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GEOMAGNETIC STORMS FORECAST USING IPS OBSERVATIONS

S. BRAVO*
A. HEWISH**
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RESUMEN

La observación del centelleo interplanetario (IPS) de radiofuentes estelares de diámetro pequeño permite la detección y el rastreo de perturbaciones en el viento solar que viajan desde los hoyos coronales en el Sol hacia la Tierra, causando a su llegada perturbaciones geomagnéticas e ionosféricas. Durante el período de julio de 1978 a septiembre de 1979, se llevó a cabo un monitoreo continuo del centelleo de 900 fuentes estelares de radio y se encontró que la mayoría de los comienzos repentinos (SC) de tormentas geomagnéticas ocurrieron más de un día después, y algunos hasta cuatro o cinco días después de que se detectó por primera vez la perturbación en el medio interplanetario a través del centelleo. Esto demuestra que un monitoreo permanente del centelleo interplanetario de las radiofuentes proporciona una herramienta muy útil en el pronóstico de las perturbaciones geomagnéticas y los efectos asociados a ellas.

ABSTRACT

IPS observations have shown to provide a very good track of the disturbances in the solar wind flowing out from coronal holes at the Sun and eventually hitting the Earth and causing geomagnetic and ionospheric perturbations. A continuous survey of IPS for 900 stellar radio sources, carried out from July 1978 to September 1979, showed that most of the sudden commencements of geomagnetic storms took place more than one day after the first IPS detection of the disturbance in the interplanetary medium, and some of them even four or five days later. This shows that IPS observations can also be a useful tool in the forecasting of geomagnetic perturbations and associated effects.

* *Instituto de Geofísica, UNAM, Ciudad Universitaria, 04510, México, D. F. MEXICO.*
** *Mullard Radio Astronomy Observatory, Cavendish Laboratory, Madingley Road, Cambridge CB3 OHE, ENGLAND.*

INTRODUCTION

With the sensitive 3.6 hectare Array at Cambridge, a programme was carried out in which 900 stellar radio sources were observed each day during more than two years. The observations were performed in two periods of about one year each (July 1978-Sept. 1979; Feb. 1980-March 1981), and some of the results for the first survey have been already published (Gapper *et al.*, 1982; Tappin *et al.*, 1983, 1984; Hewish *et al.*, 1985 and Hewish and Bravo, 1986a and b). The large number of sources observed make possible to trace daily maps of the sky where the disturbances in the interplanetary medium can be distinguished. Figure 1 shows an example of such maps in which regions of scintillation higher than normal are indicated with (+) and regions with scintillations below normal are indicated with (−). The details of the method of scintillation mapping can be found in the references given above. Tappin *et al.* (1984) have shown that the index of scintillation is directly correlated with $N^{\frac{1}{2}}$ (N is the density number of the solar wind), so the (+) regions correspond to compression regions and the (−) regions correspond to rarefaction regions in the interplanetary medium. Very often the compression regions are actually shock fronts and the rarefaction regions always correspond to high speed solar wind flows (Steinitz and Eyni, 1980). It is important to notice that this kind of maps are not instantaneous images of the sky, but each one covers 24 hrs of observations from West to East.

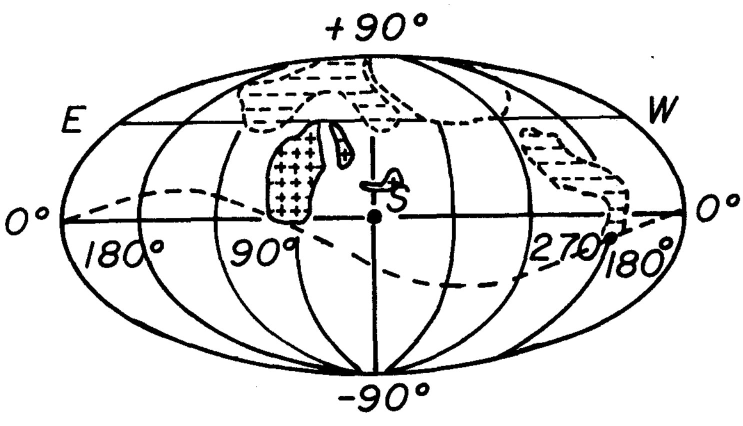

Fig. 1. Density structure of the solar wind as obtained from IPS measurements for August the 26th, 1978. (+) regions correspond to enhanced density and (−) regions to decreased density. Ecliptic coördinates were used and dotted lines indicate the boundaries set by the declination range of the radiosource survey.

From the geophysical point of view, the importance of the study of solar wind disturbances lies on the fact that these disturbances collide with the Earth very often producing effects such as geomagnetic storms and ionospheric perturbations which alter communication systems, electrical power transmission and geomagnetic surveys, and represent also possible radiation hazards to astronauts (Rust, 1982, and Lanzarotti, 1979). The forecast of such perturbations is then important to many purposes.

The most energetic disturbances in the solar wind are interplanetary shocks, accompanied by shells of increased density and followed by outflows of enhanced speed (Borrini *et al.*, 1982). It has long been thought that they are generated by major solar flares (Wolfe *et al.*, 1979; Intriligator, 1980; Cane and Stone, 1984; Cane, 1985), and more recently they were also associated with eruptive prominences (Joselyn and McIntosh, 1981).

Such associations present hard problems because some times shocks in the interplanetary medium are detected and sudden commencements of geomagnetic storms are recorded when no flare or disappearing filament is observed. Moreover, the link of an observed shock near the Earth with a solar flare previously occurring leads to very different transit speeds for the travelling shock ranging from about 400 km/s to more than 1 000 km/s (Cane and Stone, 1984). Shock velocities observed at the Earth's orbit never exceed 500 - 600 km/s so a desceleration mechanism for the shocks in the interplanetary medium must be invoked. Such a mechanism is very hard indeed to be figured out and moreover, if it really operates, the shock speed near the source must be even higher than the transit (medium) speed. Direct observations of shocks in different sites of the interplanetary medium, nearer and farther from the Sun than Earth, have shown, however, a fairly constant travelling speed for shocks (Intriligator, 1977).

Another problem with the association of shocks with flares is that there are many more flares than shocks. This leads to infer that not every single flare is able to produce a shock travelling in the solar wind plasma, but only those of certain types. Selective associations have also been tried but one-to-one association has never been obtained.

Eruptive prominences are much less frequent than solar flares but sometimes when no flare was observed and a shock reached the Earth, the disappearing of a filament was observed on the Sun several days before. A one-to-one association of eruptive prominences with shocks in the interplanetary medium is by all means impossible, but they were suggested in several particular cases as the sources of the shocks. Again, many eruptive prominences are observed without the production of an associated shock in the solar wind, but a selection of these has not been tried.

In a previous paper (Hewish and Bravo, 1986a) we report the results of the survey carried out with the radio array at Cambridge in which about 100 disturbances in the interplanetary medium were observed and tracked back to the Sun in search of their sources. The results of that survey show that the actual sources of interplanetary shocks are coronal holes of medium and low latitudes whose solar wind fluxes are not constant. From this research we were able to relate each one of the observed disturbances, including shock structures, to a coronal hole. The prediction of changes in the outflow from coronal holes is not possible at the moment, but the early observations of the disturbances generated from them, as provided by IPS observations, can help us to foresee possible effects at the Earth. In this paper we will show how good such a forecast would be, based on the observations at Cambridge for the first period.

OBSERVATIONS

From July 1978 to September 1979, 96 disturbances were detected in IPS corresponding to two different types: corotating interaction regions (CIR's) and fast radially moving shells. The former are produced by steady fast solar wind flux from holes, and the latter are the results of erupting streams from the holes (Fig. 2). Not every disturbance gave rise to a geomagnetic storm since some failed to hit the Earth or were not strong enough. 44 of the disturbances tracked with IPS were related to a sudden commencement (SC) when hitting the Earth, and they were mainly of the type of erupting streams (36 ES's', 8 CIR's). In the whole period 48 SC were registered, so only four shocks were not detected prior to its arrival at the Earth in our IPS maps, mainly because their scintillation effects overlapped those corresponding to a previous shock.

RESULTS AND DISCUSSION

For each of the shocks producing a sudden commencement (SC), the delay time (Δt) between the first IPS identification of the perturbation in the interplanetary

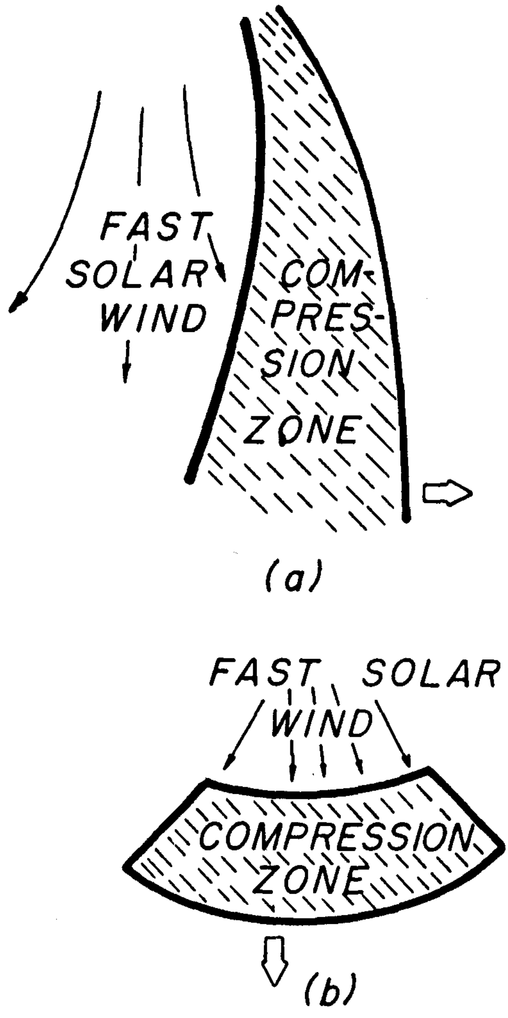

Fig. 2. The two types of disturbances observed in the interplanetary medium. *(a)* a corotating interaction region (CIR) and *(b)* a shell type compression zone.

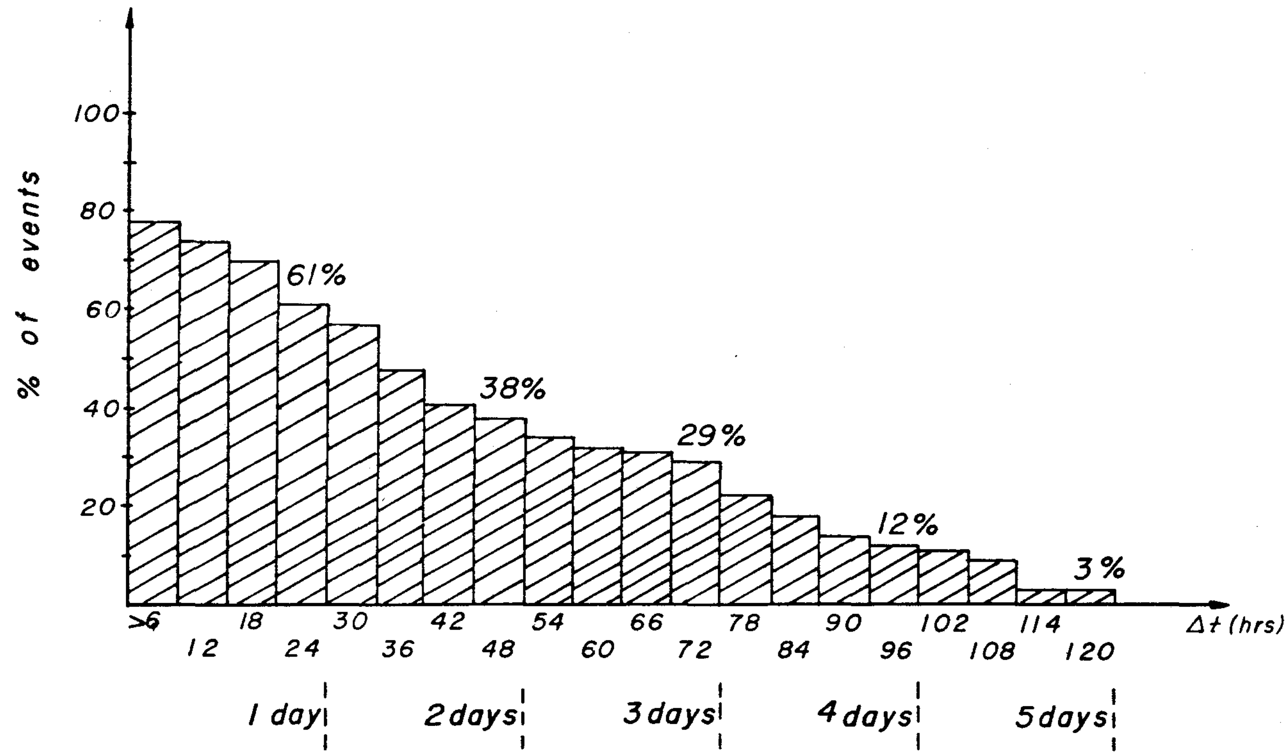

Fig. 3. Hystogram showing the percentage of events with different Δt from 6 to 120 hours. Δt is the difference between the time of arrival of the front of the perturbation at the Earth and the time of its first detection with IPS in hours.

medium and the start of the SC was registered. The results are shown in a hystogram in figure 3. As can be seen most of the perturbations were detected more than one day previous to their arrival at the Earth and even some of them were first seen four or five days in advance.

A correlation between the velocity or strength of the shock (measured as the strength in scintillation) and the intensity of the geomagnetic perturbation is not obvious. It rather seems to be that the relative orientation between the interplanetary magnetic field and the geomagnetic field is important to determine the capacity of a particular shock to perturb the magnetosphere. Such an investigation cannot be made with scintillation observations only and *in situ* magnetic measurements will be required.

Anyway, a constant IPS monitoring of the interplanetary medium covering a large grid of radiosources would be a very useful tool in the early detection of the perturbations in the solar wind responsible for geomagnetic and ionospheric disturbances as well as an efficient alarm system for possible radiation hazards to people out in space near Earth. When this kind of monitoring be operating systematically, much more knowledge about the characteristics of the shock relevant to the geomagnetic storms production will be obtained.

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