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The Earth's Electricity

We seek to understand the universe in terms of the physical phenomena which we witness in our earthly reference frame. Thus, we knew the earth had a magnetic field and were not at all surprised when we found that the sun had one as well. We discovered how the optical spectra of radiant materials reveal their nature, and it was logical that we should find similar spectra in solar radiation. Minute displacements of the spectral lines were our clues to new cosmic phenomena, and when, for some stars, these displacements became significant we were confronted with a really mystifying problem. The spectral red shifts of the quasars will long remain a unresolved problem because we have no earthly phenomenon by which to formulate comparisons. The earth cannot provide the reference needed for our understanding. Only our theories duly extrapolated can be forged into shapes able to give satisfaction, but there can be little certainty in these matters. The earth is our test bed for theory. Phenomena verified on earth can reasonably be expected to have their counterparts elsewhere in the universe. And so it must be with that phenomenon we know as atmospheric electricity. Somehow the earth retains a negative electric charge. It seems not to have been explained in our reference sources, yet it exists and, if it exists as a terrestrial phenomenon it can presumably exist on the sun. We need to understand it if we are to seek the fullest understanding of solar phenomena. When we discovered nuclear energy, the sun became a nuclear fire. Before that time the sun was a body generating heat, emitting light and somehow surrounded by luminescent clouds. It was hot gas, electrically ionized gas when ionization was discovered, and it became nuclear as our earthly minds grew to comprehend nuclear phenomena. It is indeed surprising that the thunderball, as we have seen, did not become nuclear until 1970. It has been suggested that both the sun and the thunderball are, in fact, mere spheres of rotating aether, but acceptance of this depends upon our belief in the existence of such a medium. We are, when it comes to understanding the nature of astronomical bodies, including that great solar source of our own existence, mere victims of fashion. We depend upon our understanding of phenomena in our terrestrial frame of reference. Why then are we not paying attention to the earth's electric charge? Just because we cannot explain it does not mean that it lacks great cosmic importance.

The subject was given special treatment in a book by H. A. Wilson.* Wilson writes:

> The difference of potential between the earth and a point in the air above it may be found by means of an insulated conductor provided with some device to bring it to the same potential as the surrounding air. . . . The potential difference between the conductor and the ground can be measured with an electrostatic voltmeter connected to the conductor and to the ground by insulated wires. If the conductor is on a pole 10 m. above the ground in the open air away from buildings or trees, the potential difference between it and the ground will be of the order of 1500 volts. The vertical field varies greatly. In fine dry weather it is usually directed downwards, indicating a negative charge on the earth's surface. It varies with the time of day and season of the year. The vertical field has been measured at various heights by means of balloons. It is found to diminish as the height increases, and usually becomes negligible at about 10,000 m.

Wilson then demonstrates the challenge confronting physicists. How can this charge be maintained? Wilson calculates that the conductivity of air would discharge such electricity in about 17 minutes. Yet it is sustained. Various explanations are then reviewed. Rain drops may carry charge downwards to restore loss. But observers say that raindrops are usually positively charged and this could not explain the earth's negative charge. Lightning flashes may account for the current balance. It may be that more flashes convey current upwards than convey current downwards. Hence, if enough lightning flashes occur over the whole earth's surface, we can expect a negative charge

* *Modern Physics*, H. A. Wilson, Blackie, London, 1937, Ch. XVII.

to be held by the earth in spite of steady conduction losses. This seemed quite feasible to Wilson. Note, however, that we cannot then explain the origin of lightning in terms of the existence of the earth's electric field. Wilson then mentions a suggestion by Simpson that charged particles are shot out from the sun. Some reach the earth and the positive ones are stopped in upper regions whereas the negative ones, electrons, penetrate to the lower atmosphere. The problem here is that the electrons would have to move at velocities close to the speed of light to set up the observed charge on the earth. Also experiments to collect the charge they bring with them have yielded null results. So Wilson finally concludes:

> It will be seen from this discussion that we are as yet very far from having a satisfactory theory of atmospheric electricity.

Now, we are interested in this earthly phenomenon because it might tell us more about the source of the sun's energy. So let us question the idea that electrons travelling from the sun at a speed close to that of light can be the cause of the earth's electric charge. First, why should the speed be close to that of light? Well, if the earth has an electric charge it will act on incoming electrons repulsively and slow them down. They have to have enough momentum to fight against the earth's electric field and reach the surface. The number arriving will determine the earth's charge and it will rise to the appropriate value subject mainly to this bombardment rate but also subject to conductivity leakage and lightning discharges. The earth's charge is known from the electric fields we can measure. It happens to correspond to the electron velocity of the speed of light. Is not this a coincidence? Or is it evidence of scientific import? Experimental attempts to collect charge directly from these electrons failed. A large insulated copper collector was used but it acquired no measurable charge when exposed to the sun's radiation. How do we solve this mystery?

Let me quote from another completely unrelated chapter in Wilson's book. In his chapter on Quantum Mechanics at pages 92 and 93 he writes about an experiment involving interference and diffraction of light:

The light acts like particles in this experiment . . . the electrons shot out receive energy from the light. . . . If we suppose that the source of light emits only one photon, the chance of an effect due to this photon occurring at any place will be proportional to the wave intensity, at the place, when the source is supposed to be emitting a continuous train of waves. The waves therefore carry no energy, and the wave theory may be regarded as merely auxiliary mathematics which enables the distribution of the photons to be calculated. Just why such a method of calculation is necessary and why it gives results in agreement with the facts is not known. . . . The velocity of a photon is always equal to the velocity of light, so its momentum is equal to . . . its energy divided by the velocity of light.*

Apart from the interesting recognition by Wilson that waves carry no energy, a thesis expounded elsewhere in this work, he asserts the truth that wave mechanics do not explain; they just happen to work correctly. One may yet have to analyse the aether to really understand the whys and wherefores of the utility of wave mechanics in treating the problems of Nature. But this is digressing from the point which the discerning research-minded reader will already have appreciated. If light acts like particles and electrons 'shot out' receive energy from light, we have answered the anomaly confronting us above. The sun emits light. Light travels at the speed of light. It comes in packages known as photons. Photons impart momentum to electrons in atoms and thereby ionize the air. An electric field is established in the atmosphere in appropriate relationship with the absorption of solar radiation. We do not need electrons from the sun. All we need is light. This will impart momentum to electrons in atoms and sustain their displacement towards the earth. An electric field will be maintained directly in dependence upon the sun's radiation. The earth will have an electric charge which is seemingly negative but the effect will be more analogous to the Maxwell displacement in an insulator medium when an electric field is applied. It is just that the same effect is produced by light radiation, or rather the total electromagnetic radiation from the sun.

Now, as stated above, we know that the speed of light is the

* The text has been changed in the quotation by replacing mathematical symbols for terms 'velocity of light' and 'energy'.

key to the relationship between the momentum and the energy which is needed to hold an electron down in the earth's electric field. This is easily verified because we know the earth's potential gradient at its surface and its electric charge per unit area. Hence we know the force urging this surface charge into the ionized air adjacent the earth's surface. For equilibrium the solar radiation pressure is absorbed by the earth's atoms at the surface and, though deployed to urge the displacement of electrons and ions, this displacement is effectively neutralized by the balancing field (the potential gradient) due to the earth's surplus of electrons. The rate of supply of solar radiation energy per unit area is the quantity known from measurements. Taking this quantity, the earth's electric field and the charge then deduced from this field, we find that the balance condition will occur if the momentum of solar radiation happens to be the rate of supply of solar energy divided by the velocity of light. Conversely, the earth's electric field can actually be deduced in quantitative terms from the value of solar energy radiation since it is well known that a photon imparts momentum in proportion to its energy divided by the speed of light.

Due allowances must, of course, be made for the inclination of the radiant solar beam and the heat absorption effects of the atmosphere. The earth itself will not store much of the solar heat. Its surface temperature reacts rapidly to the daily cyclic changes in the solar heat supply because the earth has a poor heat conductivity. Thus, heat received by radiation is convected or radiated upwards without the balance being upset by any significant thermal inertial effects in the earth's surface material. It is the balance of radiation energy which is really effective at the earth's surface in developing electric field. It appears that much of the upward heat transfer is by convection and convection plays no part in inducing electric fields comparable with those induced by radiation action. We must also take note of the tremendous heat capacity of the atmosphere. This does absorb solar energy during the day and it develops downward radiation throughout the night, sustaining the earth's electric field even when the sun is not visible. Of course, the measured electric field varies cyclically during the 24 hour period. Three factors cooperate in developing cyclic variation, different radiation patterns for the atmosphere, the sun and the earth's surface. The atmosphere absorbs and re-radiates solar energy and since it has a high thermal capacity its heat content will cycle about a mean value with substantial phase-lag relative to the direct action of the sun. Curve A in Fig. 10 is representative and shows maximum radiation in the early evening. The sun's radiation when resolved into its vertical components will vary as indicated in curve B. The combined effect of atmospheric and solar radiation

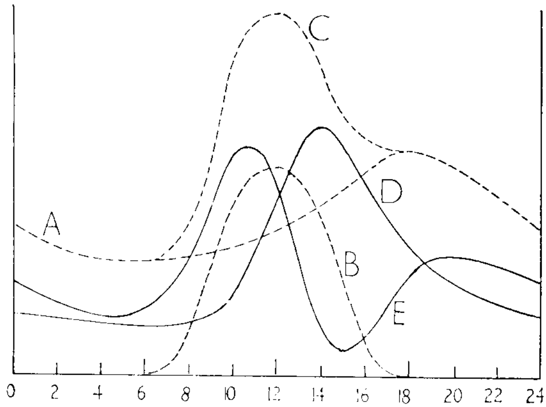

Fig. 10

is the curve C having a substantial midday peak. This radiation heats the earth and, in keeping with the heat emission properties of usual materials at earth temperature, about half will be re-radiated upwards. The effect is shown at D, with the peak in the early afternoon. The peak is significant because radiation is very sensitive to increase in temperature and the earth's surface temperature is readily changed in dependence upon incident radiation. Subtraction of curve D from C gives the resultant downward radiation, curve E, as a measure of the earth's potential gradient. The curve has two peaks during a period of 24 hours and, indeed, this is exactly what is observed experimentally.

In Fig. 11 data presented by Swann in 1919 is reproduced.* It

* *Jour. Franklin Inst.*, 188, p. 577, 1919.

applies to a typical summer day, presumably at a North American location. The curve shows that the earth's potential gradient, as measured, was of the order of 100 volts per metre but the interesting point is that the form of the curve is exactly

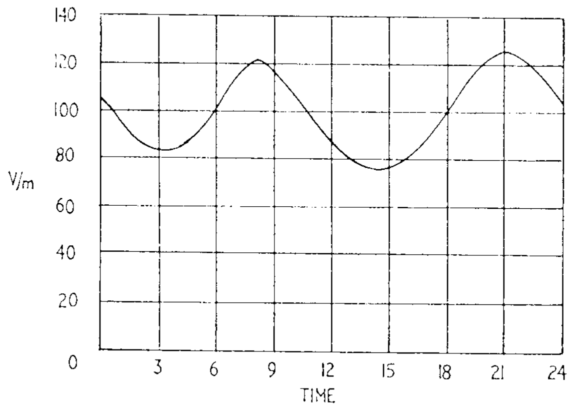

Fig. 11

that which we can predict on the theoretical account given above. Swann observes that the average potential is higher in winter than in summer. This may seem surprising at first but, in fact, it verifies the theory just presented. The curve such as A in Fig. 10 will always be representative of radiation coming vertically downwards, whereas the curve B depends upon the angle of inclination between the vertical and the sight line to the sun. In fact, curve B in the figure is developed as a full cycle of a sine wave on the assumption that at noon the sun is directly overhead. In the northerly part of the hemisphere, and particularly in winter, there is further attenuation of the direct solar radiation. Thus, curve A will become more predominant in winter and curve B will be less predominant. Additionally, since the solar radiation is impacting the earth's atmosphere more obliquely in winter relative to summer, a higher proportion of the sun's radiation energy is absorbed and this, in turn, contributes more to curve A while removing the strength from curve B. The lower temperature of the earth in winter ensures that the back radiation is significantly reduced. In summer, although the energy received is greater than in winter, the fact that more of the radiation comes in at an angle and a higher proportion re-radiated by the earth results in the actual radiation pressure and the consequent electric field being greater in winter than in summer. Of course, this distinction between winter and summer effects only applies in certain latitudes.

There can be little doubt that the earth's electric field is therefore generated by the pressure action of solar radiation as described. It is interesting to observe that Swann, writing in 1919, came very close to realizing this mechanism. He analysed the effect of gamma radiation impinging on electrons and used data for ionization based on experimental measurement of the effects of 'radiation from above'. At this time, Swann could not have been aware of the later discovered Compton Effect which showed that all the electromagnetic solar radiation received at the earth can be absorbed to impart momentum to electrons.

The above account of the origin of the earth's electric field is not an explanation of the phenomenon of lightning. Nevertheless, just as Wilson imagined that lightning might provide the current needed to sustain the earth's charge, we can now invert this argument and say that the solar radiation pressure will restore the charge dissipated by lightning flashes.

It is evident that some physical mechanism triggers discharges in the atmosphere. A cloud, for example, will absorb rather more radiation than the clear atmosphere. Therefore, the cloud will become charged. It becomes a giant capacitor floating in the sky. Atmospheric conditions conducive to the formation of dark thunderclouds will enhance this action. Then, when clouds interact electrostatically, either with themselves or with the earth, we may find a substantial positive charge is drawn towards a substantial negative charge and lightning discharges occur. What the explanation of the earth's electric field does offer is the mechanism by which charge is induced. All the many factors, such as ice or water droplets, which have been observed to contribute to the initiation of thunderstorms, may still perform their recognized roles. However, we do not preclude by the new ideas put forward in this work the prospect of cosmic lightning discharges at the sun's surface, for example. We do not need to argue that ice is an essential feature of the physical basis of lightning and that this precludes cosmic thunderstorms save, as Sir Basil Schonland concedes,* in 'dying stars having relatively cold atmospheres'.

It was not really necessary to consider the origins of lightning in this book about the aether. The topic has been included in order to show that the seemingly uncertain source of the earth's electricity can be explained in association with lightning and in such a way as to suggest that the apparent surface temperature of the sun is enhanced by lightning discharge. Heat radiation from the solar energy source induces electric fields which charge the solar atmosphere.† Lightning discharges produce high temperatures in transient striations which occur continuously, making the sun appear hotter than it really is. It is also interesting to note that Jupiter, for example, appears to have a temperature higher than it should have if all the heat it received from the sun is re-radiated. This suggests an internal heat source but equally it suggests a non-uniform temperature, inasmuch as the disproved heat balance assumes uniformity of temperature.

In the next chapter we will examine the prospect of discovering the source of the sun's energy.

* See page 13.

† The action of radiation pressure, that is photons, on electrons in stars is discussed by M. Stix at p. 161 of *Astronomy & Astrophysics*, January 1970 and used to explain charge displacement and magnetic fields resulting from stellar rotation of this charge.