Proprieties and Vagaries

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Proprieties and the Motion of the Earth*

We Lecture On the coming in of the Copernican astronomy and we are familiar with the supposed—some obvious—reasons people resisted the notion that the earth moves. We fail to be impressed by the twentieth-century resistance, less conscious and more successful, to any notion that the earth does not move. And we do not notice that the reason for our putting aside any notion that the earth stands still is the same reason which made the sixteenth century abhor the notion that it moves.

We are familiar with the logical motives of the Copernican argument: the principle of simplicity and the principle of relativity. It could be maintained, beyond this, that the principle of relativity, properly descriptive and not normative, when it grew clearer as to its depth and

* To the Johns Hopkins History of Ideas Club, November 6, 1952.
scope in this century, came to add a prohibitory aspect; at times seconding, at times overbearing the more properly normative principle of simplicity, and serving as the front-man for another but unexplicit principle, that of nonuniqueness, essentially normative, but lacking the factual and logical force of the principle of relativity and falling short of the simplicity of the principle of simplicity. That is, relativity (the principle) tells us we cannot expect to measure certain supposed motions but does not give us any basis for choice among theories except among theories of what we can and cannot measure; simplicity tells us of two rival hypotheses to prefer the simpler. Both seem logically and historically safe. Non-uniqueness, more complexly and psychologically founded, tells us to shun any hypothesis which gives man a unique place.

When the Michelson-Morley experiment measured the velocity of the earth as zero,¹ scientists did not bother to argue against the chance the earth's velocity is as measured, absent. They went to work to explain the result.

¹ Or close enough to zero to be accepted as such, plus "experimental error," by all except Dayton C. Miller. For Miller see his "The Ether Drift Experiment and the Determination of the Absolute Motion of the Earth," Review of Modern Physics, v (1933), 203-242. For the experiment see W. M. Hicks, "On the Michelson-Morley Experiment," Philosophical Magazine, iii (6th Series) (1902) 9-42, 256, 555f.; and in A. A. Michelson: Light Waves and Their Uses (Chicago, 1903). The role of the existence of the ether in the interpretation of the outcome of the experiment will be noted later.
PROPRIETIES AND THE MOTION OF THE EARTH

It will be said there are empirical proofs of the earth’s motion, if not measures of it. Even some scientists sometimes say this. A recent, evidently authoritative, and to an outsider most interesting book says of the pendulum experiment: “In 1851 Foucault devised an experiment that established once and for all that the earth rotates on its axis.” And of the orbital motion: “The final and ineluctable answer to these questions was provided by Bradley, the then Astronomer Royal, in 1727” by means of the aberration of starlight.2

But in other contexts it is a commonplace with scientists that this finality of proof is not so—not so of motionlessness and equivalently not so of motion. They know that in the best information and logic of physics it cannot be so. I think the same fallibility of evidence could have been known in the time of Copernicus.

When in 1543 the De Revolutionibus Orbium Coelestium appeared, it carried a preface, since subordinately famous. Unsigned, it was soon discovered to be the work not of Copernicus but of Osiander, Lutheran theologian, who saw the book through the press. And for the preface its “well-meaning” author, from that day to this, has suffered the reproaches of all (so far as I know) who have commented.

The anonymity of a preface so placed is obviously blamable; but this chicanery is only incidentally the cause of the reproach. The theme of the preface is this:

If, however, they wished to weigh the matter thoroughly, the author of this work has done nothing for which he merits censure. For it is the job of the astronomer to use the careful observation of an artist in gathering together the history of the celestial movements; and then—since he cannot reach the true causes by any line of reasoning—to think up or construct whatever causes or hypotheses he please for these movements, provided that by taking them as postulates he can correctly calculate from the principles of geometry the past and future movements of the heavens. This artist is especially outstanding in both of these respects....

For it is sufficiently clear that this art is absolutely and profoundly ignorant of the causes of apparently irregular movement. And if it constructs and thinks up causes—and it has certainly thought up a good many—nevertheless it does not think them up in order to persuade anyone of their truth but only in order to institute a calculus correctly....

Perhaps the philosopher demands likeness for the truth instead; but neither will grasp anything in the way of certainty or hand it on, unless it has been divinely revealed to him.

Therefore let us permit these new hypotheses to make a public appearance among old ones which are themselves no more like the truth; ... and, as far as hypotheses go, let no one expect anything in the way of certainty from astronomy, since astronomy can offer us nothing certain; for if any-
one were to take as true that which was constructed for another use, he would depart from this discipline more stultified than when he came to it. Farewell.³

Now, the relativity that Osiander appeals to is the relativity that the Renaissance learned from Aristotle by way of Simplicius, the relativity that comes to prominence in the troubles ninety years later of Galileo with Maffeo Barberini become Urban VIII (did Galileo teach the motion of the earth as something more than the mathematical hypothesis the Pope had prescribed?). This relativity, as a mathematical but not physical or metaphysical doctrine, was used by Galileo's generation vigorously, as earlier it had been used lightly, as an exculpatory for scientific theory. But in Osiander it seems (or is this just to the Einsteinianly prejudiced ear?) to be used somewhat more in the modern and honest spirit. And to be sure it had been used quite honestly, we now know, by astronomers before the year of Copernicus's book and Osiander's preface. This is that astronomical relativity or provisionalism which the age called "hypothesis." The associated, but still historically and scientifically distinct, principle of relativity—the difficulty or impossibility of assigning motion to each of two bodies which are observed to be moving in respect to each other—the principle which had been

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noticed by Nicholas of Cusa and which was to be formulated more precisely by Galileo, this too was used by Galileo and Kepler and the other Copernicans quite honestly and strongly in the negative against the arguments of the "Aristotelians" and common sense. It is a curiosity, indeed, how Galileo and the others could use the principle of observational relativity honestly in one direction to explain away the empirical evidence urged by their opponents, and use the relativity of "saving the appearances" and "hypothesis" to guard themselves from doctrinal reproach, and match these two uses with two feelings toward what were associated principles while using neither one against themselves.4

And Francis Bacon, who is often decried as enviably cool toward Copernicus, asked something better than Copernicanism expressly because he was one of those "philosophers who demand likeness for the truth," because he felt neither the Copernican nor the Ptolemaic theory could give more than a relativistic "saving of appearances."

4 This is in part, perhaps, why the detailed and negative use of the principle of relativity continued, and continued as scientifically respectable, while the more general form of it as a view of the nature of astronomy, if not of all science, was first satirically used, then denied and forgotten almost, before being revived by Einsteinian physics. Here, too, are proprieties. For a summary and clarification of the at-times controversial doctrine of "hypothesis" in the Renaissance (which was not available when this paper was written) see R. M. Blake's Chapter II in Blake, E. H. Madden, and C. J. Ducasse, Theories of Scientific Method (University of Washington Press, 1960).
PROPRIETIES AND THE MOTION OF THE EARTH

There is no room to expect any pure truth from these or the like theories: for as the celestial appearances are solved both upon the suppositions of Ptolemy and Copernicus; so common experience, and the obvious face of things, may be applied to many different theories; whilst a much stricter procedure is required in the right discovery of truth. For as Aristotle accurately remarks that children, when they first begin to speak, call every woman mother; but afterwards learn to distinguish their own; so a childish experience calls every philosophy its mother, but when grown up, will easily distinguish its true one. In the meantime it is proper to read the disagreeing philosophies as so many different glosses of nature.

Before this, but in the same fourth chapter of the Third Book of the De Augmentis Scientiarum, he says:

The pains have been chiefly bestowed in mathematical observations and demonstrations; which indeed may show how to account for all these things ingeniously, but not how they actually are in nature: how to represent the apparent motions of the heavenly bodies, and machines of them made according to particular fancies; but not the real causes and truth of things. And therefore astronomy, as it now stands, loses its dignity by being reckoned among the mathematical arts, for it ought in justice to make the most noble part of physics. And whoever despises the separation between ter-
restrial and celestial things, and well understands
the more general appetites and passions of matter,
which are powerful in both, may receive a clear in-
timation of what happens above from that which
happens below. . . .5 We, therefore report this
physical part of astronomy as wanting, in com-
parison of which the present animated astronomy is
but as the stuffed ox of Prometheus—aping the
form but wanting the substance.

And in the sixth chapter of the “Description of the
Intellectual Globe,” in the course of his longest (and a
shrewd and interesting) discussion of astronomy, he
speaks of Copernicanism as “savoring of the character
of a man who thinks nothing of inventing any figment
at the expense of nature, provided the bowls of hap-
hazard roll well.” One thinks of Einstein’s “God does
not play at dice.”

Osiander claimed relativity for the Copernican theory,
supposedly as an exculpative from popular or clerical

5 It is usual to say Newton unified the worlds above and below
the moon by extending the laws of falling bodies to the planets.
This sentence and others (“For that supposed discrepancy be-
tween the celestial and the sublunary bodies appears to us a figment
at once driveling and presumptuous”; “Description of the Intel-
lectual Globe,” ch. v) are then a clear expression by Bacon of the
ideal that Newton achieved. The different feeling in Bacon, how-
ever, suggests we might more accurately say Newton extended the
celestial to the earthly, made the laws of falling bodies an instance
of heavenly regularities, or that the laws of falling bodies are
properly astronomical laws. Bacon would make the heavens earthy,
perhaps.
blame; Bacon charged the Copernican theory with relativity and called for something “nobler” and more “physical.” Both are reproached.

What Osiander is accused of is not so much anonymity as it is cowardice—especially making Copernicus seem cowardly. That the theory was simply “hypothetical” and “calculative” was denounced as false of the intention of Copernicus and of his followers; it was taken as false of Osiander’s own belief and to have been intended by him to avert persecution by the fast-hardening intolerance both Catholic and Protestant, of which Osiander felt himself more aware than the dying Copernicus—somewhat anxious though Copernicus’s thoughts of publication had been made by the shadows of authoritarian controversy.6

The contemning of Osiander is probably historically not altogether unjust. But the anonymity was not as bad then as now, and the view expressed was not made up 

ad hoc and might have been Copernicus’. And did the

6It is significant for histories of intolerance that Copernicus, having waited, he tells us, four times Horace’s nine years, decided on publication as the storms gathered. Even so, in part thanks to Osiander perhaps, it was not until 1616 that the Congregation of the Index ordered: “Lest opinions of this sort creep in to the destruction of Catholic truth, the book of Nicholas Copernicus and others . . . are suspended until they be corrected.” (see Preserved Smith, The Age of the Reformation [New York, 1920], p. 622) Sir William Dampier says: “It was understood [in 1616] that the new theory might be taught as a mere physical hypothesis.” (Sir William Dampier, A History of Science [New York, 1918] p. 124.) Notice how Sir William reverses Bacon’s meaning for “physical.”
preface not say what is now scientifically respectable truth of the new theory? Is it not more than time we recognized it said truth? Might it not have been said that Osiander had some realization of the truth of what he said, not merely that it was true in particular but that it must be so; and further that Copernicus might have realized this; that he had at his command reasons for understanding it; that, if Osiander's imposition had not been uncovered, the prestige of Copernicus might have led us to ascribe to him not the timidity of avoidance but the perspicacity of genius?

And Bacon—does that "bright, mean" spirit not deserve our notice that his view of Copernicus is something subtler and more of insight than ignorance or envy, and that it may have been insight into the nature of mathematics, not ignorance, as is often said, that led him to give it only the "great auxiliary" (but not "substantial") place he several times and emphatically but briefly gave it? Would he now say to Descartes: "You won; where is your winning? Cartesian physics is slipping out of all the Cartesian imaginableness which based your physics and linked it into metaphysical reality. Quantum mechanics runs off into an arithmetic of probability beyond geometry, thrusts dynamics into kinematics and so, perhaps, demands my qualitative motions. 'Pictorial meaning' has become a jest with the positivists. If physics does not come to me, it has done with you."

And when physics is refined to a sheer mathematical relativity, what shall we do? Shall we try for something
more "physical" with Bacon, or with Osiander for something "divinely inspired?" Shall we with Plato seek a "dialectic" to "destroy the hypotheses?" Or shall we say, "We can know no more"; or, "There is no more?"

Both Osiander and Bacon are reproached for seeing, from different angles, relativity in the Copernican astronomy. Yet what would the Copernicans have done in their defense against the enemies of their doctrine without the appeal to the principle of relativity?

The ways of supposedly detecting the motion or motionlessness of the earth have been: by direct observation ("We see it does not move"); then by noting effects as due to uniform motion (used against the Copernicans in the assertion that such effects—a wind past the earth, a fall of bodies to the west—should appear on a moving earth and do not appear); then by the effects of acceleration (how bodies fall or liquids behave in a jerking carrier came to be appealed to as evidence for a moving earth, but only in the guise of the next test); then by distinguishing the effects of "artificial force"—centrifugal—due to "real motion" (the flattening of the poles of the earth, the trade winds, the pendulum experiments); and then by measurement of one peculiar physical process, light, which by variations in apparent speed or direction past us may be supposed to disclose to us our own motion (the aberration of starlight, which seemed to succeed, and the Michelson-Morley experiment, which seemed to fail).

145
The first two were used against the doctrine of a moving earth, and relativity was the Copernicans' answer. The last two have been used for the doctrine of a moving earth, and here the principle of relativity has been called in only to explain why the proofs of motion cannot be used as measures of where and how much. The proofs maintain our experimentalist respectability. The real basis of our faith is elsewhere.

We can see that there is motion; we may be able to describe it in a system of bodies; we may be able, with two or many more than two bodies, to say that at most one of them is motionless; but we cannot distribute the rest and motion except by taking some point as fixed.

So the Copernicans explained to the man in the street who saw the sun moving in the sky. So, accepting the sun as center, they charted the paths of the planets about it. So, taking the "fixed stars" as the frame for that system, we can speak of the sun as moving. Then we see the Milky Way as moving among the galaxies, and then all moving in space or just moving. And so our success should warn us not to be too single. These beautifully charted revolutions about the sun are, as relative motion, sufficiently certain; but they are also, if one please, a going of the sun about the earth.

It is possible to construct a model, a mechanical toy, of the planets and the sun and to operate it as that system would be projected upon the surface of a table. We will first do so holding the sun in the center of the table. Then, illustrating the motion of the whole system, we
move the sun along the table with its planets still revolving about it. And if this is possible, as it clearly is, it must be possible so to move the sun that any chosen member of the system, say the earth, shall remain stationary on its original spot on the table. Or we hold the earth still and let the rest of our mechanical toy operate, as it will, of itself.

Even for the imagination to authenticate, this is not too difficult, especially if the fixedness of the earth be just of its central point, i.e. if the axial rotation be not stopped. If this be stopped the motions become much more complex—but we know we can hold our toy either with a pin through the poles of the earth or with our hand around the equator and the mechanism will keep on swinging without any systematic discomposure.

The difference in the motions around the sun and around the axis is important for the earth-motion arguments since, when the rest of the starry universe is taken into view, the axial motion is much the harder to still with imaginative acceptability. The vast enlargement made in the universe by Copernicus (to account for the fact he could detect no stellar parallax), one of the chief sticking points to early wonderers, becomes the affront to imagination if imagination is asked to revert to a nonturning earth; for then the whole circle of the heavens must be traveled every twenty-four hours by the farthest stars, and the velocities (not to speak of the momentums) called for, and those still greater ones called for by now-accepted distances, become stupen-
dous. Thus is suggested a third or middle view, as of Brahe and (sometimes) Bacon, in which the earth turns but does not travel. This too would seem to be secure against disproof by observation.

The principle of relativity permitted the Copernicans to use the principle of simplicity in support of the heliocentric theory. Further nicety of observation (notably the phases of Venus) also supported the theory as against the Ptolemaic; since even if the sun goes around the earth the other planets still go around the sun as mathematically more central to their orbits. But as to the motion or motionlessness or centrality in the universe, as to this no observation of the motions which take place among our company of observable bodies can give any evidence. Of this the principle of relativity is the statement.

Nor can the principle of simplicity, in any descriptive sense within the system, have voice here. All relative motions remain as they are discovered to be. Our toy heavenly bodies will continue to move as they “naturally” do regardless of what we do with the whole toy so long as we do not interfere with its internal economy. And they can be described in any way in which they can be described, under the same rule. Our heavenly motions are assuredly better expressed in Copernican than Ptolemaic schematism. But as to the common sense opposition between the Copernican and Ptolemaic points of view—is our earth home staying in one place and is that place at or near the center of
things?—no answer can come from observation, and no longer can it come from mathematical simplicity, which speaks decisively for the Copernican-Keplerian-Newtonian description of the relative motions but which, since all of this remains even if the earth or any other thing be taken as the one fixed member of its company, can speak no further.7

If simplicity is to speak here it must return, and does, to some other, to some more naive, dramatic, picturesque, human simplicity. Is it simpler to have the bigger body fixed? Then which is the biggest? Is it simpler to consider ourselves central? Is it, on the contrary, simpler to exorcize “anthropocentric prejudice” by not allowing the human habitat to be set apart? Is it simpler to say that any of the vast number can equally claim preference and so it is vastly improbable to assent to any one claim, especially if that claim correspond with any prior interest? Or is it simpler to deny that there is any meaning in the question as to which is unmoving?

The last is the now sophisticated position, with the next to last leading on to it. But I think it would not be contended that as yet it is the “felt” answer except among a minority even of careful scientists. I think there

7 Kepler is the real nonrelativist. For all his enthusiasm for and his contributions to Copernicanism, he argues vigorously, on the basis of both observation and theory, to a unique place for the earth: it, and so the sun which is the center of the earth’s little system, is in a sort of “hollow round” within the encirclement of the stars. This has been pointed out, since this paper was written, by Alexandre Koyré, From the Closed World to the Infinite Universe (Baltimore, 1957), pp. 64ff, 81ff.
is ample evidence, in addition to plausibility, to show that it is based upon or accompanied by a conviction that it is meaningful and for all practical purposes truthful to say and to require it to be said that the earth does move; and that this conviction in turn is almost solely based upon the anti-anthropocentric pressure of modern science, which is the reverse of the pressure of the sixteenth century in face of the same consideration of alternatives.

The modern pressure can be, and should be, put with more breadth as a principle of nonuniqueness: Let no thing claim preference. Relevant to the motion of the earth: Whatever, from time to time and for descriptive purposes, be accepted as fixed, let the choice be accidental to "reality," at least let it be independent of extrinsic interest.

Notice that it is not proper to say, as is sometimes said and often implied, that the principle of relativity forbids or prevents this or that state of affairs in nature or the possible truth of any belief. It is a statement of a characteristic which our minds observe as essential to observation. As such it may "forbid" as illicit certain sorts of conclusions from observation; but it cannot prevent the illicit conclusion from being true, nor can it forbid any state of affairs which might falsify or bypass the principle and enable us with unobserved validity to reach that conclusion. If we decide to call some body—sun, stars, ether—fixed, partly perhaps because we do not see any chance of detecting motion on their part,
we must not object if someone takes motion with respect to that body as real; and if we find or seek a bar to our detecting motion with respect to such a body—as we did with the ether—we ought not to feel that difficulty as flowing from the principle of relativity since the principle could save itself as easily by querying the "absoluteness" of the body.

The principle of simplicity, asserting a basis for choice, may, if accepted, be said to forbid or command among material assertions; but not the principle of relativity. On my way to the art gallery I stop and consult an esthetician and an oculist. If the first tells me that blue pictures are better pictures and I believe him, I will feel some compulsion to see the blue pictures as better. If the second tells me I am color blind and cannot see which are blue and then I do see the blue pictures that others see, I will quit believing the oculist. And I would have disbelieved him from the first if he had assured me that as a necessary consequence of his diagnosis all my friends and chance acquaintances would unfailingly contrive to mislead me as to what they saw as blue simply to prevent my finding out. Thus if an observed motion be by hypothesis an absolute motion then such it is. We know it to be such only from the hypothesis and not from observation of it, if the principle of relativity be true. But it is foolish to tell us that if we accept the hypothesis we must also believe nature adds to that particular motion some extra and accurate ingredient of falsification lest the principle be violated.
PROPRIETIES AND VAGARIES

Against the sort of objection to the theory of a moving earth frequent in Copernicus's own time, that if the earth moves then things dropped from a ship's mast would be left behind to the west, that the air would be a wind counter to the motion, and that we would find it harder to walk or throw a ball one way than another, came the formulation of the principle by Galileo: In a closed system at rest or in uniform motion everything will happen irrespective of the rest or motion of the system. Acceleration is excluded from the statement. Acceleration was for long supposed to be a telltale sign, telltale of real motion precisely because the force was artificial. As Henry More somewhat contemptuously pointed out: he might be unable, just by looking at their positions, to tell whether he or his friend had run away and returned; but, if he saw his friend red in the face and panting from his exertion, he would feel safe in saying his friend was the runner and not his own cool self.

So the physicists themselves, followed by all the physically tutored world, came to explain that the side-climbing water in the twirling bucket proves the bucket is turning; and so our books can still say, as we saw, that the pendulum experiments and the flattened poles of the earth and the trade winds prove that the earth is really turning on its axis.

Yet, it is curious that not until recently was the needlessness of these conclusions noted. The water climbs up the sides of the bucket without regard to the earth's motions and changing motions in which it takes part but with regard to the rotation as between the bucket
and the gravitational surface of the earth. To be sure we know ordinarily that we have applied the motion that produces the turning, but the evidence is only that the climbing of the water follows the relative turning not that it follows only the turning of one of the bodies or only the use of a particular force.

Even after the Newtonian unification of forces under gravity it was not recognized that such a description of forces operating regularly among bodies in space made the description of motions resulting from those forces as much a matter of relativity as the visual observation of respective position.

We can say to Henry More: To be sure, your friend did the running but maybe he ran to stay still. If you suppose the whole solid earth with you on it to rush away from under your friend’s feet and then back again while he by hard running just manages to maintain his position in space, you need not be surprised that he is red and you cool even though you are the one who has indulged in a quick round trip. If some demiurge were to hold suspended in space a bucket of water and below it the globe of the earth, then, keeping the bucket still, were rapidly to twirl the earth right beneath it, the water, we may assume, would climb up the bucket’s sides. The trade winds and the flattened poles of the earth—to most people the most persuasive “proofs”—are evidence of relatively rotating masses, not necessarily of absolute motion. And the deviation in the swing of the pendulum is no more than these.

But only today, with the Einsteinian principle of equiv-
naissance, under the incitement of newer theories which doubtless have their own shortcomings of self-understanding, are we seeing the defects of insight in earlier achievements. And here we are apt to think that the correction is to be made only if we are taking over the whole of the Einsteinian theory, whereas the correction is valid independently.

The principle of simplicity again is a major factor in the Newtonian dynamics for the Copernican astronomy; much of the prestige of the Newtonian law being in its explanation of many domains in terms of its own general relations. All bodies are falling bodies. In the Newtonian scheme, given inertia and gravity and some initial distribution of masses in motion, the whole adjusts itself as a system. The scheme does not, presumably, rule out the possibility of accidental or resultant uniqueness: within the system any body might through a balance of forces turn out to be central or stationary or both (supposing a meaning for the words). But it must be any one, not an externally preferred one. Already in 1700 the scientific mind, trained in simplicity and relativity and becoming more and more careful of nonuniqueness, is "conditioned" to suspect the suggestion of a particular body as such a stationary one; and soon will refuse to consider even the possibility of, or any offered evidence for the actuality of, such a status for this body, our body, the earth.

If we toss a handful of the twenty-six letters into a groove, they may fall into the order of our alphabet just
as well as into any other one order. But if we come upon them in that order we feel pretty sure they have been arranged. The odds are no longer one against any other one in the multitude, but one, or a few, against all the rest of the multitude. And in the vastly greater multitude the universe, even if this piece of matter might, like any other one, be unique in station, this piece of matter is, we know, our home and place from which we look out on all the rest; and we refuse to believe that the adjustment in collocation of unnumbered particles would so have come out to answer our antecedent interest. If not physical law and not chance, then nothing; and our principle of nonuniqueness becomes, as against the proper principle of relativity and more than the principle of simplicity, a maxim and a prohibition in the choice of theory.

Thus the same consideration, that the earth is our home, the earth is valuationally unique for us, moved both those who fought against and, in part, those who fought for the new astronomy. And that consideration—of the concomitance of the valuationally unique and the physically unique—which leads us to reject, to ignore, the supposition of a central earth is the consideration which led the Middle Ages to accept, to refuse to question, that same supposition as imperatively proper and natural.

The realization that the principle of relativity is safe from observation of force effects as it is safe from observation of change of position should have come, we have
PROPERTIES AND VAGARIES

seen, hard after the use of the principle restricted to uniform motion; on the basis that all motions may be described as functions of the presence of other bodies. Actually this realization came, and then not generally, only after the suggestion of still another modification of theory: the assertion that motion relative to the speed of light cannot be detected.

This is sometimes put as an extension of the principle of relativity: not only to deny the possibility of observing real motion but also to deny the possibility of observing relative motion of anything with reference to anything correctly assumed or reasoned to have real rest or motion. To the outsider this would seem not only to be an exceedingly queer rule but also to open the way for a run around the principle of relativity: all we have to do is find that thing with reference to which we cannot measure our varying motion and we know, by observation, what thing has absolute rest or motion, even if we cannot know—and with light we somewhat unexplainedly do seem to be allowed to know—what that motion is. Thus the principle seems to turn out to be the barrier not to the knowledge of absolute motion so much as to our knowing our motion.

For some time before Michelson first made his interferometer in Berlin the day had been looked forward to when the changing velocity of the earth relative to that of light should be measured. To be sure the logician could point out the principle would be logically serene. We would know the motion of the earth relative to another material motion, light. If we assume light is in its
own right absolute, we do so certainly not by any observation of its absoluteness; and, doing so, we already assert a measured absolute motion. Any further assertion of other motions derived from that motion which we assume to be absolute depends upon that assumption and is not any more an offensive bit of absolute knowledge than was the original. Even if we allow ourselves to say we know by this means the motion of the earth relative to the aggregation of bodies making up our "universe," is that universe moving and how?

Nevertheless, it is hard not to sympathize with the physicist in his impatience with the last question and in his feeling as to the prior caveat that on the basis of a tremendously authenticated general physics light may be taken as moving freely through the space among all the stars. So for all his purposes, if the measurement in view were obtained, the puzzle of the motion of the earth could be taken as solved, let the logician debate as he please about the principle of relativity.

Yet, out of this comes one of the basic paradoxes or confusions in the expression of recent theories. We are told that the principle of relativity is saved by the discovery that it is impossible to detect any motion relative to the motion of light; that light always passes any body, regardless of the motion of that body, at the same speed. And this is to say that it is impossible to detect with respect to one material motion precisely that sort of motion, relative, which the principle first told us was the only sort that can be detected.

The history of it seems that the principle of relativity
PROPERTIES AND VAGARIES

was used primarily to defend the thesis that the earth moves; which became the thesis that the earth moves but that its motion cannot be measured; and the principle came to be identified with the thesis. So it comes to include the assertion of discovery: that a particular observable body or process, light, has a unique mode of observed behavior. We must then find for this thing some unique nature to bear its unique behavior, or, better, find that this thing has a unique place in our methods of observation and measurement which will enable us to account for its curiousness as an object of observation and measurement.

This is one case in which the principle of nonuniqueness is flouted. It is so, perhaps, for the sake of stricter adherence elsewhere.

For, of course, in the Michelson-Morley experiment the measurement in view was not obtained, at least the figure obtained was near zero. If the experiment had succeeded as expected, the measurement for the motion of the earth would doubtless have been accepted and soon it would have been emphasized that the principle of relativity was not radically offended.

How could the zero result of the experiment, so often varied and repeated, be accounted for? The suggestions were many. One was not made even to be cast aside—one which might seem the most natural: that the earth does not move. We experiment to determine the velocity of the earth; our result is zero; why not say the velocity of the earth is zero? To be sure the flattening of the
poles and the trade winds, the pendulum experiments, the aberration of starlight were supposed to show the earth's rotation. We were assured and are still assured we know the earth some time during the day has a minimum motion through space of more than forty miles a second. But as soon as theorists got around to it under the new compulsion to criticize the bases of the Michelson-Morley experiment, the bases of those other proofs of motion were removed.

Without intention, I have not made reference to the ether. It seems clear that the existence or nonexistence of the ether is irrelevant to the considerations in question. But, perhaps, this irrelevance should be noted, since the Michelson-Morley experiment came about in the midst of belief in the ether, since what was done and what was looked for are likely to be recounted in terms of the ether, and especially since an instance of the power of proprieties is that it became the fashion for expositors to say, when the suggestion of zero velocity was at length raised by outsiders, that the experiment was really concerned not with the motion of the earth but with the existence of the ether.

The two things involved in the attempted measurement were the earth and light, whatever either be or however either move or not move. The mathematics of the differential effects in view is the same with or without the ether. The usual (Michelson's and Eddington's) description in terms of the hindering effect on the "rower" or "swimmer" by the "current of the stream"
makes us think of the ether streaming past the earth, but the calculation is identical if instead of “opposing and assisting current” we say “retreating and approaching reflectors,” which is indeed the assumed situation. If we complain that we cannot be content without modeling some medium for a wave or some material traveler, we can replace the ether with an Einsteinian dynamic space-time or bring on the photon retaining enough wave-character not to behave like a baseball.

Michelson says, “It was considered that, if this experiment gave a positive result, it would determine the velocity, not merely of the earth in its orbit, but of the earth through the ether.” He goes on to make clear the importance of this distinction not by any interest in the ether but by reference to the presumed motion of the sun: that is, the experiment would tell the earth’s motion not merely in the solar system but along with the sun through space. “It was hoped that with this experiment we could measure the velocity of the whole solar system through space. Since the result of the experiment was negative, this problem is still demanding a solution.”

The experiment assumed that light is independent of the motion of its source, but this independence was one of the facts causing the belief in the ether, not a deduction from that belief, and it survives the rejection of the ether. Indeed, the ether was by some (by Michelson himself at first) called in after the experiment to take back what it had been expected to give: first, to be carried along by the earth and so impart earth’s velocity

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8 A. A. Michelson, Light Waves and Their Uses, p. 159.
to light's; and then to help give some how and why for the Lorenz-FitzGerald contraction. Dayton Miller, who continued the experiment and the belief in the ether for many years, held that with the assistance of the ether and some carry-along he could both account for the virtual zero of result and get sufficient basis for some deduction of an actual velocity. It is the more strange that the orthodox party, who reject both Miller's theories and the ether, should almost offhand take it that by rejecting that which to Miller seemed the exonerator of the experiment they would exonerate it.

It is sometimes said that the word "ether" came to be used by the successors of Maxwell, for whom a material rigid and elastic medium for Fresnel waves was no longer needful, just to stand for a frame of reference to allow the passage (in the equations of electromagnetism) from one system of co-ordinates to another, i.e. to serve as a sort of Newtonian absolute space and time. In this sense the "ether" is an assertion of a real space-time as against a relativistic one, and the issue can be stated so that to reject the ether is to beg the question for Einsteinian relativity. Then the Michelson-Morley experiment may be said to be set up to decide between Newton and Einstein (if these be the only alternatives) and so to decide against the ether. But this is not what "ether" has normally meant or what it means now to most hearers or, I think, most users.

The Michelson-Morley experiment, especially as

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leading on to Einstein, helped to depose the ether by illustrating its supererogatory character for a positivistic or formalistic or phenomenological physics, but the experiment does not seem in its own right to have been directed or to have demonstrated either for or against the belief in the ether, nor does the elimination of the ether affect whatever implications the experiment may have for the motion of the earth.

Perhaps the only thing that would have persuaded scientists to weigh the possibility of taking from the earth the motions ascribed to it would have been the repeated performance of a Michelson-Morley experiment on some other body with positive outcome. In the absence of that, it is assumed that the experimental zero got here would be got also on the sun or the moon, that the performance of the experiment here is the equivalent of the performance of it anywhere.

This last represents the broad, deep feeling we have called the principle of nonuniqueness; the wariness of any preferential standing in nature, the refusal above all (a sort of uniqueness in nonuniqueness) to make the earth unique among its hosts of companions, to make this of all the bodies in space motionless—this the one on which we observers chance to find ourselves, the one which the older theology told us must as man's home have a central place in God's creation as in God's interest.

In the theory of relativity we have an interpretation

Or on an artificial satellite (1960 note).
of the experiment in terms of the nature of space-time or of measurement. It may be we have the right to say that all observed motion is relative not only to other body but also to some accepted or master means of measurement, and observation. Thus all statement of motion requires correction for the messenger, a factor which cannot be corrected for but must always be a factor.

Suppose Baltimore and London were synchronizing watches. Telegraphic messages are used with correction for the time taken in transit. But is the time in both directions the same? Another correction should be made: for any increase or decrease in the figured time of transit due to the destination's coming to meet the message or running away from it. But this cannot be told. If we set up our Michelson-Morley apparatus in Baltimore and London we find the messages go by at the same speed. And since we cannot measure how and how much each is wrong in setting its watch we say each is right; or so we are told. Herein it is taken as true (a) that light in any direction passes all points on the moving earth with the same speed, and, seemingly, (b) that there have been different times required to traverse equal distances in different directions across the surface of the moving earth.

How is this last known? Even assuming that light has a constant speed in its own right (and some suspicion seems to be cast by the theory on our means of getting at this absolute), some of the paradoxicality which
people find in the theory is in the joint assertion that this constant speed shows up as unaffected by the speed of passing points, but that it is to be taken as not unaffected by the speed of passing distances: all points go by light at the same speed but distances between points do not do so.

If, as an alternative supposition, the fact that light rays go by Baltimore and London at equal speeds be taken naively to show that they took the same time to make the trip in either direction, then no indeterminable correction would be called for. Light would really act across a moving earth as if the earth were still. (This would be equivalent to the theory of a dragged-along ether but without the ether.) And the theory might be more consistently loyal to the motive of relativity. But without the dragged-along ether, this theory would seem useless or incongruous in the Michelson-Morley experiment and with or without the dragged-along ether it would seem preposterous for some ways of stating Einstein’s famous embankment story of the two rays of light coming from opposite directions to the midpoint of a moving train and to the midpoint of an embankment which were opposite one another when the two rays left sources at the two ends of the train.

It is from the embankment story rather than from the Michelson-Morley experiment, I suspect, that the majority of us outsiders are apt to get most of our impression of this “restricted” portion of the relativity theory. And the outsider, it may be, can find some
incongruity or puzzlement between the impressions he gets from the two. From the embankment story he gets the notion of different elapsed times which make a difference and an observable difference—but the different elapsed times cannot be corrected, because of the identical passing speeds. In the Michelson-Morley experiment there is no observable difference. Although the experiment was designed to measure passing speeds it does so (as all measures presumably in some way must) by means of distances and elapsed times. If the elapsed times of the two perpendicular journeys were not equal or somehow brought into equality, the result of the experiment would not have been zero. But on the embankment it seems clear that the point of observation, on the train or on the embankment, which is closer to one source of light when it is observed will then be some distance from the point on the other with respect to which it is moving, and there must be some interval between one observation and the other. It may also be supposed that one observer can observe the other and with the two rays from opposite directions can observe the contrast of one simultaneity and one before-and-after or of two before-and-afters with reversed order. And here no literal FitzGerald-Lorenz contraction will remove the differences, which are all along one direction. (Not that the differences will tell us which if either is standing still.)

It is the single ray in either direction in the embankment example that requires the two-timing of simul-
PROPERTIES AND VAGARIES

taneities. And we can refuse both the singleness and the rays and have something more like messengers walking along train and embankment; and then there will be no two-timing. We can ask for two rays of light in each direction, one for train and one for embankment: could we do anything with them? And the two-timing would seem even surer to return with distant sources of light. How can we justify light going across distance with differing speeds when the two lights are not yet aware of the differing speeds of the bodies to which they are going or (somewhat less preposterous) instantly adjusting their speeds to the speeds of the neighboring bodies they happen for awhile to traverse? Imagine two stars, one east one west, signaling in such a fashion as to be called simultaneous on the east-west embankment. Can they be so on the train?

This suggests that on the train and the embankment we could ideally use two Michelson-Morley experiments and could actually do so if we had a fast enough train. Even a one-armed apparatus would be enough, within its accuracy, to show the relative motion. So Doppler effects familiarly show that, although light may pass two points at the same speed, pulsations, and thus periodic signals, it will not pass relatively moving points at the same intervals.

We had better stop teasing the concrete illustrations or stories offered for our help by the physicist. But we can say to the already impatient physicist that he does offer them, that it is by them he attracts much of the
PROPERTIES AND THE MOTION OF THE EARTH

general interest he does attract and at least partly likes, and that when his physics calls for revision of common sense and metaphysical beliefs it must in part be tested by them. The arguments of Henry More and Newton are not more absurd and disposable than they are cogent and available.

Whatever be the proper expression for its effect on the classical principle of relativity, the theory of relativity is said to ascribe celestial motions to the distortion of space-time by the presence of bodies. "Geometry" being the systematic analysis of the order of a manifold, and a "space" being any manifold of which a geometry is possible; then our universe may be described as in or of a space with varying geometries, and the behavior of things can be attributed to the change of geometry from region to region; and the behavior can be explained systematically if there be discoverable, as there must be in a world of "natural law," any consistent basis for the alteration, as in the presence of mass. So light bends as it passes the bulk of the sun.

Here, just as the principle of equivalence of gravitational and centrifugal gives the statement of the unproving of the proofs of the motion of the earth by means of the pendulum, the bending of light gives the statement of the unproving of the second of the proofs quoted at the beginning of this paper. The aberration of starlight seems a return to the observation of change of position, but an observation of direction relative to that unique thing light, as the Michelson-Morley ex-
periment tried to reach speed relative to light. But the bending of light, even beyond that calculated from the corpuscular theory, early served the theory of relativity not only as something to be explained but also as something to give evidence for the theory. And, indeed, that the aberration of starlight could be and would be explained on relativistic grounds could be taken as clear, ahead of the particular explanation offered.

It has been noted that the sophisticated assertion is not that the earth does not move or that it moves, but that "moves" so simply used is out of place. And it may be felt this vitiates much of what has been said. But much of our concern has been historical and in this connection the objection is irrelevant. And today it is still the case that scientists, if not most of us, do say the earth moves and say this in a way they do not say the earth does not move; and they, if not most of us, do resent any intimation that the earth stands still in a way they do not at all resent straight assertion that the earth moves; and we do all this, it seems, on the same ground on which people four hundred years ago made the opposite commitments.

Someone says, "I see the sun move, not the earth." We say, "You see, from one of them, the motion of two bodies relative to one another." Someone says, "Bodies do not fall to the west as they should if the earth is moving east." We say, "They and the atmosphere are parts of the earth's system." Twice the
principle of relativity works in rebuttal. Someone says, "The poles are flattened by the spin of the earth." We say, "Science gives empirical proof." We do not say, "All are parts of a system and the effects of a turning are of a turning of one thing among a company, relative as is the change of position we see." Someone says, "We measured the change in the speed of light past the earth and got a zero result." We now say, "All are parts of a relative system and anyway we have to expect a zero result in deference to the principle of relativity."

The bases of our faith are in none of these facts but are the same bases the Middle Ages had, but used inversely. They are, if you please, metaphysical (I am not one who dislikes the word). And the metaphysics of a time is important—especially the metaphysics of the physicists of the age immediately before that in which physicists are in dominant esteem. Our physicists today are relativists; but, sharing the faith that at least and assuredly the earth does not stand still, the one application of their relativity they are most apt not to have taken the trouble to make is the unproof of their predecessors' proofs of the motion of the earth.

The Greeks seem to have had little of either the medieval or the modern jealousy. Anaximander taught a free earth and the atomists a traveling one in a wandering universe. The Pythagoreans' earth moved, but close around the center. Aristotle went back to a central and still earth and Aristarchus on to a heliocentric scheme. Epicurus, elegant economist and relativist in science,
said say whichever you like so long as you keep it “natural.” Ptolemy reached back to Aristotle. Each of these and others chose for his own reasons and without facing a conditioned uproar of response. We seem less free.

For my part, I am enough of a modern to prefer the modern use of the principles involved to the medieval use; but not by a margin I cannot imaginatively cancel. Like most people today I am apt to feel that the earth is moving—that is, I feel so in my more but not in my most scientific moments. In my least scientific moments I take the earth as still; and in my most scientific moments I say there is no absolute motion in proper meaning for physics.

But also in my more careful and cantankerous moments I am fond of annoying people by saying, honestly, that there is not demonstrative proof or experimentally decisive evidence that the earth moves, and that what experimental evidence there is might seem to say that the earth stands still.