SUB | NIEDERSÄCHSISCHE STAATS- UND UNIVERSITÄTSBIBLIOTHEK GÖTTINGEN

Werk

Jahr: 1979
Kollektion: fid.geo
Signatur: 8 Z NAT 2148:46
Digitalisiert: Niedersächsische Staats- und Universitätsbibliothek Göttingen
Werk Id: PPN1015067948_0046
PURL: http://resolver.sub.uni-goettingen.de/purl?PPN1015067948_0046

LOG Id: LOG_0021
LOG Titel: The shape of the cosmic ray modulation region of the April 30, 1976, Event, as deduced from HELIOS-1, HELIOS-2, IMP-8, and neutron monitor data
LOG Typ: article

Übergeordnetes Werk

Werk Id: PPN1015067948
PURL: http://resolver.sub.uni-goettingen.de/purl?PPN1015067948
OPAC: http://opac.sub.uni-goettingen.de/DB=1/PPN?PPN=1015067948

Terms and Conditions

The Goettingen State and University Library provides access to digitized documents strictly for noncommercial educational, research and private purposes and makes no warranty with regard to their use for other purposes. Some of our collections are protected by copyright. Publication and/or broadcast in any form (including electronic) requires prior written permission from the Goettingen State- and University Library.
Each copy of any part of this document must contain there Terms and Conditions. With the usage of the library's online system to access or download a digitized document you accept the Terms and Conditions.
Reproductions of material on the web site may not be made for or donated to other repositories, nor may be further reproduced without written permission from the Goettingen State- and University Library.

For reproduction requests and permissions, please contact us. If citing materials, please give proper attribution of the source.

Contact

Niedersächsische Staats- und Universitätsbibliothek Göttingen
Georg-August-Universität Göttingen
Platz der Göttinger Sieben 1
37073 Göttingen
Germany
Email: gdz@sub.uni-goettingen.de

J. Geophys. 46, 171–183, 1979

Journal of Geophysics

The Shape of the Cosmic Ray Modulation Region of the April 30, 1976, Event, as Deduced From HELIOS-1, HELIOS-2, IMP-8, and Neutron Monitor Data

A. Geranios

Max-Planck-Institut für Extraterrestrische Physik, D-8046 Garching bei München, Federal Republic of Germany

Abstract. During STIP (Study of Travelling Interplanetary Phenomena) II period, several disturbances of the cosmic ray flux have occured due to the enhanced activity of the sun, although this period (March-May 1976) was at the end of the past solar cycle. One of the most prominent 'events' was caused by the 2 B solar flare on 30 April (121st day of the year), at 20:47 UT, with coordinates S8 W46 in Mc-Math region 14179. This event has been 'seen' as a tangential discontinuity by both HELIOS spacecraft and as a shock wave by IMP-8. Neutron monitors recorded an increase of the counting rate on the ground level, and two days later, the onset of a Forbush decrease.

In this paper, we estimate the extension of the modulation region of cosmic rays in the ecliptic plane by correlating the observations which are related to the above mentioned solar flare.

We conclude that in the ecliptic plane the shock characteristics of this event are found only in the neighbourhood of the heliographic longitude of the causitive solar flare, i.e., of an extension 45° and 120°. The tangential discontinuity observed by HELIOS-2 and then by HELIOS-1 was of a corotative nature. The feature of the tangential discontinuity and the Forbush decrease suggest a corotation of the above modulation region.

Key words: Cosmic rays – Solar wind protons.

A Brief Description of the Event

On April 30, 1976, at 20:48 UT, day of the year 121 (shortly DOY 121), a 2B solar flare (S.FL.) occurred at S8 W46 in Mc-Math region 14179 (Dodson and Hedeman, 1977). Two days later, HELIOS-1 and -2 were radially lined up about 120° west of the flare site at radial distances of 0.67 (H-1) and 0.43 (H-2) astronomical units, respectively from the sun (Fig. 1). About 20 minutes after the occurence of the flare, a Ground Level Event (GLE) was detected

0340-062X/79/0046/0171/$02.60

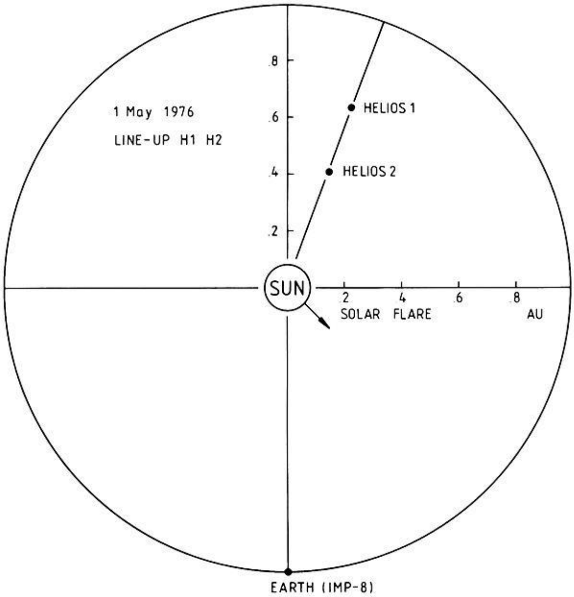


Fig. 1. The longitudinal distribution of *HELIOS-1*, *HELIOS-2*, IMP-8 and the solar flare

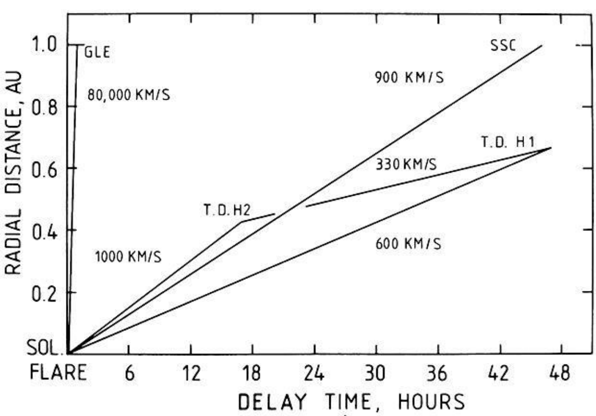


Fig. 2. The detection delay-time for the ground level event, the tangential discontinuity and the shock, or the storm sudden commencement, by neutron monitor, HELIOS-1, HELIOS-2, IMP-8 spacecraft

at the earth by neutron monitors (NM) with a cut-off rigidity below 3 GV (Duggal and Pomerantz, 1977), (Fig. 3). Later, during the same day, the electron, proton, and α-particle channels of IMP-8 detected abrupt increases (Armstrong et al., 1977). HELIOS-2 (DOY 121) and -1 (DOY 123) detected electron- and proton- but not α-particle intensity enhancements (Kunow et al., 1977). A tangential discontinuity (TD) passed HELIOS-2 and -1, 17 and 46 h respectively after the onset of the solar flare (Schwenn et al., 1977). A Storm Sudden Commencement (SSC, DOY 123, 18:29 UT), marked the passage of a shock front at the earth. This shock was also detected by IMP-8, and the commencement of a typical Forbush decrease (FD) was observed by ground NM's, (Fig. 3). A series of other correlated observations (For example type II and IV radio bursts, X-ray enhancements) are described elsewhere (Shea, 1977).

The Ground Level Event

GLE's are generally rare, especially during a minimum of solar activity. Such an event occured at the end of the past solar cycle on April 30, 1976, DOY 121, at about 21:00 UT, only about 20 min after the onset of the above mentioned flare. The enhancement of the energetic proton fluxes ejected from the solar flare was detected by low cut-off rigidity NM stations, for example Deep River (Fig. 3), Calgary and Sulphur Mountain showed relative increases of 3%, 5%, and 7% respectively (SGD, 1976). The maximum energy of the accelerated protons in this flare was 2 or even 3 GeV (Duggal and Pomerantz, 1977).

The longitudinal site of the solar flare (46°) was favorable for such a short delay time, which suggests that the particle flux was directed along the interplanetary magnetic field (IMF) lines and very little scattering occured.

According to Chirkov et al., 1977, the integral energy spectrum of the cosmic rays of this event discussed here, was:

$$A(E > 1.3\ \mathrm{GeV}) \sim E\,\exp(-2.6)$$

for energies $E > 1.3$ GeV.

A similar event which orginated also from a S.FL. in the western hemisphere occured during a complex event in August 1972, where the 3B S.FL. (August 7, 37° W) caused the Ground level Event with a time-delay of 30 min and a cosmic ray increase of 8% (Mihalov et al., 1973; Agrawal et al., 1974; Pomerantz and Duggal, 1974; Tanskanen et al., 1973).

Observations of Particles in the Energy Range Between 2 and 37, and Greater Than 51 MeV/Nucleon

All three spacecraft measured an enhancement of energetic particles. HELIOS-2 and HELIOS-1 (shortly, H2 and H1) observed proton flux increases on April 30 (DOY 121) and on May 2 (DOY 123) respectively in the energy channels:

4–13 MeV
13–27 MeV
27–37 MeV of H1, and

4–13 MeV
27–37 MeV
>51 MeV of H2 (Kunow et al., 1977).

At the end of the first of May (DOY 122), IMP-8 detected abrupt increases in the proton energy channel 2–4.6 MeV, in addition, it recorded flux enhancements of α-particles of energy 1.8–4.2 MeV/nucl. later during the same day.

A main difference between the HELIOS and the IMP-8 observations was the lack at both HELIOS of any α-particle flux enhancement. These flux increases normally are regarded as a signature of a flare shock wave. Typical differences between the observations of H1 and H2 are:

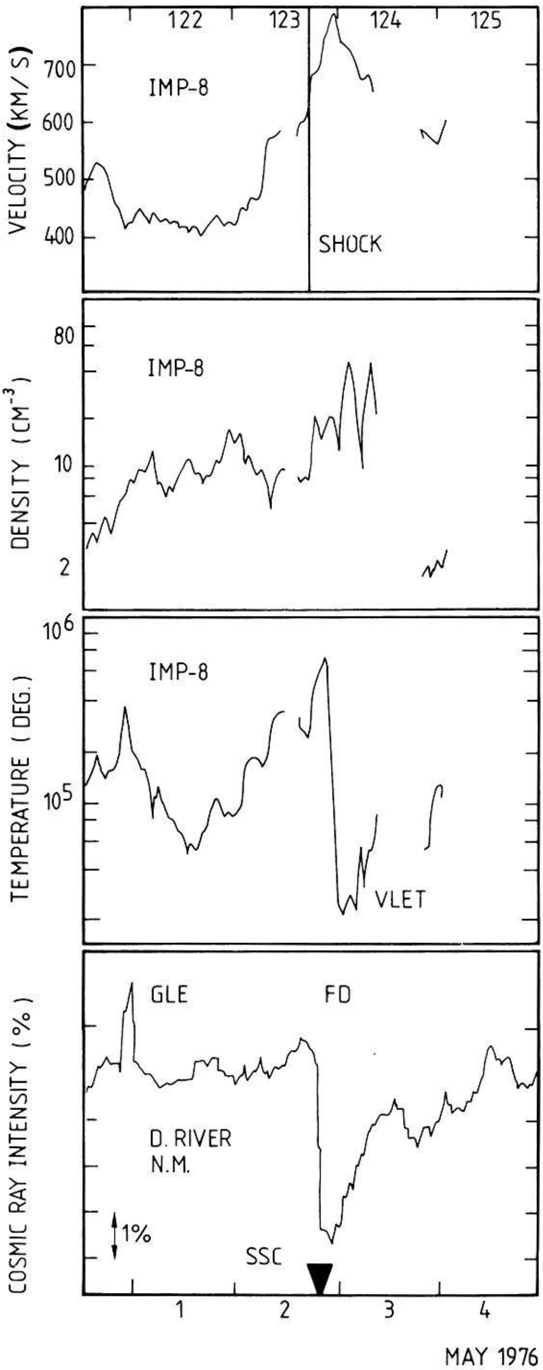


Fig. 3. Solar wind velocity, density and temperature measured by *IMP-8;* cosmic ray intensity ($E > 1$ GeV) measured by the *D. River* neutron monitor and *SSC* around the time of shock on May 2, 1976

1. The proton flux increase in the energy channel $E > 51$ MeV was clearly detected only by H2 (Kunow et al., 1977), and

2. the rise time of the proton flux increase observed by H2 compared with that of H1 was shorter by about a factor of 3, (Fig. 4a and b).

The difference between the intensity profiles during the increase phase detected by H2 and H1 may be due to the different distances of H2 and H1 from the sun.

A step-like proton intensity enhancement can be recognized as a superposition on the intensity profile during the increase phase at both H1 and H2. This step-like increase coincides with that of the solar wind velocity observed also by H1 and H2 (Fig. 4a and b).

The Tangential Discontinuity

After the occurence of the 2B S.FL. a tangential discontinuity (TD) was observed by H2 and H1 on May 1 (DOY 122) at 14:00 UT and on May 2 (DOY 123) at 19:30 UT, respectively. Apparently, the solar wind parameters are not shock characteristics, as will be explained further (Fig. 4a and b). The shape of the discontinuity is observed to be quite similar on both HELIOS spacecraft, which were about 0.25 AU distant from each other on a radial line (Schwenn et al., 1977).

According to Burlaga's classification (1968), this TD is of type T3.

For a check, the total pressures (P) just before and after the TD are calculated using preliminary solar wind data (Schwenn, 1977a; Neubauer, 1977).

$$P_1 = N_1\, k(T_1(e) + T_1(p)] + \langle B_1^2 \rangle / 8\pi$$
$$P_2 = N_2\, k[T_2(e) + T_2(p)] + \langle B_2^2 \rangle / 8\pi$$

N, k, $T(e)$, $T(p)$, $\langle B \rangle$ are the number density, the Boltzmann constant, the electron temperature, the proton temperature and the magnitude of the IMF respectively.

Parameters before the TD are marked with index 1, and after the TD with index 2. At the moment, no electron temperature data from H1 and H2 are available, therefore, we assume the following relation between the electron and proton temperatures:

$$T(e) = 1.2\, T(p) \qquad \text{(Burlaga, 1969a)}$$

and we find

for H1 $P_1 = 0.92\, P_2$ and
for H2 $P_1 = 1.3\, P_2$.

These pressures may be considered as equal within the errors of measurements, if we take under consideration that for usual shocks the total pressure in the shocked plasma is an order of magnitude higher than in the unshocked plasma.

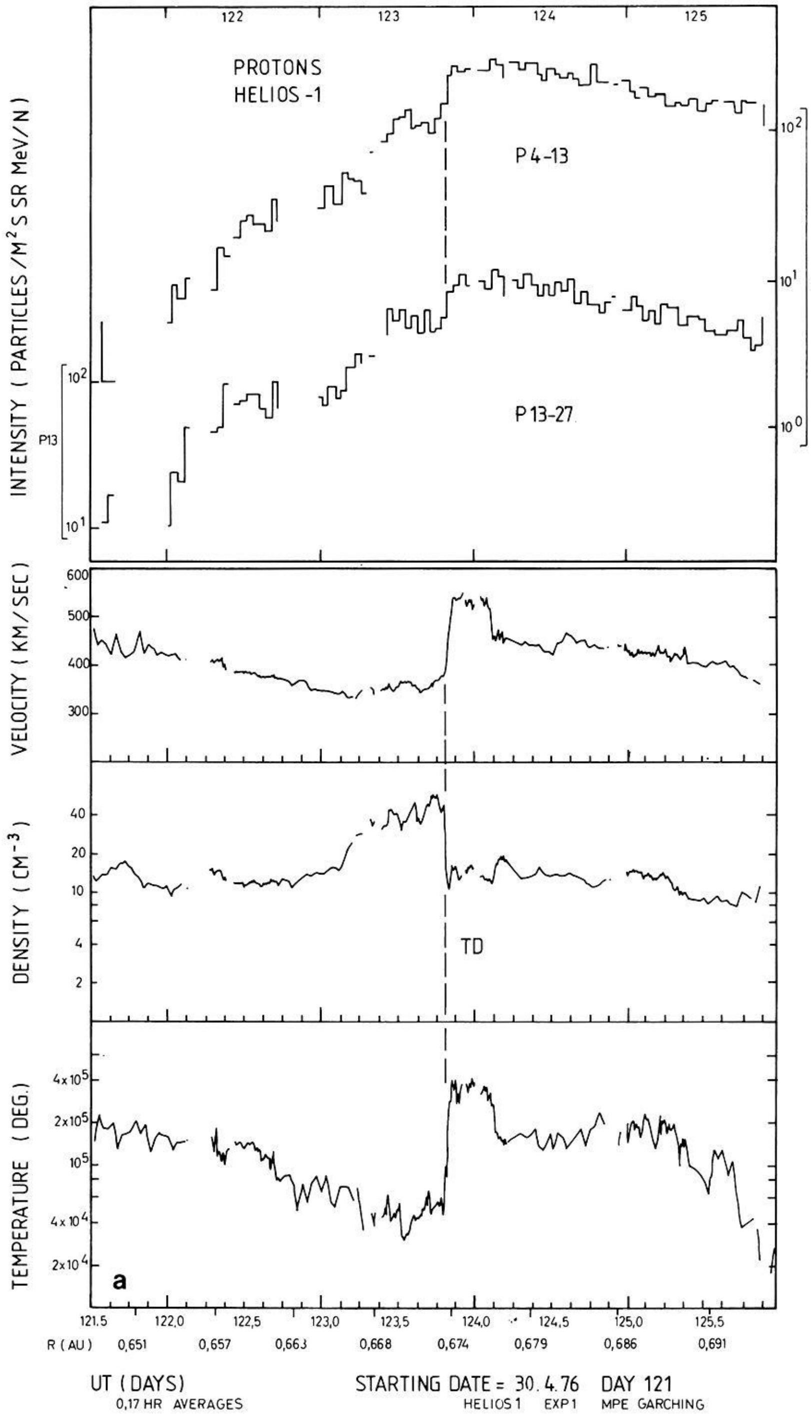
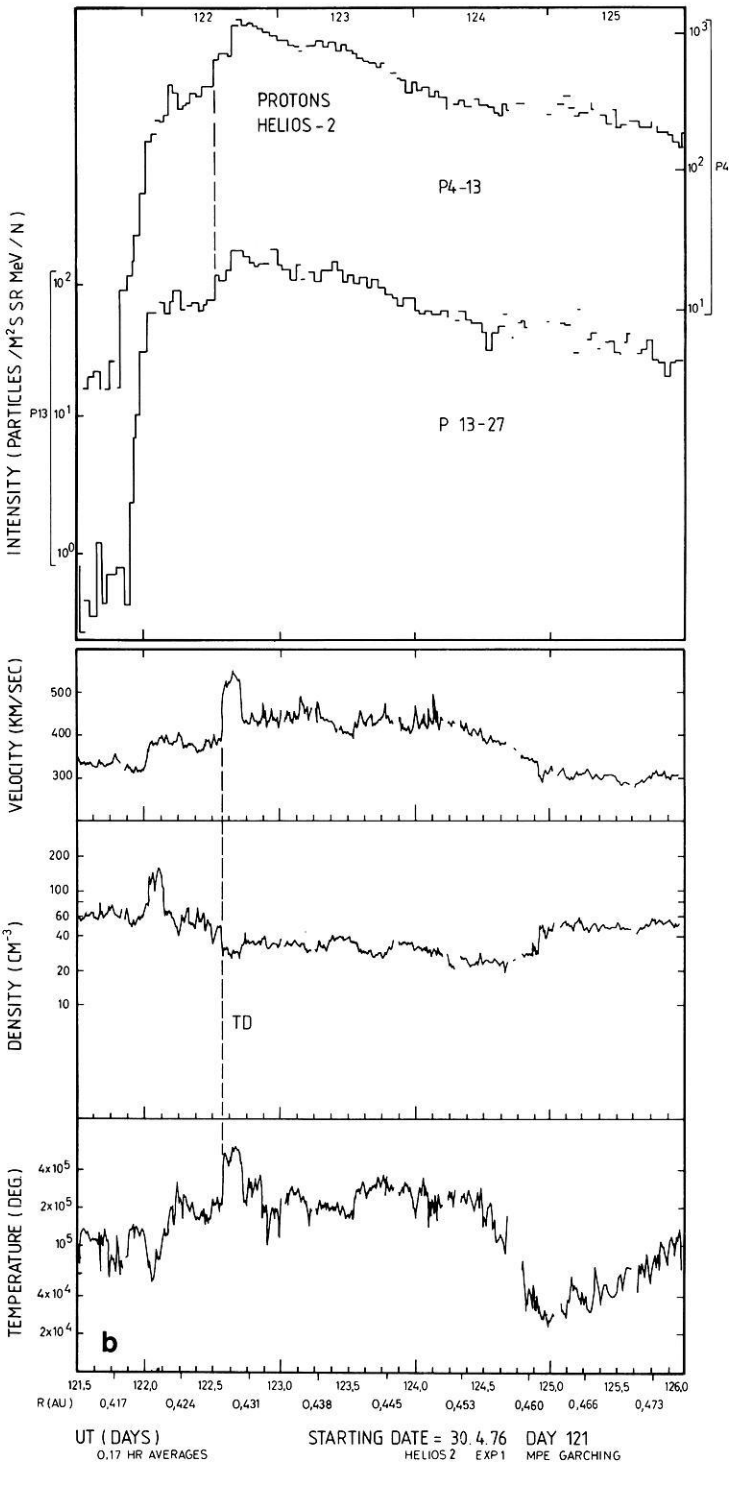


Fig. 4. **a** Solar wind proton parameters measured by HELIOS-1. **b** Solar wind proton parameters measured by HELIOS-2


PROTONS
HELIOS - 2
P4-13
P 13-27
INTENSITY (PARTICLES / M²S SR MeV / N)
VELOCITY (KM/SEC)
DENSITY (CM⁻³)
TD
TEMPERATURE (DEG.)
b
R (AU)
UT (DAYS)
0.17 HR AVERAGES
STARTING DATE = 30.4.76 DAY 121
HELIOS 2 EXP 1 MPE GARCHING

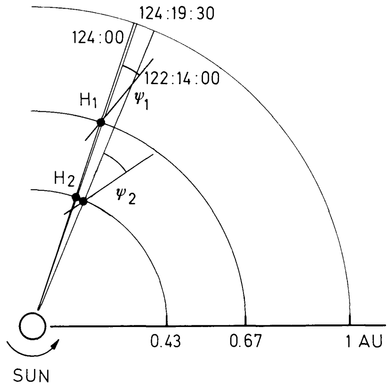


Fig. 5. The calculated angles ψ_1 and ψ_2 of the orientation of the tangential discontinuity detected by *HELIOS-1 HELIOS-2*

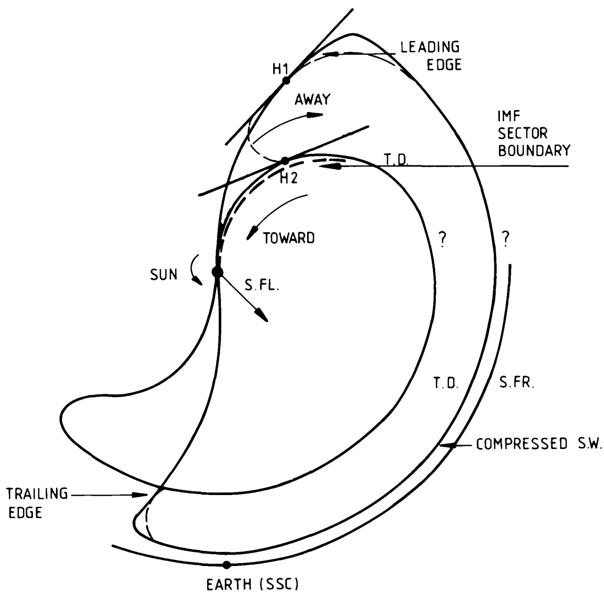


Fig. 6. A possible representation of the corotating structure, the region indicated by questionmarks is not covered by spacecraft that time. The two circumference lines represent the possible spatial structures on day 122 and day 123. The region between the shock front and the tangential discontinuity is the compressed solar wind. The *thin dashed line* indicates the possible large-scale closed magnetic structure

In order to calculate the orientation of the TD surface, we apply the method of Siscoe et al. (1969). Using the solar wind velocity data and assuming no mass flux across the discontinuity, we calculate the angle of the intersection between the surface of the TD with the ecliptic and the sun-HELIOS line (Fig. 5) for both H1 and H2 with the equation:

$$\tan \psi = \Delta V_T / \Delta V_R$$

ΔV_T, ΔV_R, are the variations of the transvers and radial solar wind velocities across the TD respectively. For H1 we obtain:

$$\psi_1 = (20 \pm 7)°$$

and for H2

$$\psi_2 = (34 \pm 10)°$$

According to Siscoe et al., 1968; Burlaga and Ness, 1969a; Burlaga, 1969b; the line formed by the intersection of a TD and the ecliptic plane lies along the spiral field direction.

Before the TD was detected by H2 the IMF changed direction from TOWARD to AWAY from the sun, (Fig. 6). This new sector lasted about 5 days. The time-delay of the sector boundary between the passages at H2 and H1 was about one and half days (Neubauer, 1977), and during this time the earth was in an IMF sector directed TOWARD the sun (SGD, 1976).

The Interplanetary Shock

While no shock indication was found by H1 and H2, IMP-8 observed on May 2 the passage of a shock front simultanously with an SSC, identified by ground based magnetometers, (Fig. 3), (Bame, 1977; SGD, 1976).

Assuming a radial direction of the shock normal, we calculate the shock velocity from the equation of mass conservation:

$$N_1(V_1-U)=N_2(V_2-U)$$

N, V, being the number density, the solar wind velocity, and U the shock front velocity. Indices 1 and 2 indicate the parameters immediately before and after the shock respectively. With:

$$N_1=8\ \mathrm{cm}^{-3}$$

$$N_2=20\ \mathrm{cm}^{-3}$$

$$V_1=600\ \mathrm{km\ s}^{-1}$$

$$V_2=680\ \mathrm{km\ s}^{-1}$$

we obtain for U:

$$U=730\ \mathrm{km\ s}^{-1}.$$

This figure compares well to the mean shock velocity $U_m=900\ \mathrm{km\ s}^{-1}$ (Fig. 2), as calculated from the time difference between the onset of the flare and shock arrival at the earth, since the shock must be expected to have slowed-down at 1 AU, compared to its propagation velocity closer to the sun. (Dryer, 1974).

The Forbush Decrease

Simultaneously, (within measurement accuracy) with the passage of the shock front the onset of a FD occured at 18:30 UT on May 2, about two days after the Ground Level Event.

The solar flare related 10 cm radio wave emission, which generally accompagnies a FD producing solar flares, was of type II and IV (Dodson and Hedeman, 1977).

Discussion

Trying to understand the described event, its following characteristics are to be taken into account:

1. the absence of any shock at HELIOS-1 and -2,
2. the relatively long time (29.5 h) spent by the tangential discontinuity to propagate from *H*2 to *H*1,
3. the occurence of a shock at the earth about the same time which the tangential discontinuity reached H1,
4. the abrupt decrease and the short recovery time of the high-energy cosmic ray particle fluxes, and
5. the orientation of the tangential discontinuity surface.

The abrupt increase of the solar wind velocity and the proton temperature but the decrease of the proton number density detected at H2 and H1 (123:14:00, 123:19:30, respectively, Fig. 4a and b) as well as the lack of any α-particle flux enhancement (due to the piston gas emitted by the solar flare) suggest that at least in the line-up region, shock- or flare material are not found. On the other hand, the abrupt increase of the solar wind velocity, the proton number density, the temperature and the α-particle flux (Armstrong et al., 1977), detected at IMP-8 (123:18:29), as well as the storm sudden commencement detected at ground level (SGD, 1976) support the existence of a shock front and a piston gas at the earth.

According to the spatial separation among IMP-8, HELIOS-1 and HELIOS-2, and the solar flare, it is suggested that the longitudinal extension of this perturbation region was at least 160° wide. Usually, such extension is about 130° wide, (Iucci et al., 1977).

If the shock with such a large width does not extend to the longitudes at HELIOS-1 and HELIOS-2, it should probably be observed close to the heliographic longitude of the flare, rather than far away. In the described event, the position of the earth relative to the flare was much nearer than of H1 and H2, and therefore, the shock has been detected at the earth but not at H1 and H2 region.

Assuming the time at the onset of the flare as zero, we give in Fig. 2 the mean propagation velocity of the tangential discontinuity between H1 and H2.

Surprisingly, the calculated angles ψ_1 and ψ_2 are in disagreement with the rule, according to which the Parker angle increases with increasing radial distance. This fact leads to the conclusion that between HELIOS-1 and HELIOS-2 the interplanetary magnetic field has an unusual shape. Ness (1966) reported a directional discontinuity observed also by two spacecraft, Pioneer-6 and IMP-3, and showed that the observed transit time from Pioneer-6 to IMP-3 was about the time required for an Archimedean spiral line corresponding to a solar wind velocity of 410 km s^{-1} to corotate from Pioneer-6 to IMP-3.

According to the feature of flare-produced interplanetary shock wave, proposed by Hundhausen (1972, p. 192), the region of the compressed ambient solar wind behind the shock is 0.1 to 0.2 AU thick. The following tangential discontinuity that is expected to separate the compressed ambient plasma from the flare ejecta is sometimes followed by a thin shell (0.01 to 0.1 AU thick) of helium-rich material. The same feature we find also here (Fig. 6), where after the shock a helium-rich material is detected by IMP-8 (Armstrong et al., 1977). For the expected tangential discontinuity, which separates the compressed ambient plasma from the helium-rich shell, it is yet not clear if it was detected at IMP-8.

In order to estimate the thickness (D) of the compressed plasma, we consider the onset of the shock (123:17:05), the peak of the α-particle flux observed at IMP-8 (123:24), and the mean solar wind velocity, (700 km/s). Under the assumption that the peak, superimposed on the main increase, is really due to the helium-rich material (Armstrong et al., 1977) we obtain:

$$D \cong 0.1\ \mathrm{AU}.$$

The abrupt decrease of the high-energy cosmic ray particles of about 5% only, and especially the short recovery time (Fig. 3), suggest that the earth was engulfed by the so called 'trailing' edge of a corotative-like modulation region (Iucci et al., 1977). A longer recovery period should be expected if the modulation region would expand only radially. The other edge, called 'leading' edge, considered as the boundary of the modulation, is considered also as corotative, bacause of the relatively long time spent by its passage from HELIOS-2 to HELIOS-1. After the shock, a very low proton temperature region (Gosling et al., 1973; Montgomery et al., 1974; Geranios, 1978) appeared, lasting for about 5 h, and coinciding with the observed Forbush Decrease (Fig. 3). Whether or not, this low temperature region suggests a closed magnetic loop, still remains an open question. For this answer, simultaneous electron temperature and interplanetary magnetic field data are necessary.

During the described event, there were unfortunately no other spacecraft between the lined-up HELIOS-1 and HELIOS-2, and the earth's heliographic longitude, which could complete the observations between 0° and 160°, (Venera-9 and -10 were fairly close to HELIOS-1 and HELIOS-2, Pioneers were in the eastern part of the ecliptic (Hilberg et al., 1977).

Conclusion

All detected enhanced interplanetary parameters obtained from data measured at HELIOS-1, HELIOS-2, IMP-8, and ground level, had a common origin: the 2B solar flare on April 30, 1976. Correlating the data measured at a separation in heliographic longitude at 160° we arrive to the following conclusions:

1. For unusually large modulation regions, the shock characteristics are not extended in the whole region, but only in heliographic longitudes close to the causitive flare. In this described event the shock characteristics were to be seen in a longitude more than 45° and less than 120° relative to the flare site.

2. The tangential discontinuity observed a HELIOS-1 and HELIOS-2, and the Forbush Decrease observed at the earth were of a corotative type.

3. During the corotation, the Archimedean spiral changed its angle in an unexpected way on the way between HELIOS-2 and HELIOS-1. This fact could

signify the detection of the upper part of a 'Wurst-like' magnetically closed region, (dashed line, Fig. 6).

4. If the modulation region is controlled by the tangential discontinuity, 'leading edge' and the Forbush Decrease, 'trailing edge' then, the whole region can be expected to corotate with the sun, (Fig. 6).

Acknowledgements. The author would like first to acknowledge Professor K. Pinkau and Dr. H. Rosenbauer for his stay at Max-Planck-Institut für Extraterrestrische Physik, and Drs. H. Rosenbauer and R. Schwenn for the support with all necessary plasma data from both HELIOS-1 and HELIOS-2 spacecraft.

The author expresses his gratitude to Professor F. Neubauer for the preliminary magnetic field data from HELIOS-1 and -2, to Dr. S. Bame for the plasma data from IMP-8 satellite, and to Professor G. Wibberentz for the permission to reproduce the upper part of Fig. 4a and b.

For final remarks and corrections I am gratefull to Dr. H. Rosenbauer.

References

Agrawal, S., Ananth, A., Bemalkhedkar, M., Kargathra, L., Rao, U.: High-energy cosmic-ray intensity increase of nonsolar origin and the unusual forbush decrease of August 1972. J. Geophys. Res. **79**, 2269–2280, 1974

Armstrong, T., Decker, R., Krimigis, S., Kohl, J.: Solar and interplanetary particles observed in the interval March 20–May 5 with IMP-8. Collected data reports for STIP intervall II, March 20–May 5, 1976, UAG-61, WDC-A, 1977

Bame, S.: Private Communication, Los Alamos Scientific Laboratories, Los Alamos, New Mexico 87544, 1977

Burlaga, L.: Micro-scale structures in the interplanetary medium. Sol. Phys. **4**, 67–92, 1968

Burlaga, L., Ness, N.: Tangential discontinuities in the solar wind. Sol. Phys. **9**, 467–477, 1969a

Burlaga, L.: Directional discontinuities in the interplanetary magnetic field. Sol. Phys. **7**, 54–71, 1969b

Chirkov, N., Novikov, A., Filippow, A., Kuzmin, A., Sergeyer, A., Okara, A., Borisov, V., Sokolova, T.: Solar cosmic ray increase on April 30, 1976. Collected data reports for STIP interval II, March 20–May 5, 1976, UAG-61, WDC-A, 1977

Dodson, H., Hedeman, E.: Overall evaluation of major centers of activity on the solar disc, March 20–May 5, 1976. Collected data reports for STIP intervall II, March 20–May 5, 1976, UAG-61, WDC-A, 1977

Dryer, M.: Interplanetary shock waves generated by solar flares. Space Sci. Rev. **15**, 403–468, 1974

Duggal, S., Pomerantz, M.: Relativistic solar cosmic rays on April 30, 1976. Collected data reports for STIP interval II, March 20–May 5, 1976. UAG-61, WDC-A, 1977

Geranios, A.: A search of the origin of VLETs. Planet. Space Sci. **26**, 571–579, 1978

Gosling, J., Pizzo, V., Bame, S.: Anomalously low proton temperatures in the solar wind following interplanetary shock waves, evidence for magnetic bottles? J. Geophys. Res. **78**, 2001–2009, 1973

Hilberg, R., Teaque, M., Vette, J.: Positions of satellites March 20–May 5, 1976. Collected data reports for STIP interval II, March 20–May 5, 1976, UAG-61, WDC-A, 1977

Hundhausen, A.: Coronal expansion and solar wind. Berlin, Heidelberg, New York: Springer 1972

Iucci, N., Parisi, M., Storini, M., Villoresi, G.: Type IV solar radio burst and forbush decreases. Proc. Int. Conf. Cosmic Rays, Plovdiv **3**, 329, 1977

Kunow, H., Müller-Mellin, R., Iwers, B., Witte., M., Hempe, H., Wibberenz, G., Green, G., Fuckner, J.: MeV protons, alpha particles, and electrons as observed aboard HELIOS 1 and 2 during STIP Interval II. Collected Data Reports for STIP Interval II, UAG-61, WDC-A, 1977

Mihalov, J., Golburn, D., Collard, H., Smith, B., Sonett, C., Wolfe, I.: Pioneer solar plasma and magnetic field measurements in interplanetary space during August 2–17, 1972. Correlated

Interplanetary and Magnetosphere Observation. Saulgau, W. Germany: Proc. ESLAB Symp. 1973

Montgomery, M., Asbridge, J., Bame, S., Feldman, W.: Solar wind electrons temperature depression following some interplanetary shock waves: Evidence for magnetic merging? J. Geophys. Res. **79**, 3103–3110, 1974

Ness, N.: Simultaneous measurements of the interplanetary magnetic field. J. Geophys. Res. **71**, 3319–3324, 1966

Neubauer, F.: Personal Communication. Braunschweig: Technische Universität 1977

Pomerantz, M., Duggal, S.: Interplanetary acceleration of solar cosmic rays to relativistic energy. J. Geophys. Res. **79**, 913–919, 1974

Schwenn, R., Rosenbauer, H., Mühlhäuser, K.: The solar wind during STIP II interval: Stream structures, boundaries, shocks, and other features as observed by the plasma instruments on HELIOS-1 and HELIOS-2. Tel Aviv: STIP II. 1977

Schwenn, R.: Private Communication. Garching F.R.G.: Max-Planck-Institut für Extraterrestrische Physik 1977a

Shea, M.: Overview of solar-terrestrial physics phenomena for the retrospective world interval of March 20–May 5, 1976. Collected data reports for STIP Interval II, March 20–May 5, 1976, UAG-61, WDC-A, 1977

SGD.: Solar geophysical data, 380, 381. Part I: April, May, June, July 1976. Boulder, Colorado, USA: U.S. Department of Comerce 1976 p. 80302

Siscoe, G., Davis, L., Coleman, P., Smith, Jones, D.: Power spectra and discontinuities in the interplanetary magnetic field: Mariner 4. J. Geophys. Res. **73**, 61–82, 1968

Siscoe, G., Turner, J., Lazarus, A.: Simultaneous plasma and magnetic-field measurements of tangential discontinuity in the solar wind. Sol. Phys. **6**, 456–464, 1969

Tanskanen, P., Kananen, H., Blomster, K.: Observations relevant to the August 1972 Storm. Collected data reports on August 1972. Solar-terrestrial events, UAG-28, WDC-A, 1973

Received June 1, 1979; Accepted July 4, 1979