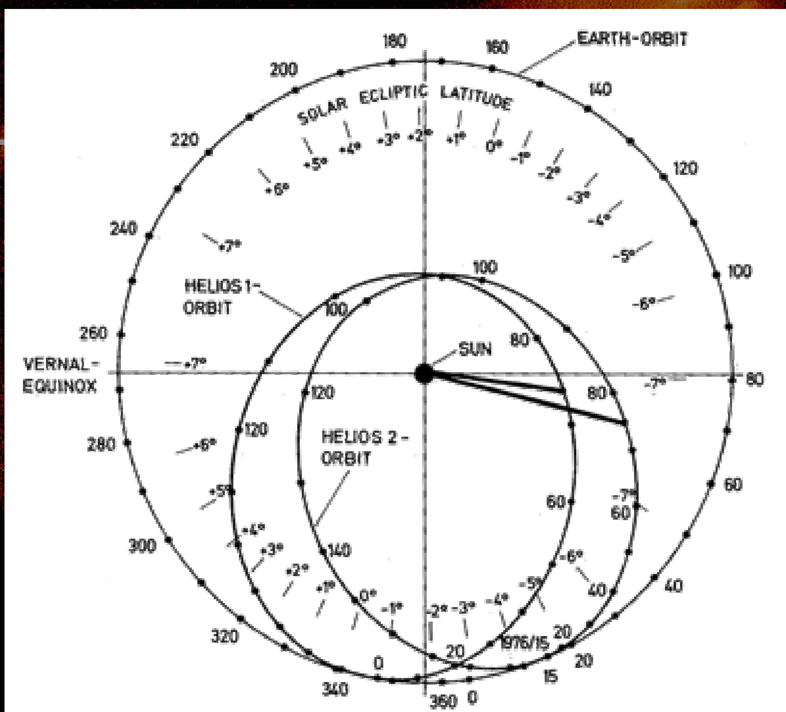
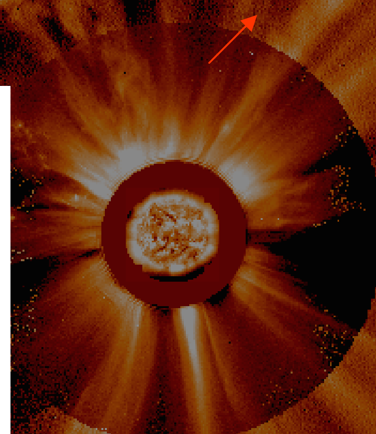
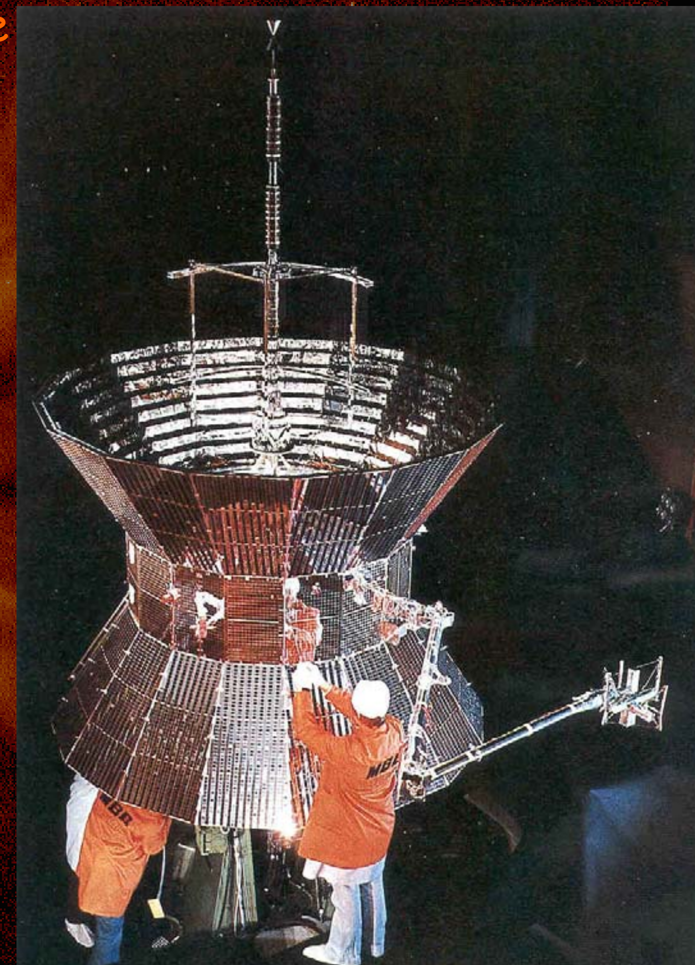
Preparing for STEREO – revisit Helios

Presented at the AGU Fall Meeting 2004
Rainer Schwenn, MPS Lindau
schwenn@linmpi.mpg.de

Topics today:
- Corotating structures,
- CMEs, ICMEs, shocks,
- Solar energetic particles

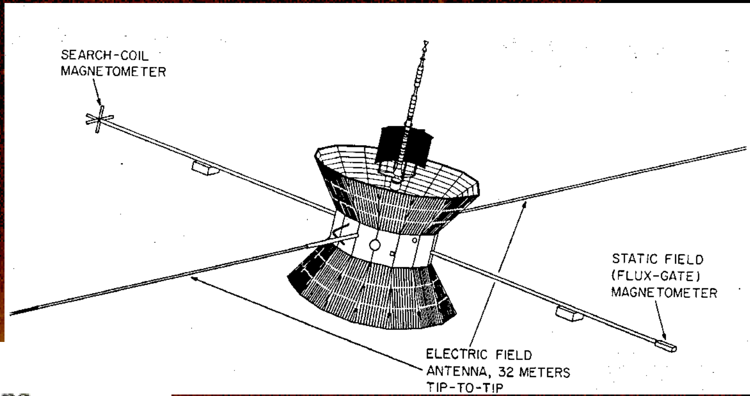






The Helios 1&2 twin solar probes approached the Sun to 0.29 AU

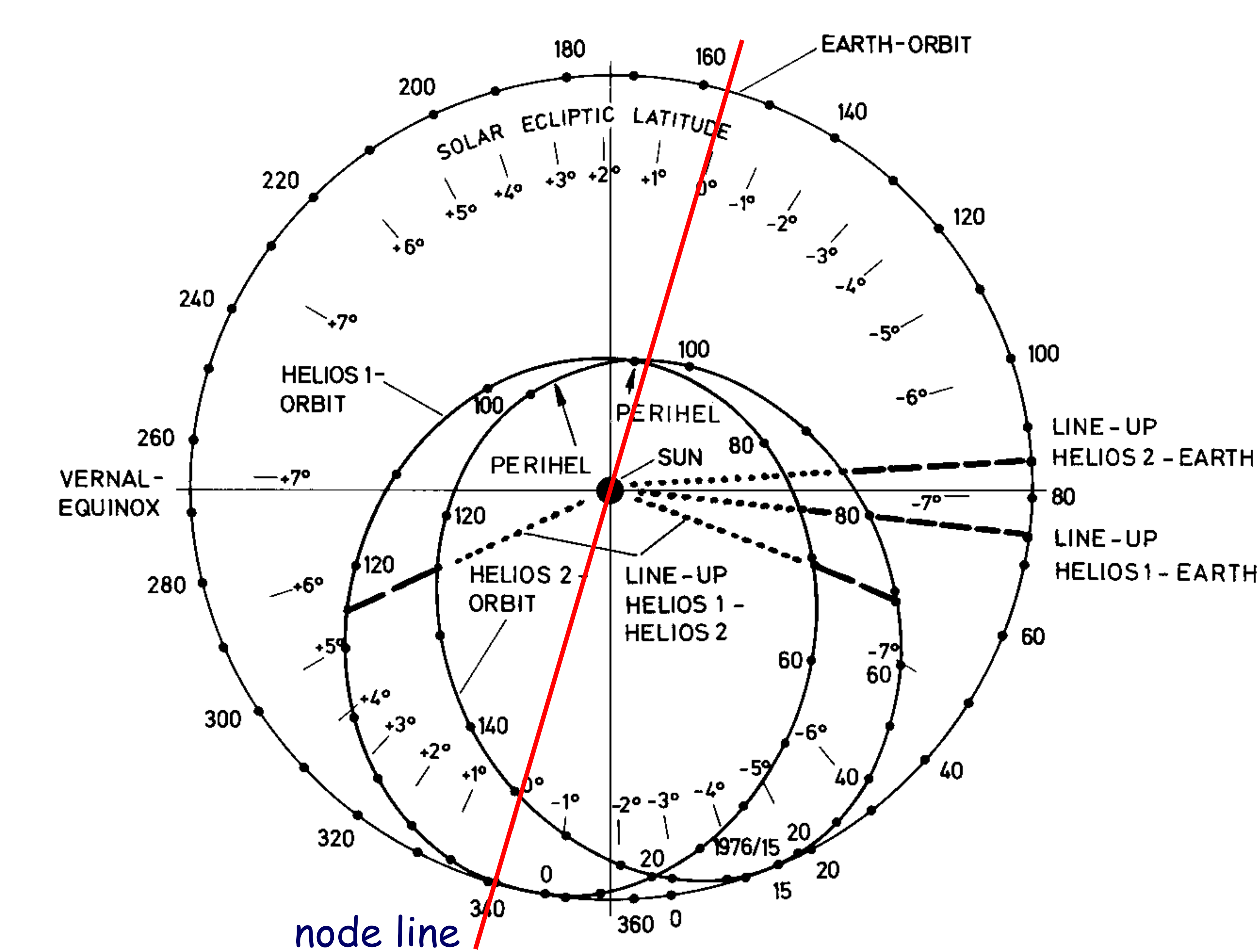
The Helios 1&2 solar probe mission



A pure particles and field payload

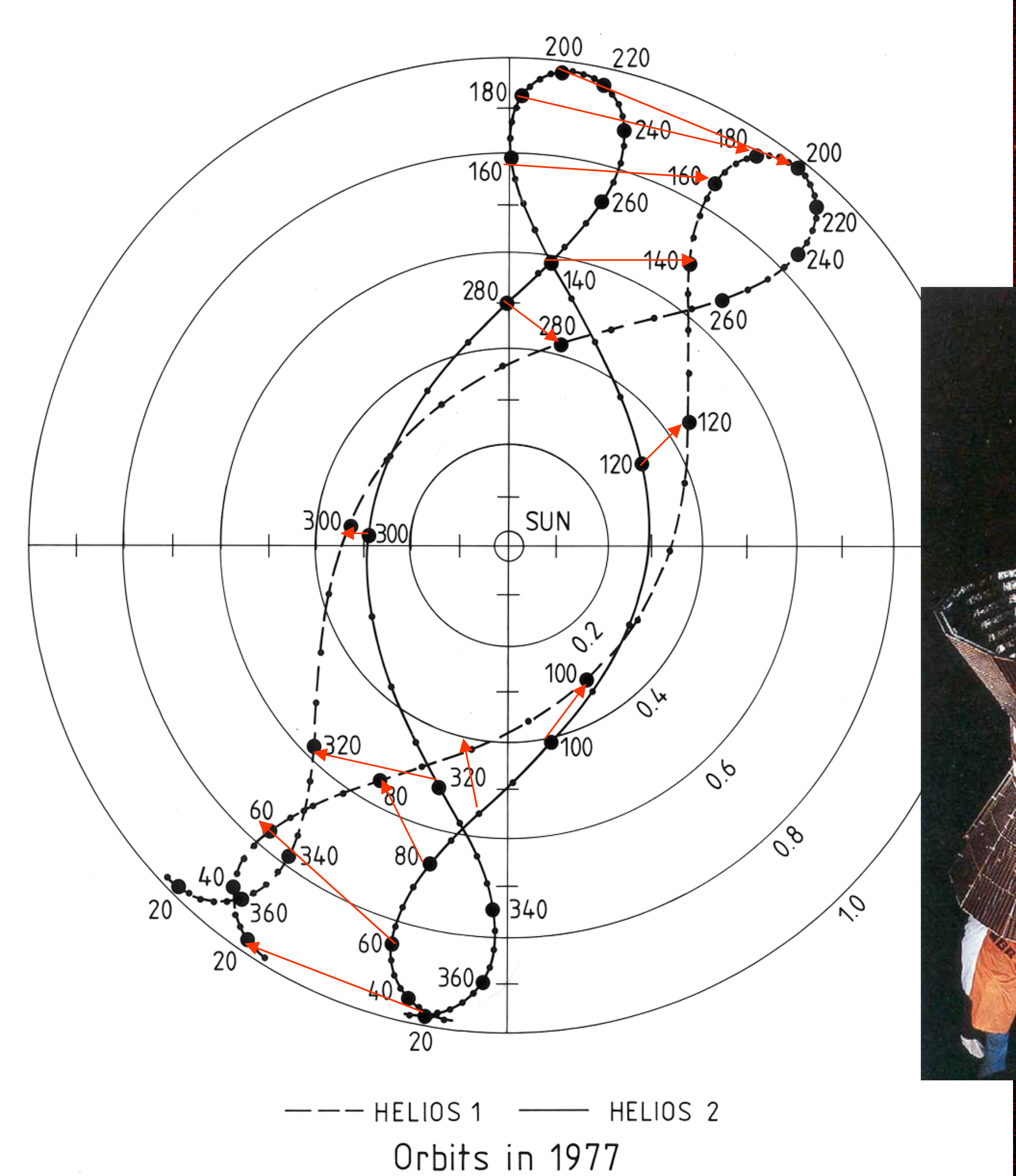
Exp. 1	Plasma Particles	H. Rosenbauer R. Schwenn	MPI für Physik und Astrophysik, Inst. für extraterr. Physik Garching
Exp. 2	Flux Gate Magnetometer	G. Musmann F.M. Neubauer	Inst. für Geophysik und Meteorologie, TU Braunschweig
Exp. 3	Flux Gate Magnetometer	F. Mariani N.F. Ness	Universita de l'Aquila, Italy NASA-GSFC Greenbelt, Md.
Exp. 4	Search Coil Magnetometer	G. Dehmel F.M. Neubauer	Inst. für Nachrichtentechnik Inst. für Geophysik und Meteorologie, TU Braunschweig
Exp. 5a	Plasma Waves	D.A. Gurnett	Univ. of Iowa, Dep. of Physics and Astronomy, Iowa City
Exp. 5b	Plasma Waves	P.J. Kellogg	Univ. of Minnesota, School of Physics and Astronomy, Minneapolis
Exp. 5c	Radio Waves	R.R. Weber	NASA-GSFC Greenbelt, Md.
Exp. 6	Cosmic Rays	H. Kunow	Inst. für Reine und Angewandte Kernphysik, Univ. Kiel
Exp. 7	Cosmic Rays	J.H. Trainor	NASA-GSFC Greenbelt, Md.
Exp. 8	Low Energy Cosmic Rays	E. Keppler	MPI für Aeronomie, Inst. für Stratosphärenphysik, Katlenburg-Lindau
Exp. 9	Zodiacallight Photometer	C. Leinert	MPI für Astronomie Heidelberg
Exp. 10	Micrometeorite Analyzer	E. Grün	MPI für Kernphysik Heidelberg
Exp. 11	Celestial Mechanics	W. Kundt W.G. Melbourne	Inst. für Theoretische Physik I Univ. Hamburg JPL Pasadena, Cal.
Exp. 12	Coronal Sounding	G.S. Levy H. Volland P. Edenhofer	JPL Pasadena, Cal. Radioastronomisches Institut Univ. Bonn DFVLR Oberpfaffenhofen

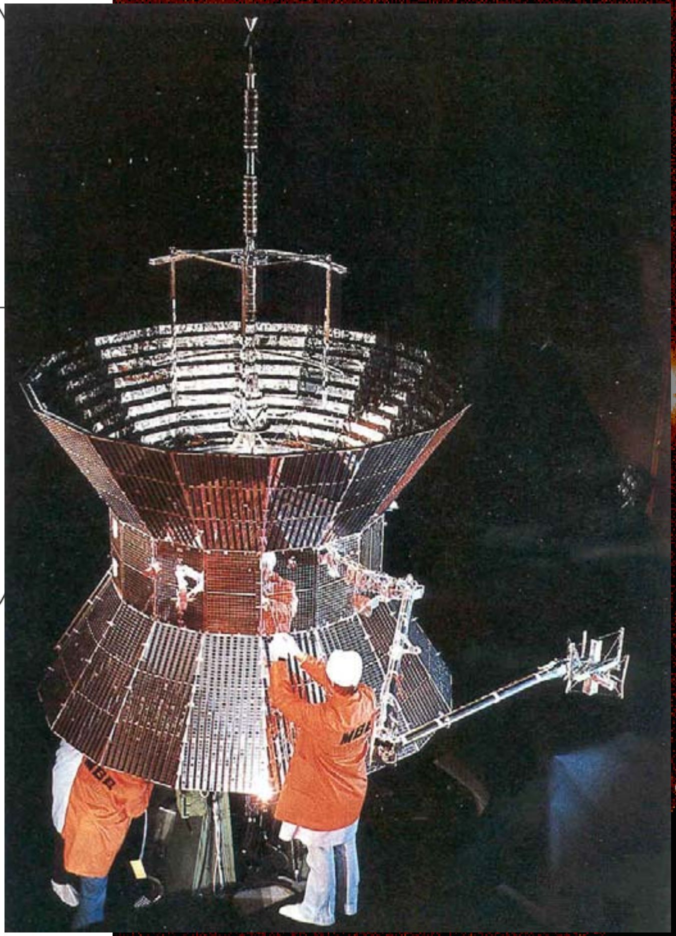
The mission lasted from Dec. 1974 to March 86



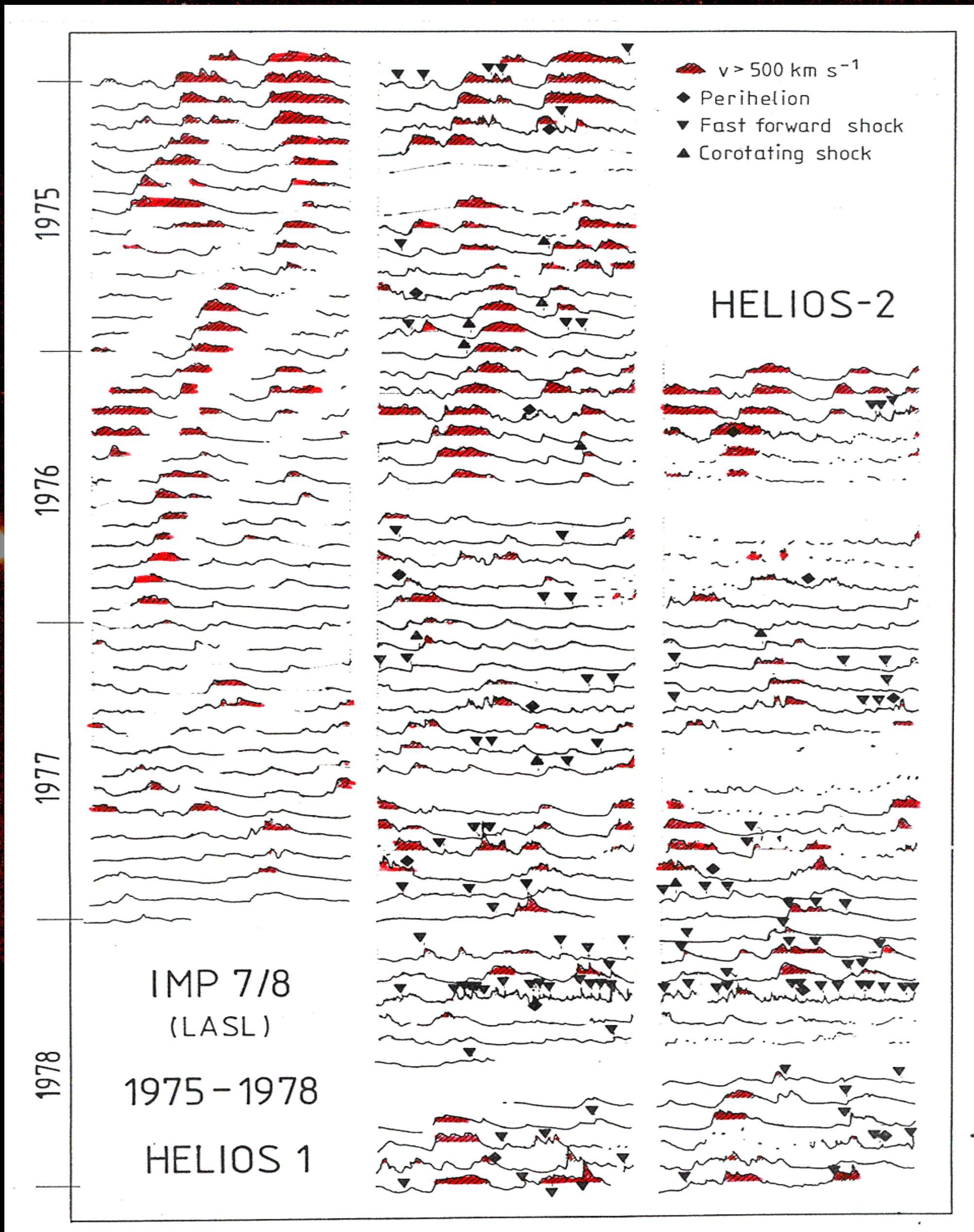
The orbits of the Helios 1&2 solar probes

Helios 1&2 a stereo-mission!





Solar wind stream structure 1974 to 1978



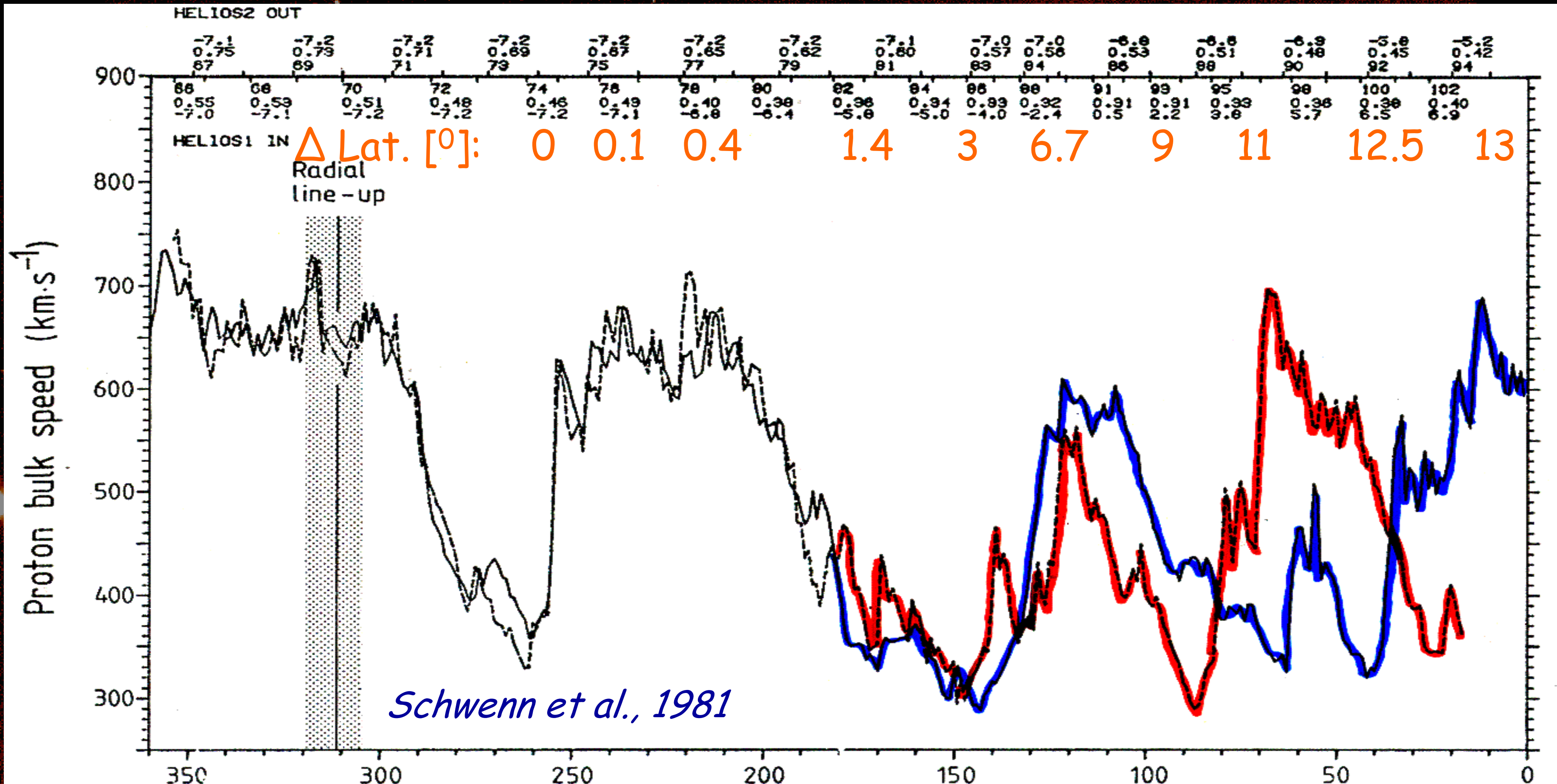
Minimum

The solar wind stream structure, observed by the Helios 1&2 and IMP spacecraft from activity minimum in 1975/76 onward.

With increasing solar activity (in 1978), many transient events destroyed any regular solar wind structure

Maximum

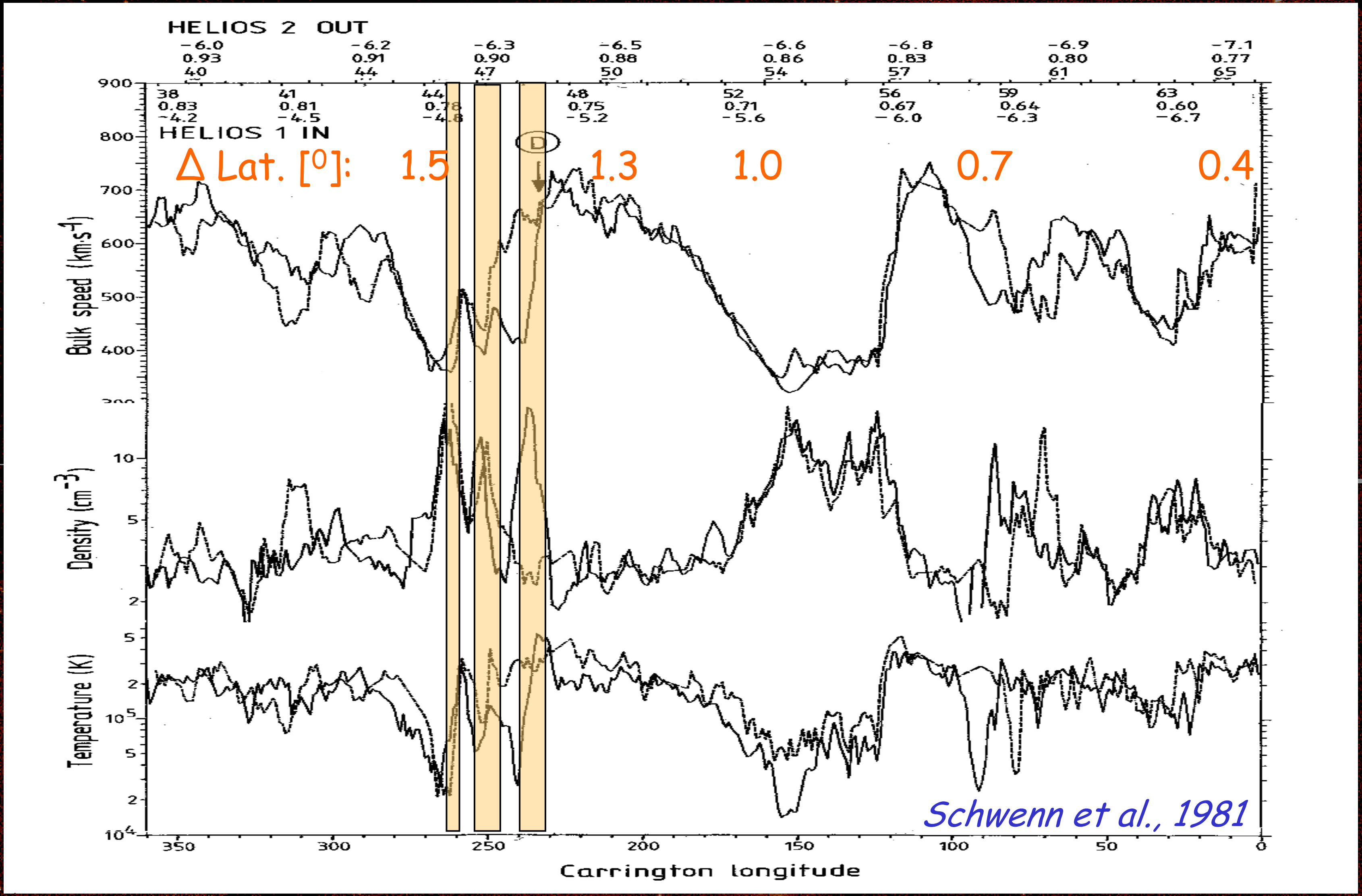
Latitudinal stream boundaries



The line-up between Helios 1 and Helios 2 in 1976,
and the succeeding divergence in latitude

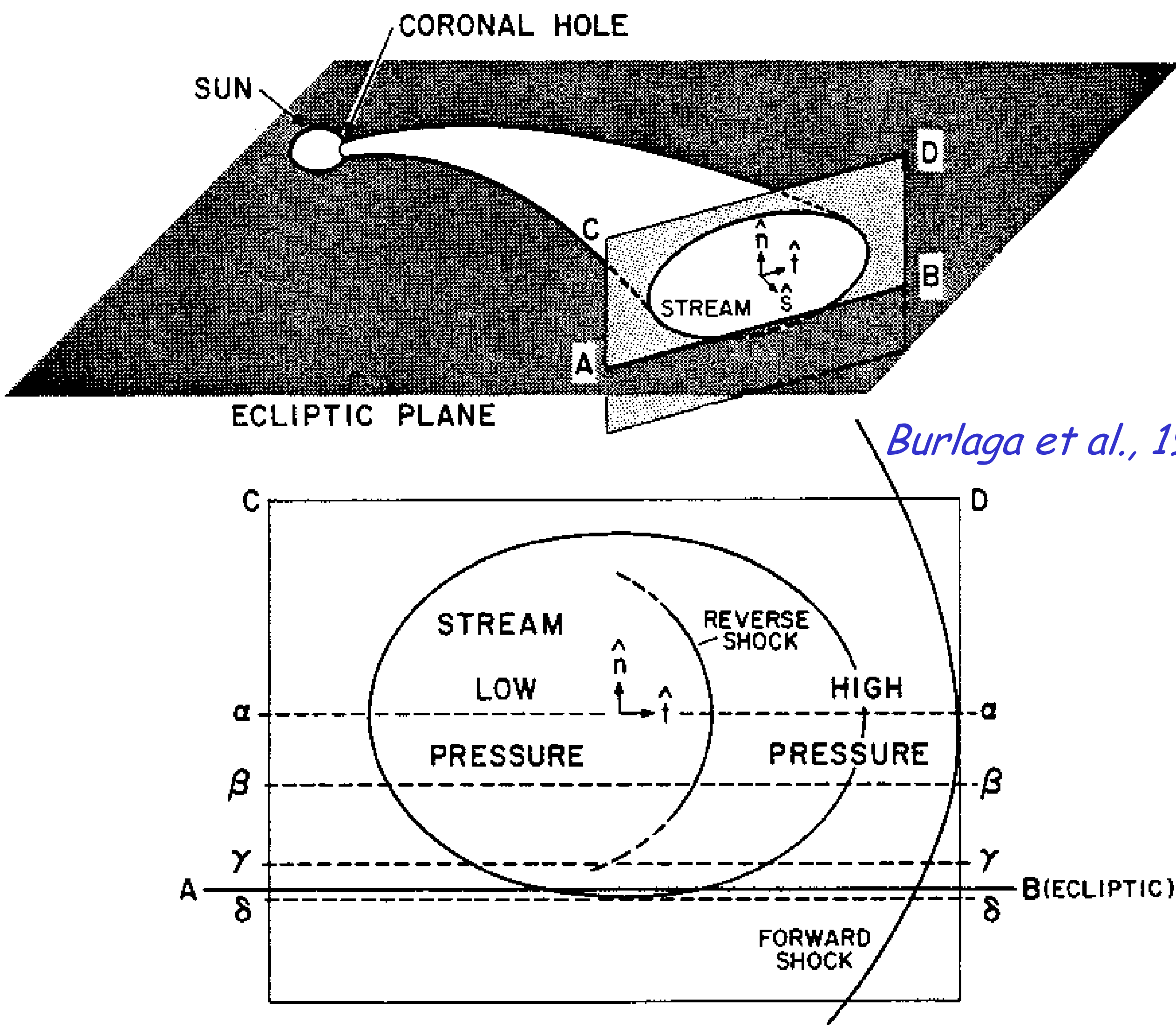
It is the latitude that makes stream structures differ,
rather than radial distance or time!

Latitudinal stream boundaries



Entry into a high-speed stream in 2 or even 3 steps,
a mere latitude effect!

Latitudinal stream boundaries

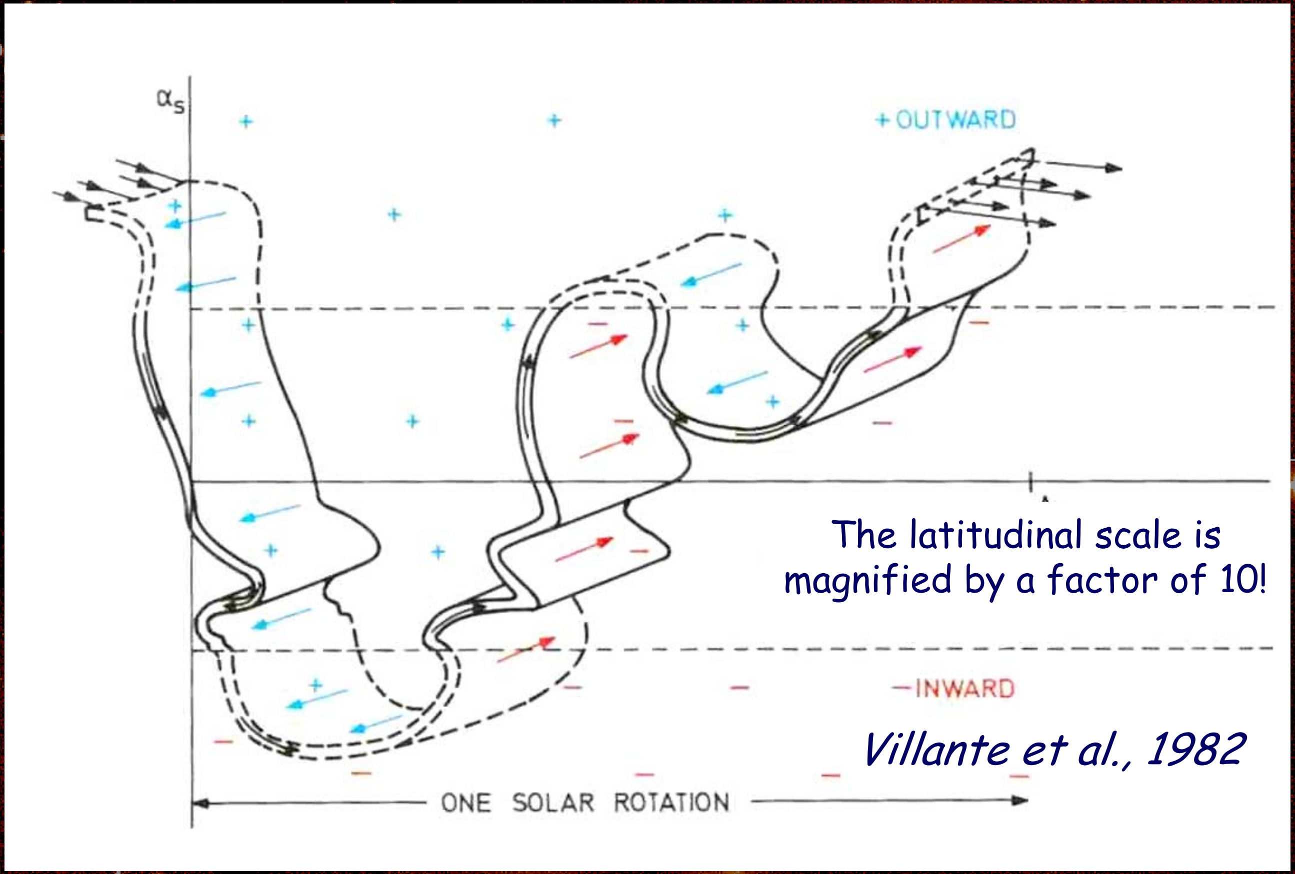


Burlaga et al., 1978

Fig. 10. A sketch illustrating how it is possible to observe a shock and corotating pressure wave without seeing a stream which may be present at latitudes above the observer, who is assumed to be in or near the ecliptic plane.

The interplanetary magnetic sector boundary

reconstructed from Helios 1&2 observations in 1976

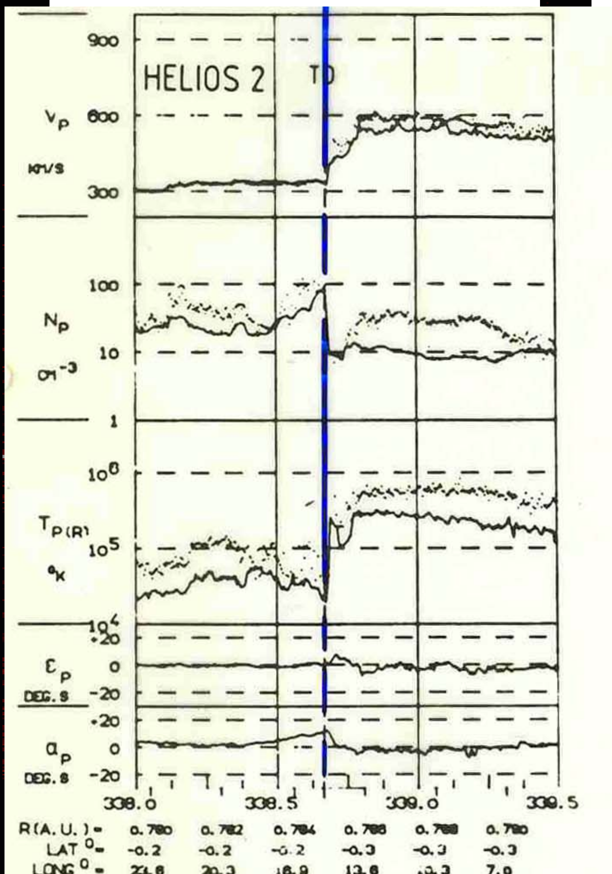


The current sheet topology was compiled from normal determinations at various crossings and from in-situ observations.

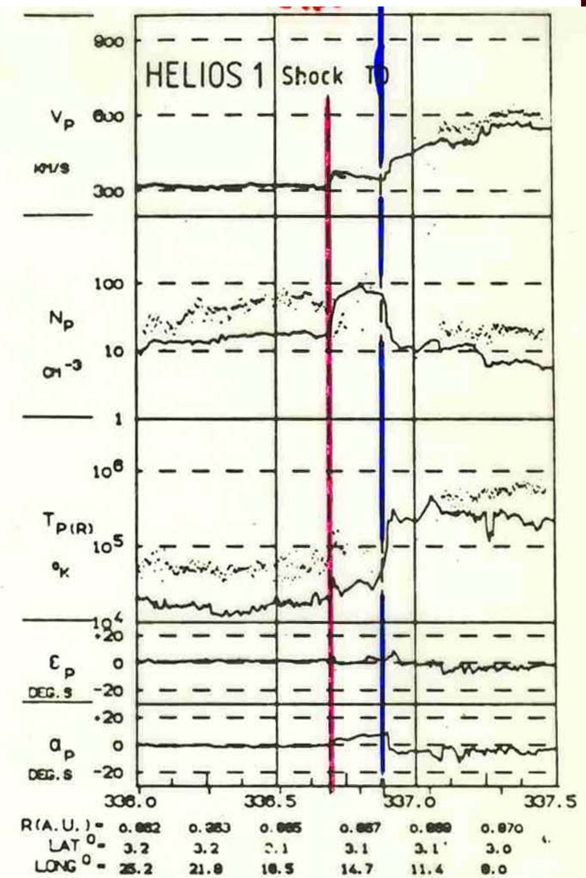
CIRs at high speed stream fronts

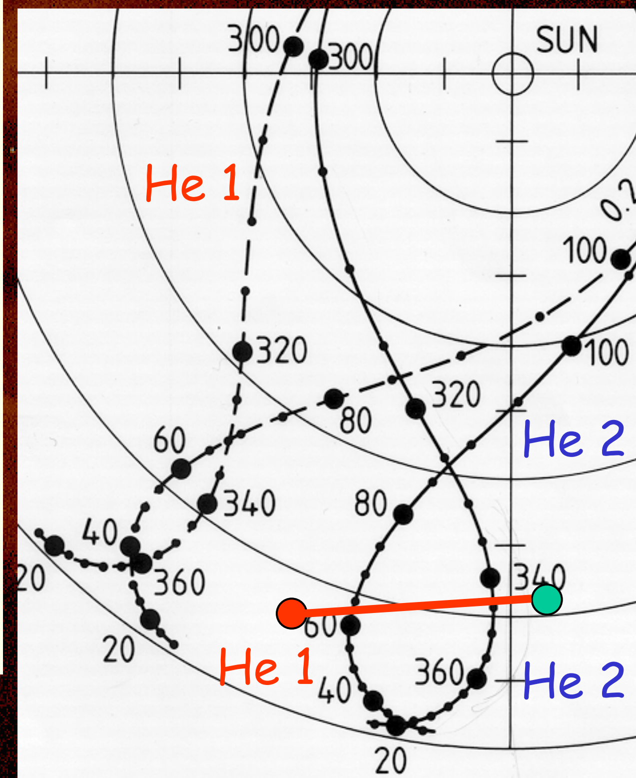
can differ substantially with latitude!

No corotating shock



CIR with corotating shock

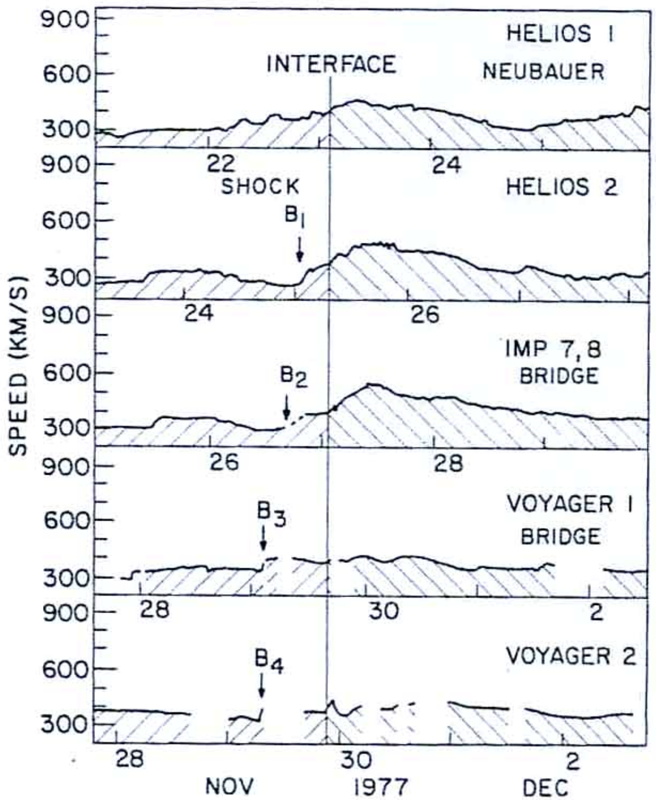




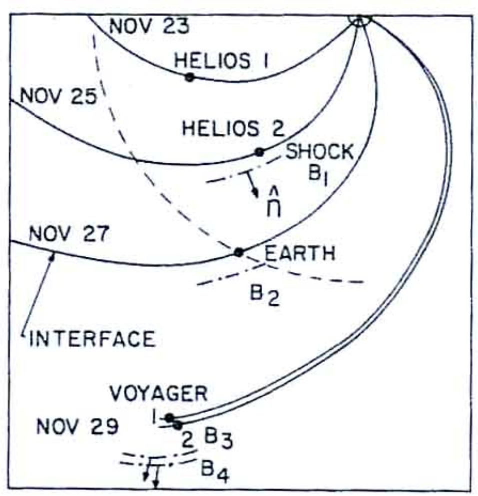
	Helios 2 (no corotating shock)	Helios 1 (CIR with corotating shock)
R =	0.78 AU	0.87 AU
Lat =	-0.2^0	$+3.2^0$
Clong =	15^0	13^0
Date =	76:338:16:00 UT	76:336:21:00 UT

A CIR

observed by 6 S/C in November 1977



Burlaga et al., 1978

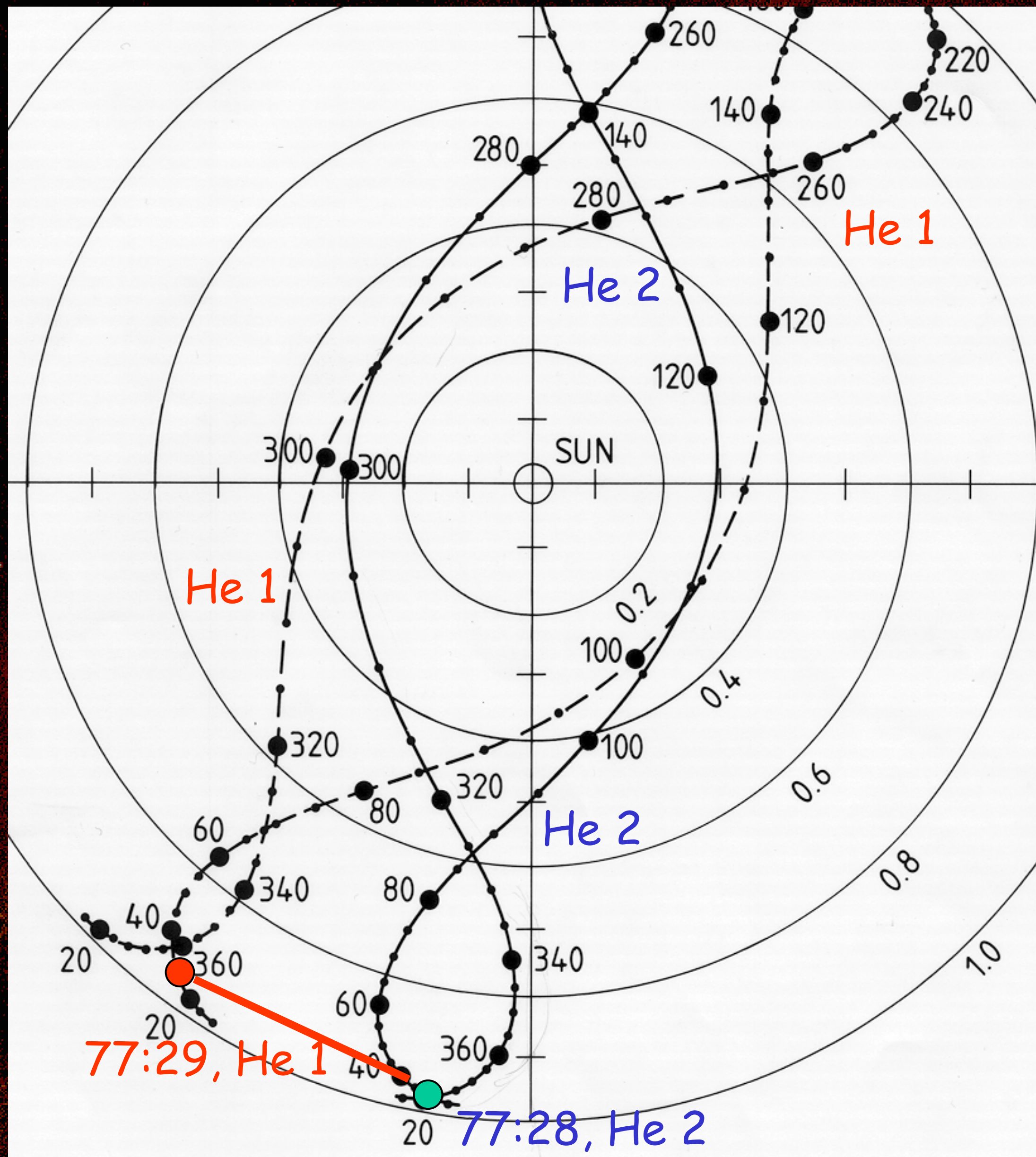


Note:

- the stream interface SI is observed at all S/C,
- He 2 is first to observe a corotating shock,
- the stream is gone at 1.6 AU, but
- the SI is still there, and
- the corotating shock is still there.

A transient shock, seen from Helios 1&2

27^0 apart in longitude

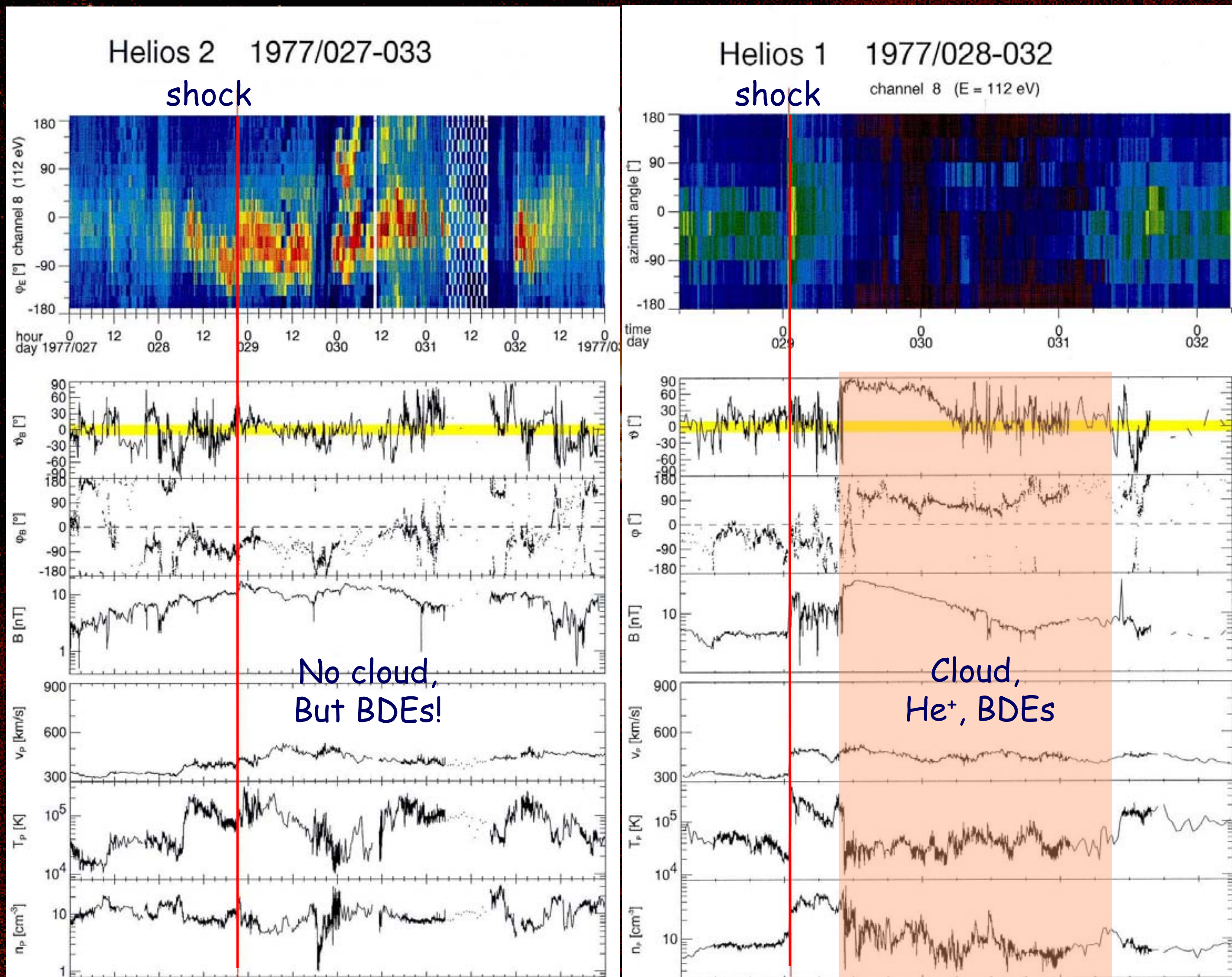


Helios orbits in 1977

A transient shock, seen from Helios 1&2

27^0 apart in longitude

0.98 AU
-5.0^0 lat
351^0 HSE



0.952 AU
-2.0^0 lat
323^0 HSE

Ejected plasma clouds and shocks in space

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 90, NO. A1, PAGES 163–175, JANUARY 1, 1985

Coronal Mass Ejections and Interplanetary Shocks

N. R. SHEELEY, JR., R. A. HOWARD, M. J. KOOMEN,[1] AND D. J. MICHELS

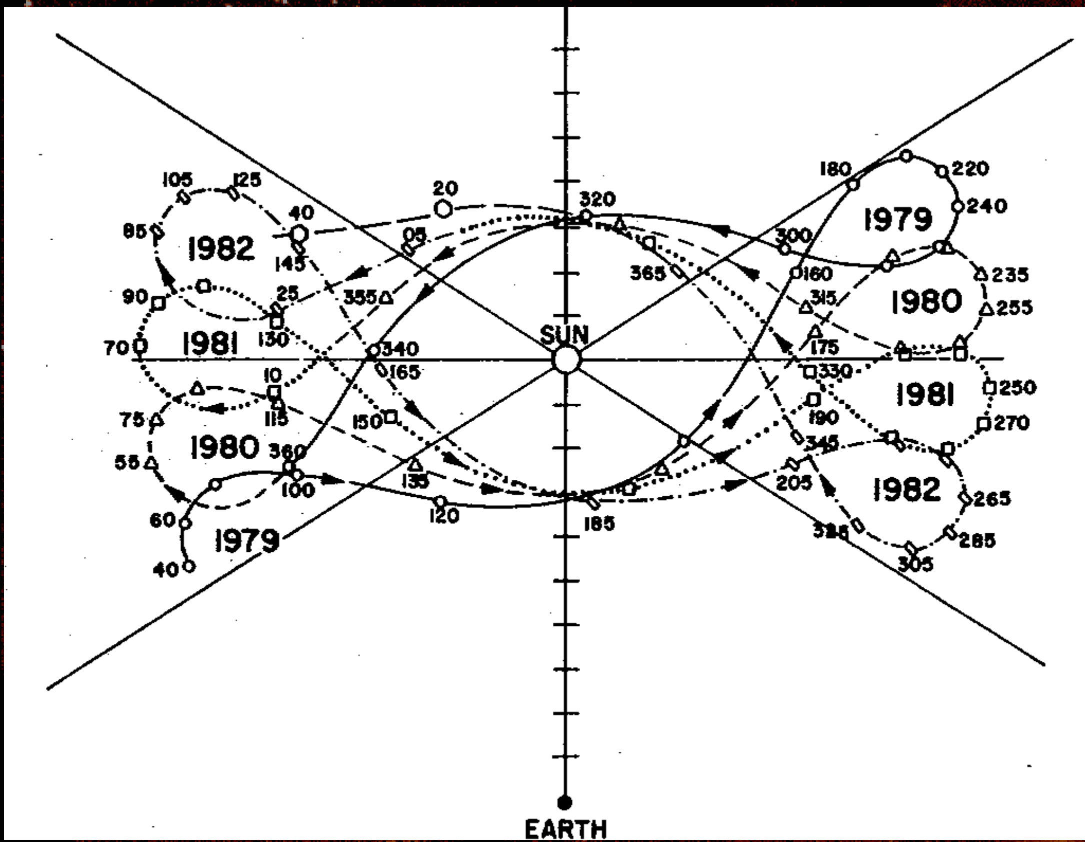
E. O. Hulburt Center for Space Research, Naval Research Laboratory, Washington, D. C.

R. SCHWENN, K. H. MÜHLHÄUSER, AND H. ROSENBAUER

Max-Planck-Institut für Aeronomie, Katlenburg-Lindau, Federal Republic of Germany

A comparison between Solwind observations of coronal mass ejections (CME's) and Helios 1 observations of interplanetary shocks during 1979–1982 indicates that 72% of the shocks were associated with large, low-latitude mass ejections on the nearby limb. Most of the associated CME's had speeds in excess of 500 km/s, but some of them had speeds in the range 200–400 km/s. An additional 26% of the shocks may have been associated with CME's, but we were less confident of these associations because the sizes and locations of the CME's did not seem appreciably different from those of the numerous CME's without Helios shocks. Only 2% of the shocks clearly lacked CME's. As the average level of sunspot activity declined during 1982, the shock frequency also declined, but the observed shocks and some of their associated CME's had unusually high speeds well in excess of 1000 km/s.

Unique radial speed measurements of limb CMEs and associated ICMEs



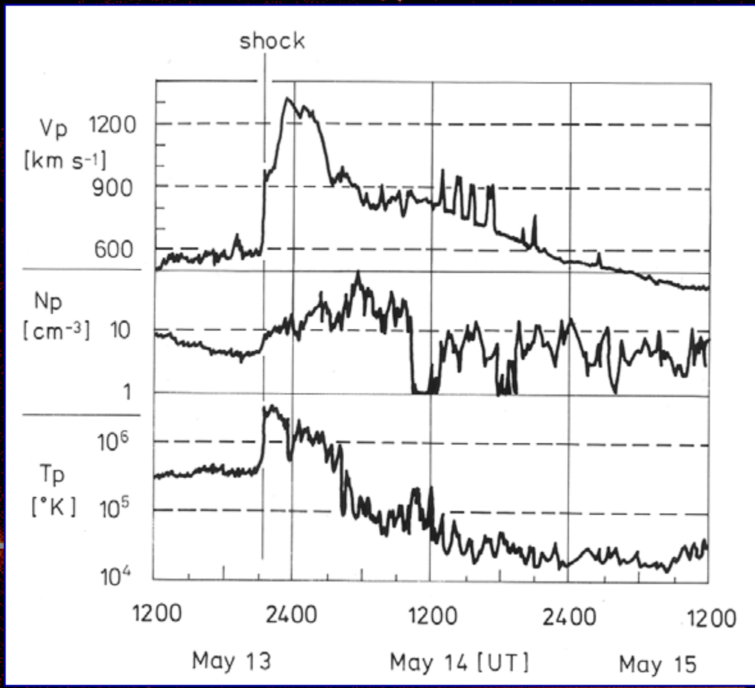
Orbit of Helios 1 with respect to the Sun-Earth line

The coronagraph on P 78-1 recorded CMEs above the limb. The plane-of-the-sky speed (which equals the radial speed for limb CMEs) of several hundred CMEs was measured.

The Helios probes happened to travel above the limb for long time periods and could observe *in-situ* the arrival of ICMEs.

For 49 events in 1979 to 1982 a unique association between CMEs seen at the sun and ICMEs observed *in-situ* (within +/- 30^0 of the sky plane) could be found and the travel time be determined.

Stereo views resolved the flare-CME controversy



Results from correlations between CMEs and interplanetary shocks:

- an observer within the angular span of a fast (>400 km/s) CME has a 100% chance to be hit by a fast shock wave,
- every shock (except at CIRs) can be traced back to a fast CME.

Sheeley et al., 1985

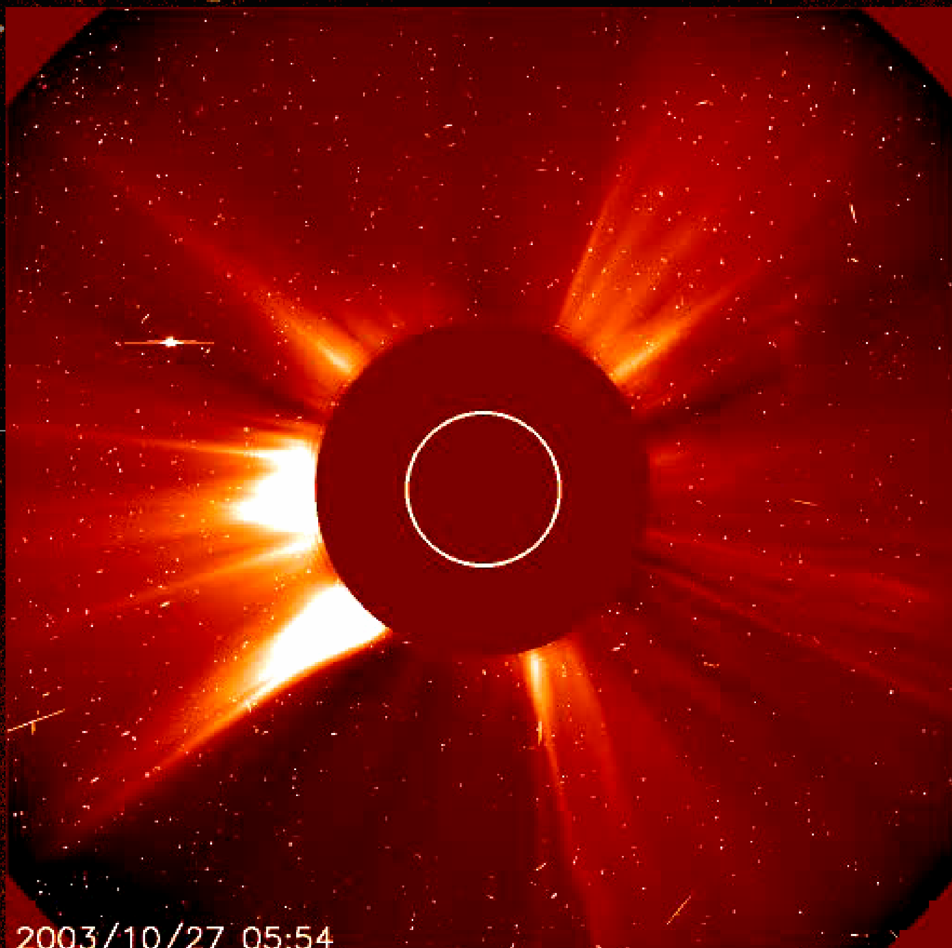
These shocks and the driver gases following them have a near 100% chance of becoming geo-effective, if ejected towards Earth.

Note: no such statement applies to flares!

Indeed: there are flares without CMEs (and geo-effects) and there are CMEs (and geo-effects) without flares.

MPS

The key problem in space weather forecasting: How to measure the CME's speed component V_{rad} along the LOS?



On October 28, 2003, in conjunction with a X13 flare, there occurred a gigantic halo CME .

By the way: 8 hours earlier a little comet had evaporated! **Coincidence?**

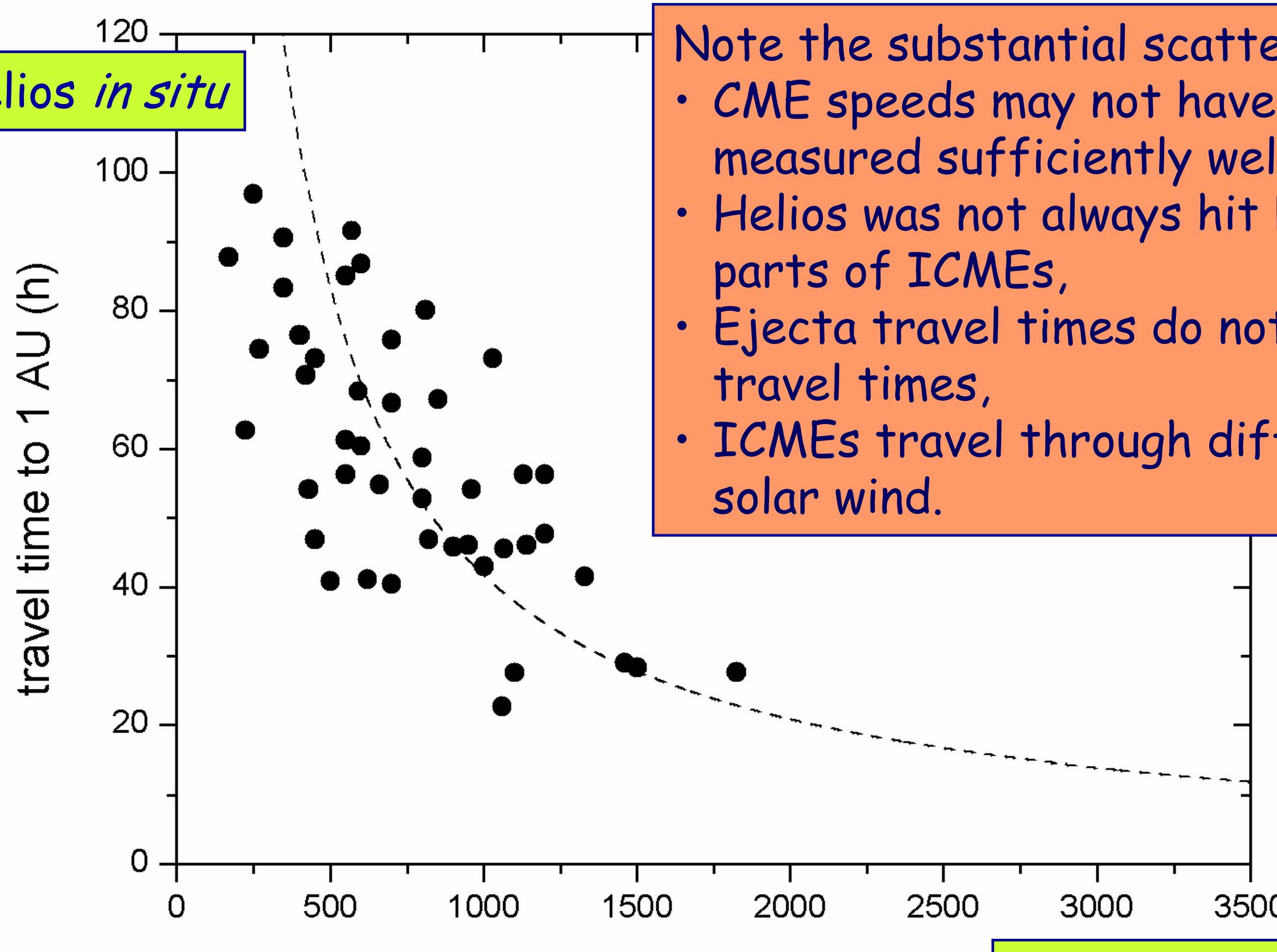
:

Note: in 9 years mission time, SOHO has seen more than 800 little comets and some 8000 CMEs…

Even if we could measure V_{rad} near the Sun, we are still in trouble. That's what we learned from Helios

Unique radial speed measurements of limb CMEs (SOLWIND) and associated ICMEs (Helios)

From Helios *in situ*



Schwenn et al., 2004

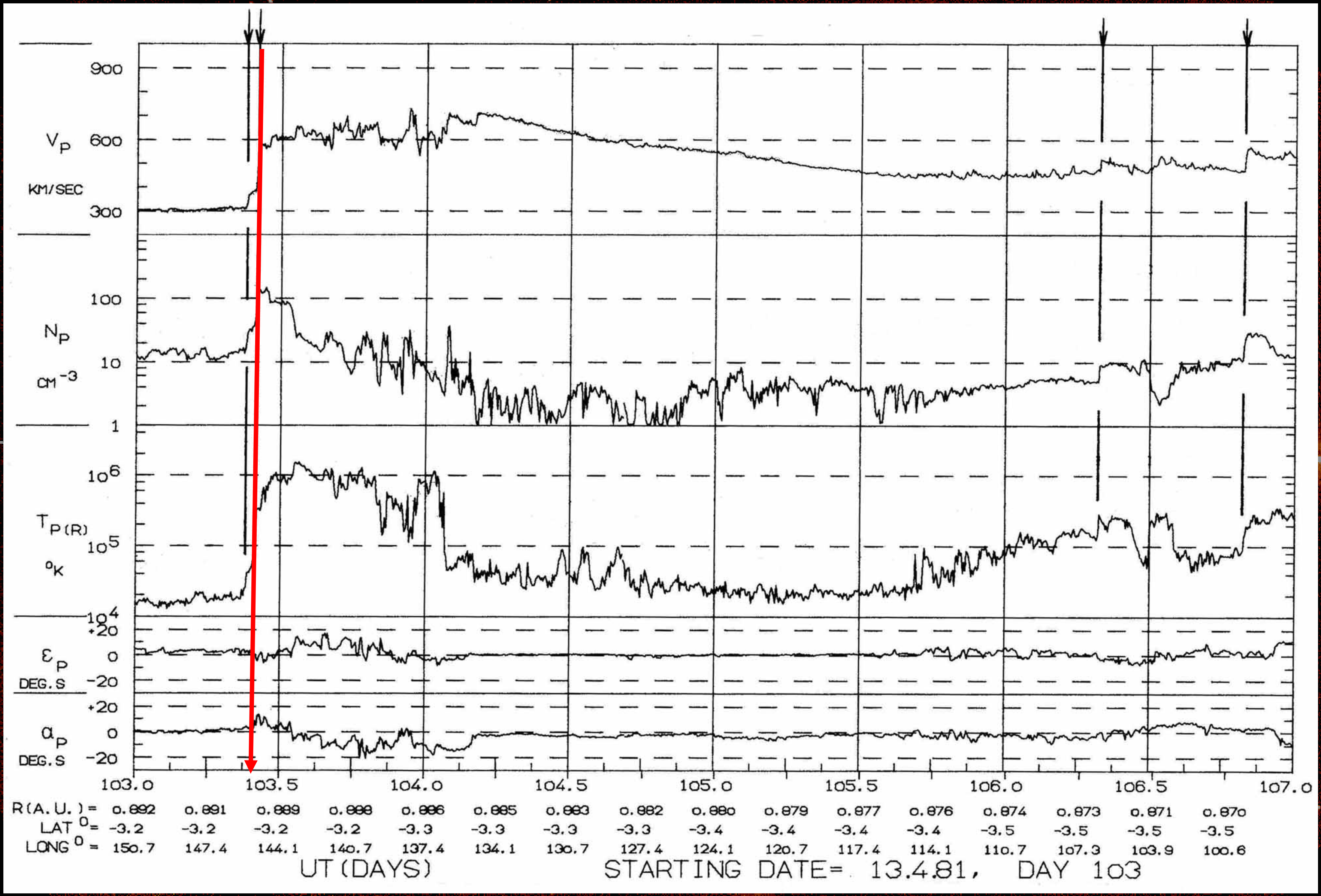
From P 78-1 coronagraph

Note the substantial scatter!

- CME speeds may not have been measured sufficiently well,
- Helios was not always hit by the fastest parts of ICMEs,
- Ejecta travel times do not equal shock travel times,
- ICMEs travel through different ambient solar wind.

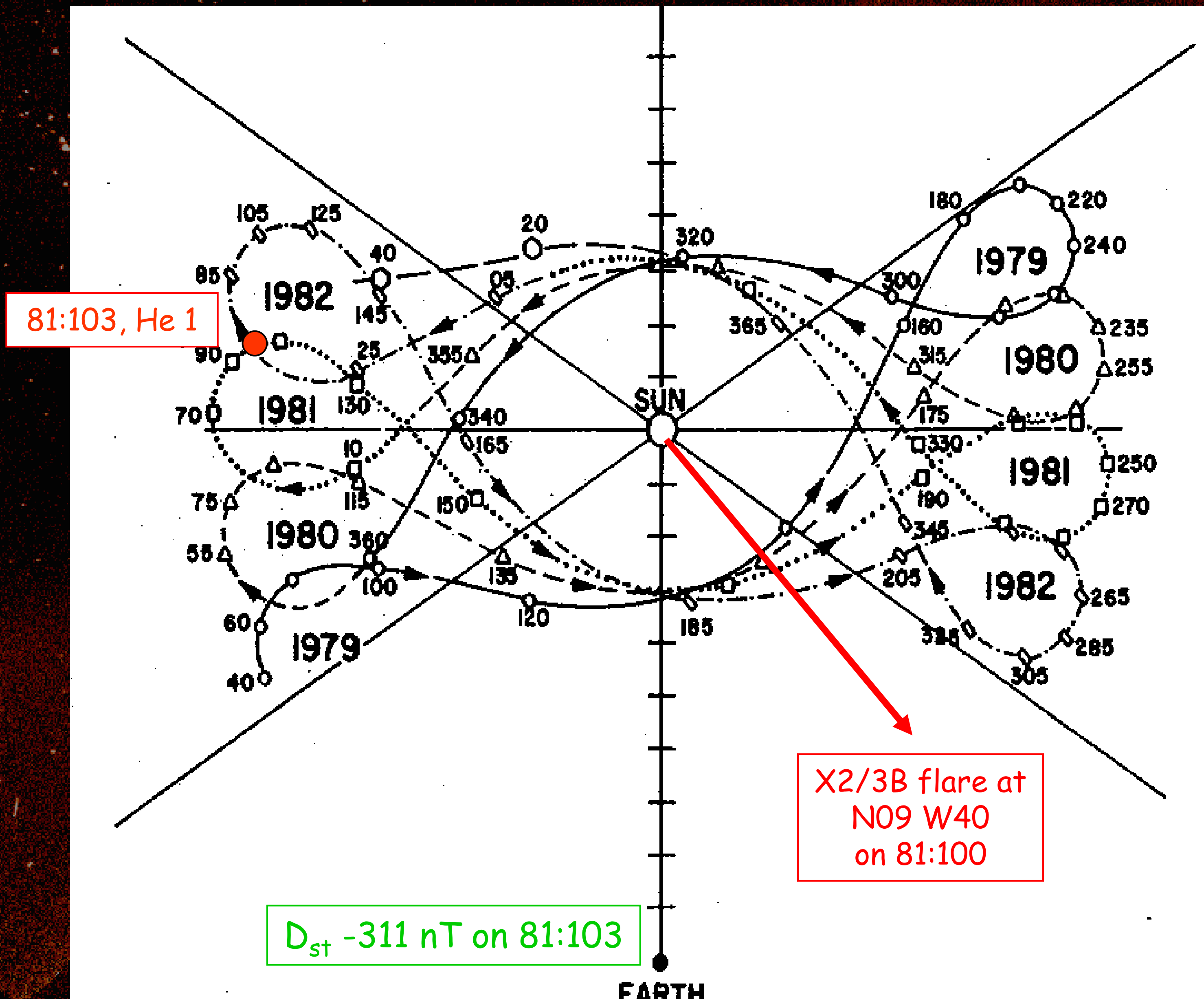
The travel time of ICME driven shock fronts from the Sun to the location of Helios 1 vs the CME radial speed V_{rad}.

Shock fronts may extend far around the Sun



The CME center was 140^0 in longitude off the Helios 1 position

Shock fronts may extend far around the Sun



JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 85, NO. A5, PAGES 2227–2242, MAY 1, 1980

An early STEREO/Sentinel study

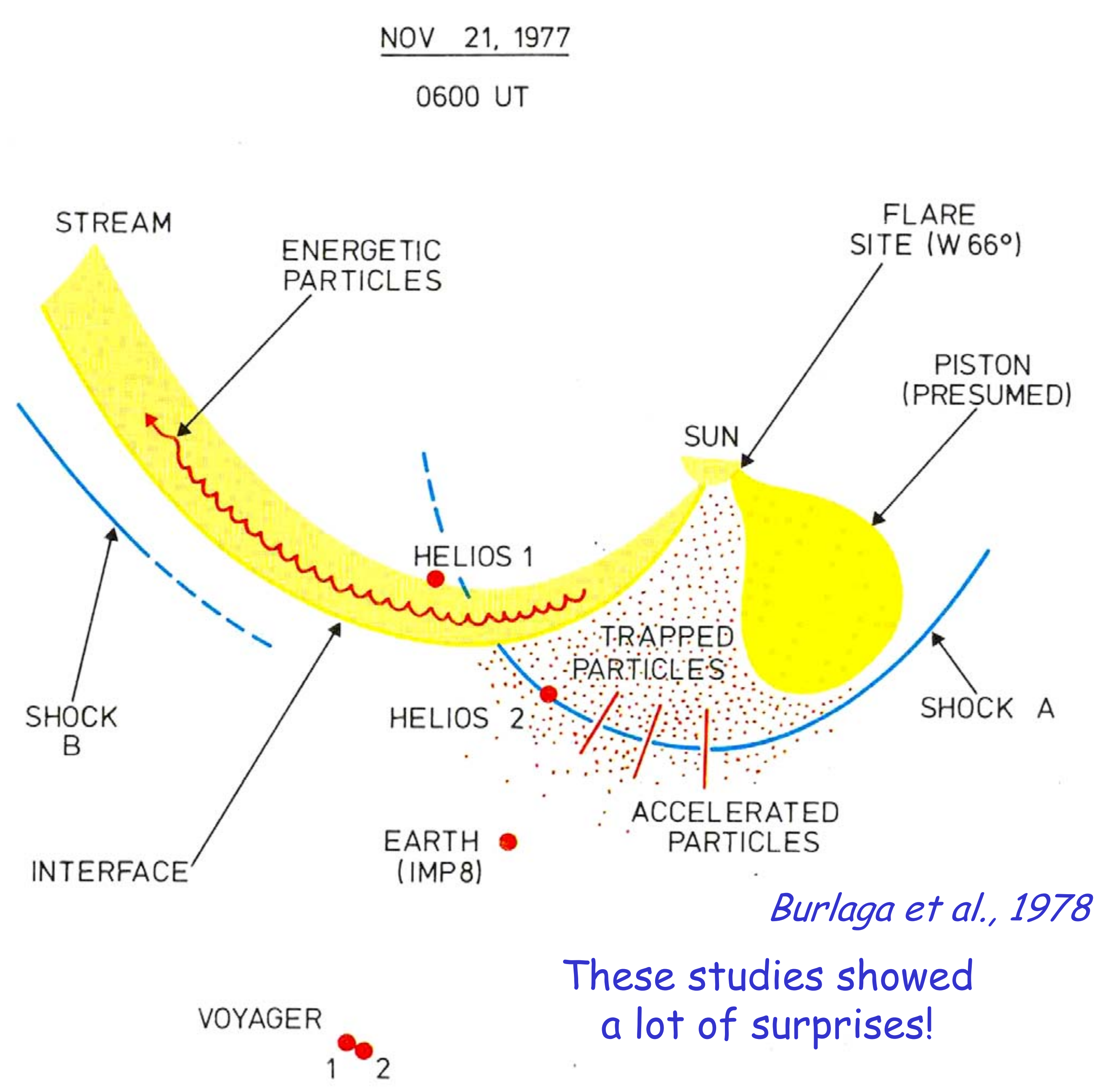
Interplanetary Particles and Fields, November 22 to December 6, 1977: Helios, Voyager, and Imp Observations Between 0.6 and 1.6 AU

L. Burlaga,[1] R. Lepping,[1] R. Weber,[1] T. Armstrong,[2] C. Goodrich,[3] J. Sullivan,[3] D. Gurnett,[4] P. Kellogg,[5] E. Keppler,[6] F. Mariani,[7] F. Neubauer,[8] H. Rosenbauer,[9] and R. Schwenn[9]

In the period November 22 to December 6, 1977, three types of interplanetary flows were observed: a corotating stream, a flare-associated shock wave, and a shock wave driven by ejecta. Helios 2, Imp 7, 8, and Voyager 1, 2 were nearly radially aligned at ≈0.6, 1, and 1.6 AU, respectively, while Helios 1 was at ≈0.6 AU and 35° east of Helios 2. The instruments on these spacecraft provided an exceptionally complete description of the particles and fields associated with the three flows and corresponding solar events. Analysis of these data revealed the following results. (1) A corotating stream associated with a coronal hole was observed at 0.6 and 1 AU, but not at 1.6 AU. The stream interface corotated and persisted with little change in structure even though the stream disappeared. A forward shock was observed ahead of the interface and moved from Helios 2 at 0.6 AU to Voyager 1, 2 and 1.6 AU; although the shock was ahead of a corotating stream and interface, the shock was not corotating, because it was not seen at Helios 1, probably because the corotating stream was not stationary. (2) An exceptionally intense type III burst was observed in association with a 2B flare of November 22. The exciter of this burst (a beam of energetic electrons) and plasma oscillations (presumably caused by the electron beam) were observed by

association with the November 22 flare. This shock
, and they coalesced to form a single shock that was
ejecta was studied. In the ejecta the density and tem-
l intensity was relatively high. This region was pre-
magnetic field intensity dropped appreciably. The
d, but locally, there were fluctuations in speed and
) Three types of electrostatic waves were observed at
vave profiles differed greatly among the shocks, even
trong dependence on local conditions. However, the
at 1.6 AU. (6) Energetic (50–200 keV) protons were
ons of the fluxes varied by a factor of 12 over longi-
gher, and the durations were lower, at 1.6 than at 0.6
≈50 keV) protons from the November 22 flare were
elios 1 observed no change in intensity when the in-
articles were injected and moved uniformly on both
in flux not seen by Helios 1, reaching maximum at
ity dropped abruptly when the interface moved past
Helios 2 did not penetrate the interface.

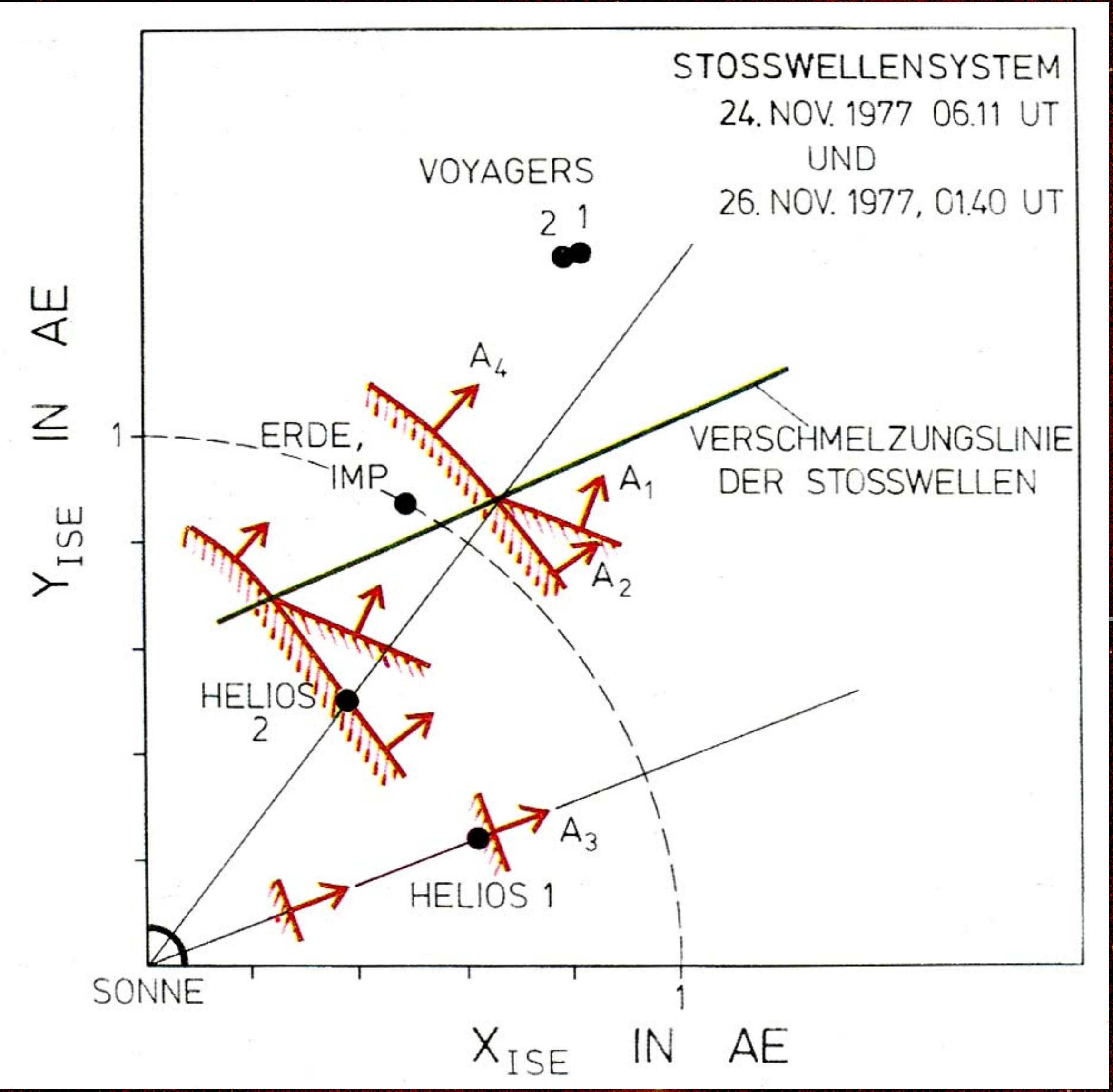
Multipoint study of shock propagation and extent



Burlaga et al., 1978

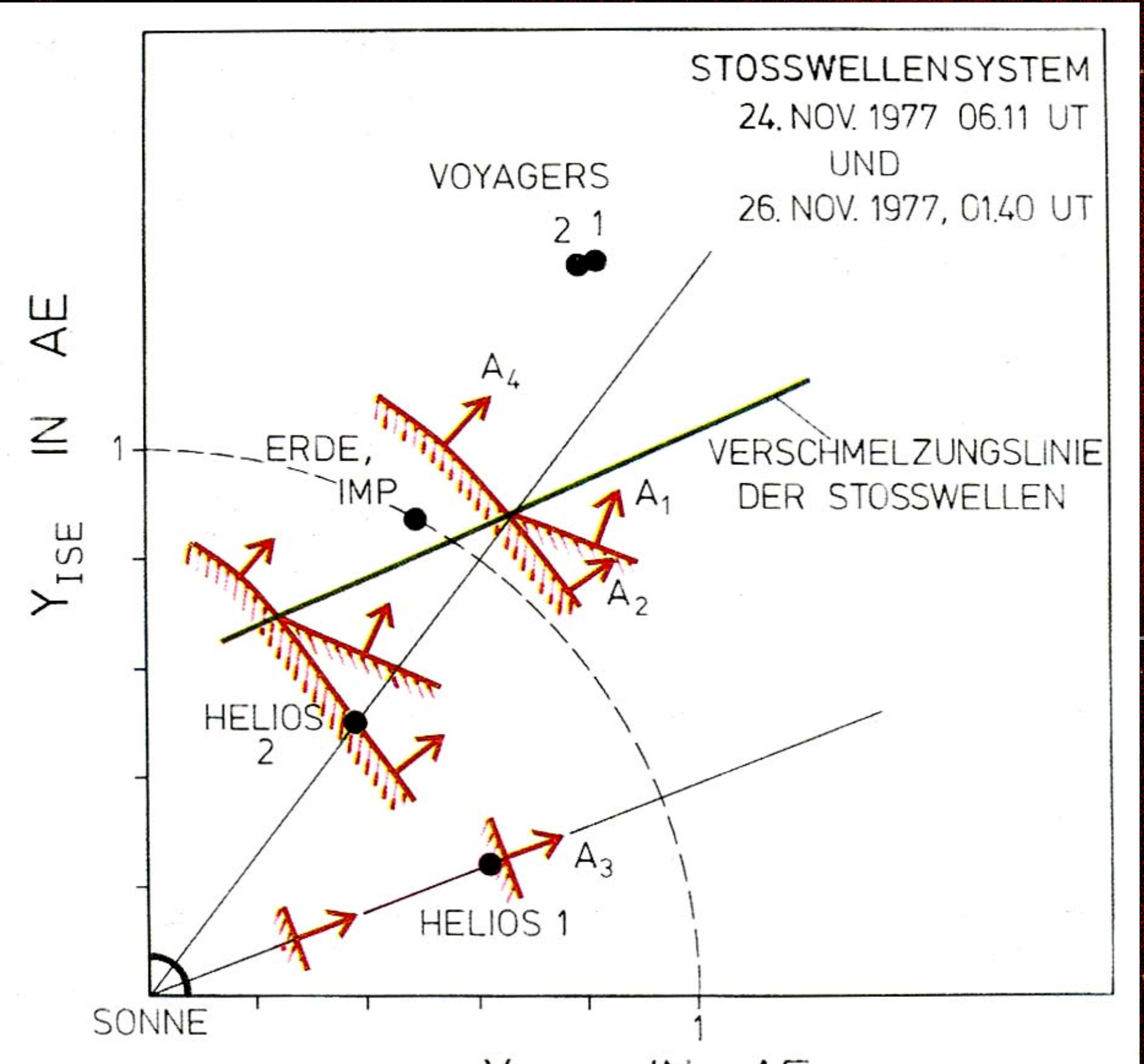
These studies showed
a lot of surprises!

Multipoint study of shock propagation and extent



The shocks A1 and A2 seen by He 2 merged,
and at Earth and at the Voyagers one single shock arrived.

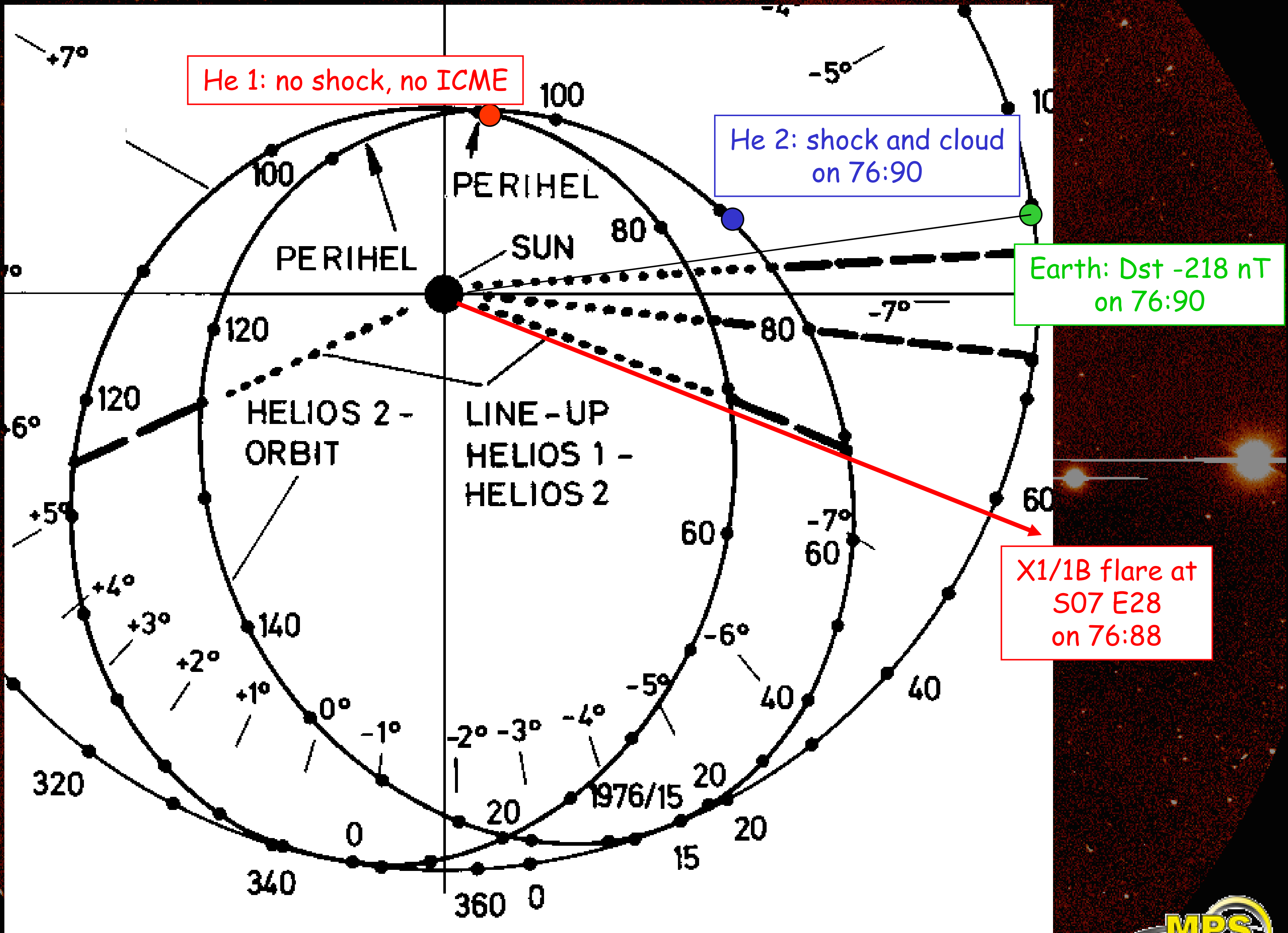
Multipoint study of shock propagation and extent



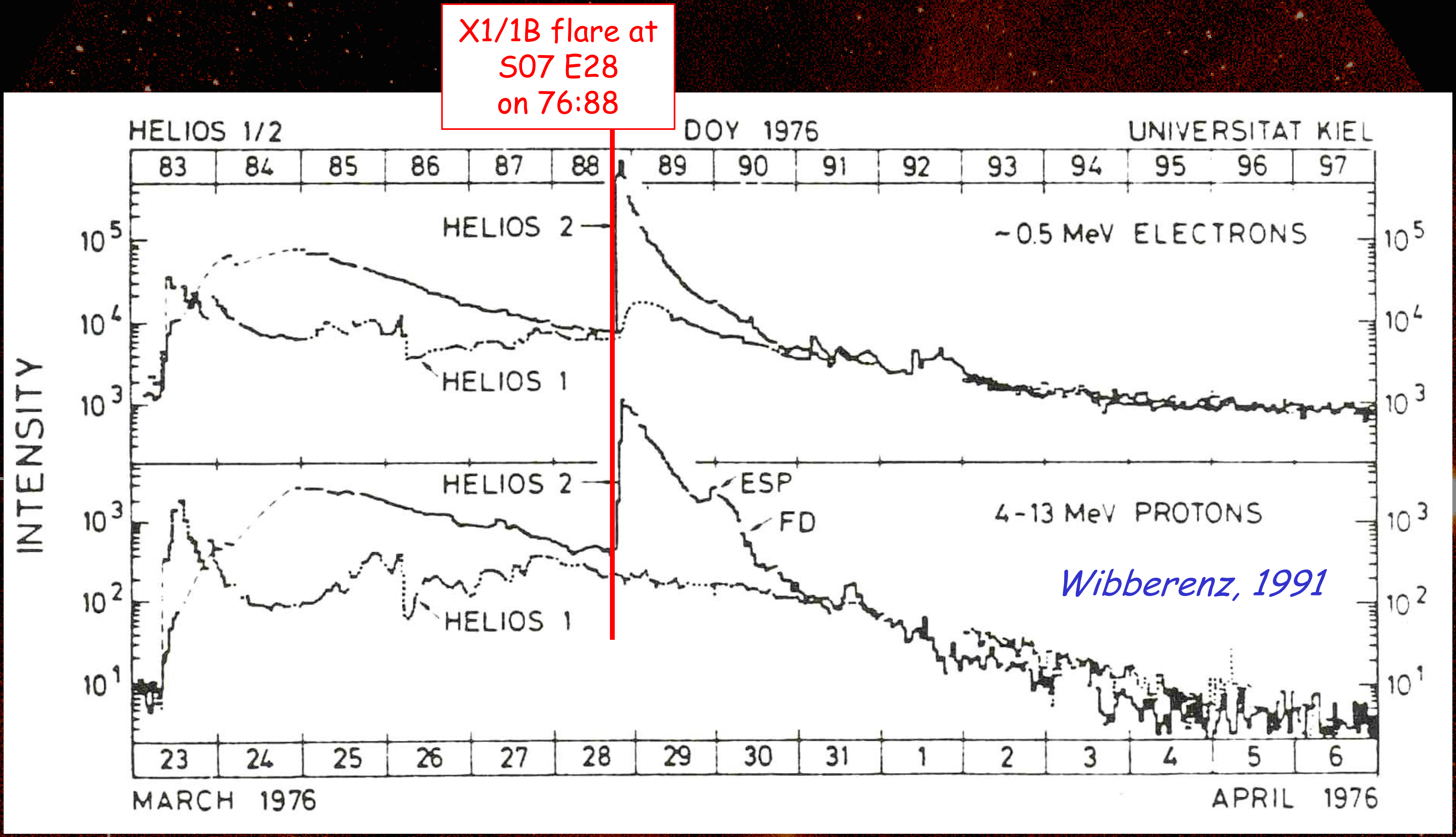
Burlaga et al., 1978

The shocks A1 and A2 seen by He 2 merged,
and at Earth and at the Voyagers one single shock arrived.

Stereo-constellation at the events in late March 1976



Multipoint study of particle propagation



Relativistic solar electrons made it to He 1, some 90^0 west of the flare site, but no protons!

Preparing for STEREO - revisit Helios

Since Helios we have learned a lot about:

- 3D-stream structure, CIRs, particle acceleration,
- CMEs, ICMEs, shocks, and their propagation,
- Solar energetic particles

The data are still available!