CMEs and Interplanetary Type II Radio Bursts

Takashi Watanabe
STELAB, Nagoya Univ
and
Denise Lengyel-Frey
GSFC/NASA

after about 25 minutes (see figure 1 for clarification). The intense low frequency outburst has been called a shock accelerated (SA) event (Cane et al., 1981). Type II bursts observed by ISEE-3 (which we call IP type II bursts) are preceeded by SA events. Since the SA event at 2 MHz begins within a minute or so of the type II burst observed at about 20 MHz, associations between ground and ISEE-3 type II events can be made unambiguously despite the lack of coverage in the regime between about 20 MHz and 2 MHz.

Figure 1 shows ISEE-3 intensities on a logarithmic scale and it is clear that the type II emission is much weaker than the SA event. The 2 and 1 MHz type II emission appears to be very weak but this is only because it is competing with the intense background emission from our Galaxy. We have detected type II emission at 2 and 1 MHz in only about 50% of the IP type II events. At lower frequencies the Galaxy decreases in intensity and the type II bursts are more easily discerned - provided other solar activity is at a minimum.

The characteristics of a type II burst at lower frequencies are shown in Figure 2. In the figure we show intensities as a function of time for eight frequencies for an event on May 16, 1981 and in this figure we use a linear

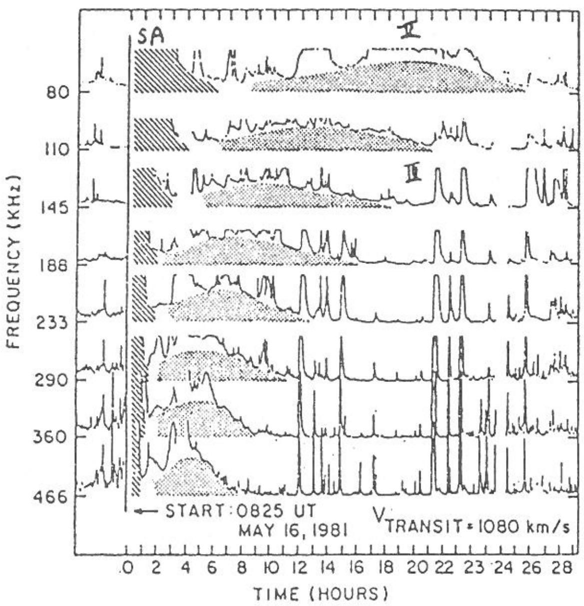
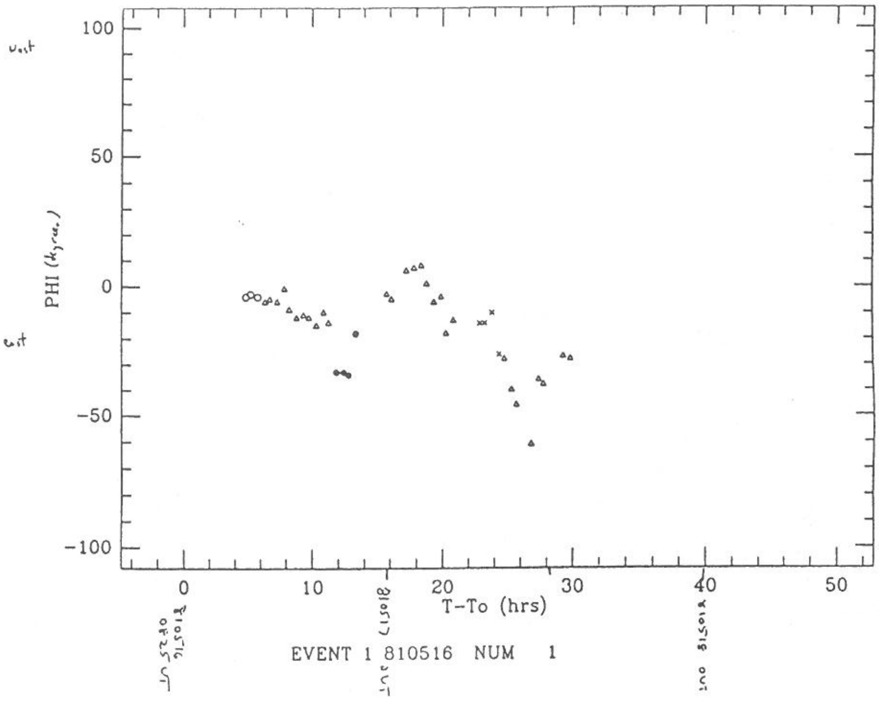
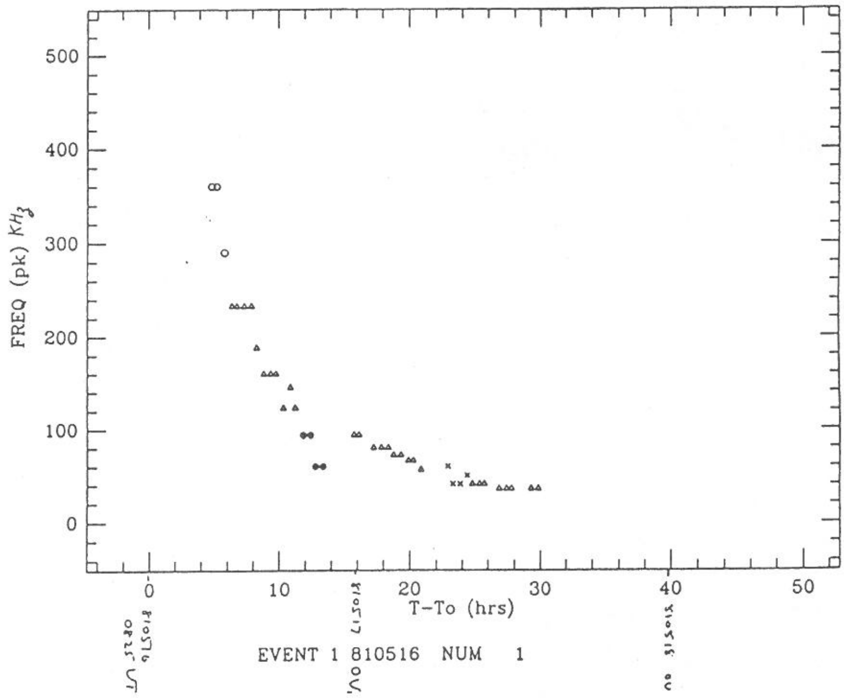


Fig. 2. Intensity versus time profiles for eight of the ISEE-3 observing frequencies. The type II emission is indicated by the stippling and the SA event by hatching.

scale. The strong type III bursts (flat-topped intensifications seen on all frequencies essentially simultaneously) have been chopped above a certain intensity to enhance the much weaker type II emission. The SA event is



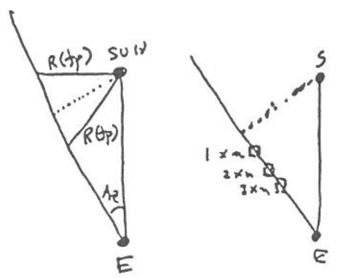


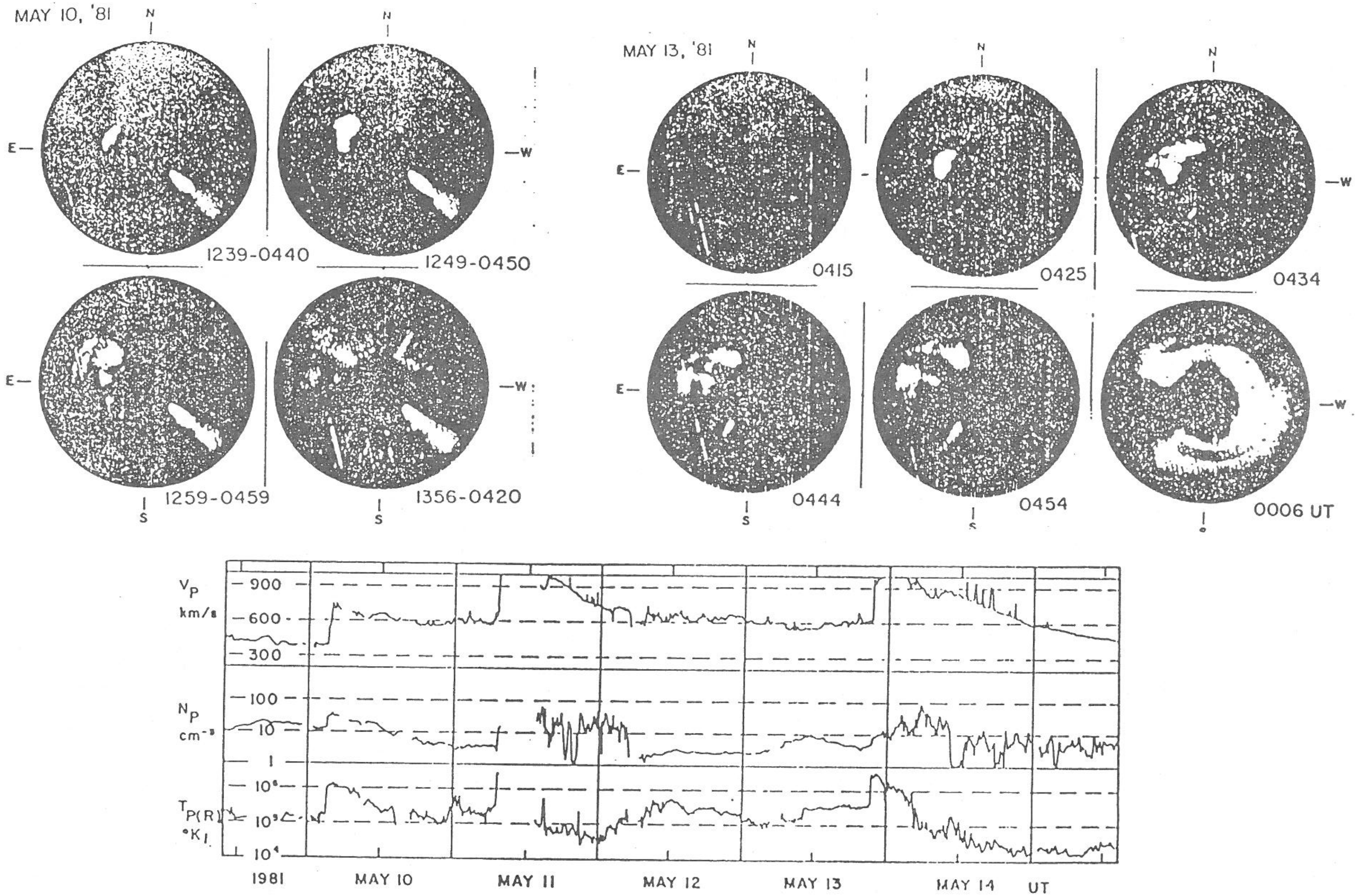
Solar Wind Density Model (BKS)

$n(R) = 6.14\, R^{-2.10}$ cm^{-3}

$f_p(R) = 22.3\, R^{-1.05}$ KHz

$R(f_p) = 19.2\, f_p^{-0.952}$ AU

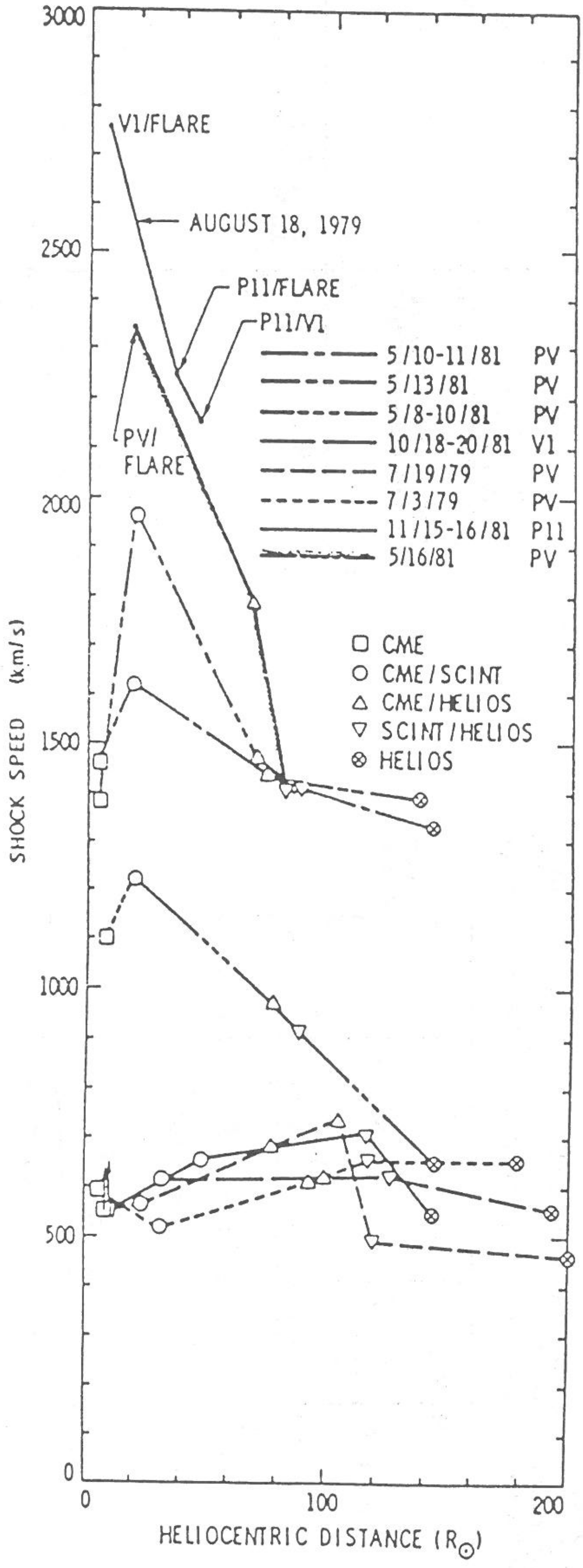




HELIOS 1 PLASMA DATA 0.66 AU E95°

Figure 3 Homologous, 1500 km/sec mass ejections on May 10 and May 13, 1981, and their associated shocks at HELIOS 1 on May 11 and 13. (The May 10 shock was associated with an earlier CME on May 8.)

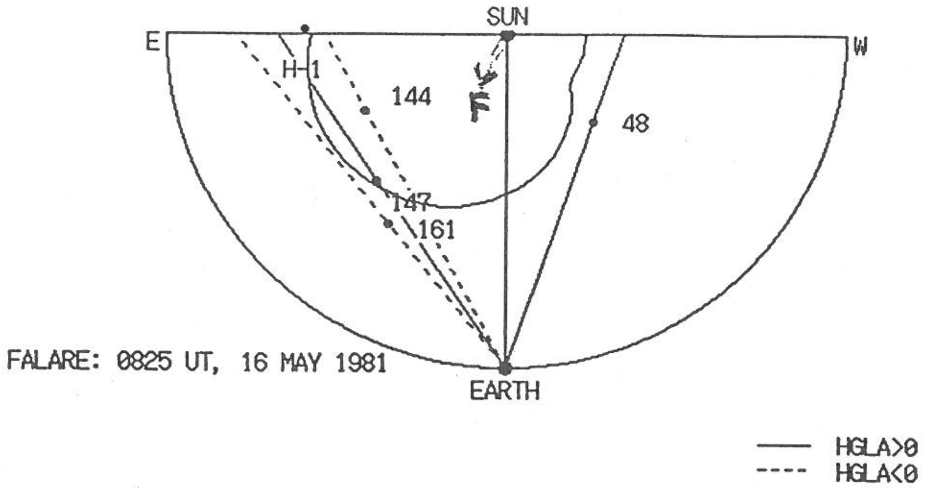
Sheeley, N.R. et al, Solar Wind Five, 693, 1983.

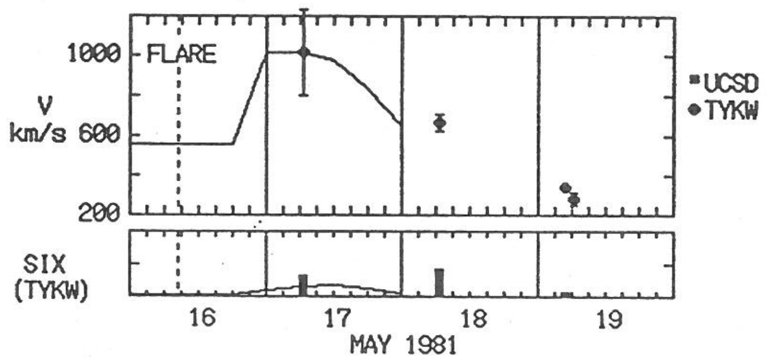


mogeneous solar wind. If, however, the interplanetary medium is highly structured in its bulk parameters (inhomogeneous solar wind) and/or if large-scale "discontinuities", e.g., those being associated with solar wind slow-speed and high-speed interaction regions, are embedded over a heliographic-longitudinal range of about $\pm(40°-60°)$ with respect to the disturbance, then the shock waves are found to be "decelerated" in the sense of *Chao and Lepping* [1974]. In turn, this result indicates that one may actually use the locally determined shock velocity V_s as a "mapping-back" quantity to correlate the observed interplanetary disturbance with its "region of origin" on the sun in at least those cases, where the solar wind is homogeneous in azimuth roughly over the range of corotation. Second, for these events one can compare either the actually observed expansion velocities V_{CME} of the CMEs at $\leq 6\ R_S$ with with their transit velocities $\langle V_{SH} \rangle$ and/or their shock speeds V_s determined by Helios at ≥ 0.3 AU (see Table 2 of *Sheeley et al.* [1983]), or their velocities V_{CME} and V_s together with their velocities V_{RS} determined by spacecraft radio scintillation measurements at $\leq 40\ R_S$, as has been done in Figure 3 [from *Woo et al.*, 1984]. The general result of these comparisons is the following one. Shock waves which start near the sun with velocities much less than 10^3 km s^{-1} are, on the average, not decelerated within 1 AU; quite to the contrary, many of them are even slightly accelerated. This has also been found by *Cane* [1983] using the drift rates of type II radio bursts propagating through the solar wind. Shock waves, however, with initial velocities much greater than 10^3 km s^{-1} are strongly decelerated before their in situ detection by the Helios spaceprobe somewhere between 0.5 and 1 AU. Moreover, for these events one finds that $V_{CME} \ll V_{RS}$. This result indicates either that in strong mass ejection events the associated shock waves decouple from their transients already rather close to the sun and then propagate very much faster out into interplanetary space, and/or that the coronal transients themselves are accelerated over the first solar radii. Although the former explanation seems rather attractive, it has been shown by *Schwenn* [1983a] (see Figure 4) from direct white light observations of propagating CMEs and by *Ivanov and Hurshiladze* [1984] on the basis of theoretical studies that the latter effect can actually occur.

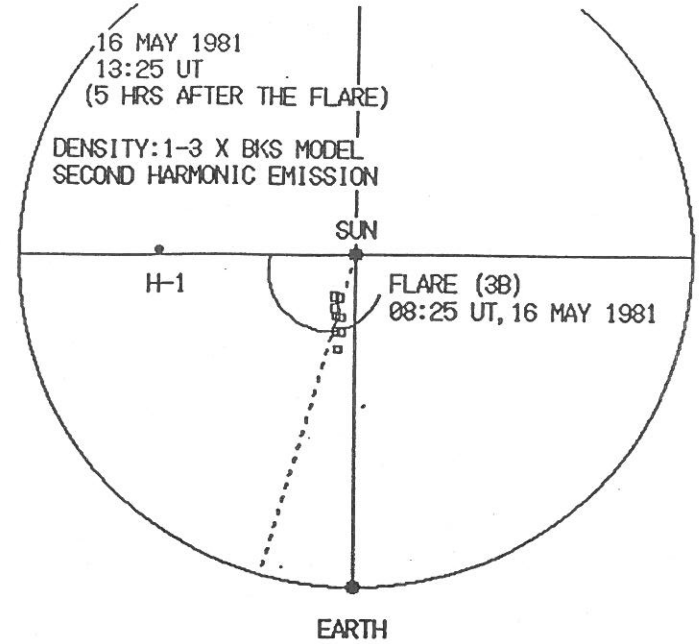
As already indicated by the results depicted in Figure 2, any study dealing with the interplanetary propagation of shock waves and with the problem of an interplanetary deceleration or nondeceleration of these disturbances will remain incomplete and may even lead to wrong conclusions, if at least the actual longitudinally inhomogeneous structure of the background solar wind is

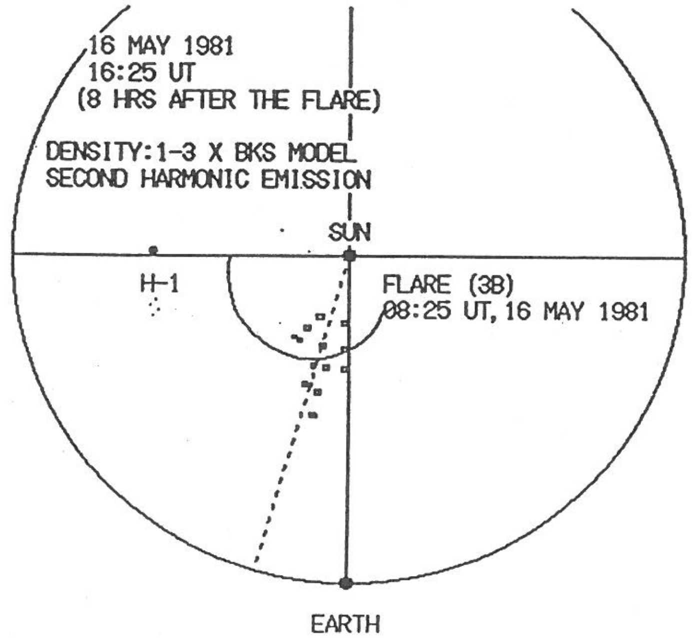
Fig. 3. Radial distribution of shock velocities of several interplanetary shock waves as determined from white light coronal (CME), spacecraft radio scintillation (SCINT) and Helios in situ solar wind observations. For the scintillation measurements the space probes used are Pioneer Venus (PV), Voyager 1 (V1), Pioneer 11 (P11) [from *Woo et al.*, 1984].

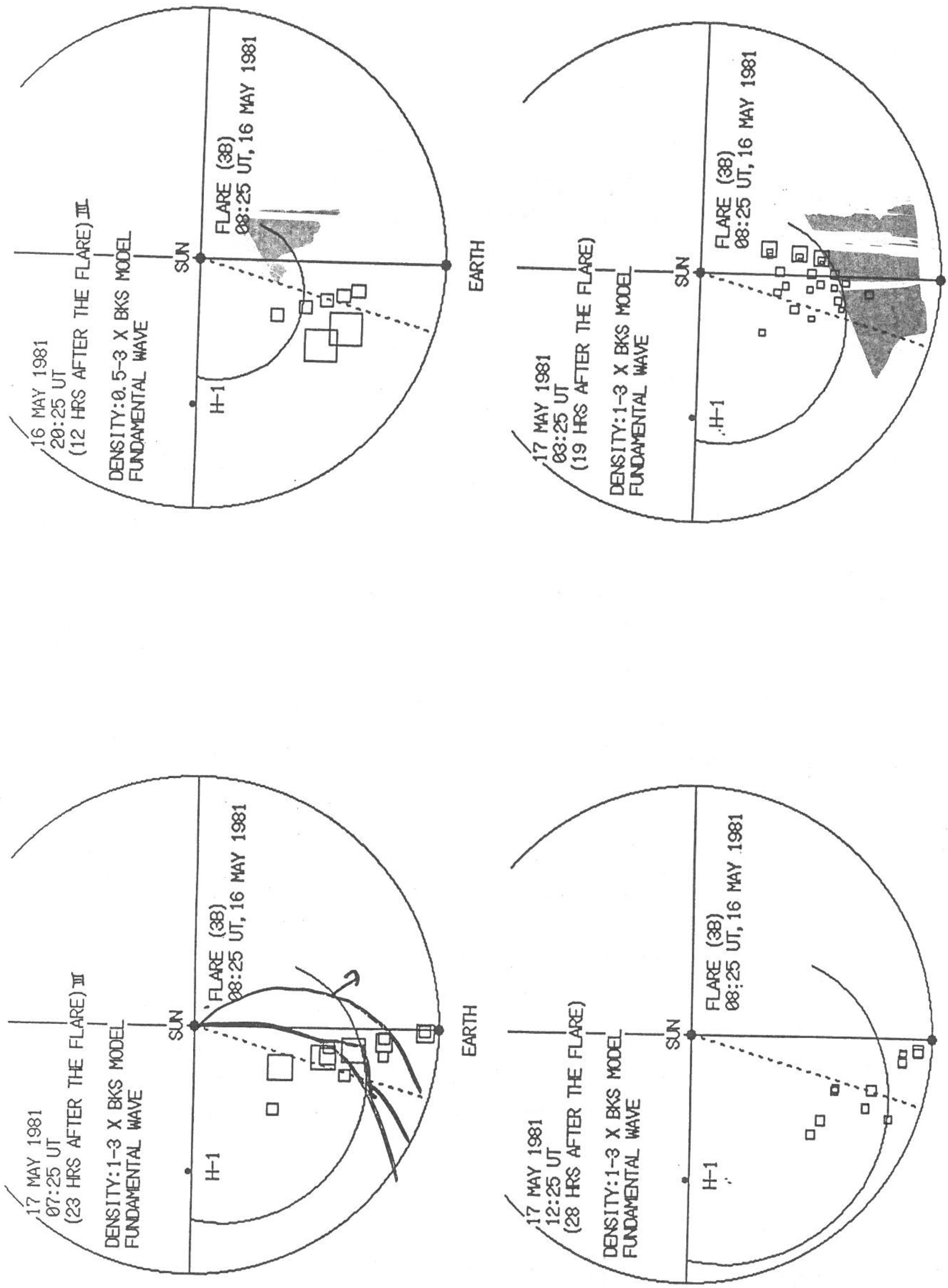




$$V_{shock} = \underbrace{2000}_{\cos[0.8(L+60)] * \cos[0.5(B-15)]} R^{-0.5} + 600 \quad km/s$$






16 MAY 1981
20:25 UT
(12 HRS AFTER THE FLARE) III
DENSITY:0.5-3 X BKS MODEL
FUNDAMENTAL WAVE
SUN
FLARE (3B)
08:25 UT, 16 MAY 1981
H-1
EARTH
17 MAY 1981
03:25 UT
(19 HRS AFTER THE FLARE)
DENSITY:1-3 X BKS MODEL
FUNDAMENTAL WAVE
SUN
FLARE (3B)
08:25 UT, 16 MAY 1981
H-1
EARTH
17 MAY 1981
07:25 UT
(23 HRS AFTER THE FLARE) III
DENSITY:1-3 X BKS MODEL
FUNDAMENTAL WAVE
SUN
FLARE (3B)
08:25 UT, 16 MAY 1981
H-1
EARTH
17 MAY 1981
12:25 UT
(28 HRS AFTER THE FLARE)
DENSITY:1-3 X BKS MODEL
FUNDAMENTAL WAVE
SUN
FLARE (3B)
08:25 UT, 16 MAY 1981
H-1
EARTH