Planetary Motions and the Einstein Theories

A Possible Alternative to the Relativity Doctrines That Would Save the Newtonian Law

By Charles Lane Poor

Professor of Celestial Mechanics, Columbia University

THE entire Einstein theory of the universe is based upon two or three pure assumptions as to the fundamental constitution of nature. These are so broad and general in character that they cannot be directly tested. But, if they are provisionally accepted as true, it is possible to build upon them a complete and logical theory of the universe and of the laws governing the motions of all the bodies therein. This Einstein has done with great technical skill, with results that are remarkable and, to say the least, very startling to our preconceived ideas of space and time. It is through these results, through the logical deductions and formulas derived from his postulates, that the hypotheses themselves can be tested.

In order, however, to establish the Einstein theories it will not be sufficient to show that the facts of nature can be explained by the Einstein formulas; it must be conclusively shown that no other hypothesis will equally well explain the observed phenomena. In the words of the mathematician, it is essential for the followers of Einstein to show that his hypotheses and formulas are *necessary and sufficient*.

For many years the Newtonian law as applied by mathematicians has failed to account accurately for the motions of Mercury, and this failure has been made the basis of many attacks upon the Newtonian law, of which Einstein's is merely the latest and best executed. The orbit, or path, of any planet, such as Mercury, about the sun is an immense oval, or ellipse, one diameter of which is longer than the others. This diameter is known as the axis of the orbit. Now, if Mercury were the sole planet in the system, then, under the Newtonian law, this axis would remain fixed in direction; but, under the Einstein law, it would rotate slowly at the rate of 43″ of arc per century. Under such conditions a clear cut issue would be presented, and observations could at once decide between the two theories. Mercury, however, is not the only planet, and the action of the earth and the other planets upon him causes a similar and a much larger rotation of the axis, the exact amount of which can be found only after long and complicated computations. These calculations give 537″ per century and, if the Newtonian law be exact and the *computations correct in every particular*, the axis of Mercury's orbit should rotate by this amount. Direct measurements upon the positions of the planet in the heavens, however, show this rotation to be 579″, or an excess of 42″ over the amount yet accounted for by the Newtonian law, and in extremely close accord with the rate of motion predicted by the Einstein formulas.

At first sight this striking agreement of figures appears to confirm the Einstein theories in a brilliant manner. But, striking as these figures are, the confirmation is not complete, for it is possible to explain the motion of Mercury in full accord with the Newtonian law and in accordance with accepted scientific facts.

The whole matter depends upon the calculations through which the figure 537″ was found. Now it is well known to every mathematical astronomer that these calculations are not complete, that they do not take fully and completely into account all of the bodies of the solar system. In the theories and formulas upon which these calculations depend the sun has been considered as a perfect sphere and all space between the sun and the various planets as free from all gravitational matter. These are necessary mathematical simplifications: Without them the equations of motion would be impossible of solution. These simplifications approximate very closely to the truth and the results obtained by their use very closely represent the motions of the planets, but they are *approximations* and it necessarily follows that the results do not represent the actual motions with complete accuracy.

Every photograph taken, every measurement made of the sun and the various planets show that these assumptions, upon which the simplifications are based, are not true. Neither the sun nor any one of the planets is a perfect sphere. The polar axis of the earth is considerably shorter than the equatorial; a glance through any telescope shows Jupiter to be decidedly elliptical. The sun-spots, which can be seen with an ordinary small telescope, show that the sun is not of uniform shape and density. Exact measurements of the shape of the sun are extremely difficult to make, yet every series of measures, heretofore made, show distinct departure from a true spherical form.

Passing outward from the sun itself one finds the corona. At times of eclipse this halo, or brilliant crown about the sun, can be seen by the unaided eye. It has been sketched many times, it has been photographed times without number. Its presence proves the sun to be surrounded by an envelop of matter of irregular shape and of vast size. This envelop is in general lens-shaped and it extends far out beyond the orbit of the earth.

The exact size, shape and constitution of this envelop is not known; its density is extremely small and the total amount of matter contained in it cannot be very large. It is known, however, that it is not a true gaseous atmosphere of the sun like that of the earth. It consists, in the main, of widely scattered, minute solid particles, each traveling about the sun in its own independent orbit. Some of these bodies may be as small as pin-heads, others many feet in diameter. The zodiacal light is recognized as mainly sun-light reflected from such minute bodies, each too small to be seen separately, but, as a group or mass, reflecting enough light to show as a faint glow against the dark sky.

While matter is thus known to exist in the vicinity of the sun and the inner planets, its effect upon the motions of these planets cannot be absolutely calculated until its distribution is fully known. It is clear that the figure 537″ per century does not accurately represent the motion of Mercury's perihelion under the Newtonian law; but, in the present state of our knowledge of the solar envelop, it is impossible to correct definitely this figure and to state what the final value should be.

Further, the discordance in the motion of Mercury is only one out of eight or ten similar discrepancies in the motions of the planets. Einstein and his followers have stressed the supposed explanation, under his theories, of the motion of Mercury, but have glossed over the necessity of finding an explanation for the remaining discrepancies. Now the theories and formulas of Einstein account partially for one or two of these other difficulties, completely fail to account in the slightest way for others, and finally greatly increase the discordance in the case of Venus. In fact, in the case of this planet, the Einstein formulas would give the orbit a rotation in the opposite direction to that which is required to fit the observations.

According to Newcomb the secular motions of the elements of the four inner planets, as observed and as computed, are as given in Table I. The column of differences contains the unexplained portions of the motions of the planets. That is, in one century the perihelion of Mercury moves 41.6″ of arc more than can be accounted for, while that of Venus does not move quite so swiftly as the computations would lead one to expect. These unexplained portions of the motions are the so-called "discordances" or "discrepancies." That of the perihelion of Mercury is especially well known and has figured prominently in many attempts to prove false the law of Newton. The perihelion of Mars shows a large discrepancy, as do also the nodes of both Mercury and Venus.

In the column of differences, after each discordance, is given the "probable error" as determined by Newcomb. While these may give some idea as to the relative accuracy of the various determinations, it must be remembered that the assignment of these probable errors is very largely a matter of judgment, and that the values may have been over or under estimated. In every step of the long and complicated computations and reductions, an estimate, rather than an exact calculation, has to be made as to the value of the probable error, and the final value, as given in the table, thus depends upon many separate estimations or judgments. But, taking these probable errors as given by Newcomb, it will be noted that out of the ten differences six are larger than the corresponding probable errors, and of these six, three stand out prominently: The perihelion of Mercury, the perihelion of Mars, and the node of Venus.

TABLE I.

PERIHELIA:	Obsd.	Compt.	Diff.	Plus or Minus	P.C.
Mercury.....	+ 579.2″	+ 537.6″	+41.6″	1.4″	+ 7.2
Venus......	+ 42.4	+ 49.7	— 7.3	22.3	—17.2
Earth.......	+1161.5	+1155.6	+ 5.9	5.6	+ 0.5
Mars........	+1605.9	+1597.8	+ 8.1	2.6	+ 0.5
INCLINATIONS:					
Mercury.....	+ 7.14″	+ 6.76″	+0.38″	0.54″	+ 5.3
Venus.......	+ 3.87	+ 3.49	+0.38	0.32	+ 9.8
Mars........	— 2.26	— 2.25	—0.01	0.14	— 0.4
NODES:					
Mercury.....	— 753.0″	— 758.1″	+ 5.1″	2.8″	+ 6.8
Venus.......	—1780.7	—1790.9	+10.2	2.0	+ 0.6
Mars........	—2248.9	—2249.8	+ 0.9	4.6	+ 0.0

The final column in the table gives the percentage that the discordance bears to the observed motion. While this is rather an unusual way of comparing results, it may be of interest and may throw some light on the problem. It will be noted that five of the differences represent very large percentages of the observed quantities, and of these five, three are among the six that exceed their probable errors. These three are in the motions of the perihelion of Mercury, the inclination of Venus, and the node of Mercury.

The discordance in the perihelion of Venus is peculiar. It amounts to over 17 per cent of the entire observed motion, and yet it is only one-third of the apparent probable error. It would seem that where the percentage is so large, the discordance must be real, and that the value of the probable error has been overestimated.

According to the Einstein theory, as noted above, the perihelia of the planets would rotate by various amounts depending upon their respective distances from the sun. This Einstein rotation is independent of the mutual action of the planets upon one another, and in order to find the total motions under the Einstein theories, it should be added to the computed motions as given in the above table. This is shown in Table II, which also gives the final outstanding differences between theory and observation, as based upon the Einstein theory.

TABLE II (Perihelia)

	Newtonian Computation	Einstein	Total	Diff.	P.C.
Mercury...	537.6″	42.9″	580.5″	— 1.3″	0.2
Venus.....	49.7	8.6	58.3	—15.9	37.5
Earth.....	1155.6	3.8	1159.4	2.1	0.2
Mars......	1597.8	1.3	1599.1	6.8	0.4

Thus the Einstein motion is sufficient to account for practically all the discrepancy in the case of Mercury and to reduce in a marked manner that in the case of the Earth. It accounts, however, for a very small part of the discordance in the case of Mars, and more than doubles the already large discrepancy in the motion of Venus. Further the Einstein law does not in any way account for the important discrepancies in the motions of the nodes and in the inclinations of the planets.

Turning now to the matter which is known to exist in the vicinity of the sun and planets, while as we have said we cannot determine its quantity and general distribution, it is perfectly possible and reasonably easy to find what distribution of this matter would under the Newtonian law, give a motion of 42″ to Mercury's perihelion, and thus make the total motion 579″, as required by observation. This problem is similar to that solved by Adams and Leverrier, which resulted in the discovery of the planet Neptune. Moreover, it is then found that the distribution that will explain the motion of Mercury will fully explain that of the other planets; it will give the orbit of Venus the necessary rotation, both in direction and in amount. What the Einstein formulas fail to explain, the presence of a great lens of matter about the sun explains fully and satisfactorily.

The quantity of matter required in the solar lens for this purpose, and the distribution which it becomes necessary to assign to it, are entirely within the limits of reason. The matter in the immediate vicinity of the sun would tend to group itself about a plane somewhere near that of the solar equator, or that of the orbit of Mercury; while matter at a considerable distance from the sun would tend more toward the invariable plane of the solar system, which is nearly the same as that of the orbit of Jupiter. Further the density of the matter will decrease as the distance from the sun increases. This general distribution can be approximated by assuming the whole mass to be made up of ellipsoids of revolution, each ellipsoid of uniform density, but the larger ones of much less density than the inner ones. Some such assumption is necessary to reduce the problem to the realm of figures; the selection of ellipsoids of revolution is naturally indicated by the fact that all the known bodies of the solar system are such ellipsoids.

For purposes of computation the mass may be supposed to be made up of superimposed ellipsoids, each of constant density. This merely makes the changes in density abrupt, instead of gradual. Three such ellipsoids are necessary and sufficient to account for the motions of the perihelia of the four planets:

a. A small central ellipsoid entirely within the orbit of Mercury, and embracing only the matter in the immediate vicinity of the sun. The position of this ellipsoid in space was determined from equations of condition derived from the discordances.

b. An intermediate ellipsoid entirely within the orbit of the earth, but extending beyond the orbit of Venus. The principal plane of this ellipsoid was assumed as being the same as that of the orbit of Jupiter.

c. An outer ellipsoid entirely within the orbit of Mars, but extending beyond the orbit of the earth. The principal plane of this ellipsoid was assumed as being the same as that of the orbit of Jupiter.

The mass, or density, of each ellipsoid is a function of its radius and cannot be independently determined. The radii can, however, be assumed arbitrarily and the corresponding masses and densities found. With an assumed ellipticity of 0.9 and assumed radii we have:

	Assumed radii	Corresponding densities
Inner ellipsoid	0.05	1.2×10^{-7}
Medium ellipsoid	0.98	1.7×10^{-13}
Outer ellipsoid	1.36	7.4×10^{-14}

where the density of the sun is unity. If the inner ellipsoid be assumed to be of larger radius, then its density would be correspondingly less.

With the assumptions thus outlined, the motions of the planets were calculated. The results appear in Table III on the following page:

The relative probabilities of two solutions of a problem are usually determined from the final differences or residuals, as these differences are called. That solution is deemed the most probable which makes the sum of the squares of the residuals the smaller. If this test be applied to the residuals obtained in Table II with the Einstein theory as the basis and to those from Table III, the results are:

Einstein theory	438.38
Solar envelop	14.07

And these clearly indicate how very much more probable is the explanation of the motions of the planets as due to the presence of matter in space, than by the hypotheses of Einstein.

TABLE III

	Motion due to Solar Envelop	Total Motion	Final Diff.
PERIHELIA:			
Mercury	+41.6″	+ 579.2″	0.0″
Venus	− 7.5	+ 42.2	+0.2
Earth	+ 5.9	+1161.5	0.0
Mars	+ 6.9	+1604.7	+1.2
INCLINATIONS:			
Mercury	+0.37″	+ 7.13″	+0.01″
Venus	+0.45	+ 3.94	−0.07
Mars	+0.12	− 2.13	+0.12
NODES:			
Mercury	+ 4.9″	− 753.2″	−0.2″
Venus	+ 9.1	−1781.8	−1.1
Mars	+ 4.3	−2245.5	−3.4

Einstein and his followers have cited the motions of the planets as conclusive proof of the truth of his hypotheses. The evidence does not sustain this—his hypotheses and formulas are neither *sufficient* nor *necessary* to explain the discordances in these motions. They are not *sufficient*, for they account for only one among the numerous discordances—that of the perihelion of Mercury; they are not *necessary*, for all the discordances, including that of Mercury, can readily be accounted for by the action, under the Newtonian law, of matter known to be in the immediate vicinity of the sun and the planets.

Thus the motions of the planets do not prove the *truth* of the Einstein theory, nor, on the other hand, do they prove its *falsity*. While these motions can be accounted for by a certain distribution of matter in the solar envelop, it has not yet been established by observation that the matter is distributed through space in the required way. In the present state of our knowledge regarding this matter, the motions of the planets do not and cannot furnish a definite answer to the question as to the validity of either hypothesis. It is then a problem of observational astronomy to investigate the actual distribution and density of the matter in the solar lens, and to determine whether or not it approximates the conditions necessary to account for the planetary motions. In 1908-10, before Einstein had developed his astronomical theories, I called attention to the desirability of doing this; but the astronomical world could not see the need of the investigation and it was never made.

NEW OBSERVATIONS ON THE VARIABILITY OF THE SUN

(*a*) SIMULTANEOUS spectro-bolometric observations of the solar constant of radiation in California and Algeria in 1911 and 1912, and in California and Chile in 1918, (*b*) comparisons of the distribution of radiation over the sun's disk with simultaneous measurements of the intensity of total solar radiation, (*c*) comparisons of the temperature of the earth with the radiation of the sun, and (*d*) several other minor evidences, have all indicated a short irregular periodicity in the sun's omission. In other words, the sun appears to be a variable star ranging through about 0.10 stellar magnitude between extremes and often changing 0.03 magnitude within a few days.

For about six years the intensity of solar radiation has almost always exceeded the mean value, 1.933 calories per square centimeter per minute, which was found from the Washington, Mt. Vernon and Mt. Whitney observations of 1902-1912, as published in Vol. 111 of the Annals of the Astrophysical Observatory. This condition of affairs was expected to attend the return of increased solar activity, otherwise evidenced by numerous sunspots, prominences, faculæ. We have now, however, long passed the period of maximum sunspots, so that we should naturally expect the sun's radiation to be falling below the mean value of 1902-1912. The results obtained by the Smithsonian observers at Calama, Chile, indicate quite otherwise.

I have computed solar radiation values for each five days' interval from July 1, 1919, to March 25, 1920. The mean value is never based on less than two observations, and this minimum occurs only in two instances. All other values depend on three days of observation, more often four, and very often five.

One is immediately struck by the wide fluctuation of the mean values shown. The fluctuation of individual days naturally had a still wider range, reaching in fact to 8 per cent. The mean values cover a range of 5 per cent. With gradually diminishing swings, up and down, the radiation fell from June, 1919, to early in October, then suddenly leaped up to a high mean value which it maintained until early in December, and then again suddenly leaped much further and remained from the end of December to the middle of March, 1920, at a mean value far in excess of anythings which we have any record of, continued for so long a time as three months during the whole fifteen years in which solar constant observations have been carried on with anything like regularity. Toward the end of March an extremely rapid fall of radiation occurred so that individual values have run as low as 1.86 calories.

In view of this extraordinary march of solar radiation values, it may be recalled that we passed through an exceptionally cold and cloudy winter from about the first of December, 1919. The cloudiness prevailed in South America as well as here, so that if it had not been for the introduction of the new method of observing, of which notice was given to the Academy at its last meeting, the observers would not have been able to give us this very continuous record.

At first sight it looks paradoxical that a cold winter could accompany extraordinarily high values of solar radiation, but it has been not only a cold winter, but a cloudy winter. Hence it may have been that the direct effect of the outburst of solar activity was to produce excessive cloudiness which by high reflection diminished the radiation available to warm the earth.—Abstract of article by C. G. Abbot, Astrophysical Laboratory, Smithsonian Institution, Washington, in Proceedings of the National Academy of Science for November, 1920.

BENGAL'S DISASTROUS CYCLONE

THE Meteorological Department of the Government of India has issued its report on the administration in 1919-1920. Observations in connection with the upper air have been developed on behalf of the aviators who are from time to time crossing India. Storm warnings for stations in the Bay of Bengal and in the Arabian Sea are said to have been carried out successfully. It is, however, admitted that the warning of the great storm on the night of September 24, 1919, was inadequate. The storm crossed the Bengal coast as a cyclone about noon on September 24. It reached Dacca at about 2:30 A. M. on September 25, and finally broke up on that day in the Assam hills. At the center the deficiency of pressure was about 1¼ inches, and the calm area at least 15 miles in diameter. The total loss of life is estimated at 3,500. The value of property destroyed was probably greater than in any storm in Bengal for the last two hundred years, but the destruction of human life was probably greater in the Bakarganj cyclone of 1876. An additional terror was caused by a vivid red glow appearing in the sky during the period of the lull.—From *Nature* (London), April 28, 1921.