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# RECENT DEVELOPMENTS IN HIGH-ENERGY PHYSICS

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# RECENT DEVELOPMENTS IN HIGH-ENERGY PHYSICS

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# PREFACE

The editors are pleased to submit to the readers the state of the art in high energy physics as it appears at the beginning of 1980.

Great appreciation is extended to Mrs. Helga S. Billings and Mrs. Connie Wardy for their assistance with the conference and skillful typing of the proceedings which was done with great enthusiasm and dedication.

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THE EDITORS

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THE VARIATION OF G AND THE PROBLEM OF THE MOON

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What is the problem of the moon? It concerns the past history of the moon. The geological evidence that we have about it contradicts the astronomical evidence.

Rocks have been obtained from the surface of the moon and their ages have been determined by radioactive dating. The ages extend from 3.1 to 4.5 aeons. (One aeon = $10^9$ years). There are none older than 4.5 aeons.

The oldest rocks found on earth are 3.9 aeons old. There is a chance that older ones may be discovered some day. This suggests that the earth-moon system was formed 4.5 aeons ago, and the oldest rocks on earth have been weathered away.

The meteorites all have the age 4.5 aeons. None more or less. So it looks as though the whole solar system was formed 4.5 aeons ago.

Now let us look at the astronomical evidence. The moon is circling the earth and its orbit is continually changing on account of tidal action. A high tide is produced on earth at approximately the point nearest to the moon and also at the antipodal point. Owing to the rotation of the earth, the axis of the tidal bulge is shifted around a little from the line joining the earth's center to the moon.

Let $\delta$ be the angle through which it is shifted. $\delta$ is a measure of the friction between the tidal bulge and the rotation of the earth below it. With no friction, $\delta$ would be zero.

The effect of the friction is to slow the rate of rotation of the earth. Angular momentum gets transferred from the earth to the orbital motion of the moon. The net result of the increase in the orbital angular momentum of the moon is that the moon's distance from the earth increases while its velocity decreases.

One can calculate the effect by using Newton's law of gravitation and conservation of angular momentum for the earth-moon system. One might also use Einstein's law of gravitation, but the difference would be negligible.

Various people have made calculations about the motion of the moon, using different degrees of approximation. I shall here use a calculation given by G.J.F. McDonald, which brings in the main features with neglect of the sun's influence. McDonald obtains the following formula for the distance a of the moon from the earth.

$$\frac{da}{dt} = \frac{3\, G^{1/2}\, m\, k_2\, R^5 \sin 2\delta}{a^{11/2}\, (M+m)^{1/2}} \quad . \tag{1}$$

Here M and m are the masses of the earth and moon, R is the radius of the earth, and $k_2$ is a Love coefficient of elasticity of the earth, which is a little less than 1.

The angle of shift $\delta$ is not a quantity that can be calculated with any accuracy, because it depends on the dissipation of tidal energy, which is not understood very well. It may change during the course of geological time. Its present value can be obtained from observations of the moon's motion. Using observations going back 250 years, one finds $\delta = 2.25^{\circ}$.

If we assume as a first approximation that $\delta$ is a constant, we can integrate equation (1). The result is

$$a = \left\{ \frac{39}{2} \frac{G^{1/2}\, m\, k_2\, R^5 \sin 2\delta}{(M+m)^{1/2}} (t-t_0) + a_0^{13/2} \right\}^{2/13} , \qquad (2)$$

with $a_0$ the present value of a and $t_0$ the present time.

Putting in numerical values, with t expressed in aeons, we get

$$\frac{39}{2} \frac{G^{1/2}\, m\, k_2\, R^5 \sin 2\delta}{(M+m)^{1/2}\, a_0^{13/2}} = 0.6 \quad . \qquad (3)$$

This leads to

$$a = \{ 0.6\ (t-t_0) + 1 \}^{2/13}\, a_0 \ . \qquad (4)$$

To apply this formula to a time 1.6 aeons ago we must put $t - t_0 = -1.6$. This gives a close to zero, so that the moon was very close to the earth. This happened at a time much more recent than the origin of the earth-moon system. If we go back still earlier, the formula obviously breaks down.

To understand what happened at this earlier time, McDonald makes a more elaborate calculation taking into account that the plane of the moon's orbit is inclined to the plane of the equator. The angle between them is now about $7^{\circ}$. The equations of motion show that this angle is decreasing. Thus it increases as one goes back into the past.

As one goes back to the time when the moon was very close to the earth, this angle increases to $90^{\circ}$. The moon then passed over the poles. At that time the moon's distance was about 3 earth radii.

If one goes back to still earlier times, the moon was in a retrograde orbit. Tidal action would then be making the moon approach the earth, instead of receding from it. So we get the picture of the moon originally in a retrograde orbit and slowly approaching the earth under the influence of tidal action. Then it drops down

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rapidly as the orbit becomes a polar one, and then the orbit becomes a direct one and tidal action causes the moon to recede, at first very rapidly and then slowly.

This picture of the moon's motion was deduced on the assumption that $\delta$ is constant. Maybe $\delta$ varied quite a bit, but any probable variation of $\delta$ would not change the character of the picture, but would just change the time of the close approach. Various people have worked on the problem using reasonable assumptions for the variation of $\delta$, and they get results giving the time of close approach as somewhere between 1.5 and 2.5 aeons ago -- in any case much less than the age of the earth-moon system.

When the moon was very close to the earth, there must have been tremendous tides, not just a few meters high like at present, but several km high. This must have very much disturbed the formation of sedimentary rocks. There is not much evidence about ancient sedimentary rocks, but what there is shows no sign of such enormous tides, and geologists do not believe they ever existed.

This provides the problem of the moon. It could be that the moon was only formed recently, after the calculated time of close approach. But there is no plausible theory of its formation at this late date.

Many people have speculated about this problem without finding any plausible solution. J.G. Ford, in a review article published in 1975, brings out a new idea. He points out that the trouble may be ascribed to a lack of congruence between the time scales of the astronomers and geologists. The astronomers use a time scale, marked out by the motion of the earth around the sun, which they call ephemeris time. It is used with the equations of motion of Newton or Einstein. This might perhaps not be the same as the geological time scale, marked out by radioactive decay.

Let us suppose that, with respect to astronomer's time, radioactive decay in the past proceeded more rapidly than now. Then the rocks would appear older than they really are according to astronomer's time. The age of the moon, as given by radioactive dating, would be reduced and could perhaps be brought to less than the calculated time of close approach.

Ford put forward this idea, but did not like it very much. He says there is some geological support for it since sedimentation rates in the past (referred to radioactive clocks) appear to be less than now, but the figures he gives show a much greater effect than would follow just from the different time scales.

The time given by radioactive decay processes is presumably the same as atomic time, given by atomic clocks. This might be different from the ephemeris time used by astronomers. If there is a difference, one should be able to detect it by careful observations. One would have to observe some events in ephemeris time, observe them also with atomic clocks, and compare the results.

The best chance for making such observations is with the angular motion of the moon in the sky. This has been observed for some centuries with ephemeris time and has been observed since 1955 with atomic time. A comparison of these observations has been made by Van Flandern. Already by 1975 he reported a difference between the two times, but the difference had the wrong sign to help with the moon problem.

However, Van Flandern has been continually modifying his results, on account of improved calculations and more recent observational data. By 1978 the sign of the difference in the two times was reversed and it now helps with the moon problem.

If one is to follow up the idea of the two time scales, one needs a general theory to support it. Such a theory is provided by the Large Numbers hypothesis and the variation of G expressed in atomic units. I spoke about this theory at the conference last year.

With this theory we have to work with two metrics, an Einstein metric $ds_E$, which we must use with the equations of motion and an atomic and an atomic metric $ds_A$. They are related by

$$ds_E = (t/t_0)\ ds_A \quad .$$

For studying the dynamics of the earth-moon system we must of course use the Einstein metric. Conservation of angular momentum will be valid with this metric.

We must now rewrite equation (1) to refer to the Einstein metric. It then reads

$$\frac{d\ a_E}{d\tau} = \frac{3\ G^{1/2}\ m\ k_2\ R_E^{\ 5}\ \sin 2\delta}{a_E^{\ 1/2}\ (M+m)^{1/2}} \quad . \tag{5}$$

Here the Einstein time $\tau$, which is the same as ephemeris time, is connected with atomic time t by

$$\tau = \frac{1}{2}\ t^2/t_0 \quad .$$

The radius of the earth is determined mainly by atomic forces, so we may take $R_A$ = constant. We then have

$$R_E = (t/t_0) R_A = (\tau/\tau_0)^{1/2} R_A = (\tau/\tau_0)^{1/2}\ R_0 \quad ;$$

where $R_0$ is the present radius. This brings a factor of $(\tau/\tau_0)^{5/2}$ into the right-hand side of equation (5), which changes the character of the solution drastically.

Instead of (2) we get

$$a_E = \{\frac{39}{14}\ \frac{G^{1/2}\ m\ k_2\ R_0^{\ 5}\ \sin 2\delta}{(M+m)^{1/2}}\ t_0 \left[ (\frac{t}{t_0})^7 - 1 \right] + a_0^{\ 13/2}\}^{2/13} \quad . \tag{6}$$

For t close to $t_0$ equation (6) goes over to equation (2).

Putting in the numerical values, we can use (3) again with $R_0$

instead of R and we find

$$a_E = \{0.5 \left[ \left(\frac{t}{t_0}\right)^7 - 1 \right] + 1\}^{2/13} a_0 \quad . \tag{7}$$

The quantity in the { } brackets now never gets small, even if we go back to t = 0. The difference arises because of the factor $R_E^5$ in (5), with $R_E::t$, which makes much smaller tides in the past.

So the problem of the moon gets solved. The argument is not invalidated by quite considerable changes in the shift $\delta$.

Thus the discussion of the past history of the moon provides evidence in favor of the variation of G and the Large Numbers hypothesis. The evidence is more positive than that provided by modern observations, which have to be carried out with extreme accuracy to show any effect at all.

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PRIMATONS

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A.J. Meyer

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## INTRODUCTION

The epistemological basis of quantum electrodynamics is weakened by the necessity of mathematically improper renormalizations associated with the existence of divergent integrals. These infinities have defeated attempts to apply standard mathematical principles to certain natural phenomena. This situation is not only annoying and mathematically absurd, but may have inhibited progress in many areas of theoretical physics. It would seem constructive to assume that these infinities are indeed perverse, that our model is incomplete and there may exist additional finite limits that have been overlooked.

Perhaps a fundamental step in this direction is to demonstrate that an invariant maximum density exists for electromagnetic radiation. Let us refer to this maximum energy density form as a primaton-photon. As I will show shortly, the primaton-photon may be defined as a photon whose three attributes: energy, spin, and "Compton" radius are sufficient to completely define an extreme Kerr black hole.

I'm not saying this primaton is a black hole, I'm just saying it uniquely maps or defines one.



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