Solar wind acceleration

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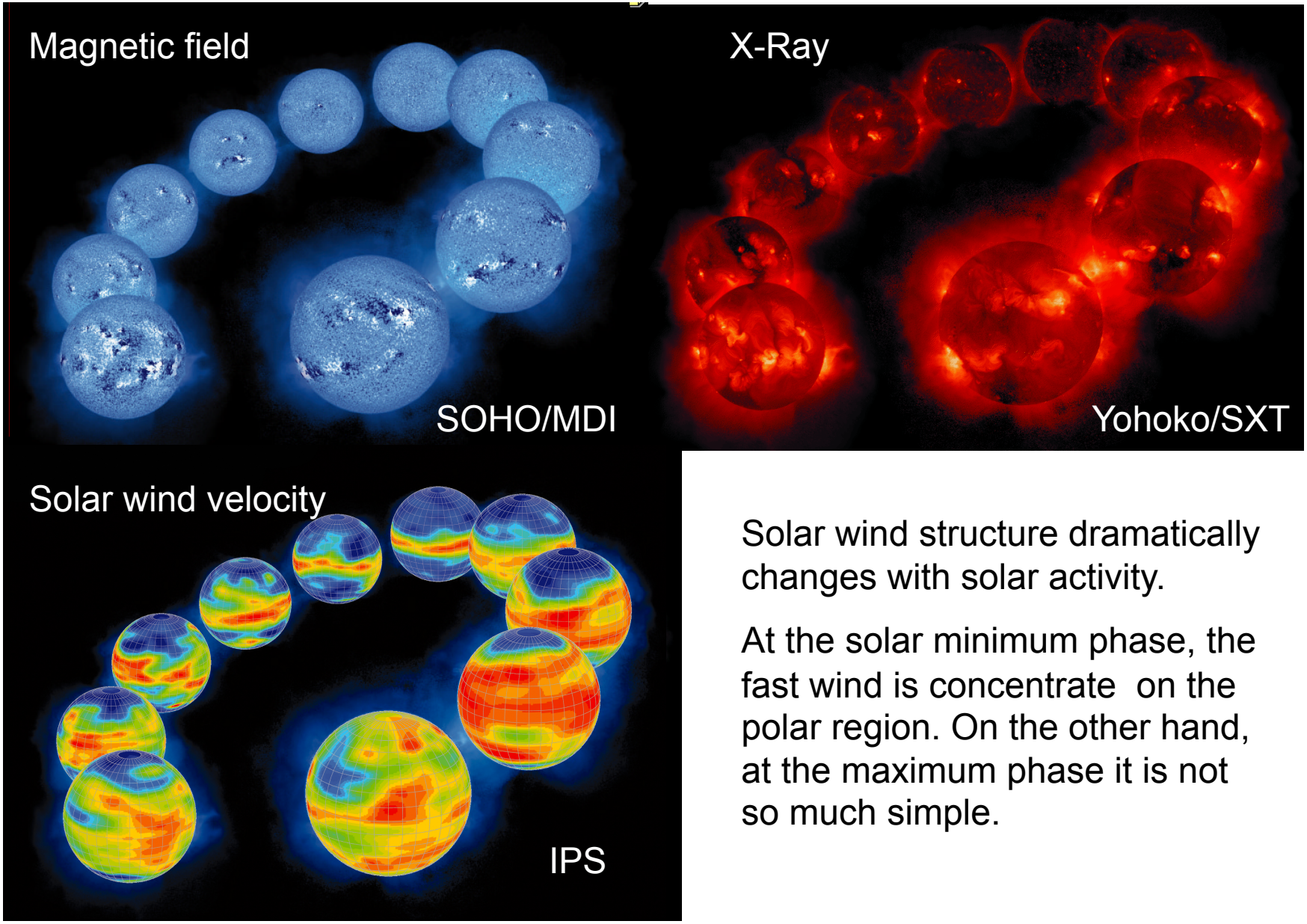
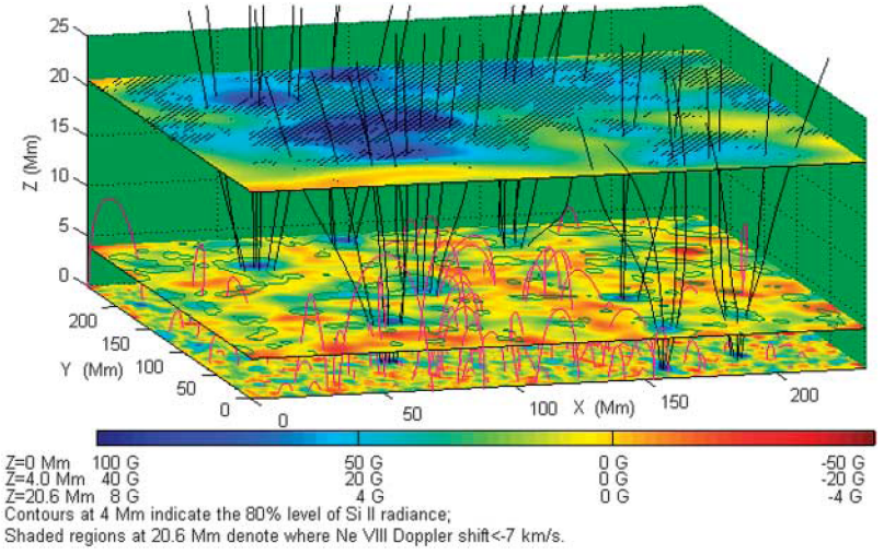
Remote-sensing Observation before Hinode



Solar wind structure dramatically changes with solar activity.

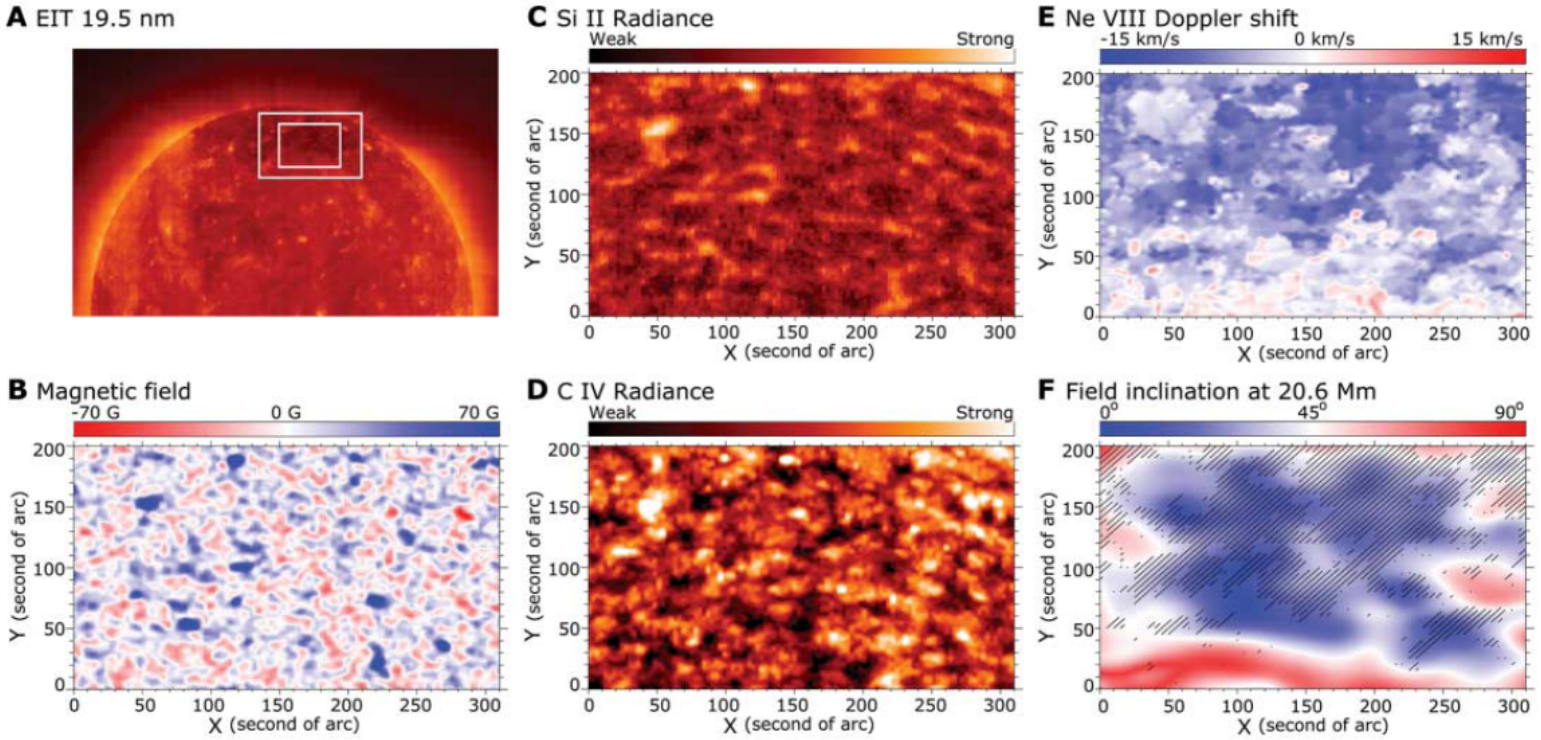
At the solar minimum phase, the fast wind is concentrate on the polar region. On the other hand, at the maximum phase it is not so much simple.

Polar Coronal hole (fast solar wind)

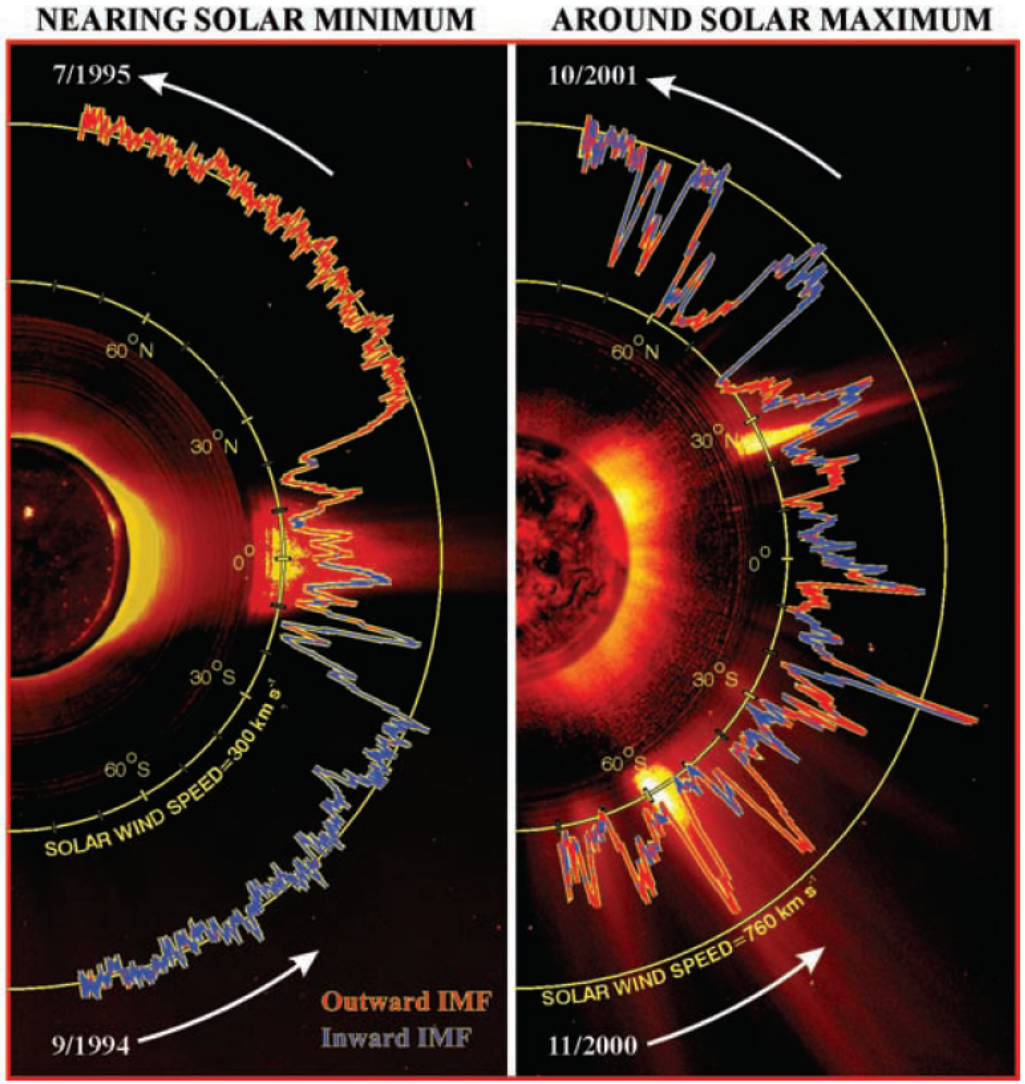


Soho/SUMER observation

Tu et al., 2005



In-situ measurement



Ulysses observation
McComas et al., 2000

Radial distance: solar wind velocity

Red: Outward IMF

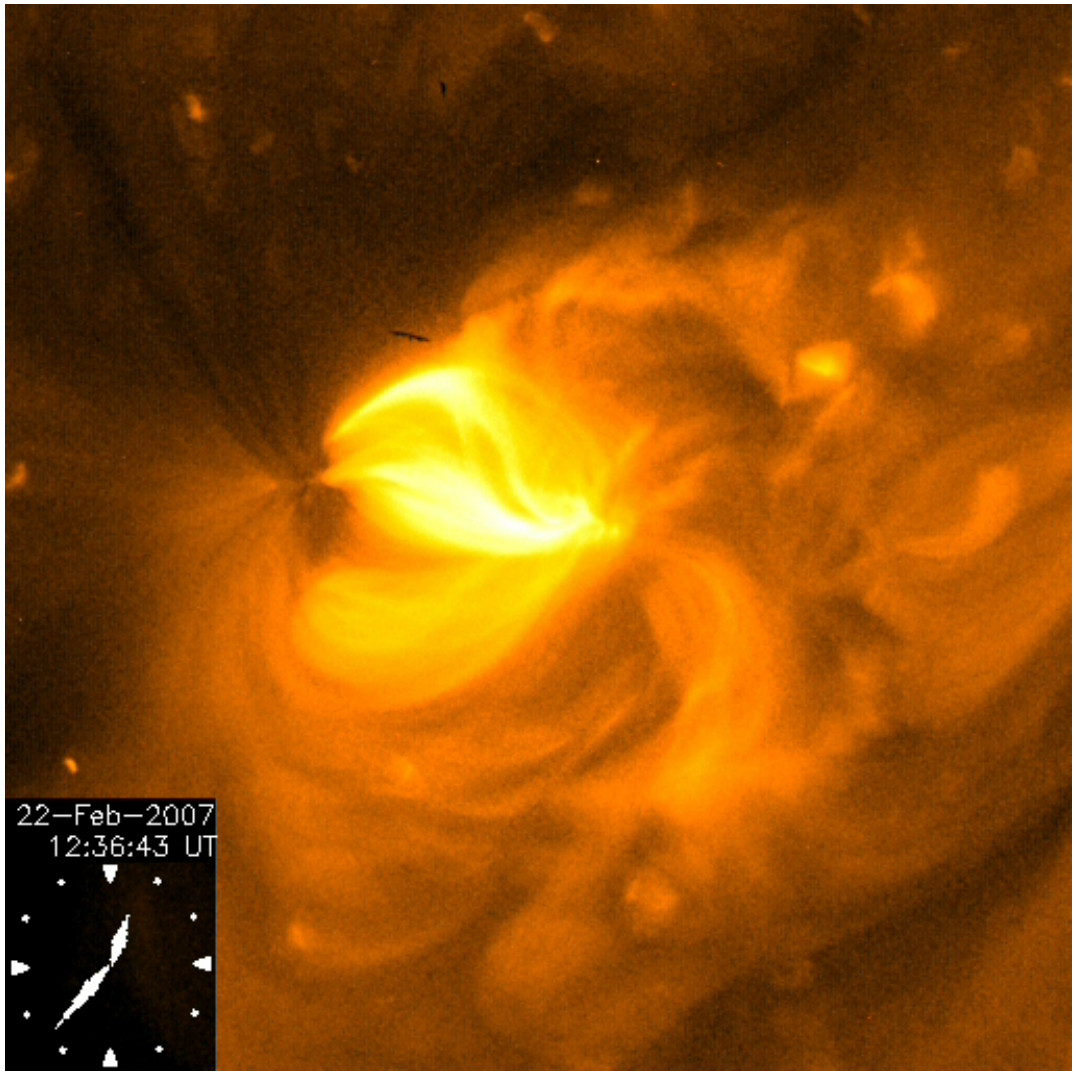
Blue: Inward IMF

Fast solar wind show the steady flow ~700km/sec, magnetic fields direction is also one polarity

On the other hand, slow wind show the fluctuate structure.

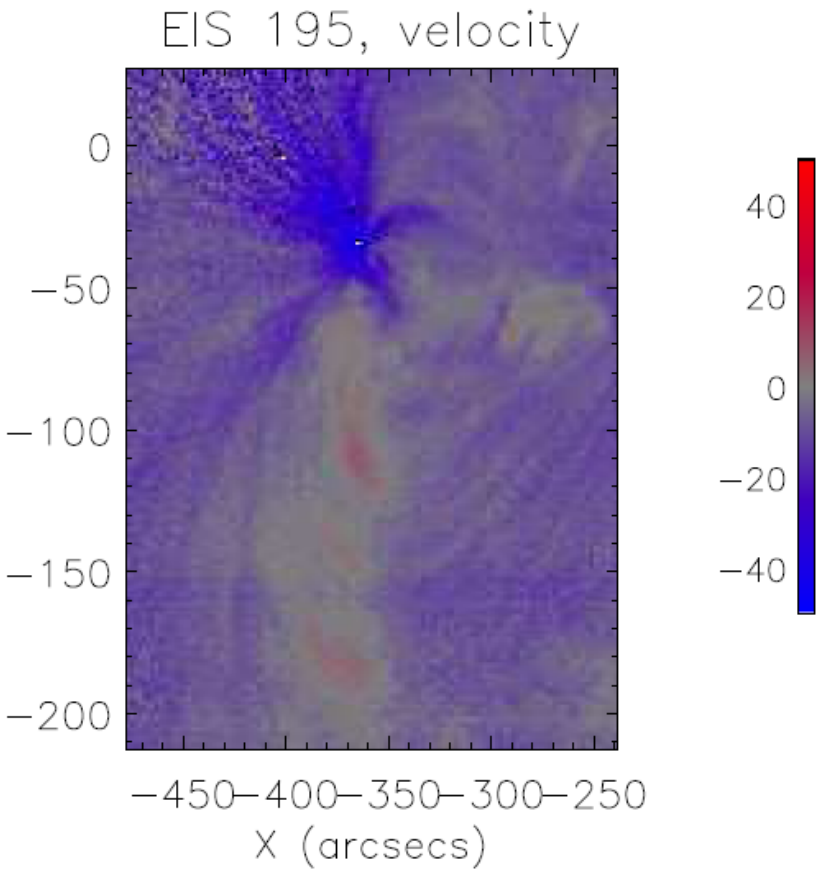
Not only the velocity but also magnetic field direction.

Hinode Observation (Slow Wind)

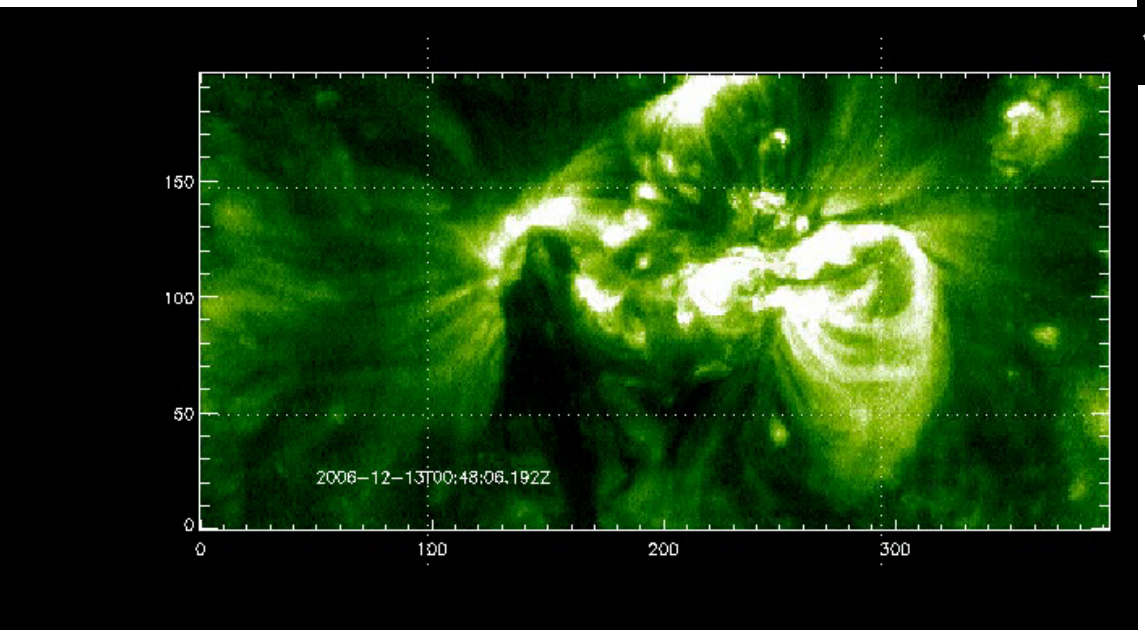


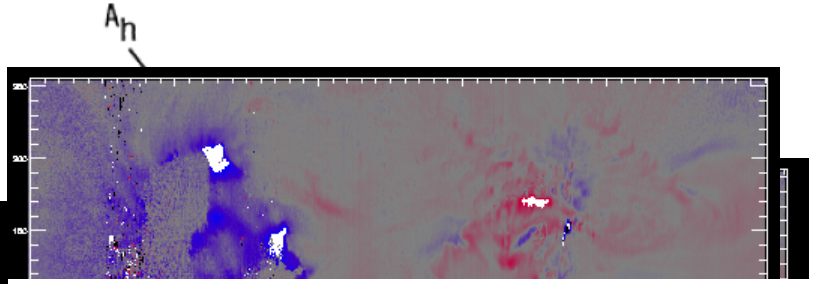
Sakao et al, 2007

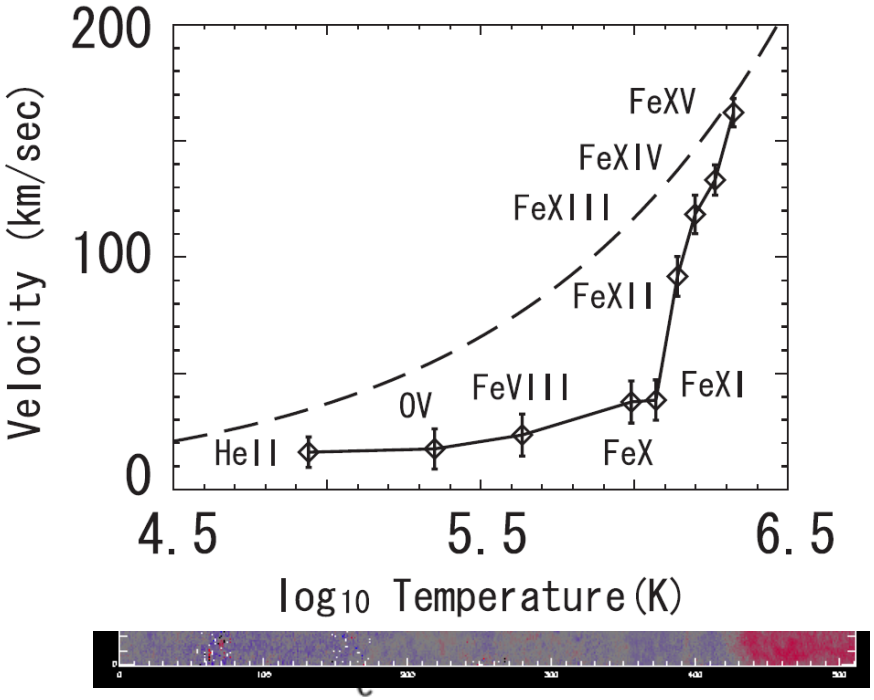
Harra et al, 2008



Transient Coronal Hole (Dimming)



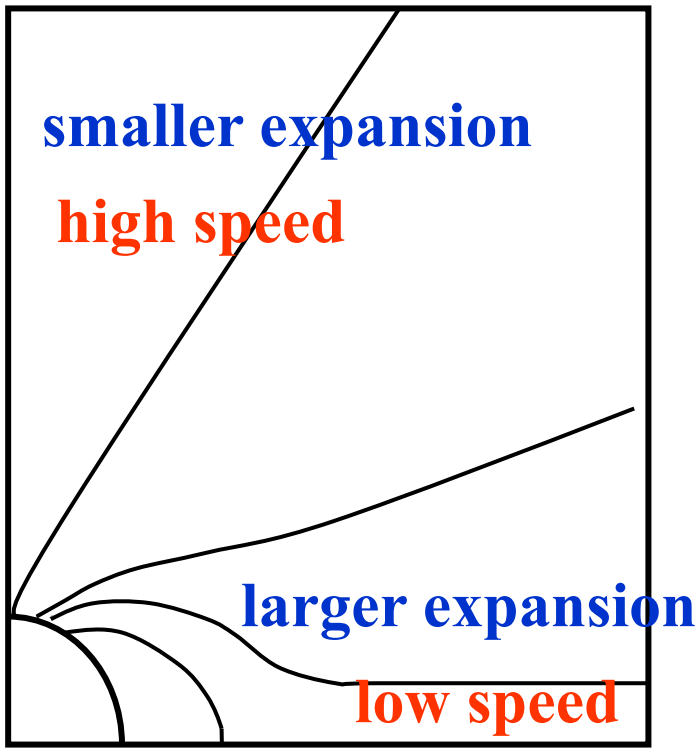




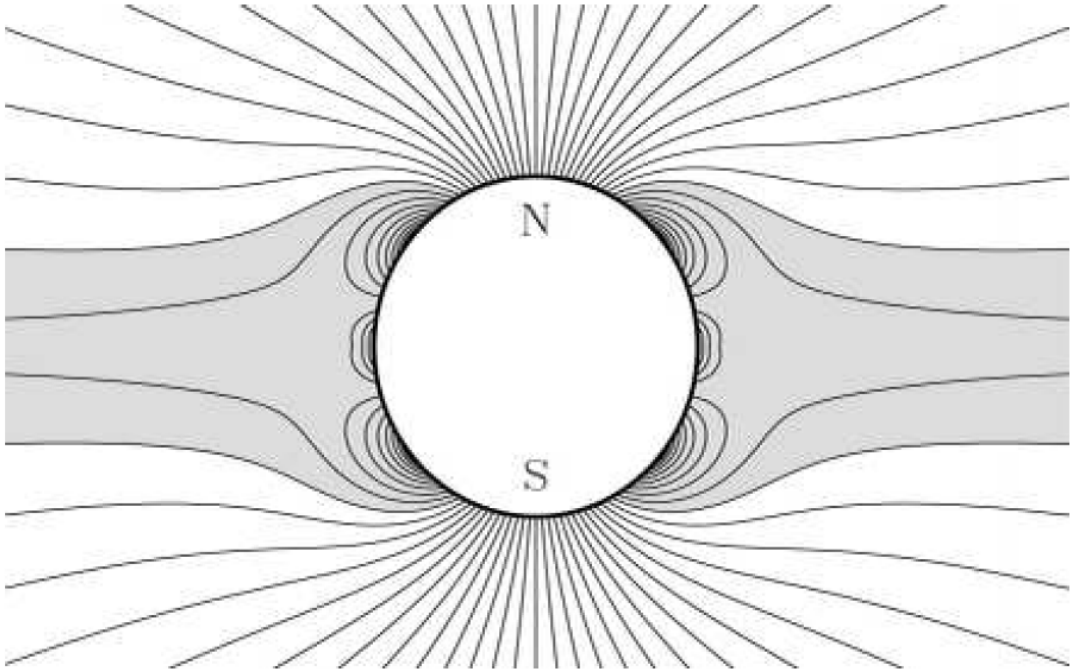
Imada et al, 2007

What is the difference between Slow and Fast?

Magnetic field configuration



Wang and Sheeley 1990



Larger expansion → Heating near the Sun

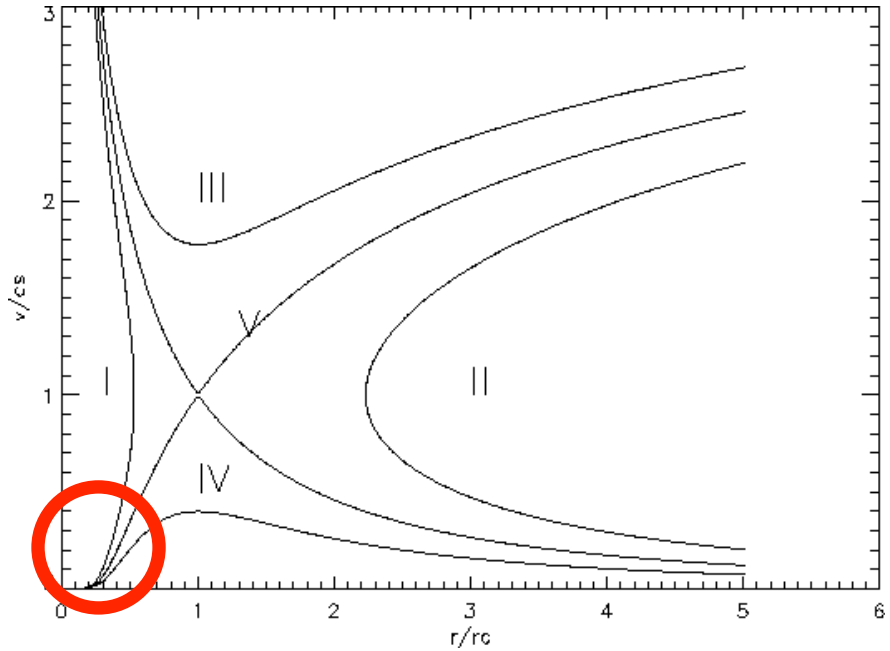
→Temperature gradient is large

→Large density (not mass flux) into interplanetary

This is one of the reason why we can observe slow wind region by Hinode

What is for Solar-C?

- The origin of steady fast solar wind. (injection to solar wind)
  This is very difficult because the density is very low. Need high-throughput EUV spectrograph (This will be discussed today).



Parker's solar wind model

Why fast solar wind is so steady?

- Slow solar wind origin is not steady
  → This will be understand in more detail with Hinode Observation.
- Is fast solar wind origin steady?

  → maybe not

  Magnetic field in the Polar region (Tsuneta-san's Talk)

  X-ray jets & Plume(Cirtain-san's Talk)

  Chromosphere (Tomorrow Talk)

What is for Solar-C?

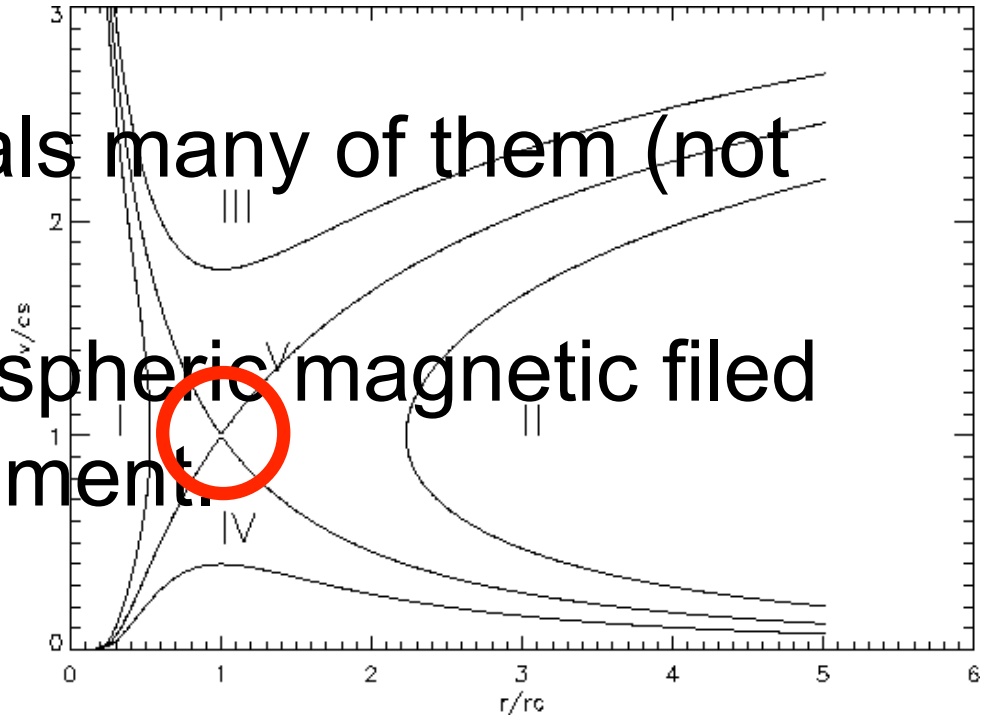
- Can we observe critical point (velocity ~ sound speed)?

  → in-situ measurement helpful

It is up to payload..

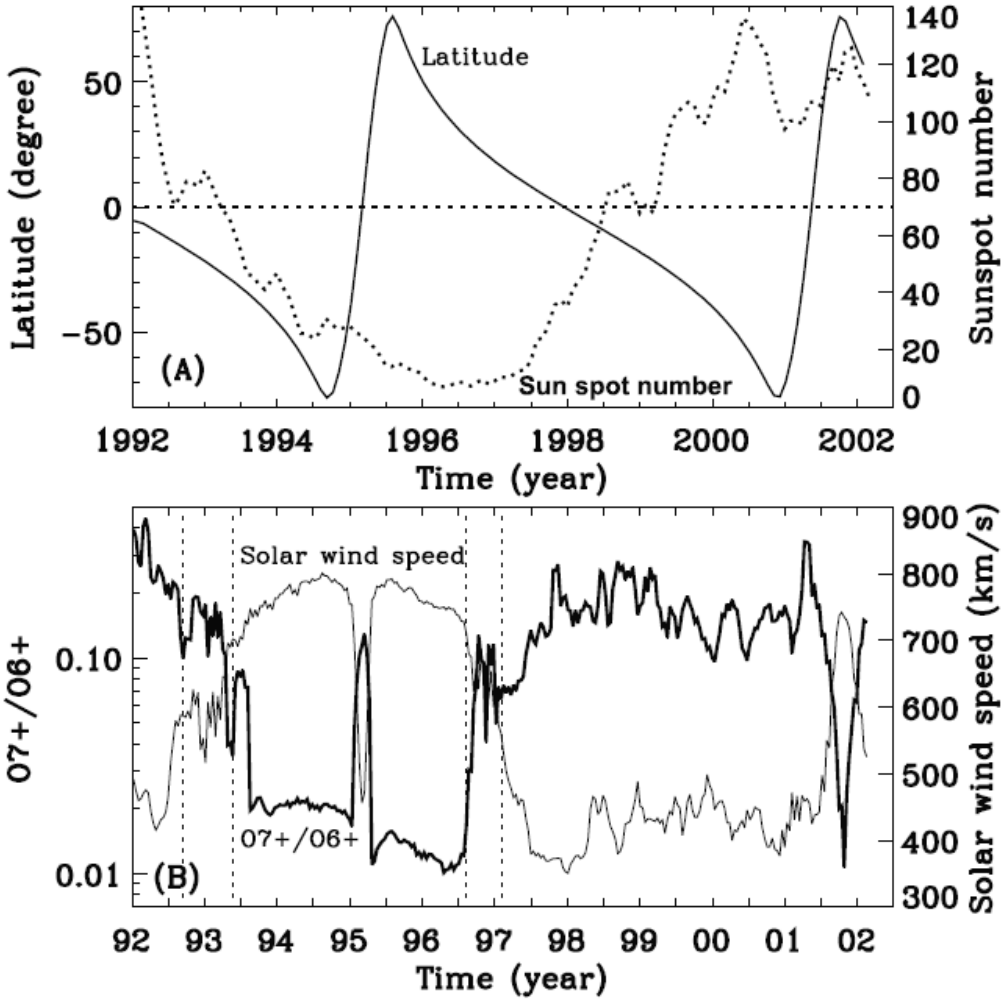
Actully, Ulysses reveals many of them (not statistically).

Combination of photospheric magnetic filed and in-situ measurement.



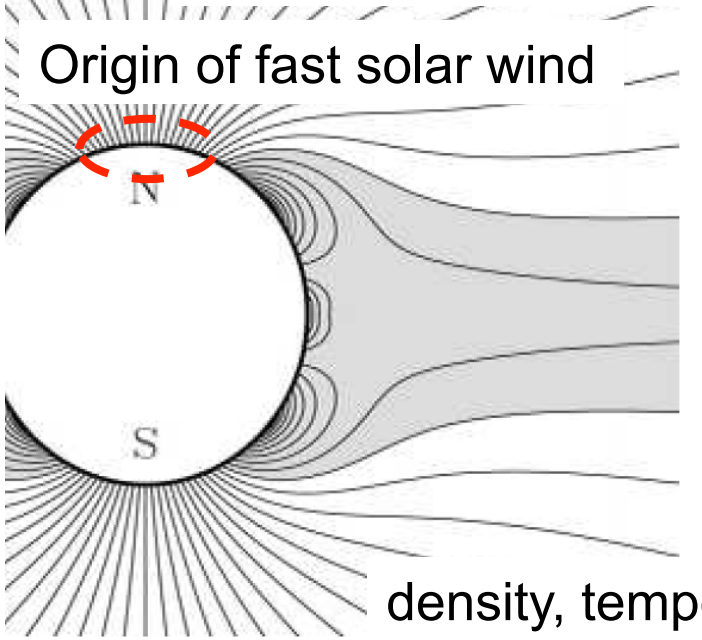
Combination remote-sensing and in-situ

Zhang et al, 2003



Magnetic field extrapolation

Origin of fast solar wind



density, temperature, velocity, waves
charge state ratio

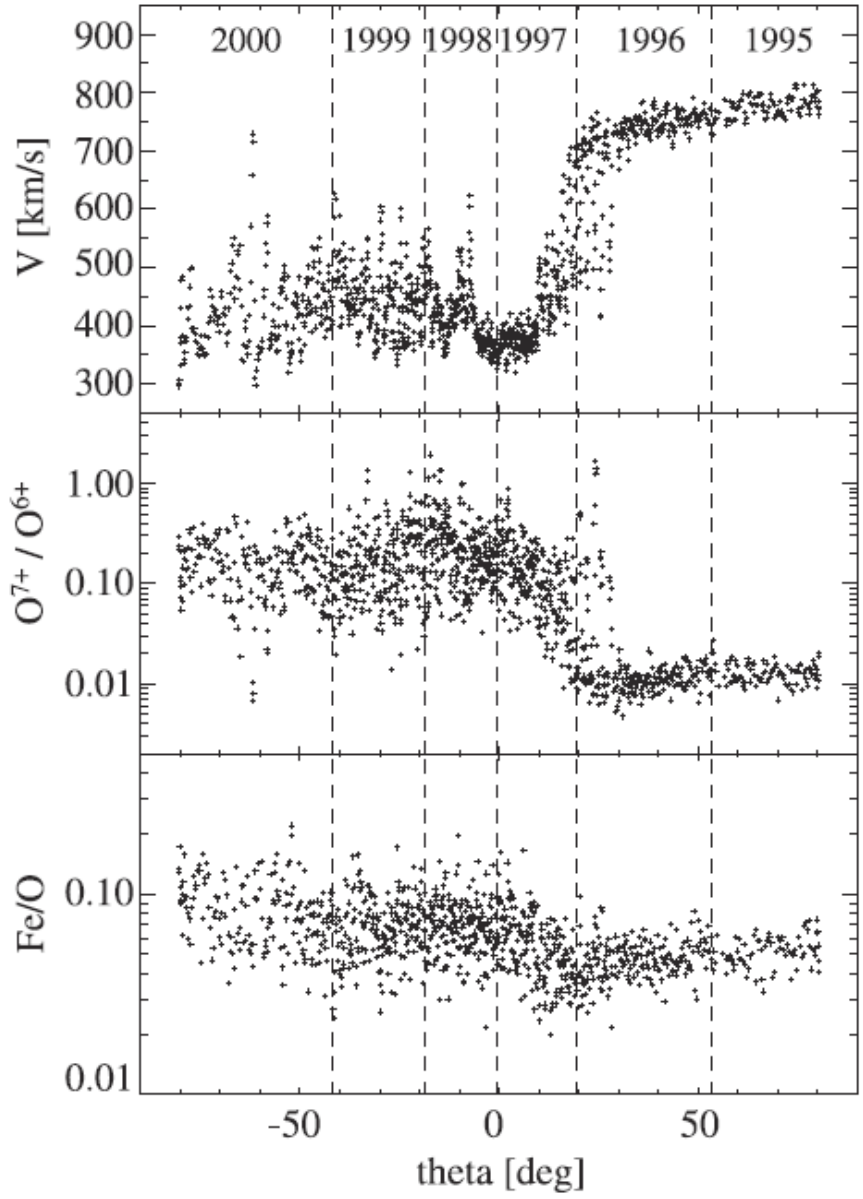
Summary

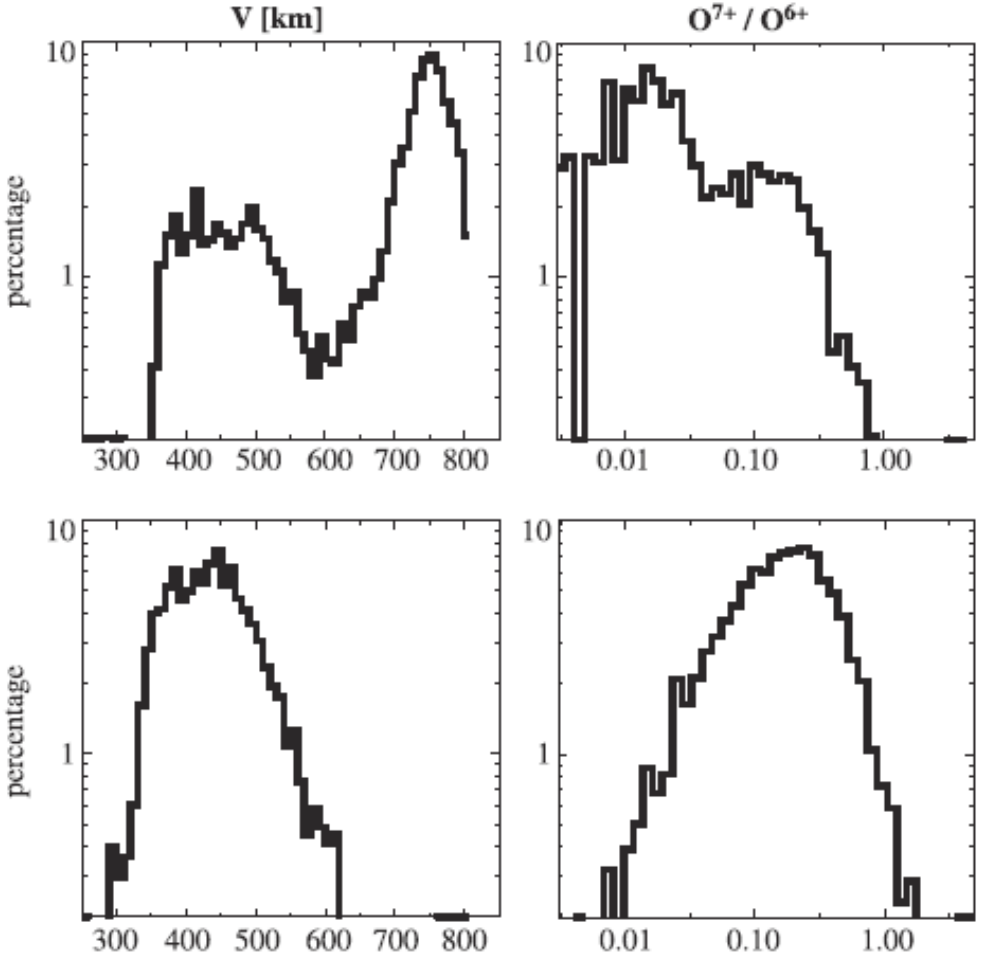
- Origin of fast solar wind. “steady or unsteady?”

→ We need high throughput EUV spectrometer to observe darker region

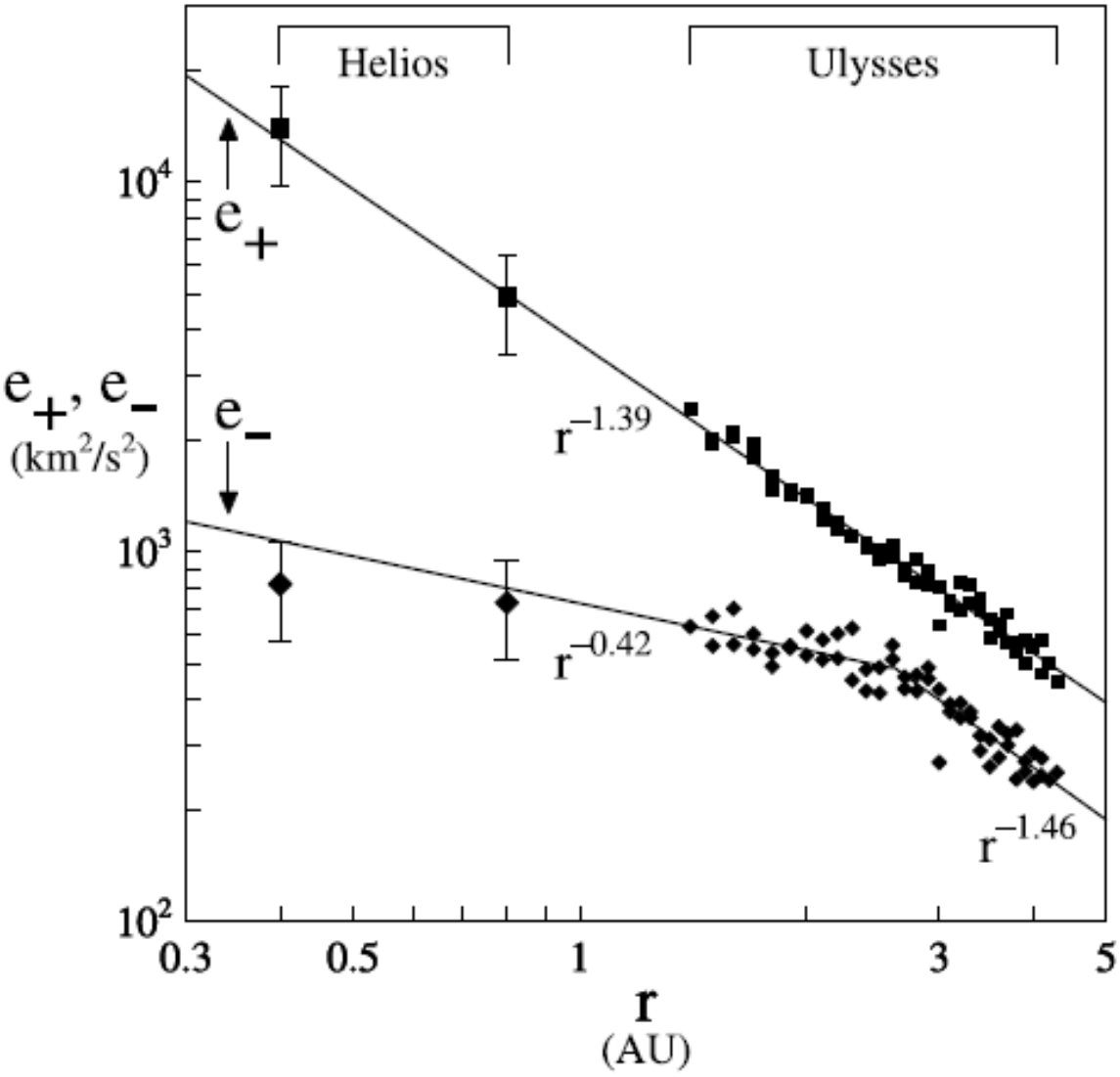
- Combination with in-situ measurement is helpful for understanding the critical point. It is up to payload.

→ This analysis need precise modeling.


2000
1999
1998
1997
1996
1995
V [km/s]
900
800
700
600
500
400
300
O7+ / O6+
1.00
0.10
0.01
Fe/O
0.10
0.01
-50
0
50
theta [deg]


V [km]
O7+ / O6+
percentage
10
1
300
400
500
600
700
800
0.01
0.10
1.00

Inward and Outward Alfenwave

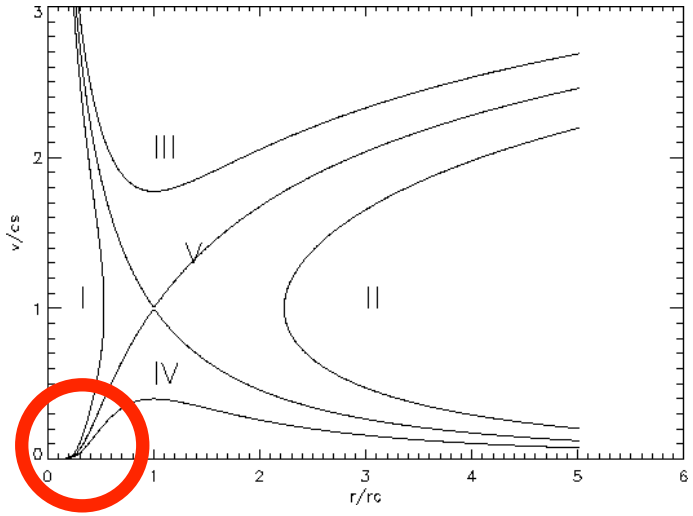


Parker's Solar wind model

$$4\pi mnur^2 = \text{constant}$$

$$u\frac{du}{dr} + \frac{1}{mn}\frac{dp}{dr} + \frac{GM_S}{r^2} = 0$$

$$p = 2nkT$$



$$\frac{1}{u}\frac{du}{dr} = \left(\frac{2a^2}{r} - \frac{GM_S}{r^2}\right) / (u^2 - a^2)$$

From Photosphere to Corona

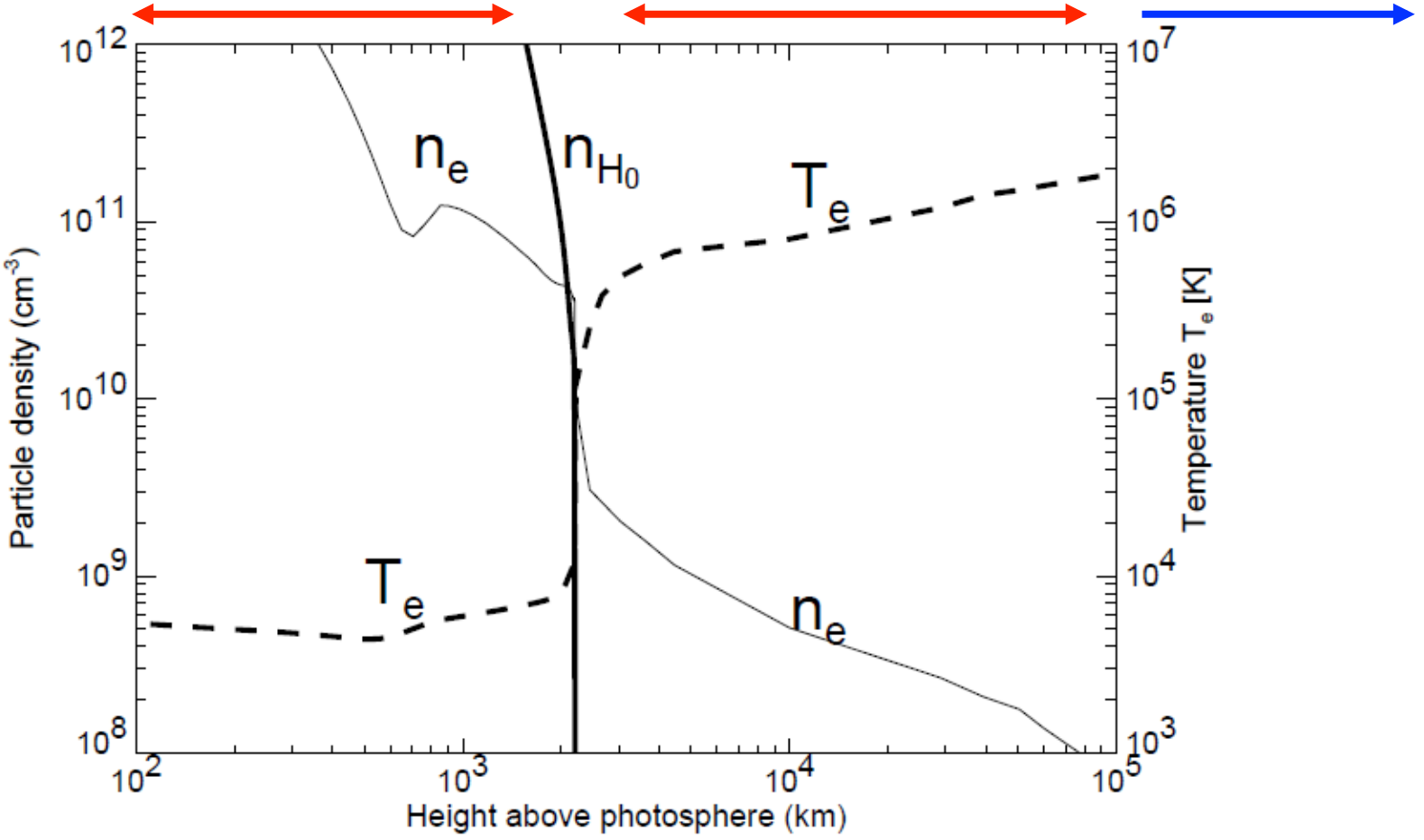
Photosphere/
Chromosphere
High **β**

Corona

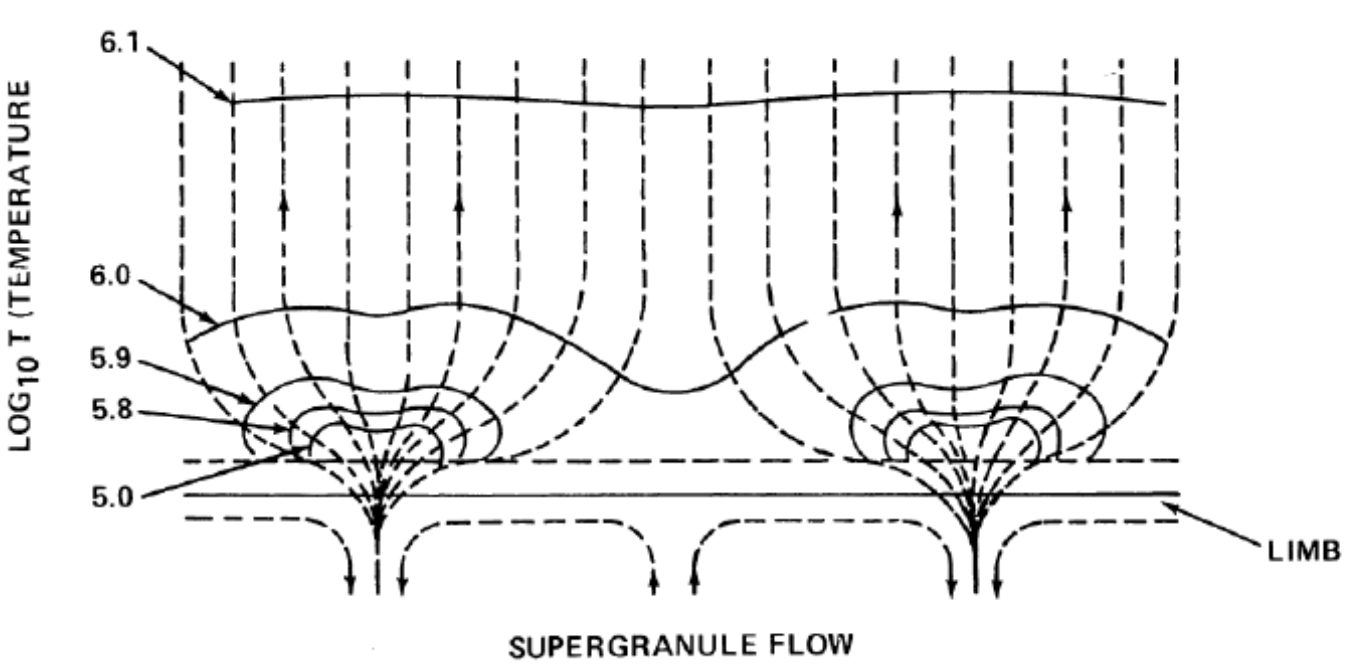
Low **β**

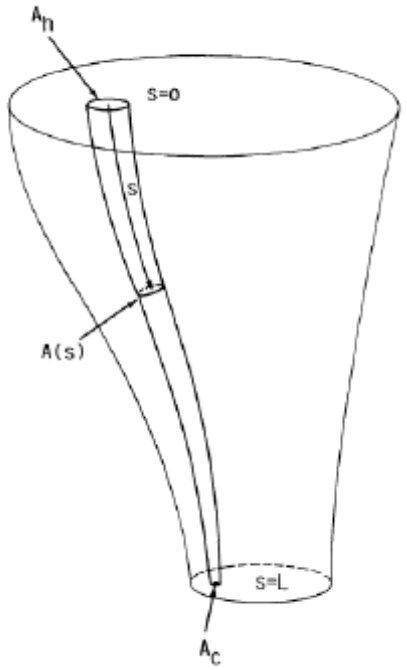
Solar wind

High **β**



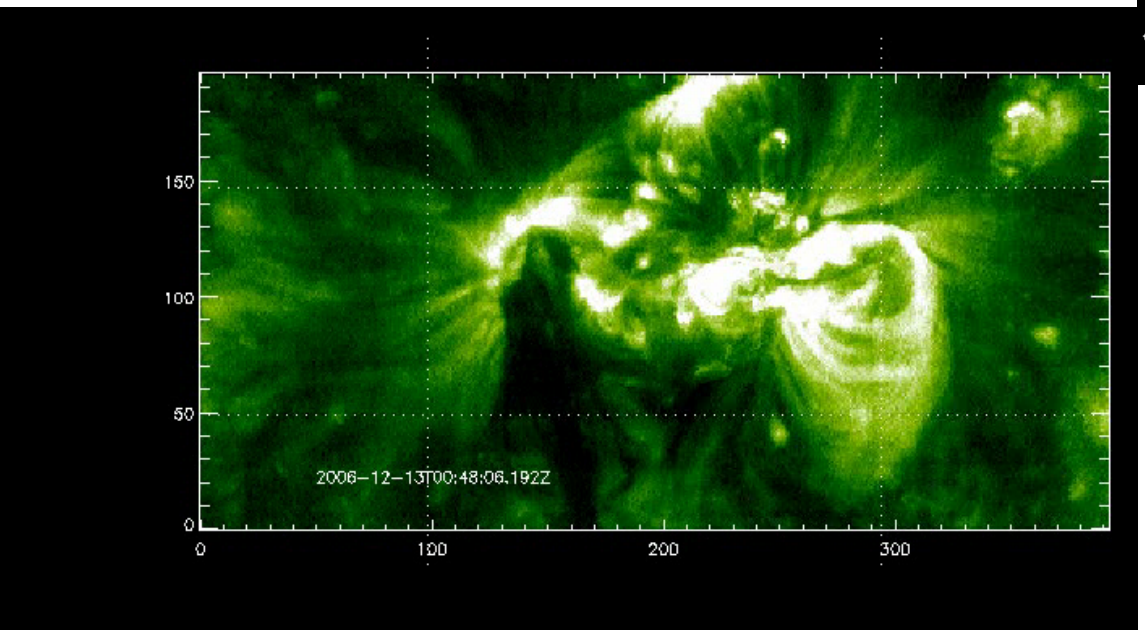
Coronal Funnel

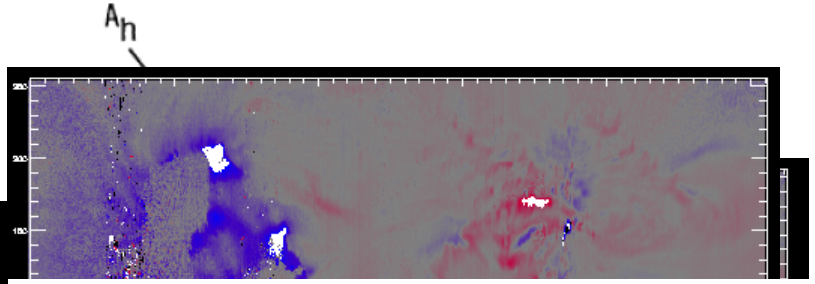


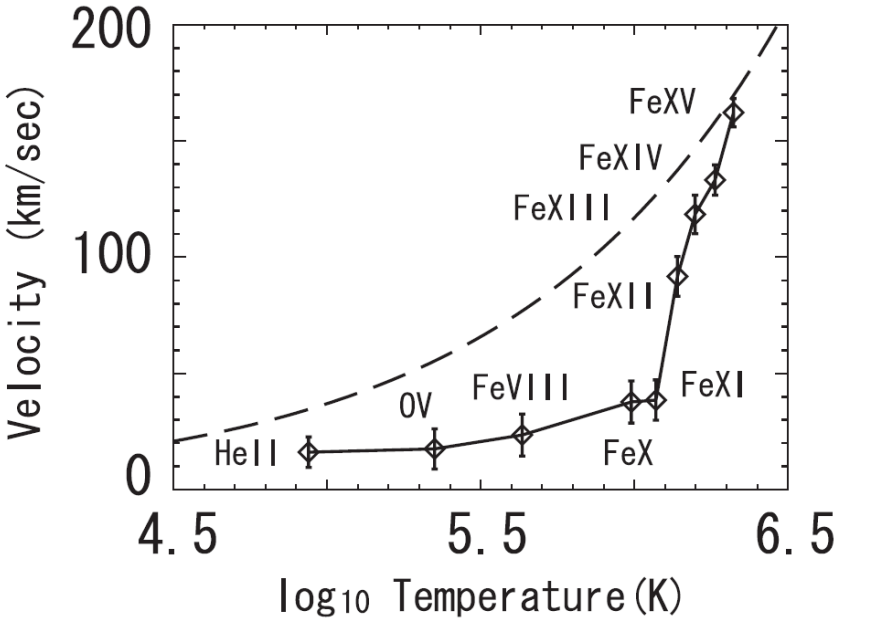


$$\left(v - \frac{c_s^2}{v}\right)\frac{\partial v}{\partial s} = -\frac{2k_B}{m}\frac{\partial T}{\partial s} + \frac{c_s^2}{A}\frac{\partial A}{\partial s} - g$$

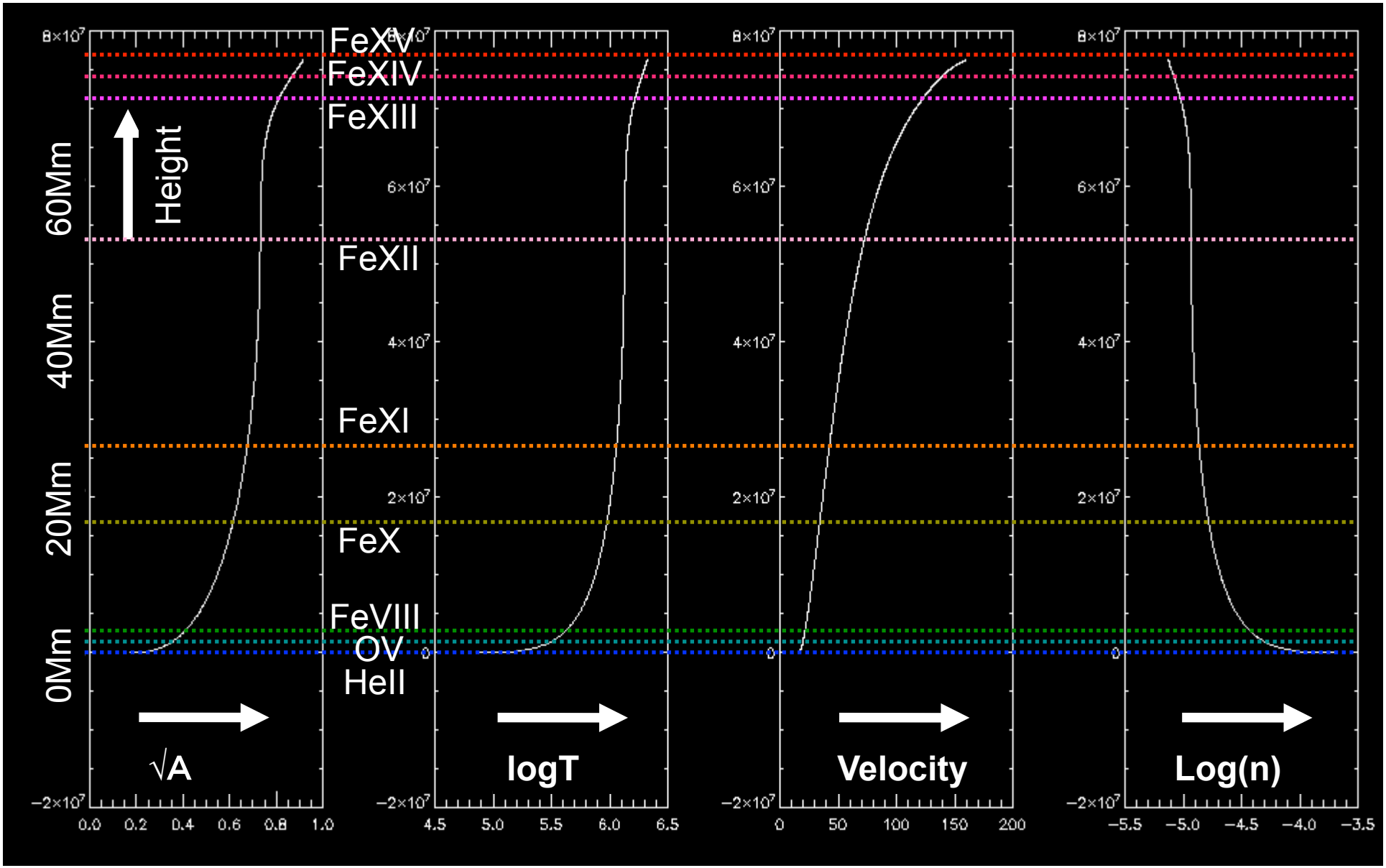
Transient Coronal Hole (Dimming)



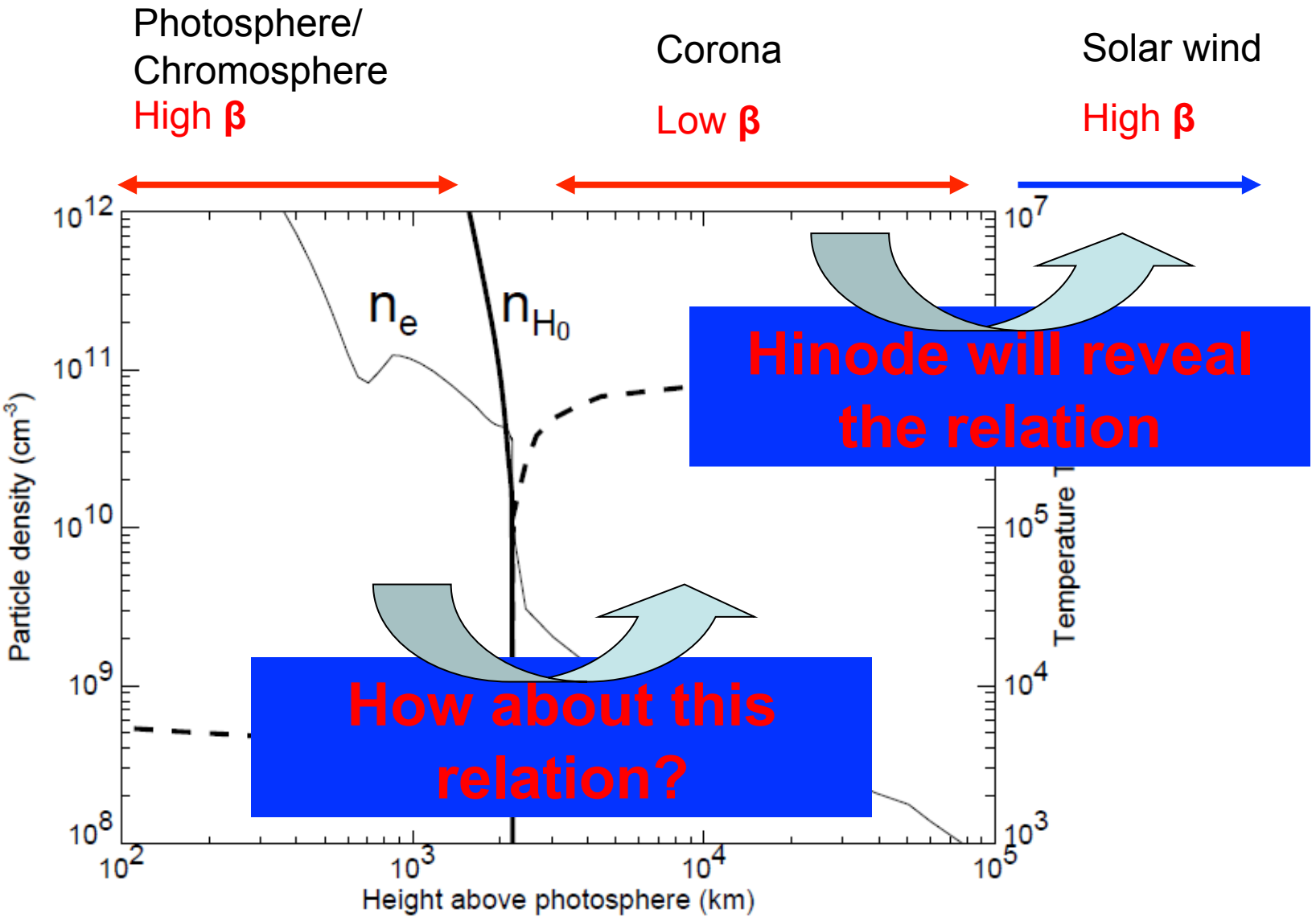




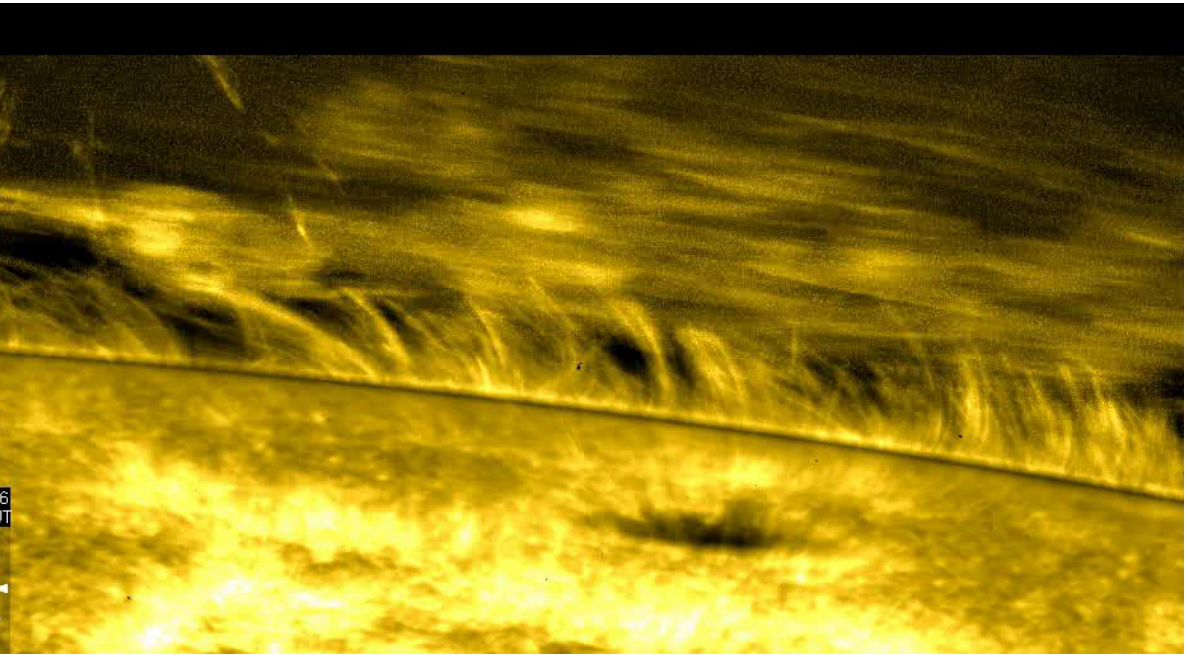
Extrapolation for Z-direction

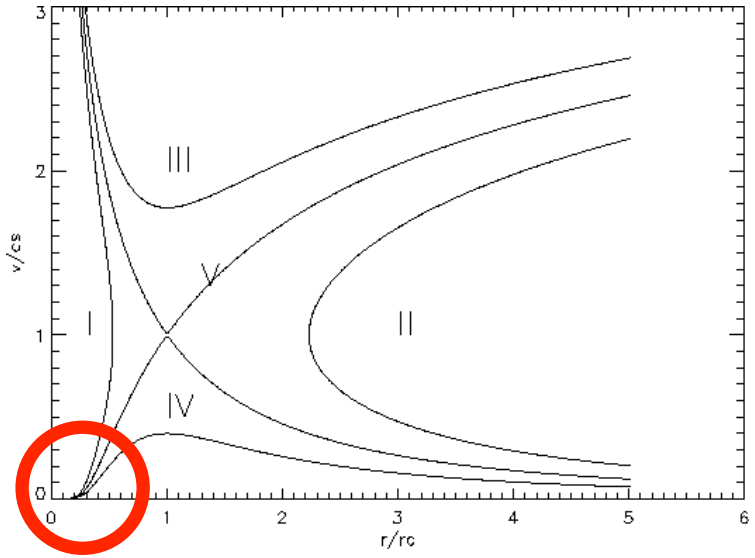


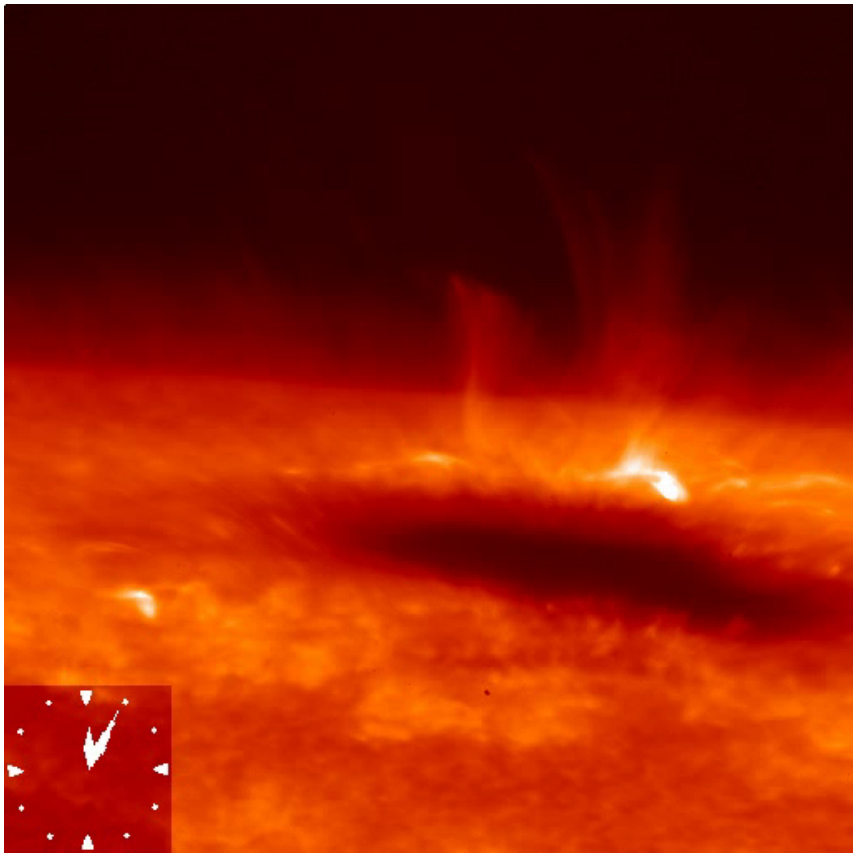
From Photosphere to Corona



Steady or Unsteady injection?







For observing injection region

- High sensitivity
  → to observe very darker region
- Magnetic field measurement in chromosphere/transition region
  → to observe expansion factor
- High cadence observation
  → to observe dynamic features

Observe from Polar region is better..