

ART. XXVII.—*On Celestial Dynamics*,¹ by J. R. MAYER.

THE surface of the sun measures 115,000 millions of square miles, or $6\frac{1}{2}$ trillions of square metres; the mass of matter which in the shape of asteroids falls into the sun every minute is from 94,000 to 188,000 billions of kilograms; one square metre of solar surface, therefore, receives on an average from 15 to 30 grams of matter per minute.

To compare this process with a terrestrial phenomenon, a gentle rain may be considered which sends down in one hour a layer of water 1 millimetre in thickness (during a thunder-storm the rainfall is often from ten to fifteen times this quantity); this amounts on a square metre to 17 grams per minute.

The continual bombardment of the sun by these cosmical masses ought to increase its volume as well as its mass, if centrifugal² action only existed. The increase of volume could scarcely be appreciated by man; for if the specific gravity of these cosmical masses be assumed to be the same as that of the sun, the

¹ Extracted from the L. E. and D. Phil. Mag., [4], xxv, 399-402, and continued from vol. xxxvii, p. 198 of this Journal.

² [Centripetal?—Tr.]

enlargement of his apparent diameter to the extent of one second, the smallest appreciable magnitude, would require from 33,000 to 66,000 years.

Not quite so unappreciable would be the increase of the mass of the sun. If this mass, or the weight of the sun, were augmented, an acceleration of the motion of the planets in their orbits would be the consequence, whereby their times of revolution round the central body would be shortened. The mass of the sun is 2·1 quintillions of kilograms; and the mass of cosmical matter annually arriving at the sun stands to the above as 1 to from 21 to 42 millions. Such an augmentation to the weight of the sun ought to shorten the sidereal year from $\frac{1}{42,000,000}$ th to $\frac{1}{85,000,000}$ th of its length, or from $\frac{1}{4}$ ths to $\frac{1}{8}$ ths of a second.

The observations of astronomers do not agree with this conclusion; we must therefore fall back on the theory mentioned at the beginning of this chapter, which assumes that the sun, like the ocean, is constantly losing and receiving equal quantities of matter. This harmonizes with the supposition that the *vis viva* of the universe is a constant quantity.

VII. *The Spots on the Sun's Disc.*

The solar disk presents, according to Sir John Herschel, the following appearance. "When the sun is observed through a powerful telescope provided with colored glasses in order to lessen the heat and brightness which would be hurtful to the eyes, large dark spots are often seen surrounded by edges which are not quite so dark as the spots themselves, and which are called penumbrae. These spots, however, are neither permanent nor unchangeable. When observed from day to day, or even from hour to hour, their form is seen to change; they expand or contract, and finally disappear; on other parts of the solar surface new spots spring into existence where none could be discovered before. When they disappear, the darker part in the middle of the spot contracts to a point and vanishes sooner than the edges. Sometimes they break up into two or more parts that show all the signs of mobility characteristic of a liquid, and the extraordinary commotion which it seems only possible for gaseous matter to possess. The magnitude of their motion is very great. An arc of 1 second, as seen from our globe, corresponds to 465 English miles on the sun's disk; a circle of this diameter, which measures nearly 220,000 English square miles, is the smallest area that can be seen on the solar surface. Spots, however, more than 45,000 English miles in diameter, and, if we may trust some statements, of even greater dimensions have been observed. For such a spot to disappear in the course of six weeks (and they rarely last longer), the edges, whilst approaching each other, must move through a space of more than 1000 miles per diem.

"That portion of the solar disc which is free from spots is by no means uniformly bright. Over it are scattered small dark spots or pores which are found by careful observation to be in a state of continual change. The slow sinking of some chemical precipitates in a transparent liquid, when viewed from the upper surface and in a direction perpendicular thereto, resembles more accurately than any other phenomenon the changes which the pores undergo. The similarity is so striking, in fact, that one can scarcely resist the idea that the appearances above described are owing to a luminous medium moving about in a non-luminous atmosphere, either like the clouds in our air, or in widespread planes and flame-like columns, or in rays like the aurora borealis.

"Near large spots, or extensive groups of them, large spaces are observed to be covered with peculiarly marked lines much brighter than the other parts of the surface; these lines are curved, or deviate in branches, and are called *faculæ*. Spots are often seen between these lines, or to originate there. These are in all probability the crests of immense waves in the luminous regions of the solar atmosphere, and bear witness to violent action in their immediate neighborhood."

The changes on the solar surface evidently point to the action of some external disturbing force; for every moving power resident in the sun itself ought to exhaust itself by its own action. These changes, therefore, are no unimportant confirmation of the theory explained in these pages.

At the same time, it must be observed that our knowledge of physical heliography is, from the nature of the subject, very limited; even the meteorological processes and other phenomena of our own planet are still in many respects enigmatical. For this reason no special information could be given about the manner in which the solar surface is affected by cosmical masses. However, I may be allowed to mention some probable conjectures which offer themselves.

The extraordinarily high temperature which exists on the sun almost precludes the possibility of its surface being solid; it doubtless consists of an uninterrupted ocean of fiery fluid matter. This gaseous envelope becomes more rarefied in those parts most distant from the sun's centre.

As most substances are able to assume the gaseous state of aggregation at high temperatures, the height of the sun's atmosphere cannot be inconsiderable. There are, however, sound reasons for believing that the relative height of the solar atmosphere is not very great.

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Since gravity is 28 times greater on the sun's surface than it is on our earth, a column of air on the former must cause a pressure 28 times greater than it would on our globe. This great pressure compresses air as much as a temperature of 8000° would expand it.

In a still greater degree than this increased gravity do the qualities peculiar to gases affect the height of the solar atmosphere. In consequence of these properties, the density of our atmosphere rapidly diminishes as we ascend, and increases as we descend. Generally speaking, rarefaction increases in a geometrical progression when the heights are in an arithmetical progression. If we ascend or descend $2\frac{1}{2}$, 5, or 30 miles, we find our atmosphere 10, 100, or a billion times more rarefied or more dense.

This law, although modified by the unequal temperatures of the different layers of the photosphere and the unknown chemical nature of the substances of which it is composed, must also hold good in some measure for the sun. As, however, the mean temperature of the solar atmosphere must considerably exceed that of our atmosphere, the density of the former will not vary so rapidly with the height as the latter does. If we assume this increase and decrease on the sun to be ten times slower than it is on our earth, it follows that at the heights of 25, 50, and 300 miles, a rarefaction of 10, 100, and a billion times respectively, would be observed. The solar atmosphere, therefore, does not attain a height of 400 geographical miles, or it cannot be as much as $\frac{1}{32}$ th of the sun's radius. For if we take the density of the lowest strata of the sun's atmosphere to be 1000 times greater than that of our own near the level of the sea, a density greater than that of water, and necessarily too high, then at a height of 400 miles this atmosphere would be 10 billion times less dense than the earth's atmosphere; that is to say, to human comprehension it has ceased to exist.

This discussion shows that the solar atmosphere, in comparison with the body of the sun, has only an insignificant height; at the same time it may be remarked that on the earth's surface, in spite of the great heat, such substances as water may possibly exist in the liquid state under a pressure thousands of times greater than that of our atmosphere.

Since gases, when free from any solid particles, emit, even at very high temperatures, a pale transparent light—the so-called *lumen philosophicum*—it is probable that the intense white light of the sun has its origin in the denser parts of his surface. If such be assumed to be the case, the sun's spots and faculæ seem to be the disturbances of the fiery liquid ocean, caused by most powerful meteoric processes, for which all necessary materials are present, and partly to be caused by the direct influence of

streams of asteroids. The deeper and less heated parts of this fiery ocean become thus exposed, and perhaps appear to us as spots, whereas the elevations form the so-called faculæ.

According to the experiments made by Henry, an American physicist, the rays sent forth from the spots do not produce the same heating effect as those emitted by the brighter parts.

We have to mention one more remarkable circumstance. The spots appear to be confined to a zone which extends 30° on each side of the sun's equator. The thought naturally suggests itself that some connexion exists between those solar processes which produce the spots and faculæ, the velocity of rotation of the sun, and the swarms of asteroids, and to deduce therefrom the limitation of the spots to the zone mentioned. It still remains enigmatical by what means nature contrives to bring about the uniform radiation which pertains alike to the polar and equatorial regions of the sun.

[To be continued.]