

### III

## GRAVITATION AND THE ETHER

**E**INSTEIN'S theory of gravitation may be compared with thermodynamics. Both start with a few fundamental principles or axioms based on experience and proceed by logical deductions without further appeal to facts. Neither attempts any explanation of the nature of the phenomena considered.

The kinetic theory of gases is an example of a different type of theory. A definite mechanism is assumed for a gas and the properties of the mechanism are worked out and compared with the known properties of gases.

If the axioms of the first type of theory are true, the theory itself must be true, unless the reasoning is at fault; both types of theory are to be tested by comparison of the results with observation.

The principles on which Einstein's theory depends are his principle of relativity and his principle of equivalence. According to the first, the laws of nature must be such that the differential equations which express them are independent in form of the coördinate system or frame of reference used, and, according to the second, a gravitational field cannot be distinguished from an apparent field due to an acceleration of the frame of reference. From these principles he shows how the form of the paths or orbits described by bodies moving in a gravitational field may be deduced.

The theory is mainly geometrical. It gives the geometrical form of the orbits. In the absence of a gravitational

field a body moves in a straight line, provided the frame of reference is suitably chosen, and in the field surrounding a heavy particle a small body describes an ellipse, as in Newton's theory, again provided the frame of reference is suitably chosen. In Newton's theory the ellipse remains stationary, while in Einstein's it slowly rotates in its own plane.

What causes the moving particle to move round an ellipse instead of along a straight line? According to Newton, there is an attraction between the particles, a force tending to pull them together. But this is merely another way of saying that they tend to move together; it is no explanation. If we regard Einstein's geometry of orbits as a geometry of space, we may say that the body describes an ellipse because the space and time around a heavy particle are not straight but curved. The path of the particle is the natural path in the curved space-time: the path of maximum interval length. This does not seem to be an explanation any more than Newton's force. Why should a particle describe a curve in a curved space, and, anyhow, what is the meaning of curved space?

The idea of space is obtained by experience; it cannot be explained. We express our experience of space by saying that bodies occupy parts of space and can move about in it; between bodies there is what is usually said to be empty space, or a vacuum. Such statements seem to be intelligible because of our experience of bodies and their motions; they would mean nothing to a being without experience similar to our own. To explain what is meant by curved space or non-Euclidean space it is customary to take the case of a surface which may be flat or curved. If we consider a sphere on which a particle is constrained to move, then we see that this particle will not move in straight lines, but along great circles of the sphere. In the same way, a par-

ticle in curved space of three or four dimensions, it is said, will move along a curve. The objection to this illustration is obvious. The sphere must be a material sphere, otherwise it could not keep the particle on its surface. There must be something curved to make a curved space. If, then, the space between bodies is empty, there is nothing in it to be curved, so it cannot be curved.

Suppose that a large number of cubical blocks were made at a certain place, all exactly equal when tested by placing any face of one against any face of the others. Then suppose these blocks were taken into the gravitational field near a heavy particle and were built up by placing them close together so as to fill up the space around the heavy particle. Suppose it was then found that they would not fit together exactly, so that the space could not be filled up completely with them. Ought we to conclude that the space was curved or that the shape of the blocks had changed? If the shape of the blocks had not changed, then they ought to fit together. If the blocks would not fit, the proper conclusion to draw would be that the gravitational field had distorted them. The experiment could not give any information about the geometry of the space itself. Empty space cannot be measured; we can only measure bodies and their distances apart. In empty space there is nothing to fix the shape or position of geometrical figures. They can be constructed in any way desired, and measurements made of them relate to the shape of the figures and give no information about the space in which they exist.

The conception of a curvature or distortion of empty space is meaningless, since only material bodies can be measured. Of course it is possible to try to deduce the geometrical properties of space from observations on material bodies, but it seems doubtful whether the results of

such attempts are anything but the geometrical properties of the material bodies. Einstein writes:<sup>1</sup> "We entirely shun the vague word 'space,' of which we must honestly acknowledge we cannot form the slightest conception, and we replace it by 'motion relative to a practically rigid body of reference.' "

This difficulty may be removed by supposing that space is not empty, but filled with a medium, the ether, and we may suppose that the properties of the ether are such that particles (which may be merely modified ether or singularities in it) move in it along paths which are straight where the ether is uniform, and curved where the properties of the ether vary from point to point. Or we may simply say that the ether is space. Since it always fills up space, we have no experience of space except when full of ether, and so we may identify space with the ether. It seems to the writer better to retain the ether and not get rid of it by supposing that space as such can have geometrical or other properties.

A space in which a particle describes a curve must have some degree of substantiality, and it seems more in accordance with experience to say that it contains a medium having the necessary properties than to attribute these properties to a vacuum.

It is admitted that in different parts of space bodies move in different ways. It is clear, then, that different parts of space have different properties, and, therefore, physical properties are present in space. But the possession of physical properties is the only known attribute of matter, so that we are entitled, if we so choose, to regard space as filled with a medium. If we do not so choose, then we must regard space itself as having properties, and we ought to

<sup>1</sup> "The Theory of Relativity," authorized translation by R. W. Lawson, page 9.

conclude that matter does not differ essentially from space, for matter merely has physical properties. If so, then space is full of matter, so that we get back to the ether in this way also.

In recent years many physicists seem to have come to the conclusion that the ether does not exist, because it is found to be impossible to detect any kind of effect due to the motion of translation of the earth through it. The old arguments for the ether, however, are still valid. Gravitational and electromagnetic actions take place across a vacuum, and light travels through a vacuum and has all the properties to be expected of a wave motion through a medium. To give up the ether merely because it fails to manifest its presence in one particular way is absurd and never ought to have been suggested.

Einstein's principle of equivalence provides a good illustration of how something which is everywhere present may fail to produce any observable effect. On a material system falling freely in a uniform gravitational field there should be no observable effect due to the field, although the system may move in it with ever-increasing velocity. The acceleration is produced by the field, but is the same for all parts of the system and so does not change the relative motion of the parts of the system, and therefore produces no observable effects.

It seems that the general principle that any action on a material system which is equal on all parts of the system will produce no effect observable in the system, might be put forward as plausible. It is only differential effects, due to variations in the action over the volume of the system, which can be observed.

If a system is moving with uniform velocity through the ether which remains everywhere at rest, then if all parts of

the system are equally affected by the relative motion, it is not surprising that no effects observable in the system are produced. The effects produced exactly compensate the action, just as in the case of a uniform gravitational field. No observable effects should be expected and none are found. It is not a case of a surprising compensation of effects, but a perfectly natural state of things. Motion through the air or through water gives observable effects because the action is not uniformly distributed over all the parts of the system.

According to the principle of equivalence, the visible universe may, for all we know, be moving with an enormous acceleration due to a uniform gravitational field produced by enormous masses outside. Such a field can produce no observable effects, and so its presence or absence cannot be determined. We may say, if we like, that it does not exist for us.

In the case of the ether, no effect due to uniform motion through it can be detected, but its presence is manifested in other ways independent of uniform motion which have been mentioned. Its presence and important functions need not be doubted. We have gravitational electric and magnetic fields which can exist together in so-called empty space, and it seems much more reasonable to say that such fields are modifications of a single medium, the ether, than to suppose that they exist in empty space or are due to modifications of empty space.

In what follows it will be supposed that there is a medium, the ether, filling up all space, and a theory of gravitation recently put forward by the writer<sup>1</sup> and based on this idea and on the electrical theory of matter will be described.

The atoms of matter, according to Rutherford, consist

<sup>1</sup> "Physical Review," January, 1921.

of a minute positively charged nucleus surrounded by a number of negative electrons, the positive charge on the nucleus being equal to the total negative charge on the electrons. This theory is confirmed in many ways and will be adopted here. An electrically neutral body is, therefore, a system of electrical charges, and its mass is probably wholly electromagnetic.

The facts which a theory of gravitation has to explain are three:

- (1) Newton's law of gravitation.
  - (2) The deflection of light by the gravitational field of the sun.
  - (3) The change of frequency of the spectral lines emitted by atoms in the sun.
- (1) Is not absolutely exact, according to Einstein.
  - (2) Was predicted by Einstein and verified by observations during the solar eclipse of 1919.
  - (3) Was predicted by Einstein and its existence is still in doubt, but the most recent results are favorable to it, so its truth will be assumed here.

If we assume matter to consist of electrical charges immersed in a medium, then, to explain Newton's law of gravitation, we must consider under what circumstances a neutral electrical system tends to move through a medium in which it is immersed.

It is well known that an electrostatic system immersed in a medium the specific inductive capacity ( $K$ ) of which varies from point to point tends to move in the direction in which  $K$  increases most rapidly. It is natural, therefore, to test the suggestion that gravitation may be due to variations of the specific inductive capacity of the ether. If we find that the three facts given above can all be explained on

such a theory, we shall have good reason to consider the theory to be a possible one.

The observed deflection of light passing by the sun requires that the refractive index ( $n$ ) of the ether be equal to  $1 + 2 m/r$ , where  $m$  denotes the sun's mass and  $r$  the distance from his center. The distance  $r$  is expressed in units of length equal to the distance traveled by light in unit time, and the mass  $m$  is expressed in units of mass which produce unit gravitational acceleration at unit distance. If the unit of time is one second, then the unit of length is  $3 \times 10^{10}$  cms. and the unit of mass is about  $4 \times 10^{33}$  grams. The refractive index of the ether is equal to  $\sqrt{\mu K}$ , where  $\mu$  is its magnetic permeability and  $K$  its specific inductive capacity. Hence, if we assume  $n = 1 + 2 m/r$ , we have  $(\mu K)^{\frac{1}{2}} = 1 + 2 m/r$ . The ratio  $m/r$  is always very small. Its greatest value in the solar system is about  $2 \times 10^{-6}$  at the surface of the sun. The equation  $(\mu K)^{\frac{1}{2}} = 1 + 2 m/r$  can be satisfied by taking  $\mu = 1 + 2 m/r$  and  $K = 1 + 2 m/r$ .

The force on a neutral electromagnetic system in a medium in which it can move freely due to variations in  $K$  and  $\mu$  is equal to  $\frac{1}{8\pi} \left\{ E^2 \nabla K + H^2 \nabla \mu \right\}$  per unit volume. Here  $E$  is the electric intensity and  $H$  the magnetic intensity. The electrical energy per unit volume is  $KE^2/8\pi$ , and the magnetic energy is  $\mu H^2/8\pi$ . Let  $W$  denote the electrical energy and  $W^1$  the magnetic energy per unit volume. Then the expression for the force becomes

$$\begin{aligned} F &= W \nabla K / K + W^1 \nabla \mu / \mu \\ &= W \nabla \log K + W^1 \nabla \log \mu. \end{aligned}$$

If  $\mu = 1 + 2 m/r$  and  $K = 1 + 2 m/r$ , then neglecting squares of  $m/r$   $\log K = 2 m/r$  and

$$F = -2 m (W + W^1) / r^2.$$

The electromagnetic mass  $m^1$  of the system in the units we

are using is equal to  $\int (W + W^1) d\sigma$ , where  $d\sigma$  denotes an element of volume, so that for a small system, in which  $r$  can be regarded as constant,

$$F_r = - 2 mm^1/r^2$$

where  $F_r$  is now the total force on the system. This is just twice the Newtonian attraction  $-mm^1/r^2$ .

It appears that if we assume for  $\mu$  and  $K$  values which give the observed deflection of light, then we get the gravitational attraction twice too big.

So far we have supposed that the electromagnetic system remains unchanged in size when  $\mu$  and  $K$  vary, but since the forces between the parts of the system depend on  $\mu$  and  $K$ , we should expect the size to vary.

If  $l$  is a quantity proportional to the linear dimensions of the system and equal to unity when  $K = \mu = 1$ , then the electrical energy of the system can easily be shown to be inversely as  $Kl$  and the magnetic energy inversely as  $\mu l$ , so that the force on the system, per unit volume, is given by

$$F = W \nabla \log Kl + W^1 \nabla \log \mu l.$$

Hence to get the observed gravitational attraction, we must have

$$\mu l = Kl = 1 + m/r \text{ or } l = 1 - m/r.$$

We should expect the dimensions of such a system to be determined by the dimensions of the electrons it contains. The size of an electron may be regarded as determined by an equilibrium between the tension inside it and the stress in the electric field outside it. The internal tension may be regarded as a sort of elastic reaction against the electric displacement at its surface. We should therefore expect the tension to be proportional to the displacement. This gives

$$K a^4 \propto \frac{1}{a^2}$$

where  $a$  is the radius of the electron, so that  $aK^{\frac{1}{2}}$  is constant. If  $K = 1 + 2m/r$ , this gives  $a \propto 1 - m/r$ .

If the linear dimensions of the system are proportional to  $a$ , we get, therefore,  $l = 1 - m/r$ , which, as we have just seen, is the value required to give the observed gravitational attraction.

Thus it appears that if we assume  $\mu = 1 + 2m/r$ , and  $K = 1 + 2m/r$ , then we can explain the deflection of light by the sun and the gravitational attraction. The contraction given by  $l = 1 - m/r$  is in agreement with Einstein's theory.

The third fact, that the frequency of the light emitted by an atom on the sun should be diminished by the gravitational field, can also be easily deduced from the present theory.

According to Bohr's theory of spectral lines, the frequency is proportional to the energy emitted when the atom passes from one stationary state to another. If the atom is in ether for which  $K = 1 + 2m/r$  instead of  $K = 1$ , its energy in each of its stationary states will be diminished in the ratio  $1 - m/r$ , and so the frequency of any line which it emits will be diminished in the same ratio exactly as predicted by Einstein.

Thus it appears that the theory proposed leads to a simple explanation of all the three facts of gravitation, and so must be regarded as a possible theory.

The squares and higher powers of the ratio  $m/r$  have been neglected, so that the results obtained are only accurate to the first order of  $m/r$ . To this order the results obtained agree with Einstein's theory, so that the theory here proposed may be regarded as a physical interpretation of his theory.

The only sort of physical theory which seems possible is one depending on the physical properties of the ether, and

$\mu$  and  $K$  are the only properties of the ether with which we are acquainted. The nature of these properties is unknown, so that we have only explained the facts of gravitation in terms of unknown quantities, and we do not know why  $\mu$  and  $K$  should be changed near matter in the way assumed.

Einstein's theory has the very great advantage that it is based on general principles derived from experience, whereas the theory just described depends on the assumption of a variation of  $K$  and  $\mu$ , chosen so as to give results in agreement with the facts. The present theory has the advantage that it is very simple and requires no elaborate analysis; it may prove useful by enabling new phenomena to be predicted.

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