PAPER 35

A NEW MODEL OF MAGNETIC STORMS AND AURORAE

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ABSTRACT

Three topics are discussed dealing with interplanetary phenomena. They are: (i) sudden commencement of magnetic storms[1]; (ii) main phase of magnetic storms[2]; (iii) cosmic ray effects associated with solar corpuscular emission[3].

To explain the sudden commencement(SC) of magnetic storms, the reverse sudden commencement (SC*), and the pre-SC disturbances, we invoke the following model: The solar eruption produces a shock-wave which arrives at the earth 22–34 hr later. *High velocity particles* having a smaller interaction precede the shock-wave and cause the pre-SC bay-like disturbances at high latitudes. The shock-wave itself is retarded by the body forces produced by the geomagnetic field, but speeds up as it enters the auroral zones. In pushing out lines of force it creates the polar SC* events. Charge separation in the shock-wave produces the driving force for the SC currents which flow in the atmosphere (in accordance with Vestine's analysis).

The storm decrease is produced by the high velocity particles following the shock-wave (up to 9 hr later) which enter because of field perturbations into the normally inaccessible Störmer regions around the dipole. Here they are trapped and will drift producing the ring-current which gives rise to the storm decrease. Particles with small pitch angle, however, can reach the earth's atmosphere and contribute to aurora, the air-glow, and ionospheric ionization. These particles are replenished by perturbations produced by solar influences having a 27-day recurrence. Many other particles are absorbed or scattered out of the trapping regions so that their number diminishes rapidly in a day or so, as does the magnetic storm decrease.

The model thus attempts to explain for the first time the cause of the reverse sudden commencement events (SC*), the atmospheric nature of SC, the delay between SC and the main phase, the formation and decay of the ring-current. A by-product is auroral particle acceleration by a shock-wave[4].

New experimental tests are suggested by the model: (i) Acoustic observations with balloons to look for the shock-wave penetrating into the atmosphere in the auroral zones. (ii) Observations with rockets or satellites to establish the location of the SC and main phase currents. (iii) Measurements of the nature and energy of the auroral particles[5].

It is suggested that the cosmic ray decrease occurring with magnetic storms

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(*Forbush events*), as well as the 27-*day decreases* of cosmic ray intensity, are modulation effects produced primarily by the deceleration of cosmic rays in interplanetary space due to the expansion of turbulent gas clouds from the sun. The detailed mechanism depends on a statistical decrease of the initially high turbulent fields and can therefore be called an 'inverse Swann effect' or 'inverse Fermi effect'. The cosmic ray intensity variation during the *solar cycle* is accounted for as the cumulative effect of this mechanism which operates in connexion with emission of solar gas. In this way it is possible also to account for the decrease lasting six months observed by Forbush starting in February 1946. Some experimental tests are suggested to discriminate between different theories for the origin of cosmic ray time variations [3].

REFERENCES

[1] Singer, S. F. *Trans. Amer. Geophys. Union*, **38**, no. 2, 175, 1957.
[2] Singer, S. F. *Nuovo Cimento*, Suppl. II, 1957.
[3] Singer, S. F. *Phys. Rev.* 1957 (in the press).
[4] Singer, S. F. *A new model of magnetic storms and aurorae*, Phys. Dept. Techn. Rep. no. 48 (University of Maryland, 1956).
[5] Singer, S. F. *Cosmic ray time variations produced by deceleration in interplanetary space*, Phys. Dept. Techn. Rep. no. 50 (University of Maryland, 1956).

Discussion

Ferraro: One general comment which I should like to make in connexion with both Alfvén's theory and Singer's is that they have only considered the motion of a single particle in the external electric and magnetic field. Because of the neglect of the interaction between the particles of the stream it is difficult to be sure of the bearing of their results on the actual phenomena.

As regards the anomalous SC and initial phase amplitudes at Huancayo, whilst this is undoubtedly an atmospheric effect, it is not necessarily adverse to the hypothesis that the sudden commencements are due to sudden increase in the earth's magnetic field outside the earth. There will be, undoubtedly, ionospheric currents induced by this impulse and these may produce local variations because of the non-uniform conductivity of the ionosphere.

Forbush: Vestine and Forbush found that the sudden commencements at Huancayo were larger on days with larger diurnal variation. How does this influence the induced effects if the larger diurnal variation arises from greater ionospheric conductivity?

Ferraro: Huancayo is a very abnormal station. I cannot see that there is necessarily anything extreme in the observed effect.

Singer: Concerning the situation of the main phase I think that the interaction between particles is taken into account when you consider the interaction between currents. There is a decrease in the magnetic field gradient which guarantees the stability.

Then we come to the second problem concerning the sudden commencement. The theory of the sudden commencement should also explain the reversed sudden commencement, i.e. the decrease in the magnetic field which immediately precedes the sudden commencement increase. This decrease should be very pronounced in the auroral regions. It may be a strong argument for the hypothesis that shock-waves penetrate to the auroral zones and not to the equator.

Now let me make some comments on the question put forward by Dr Forbush. The theory has to explain why the sudden commencement currents are enhanced on the day side of the earth and why this enhancement is large at Huancayo. There is nothing strange about this station, except that it is situated near the geomagnetic equator. The sudden commencement enhancement is increased by a factor of about 8 at Huancayo as compared to other stations which are not situated near the geomagnetic equator. Further, a comparison of the diurnal variations at Huancayo and at Cheltenham also shows that the sudden commencement currents are large at Huancayo. I think that this situation is explained by the fact that the electric conductivity at the geomagnetic equator is high in the direction parallel with the equator. This is a phenomenon well known from the investigations of the electrojet. But a high ionospheric conductivity would shield, i.e. cancel, an external current, not reinforce it.

Ferraro: What you say about the conductivity at Huancayo is quite true. However, one should not exclude other possibilities of explanation for such a complicated phenomenon as this. Chapman has, e.g. suggested that it might be due to return currents from the polar regions. This could reduce the effect of the currents which produce the 'normal' sudden commencement.

Parker: I remember having read somewhere that in auroral latitudes during years of solar activity there are auroral displays nearly every night. Does this imply that in years of solar activity nearly the entire orbit of the earth is flooded with beams and/or shock-waves, etc.?

Alfvén: If an electric field is the cause of magnetic storms and aurorae, then there is almost always an electric field in interstellar space giving a weak aurora or a strong aurora, according to the strength of the field.