

## BIGELOW'S "SOLAR AND TERRESTRIAL MAGNETISM."

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Professor Bigelow has on various occasions published the conclusions drawn by him from his magnetic investigations, but so far the details given were not sufficient to allow an independent reader to form an opinion as to the value of his work. I am glad, therefore, to find that the United States Weather Bureau<sup>1</sup> has now enabled Professor Bigelow to supply the omission; and in the small volume which has recently been circulated, those interested in the subject will find ample material whereon to base their judgment.

I may say at once that although I have to criticise severely some of Professor Bigelow's conclusions, and am obliged to put myself into antagonism to every one of his results, I am fully sensible of the great service rendered by the author in collecting together and reducing a most valuable series of facts and observations.

As Professor Bigelow's main contention lies in the assertion of a direct magnetic action of the Sun, it will be useful to consider, in the first instance, what effects such a direct action can produce.

Considering the distance and size of the Earth, any magnetic force due to the Sun must be sensibly the same in direction and magnitude all over the surface of the globe. If the Sun be magnetized parallel to his axis, we may, following Lord Kelvin,<sup>2</sup> decompose the action into components parallel and perpendicular to the earth's axis. Owing to the changing distance between the Earth and Sun, the former would yield a small periodic annual variation, directed towards the geographical north, while the second component would produce a daily variation, having the sidereal day for its period.

If the Sun is magnetized transversely, additional periods are introduced by his rotation. It has been commonly assumed that the duration of the period caused by the rotation of the Sun is the *synodic* time of revolution; but calculation shows that this view is incorrect, and that, on the contrary, no appreciable periodicity of

<sup>1</sup>"Abstract of a Report on Solar and Terrestrial Magnetism in their Relations to Meteorology." *United States Weather Bureau Bulletin*, No. 21, Washington, 1898.

<sup>2</sup>*Proc. Roy. Soc.* Vol. LII, p. 305 (1889); *Nature*, Vol. XLVII, p. 108.

26.8 days can possibly be caused by any conceivable magnetization of the Sun. The strongest period due to solar rotation has a time of about 28.5 days, and there is a second period of smaller amplitude, the time of which is that of *sidereal* revolution. An important characteristic of these periods is that the forces act in the magnetic meridian, and that the horizontal components must vary as the cosine of the latitude, while the vertical components vary as the sines. There can be no components towards the geographical west.

I may now proceed to discuss how far the effects which Professor Bigelow ascribes to the magnetization of the Sun agree with those which calculation declares to be possible.

In the second chapter examples are given of the tabulations which serve as basis to Professor Bigelow's work. After making a certain allowance for disturbances, the average daily value for the magnetic elements was calculated. The monthly mean of these daily values was taken to represent the "normal" value for the fifteenth day of the month, and interpolating between the fifteenth days of successive months the "normal" values for each day were calculated. The difference between the vectors representing the normal and actual observed forces represents what Bigelow calls the deflecting vector, the periodicities of which are to be examined.

If the angles which the deflecting forces form with the geographical meridian are arranged in tables, it is found that there is a certain persistency in them, the forces acting towards the north for a number of successive days, and such periods being succeeded by others in which the deflecting forces act southward. From this the author concludes that there must be a definite periodic disturbance acting on the needle, and by a method which must fail whenever there are several overlapping periods determines the time to be 26.67928 days. This figure agrees remarkably with the synodic revolution of the solar equator, and hence the conclusion that there is direct magnetic action of the Sun observable on the Earth. I have mentioned above that mathematical analysis declares it to be impossible that a period equal to that of the synodic revolution can be produced by such a direct action, and Professor Bigelow must be wrong, therefore, either in his periodicity or in the conclusion he draws from it. But the author's periodicity is not a periodicity of the ordinary kind, for it shows an "inversion;" that is to say, at certain intervals the maxima changes into minima, and *vice versa*. There is here a confusion of terms.

If a quantity is said to be periodic, it can only mean that at intervals equal to the length of the period the quantity repeats itself, and goes on repeating itself forever; there is no room for such an inversion as Professor Bigelow speaks of, and the very fact of the inversion disproves the periodicity. As the matter is of great importance I must enter into it a little more fully, although Lord Rayleigh has already repeatedly drawn attention to the importance of keeping our ideas clear on the subject. If a variable shows a periodicity of time  $2\pi/k$ , it can only mean that the analytical representation of the variable contains a term  $\cos(kt+a)$ , and it can mean nothing else. Such phenomenon as that called inversion by Professor Bigelow can only be produced by the superposition of at least two different periods:

$$\cos kt + \cos qt = \cos \frac{(p-q)t}{2} \cos \frac{(p+q)t}{2}$$

If  $p$  and  $q$  are nearly equal, the first factor varies very slowly, and after a certain length of time changes sign. During a limited interval we may then speak *approximately* of a periodicity  $4\pi/p+q$ , and if we compare times at which the first factor is approximately  $+1$  and  $-1$ , we get apparently such a change of phase as the author calls an "inversion."

Two tuning forks having frequencies 256 and 252 would, according to him, be periodic with a frequency 254, the periodicity showing an "inversion." But such a manner of speaking would bring total confusion into a subject, in which clear ideas are essential. The one fact which seems established by Professor Bigelow's tabulation is the *absence* of a 26.68 day period, and his position is really saved hereby, as he will still be able to believe in a direct magnetic action of the Sun; for the two periodicities  $T_1$ ,  $T_2$  which a magnetized Sun *could* produce are related to the synodic period  $T$  by the equation:

$$\frac{1}{2} \left( \frac{1}{T_1} + \frac{1}{T_2} \right) = \frac{1}{T},$$

so that if they were of equal amplitude "beats" would result which might be the cause of some such variation as Professor Bigelow believes he has discovered. One of the two periodicities has, however, an amplitude equal to three times that of the other, and without a very careful analysis it is not possible to declare whether they really exist or not.

In Chapter III we have some vague reasoning from which the conclusion is drawn that the disturbing forces are due to solar

action. But as these forces do not at all conform to the criterion pointed out above, that the north force should vary as the cosine of the latitude, and the vertical force as the sine, and as no attempt is made to separate by a vigorous analysis the outside from the inside force, we need not attach any value to the author's astounding conclusion that "the nucleus of the earth is impenetrable to the lines of magnetic force."

The most surprising of Professor Bigelow's conclusions are reserved for his Chapter IV, in which an attempt is made to account for the diurnal variations by means of a direct solar action. It is of course obvious that no ordinary magnetic influence emanating from the Sun can explain the diurnal variation, and Professor Bigelow has to invent therefore a force unknown so far to physics. The author's views are so peculiar that they must be quoted in his own words:

"The diurnal vector system depends exclusively upon the Sun's electromagnetic or sunlight field, which is a radial field and apparently induces in the ether an efficient polarization in respect to exploring magnets on the surface of the Earth." (P. 17.)

"The immense rapidity of the vibrations of light in the case of a train of waves from the source to the observer, practically integrates the system into a type of polarized ether." (P. 34.)

"The electromagnetic theory of light implies the existence of a magnetic field practically uniform in force and direction relatively to any magnet large in comparison with the wavelength of light, and hence to any magnet except of atomic and molecular dimensions." (P. 81.)

"The vibration is so rapid that the train of individual waves merges into a steady field in its action upon the Earth as a magnet or to the exploring magnets employed in observations." (P. 81.)

Whatever meaning the author may attach to these passages, they sound—to speak plainly—like nonsense to the ordinary reader. This new force is said to be implied by the electromagnetic theory of light, but though the author gives three pages of formulæ quoted from Heaviside's papers, there is not one of them that can justify his assertion. For, surely, Professor Bigelow does not take the quantity  $F$ , on page 166, to be a magnetic force, as it means a very different thing, being of different dimensions. Quite apart from any theo-

retical justification, we may be allowed to ask whether Professor Bigelow would expect a stronger or different diurnal variation if the magnets were suspended in sunlight, or whether he would expect that variation to disappear completely if the magnets were placed inside a closed metallic box which is known to be opaque to electrical vibrations? If the author can surmount this difficulty, will he explain how a force acting along the rays emanating from the Sun can produce simultaneously a westerly deflection in the northern and a southerly deflection in the southern hemisphere? Incidentally we may notice another startling assertion, that the interplanetary medium is cooled down by the passage of electromagnetic waves, and in support of this, one of Heaviside's equations is quoted, which has no connection with the subject.

Chapter VIII contains a further list of astonishing results. The magnetic period, which he ascribes to solar action, is not represented by a simple sine curve, but possesses within the period of solar rotation 9 maxima and 9 minima. Great importance is attached to these maxima, as they are all "inverted" together, and different meteorological phenomena are supposed to show a similar number of oscillations. The curves given on pages 44 and 119 leave no doubt that the author really believes that the Sun in his rotation can produce such a complicated effect. If  $\lambda$  denotes the solar longitude, the solar action must, according to Professor Bigelow, contain an appreciable term  $\cos 9\lambda$ , and probably terms involving even higher multiples of  $\lambda$ . If magnetic forces of this character exist, the theory of the potential teaches us that they must diminish very rapidly with the distance, more rapidly at any rate than the inverse 10th power. The ratio of the average distance of the Earth and Sun to the solar radius being 229, the force at the surface of the Sun must be at least  $(229)^{10}$  times the force on the Earth. Professor Bigelow's diagram allows us to make an estimate of the amplitude of the coefficient of  $\cos 9\lambda$ , which is certainly greater than .00002 C. G. S. It follows that at the Sun's equator the magnetic field must be equal to not less than  $16 \times 10^8$  C. G. S. units, or  $8 \times 10^{14}$  times greater than any magnetic force which has been observed between the pole pieces of the most powerful electromagnets.

If Professor Bigelow's curve is true, the Sun must be sliced like an orange, alternate slices having positive and negative polarities of the enormous values just mentioned.