[4] *Proc. Nat. Acad. Sci.*, **7**, p. 63, eq. (8).

[5] *Ibid.*, **7**, p. 63, eq. 10.

[6] *Proc. Amer. Acad. A. S.*, **53** (1918), pp. 269–386.

[7] I have not included cadmium in this list of metals. Bridgman studied cadmium as he did the eighteen other metals, but the value which he found for the Thomson effect in it is about ten times as great as that indicated by the observations of Fleming and Dewar (*Phil. Mag.*, **40**, 5th series, 1895). Bridgman expresses the opinion that the specimen of cadmium which he studied may have been in an unstable condition, between two allotropic forms.

[8] Although I have arrived quite independently at the number 1.50 as the mean value of q in metals, I have already (*Nat. Acad. Sci. Proc.*, **15**, p. 507) called attention to the fact that Richardson in deriving his T^2 emission formula from the "classical kinetic theory" assumed the number of free electrons per cm.^{3} of a metal to be proportional to $T^{1.5}$.

[9] I have discussed evidence bearing upon this magnitude in a recent paper, "On Electrons That Are 'Pulled Out' from Metals," *Proc. Nat. Acad. Sci.*, **15**, 241–251 (1929).

[10] *J. Frank. Inst.*, **206**, Oct., 1928.

[11] Gauthier-Villars, Paris, 1927.

TWO CONTRADICTIONS IN CURRENT PHYSICAL THEORY AND THEIR RESOLUTION

BY F. S. C. NORTHROP

DEPARTMENT OF PHILOSOPHY, YALE UNIVERSITY

Communicated November 29, 1929

When Einstein examined the electro-magnetic theory of Lorentz at the beginning of this century, he found the principle of relativity for Galilean frames of reference, and the principle of the absolute velocity of light in vacuo, to be experimentally valid, yet contradictory. The necessity of rejecting the doctrine of absolute space and time for the principle of the relativity of simultaneity, in order to escape this contradiction, led him to the discovery of the special theory of relativity.

It is the purpose of this paper to show, by precisely the same type of argument, that this theory and the general theory which came out of it have given rise to two new contradictions in current physical theory which can be escaped only by introducing a radical but essentially simple amendment to the traditional atomic theory.

The Difficulty Concerning Atomicity and Motion.—The first contradiction will be demonstrated by establishing three propositions. (1) Atomicity is an inescapable fact. (2) Atomicity and the motion which it involves necessitate the existence of a referent in addition to the microscopic particles. (3) No such referent exists, according to current scientific theory.

1. *Atomicity is an inescapable fact.* The first argument for the atomic theory was given in Greek science by the pre-Socratic philosophers. They

demonstrated, by reasoning similar to that which drove Einstein to the theory of relativity, that one cannot admit the existence of the two obvious extensive facts of stuff and change, and not accept the atomic theory, without involving one's self in a contradiction. Since these two facts cannot be denied, the same logic which makes us accept the relativity theory requires that we accept the atomic theory.

The technical investigations of modern science have supported this conclusion with many independent lines of evidence, so great in quantity as to be practically overwhelming. Only a few items in a long list need be referred to. This list begins with Newton's acceptance of the atomic theory and with LaPlace's statement of the laws of his mechanics in terms of it, and ends with the discovery of the atomic character of electricity and energy. In between is Count Rumford's discovery and Maxwell's development of the kinetic theory of heat, the modern science of chemistry, the discontinuity which statistical theories suggest, the evidence indicating the physico-chemical character of living things, Sir J. J. Thomson's isolation and Millikan's determination of the charge of the electron, and astronomical theory, beginning with LaPlace and continuing through Jeans, which conceives of the primordial state of stellar evolution as atomic in character.

It would appear that nothing more needs to be said. Recently, however, two types of theory have been proposed which suggest the reduction of atomicity to a non-atomic basis. I refer to Eddington's doctrine that mathematical forms, rather than physical atoms, are fundamental,[1] and to current developments in wave mechanics.

Three things need to be said concerning Eddington's thesis. Firstly, it rests for its validity upon the theory of relativity which in turn presupposes an atomic theory. The relativity theory has its origin and foundation in the electro-magnetic theory of Lorentz, and this is an atomic or electron theory. Secondly, Eddingtons' extremely mathematical theory derives its validity from a generalization beyond the theories of Einstein and Weyl which is not universally accepted. In fact, Einstein has unequivocally repudiated it.[2] Thirdly, even if it be accepted, it requires one to admit the primacy of physical instead of mathematical categories. For an examination of the postulates in terms of which Eddington states this extremely mathematical theory[3] reveals that they involve statements concerning "displacements" "carried by parallel displacement" from point to point. Certainly the carrying presupposes motion, and that which is carried cannot be a mathematical relation. Quite obviously, as Einstein explicitly asserts in the definition of his geometry, it is a measuring rod. Now, measuring rods and motion are physical things, and involve the existence of a plurality of objects, which is intelligible only on an atomic basis. It becomes evident, therefore, that atomic categories are really primary.

It was this necessity of defining geometry in terms of physical measuring rods and their behavior which led the pure mathematician Riemann, who invented the mathematics of the general theory, to predict, long before Einstein's discovery, that space would be found to be conditioned by matter.

The continuous and apparently non-physical emphasis in wave mechanics also turns out upon examination to be an argument for, rather than against, the atomic theory. Two considerations will suffice to make this clear. Firstly, all theories, no matter how mathematical may be their emphasis, use Plank's constant as a fundamental idea. This constant involves an atomic or discontinuous theory of energy. Furthermore, it arose from a new study of the foundations of statistical theory which rests upon the conception of finite rather than infinitesimal units in terms of which possible permutations are to be defined. In other words, Planks' constant is essentially a discontinuous or atomic idea. Secondly, even the attempt in current quantum theory, to conceive of the atom as a singularity in a continuum, breaks down when one makes this rather vague notion the least bit explicit. For in order to give it any fertility, it is necessary to determine the potential and kinetic energy of the supposed singularity, and this involves the conception of it as an actual particle to which the inverse square law applies.

Thus, even in those cases in which the atomic theory appears to be discarded, it is really a fundamental and basic factor. We are forced, therefore, by the facts to regard our first proposition as established. Atomicity is an inescapable fact.

2. *Atomicity and motion necessitate the existence of a referent in addition to the microscopic particles.* The proof of this proposition was given in Greek science by Parmenides. It was accepted by Newton and suggested by him at the beginning of the Principia. The rejection of absolute space by the theory of relativity has led many to suppose that the proof in question is invalid. A reëxamination of it indicates that this is not the case. Current scientific theories will be examined and found to support this conclusion.

Consider the proof as Parmenides gave it. Change, he said, must be due to generation or to motion. After demonstrating that it cannot be due to generation if this is a physical universe, he proved that it cannot be due to motion if the physical stuff is conceived as nothing more than one substance or many microscopic particles. For motion requires that stuff be transmitted from where it is to where it is not, and there can be no "where-it-is-not" if nothing but the stuff to be transmitted exists.

Nor can change be due to nothing but many particles and their motion—for two reasons. Firstly, the motion of many particles calls for a "where-it-is-not," as much as the motion of one. A difficulty is not removed by multiplying it many times. Secondly, there cannot be many particles if nothing exists but the stuff of which they are supposed to be made. For before there can be many parts of stuff there must be something to divide one part of stuff from another and this is impossible if nothing but the stuff to be divided exists.

The essential point in this argument is not so much the need for an intervening medium, as the need of a basis for distinguishing between one atom and another. In an atomic theory which regards the atoms as constituted of the same kind of material, the category of stuff gives only the respect in which the atoms are identical or one; it cannot prescribe the respect in which they are numerically different or many. Stated positively, this means that the individuality of a given atom cannot be defined in terms of its properties, but must be expressed in terms of its unique relation to some referent common to all the atoms. If nothing but the stuff of the atoms exists there can be no such referent, and hence atomism is impossible.

It may be said, therefore, that one can no more admit the validity of the atomic theory without accepting the existence of a referent other than the microscopic particles, than one can accept the postulates of Euclidean geometry without accepting its theorems. As Newton said, "It is from their essence or nature that they (things) are places."[4] To think one without the other is impossible.

It is to be noted that the last argument takes care of those who would attempt to define atomic motion in terms of the relation of the atoms to each other. For even the notion of relative motion involves the existence of many atoms, and the manyness, wholly apart from the motion, is impossible unless a referent other than the atoms exists.

Let us not evade the full consequence of this conclusion. It means that any physical theory of relative motion involves a more basic atomic theory of absolute motion. For, let me repeat again, relative motion involves many substances and the manyness is meaningless apart from their relation to a common referent other than them. Verified theories of contemporary science support this conclusion.

Consider the kinetic theory of gases, and a particular case—the molecules of a gas in a container. It is to be noted that when we talk about the motion of these molecules we do not mean their relation to the container. For we believe, and it is part of our theory that we must believe, that the molecules will continue to move if the container is destroyed. This could not be the case if their motion had no meaning apart from the existence of the container. Moreover, it is part of statistical theory to maintain that the container, as well as the phenomena within, is to be defined in molecular terms. Eventually, therefore, we are driven back behind all containers to the totality of molecules of the whole of nature. Since we define all molar objects in terms of their ultimate molecular motion, we cannot use them to define what we mean by molecular motion. An examination of what we mean by motion as exhibited in the phenomenon termed the Brownian movement leads to the same conclusion.[5]

These considerations remind us that there are two types of valid scientific theory in contemporary science. The one, exemplified by Newtonian and Einsteinian mechanics, states all scientific observations in terms of relations to chosen reference frames; the other, exemplified in all statistical and kinetic atomic theories, makes use of atomic entities in absolute motion relative to a common referent and escapes the relativity attaching to a use of reference frames, without the recourse to transformation equations. In the latter type of theory, motion never refers to a molar body or to a frame chosen by a scientist; it is conceived as occurring independently of any such choice.

This is clearly revealed in the astronomical theory of Jeans. This theory is particularly suitable for our purposes because it combines relativity and atomic conceptions within a single scientific theory. His appeal to the relativity theory to account for the tremendous radiation of energy from the sun is well known. This necessitates his rejection of the doctrine of absolute space. Nevertheless, when he lays down the elemental principles of his theory, he refers to original nature as a collection of atoms moving in space.[6]

Now, it is to be noted that this space is not relative space; nor will the facts which force him to this theory permit him to regard it as relative space. For relative space has no meaning apart from reference frames which involve molar bodies, and at the beginning of stellar evolution molar bodies do not exist. Nor can he mean that the atoms are moving relative to some member of their group to which a scientist chooses to refer them, for at the stage in question conditions are not very propitious for the existence of scientists. Furthermore, if he meant that the atoms are moving relatively to each other, he would be forced to refer to them, not as moving *in* space, but as giving rise, because of their motion, to a system of relationships between each other which *is* space, and this would require that he introduce some other referent to indicate what he means by motion. It must never be forgotten that a relative theory of space must define space as a relation between objects; it can never define it as a system of relations or a container relative to which or in which atoms move. The plain fact of the matter is that the kinetic atomic theory with which Jeans begins requires a referent for motion which can be neither a molar body nor a chosen particle, and since the discarded absolute space is the only one which science knows, he uses it.

The result, however, is a contradiction. For his acceptance of the theory of relativity necessitates the rejection of the absolute space upon which he founds his theory. But he is not to be singled out in connection with this fallacy. Every scientist commits it who talks about atomicity and motion while accepting the relativity theory in its current interpretation.

The point to note now, however, is that necessary current scientific theories support Parmenides' proof of our second proposition, which is that atomicity, and the motion which it involves, necessitates the existence of a referent other than the microscopic particles.

3. *No such referent exists*, according to current scientific theory. The traditional referent, absolute space, disappeared with the acceptance of the special theory of relativity. The general theory eliminates space-time as a possible referent. For it indicates that the metric of space-time is conditioned by matter and its motion. Hence, we would involve ourselves in a vicious circle if we used space-time to define what we mean by matter and motion.

With this establishment of our third proposition the contradiction in current scientific theory is made evident. Both the atomic theory and the relativity theory are supported by factual evidence, yet the latter theory as currently interpreted, denies the existence of the referent which the former theory necessitates. In other words, a situation similar to the one which drove Einstein to the discovery of the special theory is at hand. Two verified theories exist which contradict each other.

Only one course is possible in such a circumstance. Current scientific theory must be modified to fit the facts. A conception must be discovered which will permit us to accept both of these theories without contradiction. The procedure used by Einstein indicates how this new conception is to be discovered.

He argued that a contradiction between verified principles proves that the presupposition in our theory which gives rise to the contradiction must be false. He proceeded, therefore, to determine what the presupposition is, and to replace it by its negate.

In his case, this meant the rejection of the doctrine of absolute time for the doctrine of the relativity of simultaneity. In our case it means that we must cease to identify the non-existence of absolute space with the non-existence of a referent for atomic motion. Stated positively, this means that a new referent must replace the discarded absolute space. Only in this way can we accept the atomic theory and the doctrine of the relativity of space which the relativity theory necessitates, without involving ourselves in a contradiction. Thus, just as the contradiction which Einstein found in electro-magnetic theory drove him to the discovery of the special theory of relativity, so the contradiction which we have found in current physical theory drives us to the discovery that a new referent for atomicity and motion must exist.

The Difficulty Concerning Metrical Uniformity.—The question arises concerning what this new referent is. This brings us to a second contradiction in current physical theory which arose out of a difficulty first indicated by Whitehead.[7] We shall attempt to demonstrate its existence by establishing three propositions. (1) The metrical properties of space are conditioned by the motion and distribution of matter. (2) The space of this universe possesses an approximately constant metrical uniformity which extends over macroscopic distances. (3) Matter as conceived by current physical theory is incapable of producing this uniformity.

1. *The metrical properties of space are conditioned by the motion and distribution of matter.* This proposition is a consequence of the general theory of relativity. As Einstein has said: "According to the general theory of relativity the metrical character (curvature) of the four-dimensional space-time continuum is defined at every point by the matter at that point and the state of that matter. Therefore, on account of the lack of uniformity in the distribution of matter, the metrical structure of this continuum must necessarily be extremely complicated."[8] Recent astronomical observations have supported previous ones[9] to reconfirm this conclusion.

2. *The space of this universe possesses an approximately constant metrical uniformity which extends over macroscopic distances.* This must be admitted because it is presupposed in the measurement of astronomical distances.

A few considerations will make this clear. Consider a distance here on the earth. The measurement of its length presents no difficulty. One merely takes a standard rod and notes how many times it must be laid down end to end to cover the distance in question. However, the location of an astronomical distance is such as to make a direct determination of its length impossible. The difficulty is met by establishing a relation of equality between the astronomical distance and a local terrestrial one to which the rod can be directly applied. To establish this relationship, it is necessary to appeal to geometrical principles. Moreover, if the results are to be valid these principles must apply to the intervening space which relates the two distances in question.

If the metrical structure of this space varied, two difficulties would occur. Firstly, the geometrical principles to which we appeal at one time would not be those which we used at another time. Were this true it would follow that the values arrived at by an observation in one century should not combine with those determined in another to make sense. In short, the values in question would be incommensurable. Secondly, we should not know what geometrical principles to use in a single given observation until we had determined the distribution of matter in the intervening region in question at the time. But we cannot determine the distribution of matter in astronomical space without measuring astronomical distances. Thus we find ourselves in the peculiar predicament of not being able to make a single astronomical measurement of distance until we have made a large number of such measurements. The experience of astronomers does not confirm this consequence. It must be admitted, therefore, that at least an approximately constant metrical uniformity extends over macroscopic distances in space.

3. *Matter as conceived in current scientific theory is incapable of producing this metrical uniformity.* One of the most notable consequences of the general theory of relativity is its doctrine that the metric of space changes with the distribution of matter. Whitehead and others pointed out that it is difficult to understand how measuring is possible if the metrical variability which this entails exists.

To meet this and other difficulties, and to explain why we have not discovered this metrical variability before, Einstein was forced to state his general theory in terms of a conception of nature as a whole, and to assert that the metrical variability is a local microscopic factor in a general macroscopic uniformity.[8] There seems to be little doubt but that this is the case. Certainly the measurement of astronomical distances would not be possible if the general uniformity were not present. Also, recent and previous observations in astronomy indicate that the metrical variability exists.

Many have supposed that this leaves everything in a satisfactory form. Quite the contrary is the case. The difficulty on which Whitehead put his finger has been merely shifted into another form in which it becomes all the more acute. Instead of asking why microscopic variability is so rare, we now have to ask why macroscopic uniformity is so obvious. In other words, the rule rather than the exception to it presents a difficulty. For if the metric of space is conditioned by matter, as the evidence for the general theory forces us to admit, it follows from our current theory of matter that the general macroscopic metrical uniformity should not exist. In short, exactly the opposite of what the facts indicate and Einstein suggests should occur.

This becomes clear the moment one notes that a relational theory of space which is conditioned by matter means that the metric of space is defined in terms of relations between physical objects; ultimately, this means, in terms of relations between atoms. In such a theory, metrical variability exists when the relations between the atoms change; and metrical uniformity when they do not.

Now, it is a verified doctrine of physics, and an essential principle of any physical theory which would account for change, that these atoms are in motion. This means that the relation between them is changing and hence that metrical variability should be the general rule. The second law of thermo-dynamics and the modern doctrine that matter is indifferent to order or design is an expression of this same fact. It is precisely because of this that our predecessors were unable to refer the spacial characteristics of nature to matter.

Einstein attempted to avoid this consequence by defining the required metrical uniformity in terms of our traditional theory of matter.[8] As one would expect, this necessitated that he regard matter as practically at rest. Certainly it is only upon this assumption that the relations between the parts of matter will not change, and metrical uniformity can result. But this assumption is not in accord with our knowledge of the kinetic character of matter. The evidence for the kinetic atomic theory makes this way out of the difficulty impossible.

Heisenberg's principle of uncertainty[10] supports this conclusion. For the contingency which it introduces into atomic behavior necessitates not merely that metrical heterogeneity and variability should be the rule, but also that no law governing the variation can be found. We must conclude, therefore, that matter, as currently conceived, is incapable of producing the metrical uniformity which exists.

The second contradiction in current physical theory is now demonstrated, for the three propositions which constitute the demonstration are established. Let us bring them together. A constant metrical uniformity exists which extends over macroscopic distances. The metric of space is conditioned by matter. Matter as conceived by current scientific theory is incapable of producing such a metric. In other words, current scientific theory asserts that space is conditioned by matter, in its doctrine of mensuration and space; and denies this thesis in its doctrine of matter.

The Resolution of the Two Contradictions.—From such a contradiction, only one escape is possible. The last of our three propositions must be rejected, since it is the only one of the three which rests upon theory rather than fact. This means that we must admit that our traditional theory of the capacity of matter to produce order is false. As Einstein indicated, in connection with the evidence which drove him to the relativity theory, when facts contradict, the presupposition in our traditional theory which produces the contradiction must be rejected and replaced by its negate.

Consider what this means in our case. We know that a metrical uniformity extending over macroscopic distances exists, and the facts behind the general theory of relativity necessitate that we hold that the metric of space is conditioned by matter. We know also that matter, as traditionally conceived, cannot produce this uniformity. It follows therefore that our traditional theory of the capacity of matter to produce order is false and must be amended to meet new evidence.

We have noted that matter is atomic in character. Hence this second contradiction concerning space, as well as the first contradiction concerning atomicity and motion, drives us to the conclusion that an amendment must be made in our traditional atomic theory.

Moreover, a consideration of the two major characteristics of the metric of this universe is sufficient to indicate precisely what the required amendment must be. This metric combines two different characteristics. In macroscopic regions it exhibits metrical uniformity and constancy, and in microscopic regions it exhibits metrical variability.

The material basis for the latter characteristic is already at hand in our traditional atomic theory. For, if we mean by the metric of space the relation which joins the atoms to each other, and by metrical variability a change in this relationship, it follows from the kinetic and contingent character of the behavior of the microscopic atoms that metrical variability must exist. It follows also that the material basis for a constant uniform relatedness or metric cannot be found in the microscopic atomic entities. The most that can be expected from them is an occasional appearance of order and constancy which will be but an incidental factor within the general relational variability.

We discover, therefore, that some other basic entity in addition to the microscopic particles must exist in this universe. Otherwise the macroscopic metrical uniformity would not exist. In fact, we have but to note what is required to enforce a general constant macroscopic metrical uniformity upon the variable metrical relatedness of the microscopic particles to discover precisely what the properties of this new entity are.

Firstly, it must be physical. For if it is to cause the microscopic atomic entities, and the molar objects into which they compound, to take on a constant uniform order which their motion alone cannot produce, it must change the direction of their motion. This calls for the presence of an external force, which only a physical object can provide.

Secondly, this physical entity must congest and completely surround all the microscopic atomic entities of the whole of nature. Otherwise they would be merely crowded out into some other referent for their motion, and macroscopic metrical uniformity would not exist.

Thirdly, this additional physical entity must be an atom, rather than a compound substance. Otherwise some referent other than it would be needed to provide a basis and meaning for the distinction between any one of its parts and another, and the old difficulty over atomicity would recur.

We have but to bring together these three required characteristics to discover the existence of a large macroscopic atom, spherical in shape and hollow in its interior except for its inner field, which contains and congests all the microscopic atoms of the traditional atomic theory.[11] Moreover, we seem to have no alternative but to say that the facts not merely suggest but necessitate the existence of this atom. For, as we have indicated, one cannot deny its existence without denying certain facts or involving one's self in two contradictions.

Note how this radical but essentially simple addition to our traditional atomic theory meets both of the difficulties to which we have previously referred. In providing a referent for atomicity and motion it enables us to accept the atomic theory and the rejection of absolute space which the relativity theory entails. For it permits us to define space-time as a relation between objects without losing a meaning for the atomicity and motion of those objects. And by introducing a fixed spherical physical form, surrounding the microscopic particles, which congests them sufficiently to preserve a general constant relational uniformity, while not congesting them so much as to prevent their motion and the resultant local variable relatedness, it provides us with a metric, completely conditioned by matter, which must exhibit local microscopic metrical variability within a general macroscopic metrical uniformity. In short, it gives us a kinetic theory of matter which reconciles the macroscopic metrical uniformity which measuring requires, with the microscopic metrical variability and the complete dependence of space-time upon matter which the general theory of relativity necessitates. By surrounding the electrons and protons of the whole of nature with one large finite spherical macroscopic atom, atomic physics and relativity physics are brought within a single consistent physical theory. This theory, we shall henceforth refer to as the macroscopic atomic theory.

It appears that traditional science was right in insisting that atomism necessitates the existence of a referent in addition to the microscopic particles, but wrong in identifying this referent with space. It appears also that traditional relativity physics has been right in maintaining that space and time are relative, but wrong in denying the existence of any referent for atomic motion and in maintaining that all motion is relative. It appears also that the static character of astronomical matter, to which Einstein referred in his cosmological reflections, exists. But it finds its basis in the congesting pressure from without of the macroscopic atom, rather than in the conception of all matter as at rest. Thus, the relatively static character of stellar matter and the macroscopic metrical uniformity of space is reconciled with the overwhelming evidence for the kinetic character of the microscopic atoms.

Consequences and Unique Verifications.—The macroscopic atomic theory has several important consequences. Those bearing on the nature of space-time, and the three-dimensional physical interpretation of the theory of relativity which it provides, were given in the first paper on this theory.[11] Others will be indicated here.

Firstly, the universe is finite. This conclusion is not new in relativity physics. However, our argument to it is original, for it presupposes nothing more than the kinetic atomic theory, measuring, and the general theory of relativity. No assumptions concerning boundary conditions or the stability of the universe are necessary.

Secondly, there is a physical ether. But, instead of being an absolute thing independent of atomic matter, it is the varying complex field which results from the compounding of the inner field of the macroscopic atom with the many fields and central charges of the microscopic electrons and protons.[11] This compound field is the electro-magnetic-gravitational field of which we and our earth form a part, and in which we are imbedded. It is to this compound field and its potential distribution that the tensor equations of relativity theory refer. This changing compound field may also be called space-time. When so considered it is to be remembered, however, that the temporal dimension is a mere abstraction from motion.[11] This identification of the ether with this changing compound field provides a physical medium for the transmission of electro-magnetic waves.

Thirdly, the discovery of an ether-drift would not be incompatible with the theory of relativity. For the part of the ether which we call the earth might or might not move with a different velocity than the larger part of the ether which immediately surrounds the earth. If it did so move, a drift or a whole series of drifts might be detected. This would prove nothing, however, concerning the absolute velocity of the earth, since it is not known whether the part of the changing ether which immediately surrounds the earth is at rest or in motion relatively to the macroscopic atom. It is because molar objects are imbedded and move in this complex changing ether that their motion is relative; the principle of isolation which is the basis of Newton's first law of motion no longer holds. It is because the microscopic atoms produce the ether and space-time and move in the macroscopic atom that their motion is absolute.

Fourthly, neither the geometry of the general theory nor of the generalizations of Eddington[3] and Weyl[12] is adequate. They fail to provide for metrical uniformity over more than infinitely short displacements. The macroscopic atomic theory calls for metrical uniformity over macroscopic finite distances. In addition, it requires an inclusion of electromagnetic potentials. Otherwise the compound field could not be conditioned by the electrons and protons of electro-magnetic theory. Also, it must be Riemannian. Otherwise the variable potential distribution which the motion of the microscopic atoms necessitates would not be possible, for a variable g_{ik} distribution can only be stated in a law of an invariant form, by a geometry of the Riemannian type. It is a geometry with these three characteristics that Einstein has developed in his unitary field theory. His latest achievement may be regarded, therefore, as a confirmation of our theory. For a detailed development of this point, see another paper[13] *of these Proceedings.*

Fifthly, astronomical phenomena which are inexplicable on traditional principles seem to be a necessary consequence of the macroscopic atomic theory. Traditional astronomical theory has been based upon the microscopic atoms and their motion. Since our theory includes the traditional microscopic atoms it possesses all the deductive fertility of traditional theory. In addition, the influence of the macroscopic atom is present. This adds to traditional forces a rotational force resulting from the deflection of the microscopic particles from a rectilinear course by the physical spherical form of the macroscopic atom. To be sure, this deflection would occur originally, only with those microscopic atoms which are moving near the spherical shell of the macroscopic atom, but eventually it is reasonable to suppose that it would be transmitted through the whole interior of nature. We are thus provided with a force of pure rotation in addition to the forces of traditional principles. Astronomical evidence indicates that this force is required. I refer to what Jeans terms "the characteristic equiangular spiral shape of arms" which is present in "at least nine tenths of the spiral nebulae."[14] He has shown that this calls for a force of pure rotation. The attempt of Professor E. W. Brown of my university to account for this in terms of traditional forces necessitates the hypothesis of a very complicated distribution of matter.[14] The situation seems to be analogous to the problem of the motion of the orbit of Mercury in Newtonian mechanics and Leverrier's hypothesis of the undiscoverable plant Vulcan. Jeans concludes that a force of pure rotation is called for, which traditional principles cannot provide.[14] If we may be permitted to reason from purely physical and qualitative considerations, it may be said that this constitutes a unique verification of the macroscopic atomic theory. It may be noted that rotational motion has always presented difficulties for traditional physics.

Sixthly, our theory indicates that all motion is not relative. The motion of the microscopic atoms in the macroscopic atom is absolute. This means that the theory of relativity and deductions from it cannot be applied to all bodies in nature. It holds only on the molar level for measurements of molar and microscopic phenomena which are referred to molar reference frames. It owes its existence to the epistomological circumstance that the macroscopic atom, like the microscopic atoms, is not immediately visible. This makes it impossible to determine whether a given molar object is at rest or in motion relatively to it. This means that the principle of the relativity of mass holds only when the relativity of motion holds, and that it cannot be applied in a literal metaphysical sense to the microscopic atomic entities. It must be maintained, therefore, that the doctrine of the complete annihilation of atomic matter can receive no justification from relativity physics.

Finally, the second law of thermo-dynamics cannot be valid for the whole of nature. No energy can escape from this finite universe, nor can the present state of heterogeneous chemical organization decrease to a homogeneous minimum. The physical macroscopic atom prevents both of these consequences. This confirms the conclusions of Millikan concerning the second law.

I must refer, in closing, to A. N. Whitehead. He was the first one to discover the real difficulties to which the theory of relativity has given rise. Without his analysis, the contradictions which form the basis of this paper would not have been discovered.

[1] A. S. Eddington, *Space, Time and Gravitation*, Cambridge, **1921**, p. 197.

[2] A. Einstein, *Math. Annalen*, **97**, p. 100.

[3] A. S. Eddington, *The Mathematical Theory of Relativity*, Cambridge, **1924**, p. 213–4.

[4] Sir I. Newton, *The Mathematical Principles of Natural Philosophy*, Scholium foll. Def. 8.

[5] J. Perrin, *Atoms*, London, **1923** (83–133).

[6] J. H. Jeans, *Astronomy and Cosmogony*, Cambridge, **1928** (345).

[7] A. N. Whitehead, *The Principles of Natural Knowledge*, Cambridge, **1919**, Ch. 4. *The Principle of Relativity*, Cambridge, **1922**, Ch. 3.

[8] A. Einstein, *Sitz. d. Pr. Akad. d. W.* **1917**.

[9] A. S. Eddington, *The Mathematical Theory of Relativity*, Cambridge, **1924** (162).

[10] W. Heisenberg, *Zeit. f. Physik*. **43** (879–93).

[11] F. S. C. Northrop, *J. of Phil.*, New York, 25 (449–467).

[12] H. Weyl, "Gravitation and Electricity," *Sitz. d. Pr. Akad. d. W.*, 1918.

[13] F. S. C. Northrop, *The Unitary Field Theory of Einstein in Its Bearing on the Macroscopic Atomic Theory.*

[14] J. H. Jeans, *Astronomy and Cosmogony*, Cambridge, **1928** (351).

THEORETICAL INTERPRETATION OF HYPER-FINE-STRUCTURE IN SINGLY IONIZED THALLIUM, Tl II

By H. E. White[1]

PHYSIKALISCH-TECHNISCHE REICHSANSTALT, CHARLOTTENBURG, GERMANY

Communicated December 7, 1929

A recent extension of the multiplet structure of singly ionized thallium, made by McLennan, McLay and Crawford[2] shows that many of the terms have relatively large fine-structure separations. Since the lines, as stated by them, were photographed with an ordinary spectrograph only the widest fine-structures could be measured. The frequency number differences are therefore only given to 0.5 cm.$^{-1}$. Although this leaves much to be desired in the fine-structure measurements of Tl II, an explanation of its fine-structure is here given. This is based upon the theoretical interpretation of term fine-structures given by the author[3] for Cd I, Ba I, Tl I, Bi I, La I and La II. There it is pointed out (as is excellently confirmed in the spectra here discussed) that the widest fine-structures are found in those terms arising from electron configurations involving a single unbalanced *s* electron. An *s* electron being found part of the time near the nucleus and part of the time outside of all of the other electrons merely acts as a "means to an end" of coupling the nuclear angular momentum, **i**, with the electron resultant, **J**. Fine-structures in Bi I, La I,