REAL TIME PREDICTION AND OBSERVATION OF INTERPLANETARY EVENTS

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Abstract

We describe interplanetary-scintillation observations associated with solar events on 7 and 8 May 1992. The unique feature of these observations was that, for the first time, scintillation enhancements were predicted in real time by observing solar events on these dates and then detected at Ooty and Cambridge observatories. Good consistency between the all-sky images (g-maps) from both observatories were found. Ooty's high resolution ($\sim$ 100 sources sr^{-1}) solar wind velocity maps, obtained for the first time, support a simple physical model based on two dimensional MHD, time dependent, propagating shock structures.

1. Introduction

The Ooty Radio Telescope (Swarup *et al.* 1974), operating at 327 MHz was used during April – May 1992 in a coordinated campaign with the Cambridge interplanetary scintillation (IPS) array at 81.5 MHz and, also, with the Solar-Terrestrial Environment Laboratory, Nagoya University, three-station observatory. The Ooty observations, together with Cambridge data, will be discussed in this report for two interplanetary events observed in May 1992. The single-station method for estimating the velocity of the solar wind (Manoharan & Ananthakrishnan, 1990) provided the first opportunity to obtain all-sky velocity coverage of the interplanetary medium with good spatial coverage by a large number of sources ($\sim$ 100 sources sr^{-1}).

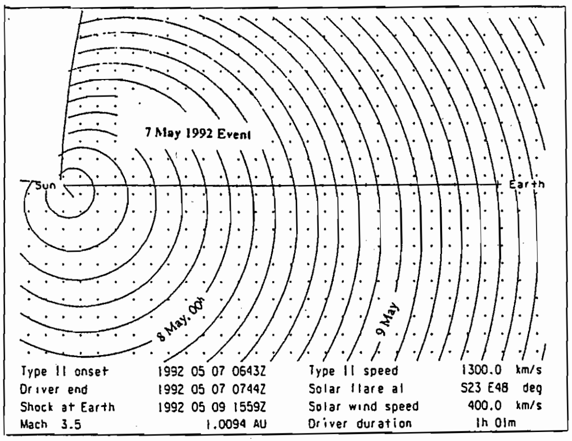
2. Observation and Data Reduction

The Cambridge array observes about 900 sources in 24 hours and routinely produces daily all-sky g-maps (*e.g.* Gapper *et al.* 1982). (The definition of g is the observed level of scintillation divided by its statistically expected value.) During the campaign period, the Ooty telescope was used to make daily observations of about 150 scintillating sources in the eastern elongation range of 10° – 65° and covering a declination range of ±45°. Each scintillating source is observed at Ooty for 3 – 5 minutes and intensity fluctuations are analyzed to give the temporal power spectrum. The solar-wind velocity estimates are obtained by fitting theoretical models to the temporal power spectrum (Manoharan & Ananthakrishnan, 1990). Further, the square root of the area under the power spectrum gives the scintillating rms, δS, which is a measure of scintillation. To compare Ooty results with the Cambridge g-values, the δS measurements are converted to g-values as follows: (a) the elongation (ϵ) dependence is removed by normalizing the observed δS, using the point source (PKS 1148-001) scintillation index at the same elongation; (b) the statistical average of δS is used to obtain the g-values.

3. Solar Events and Prediction of Shock Trajectories

At Ooty a predictive mode was used when the NOAA Space Environment Center (SESC) at Boulder was able to observe any large solar event in real time. In such a case, special attention was paid to the coverage of the specific part of the sky where a traveling interplanetary disturbance was predicted to increase the level of turbulence in the solar wind. When predictions are not there, routine observations of nearly 150 sources are made in the eastern region of the Sun.

On May 7, 1992, immediately after SESC observed a 2-ribbon flare with associated eruptive filament (2F/C3 from NOAA Region 7154 at S23°E48°) and type II shock at 0643 UT, the operational Shock Time of Arrival (STOA) simplified model (Dryer and Smart, 1984; Smart et al., 1986) was used to make a rough global estimate of the large-scale shock propagation. This model used an initial shock speed in the corona, 1300 kms^{-1}, estimated by the U.S. Air Force's Radio Solar Telescope Network observatories at San Vito, Italy. The estimate of the large scale shock propagation, shown in Fig. 1, was sent to Ooty via facsimile transmission. On the following day (May 8, 1992) another flare (4B/M7), maximizing at 1546 UT from NOAA Region 7154 at S26°E10°, took place. The STOA model was used again, assuming an initial shock velocity, 2000 kms^{-1}.



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Type II onset        1992 05 07 0643Z    Type II speed        1300.0  km/s
Driver end           1992 05 07 0744Z    Solar flare al       S23 E48  deg
Shock at Earth       1992 05 09 1559Z    Solar wind speed      400.0  km/s
Mach  3.5                   1.0094 AU    Driver duration        1h 01m
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Fig. 1. Kinematic (STOA) shock propagation model for 7 May 1992 solar event. The shock trajectory is shown in the plane that includes the solar flare (S23°E48°), the Earth, and the Sun-Earth axis. The shock is assumed to be "piston-driven" initially centered in the direction indicated by the tick mark. The length of the tick mark indicates the distance traveled by the shock at type II velocity for the duration of this piston-driven phase as suggested by GOES soft x-ray duration. Thereafter, the shock decelerates as $R^{-\frac{1}{2}}$ in the pre-shock solar wind.

4. Results and Discussion

On 7 May 1992, prior to the arrival of the shock disturbance, the g-values ranged from $0.6 < g < 1.6$. This situation changed drastically on 8 May 1992, within the elongations of $30° < \epsilon < 40°$, where g increased to values as high as 3.8 (Fig. 2a). In the Cambridge plot (Fig. 2b), enhanced IPS is seen, albeit not with higher time resolution available at Ooty due to the telescope steerability. It should also be noted that the solar events originated from the southern hemisphere of the Sun and are more easily seen in Ooty than in Cambridge. It is seen that there is good consistency between the two sets of observations. The significant increases on 8 and 9 May 1992, particularly in the Ooty g-values occurred in correspondence with the STOA predictions after the 7 and 8 May 1992 solar events. Fig. 3 shows Ooty synoptic g-maps on the source surface for 7 – 10 May 1992. The g-values have been tracked back to the Sun using the velocities obtained from the temporal power spectra (*e.g* Manoharan & Ananthakrishnan 1990). The positions of the enhanced-scintillation regions nicely agree with that of the flare sites.

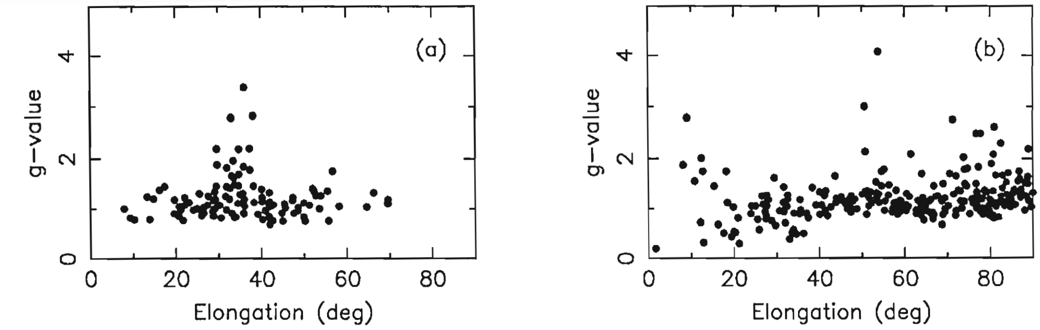

Fig. 2. Example plots of Ooty (a) and Cambridge (b) g-values as a function of eastern elongations on 8 May 1992.

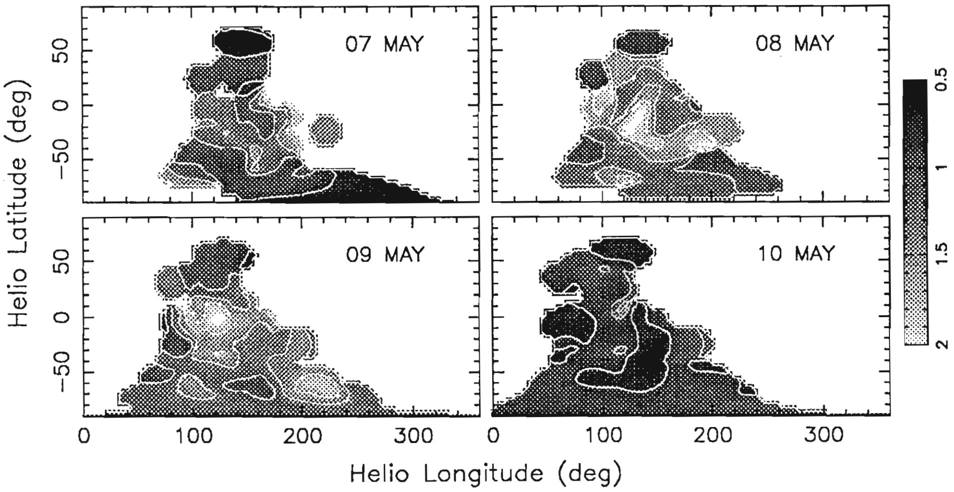

Fig. 3. Ooty synoptic g-maps for 7 – 10 May 1992. Note the large increase in g-values on 8 and 9 May, at longitude 120° and latitude −10°. These enhancements correspond to solar events on 7 and 8 May, respectively.

The Ooty velocity plots show comparatively quiet velocities on May 7 and 8 , but show significant increases on May 9 and values quieting down on May 10 (Fig. 4). The velocity measurements on 8 May suggest that the high velocities (>500 $\mathrm{km s^{-1}}$) produced by the first shock probably passed the $\epsilon \sim 45°$ line of sight within 1000 to 1300 UT on 8 May. This temporal window compares favorably with the prediction of shock position (Fig. 1).

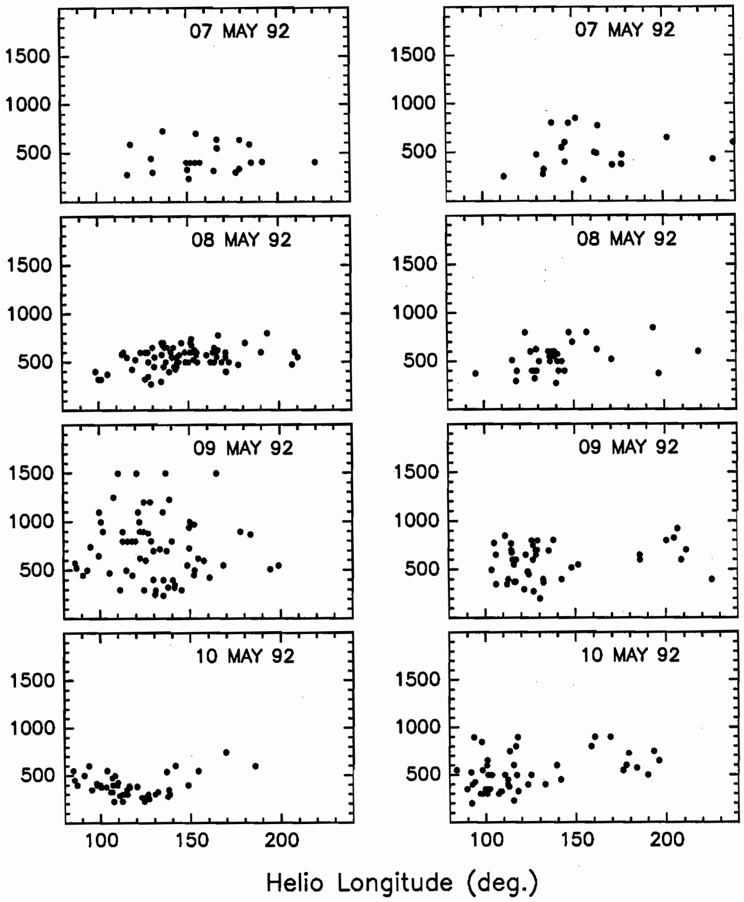

Fig. 4. Ooty velocity plots as a function of helio-longitude. Left Column – velocities for helio-latitudes -45° to 0°; Right Column – all other helio-latitudes (excluding -45° – 0°).

It is also possible to make an estimate of the second shock's local velocity by using the velocity data on 8 and 9 May 1992 at $\epsilon \sim 25°$ (0.4 AU). Choosing the 8 May observation of 600 kms^{-1}, as 'pre-shock' velocity, V_1, and the 9 May observation of 1500 kms^{-1} as the 'post-shock' velocity, V_2, assuming corresponding density values as N_1=80cm^{-3} and N_2=300cm^{-3}, one finds (from mass conservation) the shock velocity in the inertial frame to be about 1800 kms^{-1}. This velocity is consistent, taking a small deceleration into account, with the initial assumed velocity, 2000 kms^{-1}. Thus, these observations support a simple model (2-D MHD, time-dependent model) used for predicting the shock trajectory.

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