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SATURDAY, OCTOBER 6, 1928.

THE MOON AND THE TIDES; WITH A DIGRESSION ON STELLAR CATASTROPHES.

By SIR OLIVER LODGE.

IN a recent exposition of the outcome of some of the work of Sir George Darwin (son of the famous naturalist) on tidal theory and the origin or birth of the moon, some sentences indicating what might be an ultimate result of tidal action, if the solar system lasted long enough, have apparently been misinterpreted as a prediction that the moon would one day crash down upon the earth. Well, such an event is not an utter impossibility. There are causes at work which, in an almost infinitely long time, might bring it about, if nothing else happened, and if everything went on as it is now. But I never intended any sensational statement on that subject, and do not regard it as a thing likely to occur. It is not to be supposed that the earth will last for ever: no merely material assemblage of particles can be infinitely durable; and there are so many other causes at work capable of effecting a change in the condition of the solar system that any consequence based on the continuance of things as they are now must be so extremely doubtful as not to be worth taking into account.

DIGRESSION ON STELLAR CATASTROPHES.

One would prefer not to speculate on the probable end of the solar system; but if one did speculate in that direction, one would have to give due regard to certain known facts—namely, that what are called "new" stars do blaze out in the heavens from time to time. Now a "new star" does not mean a newly created mass of matter; it merely means that an already existing body, which had been either dark or only faintly luminous, encounters something which makes it blaze up into vivid luminosity for a time—reckoned as a few months or years—and then gradually subside again into its previous dim condition. We have no reason to anticipate such a fate for any given specified star, such as the sun or any of its confrères; and yet, on the other hand, we have no reason for saying that any one of them is immune from such a disturbance.

The cause of such an eruption is now thought to be most probably an encounter of a star or solar system with a cloudy mass of matter such as a nebula. There are a great number of such nebulæ, or gaseous masses, in the universe. The sun and other stars are moving at a high speed, and there is no reason why they should not occasionally encounter, or pass through, a portion of space which is not completely empty of matter. We see the operation, on a ridiculously minute scale, in what are called meteors, or shooting stars, which are small masses of matter, perhaps in some cases not much bigger than a cricket-ball or even a grain of sand, which are travelling round the sun in very elliptical or cometary orbits, and occasionally, and, so to speak, by accident, find some portion of the earth's atmosphere in their way. They are travelling at a speed of twenty-six miles a second as they pass the earth; and accordingly the friction even of highly rarefied air in the upper regions of the atmosphere is able to raise them instantly to white heat, and usually dissipate them into vapour, though some of the larger ones occasionally escape destruction and reach the earth's surface.

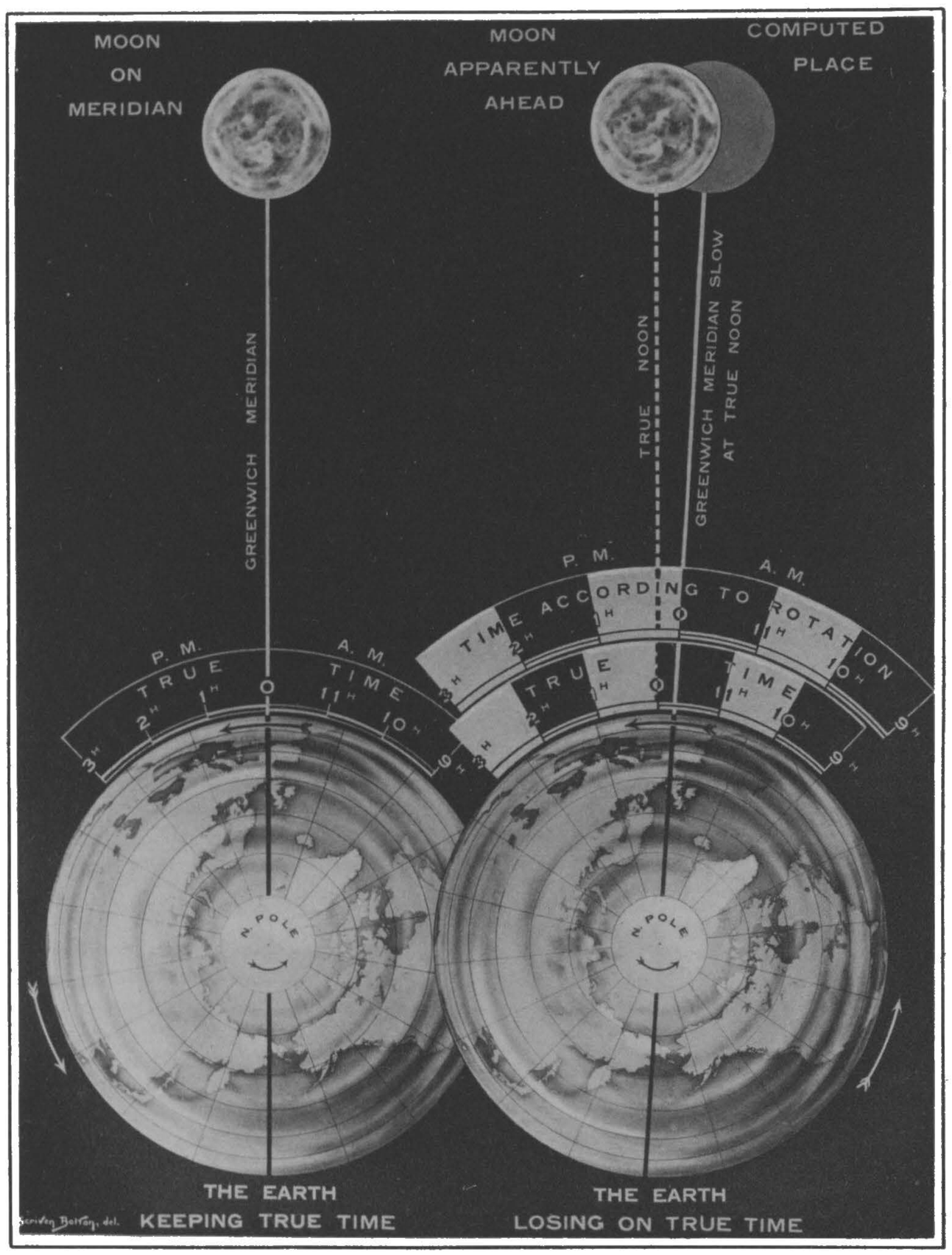
This well-known and familiar kind of thing may happen to larger bodies too, though much more rarely. The sun, in its isolated travel through empty space, is not one of the quickest stars; it is supposed to be moving, say, twelve or fourteen miles a second. But if, in the course of thousands, or perhaps millions, of years, anything like a nebulous mass of gas got in its way, it would no doubt blaze up with such vehemence that the earth itself would "melt with fervent heat." Such an event is a very remote possibility; and, inasmuch as all the known and visible bodies are at the present time tremendously distant, no one need be perturbed by such a contingency. It seems to me, however, a more likely end to the earth than any falling back of the moon.

This seemingly cruel and casual entrapping of a world by a nebula, like a fly buzzing helplessly in a spider's web, was what Tennyson probably had in his mind when he wrote ("In Memoriam, III.") apostrophising Fate or Sorrow, and not believing in her response—

> "The stars," she whispers, "blindly run;
> A web is wov'n across the sky;
> From out waste places comes a cry,
> And murmurs from the dying sun."

RETURN TO THE MOON AND THE TIDES.

What I have just said about a possible ending of the earth is foreign to an exposition of the moon and the tides; and I only mention it in order to remove any expectation of a return of the moon within any reasonable period. At the same time, other planets have satellites as well as the earth, and some of those satellites are already on the way to approach their planet; that is to say, the central body round which they are revolving. Calling the period of revolution of the satellite a month, and the period of planetary rotation a day, as is the common practice, then, when the month is longer than the day, the effect of the tides is such as to make the satellite gradually recede. Whereas, when the day is longer than the month, the tidal influence is such as to make the satellite approach. And it should not be too difficult to explain why this is so.



THE MOON APPARENTLY AHEAD OF ITS COMPUTED POSITION: A RESULT OF THE EARTH'S RETARDED ROTATION AND VARIABLE AXIAL SPIN, CAUSING A LONGER DAY.

As an interesting comparison with Sir Oliver Lodge's article, we reproduce here Mr. Scriven Bolton's drawing that appeared in our issue of July 14 last, with the following note by him. "The terrestrial day is slowly but surely lengthening. Whether our globe will continue to slow down on its axis, we cannot tell. The rate of increase may at first appear to be quite a trivial matter, amounting, as it does, to only a hundredth part of a second per century. Still, it is sufficient to produce discordant results in the computed positions of the heavenly bodies; for it was this observed error which led to the discovery of the Earth's retardation. This retardation is five times greater than could possibly be due to tidal friction, or to a change in the level of the ocean bed. While the real cause is unknown, it is thought to be due to pulsations of the Earth's crust. The speed with which the Earth rotates is never really constant. At present the Sun, Moon, Mercury, and Venus are nearly half a minute ahead of their computed positions. . . . When the Earth exhibits marked fluctuations in its rotational velocity, precisely the same fluctuations are manifested, in a minor degree, by the Moon during its voyage around the Earth."

Specially Drawn for "The Illustrated London News," by Scriven Bolton, F.R.A.S., F.R.S.A., etc. (*Copyrighted.*)

The tides can be treated in several ways, but the most elementary and, so to speak, childish method is to think of two great low-lying humps or protuberances, held still chiefly by the moon, with the earth rotating under them; so that they travel round its surface in, roughly, about twenty-five hours, which is the length of the day or period of the earth's revolution relatively to the moon. The result is friction and dissipation of energy. The energy of the tides is necessarily partially wasted on the coasts; and all that waste of energy is at the expense of the earth's rotation. The earth may be said to be rotating inside a friction brake, of which the handle is held by the moon.

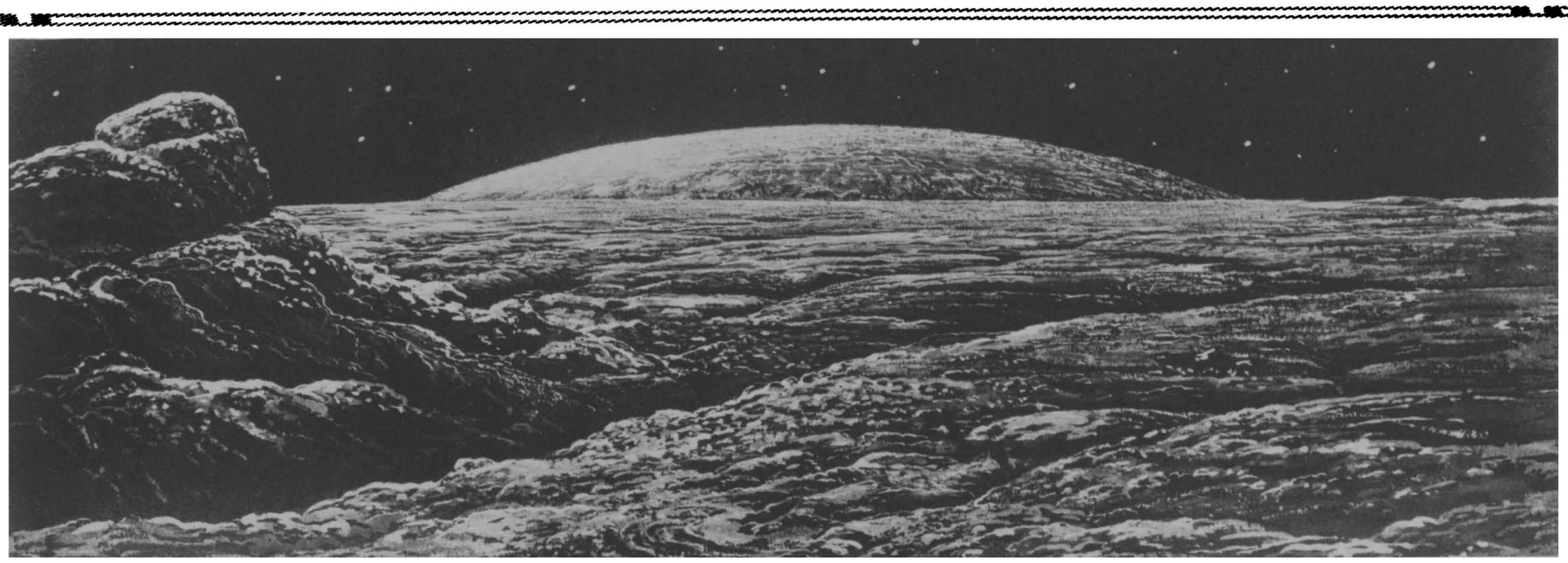
The earth's rotation is, therefore, slowly, very slowly, being wiped out. Each day is slightly longer than the one before, the difference being excessively small, only the 1/240-millionth of a second, or thereabouts. But the effect, though extremely minute, is cumulative; it always acts in one direction, it is never reversed. I do not say that there are no reversals, for if we take every cause into consideration, it would appear that there are; but still it remains true that the tidal influence—that is to say, the friction of the water on the earth's crust—is always such as to dissipate the energy of the earth's rotation and lengthen the day.

In Newtonian astronomy, as elaborated by Laplace, the orbits of the planets were constantly changing, sometimes becoming more, sometimes less, elliptical; the planets perturb each other, and accordingly they sometimes approached nearer, and sometimes receded further from, each other, or from the sun; and it then became a question whether these perturbing causes were likely to lead to catastrophe. Laplace was able to show that they would not: the forces were all periodic, like the swing of a pendulum; what was done

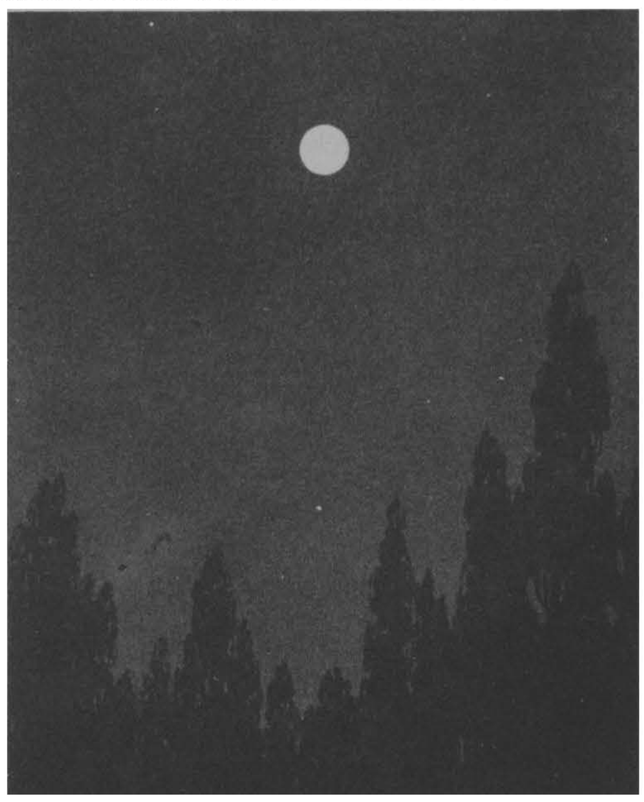
[*Continued on page 636.*

A "BRAKE" ON THE EARTH'S ROTATION: THE MOON AND ITS SURFACE.

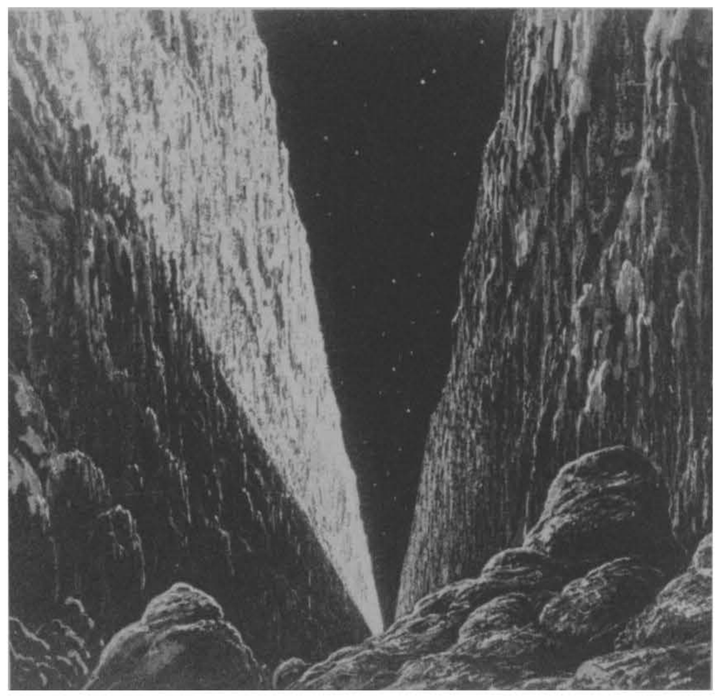
From Drawings by Lucien Rudaux, Based on the Latest Scientific Evidence.



THOUGHT TO REPRESENT THE FIRST STAGE IN THE FORMATION OF THE SO-CALLED "CRATERS" ON THE MOON: A MOUND ON THE LUNAR SURFACE NEAR "ARAGO," ON THE "SEA OF TRANQUILLITY," RECONSTRUCTED BY A FRENCH ARTIST.

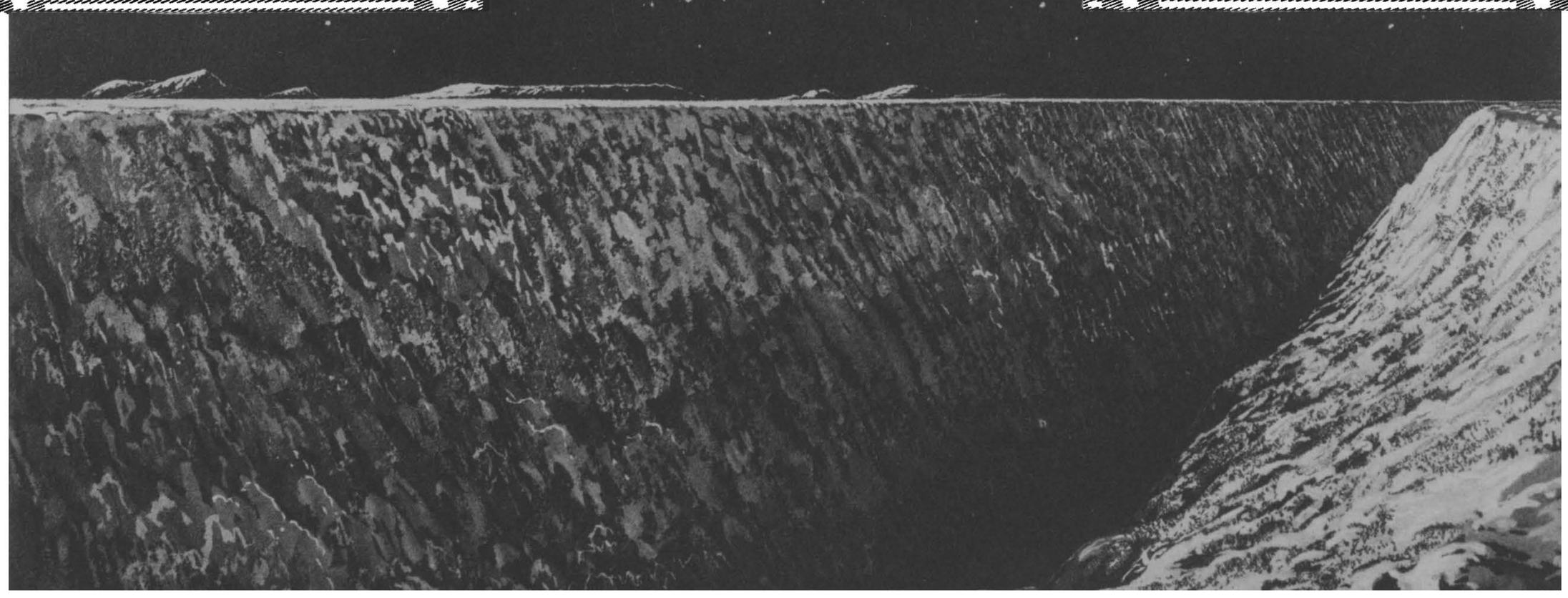


OUR SATELLITE AS WE SEE IT: MOONLIGHT ON THE EARTH COMPARES STRIKINGLY WITH THE GARISH BRIGHTNESS OF "EARTH LIGHT" ON THE MOON.



SHOWING THE BLACK SKY AND HARSH LIGHTING PRODUCED BY ABSENCE OF ATMOSPHERE: THE SCENE AT THE BOTTOM OF A GREAT CREVASSE.

WITH SHADOWS UNRELIEVED BY LIGHT ATMOSPHERICALLY REFRACTED: LUNAR NIGHT WITH THE BRILLIANT EARTH HIGH IN THE HEAVENS.

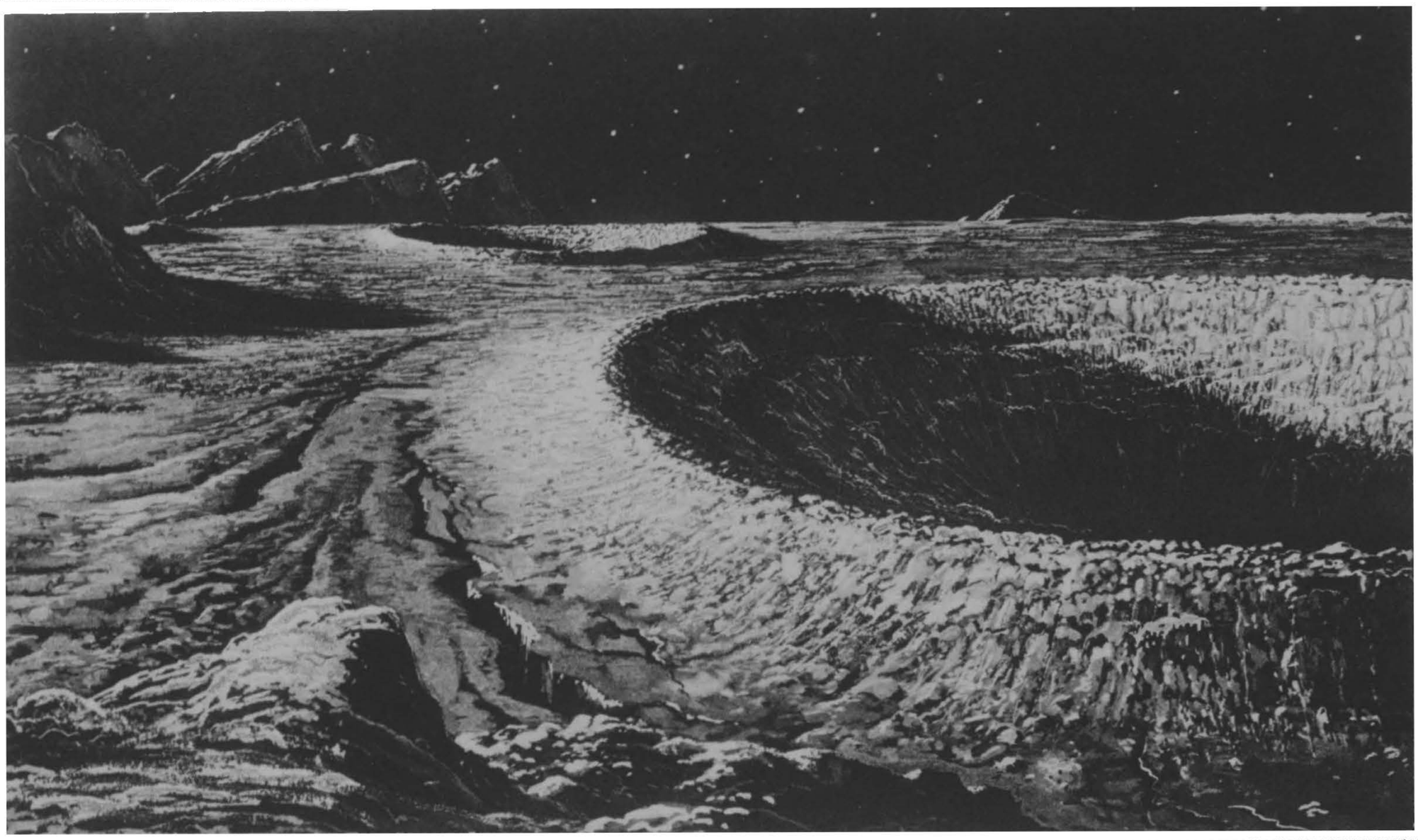


IN A LANDSCAPE UNRELIEVED BY WATER OR VEGETATION: A VIEW OF ONE OF THE VAST LUNAR CREVASSES, SOME OF WHICH RUN OVER 40 MILES ACROSS THE SURFACE, HALF A MILE ACROSS WITH PERPENDICULAR SIDES, WHILE THE LACK OF ATMOSPHERE TAKES AWAY FROM THE MOUNTAINS ON THE HORIZON THE FEELING OF DISTANCE.

How "the earth may be said to be rotating inside a friction brake, of which the handle is held by the moon," is explained by Sir Oliver Lodge in his article opposite, where he discusses the fascinating question of tidal influences. In this connection we reproduce above, and on pages 602 and 603, some remarkable studies of lunar landscape, which, though imaginary, are founded on scientific data. They are the work of a French artist, M. Lucien Rudaux, who supplements his drawings with a descriptive account. Ever since Galileo discovered the true nature of the moon's surface, M. Rudaux points out, the appearance of a world geologically so closely akin to ours has exercised a great fascination over the imagination. Yet, lacking atmosphere, the moon has lost all softness of outline, and remains a cracked and scarred world haunted by fantastic and garish lights and shades. The long, pointed shadows thrown by some of the lunar mountains at some periods during her day give an incorrect impression of dolomite-like spires soaring out of the lunar plain. But the long shadow is the effect of the oblique rays of the sun, and the mountains present quite a terrestrial outline, as shown above. The lack of an atmosphere intensifies the light on the gleaming surfaces, and leaves the shadows—except where reflected light reaches them absolutely black.

ON THE MOON, WHOSE ROTATION THE EARTH'S TIDES

FROM DRAWINGS BY LUCIEN RUDAUX, BASED ON THE



A TYPICAL LUNAR LANDSCAPE WITH SMALL CRATERS—PERHAPS OF VOLCANIC ORIGIN: SHOWING THE SURFACE MADE UP OF NAKED ROCK, UNMITIGATED BY SOIL OR VEGETATION.

SHOWING THE EARTH SURROUNDED BY A THIN SUNSET-COLOURED RING OF ATMOSPHERE: AN ECLIPSE OF THE SUN AS IT WOULD APPEAR FROM THE MOON, WITH THE BRIGHT "ZODIACAL LIGHT" SEEN IN ITS FULL GLORY.

"The tides produced in the moon's substance by the pull of the earth," writes Sir Oliver Lodge in his article on page 600, "have wiped out its rotation with reference to the earth, so that it always turns the same face towards us." Similarly, he explains, the weaker pull of the moon is slowing down the rotation of the earth, by infinitesimal degrees. "The earth's rotation is, therefore, slowly, very slowly, being wiped out." This is only one of the many fascinating questions which Sir Oliver discusses regarding the relations between the moon and the earth, as well as the remote possibilities of stellar disturbances. By way of general illustration of the lunar problem, we give above, and on page 601, some very striking studies of the moon's surface, based on scientific data, recently published by a French artist, M. Lucien Rudaux. In an accompanying description, M. Rudaux states that the absence of atmosphere on the moon, while it makes the lunar landscape harsh and garish, with unmodulated light and shade and great absence of that "feeling" of distance, must give rise to some surprisingly

HAVE STOPPED: LUNAR LANDSCAPE PICTURED BY SCIENCE.

Latest Scientific Evidence. (Copyrighted.)

WHERE THE GLORIES OF THE SOLAR PROMINENCES, UNOBSCURED BY ANY ATMOSPHERE, WOULD APPEAR AS ROSY FLAMES: A LUNAR SUNRISE WHICH TAKES A FULL HOUR.

SHOWING THE STRAIGHT SHADOW OF THE PLAIN CREEPING UP THE FACE OF THE MOUNTAINS: AN IMAGINARY VIEW OF THE LUNAR "APENNINES" AT SUNSET.

beautiful phenomena in connection with sunlight, which our atmosphere renders invisible. The lunar sunrise, which, owing to the slowness of our satellite's movement, takes a full hour to be completed, gives a full view of the rosy and flame-coloured prominences as the edge of the sun appears over the horizon. These solar prominences of fiery matter shooting out thousands of miles into space can only be seen with a telescope from the earth. When the sun is eclipsed by the earth, seen on the moon as four times as large as the sun, it would appear surrounded by a sunset-coloured ring of her atmosphere; beyond which the "Zodiacal light," a bright sphere surrounding the equatorial regions of the sun, rather after the fashion of Saturn's rings, could be seen extending. Altogether it seems as though the moon, while incapable of supporting life, would yet be a paradise for astronomers, who find in the terrestrial atmosphere their chief curse and bane.

THE MOON AND THE TIDES.

(*Continued from Page 600.*)

in one age would be undone in another. The effects were not cumulative; and accordingly, so long as the bodies were all rigid, the solar system might be perpetual: a sort of Magna Carta of permanence was established on that basis.

But in so far as the bodies are not rigid, in so far as they can be deformed, with friction and dissipation of energy, this law does not hold. Any cumulative effect, which is never reversed, but always acts in one direction, has far more important effects in the long run than alternating or periodic forces. If the National Debt were diminished by a farthing a year, and never increased, it would after the lapse of a certain time be abolished. That sort of thing is happening with the earth's rotation; and so in the course of ages the increase in the length of the day, however slight, if it always continues in the same direction, must wipe it out and make the day as long as the month. Then there would be no more lunar tides. This has actually happened in the case of the moon. The tides produced in the moon's substance by the pull of the earth, which is eighty times as strong as the moon's pull, have wiped out its rotation with reference to the earth, so that it always turns the same face towards us; the only residue of its original rotation being a slight residual oscillation or "libration"—discovered, near the end of his life, by Galileo.

But tidal influence is not limited to the body on which the tides occur. Every action has a corresponding reaction. The moon pulls and holds the earth's tides, but the earth's tides pull equally on the moon. And it is just that apparently small force—not small if we reckon it in thousands of tons—which is causing the moon gradually to recede.

The pull on the moon is an accelerating one, that is to say, a pull in the direction in which it is going; and that such a pull should make it recede and go slower is at first sight rather a puzzle. It is an immediate consequence of the law of gravitation, however, and it may be illustrated and made a little clearer by considering the opposite case, or what a retarding force would do. Suppose the moon were moving in a retarding medium, dragged back as it were, like a motor-car with the brakes on, what would be the effect of that? Strange to say, it would make the moon go quicker and cause it slowly to approach the earth in a sort of spiral. For let us remember that it is only the moon's motion which keeps it from falling in. Any cannon-ball fired with sufficient speed, even horizontally, would be able to fly for a considerable time without dropping to the ground; and if it could be fired at five miles a second, without any friction from the atmosphere, it would fly right round the world and complete a circular orbit. Anything below that speed would be insufficient, and would allow it to drop down.

The moon at its distance has not to fly so fast as that. The distance it has to travel in one revolution is 1½ million miles, and it suffices if it performs that journey in a month. Any cause which retarded its motion would bring it nearer, and any stoppage would make it drop at once. So, conversely, any cause which tries to accelerate its motion would make it recede, and as it got further away it would have to go slower and yet would still remain suspended.

Now that is just what the tides are doing by their reactionary pull: they are shortening the day and lengthening the month. And that is how George Darwin came to his most interesting conclusion, with much more detail and exact analysis than can even be indicated here, that there was a time in the past when the moon was quite near the earth, and when the day and the month were of the same length, each of them much shorter than they are now—in fact, only a few hours long. The conclusion is, therefore, that the earth and the moon were then one body, that they have gradually separated, the earth going slower, and the moon going further away, until we come to the condition of things we find to-day.

If, then, we take a flight of imagination and look forward to the time when the day and the month are again equal, and the moon still further away, and when, therefore, the lunar tides have ceased, one might think at first that that would be the end of these cumulative effects. But if we thought that we should be ignoring the solar tides; for everyone knows that, though the solar tide is less important on the earth than the lunar tide, it is not negligible. The combination of the two, when they coincide in phase, produces what we called our "spring" tides; and the opposition of the two makes our "neap" tides. The solar tides would not have stopped, they would continue to lengthen the day without affecting the month; and accordingly in those distant ages the day will slowly become longer than the month. The earth's tides would then begin to pull back on the moon, and thus cause it to approach, slowly, so very slowly that perhaps the solar system will not last long enough; but if it did last long enough the cumulative effects would go on: and the ultimate result would be that our moon would approach the earth, in the same way that Mars's moon is now approaching its planet.

The periods of time involved in these changes are of portentous magnitude; and the problem is only of interest as showing what mighty results can accrue from almost infinitesimal causes, provided they continue to act in one direction without cessation. Causes of this nature are active among all the bodies in space; and the host of heaven, which appeared stationary and were called "fixed stars" by our ancestors, must be the seat of continual and dramatic changes, occurring in periods of times to which the whole of human history is like a breath of mist on a mirror. Time is infinitely long; we can only infer the processes that are going on all round us; and our own existence, at least our terrestrial existence, is like one tick of the eternal clock.

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