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TREPIDATION

By R. S. Richardson

An article on trepidation in the astronomical sense—on the inequalities of time. There is now reason to believe that some of science-fiction's wilder guesses may be literal fact!

Illustrated by F. Kramer

Trepidation, n. 1. A vibratory oscillation; a trembling, especially, an involuntary trembling often due to fear, nervousness, excitement. 2. Hence, a state of terror, alarm, or trembling agitation; fright; as to be in great *trepidation*.

Webster's New International Dictionary.

SUCH is the meaning of the word as ordinarily used, its meaning as applied to people. But it also has another little-known connotation used to describe a certain rare phenomenon in our Solar System. The modern scientific definition might read somewhat as follows:

"Trepidation (astron.). A mysterious surge or wave of unknown origin affecting the Earth and possibly other planets. Generally appears as an abrupt and inexplicable change in the astronomical time scale."

Trepidation has been clearly recognized only within the last decade, although the data upon which it is based extend over two centuries. Out of these thousands of observations there has gradually emerged a result so strange, so contradictory to scientific experience that it seems more like the wild delusion of a paranoiac rather than the product of cold mathematical analysis. Yet many of the foremost names in theoretical astronomy may be found in the literature of trepidation. Lever-

rier was probably the first to suspect it, his intuition for the unseen carrying him beyond the figures in his tables. Simon Newcomb discussed the effect at considerable length, but refused to credit its reality to the end. Not until the twentieth century did E. W. Brown of Yale University and William de Sitter of the Observatory at Leiden demonstrate the existence of trepidation beyond all reasonable doubt. Today the question is not so much, "Is it real?" but instead, "How can such things be?"

"When you hear the tone the time will be one eleven and one half."

The tone sounds, and having sounded, we set our watch and move on about our business. It never occurs to us to challenge the young lady's statement or ask what kind of time she is talking about. How the telephone company keeps its clocks regulated interests us not at all. We have a hazy notion that it all starts back at the Naval Observatory in Washington, D. C., where the astronomers get the time very accurately from the stars. The nation has the most implicit faith in the reliability of these men. There is a nice comfortable feeling in the thought that here is one thing in the world we will never have to worry over.

It is a little disquieting, therefore,



to learn that recently sudden fluctuations have been discovered in the length of the day far larger than can be explained by the action of any known forces. The rotation of the Earth was originally selected as a measure of time principally because it was practically impossible to conceive of an appreciable variation in its motion. The astronomer has come to rely upon his apparent star positions absolutely.

He watches a fast-moving equatorial star as it steadily progresses over the illuminated field of his transit instrument, automatically recording its passage across the meridian to a hundredth of a second. There is a relentless finality about that moving speck of light that is terrifying to contemplate, something awe-inspiring in the knowledge that no power on Earth can stop it, or cause it to deviate from its path by so much as a hairbreadth. Time and tide, death and taxation, are as fickle as the wind by comparison.

No wonder that any difference between the time of meridian passage of a star and the time shown by the clock is always attributed to an error in the clock. That the mechanism controlling the clock should be right and the rotation of the Earth at fault is unthinkable.

Time thus derived from the rota-

tion of the Earth as shown by the apparent motion of the stars might be given the name of astronomical time (A. T.). It is the basis for the time that governs our daily life, from which it is easily derived.

BUT THERE IS another kind of time just beginning to be recognized that is more fundamental even than time determined from the stars. It has been called by several names, the most common being Newtonian, or Universal Time (U. T.). The concept of Universal Time is hard to grasp. It may be thought of as that quantity in the formulas describing the motions of the planets that can take any value—the so-called “independent” variable of the mathematician. An astronomer calculating the position of Venus for the epoch 1787.248 is using Universal Time. The lecturer in a planetarium running the sky back to the birth of Christ is using Universal Time, although he doesn't know it. It is a time stream that flows on entirely free from time as determined from the length of a planet's day.

The difference between A. T. and U. T. is generally of the order of a fraction of a minute, and for almost all purposes, no distinction is necessary between the two. The significant fact is not the size of the dif-

ference, but the fact that there is any difference at all.

The necessity for being so painfully precise can be blamed directly on to the Moon. It may come as something of a shock even to the astronomer to hear that in certain respects the Moon would make a better timepiece than the stars. The stars move smoothly and majestically across the heavens in parallel circles, and aside from minute variations that can be allowed for, remain fixed with respect to one another. The Moon, on the contrary, seems to be all over the place. But it is this very fact of its rapid motion that makes it such a good chronometer, just as the second hand of a watch gives the time more closely than the hour hand.

Also, the Moon is one of the most thoroughly observed bodies in the Solar System, a careful watch having been kept on its whereabouts since 1750. This long accumulation of lunar positions provides a check on every force disturbing its orbit, some thousand terms being needed to take them all into account. E. W. Brown, who devoted most of his life to the job, once remarked that keeping track of the Moon was like "playing chess in three dimensions blindfolded."

YET after each tiny perturbation has been computed and its effect properly applied, the Moon still refuses to follow the orbit prescribed for it. If we determine where the Moon should have been at the time of some ancient eclipse, we find that it was considerably off schedule according to the records, and the farther back we go the worse the discrepancy becomes. This is largely due to the slowing down of the Earth's rotation by tidal friction, chiefly by water in shallow seas such as Bering and the Irish Seas. At present it is prolonging the day by

one-thousandth of a second per century. So long as we measure time solely by the Earth's rotation we are powerless to detect it. Not until bodies exterior to the Earth begin to get seriously out of step in the march of time do we come to suspect that something is wrong.

Much more startling than the feeble drag of the tides are the sudden irregular jerks in the Moon's motion of enormous magnitude, compared with known disturbing forces. They can be explained equally well by upsets in the motion of the Moon or in the rotation of the Earth. The question can be decided by finding whether other bodies besides the Moon show similar fluctuations, for if the effect is caused by the Earth's rotation, then it should appear in the motion of every planet, being largest for the fastest-moving planets, but identical in time for all.

The best material for the test are the transits of Mercury over the Sun, most of which have been well observed since 1667. It is interesting to note that speedy little Mercury has the somewhat doubtful honor of being more valuable to science as a geometrical point than as a physical body. It was in this role that Mercury helped furnish one of the proofs of the Einstein theory, and now he is drafted again to serve as the locus of a point of space. Several other criteria are also available, such as the orbital motion of the Earth, Venus, and Mars—transits of Venus are too rare to be of service here—and eclipses of Jupiter's satellites.

After many elaborate and painfully technical discussions of these data, the results are finally in and admit of but one conclusion: *some powerful and unknown agency is at work in the Solar System which acts suddenly to create abrupt changes*

in the motion of the planets. According to Brown, it is as if a mighty wave or surge were spreading throughout interplanetary space. It was to this phenomenon that the eminent chronologist, the late Dr. Fotheringham, applied the name of trepidation.

THE FIRST ONE came in 1790 and was rather gradual, owing perhaps to uncertainties in the observations. But the other two in 1897 and 1917 were sharp and well-marked. In 1790 A. T., as shown by the Moon and Mercury, was thirty-four seconds behind U. T. Then A. T. began to gain on U. T., until by 1863 the two were equal, and in 1897 A. T. had gotten thirty-six seconds ahead of U. T. In that year *something* happened. The trend suddenly changed, and A. T. began to lose at the prohibitive rate of nearly a second per year. Twenty years later the same *something* again appeared, and A. T. has been steadily gaining with respect to U. T. ever since.

If we assume trepidation to be the result of alterations in the Earth's rotation, then we must be prepared to explain how these originate. But no forces can be imagined that could begin to alter the day by the amounts the observations demand. The frictional effect of the tides is insignificant compared with the energy at work in trepidation.

Are there surface changes due to meteorological action that might be effective? Several have been suggested that are fairly plausible qualitatively, but fail miserably as to quantity. De Sitter has calculated that if the Himalayas were removed to the pole, about one fourth of the trepidation of 1897 would be produced. Accumulation of ice and snow at the poles has been brought

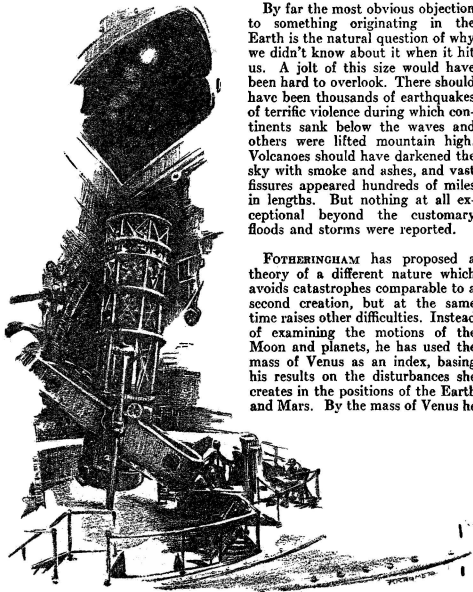
forward, but in order to be adequate, enough water would have to be frozen to lower the average sea level by one foot. Brown took the trouble to examine the hydrographic records around 1897, but found nothing unusual.

Failing to find the necessary energy outside the Earth or upon it,

geophysicists have been driven to dig inside of it for clues. The only possibility here is a pulsation similar to that supposed to account for the variation in light of certain stars, but much smaller in amount. An expansion of the entire Earth of only a few inches would be sufficient to account for the changes, but no such vibration has ever been observed.

By far the most obvious objection to something originating in the Earth is the natural question of why we didn't know about it when it hit us. A jolt of this size would have been hard to overlook. There should have been thousands of earthquakes of terrific violence during which continents sank below the waves and others were lifted mountain high. Volcanoes should have darkened the sky with smoke and ashes, and vast fissures appeared hundreds of miles in lengths. But nothing at all exceptional beyond the customary floods and storms were reported.

FOTHERINGHAM has proposed a theory of a different nature which avoids catastrophes comparable to a second creation, but at the same time raises other difficulties. Instead of examining the motions of the Moon and planets, he has used the mass of Venus as an index, basing his results on the disturbances she creates in the positions of the Earth and Mars. By the mass of Venus he



does not refer exactly to the quantity of matter in the planet, but rather to its mass considered as a perturbing force on other bodies. He obtained the remarkable result that the mass of Venus fluctuates in phase with the fluctuations shown by the Moon and the transits of Mercury. It seems impossible to believe, however, that the mass of Venus can in any way depend upon the rotation of the Earth. Hence he argues we are forced to conclude that the fluctuations in the mass of Venus are real. But we only know the mass of Venus relative to the Sun; there is no means of deciding which is actually changing.

Fotheringham thinks it is probable that all the planets fluctuate in mass, the effect being only shown in Venus because no other planet's mass can be measured in the same way. This movement, or trepidation, as he calls it, is in the nature of a vast wave spreading outward from the Sun to all the planets. Possibly as the Solar System journeys through space it may pass through regions where time and space are warped, causing slight deviations from Newtonian motion, just as a fleet of ships sailing abreast in still water would be thrown out of line on encountering a whirlpool.

Other hypotheses equally speculative have been advanced, but the cause of trepidation remains as mysterious as ever. Regardless of whether it is caused by changes in the Earth's rotation or in the motion of the planets, there can be no doubt of the reality of the effect itself. Perhaps the next time it comes its true meaning will be revealed, in what form we can only guess. This may be sooner than we think. Professor Brown, in a report to the Smithsonian Institution in 1927, shortly before his death, revealed

that "the deviation of the Earth from showing correct time is now greater than it has ever been since observations were made with sufficient accuracy, and consequently it is reasonable to suppose that a new change may soon occur."

At the last transit of Mercury, on November 11, 1940, the planet surprised astronomers by coming upon the Sun's disk a half minute ahead of the predicted time given by the Naval Observatory. The exact cause cannot be stated until the positions of the Sun and Mercury are carefully checked, but Mercury was certainly out of its calculated orbit.

In the meantime we can only await whatever may be in store for our little family of planets—with trepidation!

THE END.