Interplanetary Coronal Mass Ejections During 1996 - 2007

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Interplanetary coronal mass ejection (ICME) driving an upstream shock.
Many signatures of ICMEs
e.g., Zurbuchen and Richardson [2006] list 23!

In recent studies, we have compiled a “comprehensive” list of ICMEs at Earth since 1996 based predominantly on anomalous features in solar wind plasma, field and composition measurements.

(Current list is available on request from the authors.)
• We will:

• Summarize some of the properties of the ~300 ICMEs detected at 1 AU since 1996;

• Apply similar methods to Ulysses observations and obtain a preliminary ICME list (to add to others e.g., by Reisenfeld and Gosling, Lui et al., etc).
Example of an ICME at 1 AU preceded by a shock
ICME Signatures include:

- Bidirectional 0.5-4 MeV ion flows;
- Organized magnetic field;
- Low solar wind proton temperatures;
- Declining $V_{\text{sw}}$ profile;
- Cosmic ray Forbush decrease;
- Enhanced solar wind ion charge states (e.g., O, Fe)
Ulysses: Solar Rotation interval in November-December, 2001
(~2 AU, ~80°N)
Two clear ICMEs in high-speed, high latitude solar wind.

ICME signatures include: magnetic field, low proton temperatures, enhanced O⁷/O⁶, C⁶/C⁵, Fe/O, <Q_{Fe} >.
ICME Properties, 1996-2007

- ICME rate has nearly returned to that during the previous solar minimum;
- ICME rate does not strictly follow the sunspot number;
- Increasing trend in fraction of magnetic clouds?
- Mean ICME speeds are highest during declining phase of this solar cycle.
- ICME rate at Ulysses is comparable to that at Earth (~2/rotation), despite the variations in s/c latitude.
ICME Rates (3-Rotation Running Averages) at Ulysses and Earth

Ratio Ulysses/1AU ICME Rates vs. Ulysses Latitude, 1996-2001

Similar rates at low latitudes <~40°

Separate population of high-latitude ICMEs?

(Related to high latitude CMEs at the Sun?)
Summary

• Around 300 ICMEs have been identified in the near-Earth solar wind since 1996;

• ICME rates at 1 AU are approaching those of the last solar minimum, and the fraction of MCs may be increasing again;

• Ulysses and 1 AU ICME rates are typically comparable (see also, Riley et al. [2006]);

• There is an indication of a high-latitude ICME population unrelated to those at low latitude.