eclipse, it is likely to be not only of scientific value but may command a good price as a news feature. The world at large is always attracted by whatever things strange and beautiful are presented with authority, and a picture is an open book—one perceives at a glance what printed pages might not half so clearly reveal.

High-power oculars on objects like Jupiter give an expansive image at the expense of detail. The temptation to "strain" your lens, whatever the aperature, is sometimes very strong; but after a little practice, medium powers will be found to be the best working aids. A Barlow lens (double concave placed in front of the ocular train) is an admirable expedient in planetary work with favorable skies. It broadens the image beautifully without much loss of detail.

THE SUN-DIAL

"Ye Dial is ye Book of ye Sun on which he writes the Storie of the Day."—Robert Hegge, 1630.

OBSERVATORIES thruout the world are apparently pleased to render homage to man's first mechanism by which he linked celestial phenomena with practical daily life, since before their doors, or somewhere on their walls, are erected manifold variations of this most venerable of time-pieces—memorials of the marriage of mathematics with mundane affairs in its first form adaptable to the needs of the humble layman. From Isaiah's time, seven hundred years before Christ, to the middle of the eighteenth century the sun-dial was man's sole time-giver. It is no wonder that while its uses have been largely superceded, veneration for so noble a relic remains in all civilized communities, and thousands are set up every year as household Lares in the great family of Time. It is a living tribute—a perpetual noonday salaam to the astronomy of the ages.



SUN-DIAL erected at Fountain Oaks, California.

Sun-dials are among the world's most beautiful and treasured reliquaries; and, unlike any other that we signalize, belongs to no one nation or age, but to every people and clime where "ye Sun writes hys chronicles in ye silent Voice of Time, and without which ye Day were dumbe!" It

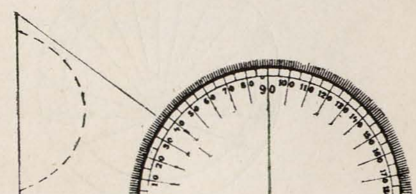
is no wonder that the story of gnomonics comprises whole libraries, and that from simple beginnings it developed into the dignity of a science at the hands of the dialling Daniels who complicated the rudimentary forms without very materially augmenting their efficiency.

Fundimentally the sun-dial has remained the same for several thousand years: a levelled and oriented surface upon which is engraved the symbols of the Sun's march from a few hours before high noon to as many hours after, his progress traced by the shadow of an upright gnomon, (Gk.: an interpreter), placed in the true meridian, and of an angle corresponding to the latitude of the place. The fact that it only approximates true Apparent Time but four times a year—April and June 15, Sept. 1, and Dec. 24—and at all times must employ an Equation of Time chart (See p. 169), in order to calculate Standard Time with only fair precision, does not greatly perturb the ambitious gnomonist. He will attain the hightest degree of accuracy within his skill; but he is bent upon producing something truly scientific and beautiful without entering into competition with the chronometer and the radio, and verily he has his reward.

Page 311.

As the gnomon is to the sun-dial what the hands are to the clock, too much care cannot be exercised in its construction. The altitude of the Pole being equal to the latitude of the observer, (and as latitudes differ thruout the length and breadth of the land save those points that are laterally indentical), commercial dials that are generalized for mere ornament are usually worthless as time-givers—at least without careful revision. To plan your gnomon (knowing your latitude), it is only necessary to strike an oblique line thru the arc of a protractor at the proper in-

A Pattern for the GNOMON is easily made by drawing a line thru a protractor at the point indicated by the Latitude of the Station.



tersection, shaping the triangle to correspond, afterwards checking with your goniometer sighted on the North Star. The permanent gnomon may be cut out of eighth-inch sheet

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brass, (or quarter-inch if the base exceeds a foot in diameter), fixed solidly in position, the whole resting upon a firm foundation proof against jarring out of place.

The Equation of Time Chart, (p. 169), which is computed to mins.—as close as any common or garden sun-dial demands—may be copied and waterproof-framed to be fixed to the standard for easy consultation; or better still, etched in bronze, and secured to the time-plate below the gnomon.

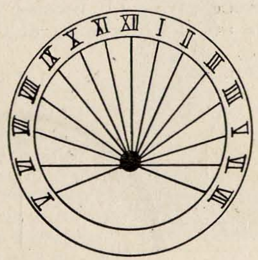
Having placed the gnomon with utmost precision, when the next date falls whereon Civil Time and Apparent (sun-dial) Time are identical—i. e., April 15, June 15, Sept. 1, or Dec, 24 — a check may be made on the hour-divisions and subdivisions with an accurate timepiece, since on these dates only of the entire year no plus nor minus calculation is necessary. The division-points, thus checked, may be made permanent.

Variations in dial-making may be gathered from authorities comprising some of the most ingenious exponents of the noble art of gnomonics for the past thousand years, the products of whose genius are still "recording sunny hours" wherever on earth—

> "the golden Sun
> Gallops the Zodiac in his glittering coach,"

and scores of forms are readily accessible to the seeker after the archaic and unconventional. (See Book List).

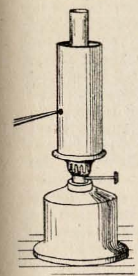
> "Till now you dreamed not what could be done
> With a bit of rock and a ray of sun!"—Lowell.



In laying off the design for the Dial, the point of radiation should lie midway on the line drawn between the figures VI, as indicated.

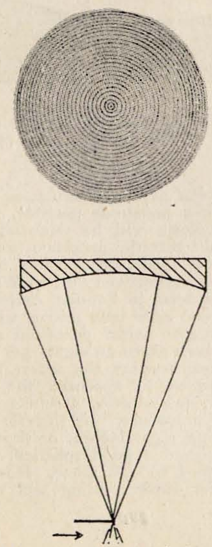
APPENDIX

MIRROR TESTS. (Reference from p. 232).



The principle of the Foucault knife-edge test is easily grasped; but in practice so many variations of light and shadow arise that the student may often find himself puzzled to know just wherein the faults may lie, and particularly what remedies may be applied to correct them. Many have given up in despair and taken their handicraft to a professional, paying a generous fee to have their mirrors brought to perfection, while others have stuck it out, as it were, and been finally rewarded with complete success, gaining very valuable experience by the way. No part of the optician's job requires such patience and care in every detail, and yet nothing gives greater satisfaction than this process of correction well accomplished.

Once the true center of curvature is found, (a lighted candle or the lamp minus its shade will aid in determining it approximately), and both the artificial star and knife-edge set with extreme accuracy, it will be noted that if

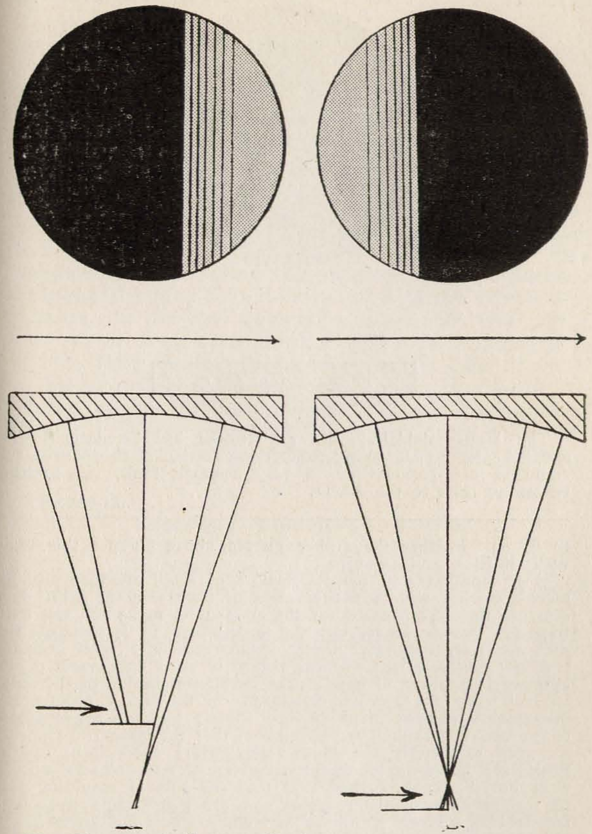


Spherical Mirror under the knife-edge test.

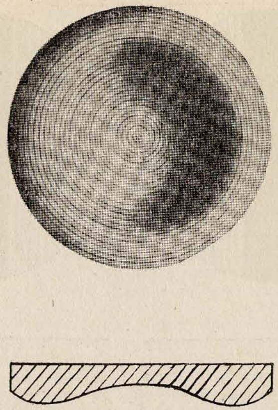
the latter is passed into the cone of light from the mirror at a point inside the true center of curvature, the mirror will appear to darken on the same side as the knife-edge; while if the latter is withdrawn beyond the center, the shadow will be seen to move across the field from the opposite side. At the true point all rays from the pin-hole "star" will be reflected back with even illumination all over the field, if it be a true sphere. It is then that any inequalities become distinguishable as seen by the highlights and shadows over the various zones of the disc, denoting the high or low areas. It is somewhat confusing at first to interpret these lights and shadows, but in a general sense it may be said that excessive high lights denote the areas that are slightly raised, while the shadows indicate depressions. It is the art of the optician to interpret these evidences of deviation from the true sphere, and by altering the tool and stroke in polishing, wear down these zones which are high, or bring the entire surface to the level of the areas that are seen to be low. This is a very delicate procedure and frequent testing is imperative to avoid overdoing it, for a condition of under-correction is far better than over-correction—a fault that is prevalent in even professional handicraft. Glass is the most sensitive material to work on that can be imagined; and a correction of some thousanths of an inch is enough to make or mar a polished surface, approaching perfection or working away from it. Repeated tests are the only criteria of progress.

A cross section of the parabolized Mirror of comparatively short Focus. The depth of the curve of one of longer focus is very appreciably less.

In order to attain a perfect parabolic figure, as faultless a spherical surface, with as high a polish as possible, is essential; else the delicate parabolic shadows will be misinterpreted or missed entirely. There is no doubt that the parabolic form tends to bring all rays to a more perfect focus, particularly in larger mirrors where parabolizing is quite imperative; but, as Wright has pointed out in his article on this subject in Popular Astronomy, (No. 387, q. v.), "a perfectly spherical eight-inch mirror with a focal length of eight feet will usually give better definition than one of four feet focal length that has been given an eighty per cent correction." There is so little difference between the sphere and the parabola that the optician is tempted to approach the hyperboloid (as shown in the illustration), necessitating a return to first principles —always a discouraging procedure. If, therefore, the mirror be of a diameter not exceeding eight inches, or thereabouts, and the amateur optician has achieved a good spherical form under test, it might be well to let good enough alone. However, it is quite likely that his passion for experimenting will rarely allow him



The Foucault knife-edge Shadow as seen passing over the surface of the Mirror when the cone of light is cut into from a point inside the center of curvature (left), and also when the rays are cut into from a point outside the true center. At the true center, however, the entire field of the sphere is illumined with an uniform greyish sheen, whose faint lights and shadows, if such there are, instantly become evident. (Drawn by Dr. von Krudy).



The Hyperboloidal Figure as attested by the deep shadow and indicated by the exaggerated cross section of the Mirror, the result of over-parabolizing—a very common fault, necessitating refiguring back to the sphere.

to do so. Further the author quoted above pursues this topic with clearness and authority:—

It is amazing that more reflectors of small aperture are not made spherical with aperture ratios of from f 10 to f 13. Not only are they much easier for the amateur to make and test than those of shorter focus, but the aberrations for points off the axis are less, they give better results generally with ordinary two lens eyepieces, and are less critical of exact adjustment of the eyepiece to position of best focus. Perhaps it is due to the tendency to copy the relative dimensions of the larger professional instruments without inquiring very closely into the requirements of the case. It should be remembered that the larger instruments are used exclusively for photography where short focus instruments are desirable to obtain negatives of faint objects with a minimum of exposure time, and that the cost of mounting and the accessibility of the eyepiece end are increasingly important factors with increase in aperture. None of these limitations apply to a small instrument. A reflector 6 to 8 feet long is inexpensive to house and convenient to use, and the amateur's photographic efforts if any are likely to be confined to the brighter objects unless he is blessed with a precision mounting that few of us can afford. It is perhaps significant that most of the early reflectors built before the advent of photography were of f 10 or longer, particularly those of moderate aperture.

COMPUTING RADII FOR SMALL TELESCOPE OBJECTIVE. (Reference frcm p, 250).

A simple rule frequently used to determine the radii for a telescope objective of Chance (Eng.), crown and flint glass is given by Mr. Donald E. Sharp, Hamburg, N. Y., as follows:

Make the first three radii numerically equal to four-tenths (0.4) the desired focal length. The last radius is found by multiplying the first radius by the flint dispersion and dividing the product by the difference between the flint dispersion and twice the crown dispersion. If the flint dispersion is greater than twice the crown dispersion the last radius is convex; if it is less, then the last radius is concave. The crown is in front and is equiconvex. The flint is concave to fit the crown on one side and may be cemented if desired. Quite commonly the last surface of the flint has such a long radius that it may be finished flat.

Example:

Flint has dispersion 0.01670
Crown has dispersion 0.00800
Desired focal length 64 inches

Crown 1st radius = (0.4) (64) = + 25.6"
(Convex)

Crown 2nd radius = (0.4) (64) = + 25.6"
(Convex)

Flint 3rd radius = (0.4) (64) = — 25.6"
(Concave)

Flint 4th radius

$$= 25.6'' \times \frac{0.0167}{(0.0167) - 2(0.008)} = +\ 611'' \text{ convex}$$

When the flint dispersion is twice the crown dispersion (or very nearly so) the last surface of the flint is plane and the objective consists of a double convex lens and a plano concave flint. The first three curved surfaces are of equal radius in any case. The ratio of diameter of focal length is usually not over 1 to 15.

SILVERING

U. S. Bureau of Standards. Circular 32. (Supplementary to p. 234)

Cleaning the surface to be silvered is the most important part of the process, whatever formula is used.

Make a swab by winding absorbent cotton on the end of a glass spatula or glass rod, with sufficient thickness of cotton so that there will be no danger of scratching the glass with the rod. With such a swab and pure nitric acid, to which a little distilled water may be added, clean *every* part of the surface; considerable pressure should be used in rubbing with the swab. Do not let any part of the glass become dry in this process; if it does, swab and clean again. Rinse off the nitric acid, for which ordinary water may be used at first, followed by distilled (or rain) water. Finally leave the mirror in a tray or other container, covered with distilled water, until ready to silver. *No part of the mirror should be allowed to become dry.*

THE BRASHEAR FORMULA

This process is probably used more than any other for silvering the surface of large mirrors used in reflecting telescopes, and laboratory mirrors where a thick coat is desired.

For most work the following proportions will be found adequate:

Sq. cms., divided by 40, (or, Sq. inches by 6), equals Grams of Silver Nitrate required. (For very thick coat: substitute 27 for 40 and 4 for 6).

CAUTION: In using the Brashear process keep the solutions, and do the silvering, at a temperature of about 15°C, or 59°F. In hot weather it is advisable to use ice to keep the temperature of the solution below 18°C. (64°F). If warmer than this the resulting coat is apt to be soft, and there is danger of the formation of small amounts of silver fulminate, *which is very explosive.*

The reducing solution:

Rock candy	90 grams
Nitric acid (sp. gr. 1.22)	4 cc
Alcohol	175 cc
Distilled water	1000 cc

This reducing solution is preferably made up in advance; the older it is, the better it will work. If necessary to use at once, the action may be improved by boiling it, adding the alcohol after it has cooled.

The silvering solution: (Make up just before silvering.)

A	Distilled water	300 cc
	Silver nitrate	20 grams
	Strongest ammonia, as may be needed (see below)	
B	Distilled water	100 cc
	Caustic potash	10 grams
C	Distilled water	30 cc
	Silver nitrate	2 grams

In solution A, after the nitrate is all dissolved, add ammonia gradually. The solution will at once turn a dark brown. Continue adding ammonia, drop by drop toward the close of the process, until the solution just clears up; avoid an excess of ammonia. Then pour in Solution B; the mixture will again turn dark brown or black. Again add ammonia, drop by drop toward the close, and stirring constantly, until the solution just clears up again. It should now be a light brown or straw color, but transparent.

Next add slowly, stirring constantly, as much of the reserve silver solution, C, as the mixture will take up without turning too dark; it is important that the nitrate of silver be in excess. Continue this till there is quite a little suspended matter, which the solution refuses to take up. Filter through absorbent cotton.

When ready to silver, pour into this mixture about 6 cc of the reducing solution for each gram of silver nitrate used, and pour at once upon the mirror, which has been lying covered by about the same amount of water as is used in the solutions; this water need not be poured off.

The process will be finished in from three to eight minutes, depending on the temperature of the solutions, which should never exceed 18°C (64°F). It is well to make preliminary tests in small beakers or drinking glasses to get the time necessary as the coat is apt to bleach if process is continued too long. Keep solution in motion so that the thick sediment which forms will not deposit on the silver coat. A *very* light swabbing with loose absorbent cotton over *every* part of the mirror, will be found advantageous in large mirrors, as soon as the coat begins to form. Avoid exposing the surface to the air for more than a second or two at a time to observe progress.

Get the spent solution off quickly at the close of the process, rinse thoroughly, first with ordinary and then with distilled water; swab lightly with absorbent cotton while rinsing if there is much "bloom" on the surface.

THE ROCHELLE SALTS PROCESS

Solution A:

Silver nitrate	10 grams
Distilled water	100 grams

To this add concentrated ammonia until the precipitate first formed is just redissolved (care used in mixing well).

Then drop by drop add 10 per cent solution of silver nitrate in water until the solution is opalescent.

Dilute to 1 liter, filter and bottle.

Solution B:

Silver nitrate	2 grams
Rochelle salt	1.66 grams
Distilled water	1 liter

Bring the solution of silver nitrate in distilled water to a boil. Then add Rochelle salt dry. Boil 5 minutes, stirring all the time. Filter and keep in dark bottle.

To silver:

Use equal parts A and B at room temperature. The deposition of silver on the glass surface will be more rapid and complete if that surface is several degrees warmer than the solution.

THE FORMALDEHYDE PROCESS

The Reducing Solution:

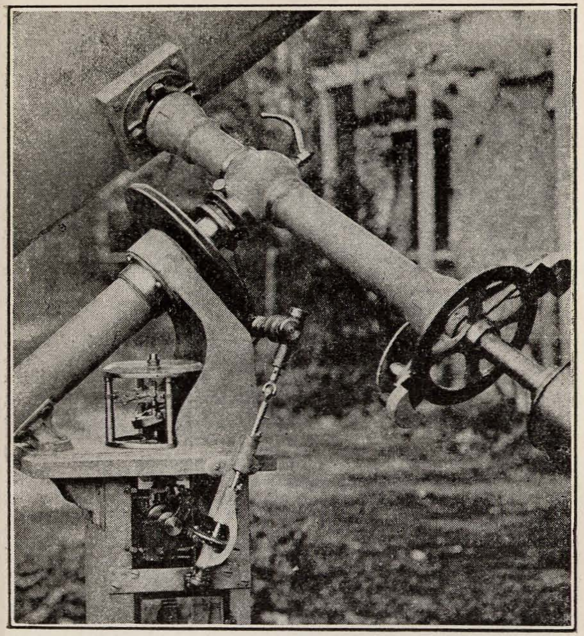
Distilled water	200 cc
Merck's formaldehyde	40 cc

The Silver Solution:

Distilled water	1000 cc
Silver nitrate	21.6 grams

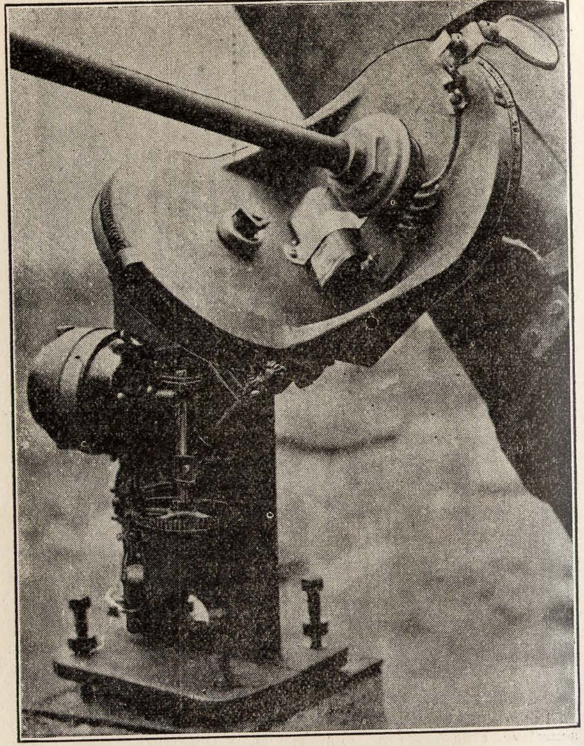
Add strong ammonia gradually and clear up fully.

Mix these two solutions thoroughly and quickly and pour on the mirror; keep solution in motion. When the solution is clear with the exception of small black grains like gunpowder, and these appear to be depositing on the silver coat, the process is complete. Rinse thoroughly. Temperature about 20°C (68°F).



JOHNSON'S WEIGHT-DRIVE CLOCK

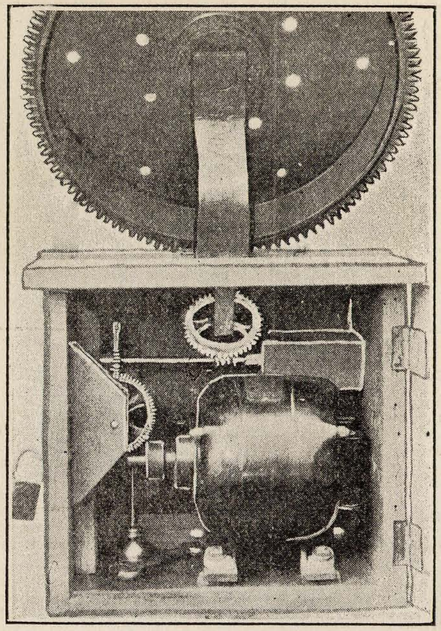
This clock is of the weight-drive type, controlled by a very sensitive ring-governor enclosed in a plate-glass case. The gears are of standard 48 pitch. The winding barrel is five inches long and three inches in diameter. The plates are made of bronze—a pattern is made of wood and casting made from it. The separators for separating the plates are made of five-sixteenth cold rolled steel; but the shafts of five-sixteenths drill rod, and pivots not less than one-eighth inch diameter. The gear ratios are as follows: The barrel should make 8 RPM, the main drive shaft 16 RPM, and the governor 150 RPM. From the main shaft to driving worm there should be a 12 to 1 reduction gear as the worm should make one revolution in four minutes, and the polar axis one degree per minute. I am using a five-eighths worm with eighteen threads per inch.



A 10″ WITH MOTOR-DRIVE AND GOVERNOR

Designed and built by Raymond D. Cooke, Nameoki, Ill.

The speed of the motor is 2400 RPM. The first worm gear has 30 teeth, the second 20, the third 30, giving the last worm a speed of one revolution in 7.5 min. The six-inch gear on the polar axis has 192 teeth, giving the required one revolution in 24 hours. This view also shows the declination circle with the reading glass and the flashlight and battery. The motor is shunt wound for six volts. Just below the binding posts can be seen a small resistance, which is normally in the armature circuit. When the governor falls low enough to make contact with the small spring below it, this short circuits the resistance and causes the motor to run faster.

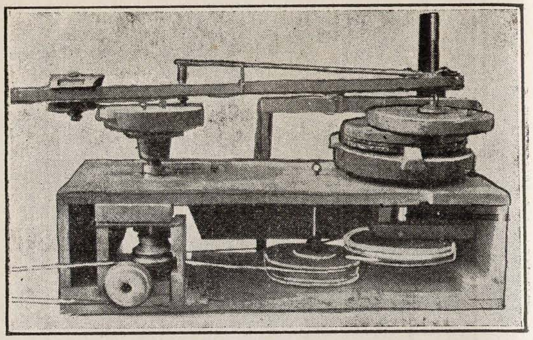


A MOTOR-DRIVE CLOCK FOR 12″ REFLECTOR

Designed and built by Dr. J. J. Byl, San Jose, Calif.

The motor in this electric drive is of the induction type of a rated speed of 1725 RPM. As the load is light for the ¼ HP capacity, this speed will be reduced but little, making the movement of the telescope in right ascension just about right with the following assemblage of gears and worms: 24 pitch worm on motorshaft on 24 pitch gear, 72 teeth; 24 pitch worm on 24 pitch gear, 72 teeth; 16 pitch worm on 16 pitch gear, 48 teeth. The last gear is on a shaft that is fitted into the assemblage of an automobile starter and is either held or released by the set screw on this assemblage. The pinion of this assemblage has 12 teeth which engage the ring gear of 119 teeth. The pinion can be thrown out of connection with the ring gear by loosening the set screw and turning this sleeve on barrel.

The ring gear is shrunk on a brake drum, which happened to be just the right size. The pulley on the motor shaft can be fitted with a friction band to slightly reduce the speed of the motor should this be necessary.



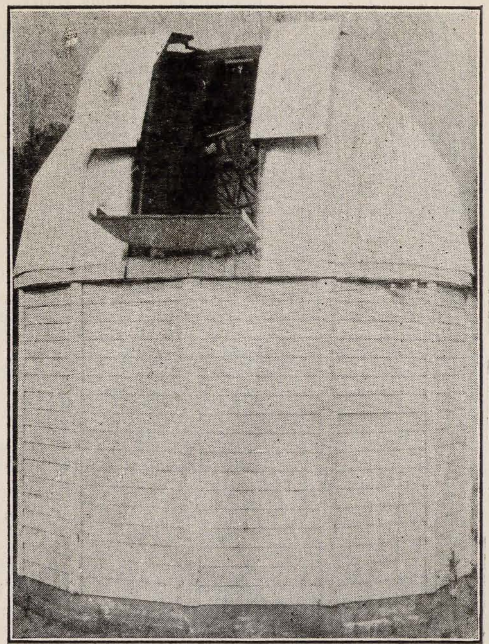
A PRACTICAL GRINDING MACHINE

After having ground and polished his third or fourth mirror, the amateur optician will likely turn his fancy toward some sort of a machine that will possibly lighten his labors, and at the same time meet the requirements in general efficiency. There are many practical types of grinding and polishing machines, but for the most part they are for use in commercial instrument works, highly technical and costly. However, there are some of less intricate design, like that seen here, which the mechanically-minded experimenter will be able to build almost from sight from the clearness and simplicity of the parts as shown in the reproduction—a serviceable auxiliary to any optician's bench, and a very palpable test of one's skill with tools.

The portable grinding and polishing machine shown above was built by Donald Perry, Glendale, Calif., a member of the Amateur Telescope Makers Society of Los Angeles, Calif.

The top of the right hand vertical shaft carries a hardwood plate (having 3 clamping jaws). Upon this plate is placed the glass disc for grinding. Shaft is driven by ¼ HP motor whose speed is reduced by pulleys until plate revolves about 60 times per minute (worm gear drive may be used in place of pulleys and belting).

The top of the worm driven rotating shaft (both the shafts are driven at about the same speed) carries a hardwood disc, the upper side of which is slotted to hold an adjustable bearing, that provides eccentric motion for the slotted hardwood connecting rod, which transmits the reciprocating motion to the grinding disc. The left end of the connecting rod has adjustable counterbalances so that the weight on grinding tool may be lessened as fine grinding and polishing begins. The opposite end of the connecting rod carries a pawl on the end of rod to rotate the holder, giving it a slow ratchet motion. The adjustable arm is anchored at one end, the other being clamped in the slot of the arm and provides a method of regulating the stroke.

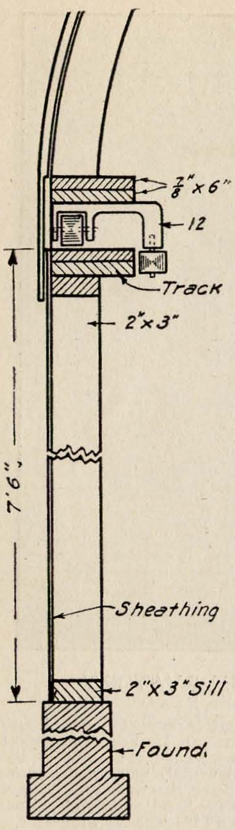


A LOW-COST OBSERVATORY

Constructed by E. H. Morse, Pasadena, Calif.

While an observatory is not an imperative necessity for the housing of either reflector or refractor in most temperate localities, (since most any sort of covering will suffice when the instrument is not in use), there is something quite "professional" and cosy withal about a walled enclosure, whether with sliding roof or revolving dome, that makes for privacy and concentration on the observing program at hand, and many will wish to build them. Mr. Morse observes with a 15″ home-built reflector.

The building shown in above cut is 12′ in diameter and 14′ high, is built of 12 sections, 3′ each. The foundations are 6″ concrete, with 10″ footing and of sufficient depth to reach below frost line. Anchored to this foundation is a 2x4 mud sill. The upright side studding is 2x3 set 1′ 6″ centers. These also built in 12 sections of 3′ each and spiked to mud sill. On top of this studding is spiked a 2x3 plate. On this plate is nailed a circular wooden track plate built up of two thicknesses of ⅞x6″ boards (joints lapped, hardwood preferable, the circular tracks should be cut on a band saw). Run 12 sets of rollers upon this track plate to carry the dome. These rollers are fitted in a cast-iron



bracket so that one roller 2" face and 3" diameter rides on top of the circular track and one roller 1½" face by 2" diameter runs on inside edge of circular track, to keep the dome in place. Resting upon, and bolted to the top of the roller brackets, is a built-up circular dome plate, consisting of two pieces ⅞x6" wood, same size and construction as track plate. Upon this dome plate is built the ribbed revolving dome. The framing of the dome consists of 12 ribs, 2x3, sawed on a 6' radius and spiked to dome plate. These ribs framed together at the top having two or three lines of 2x3 horizontal stiffeners spaced equally. All lumber dressed.

After framing dome, construct in one of the 3' openings a parallel opening for the two hinged curved shutters. These shutters are made with over-lapping edges to prevent leakage. The entire dome is covered with 28-gauge galvanized iron, tacked on ribs with double thickness strip of roofing paper and 2"x½" wood strips to fasten same to ribs. The galvanized iron should extend 3" below the level of the track plate for protection from weather. Below the track plate cover with sheathing; locate door and window to suit and paint the whole two coats of good oil and lead paint.

The dome may be revolved either by hand or motor. The size of the dome is governed by the size of the telescope. This dome was originally built for an 8½" reflector and now houses a short focus 15" reflector. The height will depend on possible interference by nearby trees and buildings; avoid proximity of heated chimneys as heated currents of air prevent good visibility. The concrete foundation of the telescope is separate from and independent of the floor or building.

This plan may be modified to lessen labor and material cost. The foundation and building up to the height of a circular track might be made square in the place of 12-sided, as shown in cut.

Use 4x6 mud sills, anchored to posts of either wood or concrete in place of all concrete foundation.

Build dome square or hexagonal, without curves, and cover with double thickness of tar paper or single thickness of heavy painted canvas.

BCOK LIST

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Gaertner Scientific Corp., 1201 Wrightwood Ave., Chicago, Ill.
Wm. Mogey & Sons, Inc., Interhaven Ave., Plainfield, N. J.
S. Junkunc, 213 So. Aberdeen St., Chicago, Ill.
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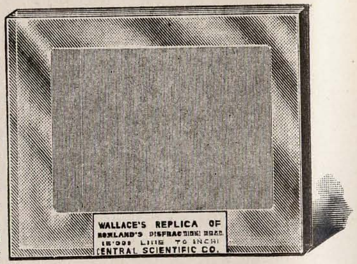

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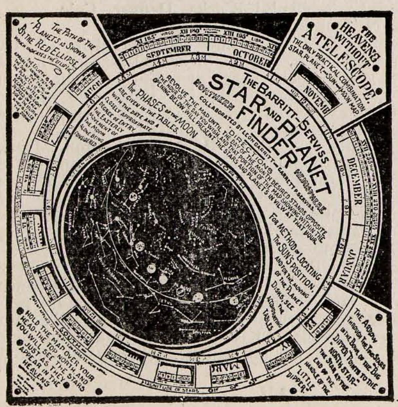

(See p.306).

The John M. Pierce Telescope Works, of Springfield, Vt., assists amateurs with advice and supplies of all kinds for reflector building, etc. Correspondence invited.

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GENERAL INFORMATION
AND
GLOSSARY OF TERMS

ASTRONOMICAL CONSTANTS AND SIGNS - TIME RECKONING - SIDEREAL TIME OF MEAN NOON TABLE - EQUATION OF TIME CHART - VARIABLE STAR OBSERVATIONS - CLASSIFICATION OF VARIABLES - DIAGRAM OF CIRCUMPOLAR REGIONS - CHART OF NEARER STARS - MEASUREMENTS OF PARALLAX - MISC., AND GLOSSARY

ASTRONOMICAL CONSTANTS, SIGNS, ETC.

Solar Parallax, 8″.80
Constant of Aberration, 20″.47
General Precession, 50″.2564
Moon's Eq. Hor. Parallax, 57′2″.70
Obliquity of Ecliptic, 23° 27′ 8″.26

LENGTH OF YEAR:
- Tropical (Equinox to Equinox), 365d 5h 48m 46s
- Sidereal, : : 365d 6h 9m 9.5s
- Anomalistic 365d 6h 13m 53.1s

LENGTH OF MONTH:
- Synodical (New Moon to New Moon), 29d 12h 44m 2.8s
- Tropical, : : 27d 7h 43m 4.7s
- Sidereal, : 27d 7h 43m 11.5s
- Anomalistic, 27d 13h 18m 33.1s
- Nodical, : : 27d 5h 5m 35.8s

LENGTH OF DAY:
- Sidereal, 23h 56m 4.091s, m. s. t
- Mean Solar, 24h 3m. 56.55s, sid. t.

EARTH: Polar Radius, 3949.99 mi.
Equatorial Radius, 3963.34 mi.
Mean Orbital Speed, 18.496 mi.-sec.
Mean Density, 5.53. Water = 1.
1° Lat.: 69.0569 statute miles.
1° Long.: 69.2316 statute miles.
1 Statute Mile: 0.868362 nautical.
1 Naut. Mile: 1.151594 statute.

Number of Stars brighter than →

Mag. *0* - 3	Mag. *8* - 46,200
1 - 11	*9* - 139,300
2 - 39	*10* - 380,000
3 - 133	*11* - 1,026,000
4 - 446	*12* - 2,590,000
5 - 1,466	*13* - 5,890,000
6 - 4,730	*14* - 13,120,000
7 - 15,000	*15* - 27,500,000
	16 - 57,100,000

(Harvard Visual Scale).
Limit of naked-eye vision, Mag. 6.
Ditto, telescopic, see page 18.

☌ Conjunction: two celestial units in same Longitude or R. A.—0°
☍ Opposition: Planet on opposite side of Earth from Sun — 180°.
□ Quadrature: Planet is in Long. 90° east or west from the Sun.
⚹ Sextile: 60° difference in Long., or Right Ascension.
△ Trine: 120° difference in Long., or Right Ascension.
☊ Long. of ascending node. Planet crosses Ecliptic from S. to N.
☋ Long. of descending node. Planet crosses Ecliptic from N. to S.
P — Period in years.
T — Time of perihelion passage.
M — Mean anomaly.

π Long. of perihelion point of orbit, reckoned from Vernal Equinox.
e Eccentricity of orbit; ratio of dist. focus to center to vertex to center.
a Semi-major axis; half the greatest diameter of orbit.
q Perihelion distance: shortest distance planet to Sun.
μ Mean angular motion of celestial body in unit of time
ω Angle of ascending node to perihelion point of orbit.
i Inclination of orbital plane to the plane of the Ecliptic.
G. C. T. — Greenwich Civil Time.
L. C. T. — Local Civil Time.
(Other signs and symbols, page 21).

TIME, Civil—Astronomical.—Beginning 1925, by international agreement, the astronomical day, computed from noon to noon, was changed to agree with the civil day, beginning at midnight. Astronomical twenty-four hour clocks were set forward twelve hours; but sidereal clocks remain unchanged. This change in no wise affects star-places or sidereal time relating to them, dealing only with the prediction of phenomena, the ephemerides of planets, comets, etc.; nor does it affect the Julian Calendar used in Variable Star work. Instead of A.M. and P.M., the twenty-four hour notation is employed: Hrs. 0 to 12 from midnight to noon, Hrs. 12 to 24, from noon to midnight. Greenwich time is quickly changed to Standard time by subtracting the number of hours of the observer's Standard time zone.

Sidereal Time of Mean Noon.—Good timepieces are essential to accurate star-work, especially a good clock or watch giving mean standard time from which the sidereal time may be reduced. A clock may be so regulated as to gain four minutes a day (3 min. 56.5 sec., to be exact), which is the star-time lead over the mean-time interval in twenty-four hours. Or, correcting the standard time noon radio signals for the observer's meridian, a reasonable approximation to sidereal time may be arrived at by computing the months, days, hours and minutes which have elapsed since the Vernal Equinox—noon of the previous March 22—and checking on a star of known right ascension as found in the charts.

For instance, at eight o'clock of the evening of Oct. 23rd, you begin observing and wish to check your sidereal time.

Noon, Mar. 22, to noon, Oct. 22, 7mo., at 2hr. per mo.	14hr.
Noon, Oct. 22, to noon, Oct. 23, 1 day	4m.
Noon, Oct. 23, to 8 P.M., observing hour	8hr.
Total, or Sidereal Time of observing hour	22hr. 4m.

Referring to Chart XXIII-C, opp. p. 159, we find that **alpha Aquarii,** directly on the celestial equator, culminates at R. A. 22hr. 1m. With telescope set in the true meridian, clamped in declination at 0hr., the instant **alpha Aquarii** reaches the center of the field of vision indicates the true sidereal time. Set your sidereal clock accordingly.

A still simpler method, without reduction, is to consult the following table which approximates sidereal time for the first, tenth and twentieth day of every month in the year.

SIDEREAL TIME OF MEAN NOON

To Mean Time Noon on the following dates, add the hrs., and mins., given in italics. The result will approximate Sidereal Time.

h. m.	h. m.	h. m.	h. m.
APR. 1 - *0 30*	JUL. 1 - *6 33*	OCT. 1 - *12 35*	JAN. 1 - *18 39*
10 - *1 11*	10 - *7 08*	10 - *13 11*	10 - *19 15*
20 - *1 52*	20 - *7 48*	20 - *13 50*	20 - *19 54*
MAY 1 - *2 32*	AUG. 1 - *8 35*	NOV. 1 - *14 38*	FEB. 1 - *20 41*
10 - *3 08*	10 - *9 10*	10 - *15 11*	10 - *21 17*
20 - *3 47*	20 - *9 50*	20 - *15 53*	20 - *21 56*
JUN. 1 - *4 34*	SEPT. 1 - *10 37*	DEC. 1 - *16 36*	MAR. 1 - *22 32*
10 - *5 10*	10 - *11 13*	10 - *17 11*	10 - *23 07*
20 - *5 50*	20 - *11 52*	20 - *17 51*	20 - *23 47*

Use

March 20 - noon = O (Zero) hour Sidereal time

See Page 17

Instructions—Find nearest date in left-hand column. Subtract or add 4m. for each day before or after observing date. Add time elapsed from noon to observing hour. If sum exceeds 24h., subtract 24. Result will be Sidereal Time of observing hour. Verify on some star of known R. A.

Ex.: Wanted—Sidereal Time of observing hour, 8 p. m., M. S. T., Mar. 17.

Nearest date, Mar. 20. Sid. Time, noon, as per above chart	23h. 47m.
Subtract 4m. per day for three days, Mar. 17 to 20	12
Sidereal Time of mean noon, Mar. 17	23h. 35m.
Add time elapsed from noon to observing hour	8 00
	31h. 35m.
Subtracting twenty-four hours	24 00
We have the Sidereal Time, 8 p. m., Mar. 17	7h. 35m.

Reference to Chart 8-C shows that Procyon (alpha Canis Minoris) comes to the meridian at 7h., 35m., decl. 5° 29′, north.

Equation of Time.—If the Earth's orbit around the Sun were a perfect circle, with no perturbing influences, sun-time would be uniform from noon to noon throughout the year; but such is very far from being the case. The Sun is sometimes "fast" by more than a quarter-hour, and sometimes "slow" by almost the same amount. This necessitates striking an average for the entire year and affixing it to a "fictitious" Sun whose noon-to-noon rate is constant to insure uniform time-service. Sun Dials, accurately oriented, give apparent time of the true Sun. In order that it may agree with the Civil Time of our work-a-day world, a fixed Equation of Time Chart is consulted so as to add or subtract the intervals between the varying apparent time and the uniform "fictitious" Civil Time. As ordinary Sun Dials approximate apparent time to the accuracy of minutes only, the seconds in the Equation Charts are discarded. Etched in metal (with a suitable motto), these charts may be made artistic as well as indispensable accessories to mounted dials.

EQUATION OF TIME CHART

Plus: Add mins. — italics — to Apparent Time on days indicated in left-hand column. **Minus**: Subtract from Apparent, or Sun Dial, Time.

JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.
Plus	1-*13*	1-*12*	1-*4*	1-*2*	1-*2*	1-*3*	1-*6*	1-	1-*10*	1-*16*	1-*11*
1-*3*	4-*14*	4-*11*	3-*3*	2-*3*	4-*1*	4-*4*	5-*5*	**Min.**	4-*11*	11-*15*	2-*10*
3-*4*	20-*13*	9-*10*	5-*2*	30-*2*	10-*0*	10-*5*	13-*4*	5-*1*	8-*12*	18-*14*	4-*9*
5-*5*	27-*12*	13-*9*	9-*1*		**Plus**	19-*6*	18-*3*	8-*2*	11-*13*	22-*13*	7-*8*
7-*6*		16-*8*	12-*0*		19-*1*		22-*2*	11-*3*	15-*14*	26-*12*	9-*7*
9-*7*		20-*7*	**Min.**		24-		26-*1*	14-*4*	20-*15*	29-*11*	11-*6*
12-*8*		23-*6*	21-*1*		29-*3*		30-*0*	17-*5*	27-*16*		13-*5*
14-*9*		26-*5*	26-*2*					19-*6*			16-*4*
17-*10*		30-*4*						22-*7*			18-*3*
20-*11*								25-*8*			20-*2*
24-*12*								28-*9*			22-*1*
29-*13*											24-*0*
											Plus
											26-*1*
											30-*2*

THE PRACTICAL OBSERVING OF VARIABLE STARS

ONE of the most fruitful fields of endeavor in practical astronomy, both from the standpoint of intellectual benefits to the observer and the advancement of science, is a systematic study of Variable Stars. There are many thousands of amateur—or, as Prof. Turner, of Oxford, chooses rather to term them, non-professional—astronomers thruout the world, who, while keeping alive the deepest interest in celestial phenomena, and possessing instruments either purchased or of their own construction, are nevertheless without a definite program in their observational activities, lacking the stimulus of concerted effort under professional guidance. The advantages of fellowship with co-workers in so admirable a pursuit is just what is offered by the American Association of Variable Star Observers—a society founded in 1911, with a present membership approaching four hundred in all parts of the world, and a quarter of a million recorded observations to their credit in the archives of the Association at Harvard Observatory.

"Long-period Variables, on account of their large range and slow variations, are well suited to the skill and requirements of the amateur observer. Continuity of observation for these and many of the irregular Variables is a great desideratum," says Leon Campbell, of that institution.

A Bulletin is issued bi-monthly from Harvard Obs., classifying Variables according to their predicted brightness:
(1) Stars brighter than mag. 8, for observers using small instruments, field or opera-glasses, or even the naked eye.
(2) Stars of mags. 8 to 10, for somewhat higher powers.
(3) Stars of mags. 10 to 12, for 3″ telescopes, or larger.
(4) Stars of mags. 12 to 14, for 5″ telescopes, or larger.
(5) Stars fainter than mag. 14, for large instruments only.
(See page 18: "Powers of Telescopes of Various Apertures").

As provided by the Constitution and By Laws of the Association, "Any person interested in the advancement of Variable Star work is eligible to membership." This presupposes neither wide technical training, the employment of any but low-priced, or better still, home-built equipment—anything, in fact, but good eyesight, clear skies, a little patience, and the wish and will to do a reasonable service in the furtherance of this important and progressive branch of practical astronomy. The Association does the rest: with

full printed instructions, the enlarged Fr. Hagen maps showing each Variable and its comparison-stars with their Harvard photometric magnitudes, and such personal assistance as the novice may require to attain true proficiency.

The magnitude-estimates as received monthly from observers in various parts of the world are carefully recorded, and duplicate lists published in "POPULAR ASTRONOMY" for comparison.

The Julian Day is the chronological reckoning employed in Variable Star work, since in calculations involving events often centuries apart, simple subtraction of one "J. D." from another suffices.

JULIAN DATE, ZERO HOUR, FOR EACH MONTH, 1927-1935
Add Number of Days and Tenths of a Day, (see Table), up to Observing Hour

	1927	*1928*	*1929*	*1930*	*1931*	*1932*	*1933*	*1934*	*1935*
JAN.	24881	25246	25612	25977	26342	26707	27073	27438	27803
FEB.	24912	25277	25643	26008	26373	26738	27104	27469	27834
MAR.	24940	25306	25671	26036	26401	26766	27131	27496	27861
APR.	24971	25337	25702	26067	26432	26797	27162	27527	27892
MAY	25001	25367	25732	26097	26462	26827	27192	27557	27922
JUN.	25032	25398	25763	26128	26493	26858	27223	27588	27953
JUL.	25062	25428	25793	26158	26523	26888	27253	27618	27983
AUG.	25093	25459	25824	26189	26554	26919	27284	27649	28014
SEP.	25124	25490	25855	26220	26585	26950	27315	27680	28045
OCT.	25154	25520	25885	26250	26615	26980	27345	27710	28075
NOV.	25185	25551	25916	26281	26646	27011	27376	27741	28106
DEC.	25215	25581	25946	26311	26676	27041	27406	27771	28136

STANDARD TIME IN TENTHS OF A DAY, Greenwich Mean Time.

Tenths	Eastern S.T.	Central S.T.	Mount. S.T.	Pacific S.T.
0.5	5:49 - 8:12	4:49 - 7:12	3:49 - 6:12	
0.6	8:13 - 10:36	7:13 - 9:36	6:13 - 8:36	5:13 - 7:36
0.7	10:37 - 13:00	9:37 - 12:00	8:37 - 11:00	7:37 - 10:11

Example: Observing Hour, 9 P. M., Pac. S. T., June 20, 1930. In Julian Day reckoning this becomes J. D. 26128, plus 20 ds., plus 0.7hr., or J. D. 26148.7.

"One field of astronomical work is largely the amateur's own: a large portion of the Variable Stars can best be observed with small telescopes. . . Their laws can be learned only by many observers widely distributed, to secure observations uninterruptedly in all longitudes."—The late Prof. Pickering, Harvard.

"The keynote of success in this work is perseverance. In finding a new field there is a joy akin to the discovery of a rare treasure."—W. T. Olcott.

"Variable Stars present one of the most important problems of the sidereal universe, and indirectly related to our solar system. . . An unlimited field is open to the careful and interested observer. No other branch of research is so suitable to the resources of the amateur astronomer. . . Unlimited aid and resources are freely offered by those who are anxious to further the cause of the amateur toward accomplishing something of value to science."—Leon Campbell.

For full information, address, Wm. Tyler Olcott, Secy., A. A. V. S. O.,
No. 62 Church street., Norwich, Ct.

CLASSIFICATION OF VARIABLE STARS. Steavenson.

Character	Period		Typical Star
Regular	Short per.	(a) "DARK" ECLIPSING	Algol
		(b) "BRIGHT" ECLIPSING	Beta Lyrae
		(c) CEPHEIDS	Delta Ceph.
		(d) CLUSTER VARS.	In Glob. Cls.
	Long-per. Vars.	(See Appendix for full information).	
Irregular	No definite period.	(a) Faint, with occasional rises	SS Cygni
		(b) Bright, with occasional falls	R Cor. Bor.
		(c) Long continued irreg. changes	Eta Argus
		(d) Single gigantic outburst	Nova Aquil. III

All of the above type-stars are mapped and annotated in the preceding pages, excepting Eta Argus, not visible in our latitudes.

The Regular short-period Class (a) type deals with visual binaries in which a relatively darker body orbits with its primary about a common center of gravity in the line of sight, partially obscuring it periodically.

Class (b) assumes that both these suns are bright, close and possibly elongated by tidal action.

Class (c) is a type of small variation due to internal "pulsations" or a dense surrounding and resisting medium through which the star is seen brightly or dimmed, depending on its orbital position as viewed from Earth.

Class (d) is also of the Cepheid type, but of periods less than one day, and of which hundreds have been found in star-clusters, leading up to a determination of the approximate distances of these remote aggregations.

Short-period Variables are part of the routine work of the great observatories specially equipped for such observations; but those of long-period are, as Prof. Pickering said, "a field for the amateur largely his own."

"The observer of Variable Stars will gradually acquire a closer acquaintance with selected regions of the sky than could be gained by observational work of any other kind; and he will find a fascination in the study of these Variables, many of which are sidereal puzzles, which will far more than compensate him for the time and trouble expended."—*Memoirs, Brit. Ast. Assn.*

"The thrill of seeing one of the lucid stars of the sky periodically dimming or enhancing its brightness is an experience never to be forgotten. The study of stellar variation has been not only a hobby or useful diversion for the amateur, but has commanded the efforts of nearly all the greatest astronomers of the last hundred years. About one-third of the time of the 100-inch telescope at Mt. Wilson is now devoted to variable stars of different kinds."—*Joy.*

"Not desultory observation, no matter how interesting, but it is work with a purpose that counts. The small telescope should not be relegated to any narrow line of observation. The employment of instruments of moderate power is not yet closed to the amateur; and the more our beloved science is pursued by such in the finest spirit of enquiry, the greater its future will be."—Rumrill.

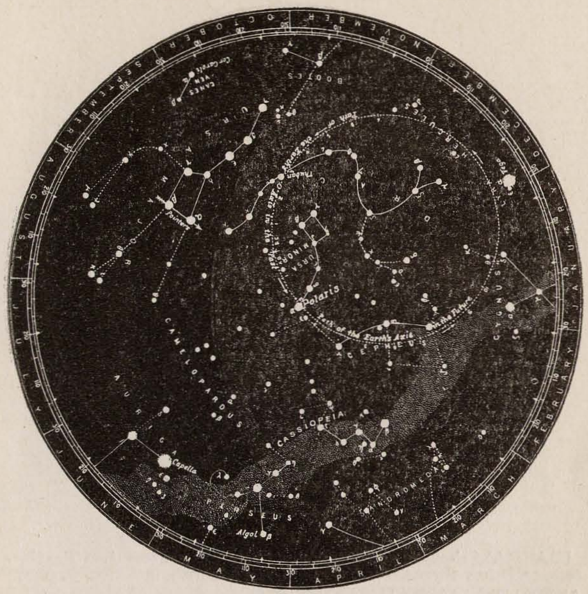


CHART OF CIRCUMPOLAR REGIONS, illustrating the phenomenon of the Precession of the Equinoxes, (p. 149), and indicating position of Thuban, the Pole Star at the time of the building of the Pyramids, 2750 B. C. Thuban (p. 107), lies 26° from Polaris on the circle drawn to represent the path of the Earth's axis during a complete cycle of 25,900 years. The true Pole is located by the tiny dot directly above Polaris, distant 1° 6′, about which it revolves every 24hrs. Nearly opposite, close to the circle, stands Vega, the Pole Star 12,000 yrs. hence. (p. 29). The chart shows the constellations within 55° of the Pole.

***The Galactic System*.—A flattened disc or watch-shaped aggregation of stars, diameter about 300,000 light years, thickness, about one-eighth, or 37,500 light years, with Sun 50,000 light years from center. *(Shapley.)* Includes all observable stars, together with planetary nebulae and irregular galactic nebulae, both light and dark. *(Hale.)* From Cygnus to Centaurus the Milky Way is divided into two nearly parallel streams, with dark irregular central band. Central line of great galactic circle inclined about 63° to the Equator. Galactic Poles, R.A. 12° 40′ Dec. +28 (in Coma Berenices), and 0° 40′, Dec. —28° *(Sculptor)* Galactic Long. and Lat. are computed from a point in Aquila, R.A. 18° 40′, the ascending node on the celestial equator.**

Vast regions in the Milky Way, says Prof. Bailey, are more or less obscured by occulting clouds. The number of stars thus lost to view by this obscuration is ten thousand or more to the square degree!

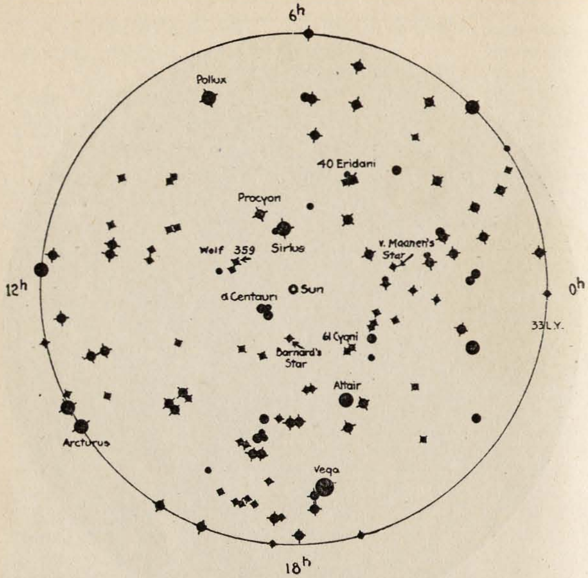


DIAGRAM showing all Stars whose Distances are less than Ten Parsecs, or Thirty-three Light Years. (Van Maanen, in A. S. of P. pubs.)

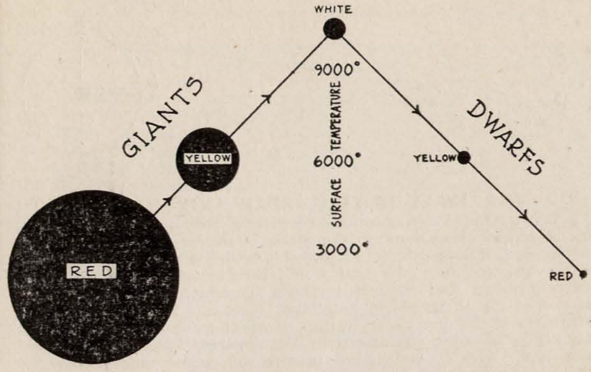
ABSOLUTE MAGNITUDE: –

● Brighter than 0.0. ◉ Mag. 0.0 to 3.0. • 3 to 8. • Fainter than 8.

At present about 125 stars are known to have distances of less than 33 light-years. These have been plotted in the diagram in such a way that the distance from the center is proportional to the actual distance from the Sun.

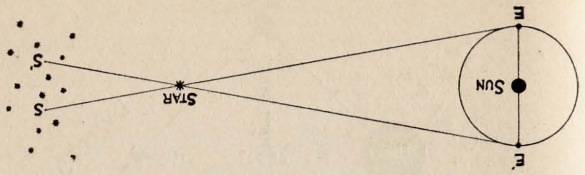
The "Absolute Magnitude," (which represents the intrinsic brightness and not the diameter of the star), is roughly indicated by the size of the dot. For instance, Vega is intrinsically brighter than Arcturus; but Vega's diameter is less than one-tenth that of Arcturus, whose diameter is about 23 million miles. On the scale here employed, one linear inch represents a distance of about 25 light-years, or 147 million million miles. On such a scale the diameter of Arcturus would have to be represented by a dot less than one six-millionth of an inch in diameter, a dimension wholly indiscernible under the most powerful ultra-microscope.

Absolute magnitude represents a star's apparent brightness at a standard of one-tenth of a second of arc, or 32.6 light years. Referring to p. 87, we find that an object whose parallax is one second of arc would lie at a distance of 3.26 light years. A value ten times that is adopted as a criterion of absolute magnitude, bringing all measurable stars to standard scale, and removing the nearer stars to conform to it. Thus the absolute magnitude of our Sun, that is, if it were removed to a distance of 32.6 light years, would be about mag. 5, barely visible with the unaided eye.



STELLAR EVOLUTION.—A theory of stellar evolution which is now favored by most astronomers assumes that stars form from dark matter in some matter, the details of which are not known. At first they are of enormous size, 10,000,000 miles or more in diameter, but extremely tenuous, the mean density being of the order of one hundredth or less that of the air we breathe. As they contract under their own gravitation, they grow hotter, so that the effective brightness remains nearly the same, although the color slowly changes from red to white. They are now a small fraction of their original size, and further contraction cannot maintain their temperatures as they will radiate heat faster than it is manufactured by contraction. Hence they begin to cool off and will pass through the same temperatures and colors as before but in the reverse order. Moreover they now grow steadily fainter. There will thus be two kinds of yellow and red stars, one on the ascending and the other on the descending temperature branch. These were named by Hertzsprung "giants" and "dwarfs," respectively, and these terms have come into wide use in this connection. The giants are large and tenuous, the dwarfs small and dense. This scheme of stellar development is represented by the diagram. The process begins with the large star at the lower left corner and proceeds towards the right. As the star shrinks the temperature increases to maximum at the top of the diagram and drops steadily thereafter until the star becomes too faint to be visible.

The color of our Sun is white or yellowish, clearly intermediate between the cool red stars and the very hot bluish ones. But on which branch of the evolutionary ladder does he belong? The sad truth is that our glorious Sun is on the dwarf or declining branch, well past middle life. As ruler of the planetary system he plays a magnificent role, but looked at from a cosmical view point he must be recognized as a big toad in a little puddle. He has still a long time to live and shine, undoubtedly millions of years, but he is well past the prime of life. (Dr. Merrill, in A. S. of P. Pubs.)



HOW FAR AWAY IS THAT STAR AND HOW DO YOU KNOW?—These are questions frequently asked, and with reason, for the vast dimensions of the stellar universe appeal powerfully to the imagination. It is not possible within this space to answer either question fully, for that would involve an account of all the dfferent direct and indirect methods by which astronomers have measured the distances to individual stars and have secured close estimates of the average distances of great groups of stars classed according to some characteristic like apparent brightness or spectral type. But it will be of interest to outline one method of solving the problem, the so-called trigonometric method.

The principle on which this method rests is the same as that upon which the surveyor depends for his measures of the distance to an inaccessible terrestial object and will be readily understood from the diagram that is given above.

In its motion about the Sun the Earth passes from the point E to the point E' in six months, as for example, in the interval from March 1 to September 1. That is, at these two dates it is at the opposite extremities of a diameter of its orbit; a diameter 186,-000,000 miles long. Measures of the direction of the star at the two dates provide the angles, which, with this base line, determine the triangle. But while the principle is simple, its practical application is exceedingly difficult and makes the most exacting demands upon the observer's skill; just how exacting will be realized when it is stated that to draw our triangle to scale in the case of the very nearest star, if we let the distance from the Earth to the Sun be one foot (i. e., let the line E — E' be two feet long) the lines E — Star and E' — Star must be extended about 50 miles! It is not surprising therefore that by 1900 the approximate distances of only three score of the nearest stars were known.

Early in the present century, however, photographic processes had been so far perfected, and the technique of applying them to this problem had been so thoroughly mastered that for greater accuracy was attainable than by any of the older visual methods. The procedure is to take photographs of the star whose distance or "parallax" is desired and of the fainter stars that are apparently near it in the sky at the proper time intervals, and with the most scrupulous attention to every detail, to avoid errors of observation. It is assumed that practically all of the fainter stars will be so distant that their apparent positions will not be appreciably affected by the Earth's orbital motion and that the parallax star will be seen among them in the direction E S when the Earth is at E and in the direction E' S' when the Earth is at E'. The background stars serve as reference points by means of which the displacement S—S'

(which is, of course, erroneously exaggerated in the diagram) is measured.

Six American and one English Observatory have for a number of years carried out a cooperative program of measures of stellar distances by this method and the results have been most gratifying. Dr. Schlesinger of Yale University Observatory has recently gathered all the available measures into a single (preliminary) catalogue. This has 1870 entries. Some of the distances (parallax) given are very accurate; others, naturally, are subject to a considerable uncertainty; for to make our triangle represent the most distant stars now measured by the trigonometric method it would be necessary (keeping the line E E' 2 feet long) to have E—Star and E' — Star nearly 4,000 miles long! Even so it is obvious that only the stars comparatively near us are within reach of direct measurement by this method. (Dr. R. G. Aitken in A. S. of P. leaflet).

ETHER-WAVES—HERTZIAN TO COSMIC.

Astrology, reputed "father of Astronomy," seems to be discounted today in every other assumption save that we are constantly beset with many forms of skiey influences. Modern astrophysics demonstrates that all inter-stellar space is eternally bombarded by ether-waves of various kinds and degrees of force whose manifestations have been measured, analyzed and even utilized industrially. Of the longest of these waves—the Hertzian—we have a daily demonstration in the our familiar radio—waves measured in kilometers. Next in the series are the short electric and the infra-red, detected by the bolometer and measurable in Angstrom units (one ten-millionth of a millimeter), giving rise to the phenomenon of heat. Then follow the visible spectrum and the ultra-violet, photographic and chemical; X-rays due to the ionization of gas, and the *gamma*-rays given up by radio-active substances such as radium, thorium and uranium. And now behold the shortest, most penetrating of all, latest discovered and as yet least understood—the cosmic: "signals sent out through the heavens of the *creation of the common elements out of positive and negative electrons.*" And therein lies the astounding reversal of Nature's laws in that while all other wave-emanations that fill the primordial void appear to be the result of the disintegration of the elements—the breaking down or transmutation of the higher forms into the lower—these cosmic rays appear to offer reasonable proof that a process of evolution on an ascending scale is proceeding throughout the universe, creating from the basic element, hydrogen, actual atoms of helium, oxygen, silicon, magnesium and possibly iron. Here at last is an authoritative answer to the query of ages: Why, with this eternal outpouring of energy incident upon the breaking up of the elements, has not the universe run down and the suns gone dead countless billions of years ago? Hitherto it has seemed as if only Siva, the Hindu god of heat-death and destruction has presided over the cosmos; but now the prophet Millikan in his cosmic ray demonstrates also the mightier presence of a Brahma and Vishnu, Creator and Preserver of the eternal verities, and science takes on a new lease of life.

With a small mirror, a few bits of paper and cardboard, some fine hairs and a couple of knife-blades, the astronomer Young laid the foundations of the wave theory of light, and discovered the principle of the interferometer which now measures the angular diameter of stars scores of light years distant. In the hands of a master, what earthly thing is so small and mean that it may not be used to some transcendent end?

GLOSSARY

ASTRONOMICAL, ASTROPHYSICAL AND OPTICAL TERMS

Aberration. Failure of lens or mirror to bring all light-rays to focal point. **Chromatic**—unequal refraction of colors. **Spherical**—distribution of rays along optical axis instead of a single focal point. (Mirrors only may have the latter defect, while a lens may have both). Astronomically, Aberration signifies the apparent displacement of a star due to earth's rotation, atmospheric refraction, etc.

Abrasive. Any grinding medium such as carborundum, steel filings, emery, etc.

Absolute Magnitude. A star's brightness at a hypothetical uniform distance of 0.1″ of arc. Our Sun's absolute magnitude, thus removed, would be about plus 5, or at an approximate distance of 32.6 light years.

Achromatic. A lens free from color interference.

Albedo. Percentage of Sun's reflected light from planet or satellite.

Algol Type. Eclipsing Variable Stars resembling Algol (Beta Persei), in general behavior.

Altitude. Angular elevation above the horizon.

Altazimuth. A telescope mounting which provides for vertical and horizontal adjustment. (Surveyor's transit type).

Aperture. Available diameter of mirror or lens.

Apogee. Moon's farthest distance from the Earth. (Opposed to **perigee,** nearest).

Atom. The Greeks, believing it the smallest universal particle in nature, called it "the indivisible" **(a-tomos)**; but we now know that it is divisible into 1800 parts, called electrons, (as in the case of hydrogen); negative charges of energy around a central positive nucleus, called by Rutherford, a proton. Newton believed atoms infinitely hard particles in various geometrical forms; Lord Kelvin reversing this theory with a conception of vortex rings in ether; and later Bohr advanced his theory of its purely electrical structure. More recently we have the wave atom of Schrodinger—the entire charge not being localized but spread thruout the entire volume of the atomic sphere. Whatever the argument with regard to its potential form, it is fairly definitely established that the atom consists merely of electrons and positive electricity.

Azimuth. Angular position of star measured along horizon from point of star's meridian eastward to that of the observer. Corresponds to Right Ascension in Celestial reckoning.

Bolometer. An electrical device of extreme precision for measuring heat-rays from celestial bodies. **(Bolo**—shaft, dart).

Bolide. A fireball of meteoric matter, far more brilliant than a meteor or shooting-star, frequently visible by day.

Cassegrainian. Type of reflecting telescope especially adapted

to spectroscopic and astro-photographic work, in which the mirror is usually centrally pierced, allowing the star-beams to be reflected back from a convex mirror to the eyepiece or camera behind the speculum, instead of being reflected outward from a Newtonian flat at the upper end of the tube or mounting. With unpierced speculum the rays are reflected outward to the eyepiece by means of another prism fixed between speculum and concave mirror above.

Coelostat. (Coelum, the heavens). A plane mirror rotated by clockwork to produce a stationary beam from a celestial object for long periods of observation or photography. A secondary mirror is employed to keep the image in the focal plane. Variations of this mounting such as the **Siderostat** and **Heliostat** are adapted to special uses.

Colures. The two great circles passing through the poles of the heavens, intercepting the Equator at the Vernal Equinox **(Equinoctial c.,)** and 90° therefrom **(Solstitial).**

Constants. Fixed values in astronomical calculations. (188)

Culmination. The instant when a celestial unit crosses the observer's meridian. **Upper** and **Lower C.,** the position of Polaris above or below the true north polar point (14)

Cylindrical Lens. For broadening or lengthening a spectral image to give greater detail. Designed as if a section cut lengthwise from a solid rod of glass (plano-cylindrical—positive), or plano may be ground to correspond to convex side, giving double power, and set at right angles to the meridian of the axis.

Diffraction. (Frangere, to break). The deviation of light-rays from a straight course when monochromatic radiations are passed through small openings, as a slit in a prism spectroscope, a diffraction-grating replica, or as reflected back from a speculum-metal grating. **Diffraction Grating.** A plane (or concave) metal plate diamond-ruled with fine lines, ten to twenty thousand to the inch, upon which a light-beam falls and is reflected back in part, other portions being diffracted according to wave-length, forming a spectrum. Metal gratings are very expensive; but excellent replicas are in the market at reasonable prices, giving brilliant results.

Eccentricity. Deviation from a true circular orbit.

Elements. The six quantities required to determine an orbit: (e) eccentricity, (a) semi-major axis, (i) inclination of orbital plane to plane of the Ecliptic, (l) longitude of ascending node, (p) period of revolution, and (t) time of perihelion passage.

Elongation. Angular distance eastward or westward from the Sun of Venus or Mercury, the Moon from Earth, or Polaris from the true north polar point.

Epoch. Reference to dates of determined star-places. Example: Epoch 1920. Epochs are usually computed ten years apart.

Galaxy. Reference to our own Milky Way, to remote spiral systems of stars, or as lately, to still farther "Galaxies of Galaxies" as revealed by our giant telescopes.

The thin watch-like disc of overwhelming extent which we call the Milky Way and our "universe," is in well-determined motion. As a whole, according to Dr. Shapley, it is turning about a distant but wholly mysterious center situated in the heart of the solidly

packed constellation of Sagittarius, with a velocity of two hundred miles a second. What is at that center—that illimitable heart of hearts? No one can even conjecture. Vast conglomerations of cosmic clouds, radiantly effulgent or bleakly dark, conceal from us forever that eternal secret; and whether it is some central super-sun—some all-compelling nuclear mass about which revolve all the other suns of our universe—including our own and its tiny retinue of planets—man will probably never know for many millions of years, even if he survives that long, as science proves he has lived in the past, and doubtless will in the future. At best we have but "lifted a corner of the veil in which the cosmos is shrouded."

Galactons. "Island universes" or groups of galaxies, each resembling our own, of perhaps 170,000 light years diameter.

Cosmons. Still vaster and more remote "galaxies of galaxies," as the Coma-Virgo groups. (Shapley). Of these immeasurably distant objects barely a half dozen have been even approximately measured. The countless thousands more remain as problems for the astronomer of the future.

Heliocentric. The Sun's center as a point of reference in computations of parallax, etc.

Hour Angle. The angle between the celestial meridian and the hour-circle of a star. Quickly determined by noting the sidereal time and subtracting therefrom the star's Right Ascension as given in the Ephemeris.

Index of Refraction. The ratio of the sine of the angle of incidence (entering ray), to the sine of the angle of refraction (emergent ray), passing from air into any denser medium. Symbol, **mu.**

Ionization. The process of stripping negative electrons from their positive nuclei, accomplished on a minor scale in the laboratory, but in the interior of stars proceeding with an intensity many million fold, of which the spectroscope gives direct evidence.

Isostacy. A geological condition of equilibrium under terrestrial gravitation. **Iso**—equal.

Isotropic. Light transmitted equally in all directions.

Kepler's Laws governing planetary motion. (1) All orbits are elliptical, with Sun at one of the foci. (2) The radius vector (line joining planet and Sun), sweeps equal areas in equal times. (3) "Harmonic." The squares of the periods of revolution are proportional to the cubes of their mean solar distance. Thus, one term of the equation known, the other is quickly computed.

Libration. Reciprocal positions of Earth and Moon in lat., and long., by which we are able to glimpse more than the half of the Moon's sphere as presented to us.

Mass. Quantity of matter contained in a body. **Volume:** amount of space it occupies. **Density:** the mass contained per unit of volume.

Meridian Circle. A transit instrument mounted permanently to swing in the exact north-and-south line, provided with graduated circle of utmost precision (1" of arc, equal to 1/17,000 of an inch), to time the transit of celestial bodies.

Micrometer. An instrument of precision attached to a telescope for measuring the angular separation of celestial units. **Filar:** provided with spider-threads and screwhead graduations of extreme exactness.

Motion. Direct, apparent eastward advance of a planet among the stars; **retrograde:** apparent westward, owing to Earth's and the planet's reciprocal positions in their orbits.

Nadir. The point beneath the observer's station, as opposed to **zenith,** the point directly overhead.

Newton's Law of Gravitation. All bodies attract one another with a force proportional to their masses and inversely as to the square of their distances. This law holds good in the infinitesimal as well as remotest suns in space.

Node. Point where an orbital plane intersects the Ecliptic. **Ascending:** passing from south to north; **descending,** from north to south.

Nutation. Unstable motion of Earth's pole around the pole of the Ecliptic by reason of solar and lunar attraction, since our globe is not a true sphere, but an oblate spheroid having more than 26 miles greater equatorial diameter than polar.

Optical Principles. Light-waves move at right angles to their wave-fronts except when intercepted by another medium,—say, a convex or concave lens—when these waves are converged or diverged from their straight-line course, how much or little depending upon the amount of interposed curvature. A convex lens, being thicker at the center than at the periphery, retards the central beams and causes a curvature of the wave-front to a point where the rays cross one another—the focus. Such lenses are positive, or plus +. A concave lens, being thinner at the center, imprints a bulging curvature on the otherwise parallel wave-front, causing the beams to diverge to a degree indicated by the concavity of the lens. Such lenses are negative, or minus —. The optician's unit of curvature of both plus and minus lenses is the diopter (Gk.: to see through), of standard focal length of one meter. To convert diopters to inches, divide 40 (or, to be exact, 39.3708), by the number of diopters. To convert inches to diopters, divide 40 by the number of inches. The diopter is also a simple pocket lens-measurer on the principle of the spherometer explained on page 227, and adjusted to allow for the refractivity of crown glass, 0.51. (English spelling, dioptrie).

Though telescopic instruments are of comparatively recent invention, lenses themselves are known to be very ancient. Sir Henry Layard discovered in the ruins of Nimrud (B. C. 1500) a crystal lens used as a magnifier by the skilled carvers of cuniform inscriptions on signet-cylinders of the early kings of Ur, "City of the Moon."

Orientation. Relating to the cardinal points of the compass.

Position Angle. In binary star work, the angle between the Earth's polar plane and those of the stars under observation.

Quantum. A theory to explain the propagation of light-waves from various sources by successive small accretions or outbursts of energy, in contradistinction to the older wave-theory of a continuous emission. This recent and very abstruse concept is founded on Planck's quantum constant, represented by the letter **h,** whose numerical value is 6.55.

Reflective Power of Metals. Before the invention of Leibig's silvering on glass process, specula (from which the name), were made of various alloys, still in use for many purposes—combinations of copper, tin, silver, aluminum, etc., magnesium, in various proportions, with an average reflective value from 63 to 84 per cent, as against 71 to 92 per cent for polished silver-on-glass. Silver alone gives a reflective power of about 92 per cent; platinum, 66; nickel, 64; gold, 81; and copper, 70, (average for the entire spectrum).

Refraction. Light rays bent in passing through various transparent mediums—glass, quartz, water, etc.

Refractive Indices. Silicate crown, 1.5182. Silicate flint, 1.62071. Dense flint, 1.6372. Very dense, 1.7782. Fused quartz, 1.4585 (D - line). Rock salt, 1.5442. Canada balsam, 1.526. Castor oil, 1.490. Alcohol, 1.3638. Carbon bisulphide, 1.6303. Water, 1.3336.

Secular. Reference to long periods of time. (**Seculum,** age).

Spectra. Emission: (1) Continuous, from solids or liquids rendered incandescent. **Bright-line,** emitted by incandescent gases or vapors. **Fluted,** incandescent vapors of carbon compounds, etc., and certain of the elements. **Absorption:** band-spectra, as seen through colored transparent liquids, solids or gases. **Line-spectra:** as seen in the spectrum of the Sun and stars—the Fraunhofer lines—due to the absorption of light from a continuous source in passing through transparent incandescent metallic vapors enclosing the celestial body, each set of lines in constant positions, so that, when duplicated in the laboratory, we know the nature of the elements existing in those distant luminaries. Some elements give few lines, others hundreds. Of the ninety-two chemical elements, from hydrogen to Uranium, fifty-eight have thus been found to exist in the Sun.

Syzygy. Points in the Moon's orbit when in conjunction or opposition to the Sun. (Gk. yoked together).

Thermopile. An electrical device of extreme delicacy for measuring radiation from planets and stars in which a sensitive galvanometer plays an important part. (Thermocouple).

Zodiac. An imaginary belt through the heavens about 16 degrees wide and bisected by the Ecliptic, known as "the path of the planets," locating the 12 signs. (Gk. zodiakos, pertaining to animals). Owing to the precession of the Equinoxes, the Signs no longer correspond to the zodiacal constellations, but have moved westward so that the Sign of Aries is now in the constellation of Pisces, etc. (p. 149).

"The Jacob's Ladder of Truth, let down from heaven, is now the common highway upon which the many toil upward."—Coleridge.

"No one will doubt that in astronomy, as in every other science, the advance depends largely on individual genius and initiative."

"The more distant objects are in space the more they excite the attention of the astronomer, if only he may hope to acquire positive knowledge about them. Not because he is more interested in things distant than in things near, but because he may more completely embrace in the scope of his work the beginning and the end — the boundaries of things—and thus indirectly more fully comprehend all that they include. From his standpoint,

'All are but parts of a stupendous whole,
Whose body nature is and God the soul.' "—Newcomb.

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CHART SECTION

Selected and General Chart Indices, following p. 165.
Index to Constellations, p. 19.

AUTHORITIES QUOTED:—

INDEX TO PART II.

INSTRUMENT-BUILDING SECTION

عَلَا نَجْمُكَ

"May thy Star rise high!"