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The Einstein Theory of Relativity

A Concise Statement

by

Prof. H.A. Lorentz of the University of Leyden

NOTE

Whether it is true or not that not more than twelve persons in all the

world are able to understand Einstein's Theory, it is nevertheless

a fact that there is a constant demand for information about this

much-debated topic of relativity. The books published on the subject

are so technical that only a person trained in pure physics and

higher mathematics is able to fully understand them. In order to

make a popular explanation of this far-reaching theory available,

the present book is published.

Professor Lorentz is credited by Einstein with sharing the development

of his theory. He is doubtless better able than any other man--except

the author himself--to explain this scientific discovery.

The publishers wish to acknowledge their indebtedness to the New

York Times, The Review of Reviews and The Athenaeum for courteous

permission to reprint articles from their pages. Professor Lorentz's

article appeared originally in The Nieuwe Rotterdamsche Courant of

November 19, 1919.

INTRODUCTION

The action of the Royal Society at its meeting in London on November

6, in recognizing Dr. Albert Einstein's "theory of relativity"

has caused a great stir in scientific circles on both sides of the

Atlantic. Dr. Einstein propounded his theory nearly fifteen years

ago. The present revival of interest in it is due to the remarkable

confirmation which it received in the report of the observations

made during the sun's eclipse of last May to determine whether rays

of light passing close to the sun are deflected from their course.

The actual deflection of the rays that was discovered by the

astronomers was precisely what had been predicted theoretically by

Einstein many years since. This striking confirmation has led certain

German scientists to assert that no scientific discovery of such

importance has been made since Newton's theory of gravitation was

promulgated. This suggestion, however, was put aside by Dr. Einstein

himself when he was interviewed by a correspondent of the New York

Times at his home in Berlin. To this correspondent he expressed the

difference between his conception and the law of gravitation in the

following terms:

"Please imagine the earth removed, and in its place suspended a box as

big as a room or a whole house, and inside a man naturally floating

in the center, there being no force whatever pulling him. Imagine,

further, this box being, by a rope or other contrivance, suddenly

jerked to one side, which is scientifically termed 'difform motion',

as opposed to 'uniform motion.' The person would then naturally reach

bottom on the opposite side. The result would consequently be the

same as if he obeyed Newton's law of gravitation, while, in fact,

there is no gravitation exerted whatever, which proves that difform

motion will in every case produce the same effects as gravitation.

"I have applied this new idea to every kind of difform motion and

have thus developed mathematical formulas which I am convinced give

more precise results than those based on Newton's theory. Newton's

formulas, however, are such close approximations that it was difficult

to find by observation any obvious disagreement with experience."

Dr. Einstein, it must be remembered, is a physicist and not an

astronomer. He developed his theory as a mathematical formula. The

confirmation of it came from the astronomers. As he himself says, the

crucial test was supplied by the last total solar eclipse. Observations

then proved that the rays of fixed stars, having to pass close to

the sun to reach the earth, were deflected the exact amount demanded

by Einstein's formulas. The deflection was also in the direction

predicted by him.

The question must have occurred to many, what has all this to do with

relativity? When this query was propounded by the Times correspondent

to Dr. Einstein he replied as follows:

"The term relativity refers to time and space. According to Galileo and

Newton, time and space were absolute entities, and the moving systems

of the universe were dependent on this absolute time and space. On

this conception was built the science of mechanics. The resulting

formulas sufficed for all motions of a slow nature; it was found,

however, that they would not conform to the rapid motions apparent

in electrodynamics.

"This led the Dutch professor, Lorentz, and myself to develop

the theory of special relativity. Briefly, it discards absolute

time and space and makes them in every instance relative to moving

systems. By this theory all phenomena in electrodynamics, as well as

mechanics, hitherto irreducible by the old formulae--and there are

multitudes--were satisfactorily explained.

"Till now it was believed that time and space existed by themselves,

even if there was nothing else--no sun, no earth, no stars--while

now we know that time and space are not the vessel for the universe,

but could not exist at all if there were no contents, namely, no sun,

earth and other celestial bodies.

"This special relativity, forming the first part of my theory,

relates to all systems moving with uniform motion; that is, moving

in a straight line with equal velocity.

"Gradually I was led to the idea, seeming a very paradox in science,

that it might apply equally to all moving systems, even of difform

motion, and thus I developed the conception of general relativity

which forms the second part of my theory."

As summarized by an American astronomer, Professor Henry Norris

Russell, of Princeton, in the Scientific American for November 29,

Einstein's contribution amounts to this:

"The central fact which has been proved--and which is of great interest

and importance--is that the natural phenomena involving gravitation

and inertia (such as the motions of the planets) and the phenomena

involving electricity and magnetism (including the motion of light)

are not independent of one another, but are intimately related, so

that both sets of phenomena should be regarded as parts of one vast

system, embracing all Nature. The relation of the two is, however, of

such a character that it is perceptible only in a very few instances,

and then only to refined observations."

Already before the war, Einstein had immense fame among physicists,

and among all who are interested in the philosophy of science,

because of his principle of relativity.

Clerk Maxwell had shown that light is electro-magnetic, and had reduced

the whole theory of electro-magnetism to a small number of equations,

which are fundamental in all subsequent work. But these equations

were entangled with the hypothesis of the ether, and with the notion

of motion relative to the ether. Since the ether was supposed to be

at rest, such motion was indistinguishable from absolute motion. The

motion of the earth relatively to the ether should have been different

at different points of its orbit, and measurable phenomena should

have resulted from this difference. But none did, and all attempts to

detect effects of motions relative to the ether failed. The theory of

relativity succeeded in accounting for this fact. But it was necessary

incidentally to throw over the one universal time, and substitute

local times attached to moving bodies and varying according to their

motion. The equations on which the theory of relativity is based are

due to Lorentz, but Einstein connected them with his general principle,

namely, that there must be nothing, in observable phenomena, which

could be attributed to absolute motion of the observer.

In orthodox Newtonian dynamics the principle of relativity had a

simpler form, which did not require the substitution of local time

for general time. But it now appeared that Newtonian dynamics is only

valid when we confine ourselves to velocities much less than that

of light. The whole Galileo-Newton system thus sank to the level

of a first approximation, becoming progressively less exact as the

velocities concerned approached that of light.

Einstein's extension of his principle so as to account for gravitation

was made during the war, and for a considerable period our astronomers

were unable to become acquainted with it, owing to the difficulty

of obtaining German printed matter. However, copies of his work

ultimately reached the outside world and enabled people to learn more

about it. Gravitation, ever since Newton, had remained isolated from

other forces in nature; various attempts had been made to account

for it, but without success. The immense unification effected by

electro-magnetism apparently left gravitation out of its scope. It

seemed that nature had presented a challenge to the physicists which

none of them were able to meet.

At this point Einstein intervened with a hypothesis which, apart

altogether from subsequent verification, deserves to rank as one

of the great monuments of human genius. After correcting Newton,

it remained to correct Euclid, and it was in terms of non-Euclidean

geometry that he stated his new theory. Non-Euclidean geometry is

a study of which the primary motive was logical and philosophical;

few of its promoters ever dreamed that it would come to be applied

in physics. Some of Euclid's axioms were felt to be not "necessary

truths," but mere empirical laws; in order to establish this view,

self-consistent geometries were constructed upon assumptions other

than those of Euclid. In these geometries the sum of the angles of

a triangle is not two right angles, and the departure from two right

angles increases as the size of the triangle increases. It is often

said that in non-Euclidean geometry space has a curvature, but this

way of stating the matter is misleading, since it seems to imply a

fourth dimension, which is not implied by these systems.

Einstein supposes that space is Euclidean where it is sufficiently

remote from matter, but that the presence of matter causes it

to become slightly non-Euclidean--the more matter there is in the

neighborhood, the more space will depart from Euclid. By the help of

this hypothesis, together with his previous theory of relativity, he

deduces gravitation--very approximately, but not exactly, according

to the Newtonian law of the inverse square. The minute differences

between the effects deduced from his theory and those deduced from

Newton are measurable in certain cases. There are, so far, three

crucial tests of the relative accuracy of the new theory and the old.

(1) The perihelion of Mercury shows a discrepancy which has long

puzzled astronomers. This discrepancy is fully accounted for by

Einstein. At the time when he published his theory, this was its only

experimental verification.

(2) Modern physicists were willing to suppose that light might be

subject to gravitation--i.e., that a ray of light passing near a

great mass like the sun might be deflected to the extent to which a

particle moving with the same velocity would be deflected according

to the orthodox theory of gravitation. But Einstein's theory required

that the light should be deflected just twice as much as this. The

matter could only be tested during an eclipse among a number of

bright stars. Fortunately a peculiarly favourable eclipse occurred

last year. The results of the observations have now been published,

and are found to verify Einstein's prediction. The verification is not,

of course, quite exact; with such delicate observations that was not to

be expected. In some cases the departure is considerable. But taking

the average of the best series of observations, the deflection at

the sun's limb is found to be 1.98'', with a probable error of about

6 per cent., whereas the deflection calculated by Einstein's theory

should be 1.75''. It will be noticed that Einstein's theory gave a

deflection twice as large as that predicted by the orthodox theory,

and that the observed deflection is slightly larger than Einstein

predicted. The discrepancy is well within what might be expected in

view of the minuteness of the measurements. It is therefore generally

acknowledged by astronomers that the outcome is a triumph for Einstein.

(3) In the excitement of this sensational verification, there has

been a tendency to overlook the third experimental test to which

Einstein's theory was to be subjected. If his theory is correct as it

stands, there ought, in a gravitational field, to be a displacement

of the lines of the spectrum towards the red. No such effect has

been discovered. Spectroscopists maintain that, so far as can be

seen at present, there is no way of accounting for this failure if

Einstein's theory in its present form is assumed. They admit that some

compensating cause may be discovered to explain the discrepancy, but

they think it far more probable that Einstein's theory requires some

essential modification. Meanwhile, a certain suspense of judgment

is called for. The new law has been so amazingly successful in two

of the three tests that there must be some thing valid about it,

even if it is not exactly right as yet.

Einstein's theory has the very highest degree of aesthetic merit:

every lover of the beautiful must wish it to be true. It gives a

vast unified survey of the operations of nature, with a technical

simplicity in the critical assumptions which makes the wealth of

deductions astonishing. It is a case of an advance arrived at by

pure theory: the whole effect of Einstein's work is to make physics

more philosophical (in a good sense), and to restore some of that

intellectual unity which belonged to the great scientific systems of

the seventeenth and eighteenth centuries, but which was lost through

increasing specialization and the overwhelming mass of detailed

knowledge. In some ways our age is not a good one to live in, but

for those who are interested in physics there are great compensations.

THE EINSTEIN THEORY OF RELATIVITY

A Concise Statement by Prof. H. A. Lorentz, of the University of Leyden

The total eclipse of the sun of May 29, resulted in a striking

confirmation of the new theory of the universal attractive power

of gravitation developed by Albert Einstein, and thus reinforced

the conviction that the defining of this theory is one of the most

important steps ever taken in the domain of natural science. In

response to a request by the editor, I will attempt to contribute

something to its general appreciation in the following lines.

For centuries Newton's doctrine of the attraction of gravitation has

been the most prominent example of a theory of natural science. Through

the simplicity of its basic idea, an attraction between two bodies

proportionate to their mass and also proportionate to the square

of the distance; through the completeness with which it explained

so many of the peculiarities in the movement of the bodies making

up the solar system; and, finally, through its universal validity,

even in the case of the far-distant planetary systems, it compelled

the admiration of all.

But, while the skill of the mathematicians was devoted to making

more exact calculations of the consequences to which it led, no

real progress was made in the science of gravitation. It is true

that the inquiry was transferred to the field of physics, following

Cavendish's success in demonstrating the common attraction between

bodies with which laboratory work can be done, but it always was

evident that natural philosophy had no grip on the universal power

of attraction. While in electric effects an influence exercised

by the matter placed between bodies was speedily observed--the

starting-point of a new and fertile doctrine of electricity--in

the case of gravitation not a trace of an influence exercised by

intermediate matter could ever be discovered. It was, and remained,

inaccessible and unchangeable, without any connection, apparently,

with other phenomena of natural philosophy.

Einstein has put an end to this isolation; it is now well established

that gravitation affects not only matter, but also light. Thus

strengthened in the faith that his theory already has inspired,

we may assume with him that there is not a single physical or

chemical phenomenon--which does not feel, although very probably in

an unnoticeable degree, the influence of gravitation, and that, on the

other side, the attraction exercised by a body is limited in the first

place by the quantity of matter it contains and also, to some degree,

by motion and by the physical and chemical condition in which it moves.

It is comprehensible that a person could not have arrived at such a

far-reaching change of view by continuing to follow the old beaten

paths, but only by introducing some sort of new idea. Indeed,

Einstein arrived at his theory through a train of thought of great

originality. Let me try to restate it in concise terms.

THE EARTH AS A MOVING CAR

Everyone knows that a person may be sitting in any kind of a vehicle

without noticing its progress, so long as the movement does not vary

in direction or speed; in a car of a fast express train objects fall

in just the same way as in a coach that is standing still. Only when

we look at objects outside the train, or when the air can enter the

car, do we notice indications of the motion. We may compare the earth

with such a moving vehicle, which in its course around the sun has

a remarkable speed, of which the direction and velocity during a

considerable period of time may be regarded as constant. In place

of the air now comes, so it was reasoned formerly, the ether which

fills the spaces of the universe and is the carrier of light and of

electro-magnetic phenomena; there were good reasons to assume that the

earth was entirely permeable for the ether and could travel through it

without setting it in motion. So here was a case comparable with that

of a railroad coach open on all sides. There certainly should have

been a powerful "ether wind" blowing through the earth and all our

instruments, and it was to have been expected that some signs of it

would be noticed in connection with some experiment or other. Every

attempt along that line, however, has remained fruitless; all the

phenomena examined were evidently independent of the motion of the

earth. That this is the way they do function was brought to the front

by Einstein in his first or "special" theory of relativity. For him

the ether does not function and in the sketch that he draws of natural

phenomena there is no mention of that intermediate matter.

If the spaces of the universe are filled with an ether, let us suppose

with a substance, in which, aside from eventual vibrations and other

slight movements, there is never any crowding or flowing of one part

alongside of another, then we can imagine fixed points existing in it;

for example, points in a straight line, located one meter apart, points

in a level plain, like the angles or squares on a chess board extending

out into infinity, and finally, points in space as they are obtained

by repeatedly shifting that level spot a distance of a meter in the

direction perpendicular to it. If, consequently, one of the points

is chosen as an "original point" we can, proceeding from that point,

reach any other point through three steps in the common perpendicular

directions in which the points are arranged. The figures showing how

many meters are comprized in each of the steps may serve to indicate

the place reached and to distinguish it from any other; these are, as

is said, the "co-ordinates" of these places, comparable, for example,

with the numbers on a map giving the longitude and latitude. Let

us imagine that each point has noted upon it the three numbers that

give its position, then we have something comparable with a measure

with numbered subdivisions; only we now have to do, one might say,

with a good many imaginary measures in three common perpendicular

directions. In this "system of co-ordinates" the numbers that fix

the position of one or the other of the bodies may now be read off

at any moment.

This is the means which the astronomers and their mathematical

assistants have always used in dealing with the movement of the

heavenly bodies. At a determined moment the position of each body

is fixed by its three co-ordinates. If these are given, then one

knows also the common distances, as well as the angles formed by the

connecting lines, and the movement of a planet is to be known as soon

as one knows how its co-ordinates are changing from one moment to

the other. Thus the picture that one forms of the phenomena stands

there as if it were sketched on the canvas of the motionless ether.

EINSTEIN'S DEPARTURE

Since Einstein has cut loose from the ether, he lacks this canvas, and

therewith, at the first glance, also loses the possibility of fixing

the positions of the heavenly bodies and mathematically describing

their movement--i.e., by giving comparisons that define the positions

at every moment. How Einstein has overcome this difficulty may be

somewhat elucidated through a simple illustration.

On the surface of the earth the attraction of gravitation causes

all bodies to fall along vertical lines, and, indeed, when one omits

the resistance of the air, with an equally accelerated movement; the

velocity increases in equal degrees in equal consecutive divisions of

time at a rate that in this country gives the velocity attained at

the end of a second as 981 centimeters (32.2 feet) per second. The

number 981 defines the "acceleration in the field of gravitation,"

and this field is fully characterized by that single number; with its

help we can also calculate the movement of an object hurled out in an

arbitrary direction. In order to measure the acceleration we let the

body drop alongside of a vertical measure set solidly on the ground;

on this scale we read at every moment the figure that indicates the

height, the only co-ordinate that is of importance in this rectilinear

movement. Now we ask what would we be able to see if the measure were

not bound solidly to the earth, if it, let us suppose, moved down or

up with the place where it is located and where we are ourselves. If

in this case the speed were constant, then, and this is in accord with

the special theory of relativity, there would be no motion observed at

all; we should again find an acceleration of 981 for a falling body. It

would be different if the measure moved with changeable velocity.

If it went down with a constant acceleration of 981 itself, then an

object could remain permanently at the same point on the measure,

or could move up or down itself alongside of it, with constant

speed. The relative movement of the body with regard to the measure

should be without acceleration, and if we had to judge only by what

we observed in the spot where we were and which was falling itself,

then we should get the impression that there was no gravitation at

all. If the measure goes down with an acceleration equal to a half

or a third of what it just was, then the relative motion of the body

will, of course, be accelerated, but we should find the increase

in velocity per second one-half or two-thirds of 981. If, finally,

we let the measure rise with a uniformly accelerated movement, then

we shall find a greater acceleration than 981 for the body itself.

Thus we see that we, also when the measure is not attached to the

earth, disregarding its displacement, may describe the motion of the

body in respect to the measure always in the same way--i.e., as one

uniformly accelerated, as we ascribe now and again a fixed value to

the acceleration of the sphere of gravitation, in a particular case

the value of zero.

Of course, in the case here under consideration the use of a measure

fixed immovably upon the earth should merit all recommendation. But

in the spaces of the solar system we have, now that we have abandoned

the ether, no such support. We can no longer establish a system of

co-ordinates, like the one just mentioned, in a universal intermediate

matter, and if we were to arrive in one way or another at a definite

system of lines crossing each other in three directions, then we should

be able to use just as well another similar system that in respect to

the first moves this or that way. We should also be able to remodel the

system of co-ordinates in all kinds of ways, for example by extension

or compression. That in all these cases for fixed bodies that do not

participate in the movement or the remodelling of the system other

co-ordinates will be read off again and again is clear.

NEW SYSTEM OR CO-ORDINATES

What way Einstein had to follow is now apparent. He must--this

hardly needs to be said--in calculating definite, particular cases

make use of a chosen system of co-ordinates, but as he had no means

of limiting his choice beforehand and in general, he had to reserve

full liberty of action in this respect. Therefore he made it his aim

so to arrange the theory that, no matter how the choice was made, the

phenomena of gravitation, so far as its effects and its stimulation

by the attracting bodies are concerned, may always be described in

the same way--i.e., through comparisons of the same general form,

as we again and again give certain values to the numbers that mark

the sphere of gravitation. (For the sake of simplification I here

disregard the fact that Einstein desires that also the way in which

time is measured and represented by figures shall have no influence

upon the central value of the comparisons.)

Whether this aim could be attained was a question of mathematical

inquiry. It really was attained, remarkably enough, and, we may say, to

the surprise of Einstein himself, although at the cost of considerable

simplicity in the mathematical form; it appeared necessary for the

fixation of the field of gravitation in one or the other point in

space to introduce no fewer than ten quantities in the place of the

one that occurred in the example mentioned above.

In this connection it is of importance to note that when we exclude

certain possibilities that would give rise to still greater intricacy,

the form of comparison used by Einstein to present the theory is

the only possible one; the principle of the freedom of choice in

co-ordinates was the only one by which he needed to allow himself to

be guided. Although thus there was no special effort made to reach a

connection with the theory of Newton, it was evident, fortunately,

at the end of the experiment that the connection existed. If we

avail ourselves of the simplifying circumstance that the velocities

of the heavenly bodies are slight in comparison with that of light,

then we can deduce the theory of Newton from the new theory, the

"universal" relativity theory, as it is called by Einstein. Thus

all the conclusions based upon the Newtonian theory hold good, as

must naturally be required. But now we have got further along. The

Newtonian theory can no longer be regarded as absolutely correct in all

cases; there are slight deviations from it, which, although as a rule

unnoticeable, once in a while fall within the range of observation.

Now, there was a difficulty in the movement of the planet Mercury

which could not be solved. Even after all the disturbances caused by

the attraction of other planets had been taken into account, there

remained an inexplicable phenomenon--i.e., an extremely slow turning

of the ellipsis described by Mercury on its own plane; Leverrier had

found that it amounted to forty-three seconds a century. Einstein

found that, according to his formulas, this movement must really

amount to just that much. Thus with a single blow he solved one of

the greatest puzzles of astronomy.

Still more remarkable, because it has a bearing upon a phenomenon which

formerly could not be imagined, is the confirmation of Einstein's

prediction regarding the influence of gravitation upon the course

of the rays of light. That such an influence must exist is taught

by a simple examination; we have only to turn back for a moment to

the following comparison in which we were just imagining ourselves

to make our observations. It was noted that when the compartment is

falling with the acceleration of 981 the phenomena therein will occur

just as if there were no attraction of gravitation. We can then see

an object, A, stand still somewhere in open space. A projectile,

B, can travel with constant speed along a horizontal line, without

varying from it in the slightest.

A ray of light can do the same; everybody will admit that in each case,

if there is no gravitation, light will certainly extend itself in a

rectilinear way. If we limit the light to a flicker of the slightest

duration, so that only a little bit, C, of a ray of light arises,

or if we fix our attention upon a single vibration of light, C, while

we on the other hand give to the projectile, B, a speed equal to that

of light, then we can conclude that B and C in their continued motion

can always remain next to each other. Now if we watch all this, not

from the movable compartment, but from a place on the earth, then we

shall note the usual falling movement of object A, which shows us that

we have to deal with a sphere of gravitation. The projectile B will,

in a bent path, vary more and more from a horizontal straight line,

and the light will do the same, because if we observe the movements

from another standpoint this can have no effect upon the remaining

next to each other of B and C.

DEFLECTION OF LIGHT

The bending of a ray of light thus described is much too light on the

surface of the earth to be observed. But the attraction of gravitation

exercised by the sun on its surface is, because of its great mass, more

than twenty-seven times stronger, and a ray of light that goes close by

the superficies of the sun must surely be noticeably bent. The rays of

a star that are seen at a short distance from the edge of the sun will,

going along the sun, deviate so much from the original direction that

they strike the eye of an observer as if they came in a straight line

from a point somewhat further removed than the real position of the

star from the sun. It is at that point that we think we see the star;

so here is a seeming displacement from the sun, which increases in the

measure in which the star is observed closer to the sun. The Einstein

theory teaches that the displacement is in inverse proportion to the

apparent distance of the star from the centre of the sun, and that for

a star just on its edge it will amount to 1'.75 (1.75 seconds). This is

approximately the thousandth part of the apparent diameter of the sun.

Naturally, the phenomenon can only be observed when there is a total

eclipse of the sun; then one can take photographs of neighboring stars

and through comparing the plate with a picture of the same part of

the heavens taken at a time when the sun was far removed from that

point the sought-for movement to one side may become apparent.

Thus to put the Einstein theory to the test was the principal aim of

the English expeditions sent out to observe the eclipse of May 29,

one to Prince's Island, off the coast of Guinea, and the other to

Sobral, Brazil. The first-named expedition's observers were Eddington

and Cottingham, those of the second, Crommelin and Davidson. The

conditions were especially favorable, for a very large number of

bright stars were shown on the photographic plate; the observers at

Sobral being particularly lucky in having good weather.

The total eclipse lasted five minutes, during four of which it was

perfectly clear, so that good photographs could be taken. In the

report issued regarding the results the following figures, which are

the average of the measurements made from the seven plates, are given

for the displacements of seven stars:

1''.02, 0''.92, 0''.84, 0''.58, 0''.54, 0''.36, 0''.24, whereas,

according to the theory, the displacements should have amounted to:

0''.88, 0''.80, 0''.75, 0''.40, 0''.52, 0''.33, 0''.20.

If we consider that, according to the theory the displacements must

be in inverse ratio to the distance from the centre of the sun, then

we may deduce from each observed displacement how great the sideways

movement for a star at the edge of the sun should have been. As the

most probable result, therefore, the number 1''.98 was found from

all the observations together. As the last of the displacements given

above--i.e., 0''.24 is about one-eighth of this, we may say that the

influence of the attraction of the sun upon light made itself felt

upon the ray at a distance eight times removed from its centre.

The displacements calculated according to the theory are, just because

of the way in which they are calculated, in inverse proportion to the

distance to the centre. Now that the observed deviations also accord

with the same rule, it follows that they are surely proportionate

with the calculated displacements. The proportion of the first and

the last observed sidewise movements is 4.2, and that of the two most

extreme of the calculated numbers is 4.4.

This result is of importance, because thereby the theory is excluded,

or at least made extremely improbable, that the phenomenon of

refraction is to be ascribed to, a ring of vapor surrounding the

sun for a great distance. Indeed, such a refraction should cause a

deviation in the observed direction, and, in order to produce the

displacement of one of the stars under observation itself a slight

proximity of the vapor ring should be sufficient, but we have every

reason to expect that if it were merely a question of a mass of

gas around the sun the diminishing effect accompanying a removal

from the sun should manifest itself much faster than is really the

case. We cannot speak with perfect certainty here, as all the factors

that might be of influence upon the distribution of density in a sun

atmosphere are not well enough known, but we can surely demonstrate

that in case one of the gasses with which we are acquainted were held

in equilibrium solely by the influence of attraction of the sun the

phenomenon should become much less as soon as we got somewhat further

from the edge of the sun. If the displacement of the first star, which

amounts to 1.02-seconds were to be ascribed to such a mass of gas, then

the displacement of the second must already be entirely inappreciable.

So far as the absolute extent of the displacements is concerned, it

was found somewhat too great, as has been shown by the figures given

above; it also appears from the final result to be 1.98 for the edge

of the sun--i.e., 13 per cent, greater than the theoretical value

of 1.75. It indeed seems that the discrepancies may be ascribed to

faults in observations, which supposition is supported by the fact

that the observations at Prince's Island, which, it is true, did not

turn out quite as well as those mentioned above, gave the result,

of 1.64, somewhat lower than Einstein's figure.

(The observations made with a second instrument at Sobral gave a

result of 0.93, but the observers are of the opinion that because of

the shifting of the mirror which reflected the rays no value is to

be attached to it.)

DIFFICULTY EXAGGERATED

During a discussion of the results obtained at a joint meeting of

the Royal Society and the Royal Astronomical Society held especially

for that purpose recently in London, it was the general opinion that

Einstein's prediction might be regarded as justified, and warm tributes

to his genius were made on all sides. Nevertheless, I cannot refrain,

while I am mentioning it, from expressing my surprise that, according

to the report in The Times there should be so much complaint about

the difficulty of understanding the new theory. It is evident that

Einstein's little book "About the Special and the General Theory of

Relativity in Plain Terms," did not find its way into England during

wartime. Any one reading it will, in my opinion, come to the conclusion

that the basic ideas of the theory are really clear and simple; it is

only to be regretted that it was impossible to avoid clothing them in

pretty involved mathematical terms, but we must not worry about that.

I allow myself to add that, as we follow Einstein, we may retain

much of what has been formerly gained. The Newtonian theory remains

in its full value as the first great step, without which one cannot

imagine the development of astronomy and without which the second

step, that has now been made, would hardly have been possible. It

remains, moreover, as the first, and in most cases, sufficient,

approximation. It is true that, according to Einstein's theory,

because it leaves us entirely free as to the way in which we wish to

represent the phenomena, we can imagine an idea of the solar system

in which the planets follow paths of peculiar form and the rays of

light shine along sharply bent lines--think of a twisted and distorted

planetarium--but in every case where we apply it to concrete questions

we shall so arrange it that the planets describe almost exact ellipses

and the rays of light almost straight lines.

It is not necessary to give up entirely even the ether. Many natural

philosophers find satisfaction in the idea of a material intermediate

substance in which the vibrations of light take place, and they

will very probably be all the more inclined to imagine such a medium

when they learn that, according to the Einstein theory, gravitation

itself does not spread instantaneously, but with a velocity that at

the first estimate may be compared with that of light. Especially in

former years were such interpretations current and repeated attempts

were made by speculations about the nature of the ether and about

the mutations and movements that might take place in it to arrive

at a clear presentation of electro-magnetic phenomena, and also of

the functioning of gravitation. In my opinion it is not impossible

that in the future this road, indeed abandoned at present, will once

more be followed with good results, if only because it can lead to the

thinking out of new experimental tests. Einstein's theory need not keep

us from so doing; only the ideas about the ether must accord with it.

Nevertheless, even without the color and clearness that the ether

theories and the other models may be able to give, and even,

we can feel it this way, just because of the soberness induced

by their absence, Einstein's work, we may now positively expect,

will remain a monument of science; his theory entirely fulfills

the first and principal demand that we may make, that of deducing

the course of phenomena from certain principles exactly and to the

smallest details. It was certainly fortunate that he himself put the

ether in the background; if he had not done so, he probably would

never have come upon the idea that has been the foundation of all

his examinations.

Thanks to his indefatigable exertions and perseverance, for he had

great difficulties to overcome in his attempts, Einstein has attained

the results, which I have tried to sketch, while still young; he is

now 45 years old. He completed his first investigations in Switzerland,

where he first was engaged in the Patent Bureau at Berne and later as a

professor at the Polytechnic in Zurich. After having been a professor

for a short time at the University of Prague, he settled in Berlin,

where the Kaiser Wilhelm Institute afforded him the opportunity to

devote himself exclusively to his scientific work. He repeatedly

visited our country and made his Netherland colleagues, among whom he

counts many good friends, partners in his studies and his results. He

attended the last meeting of the department of natural philosophy of

the Royal Academy of Sciences, and the members then had the privilege

of hearing him explain, in his own fascinating, clear and simple way,

his interpretations of the fundamental questions to which his theory

gives rise.

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