PROPOSAL FOR AN INTERPLANETARY MISSION TO SOUND THE OUTER REGIONS OF THE SOLAR CORONA

H.Porsche[1], H. Volland[2], K. Bird[2] and P. Edenhofer[3]

1 Deutsche Forschungs- und Versuchsanstalt für Luft- & Raumfahrt e.V. Forschungszentrum Oberpfaffenhofen, D 8031 Wessling
2 Institut für Radioastronomie der Universität Bonn, D 5300 Bonn
3 Institut für Hoch- und Höchstfrequenztechnik der Ruhr-Universität D 4630 Bochum
Federal Republic of Germany

The mission of HELIOS had been started in order to investigate in situ the innermost regions of the interplanetary space. The two spacecraft achieved a perihelion of about 0.3 AU solar distance. Fig. 1 is a sketch of the two orbits. The orbital periods are 190 resp. 186 d.

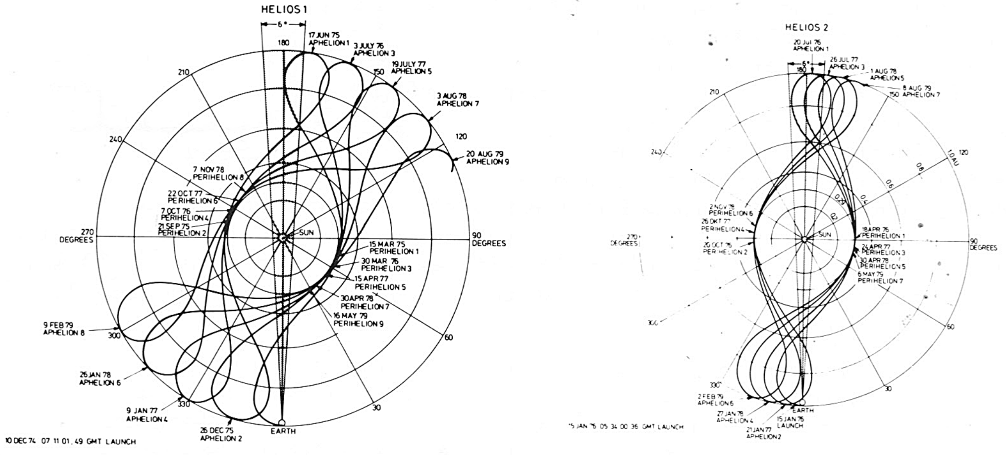


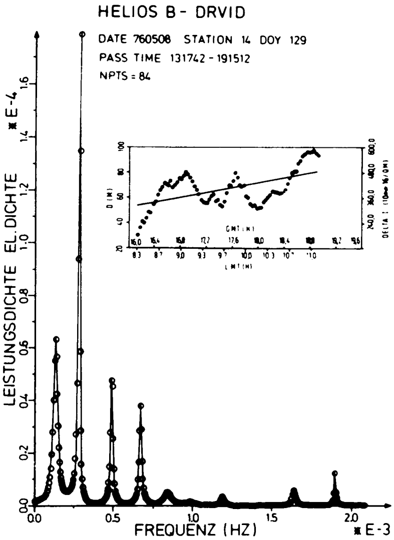
Fig. 1: Orbits of HELIOS 1 and HELIOS 2

This is pretty close to a half-year orbit (182.6 d). Therefore, the spacecraft are standing in and near outer conjunction for a relatively long time. Even now, almost five years after launch of HE1, each of the two spacecraft is running through a blackout in outer conjunction once a year. This is a reason of undesired data loss. On the other hand, however, this constellation gives the opportunity to investigate Sun's corona by sounding using radio science means, i.e. evaluation of polarization, of signal propagation time, of Doppler shift, of spectral line width, etc. (1,2,3,4). It is possible thus to measure the electron content, from which

M. Dryer and E. Tandberg-Hanssen (eds.), Solar and Interplanetary Dynamics, 541-545.

normally the electron density distribution can be deduced, the velocity and the size of transients travelling through the field of view (5), the magnetic field distribution, density waves, etc., i.e. many characteristics of the corona which define the source conditions of the interplanetary plasma farther out. As an example Fig. 2 gives the frequency spectrum of a pass, as it has been deduced by Edenhofer et al. (3).

Fig. 2: Example of a power density spectrum of the electron density fluctuations during DRVID-Pass abscissa: frequency (mHz)



The HELIOS corona sounding experiment did unfortunately not perform as we had desired. In general the ground stations are overloaded with projects. Therefore the number of long passes of big ground stations was small, in spite of relatively good coverage. Short passes have turned out to be of little value for part of these investigations. Moreover after 18 months of operation of HELIOS 1 the transponder failed. The analysis of the failure resulted in suspecting a certain IC to operate insuffifiently. As a consequence the transponder on HELIOS 2 was also turned down in order not to jeopardize the spacecraft. This all together may be considered as only a partial success of the corona sounding experiment on one side; on the other side it showed that radio science methods are well suitable and powerful tools to investigate Sun's corona, especially those regions which neither can be observed optically nor by in situ experiments out to say 20 R_O. Data of the plasma behaviour out of that region are urgently needed, however.

A proposal is given here, how to overcome this difficulty. For a detailed and thorough investigation of the corona by sounding, a spacecraft is needed which is standing near outer conjunction for a long time. This condition is fulfilled for a spacecraft on earth-orbit, but orbiting the Sun near the opposite side of the sun, i.e. near outer conjunction. However such a spacecraft would either never be seen from Earth, if it is standing exactly in conjunction, or it would stand at the same point forever, if it is shifted a little bit to the west or east of the Sun. I disregard orbit perturbations (etc) which obviously would lead to orbit changes.

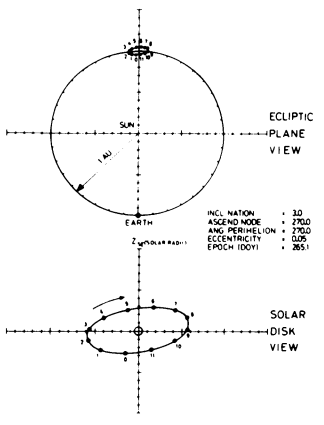
Consider now a spacecraft on an orbit with major axis equal to that of the Earth, but at a slightly larger eccentricity near outer conjunction. This spacecraft would oscillate between two points west and east of the Sun. The period would be exactly one year. The amplitude of the oscillation depends on the eccentricity of the orbit. Thus one would

https://doi.org/10.1017/S0074180900068078 Published online by Cambridge University Press

be able to sound the corona in or near the ecliptic plane. The blackout periods would be short compared to the whole mission time, i.e. of the order of a few days each.

The next step would be the extension of the mission to high solar latitudes by giving the orbit not only an eccentricity but also a small inclination. Depending on the phase angle one can end up in an orbit virtually surrounding the Sun in a short angular distance. Fig. 3 is a plot of such an orbit.
The real period as well as the virtual period is exactly one year, i.e. it takes one year to travel from the north pole of the Sun to the south and back. Thus not only equatorial regions of the corona can be sounded, but also high solar latitudes including the polar regions.

Fig. 3: Suggestion for an orbit of a Coronal Sounding Probe



This might be of a special interest during that period, when ISPM is in its primary mission. One of the two ISPM-probes will run from north to south, the other one vice versa. The travel time from the first polar passing to the next will be about 200 d. This is in fairly good agreement with the 182.6 d of the coronal sounding mission. Thus the proposed mission could be understood as directly correlating with ISPM. A linear or a near-linear alignment would occur at the polar crossings. In between ISPM and Corona Sounding Mission are almost on the same latitude but shifted a few degrees in longitude.

Unfortunately it is not possible to arrive at the desired orbit without maneuvering. There are a few transfer orbit options. The transfer time is either about half a year or about 1.5 or 2.5 years (Hohmann transfer). The 2.5 y transfer needs least maneuvering power. This would fit very well into a time frame in accordance with ISPM, having a transfer time of about 3.5 y between launch and first solar polar passing. At least 1 y between the launch of ISPM and Corona Sounding Mission would be left for the preparation of the latter.

The scientific objective of the Corona Sounding Mission is of course the investigation of Sun's corona.
1. Faraday rotation: Linear polarization of S-band and X-band links allow the determination of $\varphi \approx \int \vec{B} . n_e . d\vec{s}$ to an accuracy of better than 1 angular degree and a time resolution of better than 1 second. Typical coronal oscillations of the order of some mHz may be expected. Therefore the consecutive pass length should be of the order of 20 h, preferably continuous over periods of several days. Special attention must be given to observe transients in those regions which correlate with ISPM and where the boundaries between fast and slow solar wind regimes may be expected.

https://doi.org/10.1017/S0074180900068078 Published online by Cambridge University Press

2. Ranging: Determination of the signal propagation time between spacecraft and ground station in S-band and X-band. Plasma influences as well as gravity effect delays have to be considered. The plasma-generated time delay is a measure of the electron content between transmitter and receiver. The achievable time resolution is of the order of some 10 min. By comparison of two frequencies plasma- and gravity contributions to the time delay can be separated.
3. Range rate (Doppler): In addition to the determination of the relative velocity of transmitter and receiver the Doppler shift of the transmitted frequencies depends on the electron density between transmitter and receiver. It influences the phase velocity of the wave. Therefore the Doppler shift is a sensitive indicator for changes in electron density anywhere along the ray path of the wave, especially in the corona at high time resolution (better than 1 sec).
4. DRVID (Differentiated Ranging Versus Integrated Doppler): This is a combination of phase- and group-velocity measurement. It determines the electron content between transmitter and receiver.
5. Linewidth determination: The line width of the received signals comprises information about the dynamical state of the matter between transmitter and receiver, i.e. about turbulences etc.

All those data include local information of the observed transients. It can be extracted by correlation methods. Thus such a mission is able to give a comprehensive review of the state and of the dynamical behaviour of the corona. It is obvious that the spacecraft can additionally be equipped with in situ experiments or with experiments to observe the Sun optically (spectroheliograph,coronagraph, etc.) to become a solar-backside probe.

References:

1 H. Volland, M.K. Bird, G.S. Levy, T.C. Stelzried and B.L. Seidel HELIOS 1 Faraday Rotation Experiment: Results and Interpretations of the Solar Occultation in 1975; J.Geophys. 42, 659, 1977

2 P. Edenhofer, P.B. Esposito, R.T. Hansen, E. Lüneburg, W.L. Martin and A.I. Zygielbaum, Time Delay Occultation of Data of the HELIOS Spacecrafts and Preliminary Analysis for Probing the Solar Corona; J.Geophys. 42, 673, 1977

3 P. Edenhofer, M.K. Bird and H. Volland, Comparison of Time Delay and Faraday Rotation Measurements from HELIOS Spacecraft; Kleinheubacher Ber. 21, 305-312, 1977 and H. Süss, Privat Communication

4 R. Woo, Radial Dependence of Solar Wind Properties Deduced from HELIOS 1 and 2 and PIONEER 10/11 Radio Scattering Observations, Astroph. J. 219, 727, 1978

5 E. Lüneburg and P.B. Esposito, A Method for the Evaluation of Solar Coronal Plasma Propagation Speeds by Radio Occultation of Space Probes; Nat. Radio Sci. Meeting, U of Washington, Seattle, Wash. 18 - 22 June 1979, p. 284 and JPL - Engineering Memo 315 - 90, 1979

DISCUSSION

Bratendal: Do we need Venus or some other clever scheme to inject into earth orbit in opposition?

Porsche: The spacecraft needs a motor for orbital corrections, but no swingby maneuver at a planet to achieve the desired orbit and position in superior conjunction.

https://doi.org/10.1017/S0074180900068078 Published online by Cambridge University Press