THE SOURCES OF MAJOR HELIOSPHERIC DISTURBANCES

A. Hewish
Cavendish Laboratory
Madingley Road
Cambridge
CB3 OHE

ABSTRACT. Observations of interplanetary scintillation on about 900 sources made with the 3.6 hectare array at Cambridge have been used to map, and to track, 96 heliospheric transients during August 1978 - September 1979. This sample included most of the interplanetary shocks recorded by near-Earth spacecraft in the same period.

Some corotating interaction regions were observed but the most frequent disturbances were "erupting streams" in which spherical shells of enhanced density were driven by the birth of high-speed solar wind streams which persisted for several days. Although these transients were of the type traditionally associated with solar flares or disappearing filaments they were not caused by such processes. Back-projection to the Sun indicated that the sources were always associated with coronal holes. It is concluded that the sources of the most energetic interplanetary transients are mid-latitude coronal holes which, near solar maximum, produce sporadic high-speed streams lasting several days, in contrast to the more stable flows typical of the declining phase of the solar cycle.

1. INTRODUCTION

The most energetic interplanetary transients near 1 AU are shocks followed by shells of enhanced density about 0.1-0.2 AU thick. It has long been thought that they are generated by solar flares but the occurrence of major shocks in the complete absence of flares has led to the notion that they are also related to disappearing filaments. More recently it has been shown that white light transients near the Sun are often associated with interplanetary shocks (Sheeley et al 1984) but the sources of white light transients are unclear. While 10-17% of white light transients have been associated with flares alone, and 30-34% with erupting prominences alone, the largest fraction amounting to 30-48% is unrelated to any near-surface events on the Sun (Wagner, 1984).

I wish to describe new information based on two important advances in the techniques of interplanetary scintillation. The

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first advance is the routine daily observation of several thousand sources which enables major disturbances to be located with some accuracy even when they are well outside the ecliptic. The second is the accurate calibration of scintillation against in situ spacecraft observations which has shown that scintillation provides a reliable measure of the mean plasma density along the line of sight under a wide variety of conditions including transients (Tappin, 1985).

The application of these methods to the quantitative analysis of a few typical disturbances has been described in detail (Tappin et al 1983, 1984) and the relationship of strong shocks to "erupting streams" from coronal holes has been discussed by Hewish (1985). In collaboration with S.S. Bravo Nunez a full analysis of the scintillation maps of Gapper et al (1982) has now been completed. The results strongly confirm that coronal holes are the cause of most interplanetary transients.

2 THE OBSERVATIONS

The sky survey was carried out at 81.5 MHz during August 1978 - September 1979 using the Cambridge 3.6 hectare array. About 900 sources were used in constructing daily maps of the disturbances (Gapper et al, 1982). 96 disturbances, most of which could be tracked for several days, were identified. Disturbances were recorded only for scintillation enhancements $g \geqslant 1.25$ corresponding to an increase of density by a factor $\geqslant 1.5$. 73 erupting streams occurred, and in 34 cases the outer boundary of the shell of enhanced density was accompanied by a shock at 1 AU. 23 of the distrubances were classified as CIRs although a clear distinction could not always be made and even the most long-lived high-speed stream exhibited considerable variability.

The angular spread of the erupting streams was estimated by two independent methods to be 90°-100°. Back-projection to the Sun, allowing for errors in the transit-time and in the estimated direction relative to the Sun-Earth line, could be made to an accuracy of about ±25°. The locations of the sources are shown in synoptic charts in Fig 1. A very strong association was found with coronal holes. A histogram of the angular differences between the centres of the back-projected sources and the associated coronal holes is shown in Fig 2. The significance of the alignments was estimated by making the same analysis when our source positions were displaced in longitude by +90° and -90°. Chance associations occur with much lower probability as illustrated in Fig 2.

In contrast to the strong association with coronal holes we found only weak associations with flares and disappearing filaments. These were 20 possible flare associations and 17 possible associations with disappearing filaments, 4 of which were in common. Some "confident" flare associations previously made by others were inconsistent with our new observations (eg Hewish, 1985). We also found that 10 disturbances occurred with no flare or disappearing filament anywhere on the disk within a suitable time interval.

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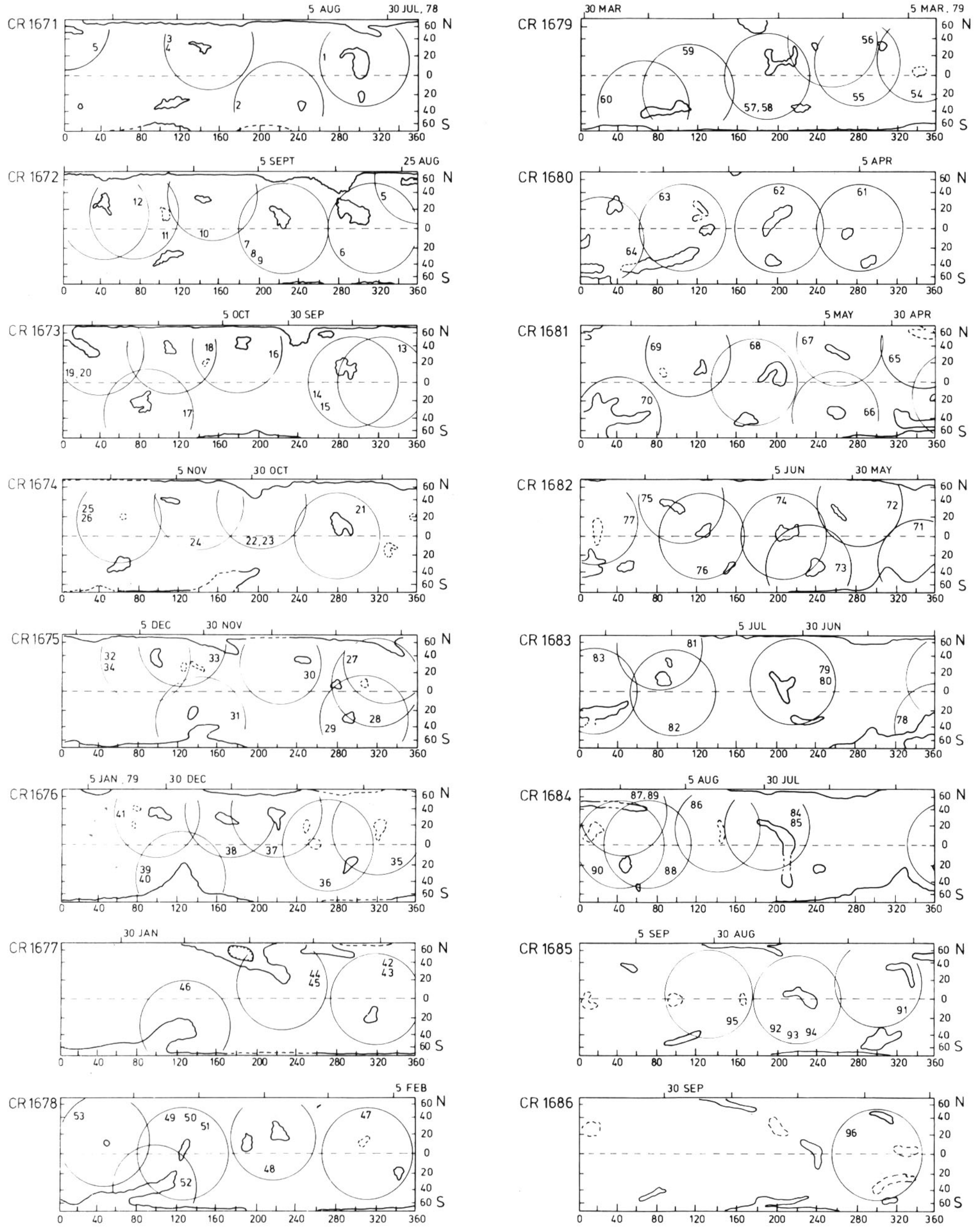

Fig 1 Synoptic maps showing the back-projected sources (circles) of 96 disturbances observed by scintillation during August 1978 - September 1979. Also shown are the boundaries of coronal holes obtained from Kitt Peak HeI 10,830 A° images.

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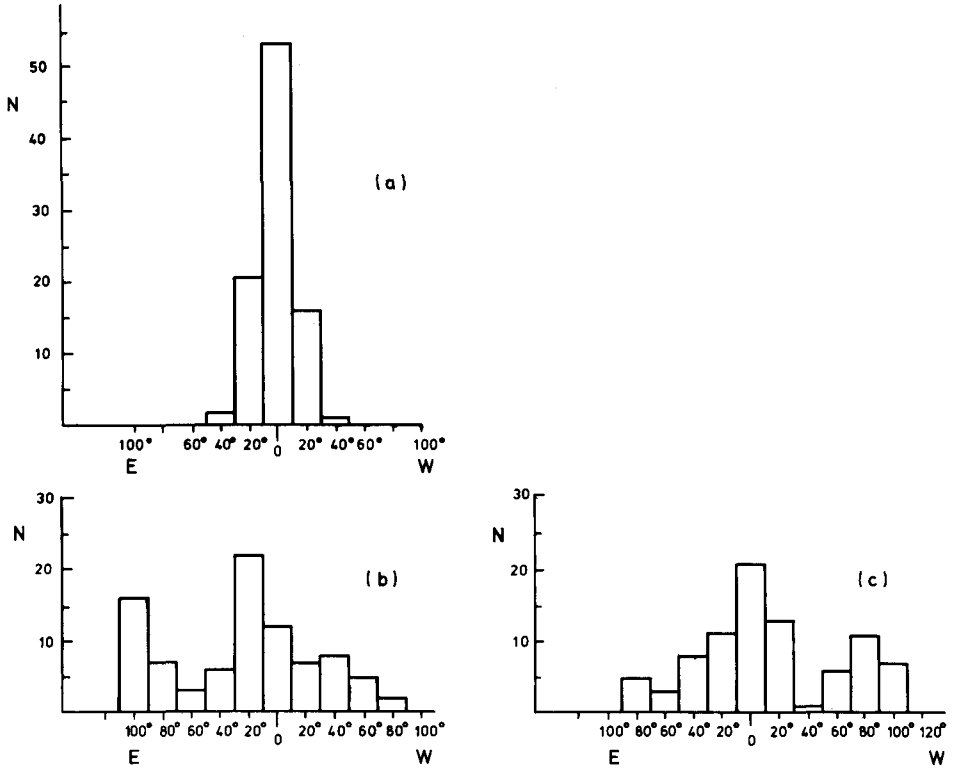

Fig 2 (a) Histogram of angular differences between the centres of the estimated source locations and associated coronal holes.

(b) and (c) The same as in (a) but with the source locations displaced in longitude by +90° and -90°.

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3 CONCLUSION

The main conclusions arising from the mapping of heliospheric transients during 1978-79 are that energetic, shock-associated disturbances take the form of shells of enhanced density 0.1-0.2 AU in thickness driven by the eruption of plasma flows similar to normal high-speed streams, but of shorter duration. The sources of these disturbances are mid-latitude coronal holes. It is possible that a small fraction of the major disturbances are associated with flares and disappearing filaments, but such activity is peripheral to the erupting streams. The association of white light transients with interplanetary shocks suggests that the former are manifestations of erupting streams much nearer the Sun.

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