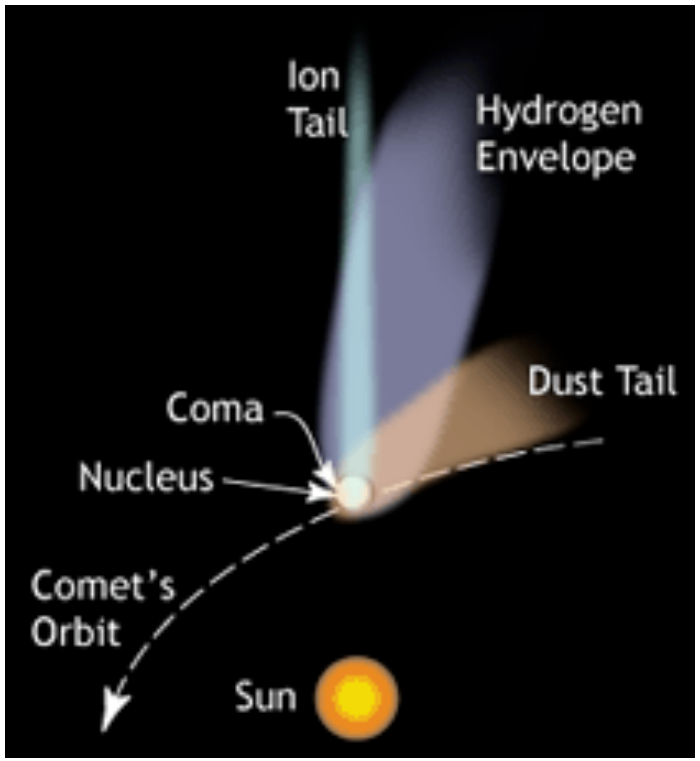
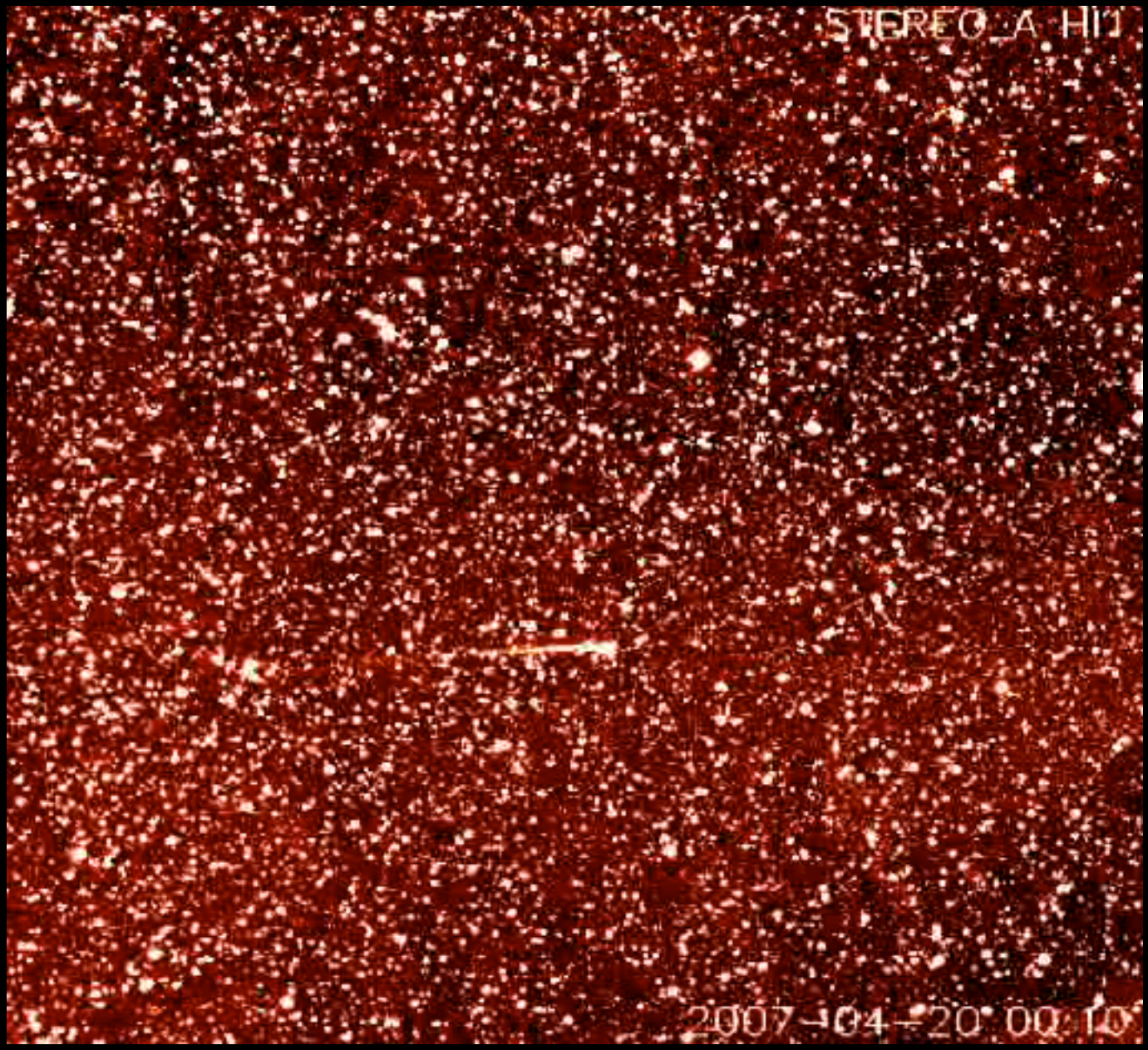
Evidence of Solar Wind: Comets



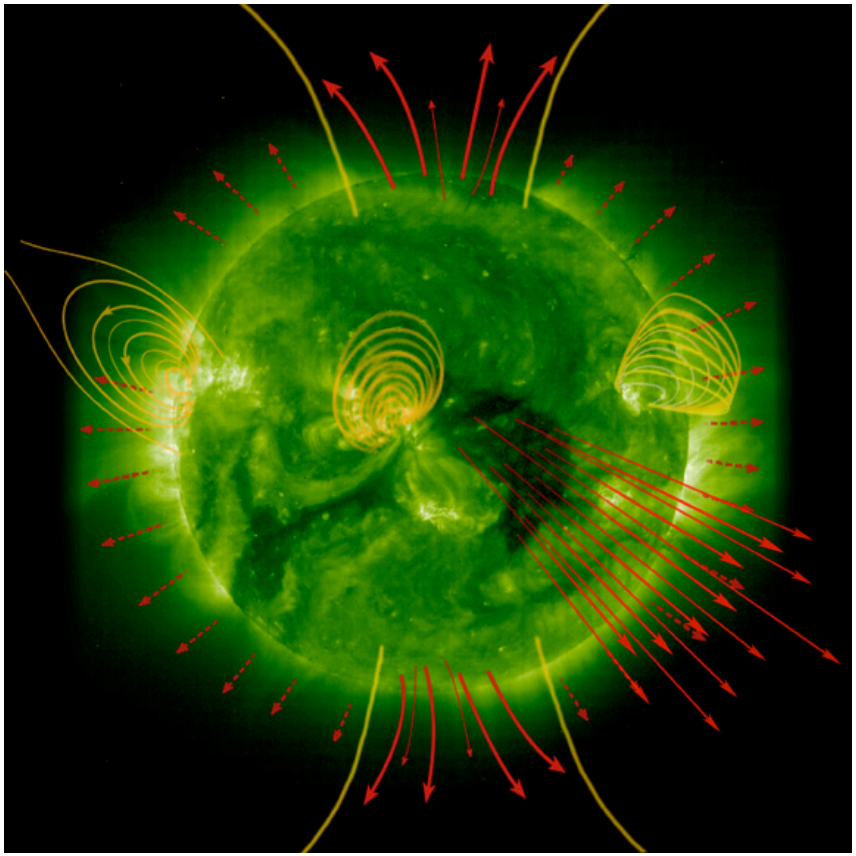
Solar wind ripping off the tail of a comet



Slow Solar Wind

Slow Solar Wind (dotted red lines)

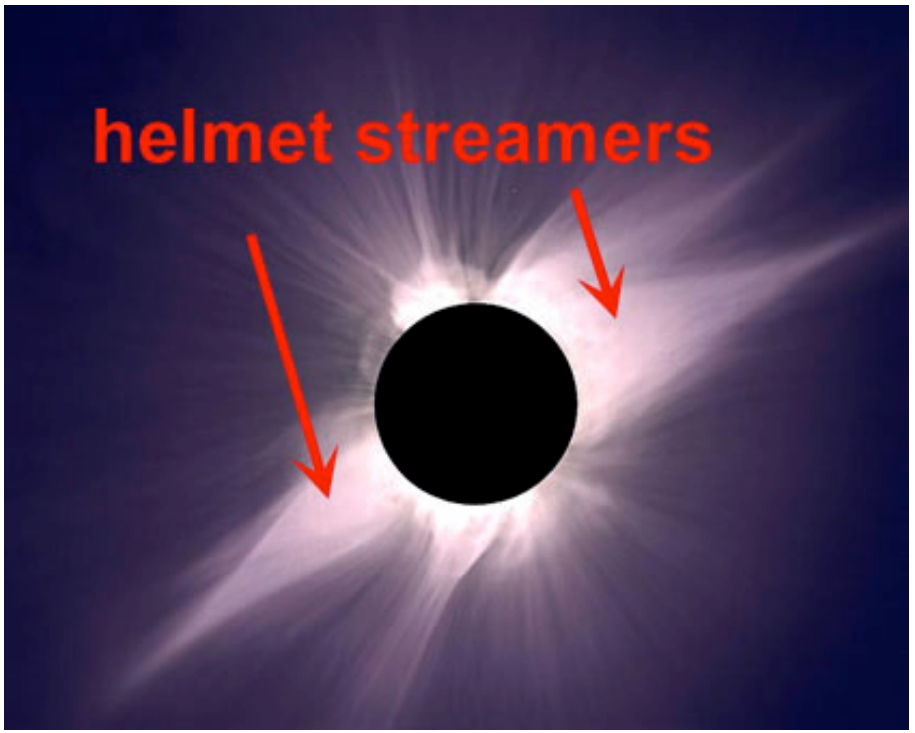
- 200-600 km/s
- Very Low Density: about 5-10 particles (electrons and protons) per cm^3 at 1AU
- Highly variable, can change by factor of 2 in 24 hrs
- Lower latitudes, thus affects the planets more than fast wind
- Associated with closed field lines



Extreme UV from SOHO Spacecraft

Slow Solar Wind

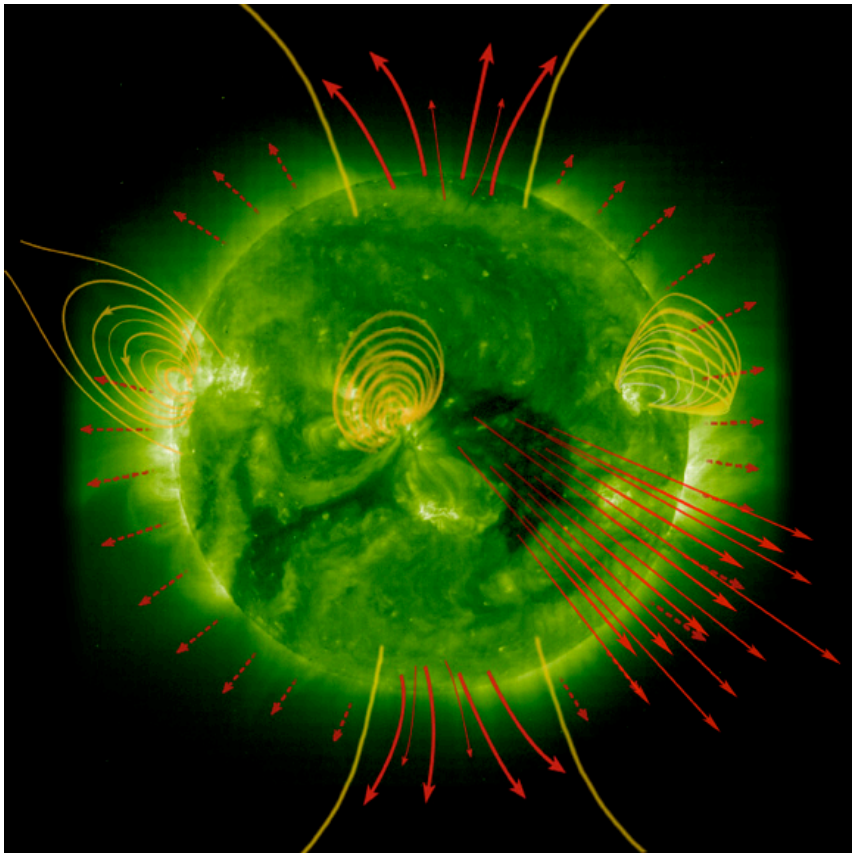
- Slow solar wind originates from closed magnetic field lines at base of helmet streamers that are confined to low latitudes



Fast Solar Wind

Fast Solar Wind (solid red lines)

- ~ 750 km/s
- Very Low Density: about half as dense as the slow solar wind
- Associated with open field lines (coronal holes)



Extreme UV from SOHO Spacecraft

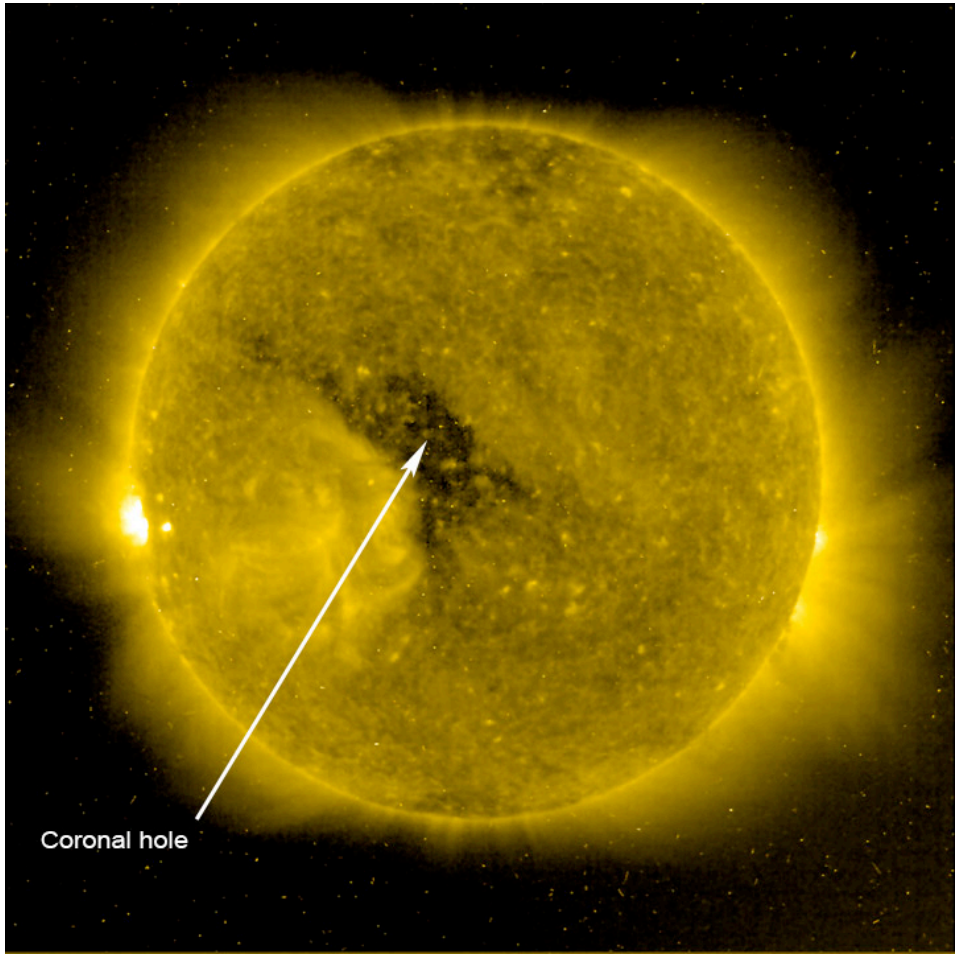
Coronal Holes

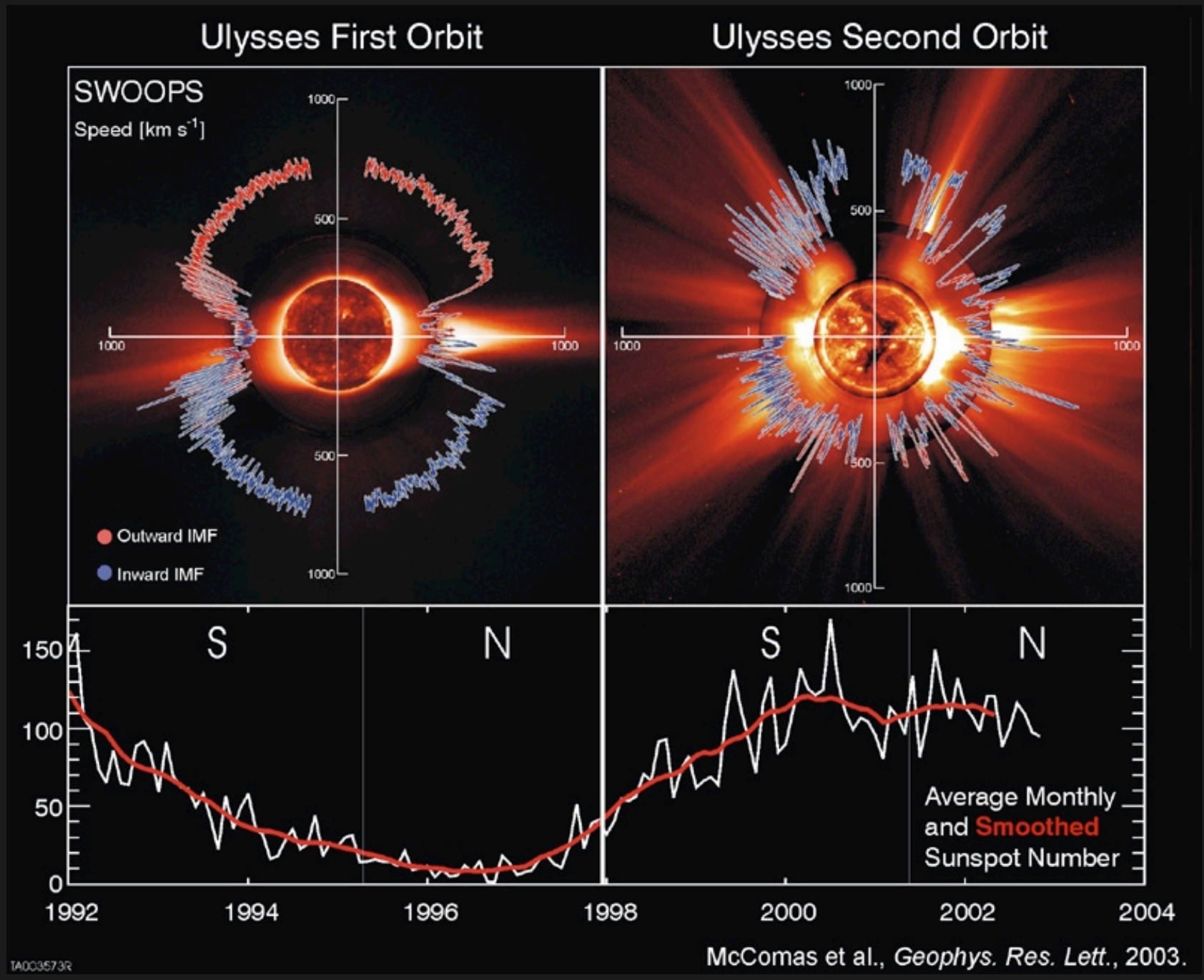
• A coronal hole is a region of very low plasma density in the corona that shows up as a dark region in X-ray images.

• The correspond to regions of the solar magnetic field that extend radially away from the photosphere (no looping).

• The low plasma density is due to the radial nature of the field, plasma escapes by moving along the magnetic field.

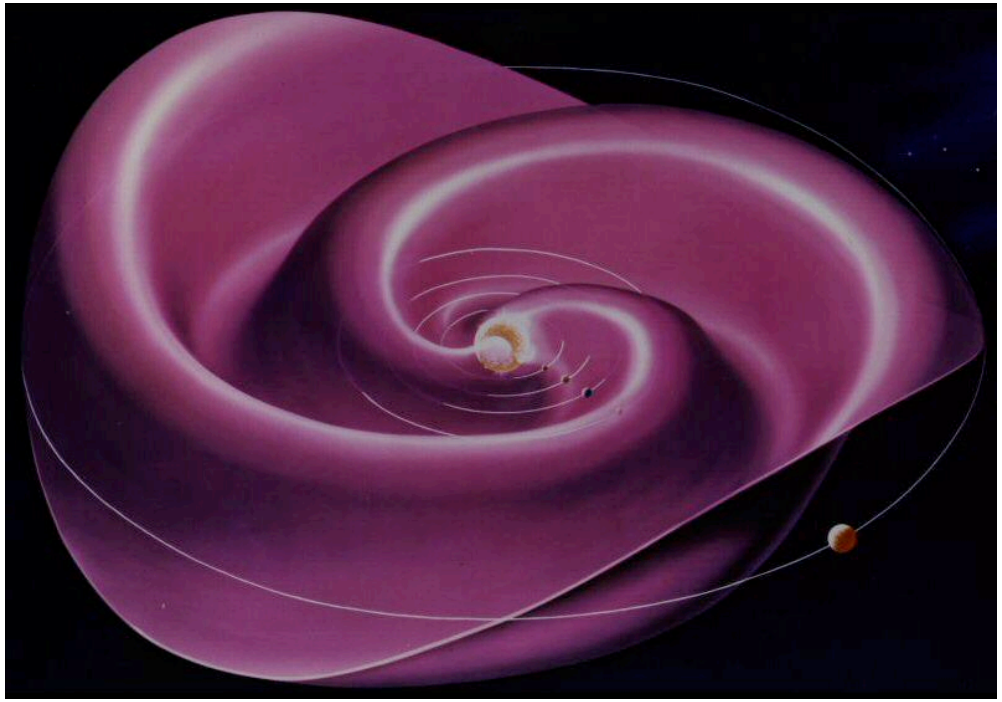
• The result is a directed beam of very high velocity plasma.




Ulysses First Orbit
Ulysses Second Orbit
SWOOPS
Speed [km s-1]
1000
500
1000
1000
500
1000
Outward IMF
Inward IMF
1000
500
1000
1000
500
1000
S
N
S
N
150
100
50
0
1992
1994
1996
1998
2000
2002
2004
Average Monthly
and Smoothed
Sunspot Number
TA003573R
McComas et al., Geophys. Res. Lett., 2003.

Parker Spiral

- Sun rotates (~25 day period at equator)
- Solar wind flows out radially with magnetic field "frozen" in it
- Field lines tied to the sun, so rotation results in a spiral magnetic field
- Resultant field is like a lawn sprinkler
- Eugene Parker theorized this in the 1950's

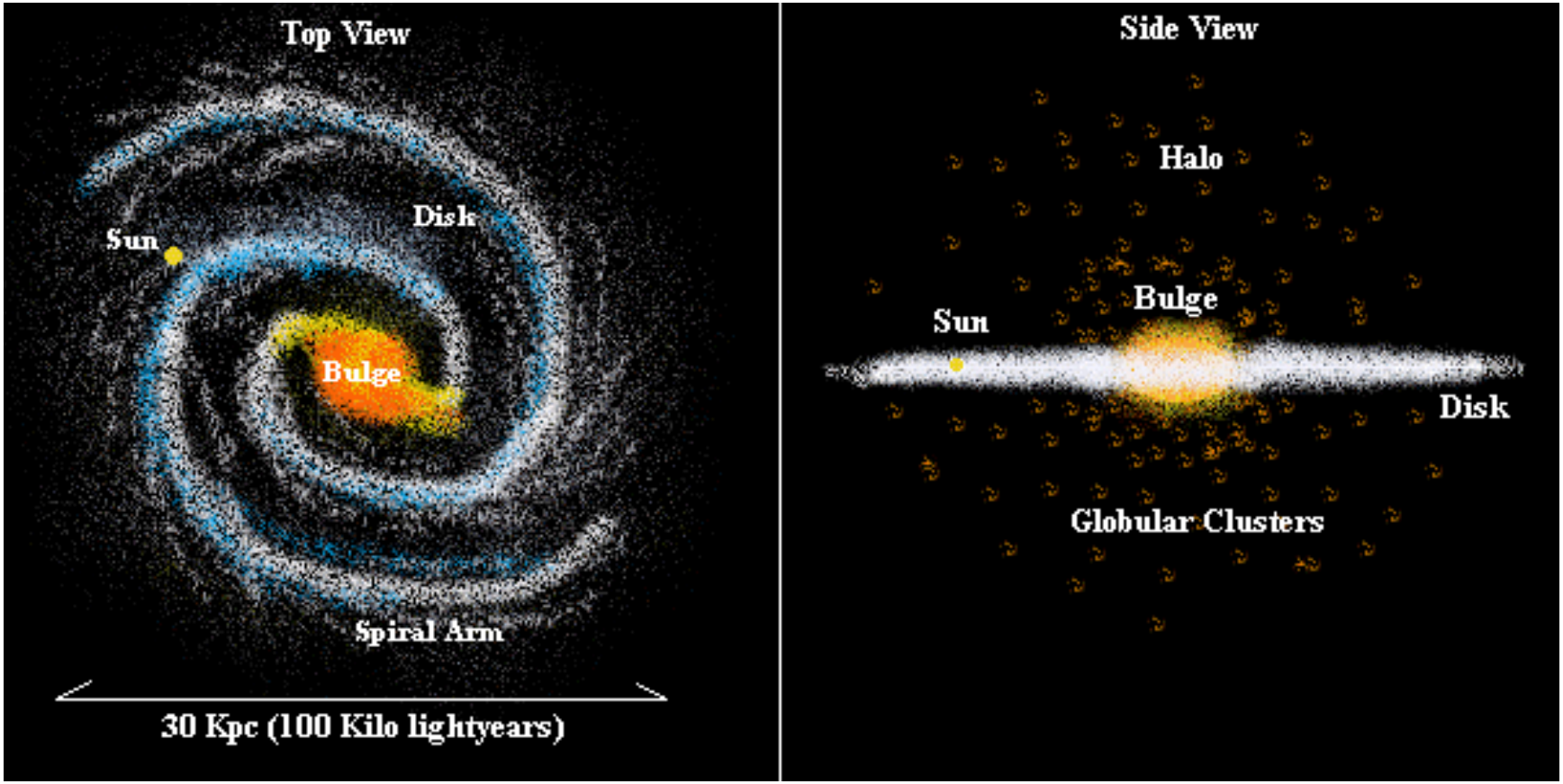


Parker Spiral and the Planets

- At increasing distances from the sun, the magnetic field gets more and more twisted
- 45^0 at Earth
- 90^0 at Jupiter's orbit (~10 AU)

Where does the solar wind stop?

- Other stars have winds too, called stellar winds
- Hence, universe is not really a vacuum.
- Tenuous magnetized plasma (and a little dust) known as the local interstellar medium (LISM) fills interstellar space.
- But “near” to our sun, the solar wind dominates over the LISM.
- This bubble where the solar wind dominates is known as the heliosphere



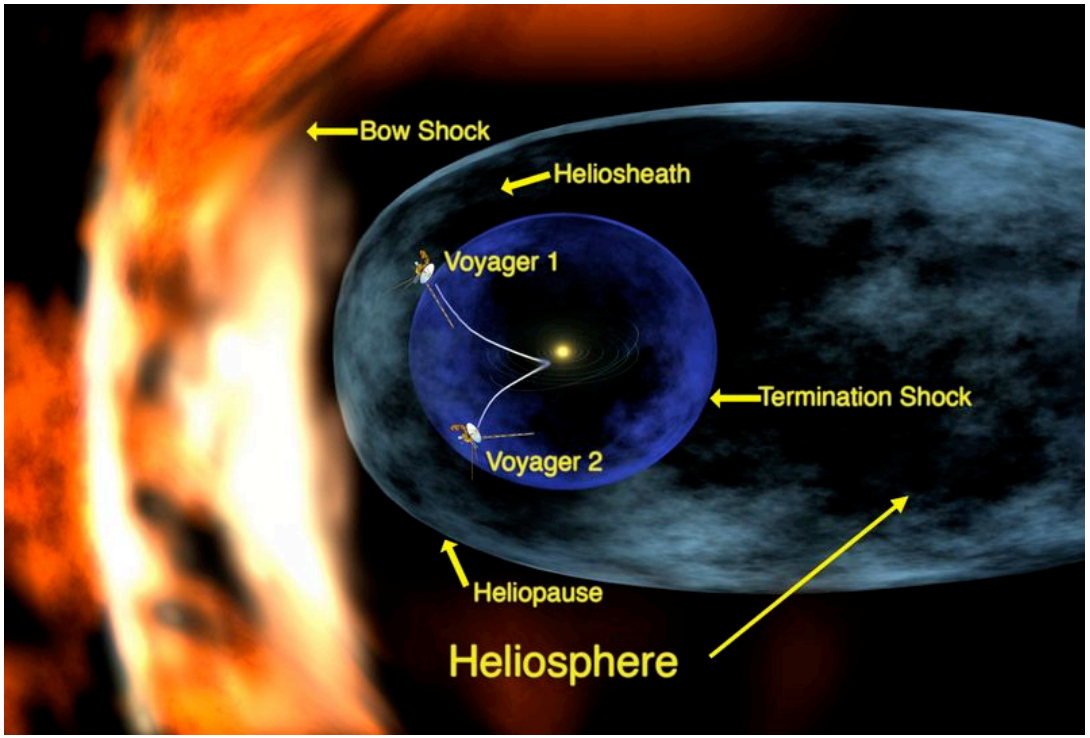
Sun's galactic rotation period = 250 million years

Spiral arm rotation period = 50 million years

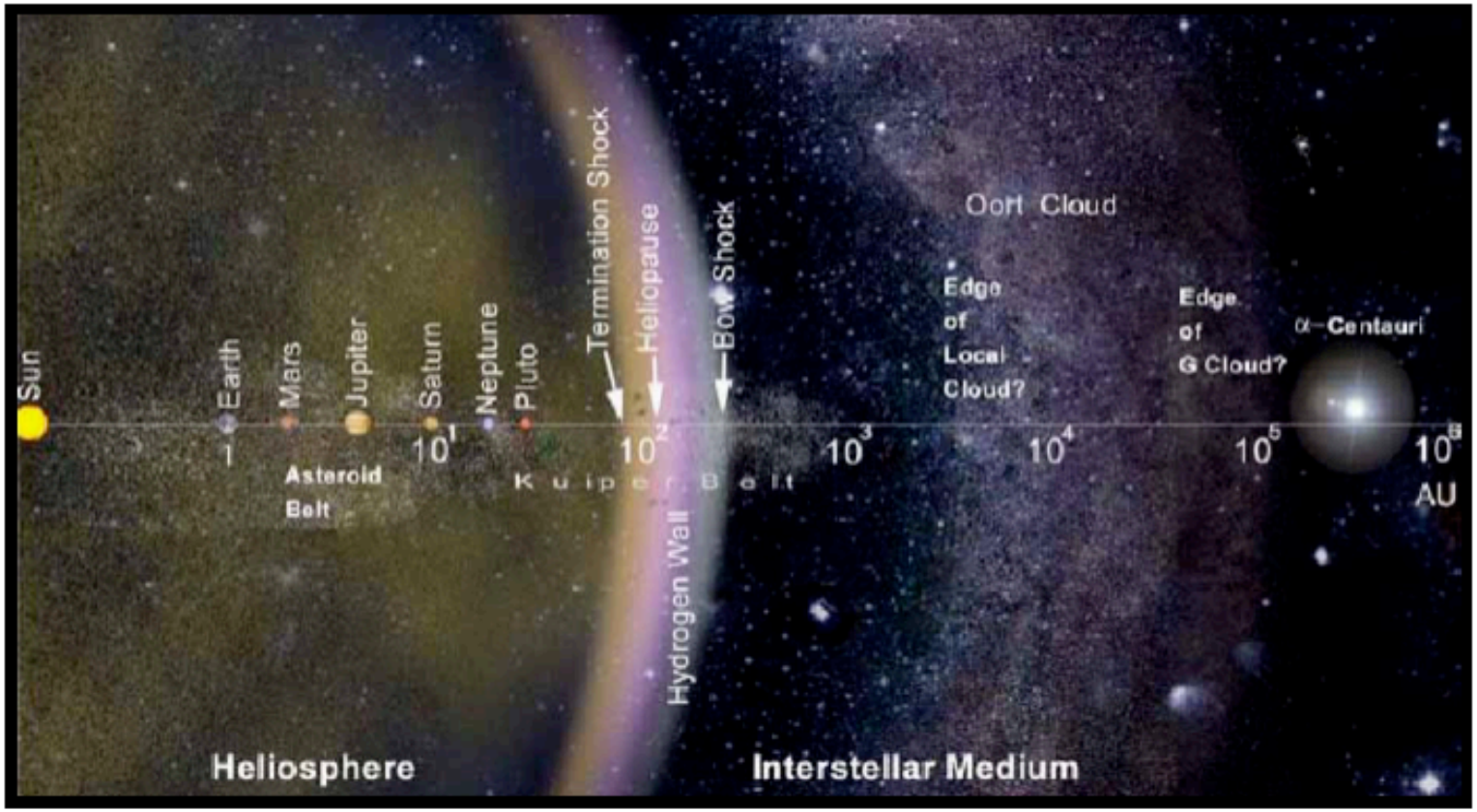
The boundary between the solar wind and interstellar medium

The two magnetized plasmas “bounce” off of each other in the outer solar system. At the boundary:

1. *Bow shock*: region where the LISM begins to slow
2. *Termination shock*: region where the solar wind begins to slow
3. *Heliopause*: region where the solar wind and LISM are in balance

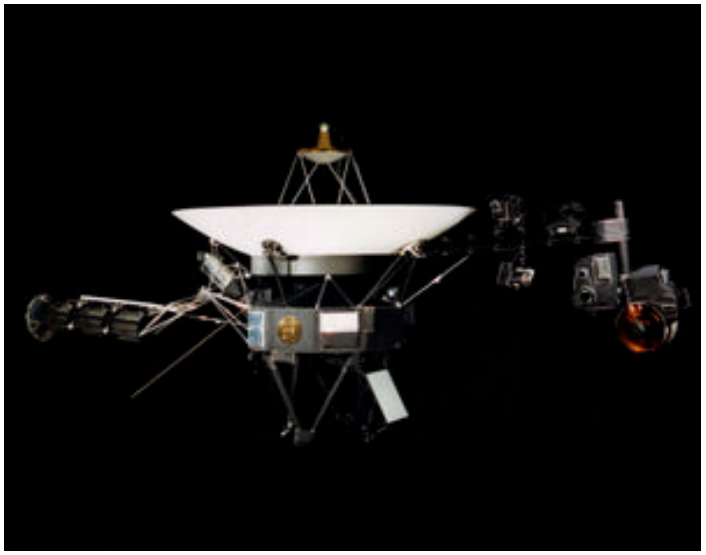


Heliopause is well past orbit of Pluto



Do we know exactly where the heliopause is located?

- Voyager I and II spacecrafts
- Launched in 1977
- First close-up images of Jupiter, Saturn, Uranus, Neptune
- Presently about 104 and 84 AU from earth (or 13/11 light hours)



Do we know exactly where the heliopause is located?

- Voyager I passed the termination shock in 2004, *maybe*.
- Voyager II passed the termination shock *five times* in 2007.
- The boundaries are not static, but depend on solar activity (solar wind, CMEs…)
- Scientists are waiting for them cross the heliopause