SOLAR ACTIVITY DEPENDENCE OF INTERPLANETARY DISTURBANCES

P.K. MANOHARAN
Radio Astronomy Centre (TIFR), P.O. Box - 8, Ooty - 643001, India.

May 19, 1995

Abstract. Interplanetary scintillation measurements obtained inside 200 $R_\odot$ using the Ooty Radio Telescope during August 1986 – April 1991 have been analysed to study the interplanetary disturbances (or events) and their occurrence rates at various phases of the solar cycle. The disturbances are identified by the increase in the level of scintillation compared with the expected value. In total, 735 events have been identified. The results show a rate of 0.49 events per day near solar maximum and a low rate of 0.16 events per day during minimum of activity. The results are compared with coronal mass ejection (CME) rates and transients rates obtained from the Doppler scintillation measurements.

1. Introduction

Study of interplanetary disturbances and their associations with solar events is of great importance in the field of solar physics. In general, interplanetary disturbances are identified by the increase in turbulence level and/or velocity compared with the background solar wind. Interplanetary scintillation (IPS) measurements using compact radio sources (such as quasars) constitute a powerful tool for identifying and studying such disturbances in the inner heliosphere ($\leq$ 200 $R_\odot$) at various heliographic latitudes (e.g., Manoharan *et al.*, 1995). Here, we report the study of large number of interplanetary disturbances obtained from the IPS measurements made using the Ooty Radio Telescope (ORT) between August 1986 and April 1991. [The ORT operates at 327 MHz (cf., Swarup *et al.*, 1971).]

2. Identification of Interplanetary Events

The interplanetary scintillation (IPS) is evidently governed by the density fluctuations and velocity of the solar wind plasma along the line of sight to the radio source. The measured scintillation index, m(=*r.m.s. intensity fluctuation/mean source intensity*), of a radio source at a given heliocentric distance is corrected for a R^{-2} fall-off in density fluctuations with radial distance and normalized with the statistical average of the same source to compensate for the reduction in scintillation caused by the diameter of the radio source (Manoharan *el al.*, 1995). The above normalized scintillation index (called g-value) of an individual source on any given location in space

Astrophysics and Space Science **243**: 221-224, 1996.

https://doi.org/10.1017/S0252921100030220 Published online by Cambridge University Press

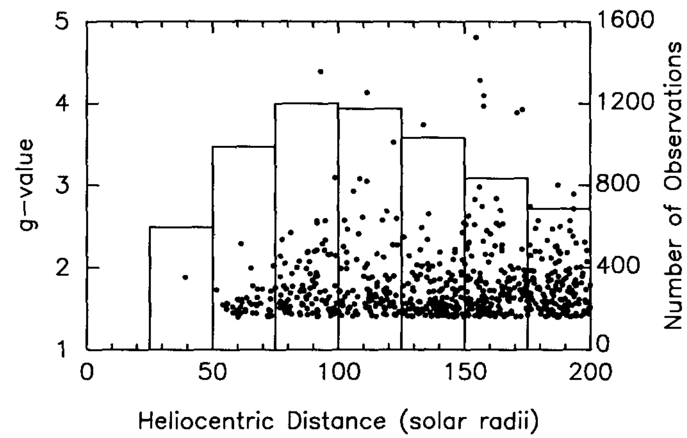

Fig. 1. Distribution of all the 7000 observations over the heliocentric distance. The measured g-values at various distances are shown as dots.

may be used to indicate enhancement ($g > 1$) or depletion ($g < 1$) of density fluctuations over the expected average value ($g \approx 1$).

The Ooty IPS data have been used to identify "*interplanetary events*" or "*scintillation enhancements*" at various radial distances from the Sun. These enhancements are selected by the criterion that the observed g-value is greater than the mean by more than 40%. In total, 735 interplanetary events are identified out of ~7000 IPS measurements made during the period of study. Although, there is a gap in the data between January and May 1987, the size of the data set is considerably large and nearly uniformly distributed in the inner heliosphere.

3. Results and Discussion

Figure 1 shows the distribution of observations and measured g-values over the heliocentric distances of the closest approach point of the radio signal path. The present analysis indicates that the interplanetary events are observed at all distances (50 – 200 $R_{\odot}$), considered under the study. However, chances of seeing an event is high at larger distance from the Sun. Figure 2 displays the histogram of events percentage (percentage of ratio between number of events observed in a distance range and total number of events) observed at various distance range bins. This distribution is broad and most of the events (~70%) are observed at distances greater than 120 $R_{\odot}$.

The above distribution (Figure 2) does not change significantly with the solar cycle activity. However, the rate at which interplanetary events are observed (number of events per day) exhibits variation with the phase of

https://doi.org/10.1017/S0252921100030220 Published online by Cambridge University Press

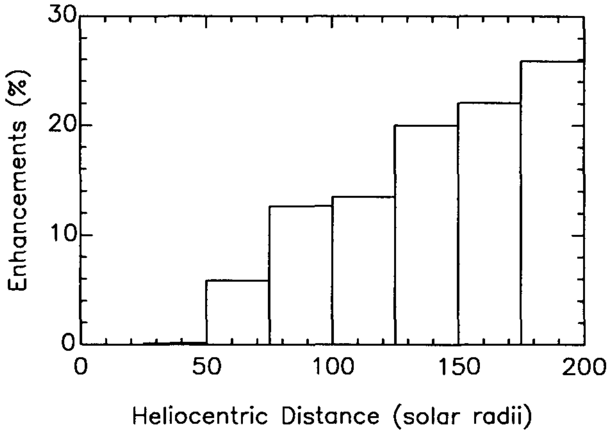

Fig. 2. Distribution of events percentage as a function of heliocentric distance.

the solar cycle. Figure 3 shows the comparison between sunspot numbers and event occurrence rates. Thus, a high rate of 0.49 is observed in 1990 and a low of 0.16 in 1986 and events rate closely follows the sunspot activity. A factor of three variation in the event rates between the solar minimum and maximum is in agreement with the Doppler scintillation measurements of transients during 1979 – 1987 (Woo, 1993). However, for a study of events rate corresponding to the full solar disk, the following facts are to be considered. That is, these Doppler scintillation measurements of Pioneer Venus Orbiter have been (1) confined to the ecliptic plane, (2) made at one of the limbs (east or west limb of the Sun) direction of the solar wind, and (3) obtained inside 100 $R_\odot$. Further, the IPS measurements have been made for about 6 hours in a day and a multiplication factor of four to be taken into account.

Woo (1993) also shows that the transient rates obtained inside 100 $R_\odot$ are in agreement with the full disk coronal mass ejection (CME) rates (Webb, 1991). The present analysis indicates that the event rate is smaller (nearly 25%) than the CME rate during solar maximum and higher (nearly 25%) for the minimum activity period. It is likely that our criterion for selecting the disturbances ($g \geq 1.4$) may be at a higher level, causing less number of identification. The other possibility is that all the CMEs do not produce interplanetary events. The increased rate of events during the minimum period may be due to the fact that at larger distances from the Sun (> 120 $R_\odot$) corotating interaction regions (CIR) are also causing interplanetary disturbances. The present data also indicate that most of the interplanetary events are observed near the ecliptic (within $\pm$ 30° latitudes) during the solar minimum period and with increasing activity, the events are observed at higher heliographic latitudes. This result is consistent with the latitudinal

https://doi.org/10.1017/S0252921100030220 Published online by Cambridge University Press

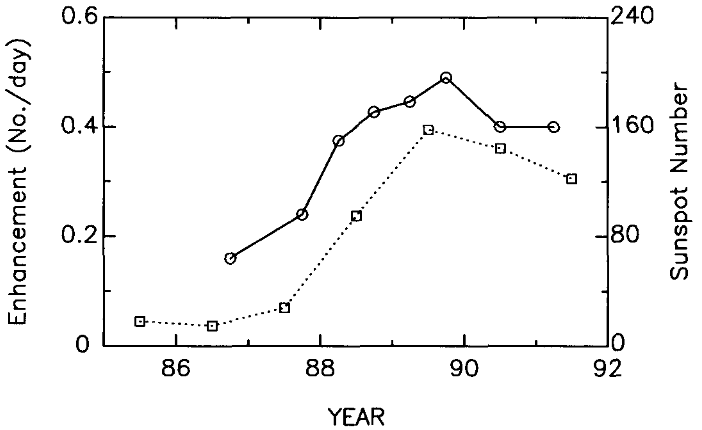

Fig. 3. Comparison of interplanetary event rates (*circles*) with solar activity indicated by sunspot numbers (*squares*).

distribution of CMEs over many years (Hundhausen, 1993). A more detail paper is in preparation.

4. Summary

By examining the level of scintillation, interplanetary disturbances have been detected in the distance range 50 – 200 $R_\odot$ during August 1986 – April 1991. The study shows that the rate of disturbance occurrence increases with solar activity. The results are in agreement with the Doppler scintillation measurements and consistent with the CME rate variations with the solar cycle. The present study also indicates that during solar minimum considerable number of disturbances are caused by the corotating interaction regions (CIR).

References

Hundhausen, A.J.: 1993, *J. Geophys. Res.* **98**, 13177.
Manoharan, P.K., Ananthakrishnan, S., Dryer, M., Detman, T.R., Leinbach, H., Kojima, M., Watanabe, T. and Kahn, J.: 1995, *Solar Phys.* **156**, 377.
Swarup, G., Sarma, N.V.G., Joshi, M.N., Kapahi, V.K., Bagri, D.S., Damle, S.H., Ananthakrishnan, S., Balasubramanian, V., Bhave, S.S., and Sinha, R.P.: 1971, *Nature Phys. Sci.* , **230**, 185.
Webb, D.F.: 1991, *Adv. Space Res.* **11(1)**, 37.
Woo, R.: 1993, *J. Geophys. Res.* **98**, 18999.