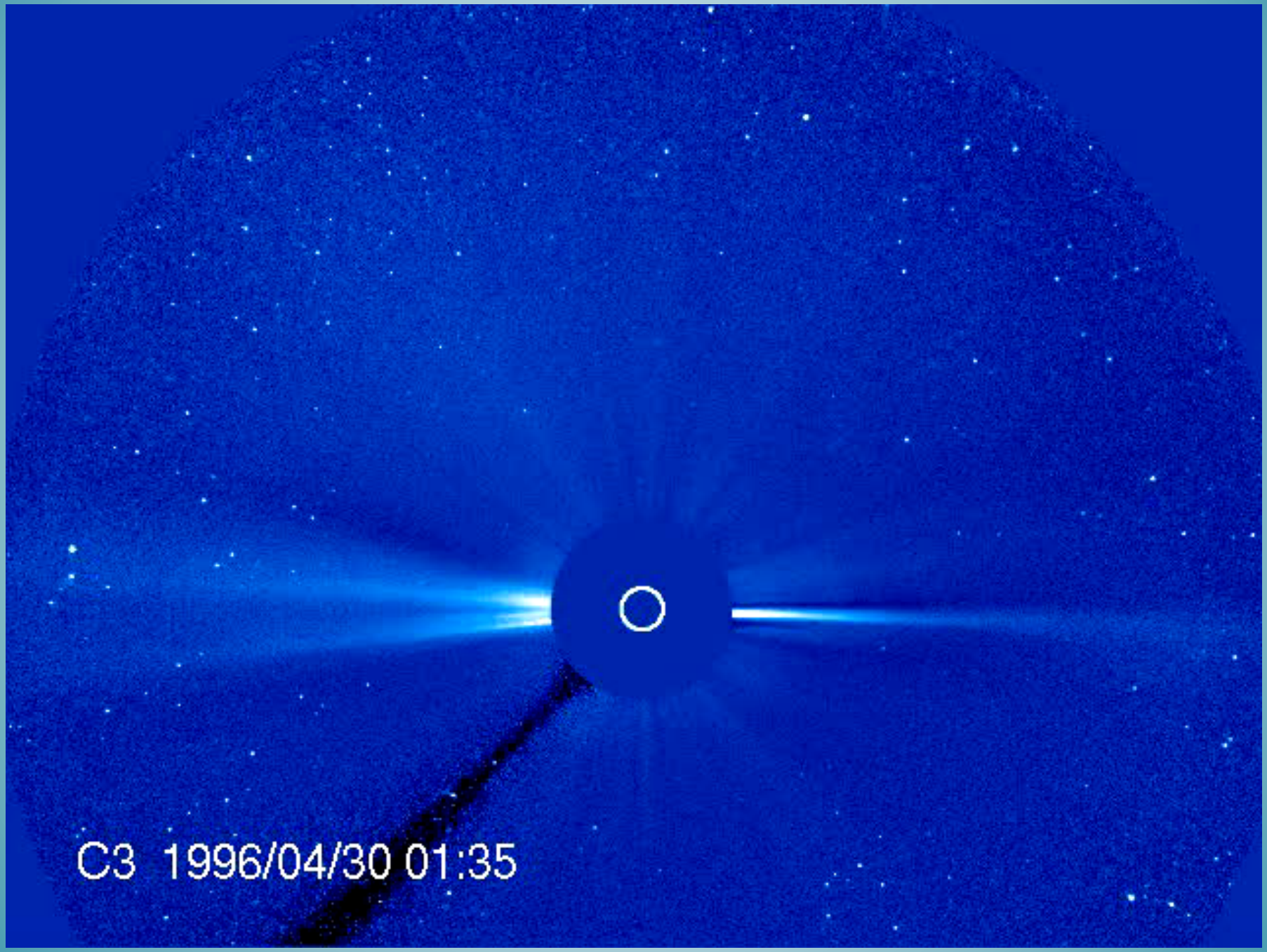
On the Origins of the Solar Wind

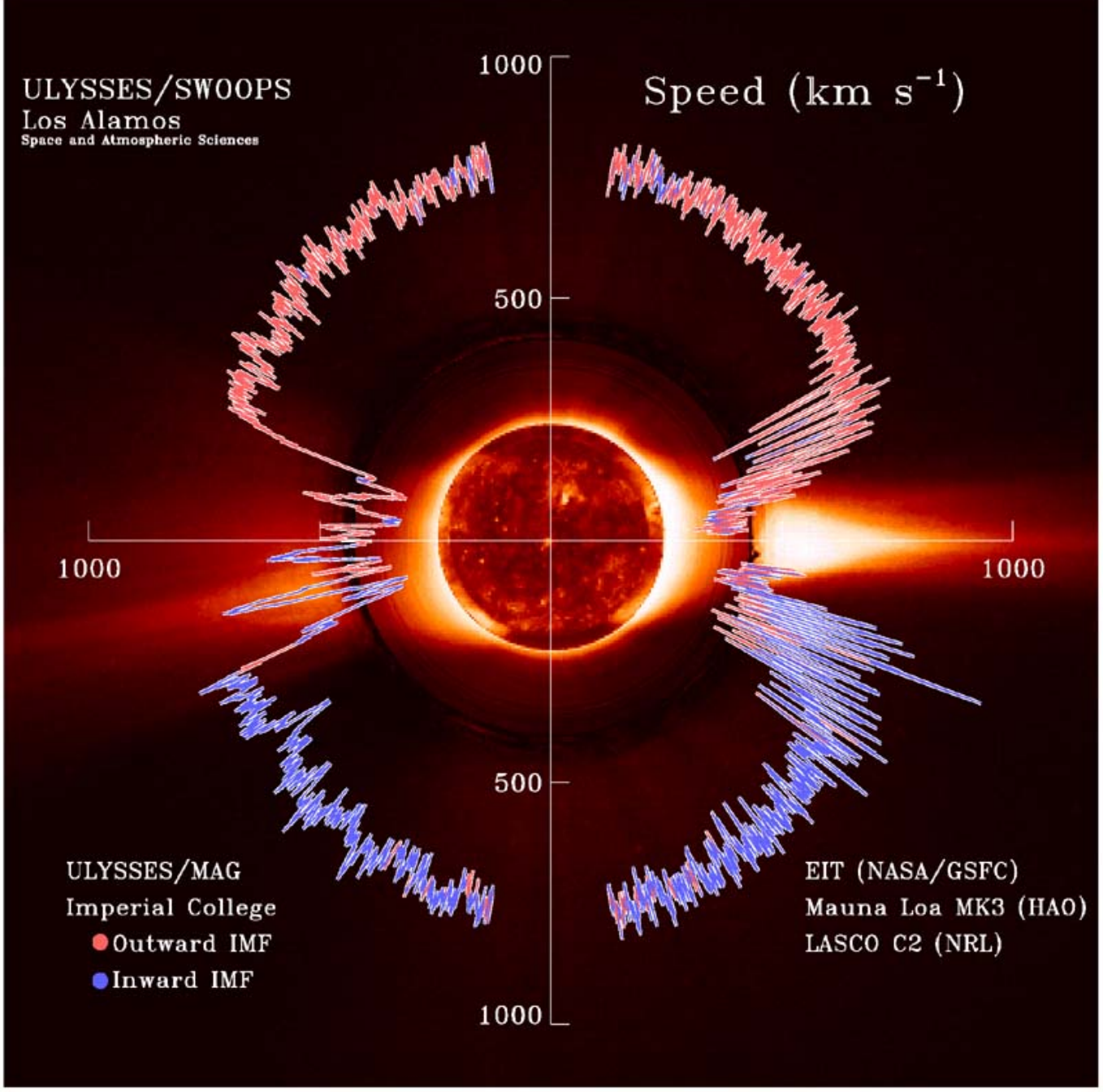
Sarah McGregor

PPPL seminar

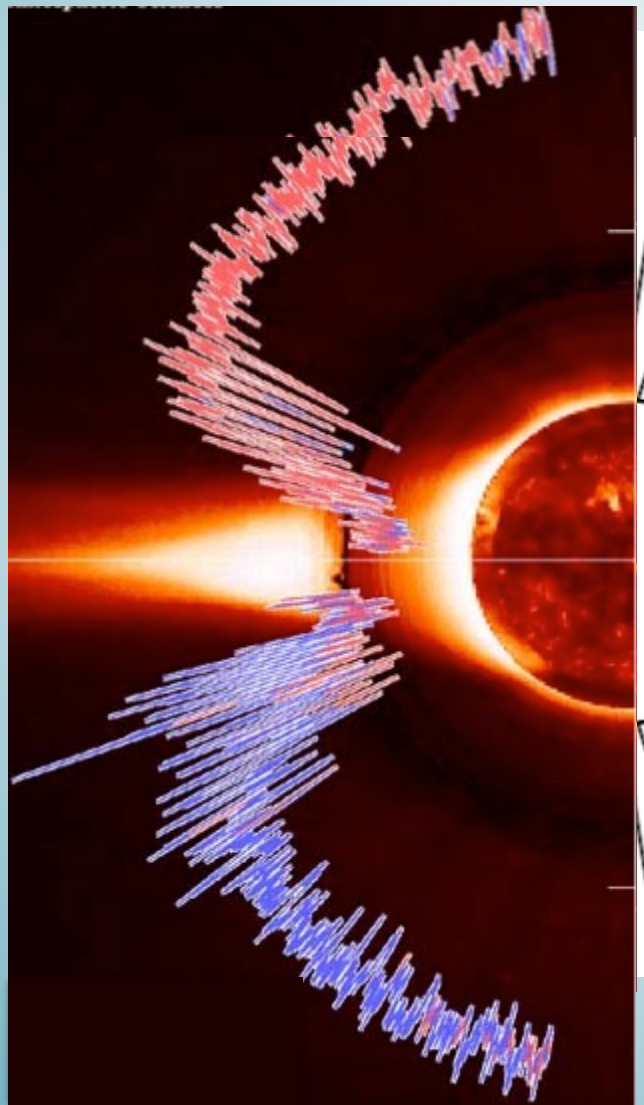
January 8th, 2014

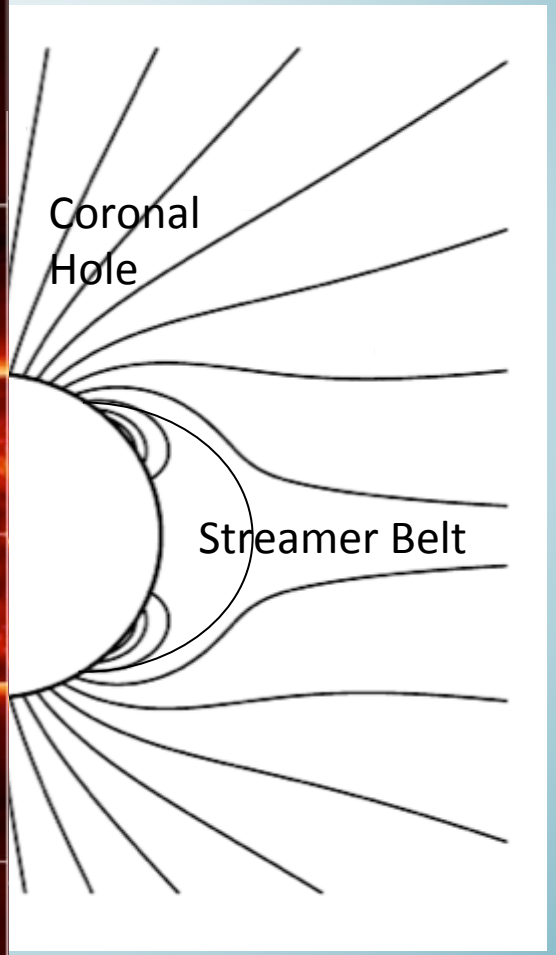

C3 1996/04/30 01:35

The Solar Wind

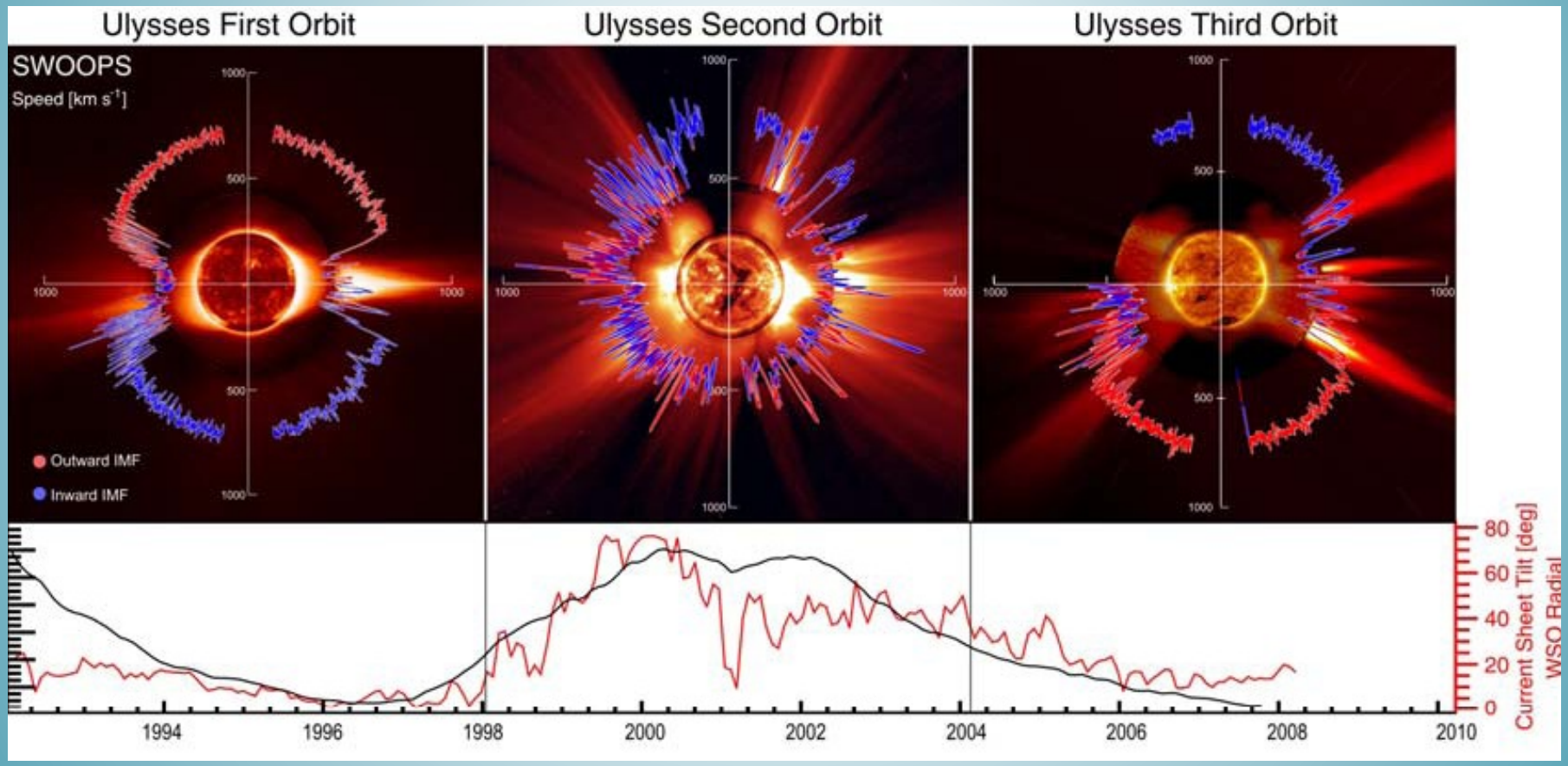

ULYSSES/SWOOPS
Los Alamos
Space and Atmospheric Sciences
Speed (km s^{-1})
1000
500
1000
1000
500
1000
ULYSSES/MAG
Imperial College
Outward IMF
Inward IMF
EIT (NASA/GSFC)
Mauna Loa MK3 (HAO)
LASCO C2 (NRL)

Coronal Magnetic Field and the Solar Wind



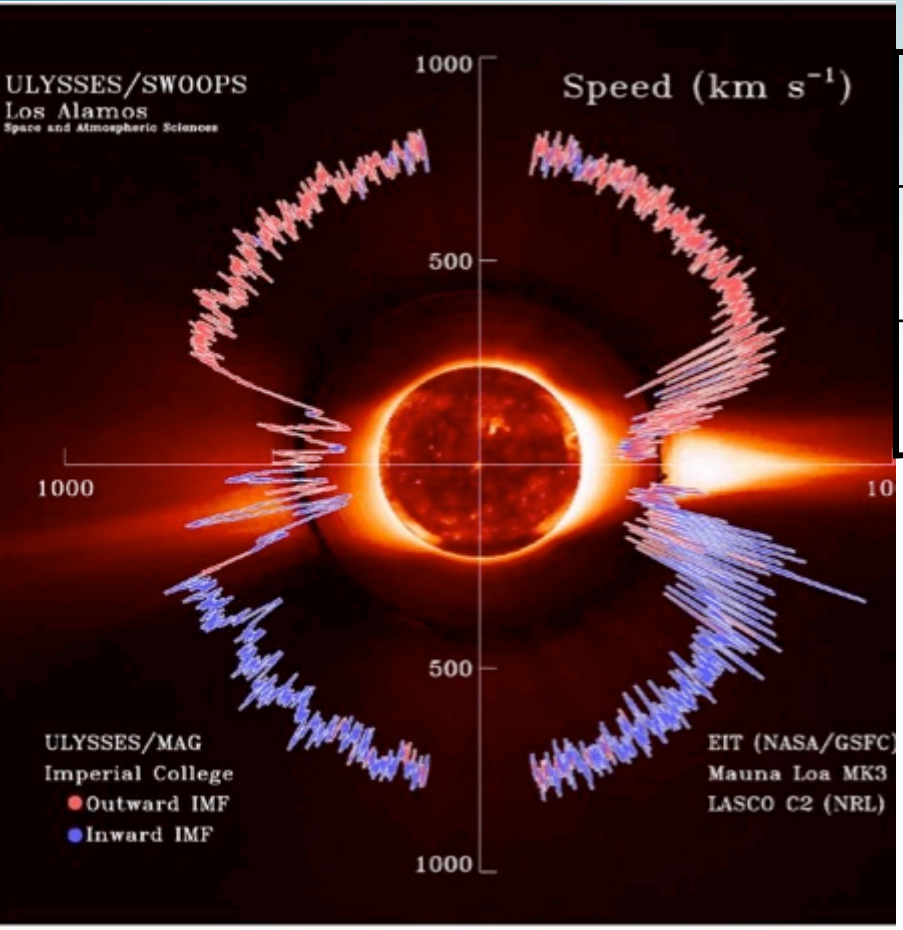


- At solar maximum the large polar coronal holes disappear and are replaced by smaller, generally short lived coronal holes at all latitudes. Ulysses observed fast and slow wind at all latitudes in the southern hemisphere.

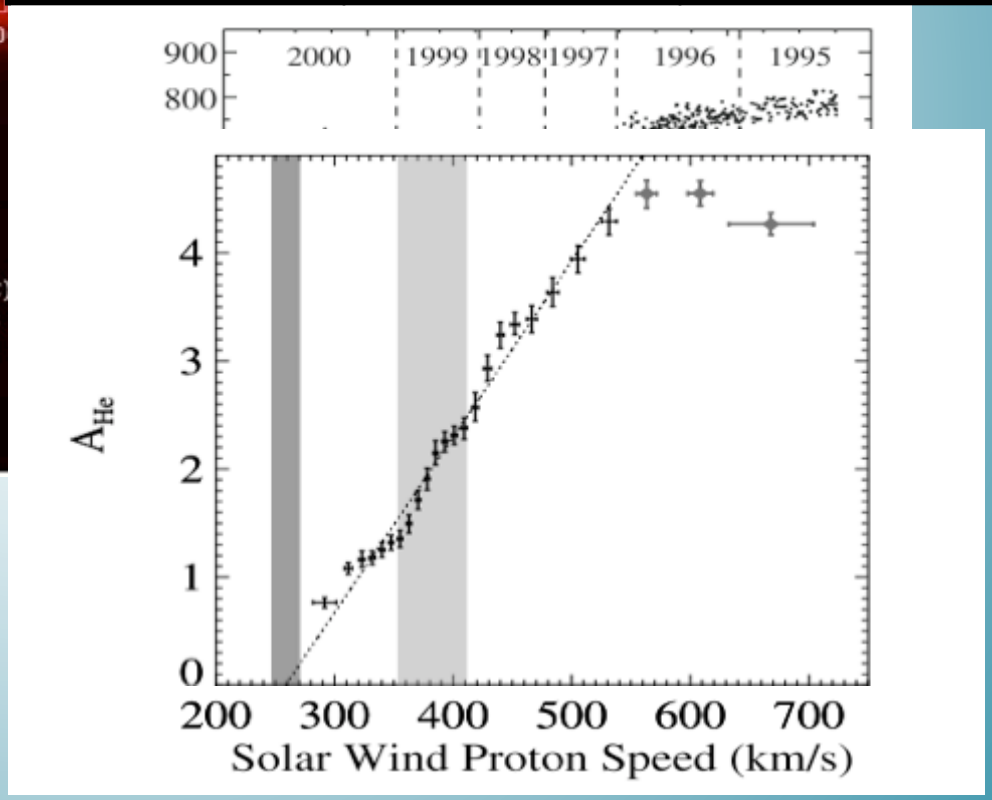


McComas et al, (2008)

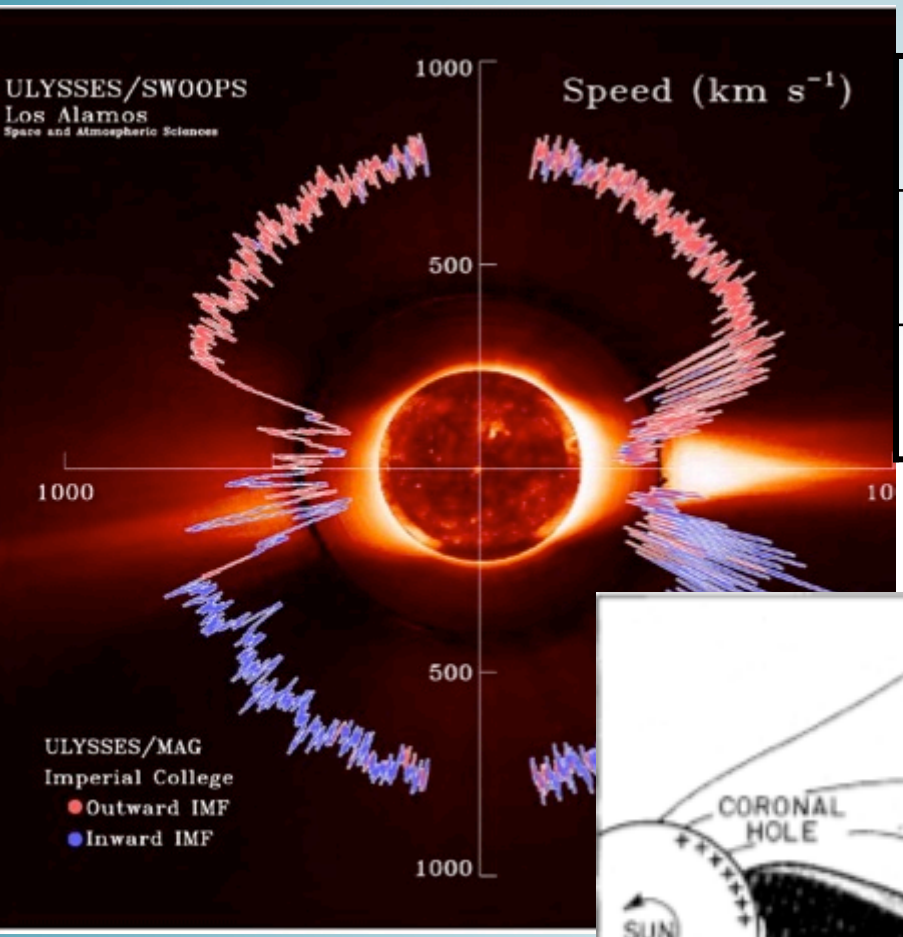
Compositional Variations in the Solar Wind



	Fast Solar Wind	Slow Solar Wind
Alpha Abundance	high	low
Ionic Charge States ratios	low	high



Paradigm of Solar Wind Composition



	Fast Solar Wind	Slow Solar Wind
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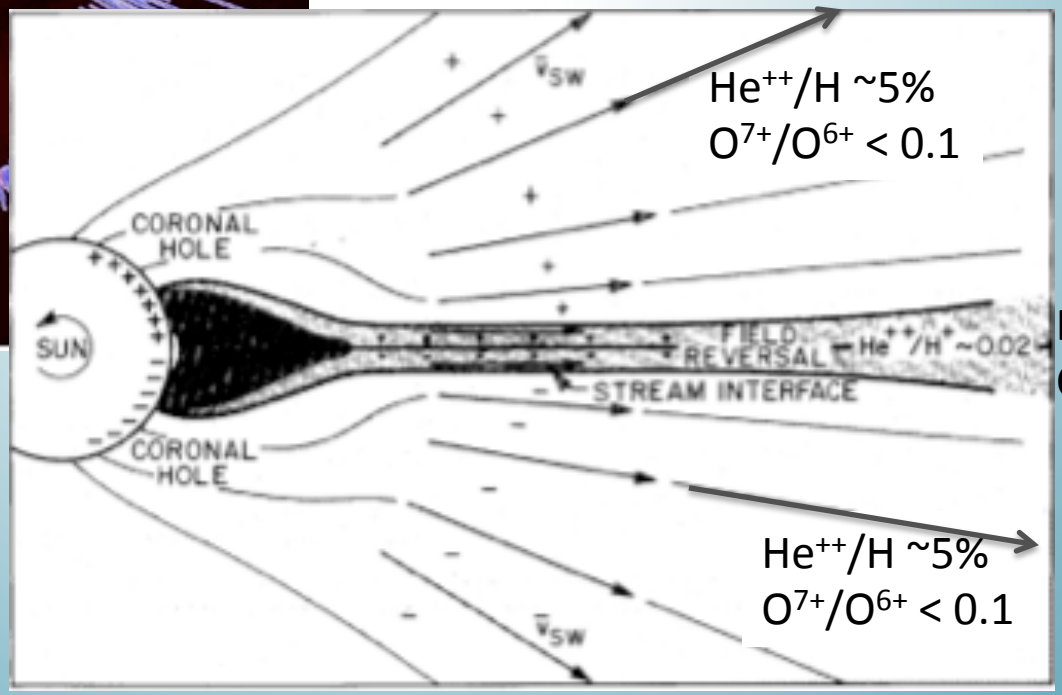
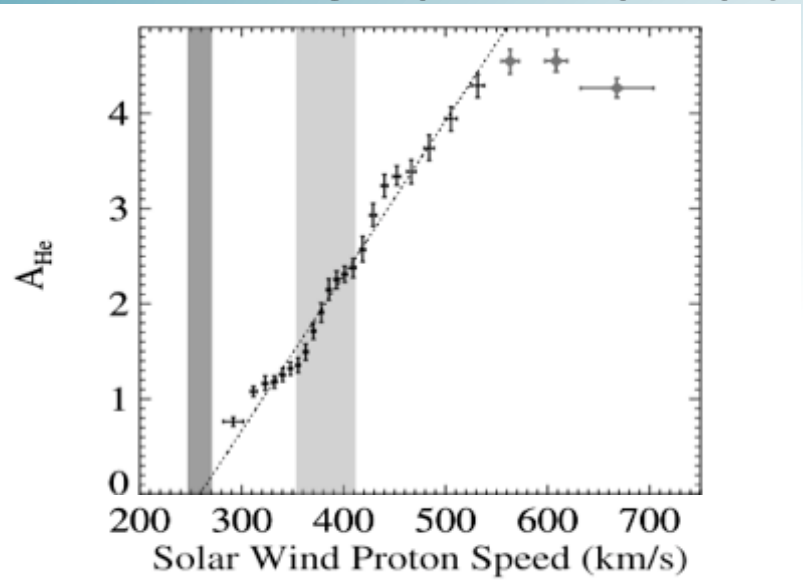
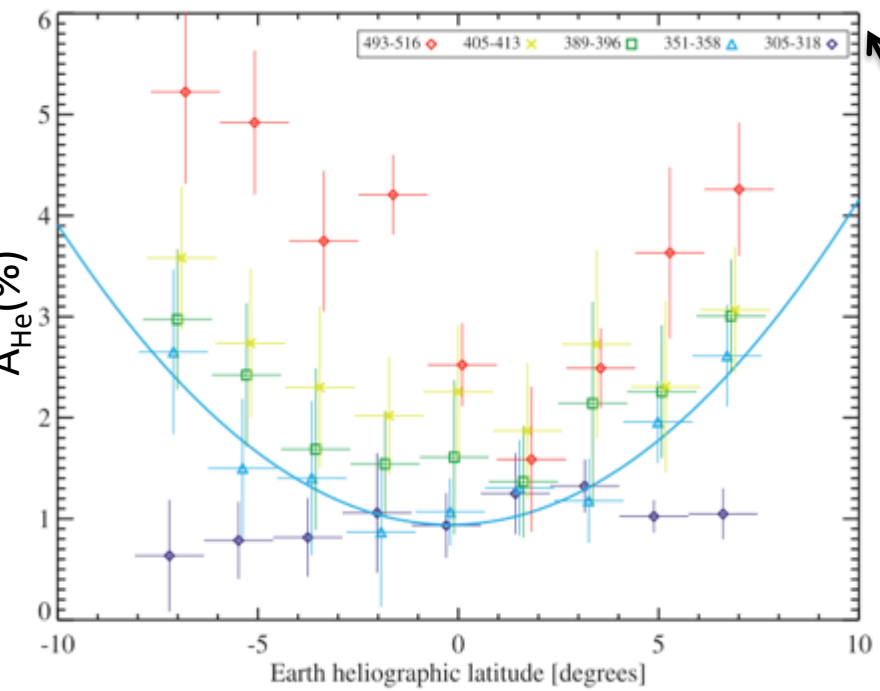
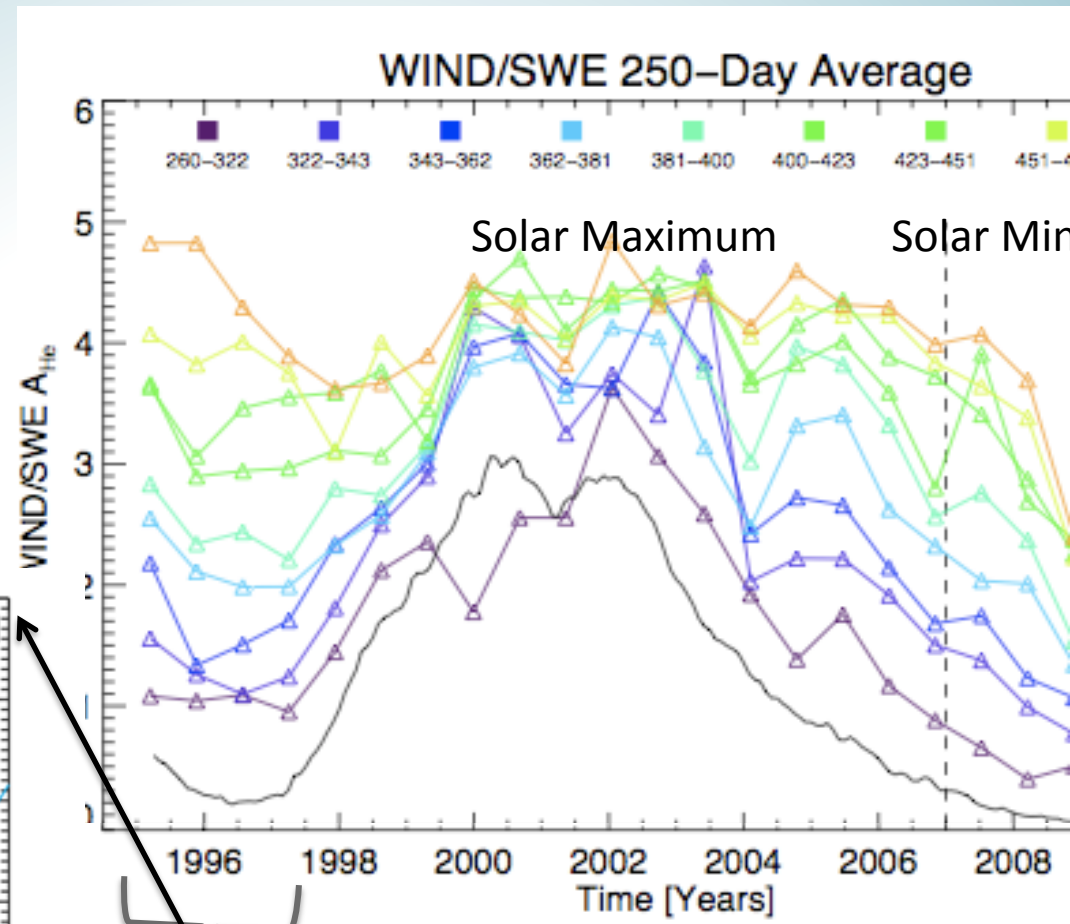


He^{++}/H ~2%
$O^{7+}/O^{6+} > 0.1$

Helium Variations in the Solar wind



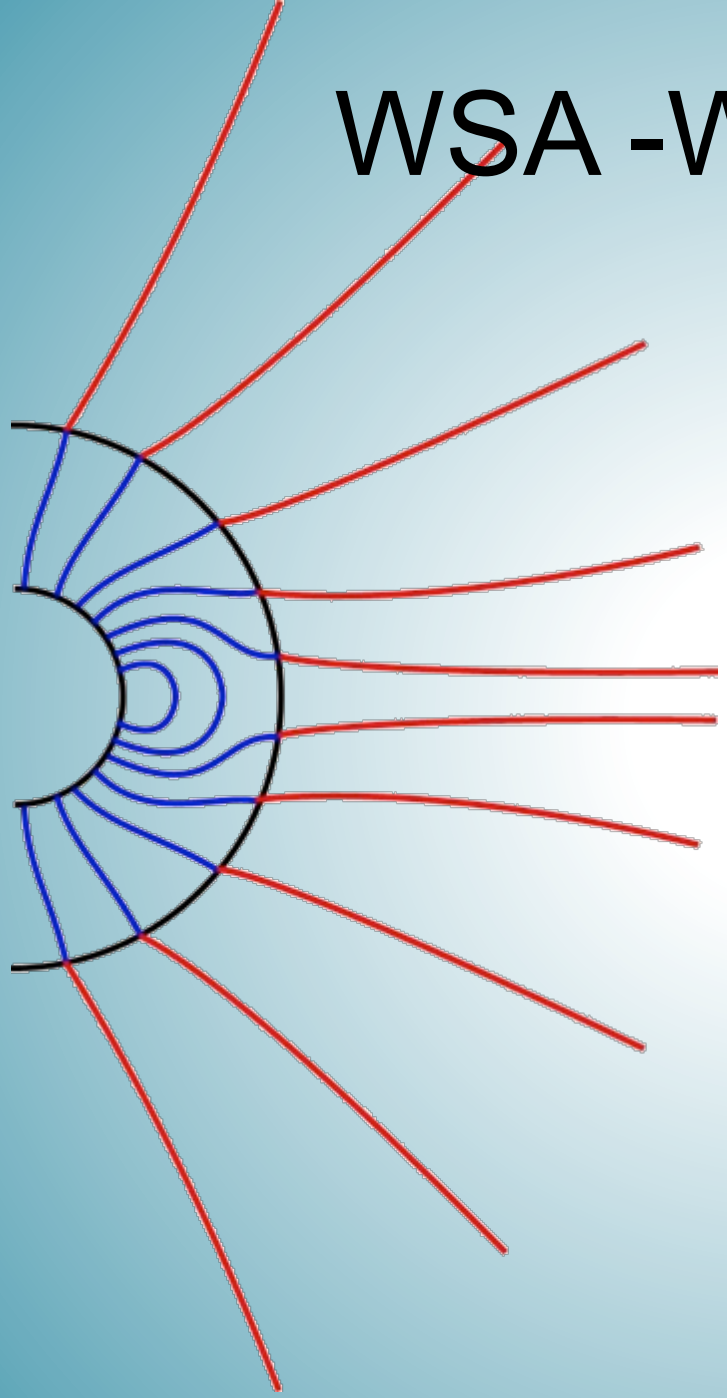




$$A_{He} = 100 * n_{alpha}/n_{proton}$$

- What causes the variability in the composition of the slow and fast solar wind?
- What are the sources of the slow solar wind?

WSA -Wang Sheeley Arge



Solves **P**otential **F**ield **S**ource **S**urface and **S**chatten **C**urrent **S**heet model

Assuming:

$$\nabla \times B = 0$$

$$B = -\nabla \phi$$

$$\nabla^2 \phi = 0$$

Solution domain: 1 Rs to 21.5 Rs

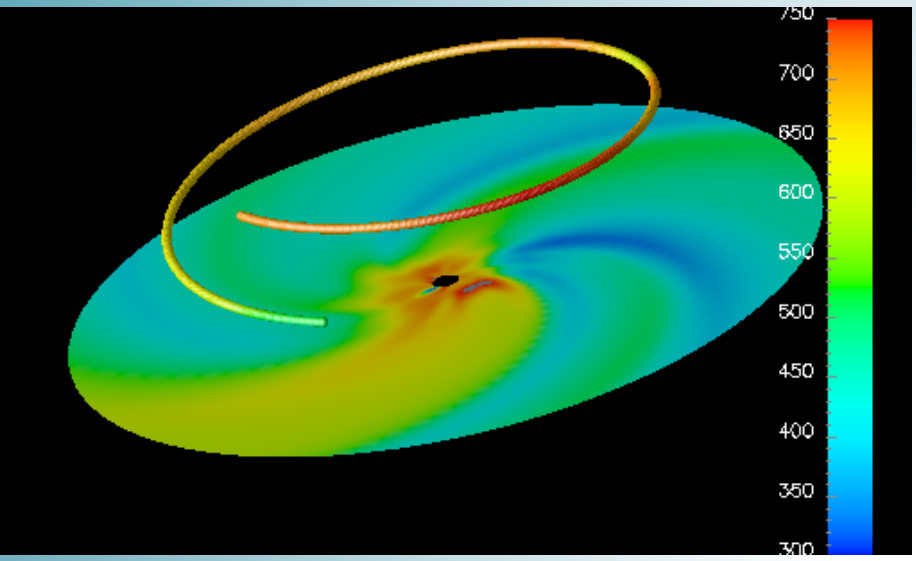
Uses NSO Kitt Peak Magnetograms

Calculates the solar wind speed on the outer boundary (21.5 Rs) based on:

~~expansion factor

~~magnetic foot point boundary distance

Enlil (Heliosphere Model)



Carrington Rotation, 1894
equatorial cut plane of Solar Wind Speed (km/s)

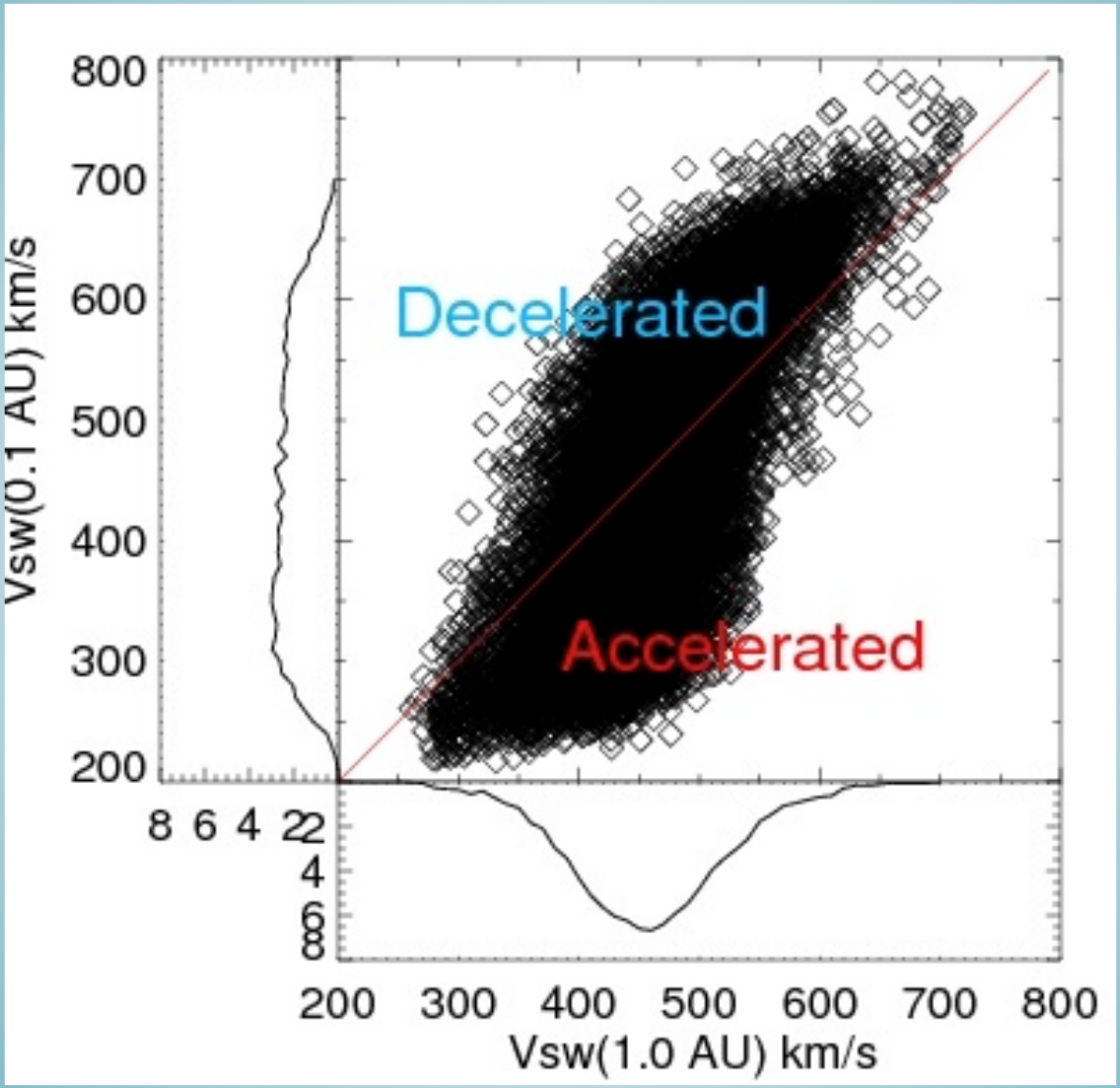
Solves 3D ideal Magnetohydrodynamic equations

Solution domain: 0.1AU - 1.5 AU

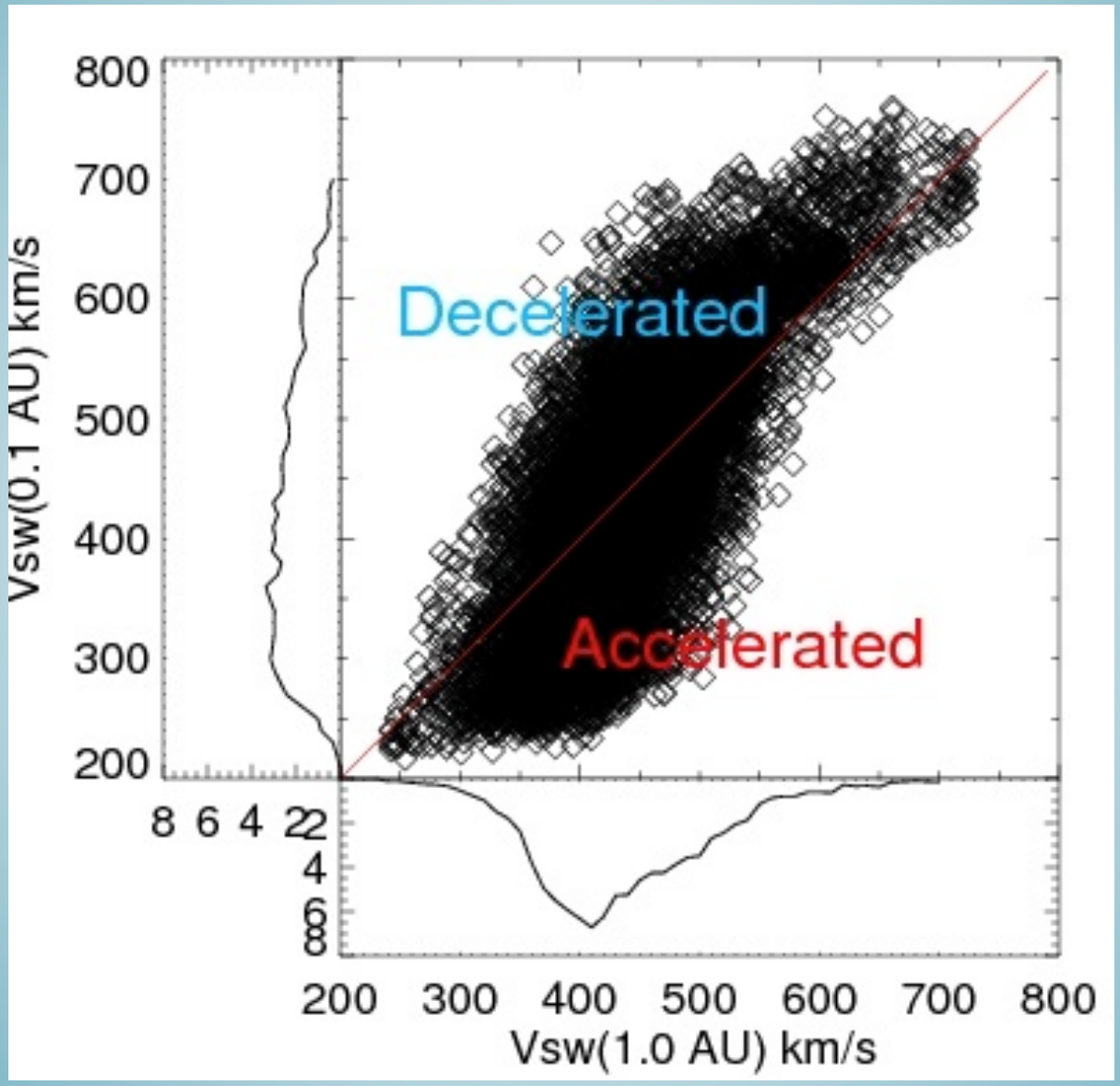
Grid Resolution: 4 degrees

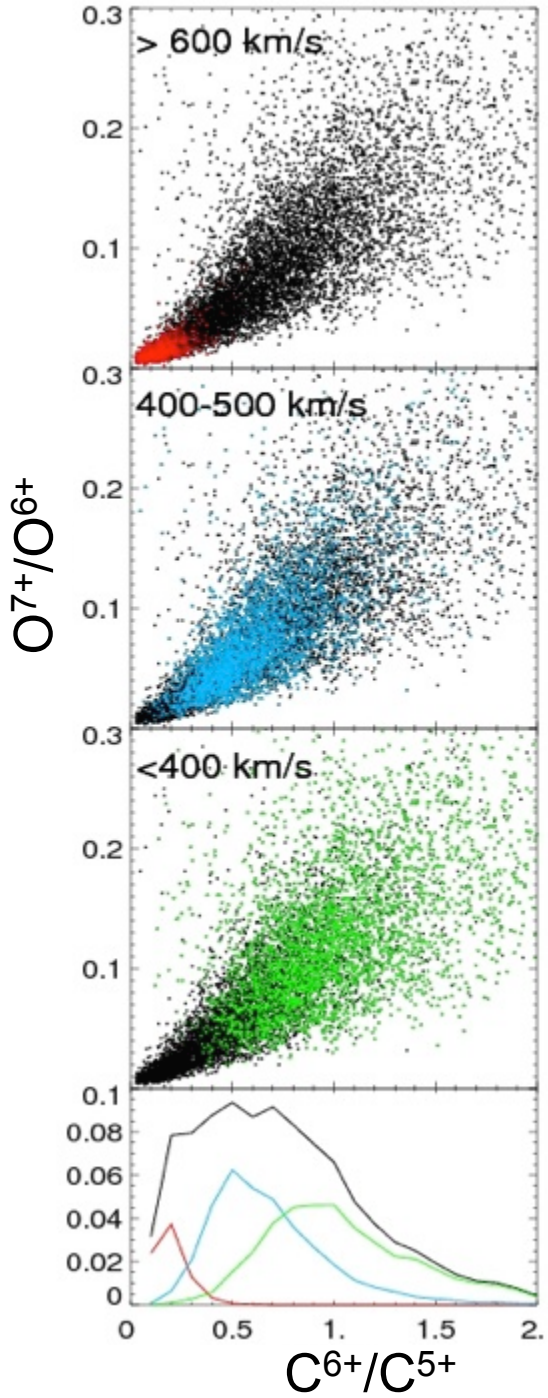
Inner boundary (21.5 R_{solar} ~ 0.1AU):
*Uses velocity and magnetic field from WSA
*Assumes momentum flux conservation and pressure balance to calculate
~~mass density
~~temperature

Solar Minimum: 1995-1997



Solar Minimum: 2007-2008





Solar Minimum, 2007-2008

Black: ACE Ionic Charge State Ratios

Red: V_{sw} > 600 km/s
(pristinely fast wind)

Blue: **500 km/s < V_{sw}< 400 km/s**

Green V_{sw}< 400 km/s:

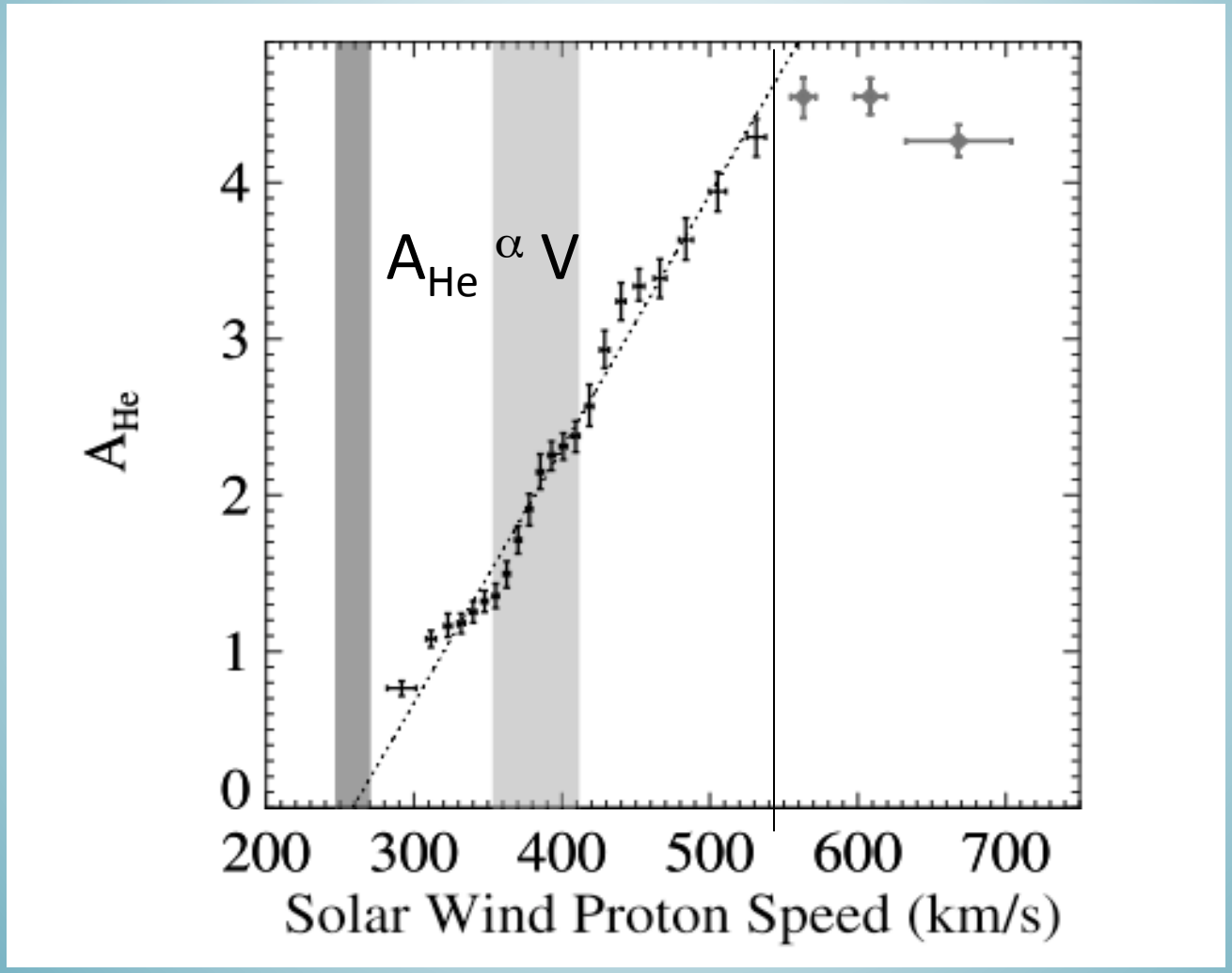
Not so Shocking Revelation

- The Solar wind speed ‘evolves’ as it propagates through the heliosphere

- But how does this help us to understand solar wind compositional variations?

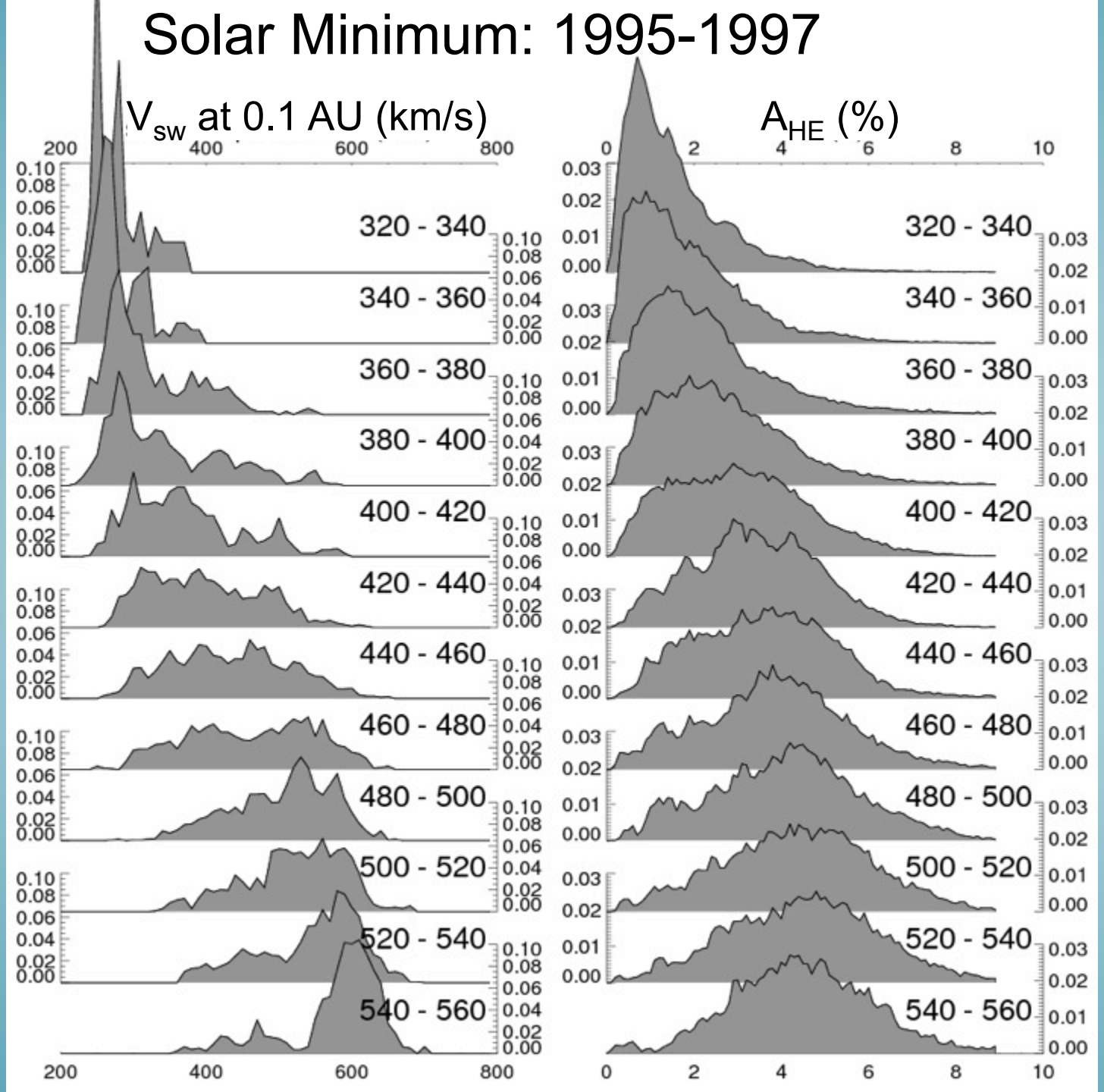
Alpha to Proton Ratio (A_{He})

$A_{He} = 100 * n_{alpha}/n_{proton}$

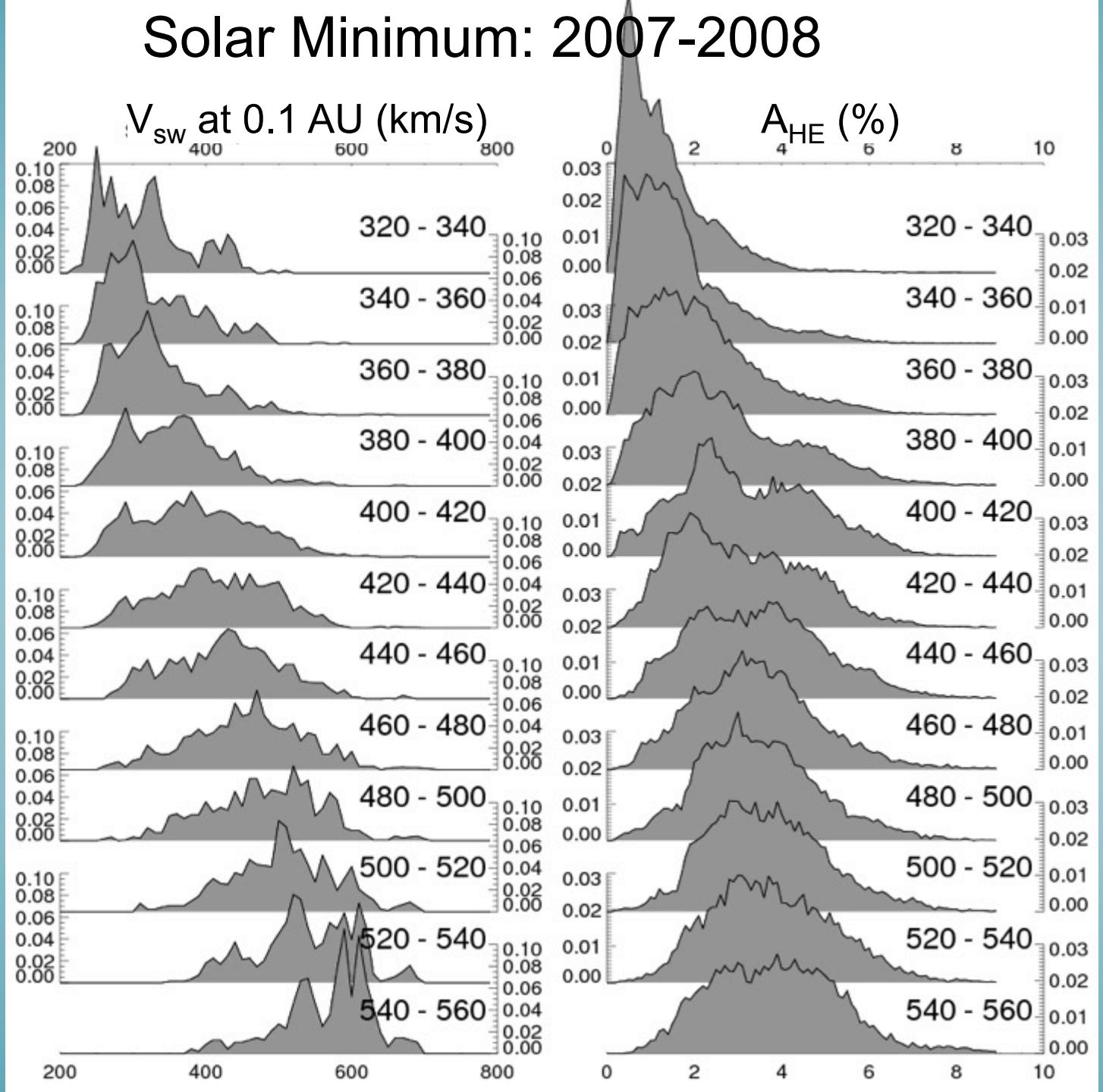


Kasper et al., 2007

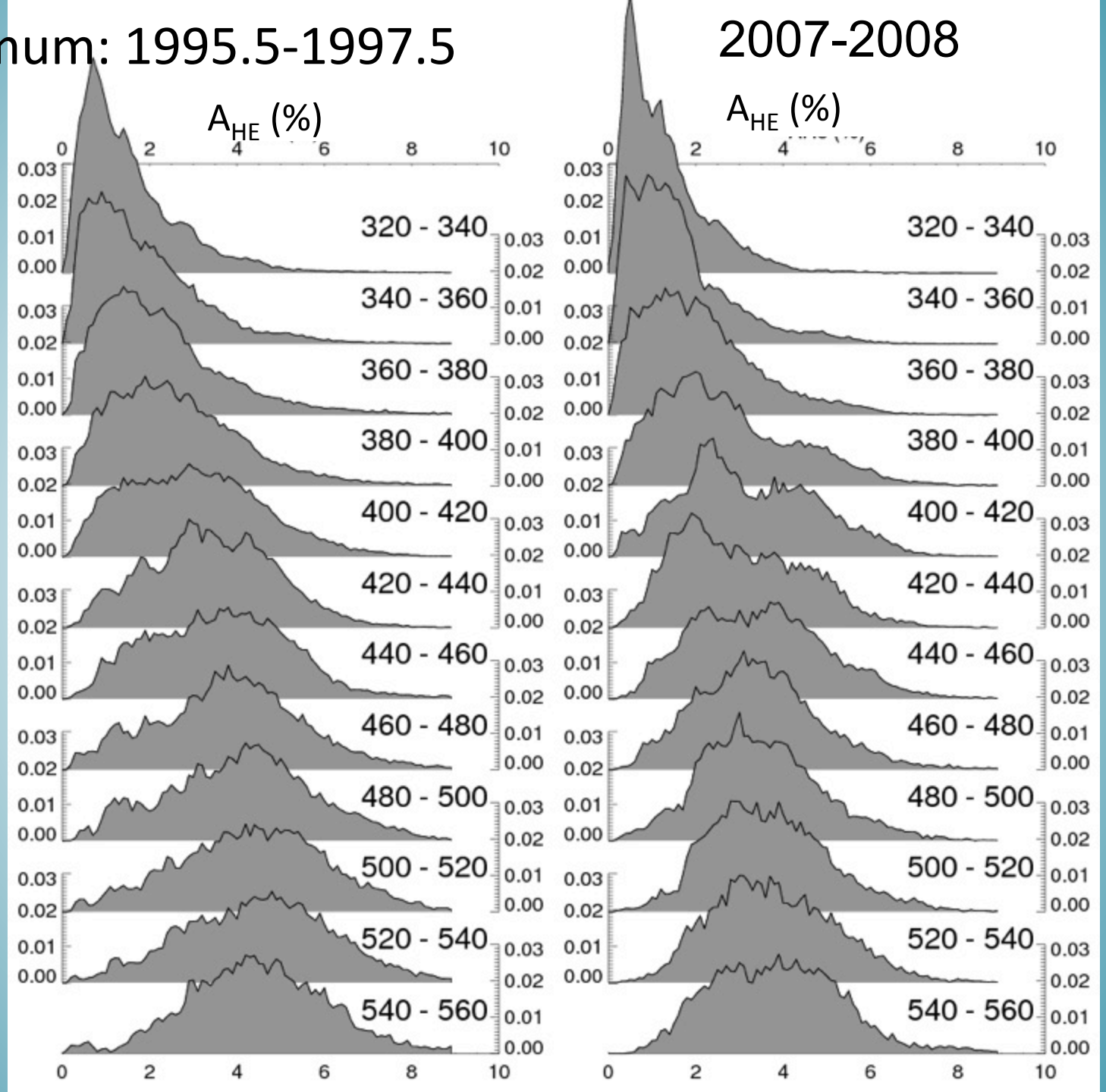
Solar Minimum: 1995-1997



Solar Minimum: 2007-2008

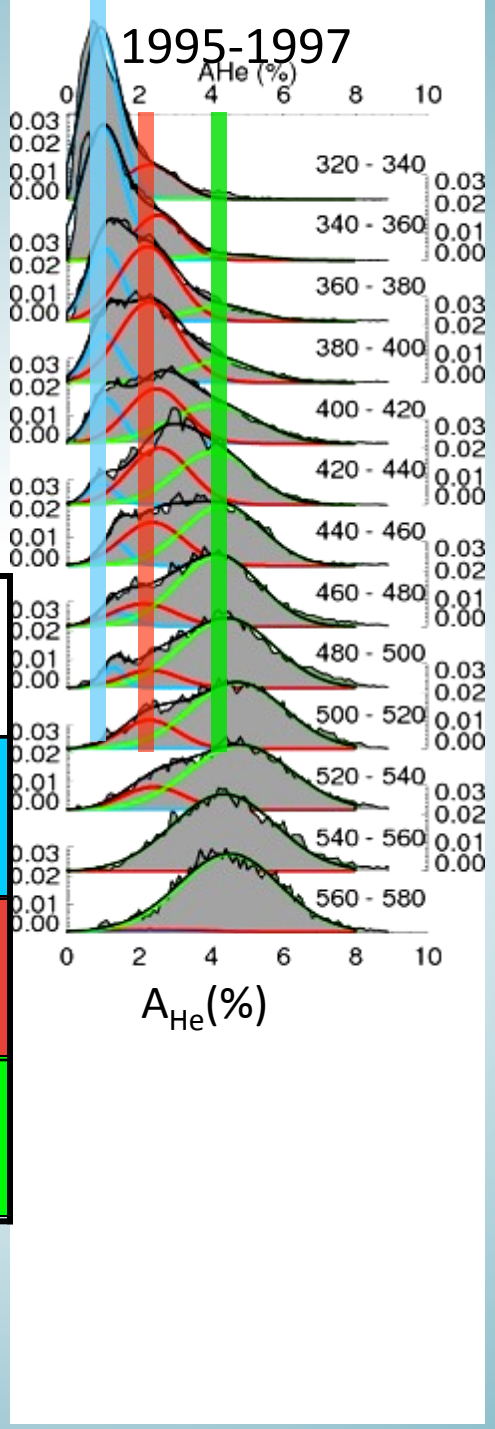


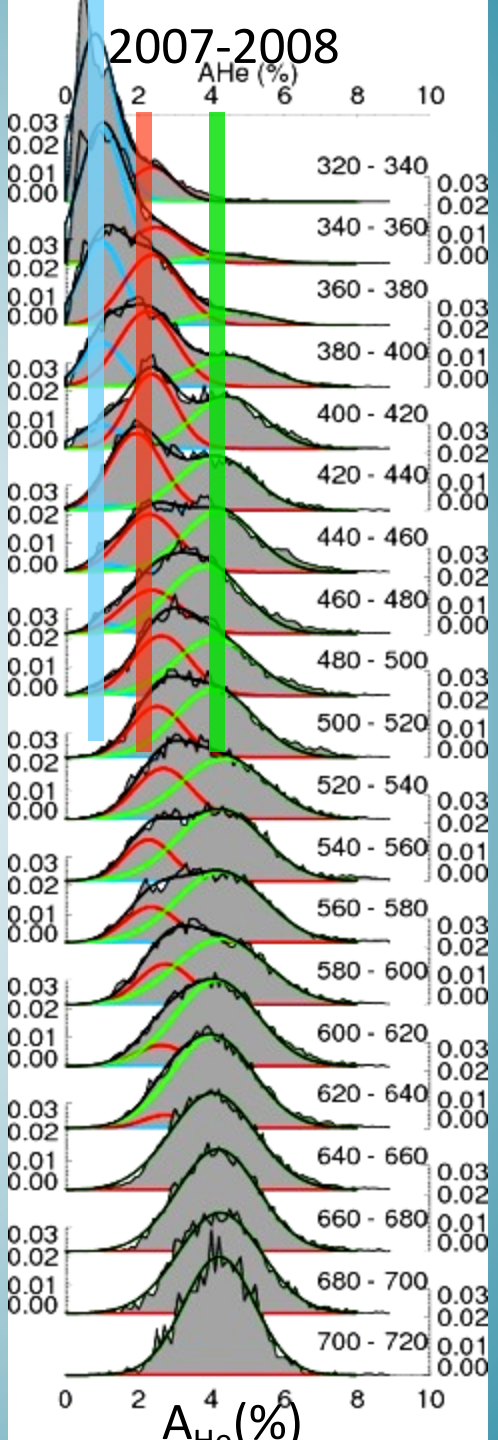
Solar Minimum: 1995.5-1997.5

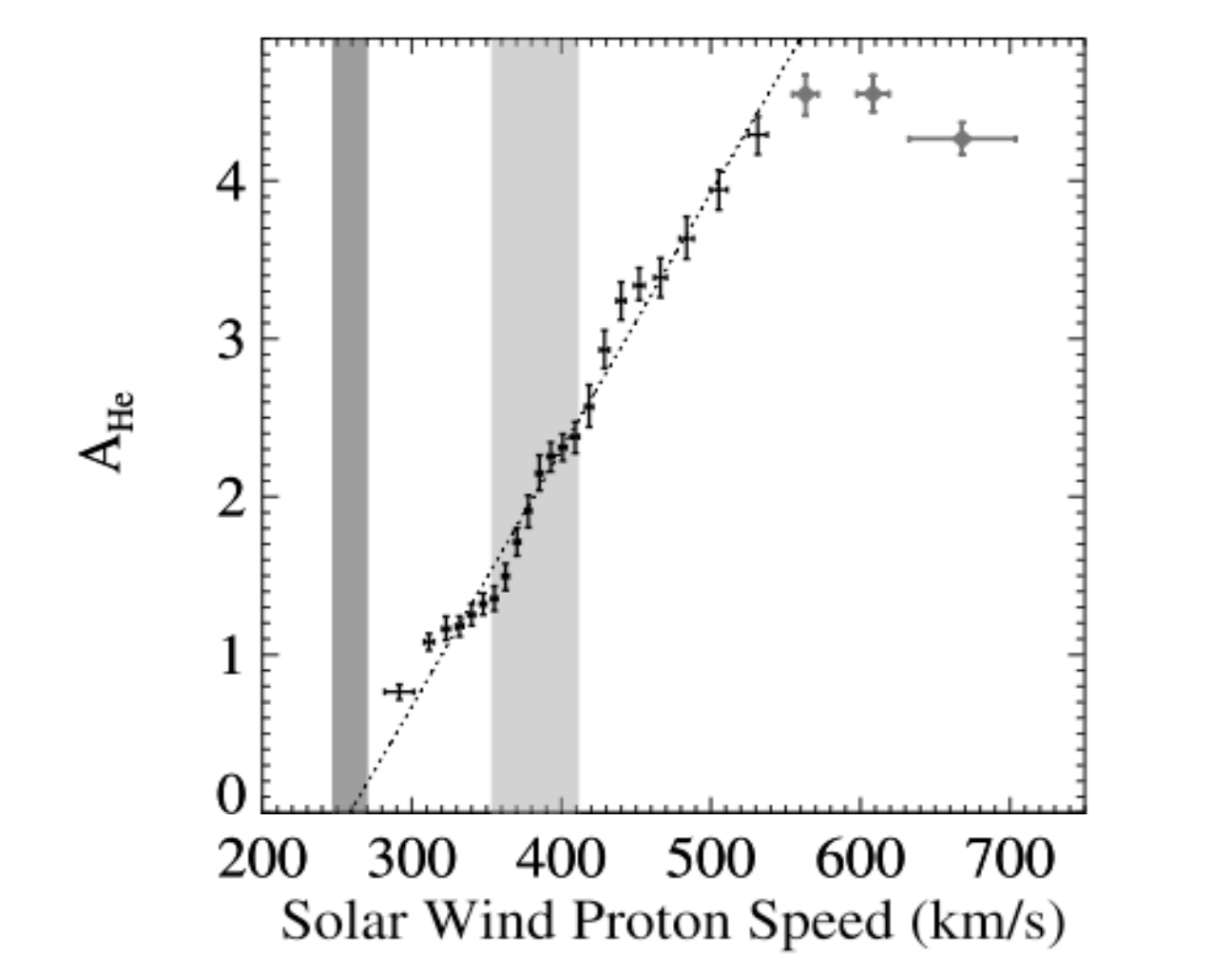


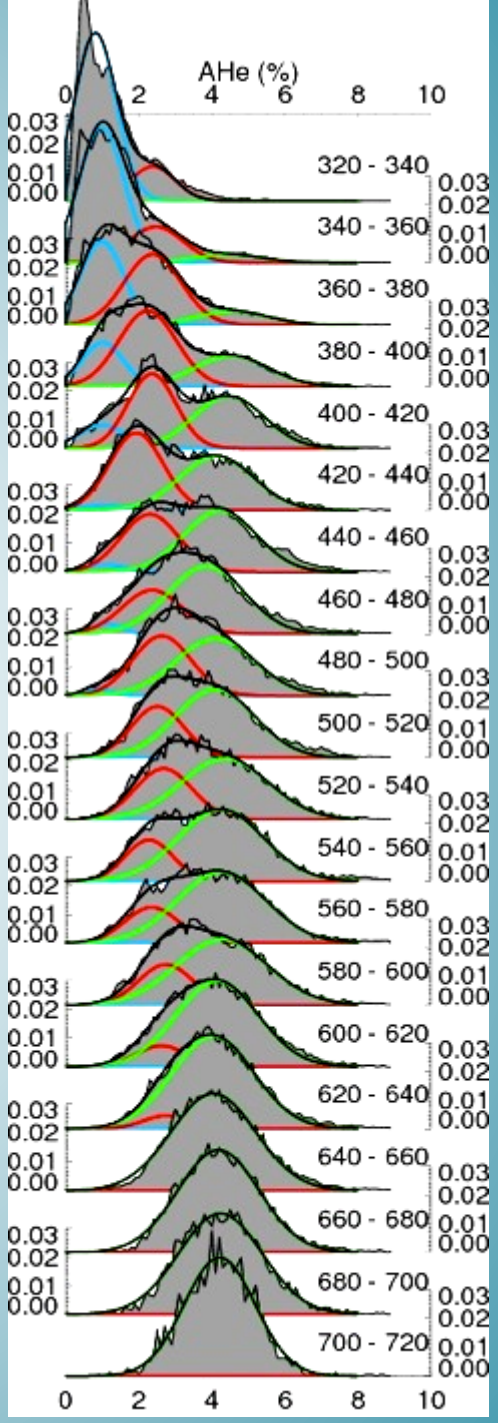
Three distinct A_{He} populations in the Solar Wind

	Mean centroid	Mean FWHM
Blue	**1.1±0.2**	**0.5±0.1**
Red	**2.4±0.2**	**0.8±0.1**
Green	**4.3±0.2**	**1.1±0.1**

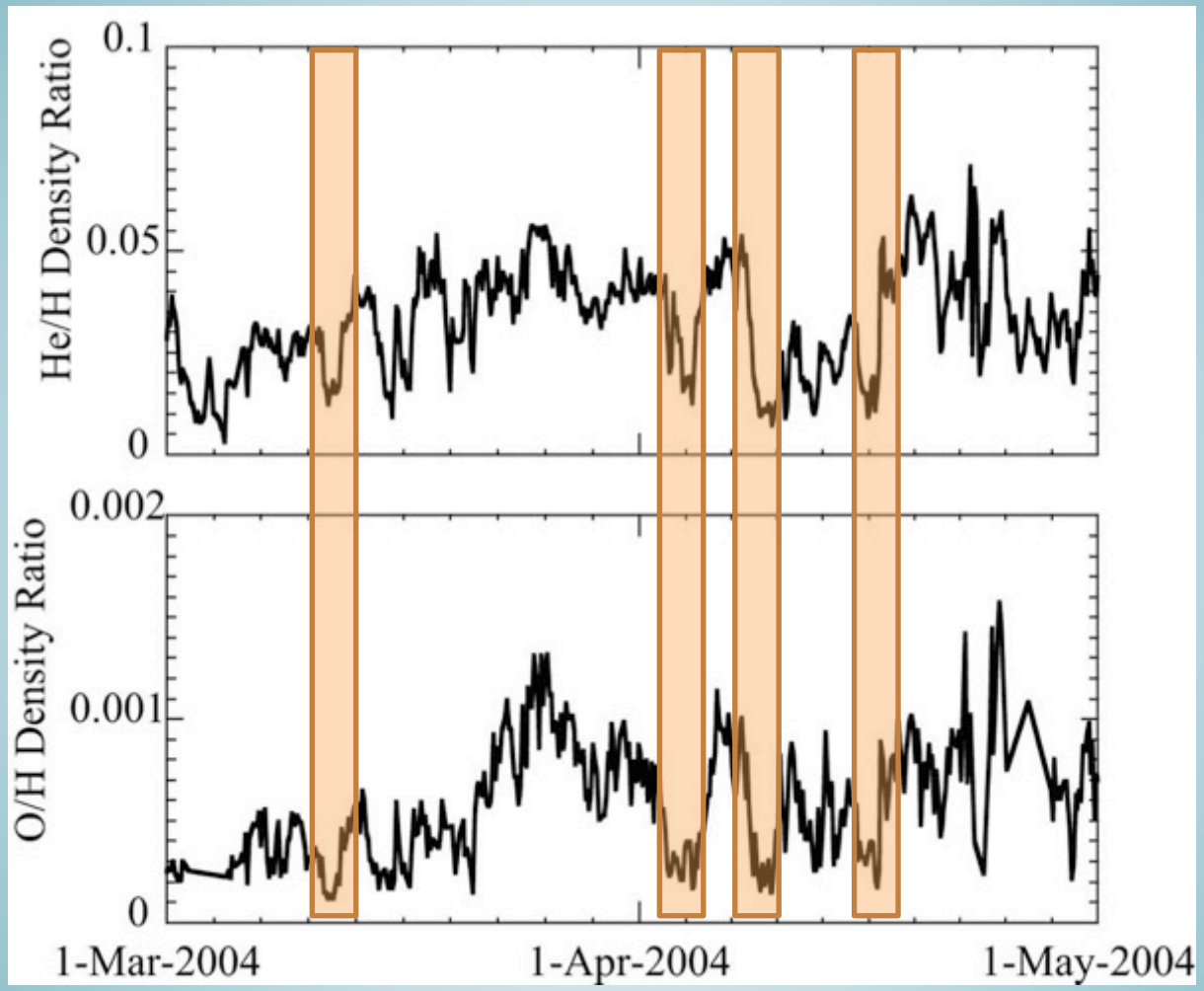





A_{He}
0
1
2
3
4
200
300
400
500
600
700
Solar Wind Proton Speed (km/s)

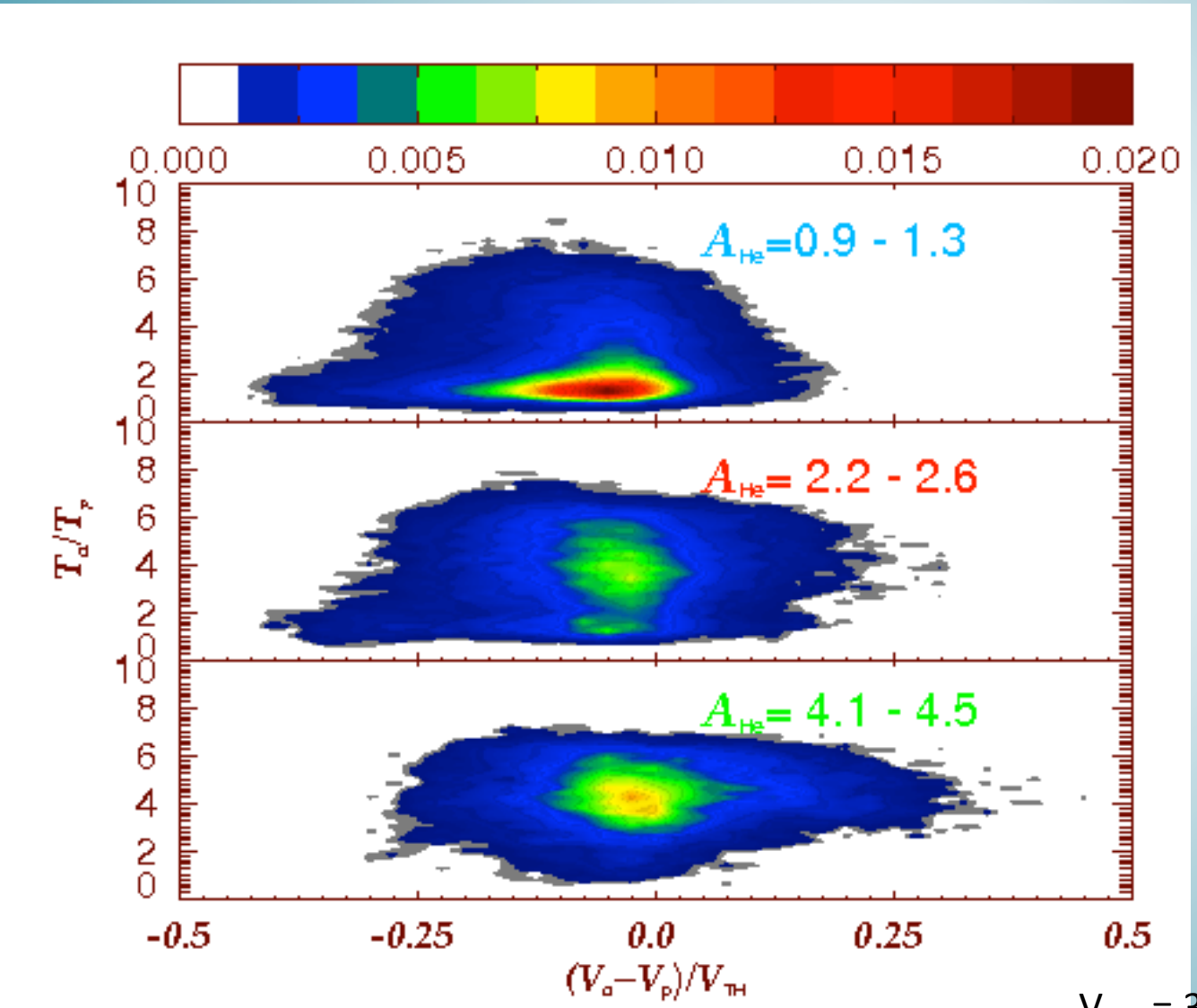

AHe (%)
0
2
4
6
8
10
0.03
0.02
0.01
0.00
320 - 340
340 - 360
360 - 380
380 - 400
400 - 420
420 - 440
440 - 460
460 - 480
480 - 500
500 - 520
520 - 540
540 - 560
560 - 580
580 - 600
600 - 620
620 - 640
640 - 660
660 - 680
680 - 700
700 - 720

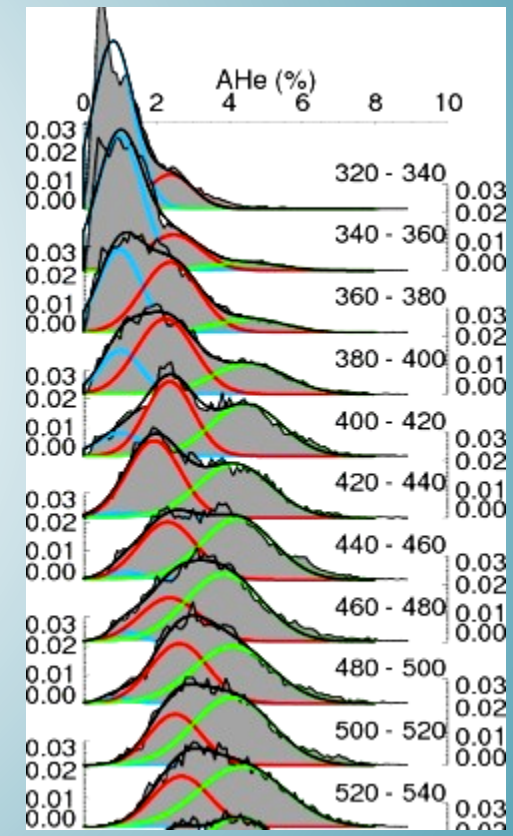
Strong Correlation of A_{HE} and O/H



SOHO/UVCS spectroscopic measurements of abundances in the ***core* of streamers** have shown that they are often (but not always) depleted in O/H.

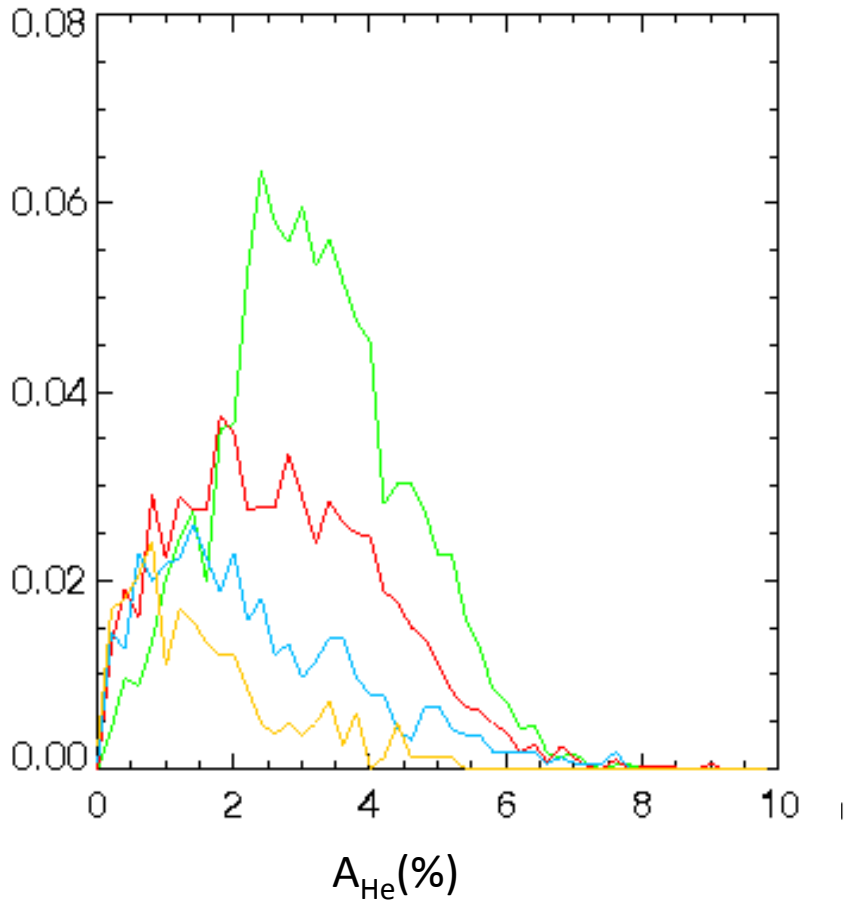
Temperature Ratios

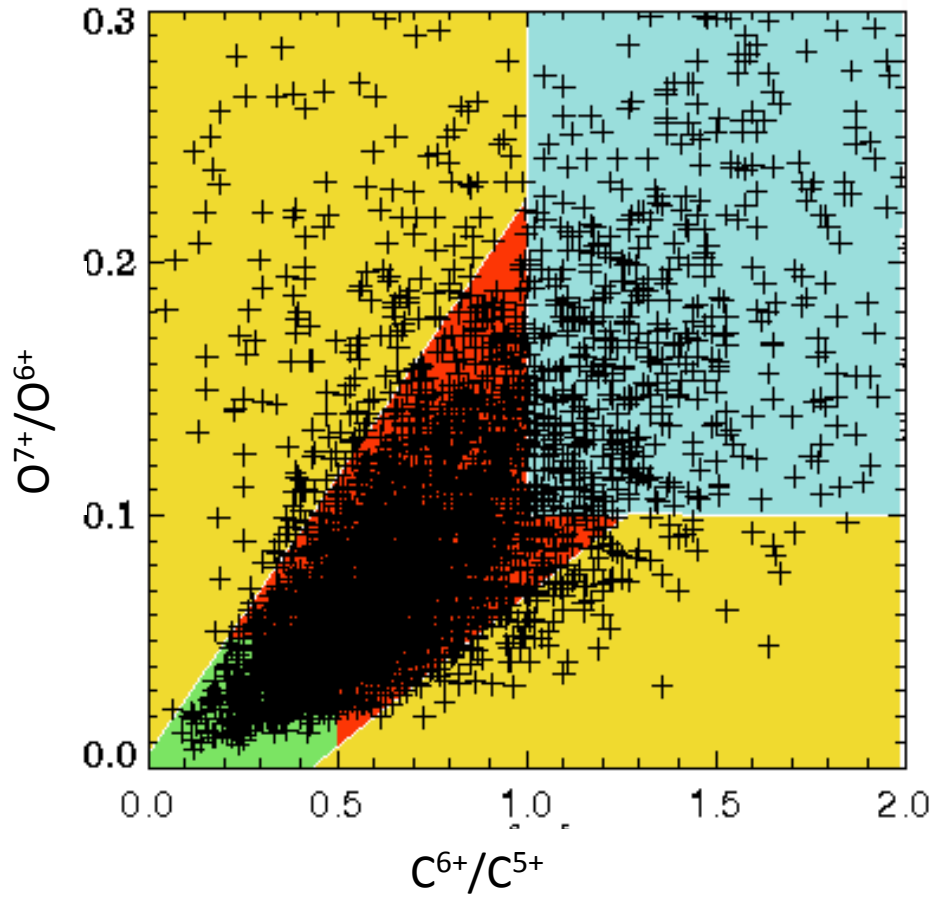




V_{SW} = 320-520 km/s

Ionic Charge State Ratios and A_{He}

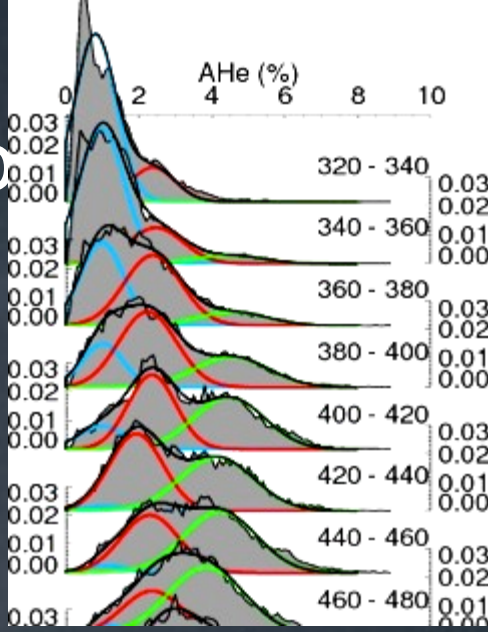




V_{SW}=<500 km/s

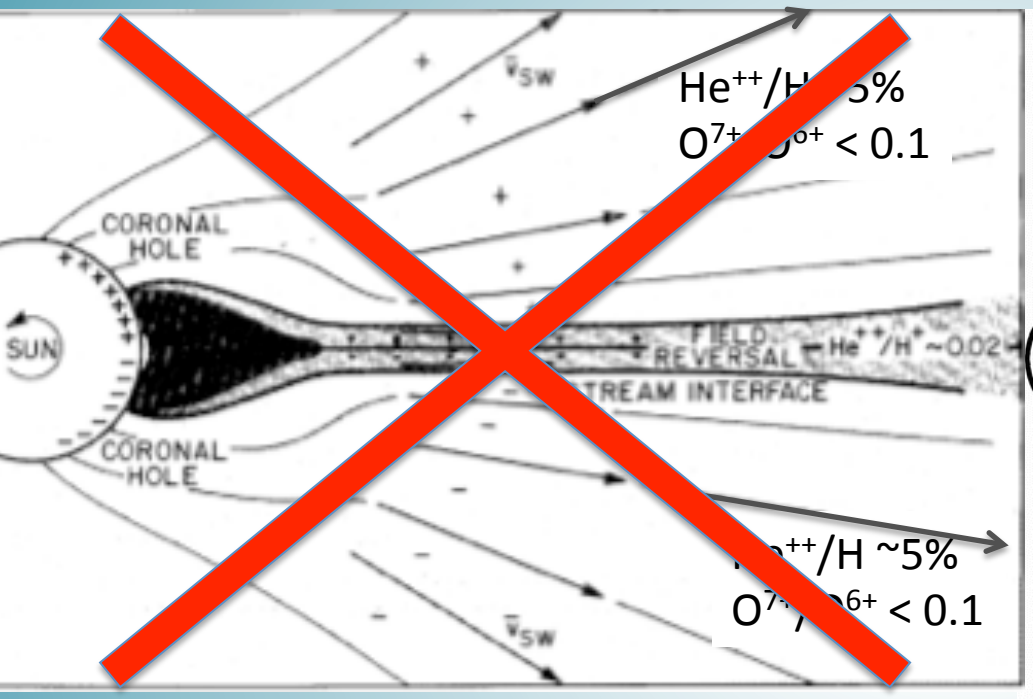
ACE 1 hr observations for 2007-2008

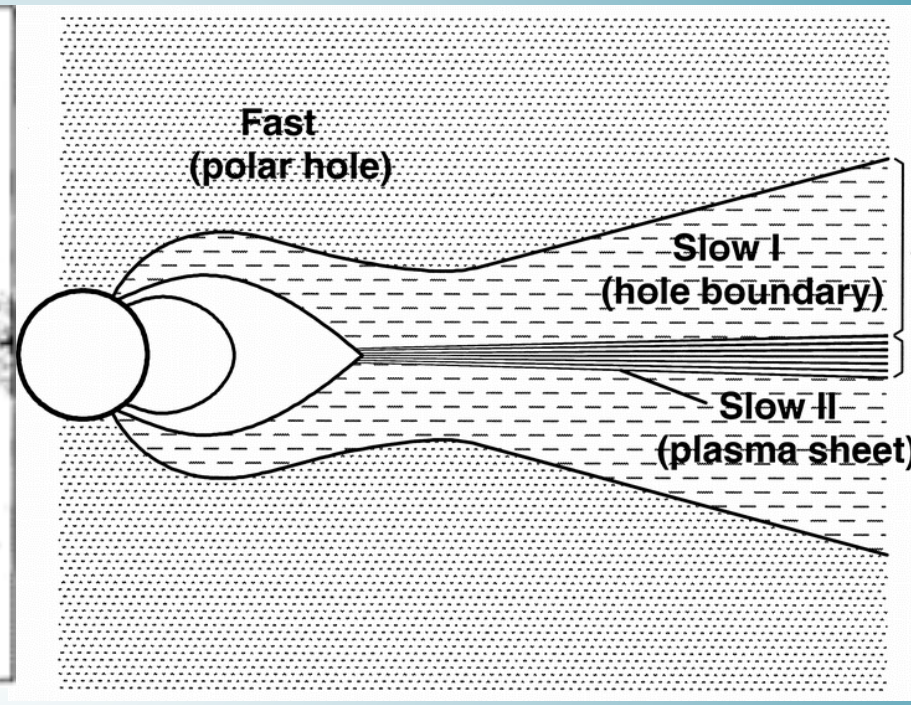
Possible Solar Source Regio



	FCW-I	SCW-II	SCW-I
A_{He} Peak	~4.3	~1.1	~2.4
$T\alpha/Tp$	~5	Isothermal	~4
Ionic charge state ratios	Low O^{7+}/O^{6+} and low C^{6+}/C^{5+}	At least one (O^{7+}/O^{6+} or C^{6+}/C^{5+}) is high	Intermediate O^{7+}/O^{6+} and C^{6+}/C^{5+}

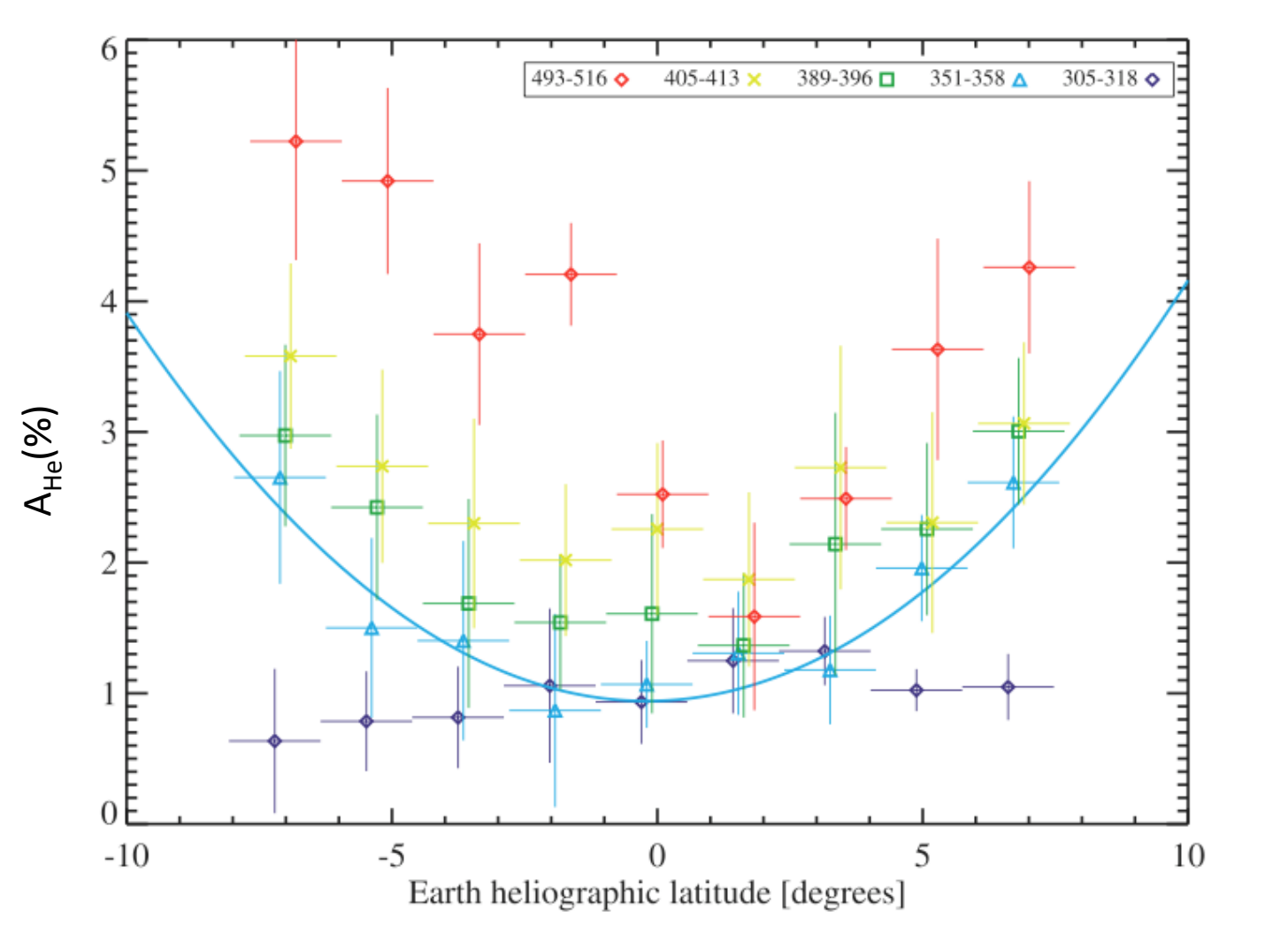
Streamers: open and/or closed?



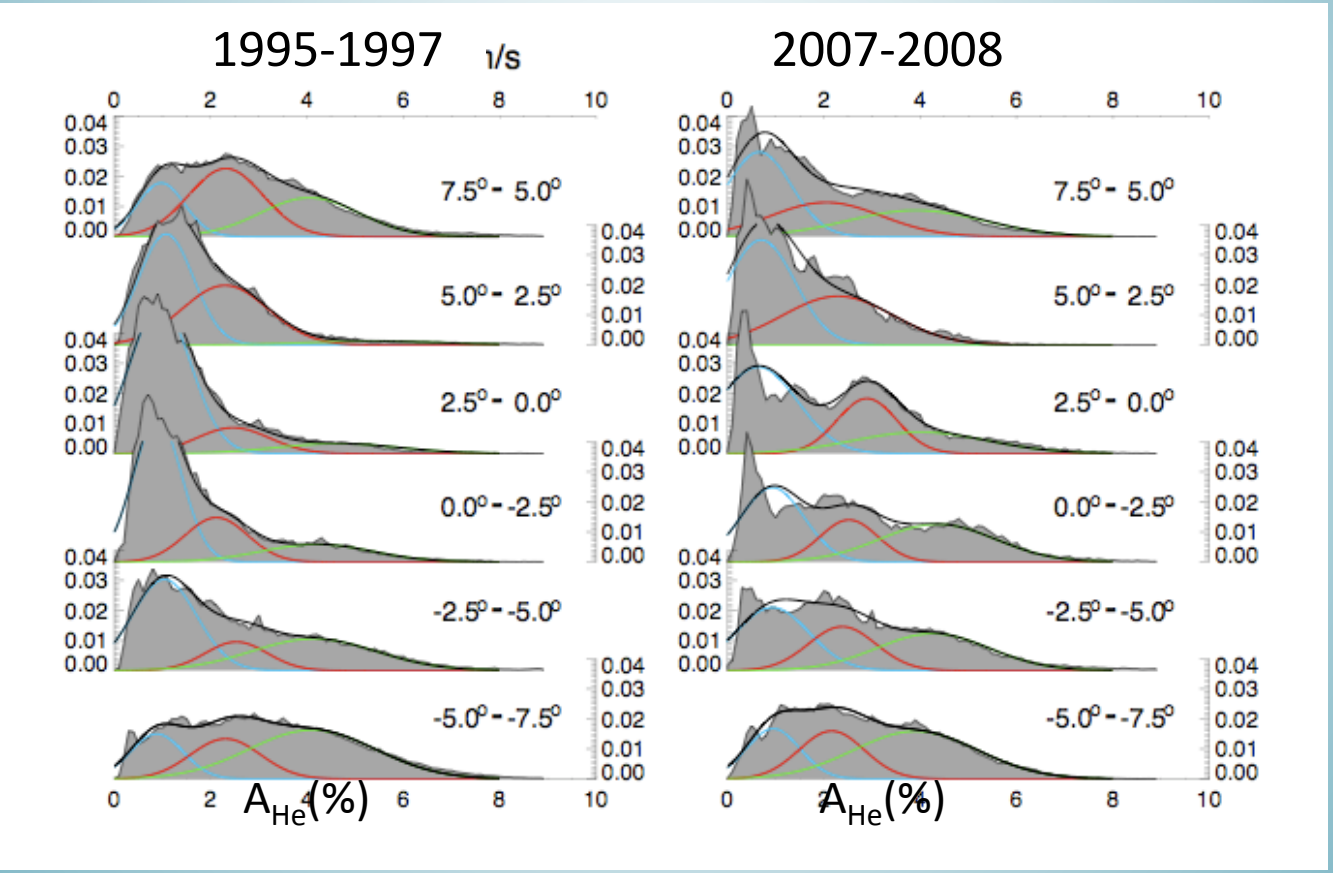


Wang et al. (2000)

But what about variations in Heliographic latitude in 1996 (but not 2008)?



Heliographic latitude variations of A_{He} at Wind

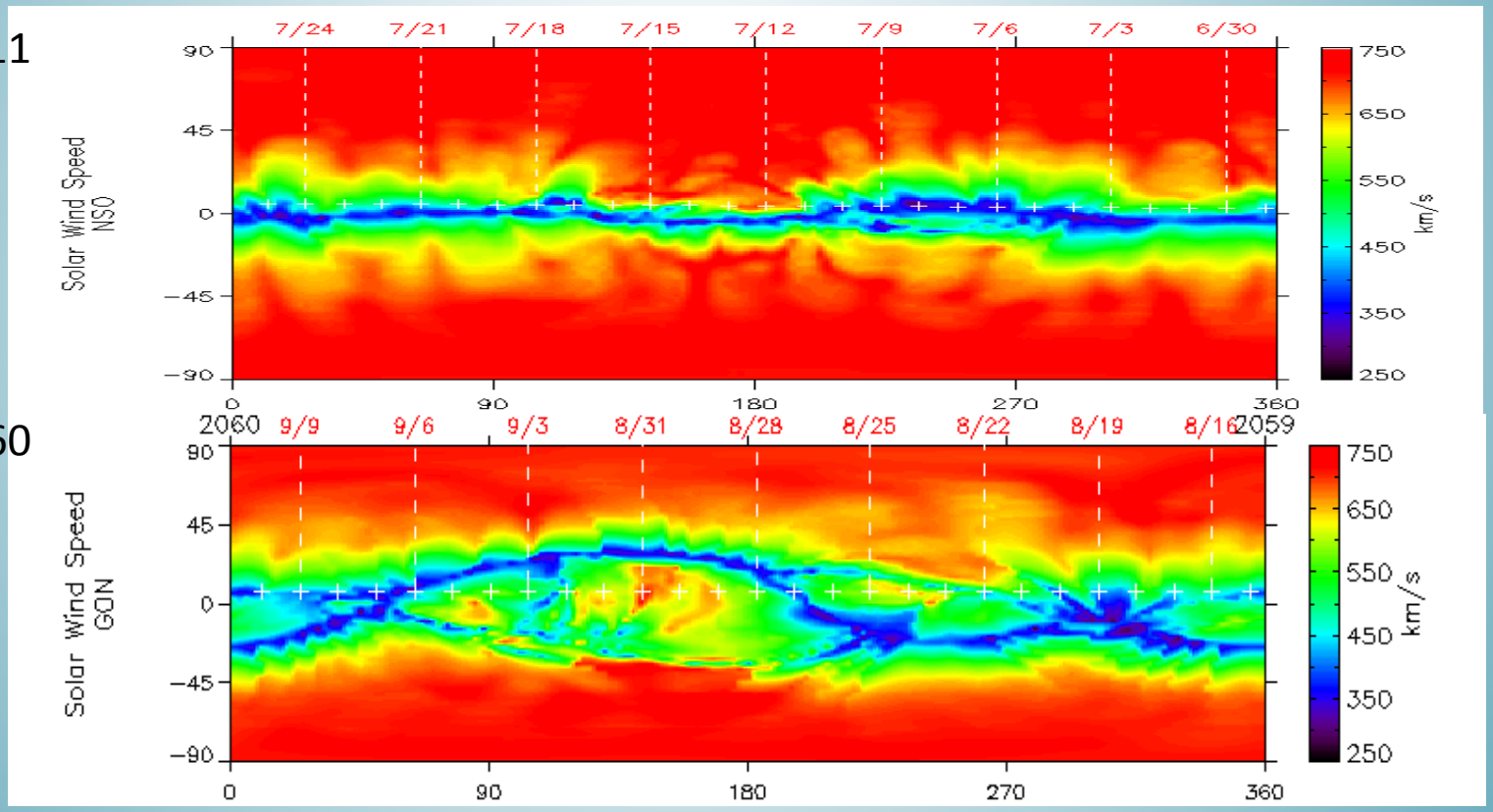


Vsw=300-550 km/s

Global Solar Wind Structure

CR1911
1996

CR2060
2008



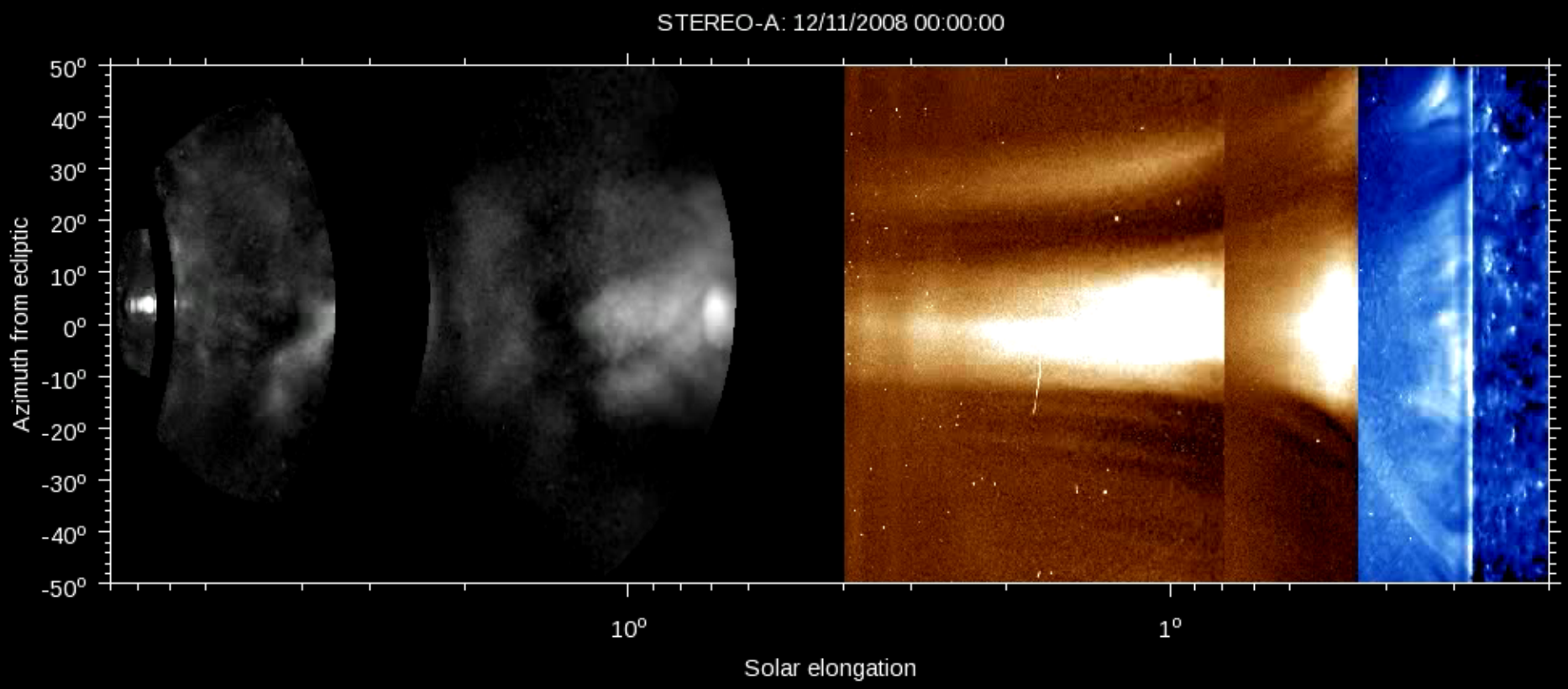
Summary/Conclusions

- The solar wind evolves as it propagates outward, muddying in-situ observations

- There are 2 slow solar wind populations, defined by A_{HE} and arising from different locations in the corona.
  - Low A_{HE} values, isothermal temperature ratios and oxygen depletion in the **SCW-II** strongly indicate the source of this wind is within the cores of streamers
  - **SCW-I** – edge of streamer belt/coronal hole boundary, evidence of wave particle interactions, low ionic charge states.

- Observed variations in A_{He} are caused by varying frequency of contributions from three A_{He} populations from different source regions.
  - Seemingly linear relationship between A_{HE} and speed
  - Increase in A_{HE} with heliographic latitude during 1995 Minimum

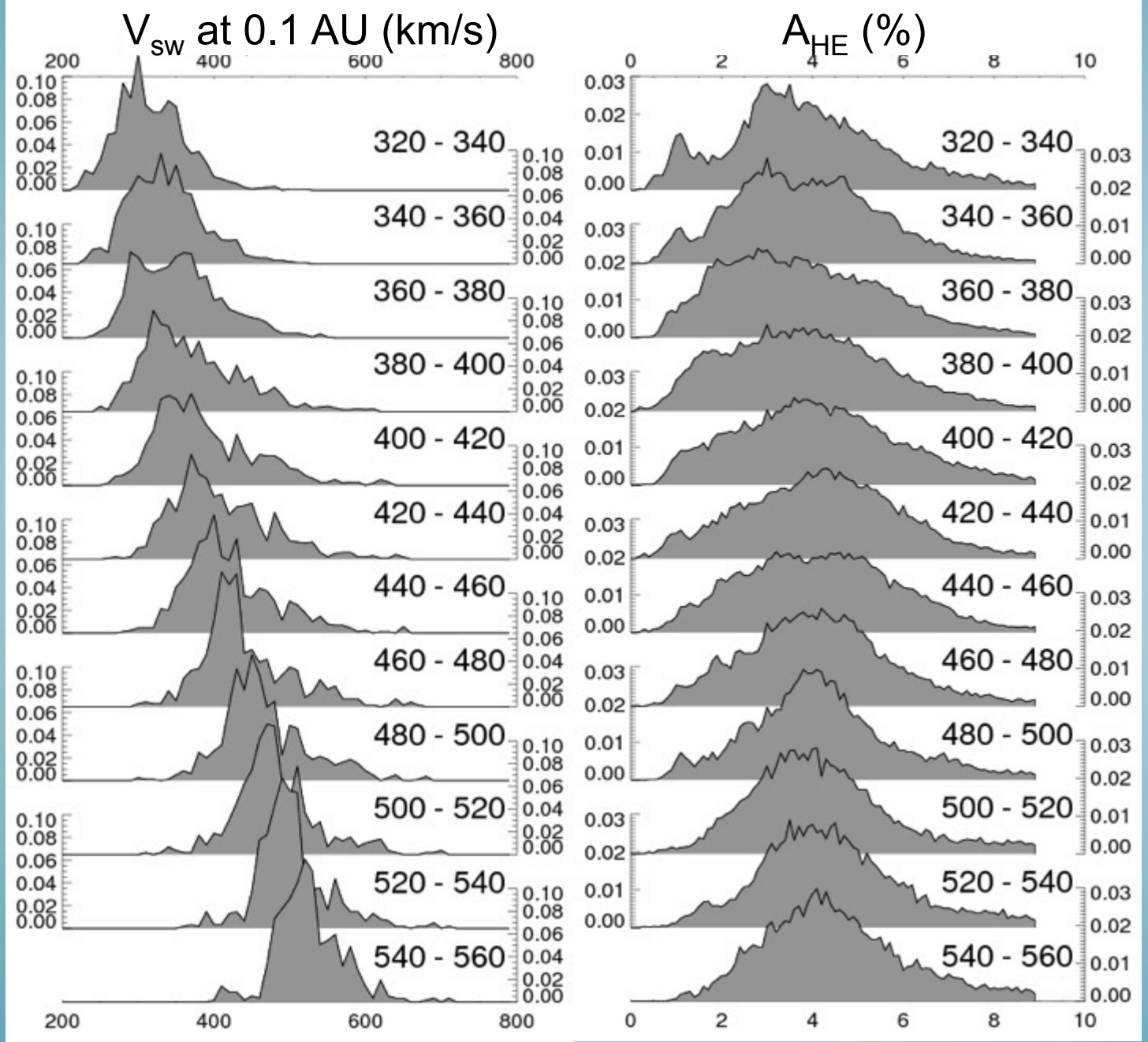
Thank You!



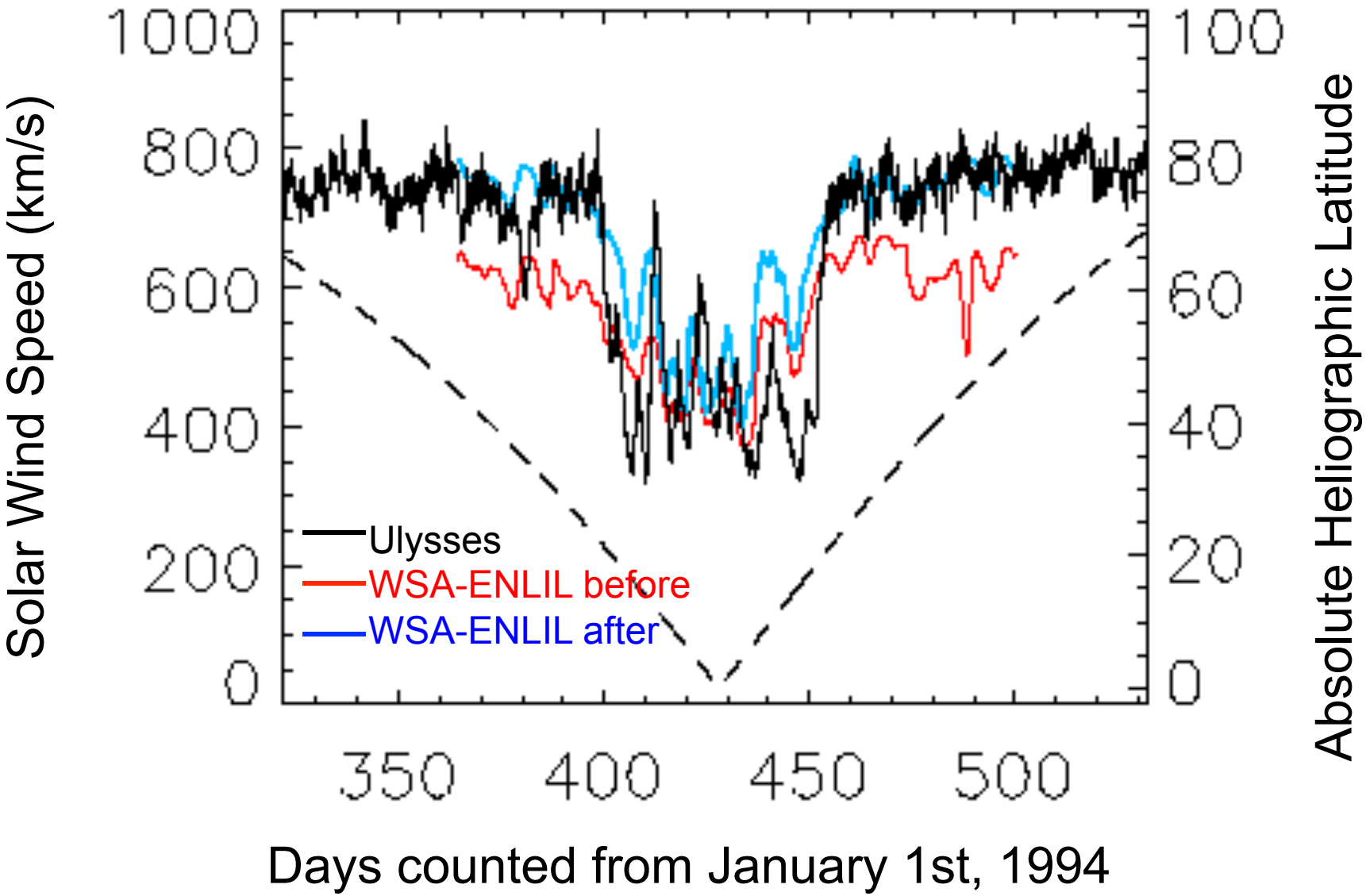
Video Curtesy of Craig DeForest

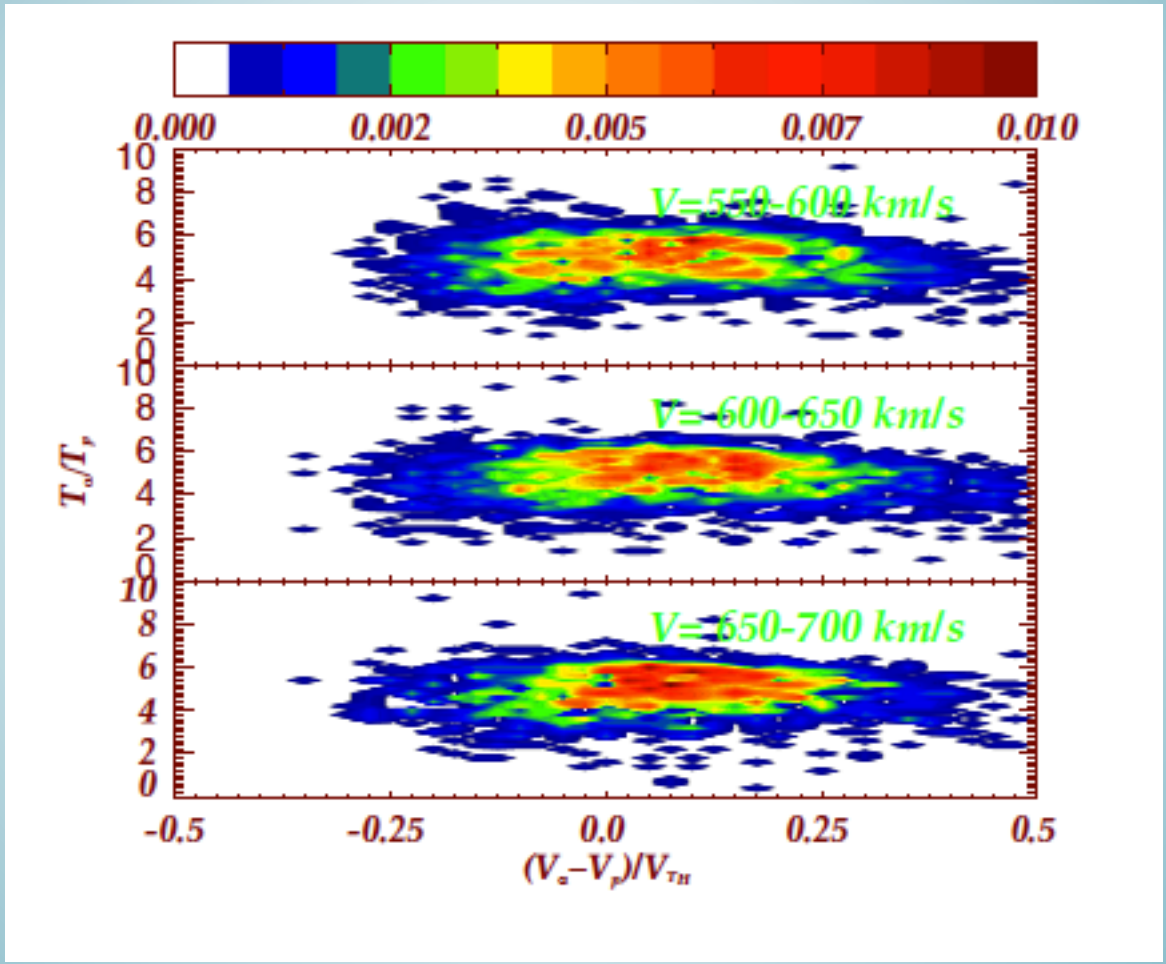
Extra slides

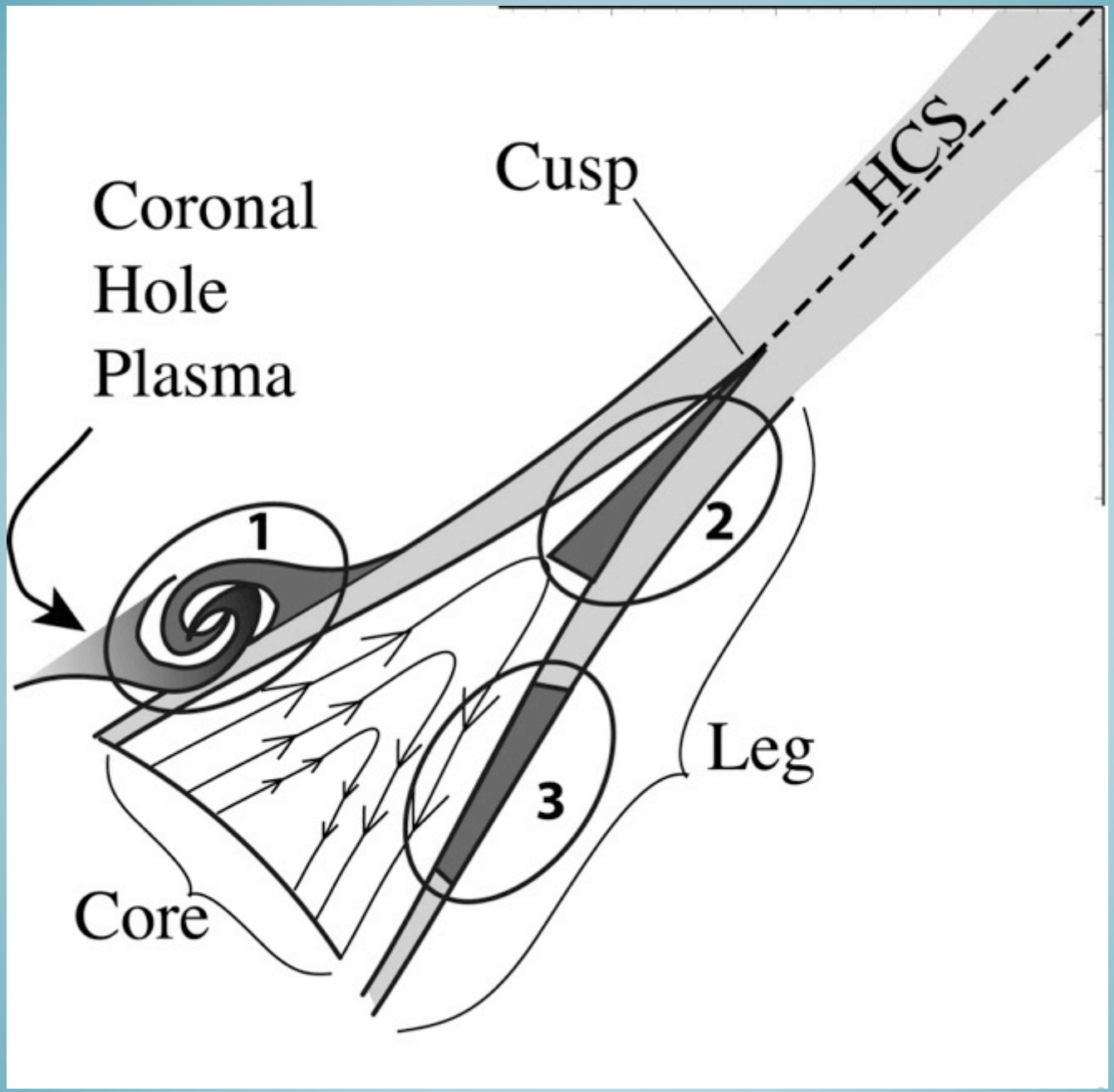
Solar Maximum: 1999-2000



Ulysses Fast Latitude Scan Comparison




0.000
0.002
0.005
0.007
0.010
V=550-600 km/s
V=600-650 km/s
V=650-700 km/s
T_α/T_p
-0.5
-0.25
0.0
0.25
0.5
$(V_\alpha-V_p)/V_{TH}$


Coronal
Hole
Plasma
Cusp
HCS
1
2
3
Leg
Core