10. Solar Wind Plasma Structure near a "HELIOS-Perihelion"

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On December 10, 1974, the solar probe "HELIOS-A" was launched into an ecliptic orbit around the sun under a German-American cooperative project and another solar probe "HELIOS-B" was on a separate but similar orbit on January 15, 1966. Both probes are working very well and are transmitting various kinds of wealthy data. Direct measurements near the sun as close as 0.3 AU in perigie will make an epoch in solar physics, so far based on indirect measurements on the ground and from satellite near the earth. The present purpose is to introduce a couple of preliminary but important results obtained from HELIOS concerning solar wind plasma structure near a "HELIOS-Perihelion" among data analyses in progress, partly in relation to laboratory plasmas.

1. Relation to Coronal Holes

Fig. 1 summarizes idealized profiles based upon correlative plasma measurements from the satellite IMP-7/8 and the solar probe HELIOS-A as well as the K-coronal intensity measurement.[1,2] Upper three panels represent solar wind bulk velocity, density and temperature profiles near 0.3 AU, and the lowest panel shows latitudinal and longitudinal distributions of coronal holes. Accordingly, one can infer solar latitudinal distributions for the upper three quantities but indirectly.

During 1974-1976, the sun was in the period of declining cycle and the coronal holes had expanded to lower latitudes from northern and southern holes, approaching and crossing the solar equator. Fig. 1 is idealized profiles for this period, and the northern and southern coronal holes exhibit positive and negative polarities in general, respectively. Each region is nearly symmetric to other region of coronal holes with respect to the equator apart from a longitudinal shift. Most of northern coronal holes tend to locate within a half width of 30° - 45° around 270° in solar longitude and the southern coronal hole tends to locate within 40° - 45° around 120° in longitude. There is a general tendency that the northern coronal hole is somewhat larger than the southern coronal hole. Consequently, coronal holes are the polar cap regions beyond 40° in latitude over a whole range of longitudes. These holes tend to penetrate towards lower latitudes uniformly over a range of approximately 90° in longitude during the period of declining and minimum phase of solar cycles and tend to exceed the solar equator as much as 20° in latitude.

In regard to solar wind velocity, there are two fast stream regions as high as 800 km/s in velocity. These fast streams are injected from coronal holes that are composed of a rarefied plasma as low as $10/cm^3$ and are lower in density by one order of magnititude than the background plasma of $100/cm^3$, accordingly exhibiting low density character of coronal holes. Based upon "SKYLAB" observations, the temperature of coronal holes is normally thought to be fairly lower than that of the background plasma. From HELIOS data, however, such a tendency can not be identified for the region of 0.3 AU as far as available data are concerned.

2. "Beam", "Core" and "Halo" Electrons

Fig. 2 represents an electron spectrum measured near a HELIOS-Perihelion (0.3 AU, March 15, 1975) approximately in the solar direction. One can distinguish three regions in velocity distribution with two boundaries of 1,000 km/sec. (2.8 eV) and 5,700 km/sec. (92.4 eV):

(I) Photo electron : $E < 2.8$ eV,

(II) Core : $2.8 \text{ eV} < E < 92.4$ eV,

(III) Halo : $E > 92.4$ eV.

In the region (I), photo electron spectrum exhibits a maximum and arises from photo electron emissions of the spacecraft due to the solar UV irradiation. Therefore, this region is not a component of background plasmas. The core region forms a cold component trapped by magnetic lines of force and represents a principal part of the electron distribution of thermal plasma characterized by a Bi-Maxwellian distribution. This component is, however, not directly related to the "beam" or "strahl" which is a manifestations of medium energy electrons elongated in the anti-sunward direction along the magnetic field. The Halo component is composed of a hot plasma with high-energy tail and can be regarded as a component composed of escaping or scattered electrons. Its formation mechanism is not clear at the present stage. From laboratory experiments on charged-particle beams in plasmas, we have also found the component of a high-energy tail corresponding to the halo region.[3] Therefore, one can infer that its formation mechanism seems to resemble that for the solar wind plasmas.

Fig. 3 represents a density contour of solar wind electrons in velocity space for the case when the magnetic field direction is close to the plane of observation. Narrow beam-like characteristics along a magnetic field direction appear to be remarkable for the intermediate range of energy, 50 eV - 300 eV within the halo region. For a photo electron region below about 3 eV and a halo region beyond 300 eV, beam characteristics tend to be lost and are converted to isotropic characters. When the magnetic field direction is oblique nearly perpendicular to the plane of observation, a density contour exhibits an isotropy in electron velocity without beam-like characters. Accordingly, beam characteristics are thought to appear for medium energy electrons along the magnetic field direction.

The writer expresses his sincere thanks to Dr. H. Porsche for making HELIOS data available.

References

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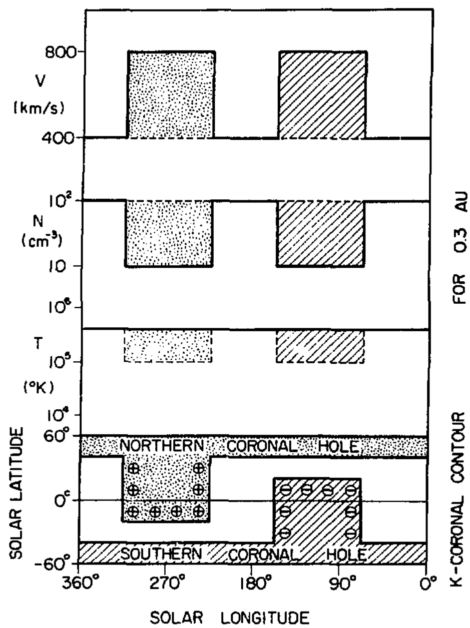

Fig. 1. Idealized profile of solar wind bulk velocity, density and temperature near 0.3 AU as deduced from HELIOS A data and correlated K-coronal contours.

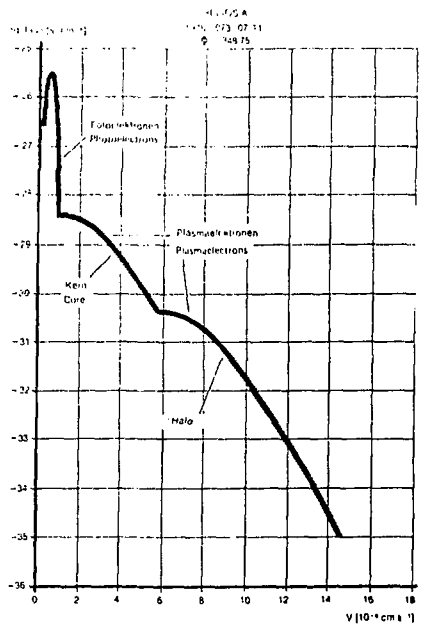

Fig. 2
An electron spectrum measured near a HELIOS-perihelion (0.3 AU) approximately in the solar direction.

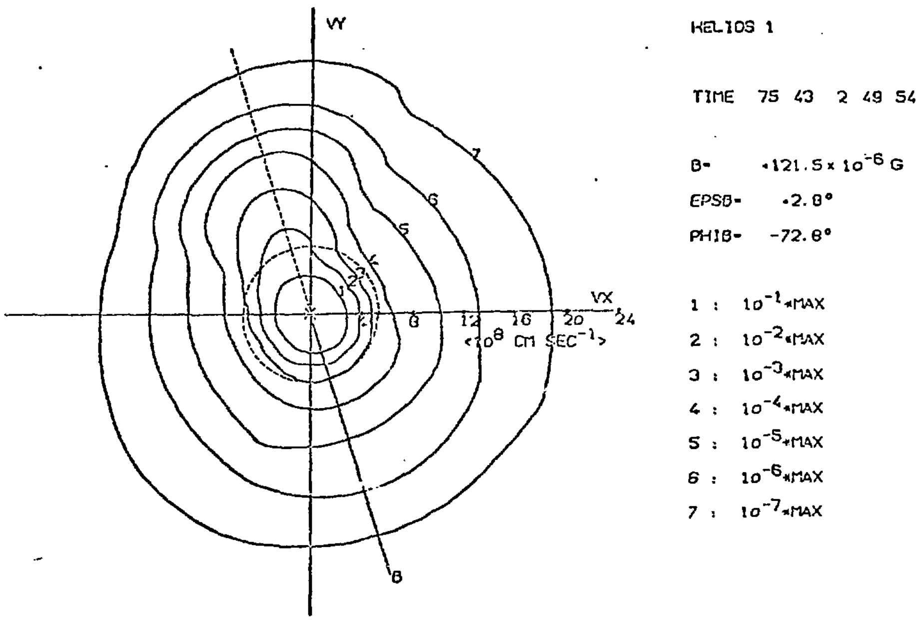

Fig. 3. Density contours of solar wind electrons in velocity space exhibiting a narrow "beam" of electrons in the magnetic field direction close to the plane of observation.