How are the present solar minimum conditions transmitted to the outer heliosphere and heliosheath?

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Heliosphere Overview

Heliopause: boundary of LIC and SW plasma

Termination shock: transition of SW from supersonic to subsonic

Bow shock? If LIC is supersonic, it changes to subsonic

Mueller et al.
V1 crossed TS in 2004 at 94 AU at 33 deg N

V2 crossed TS in 2007 at 84 AU at 27 deg S

HP distances from Opher et al.
Voyager observations: 2 points (1 for plasma)  
(IBEX will provide 3-D map of neutral atoms,  
first heliosphere map released next month)

Solar wind environment at solar minimum affected by

1) solar source (flux and magnetic field decrease)

2) current sheet tilt - higher than usual  
   (latitudinal gradients)

3) Transition from low to high speed wind; higher  
   latitude and more extended

4) boundary motions: TS and HP move inward

5) less solar activity
|B| and P similar before TS

GCR intensity higher at V2
Solar minimum: rapid transition from slow to fast wind.

Dipole tilt causes boundary to change as Sun rotates.

Expect transition region to thicken with distance.

We can look at previous solar minima
Solar Minima: Speed a function of heliolatitude
Not seen at current solar minimum before TS crossing
V2 crosses the TS in Aug. 2007 at 84 AU

- V2 TS Overview
- Speed decrease starts 82 days (0.7 AU) before TS
- Crossing clear in plasma data
- Flow deflected as expected
- Crossing was at 84 AU, 10 AU closer than at V1
- New region of space - makes sorting out solar cycle effects difficult.

Richardson et al., 2008
1 AU and V2 flux comparable until ~60 days before TS.
V2 flux decreases ~30% before TS.
V2 flux decreases faster than 1 AU flux in heliosheath.
PROBLEM : Flux decrease before TS
Possible solution: V2 in transition region from low to high speed wind.

Supporting evidence:
1) Ulysses flux decrease at \(~V2\) heliolatitude.
2) V2 flux decreases to Ulysses level.
3) Speeds higher than expected in V2 HSH.

Note: Ulysses at 1 AU flux during fast latitude scan.

Problems: V1 should also be in high speed wind?
Speed and flux observed by Ulysses in 2006 (fast latitude scan).

Speed decrease starts at higher latitude than flux change.
What speeds do we expect in HSH?

Model (Pogorelov) 4 $\mu$G, field in HDP, tilted 30° from ecliptic plane

• $V_R$ decrease
• $V_1 V_R \sim V_2 V_R$
V1 speeds determined from keV ions using Compton-Getting effect.

VR decreases from 90 to 20 km/s.

VT constant. (Decker)

V2 VR twice as fast.
V2 Heliosheath data, plasma experiment)

V constant

N and T down a factor of 2

flow angles increasing

Combined result of source, boundary motion, and evolution in heliosheath

PROBLEMS:

V2 > V1

V2 ~ constant
• V1 and V2 speeds from different instruments; does this cause speed differences?
  • NO
  • $V_R$, $V_T$ LECP and PLS values agree on V2
  • V1 and V2 speed difference real
  • SOLUTION? V2 crossing transition region
Normalize time-shifted fluxes at TS.

V2 fluxes decrease faster than 1 AU fluxes.
Why a larger flux decrease at In HSH than at 1 AU?

Flux moving around Heliosphere?

Can compare radial flux into HSH to flux out sides of HSH, But need to know how deep V2 is in HSH (how far TS has moved inward.)
TS distance from Wang model (normalized to V2 TS crossing at 84 AU) and SW pressure at 1 AU.

TS responding to pressure change in 2009, by mid-2009 it was at ~80 AU
Why a larger flux decrease at In HSH than at 1 AU?

Flux moving around Heliosphere?

Outward flux at TS $5.6 \times 10^{28}$

$V_2$ $45^\circ$ from nose, TS at 84 AU, N and V at TS.

Sideways flux $1 \times 10^{27}$ ($V_2$ 10 AU into HSH width, observed V and N): 18% of flow moves out sides, ~20-25% flux reduction observed
Ancient Heliospheres

Can estimate past TS distances based using empirical relations between solar wind pressure and aa index.

Current distance is lowest in past 70 years, but smaller heliospheres were common before 1930.
Solar wind pressure changes versus solar cycle.

Pressure minima at solar maxima, then factor of 2 increase in 1-2 years, then slow decrease.

Current pressure minimum is at solar minimum; pressure should keep decreasing.

TS and HP shrink.
Summary

1) HSH data reflects solar source changes (30% flux decrease, B decrease)

2) HCS tilts (which are unusually high) affect V2 observations; high V2 speeds and low fluxes suggest V2 transitioning to high-speed flow.

3) Low SW pressure causes TS and HP to move inward; the decrease in flux in HSH may result from flow down heliotail and occur sooner than expected due to V2 being deeper into HSH than expected.

4) Heliosphere small by recent standards, but not by historical measures. But may shrink more based on recent SW pressure profiles.