Solar wind

Note
This page covers both the solar wind and the interplanetary magnetic field (IMF) it carries with it.

Introduction

The concept of continuous solar wind developed in 1950's. First, Biermann (1951, 1957) observed comet tails as they passed close to the Sun, and explained the observed tail deflection by a continuous flux of protons from the Sun. Then Parker (1959) showed that the solar corona must expand, and called the outward streaming coronal gas 'solar wind'.

The outermost region of the Sun, corona, is indeed very hot, so hot that the hydrogen and helium can escape gravitational attraction and form a steadily streaming outflow of material called the solar wind. Because of its high temperature and constant illumination by the Sun, solar wind is fully ionized plasma. Furthermore, because of the heating, compression, and subsequent expansion, the solar wind becomes supersonic above a few solar radii. At Mercury, the solar wind Mach number is about 3, while at the outer planets, Mach number can be 8 and above.

The expanding solar wind drags also the solar magnetic field outward, forming what is called the **interplanetary magnetic field** (IMF). The region of space in which this solar magnetic field is dominant is called the heliosphere. Although the solar wind moves out almost radially from the Sun, the rotation of the Sun gives the magnetic field a spiral form (garden hose effect). At the orbit of the Earth the angle between the field lines and the radial is about 45 degrees. Furthermore, sectors (typically four) with alternating inward and outward directed magnetic fields can be identified.

Characteristics

Parameter	Minimum	Average	Maximum
Flux (cm^-2^{s}-1^)	1	3	100
Velocity (km/s)	200	400	900
Density (cm^-3^)	0.4	6.5	100
Helium %	0	5	25
B (nT)	0.2	6	80

The solar wind plasma consist of primarily of hot electrons and protons with a minor fraction of He2+ ions and some other heavier ions (typically at high charge states). The table lists the basic solar wind characteristics.

The solar wind originating from the streamers (closed field lines) is slow, while that originating from the coronal holes is fast. This creates the so-called "corotating interaction regions" (CIR) in the interplanetary space. As the solar wind moves away from the Sun, tangential discontinuities and interplanetary (fast) shocks are formed, creating pressure variations.

In addition, the variables shown in the table are functions of solar latitude: for example, density is at maximum, speed at minimum around the equator (Kojima and Kakinuma, 1990; Rickett and Coles, 1991). However, the hemispheres are not exactly symmetric (see the annual variability of geomagnetic activity).

Typical periodicities in the solar wind can be divided into those that reflect the time scales of the solar processes themselves, those that reflect the rotation of the Sun, and those that reflect the orientation of Earth (the most typical observation point) with respect to the Sun. The first include the 11- and 22-year solar cycles and the 1.3 year and 154 day cycles. Others will be discussed in the geomagnetic activity section (see also below).

Scale sizes

The scale sizes of solar wind/IMF structures is typically smaller than the extent of the Earth's magnetosphere (about 40 Re; see, e.g., Russell et al., 1980; Crooker et al., 1982). Collier et al. (AFU Fall Meeting 1998) suggest that IMF has two length scales. The first is a few tens of Re and represent the scale over which changes in B are observed at multiple satellites. The second scale length of order of a couple hundred Re may present the characteristic radius of curvature in IMF structures.

Effects on Earth and other planets

All planets are surrounded by the hot, magnetized, supersonic collisionless solar wind plasma capable of conducting electrical current and carrying a large amount of kinetic and electrical energy. Due to the supersonic nature of the solar wind, shock waves are formed in front of the planets (see bow shock). Some of the solar wind energy finds its way into the Earth's magnetosphere, ionosphere and atmosphere, and

- drives the magnetospheric convection system via the electric field it creates, and energizes much of the plasma on the Earth's magnetic field lines

- drives field line resonances and other geomagnetic pulsations
- creates geomagnetic activity
- heats the polar upper atmosphere
- drives large neutral atmospheric winds

Because of these effects, the changes in the solar wind plasma parameters (density, velocity, etc.) and IMF (especially direction in relation to Earth's own field) are very important for magnetospheric and ionospheric physics, and the scientific community tries to have continuous monitoring of these parameters via satellites like IMP-8, ISEE, and Wind. However, there are difficulties, because there is - at any given time - at most two or three satellite within the solar wind (quite often none at all), and the solar wind/IMF system is not homogeneous, as discussed above. See also the discussion about substorm triggering.

Solar wind event categories

Solar wind event categories:

Code	Description
BzN	Strong northward Bz for extended period
BzS	Strong southward Bz for extended period
CME	Coronal Mass Ejections
EyC	Change in **E**y=**V**x**B**z
HSS	Very high speed stream for extended period
IMC	Interplanetary magnetic cloud
IR	Interaction Region
IS	Interplanetary shock
LSS	Very low speed stream for extended period
MISC	Miscallaneous
PC	Pressure change
SBC	Interplanetary sector boundary crossings

Changes in solar wind characteristics, so called solar wind events, can be categorized in several groups (see, e.g., ISTP Solar Wind Catalog).

References

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