STEREO/PLASTIC: In Situ Observations of Proton Entropy Enhancements

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The STEREO/PLASTIC Team

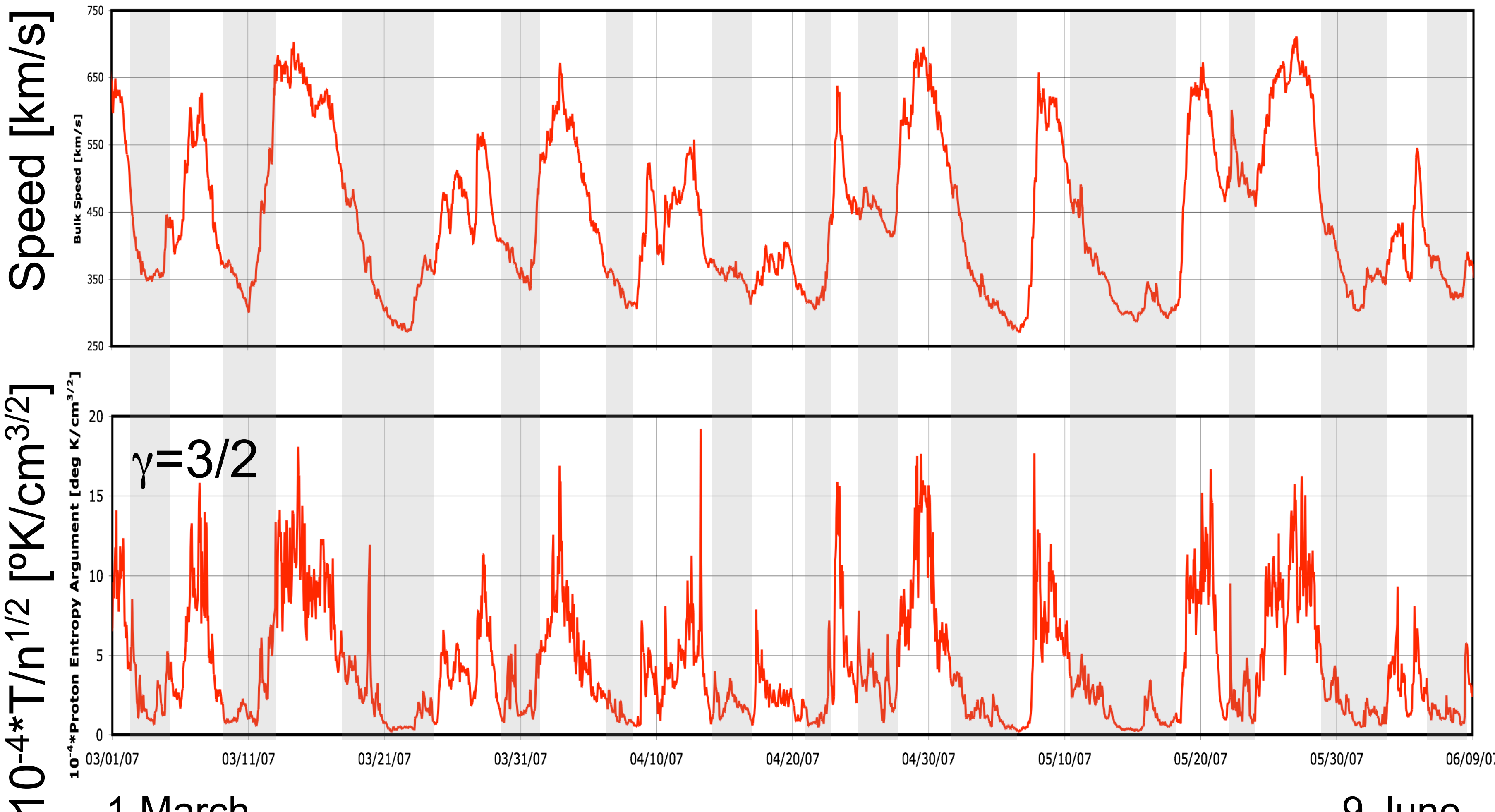
April, 2008

Observatoire de Paris, Meudon

Outline

- Relationship between solar wind speed and proton entropy
- Multi-spacecraft observations: Do features in the solar wind really have Parker Spiral geometry? (A test of the well-known CIR schematic cartoon.)
- Results and On-going Work

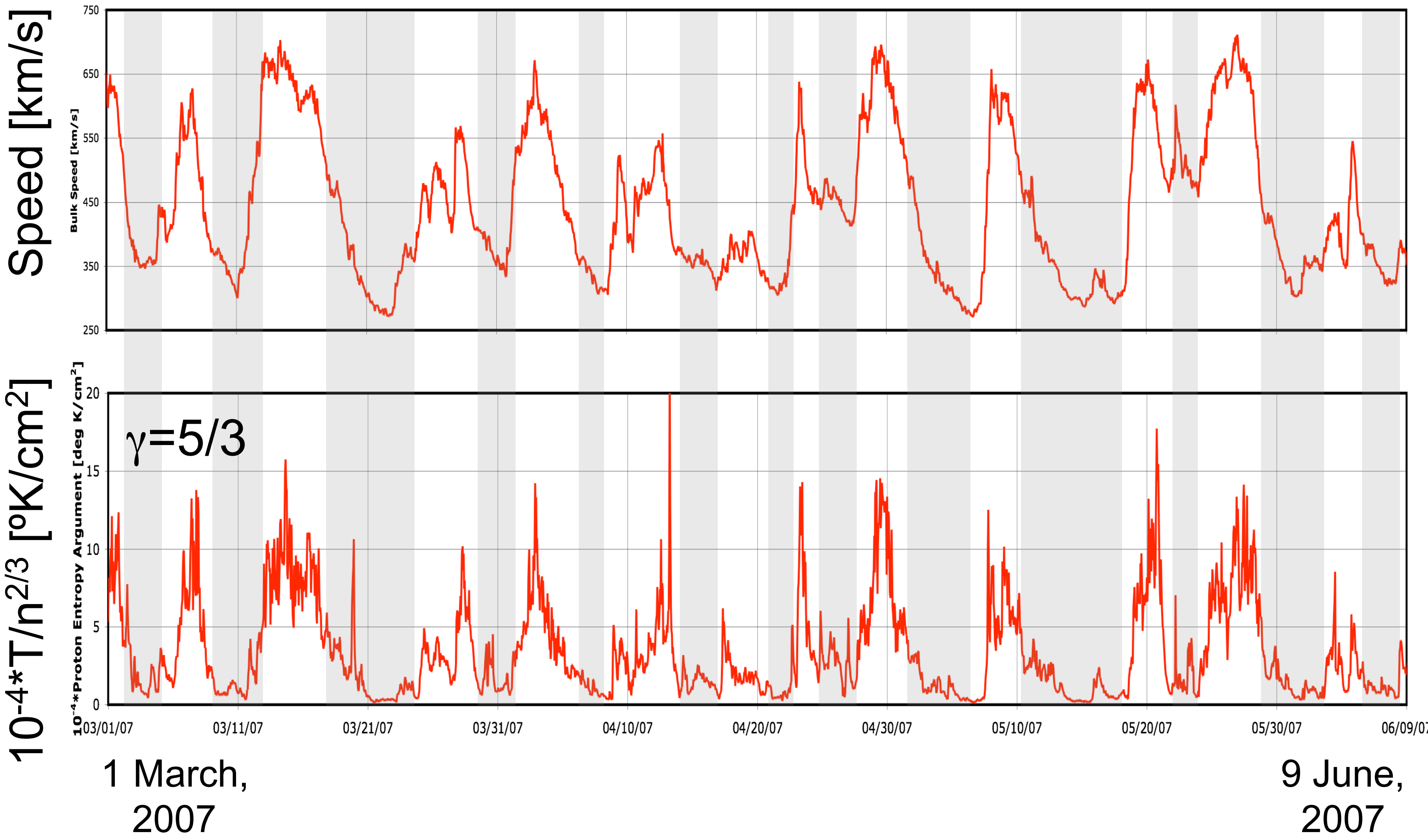
Speed and Entropy



1 March, 2007

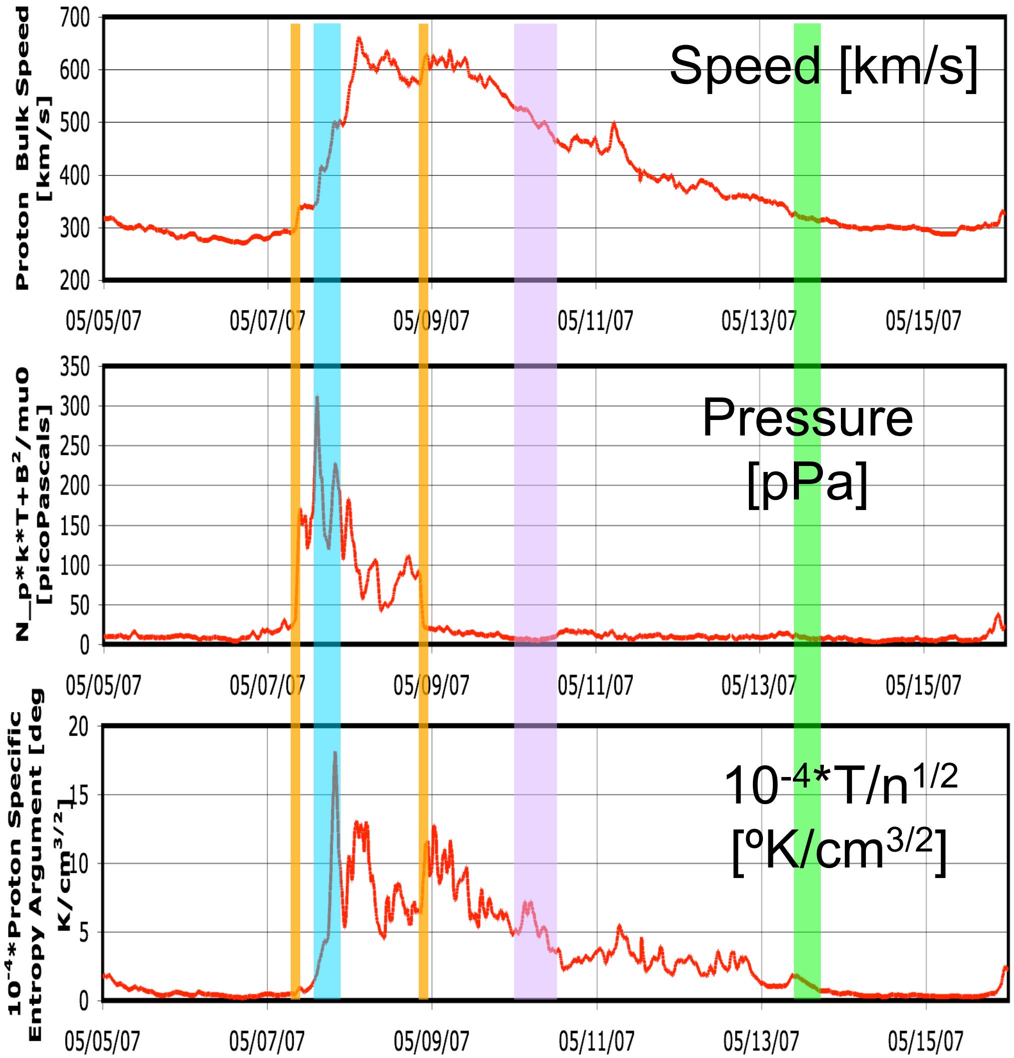
9 June, 2007

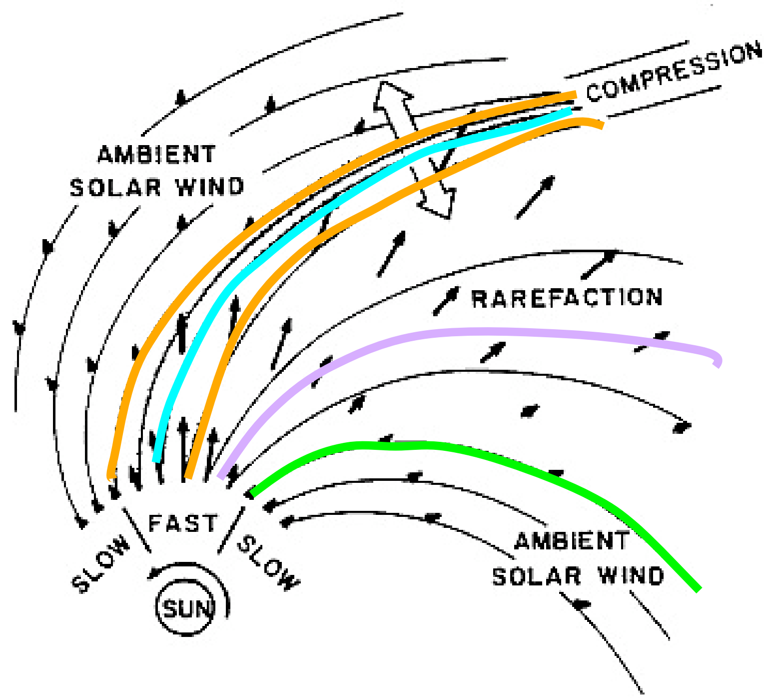
Speed and Entropy



Conceptual Picture and *In Situ* Data

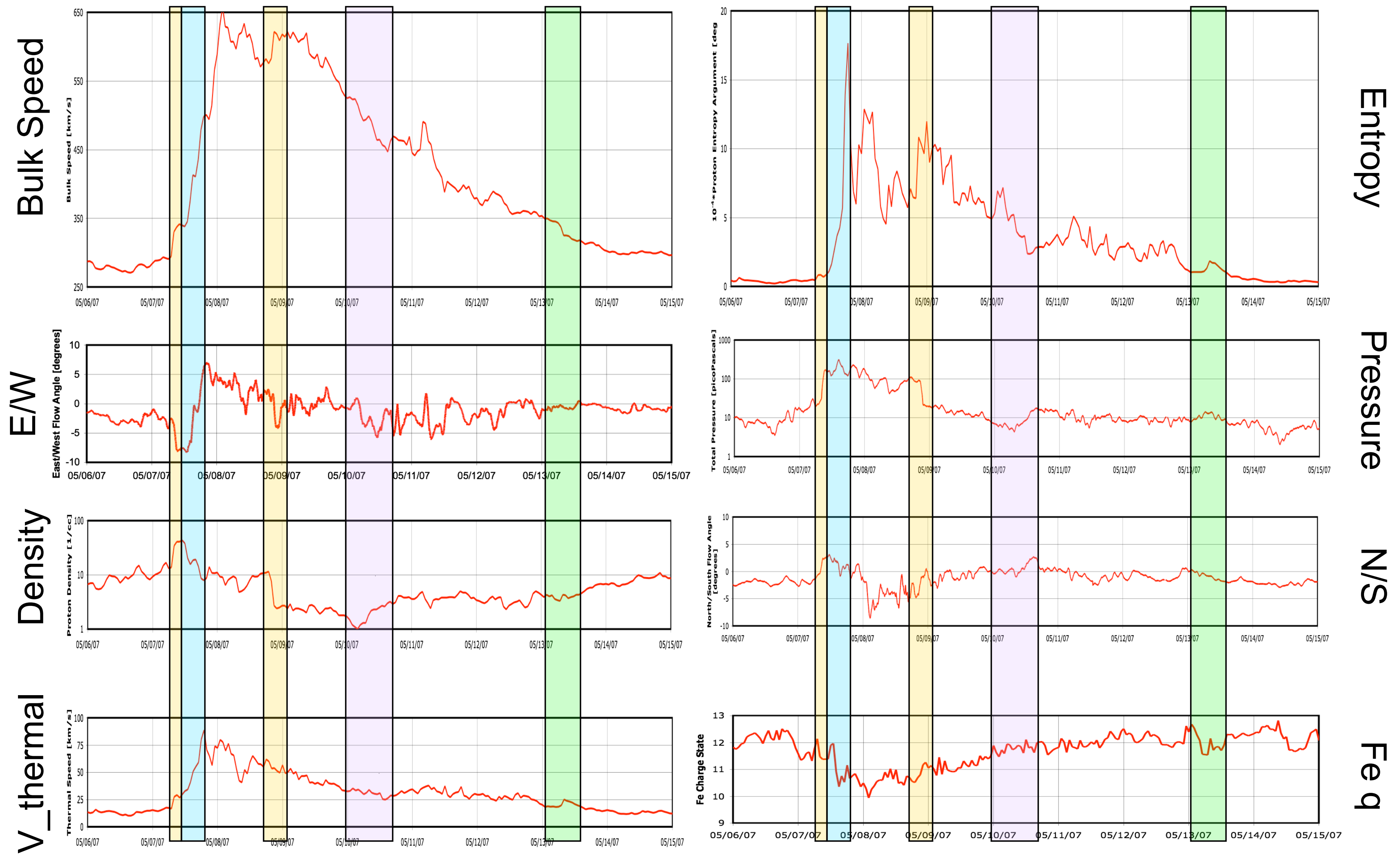
(STEREO/PLASTIC-A, May 2007)





Pizzo, V., *J. Geophys. Res.*, 83, 5563–5572 (1978).

More *In Situ* Data



Geometry Study with Multiple Spacecraft Observations

Methodology

Parker spirals are fit to the increase (or decrease) in entropy to determine effective propagation speeds.

$$v_{effective} = \frac{\Omega_{sun}(R_B - R_A)}{\varphi_B - \varphi_A - \Omega_{sun} t}$$

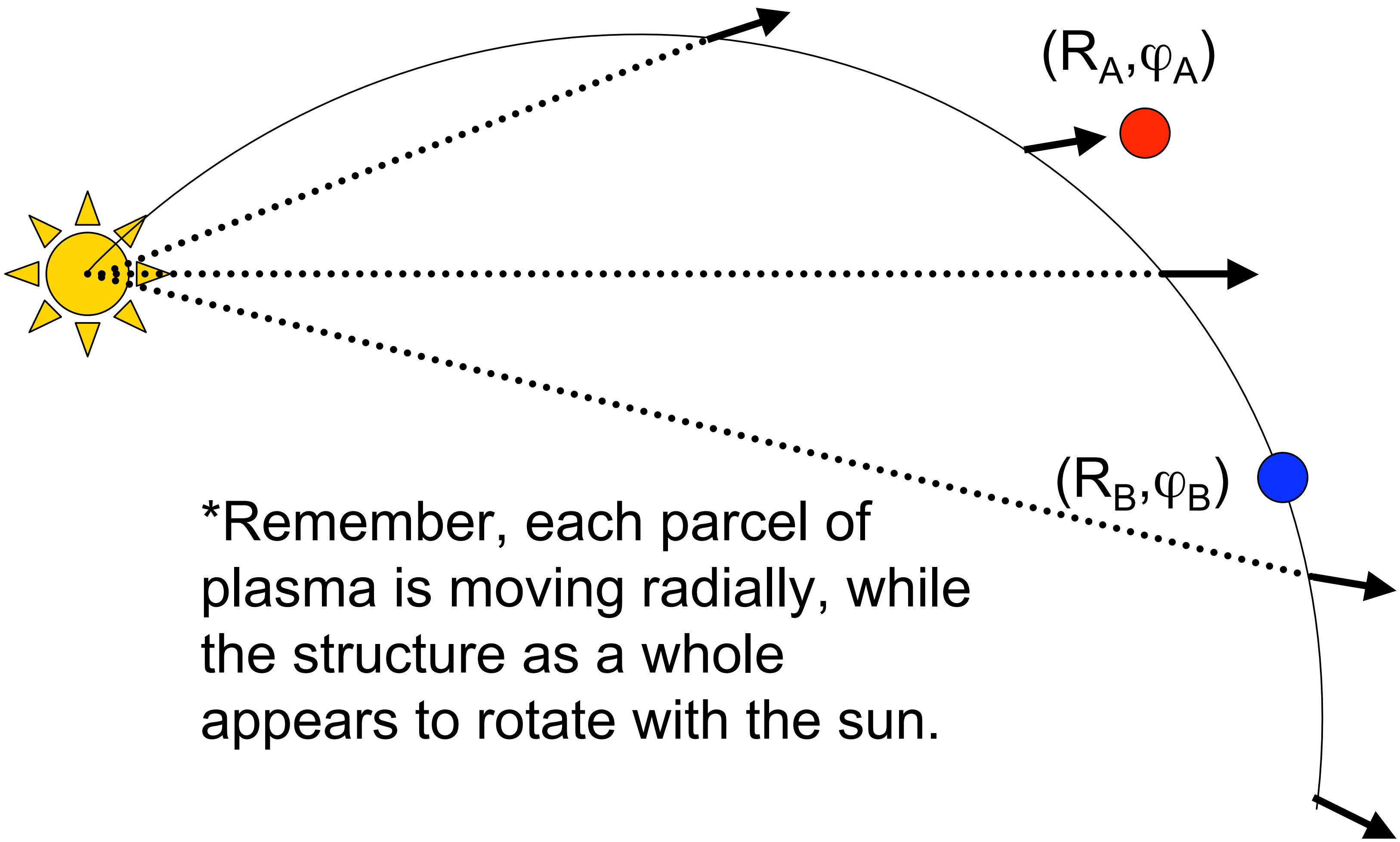
Ω_{sun} = angular speed of Sun

R_A, R_B = orbital radii

φ_A, φ_B = longitude (HCI)

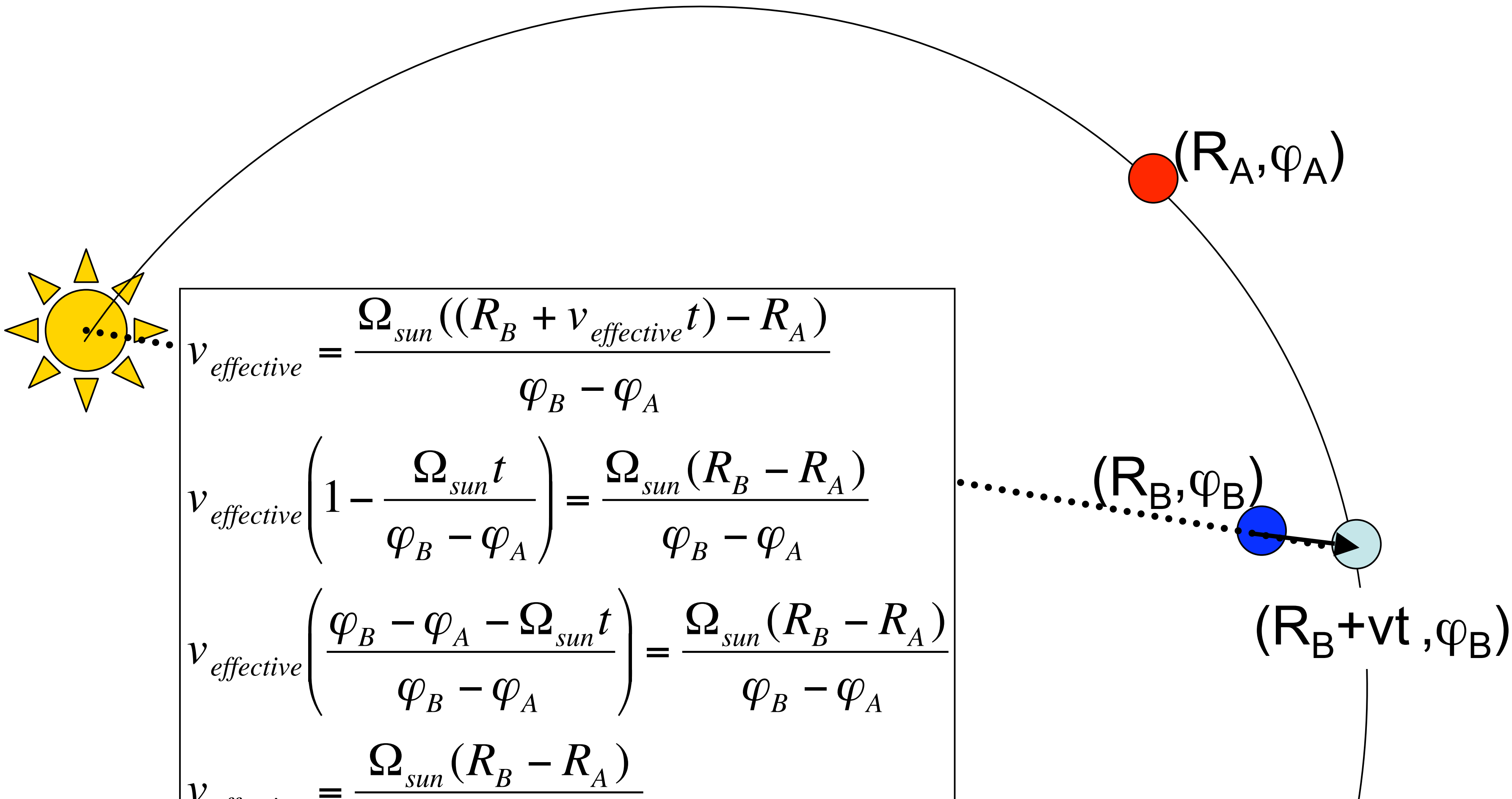
t = difference in arrival time

Schematic Cartoon: Time = 0



*Remember, each parcel of plasma is moving radially, while the structure as a whole appears to rotate with the sun.

Schematic Cartoon: Time = t



$$v_{effective} = \frac{\Omega_{sun}((R_B + v_{effective}t) - R_A)}{\varphi_B - \varphi_A}$$

$$v_{effective}\left(1 - \frac{\Omega_{sun}t}{\varphi_B - \varphi_A}\right) = \frac{\Omega_{sun}(R_B - R_A)}{\varphi_B - \varphi_A}$$

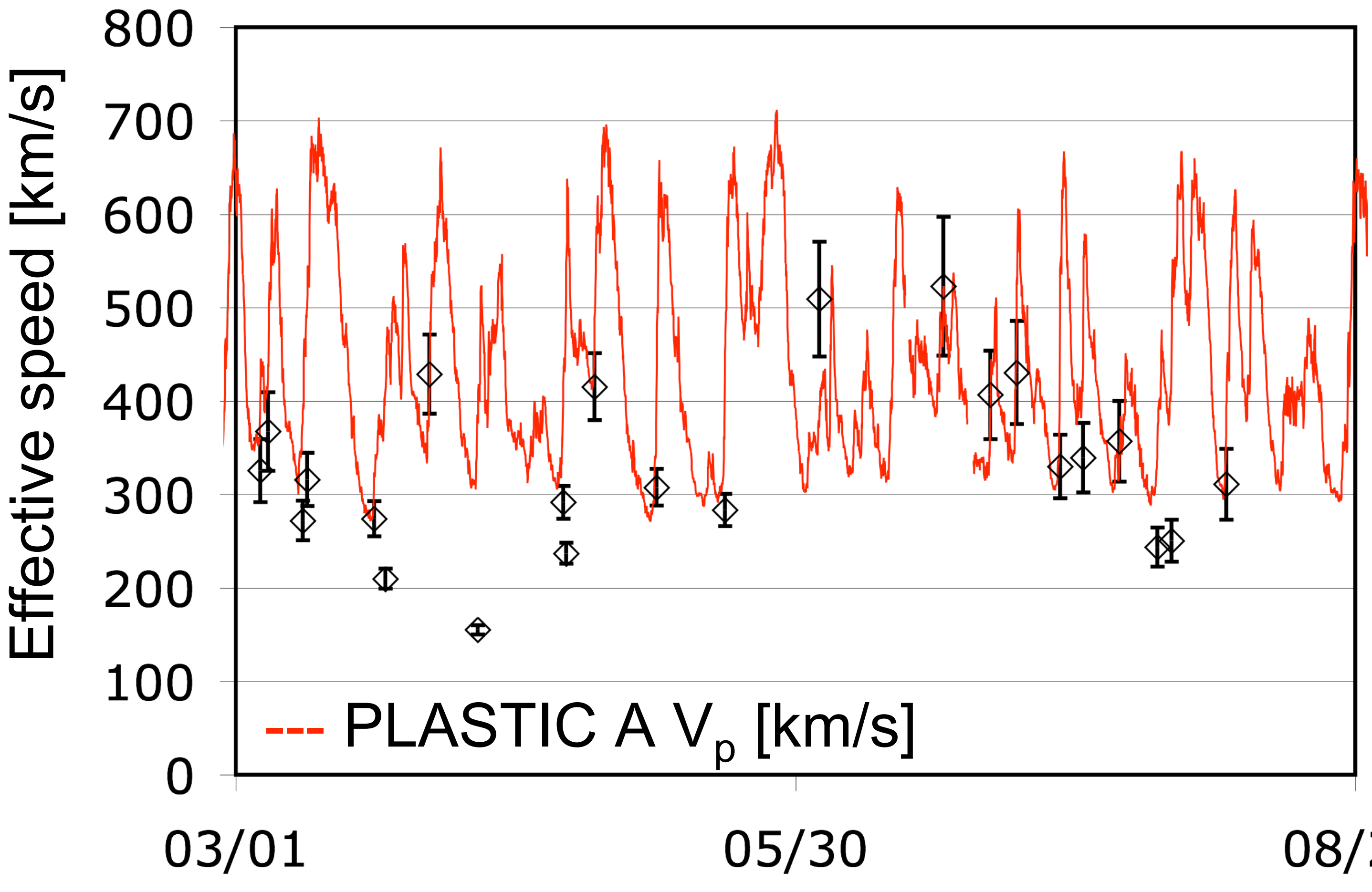
$$v_{effective}\left(\frac{\varphi_B - \varphi_A - \Omega_{sun}t}{\varphi_B - \varphi_A}\right) = \frac{\Omega_{sun}(R_B - R_A)}{\varphi_B - \varphi_A}$$

$$v_{effective} = \frac{\Omega_{sun}(R_B - R_A)}{\varphi_B - \varphi_A - \Omega_{sun}t}$$

What do we expect?

- Propagation speed of entropy increase (Stream Interface) will be bounded by local minimum solar wind speed.
- Entropy decrease will have greater curvature (slower propagation speed) as plasma has expanded into the rarefaction region.
- If entropy transitions really follow Parker Spiral geometry, we should be able to calculate the same effective speeds using data from either one of the STEREO observatories and WIND/SWE or both STEREO A and B.

Slow-to-Fast Stream Interface Effective Speeds (Entropy Increase)



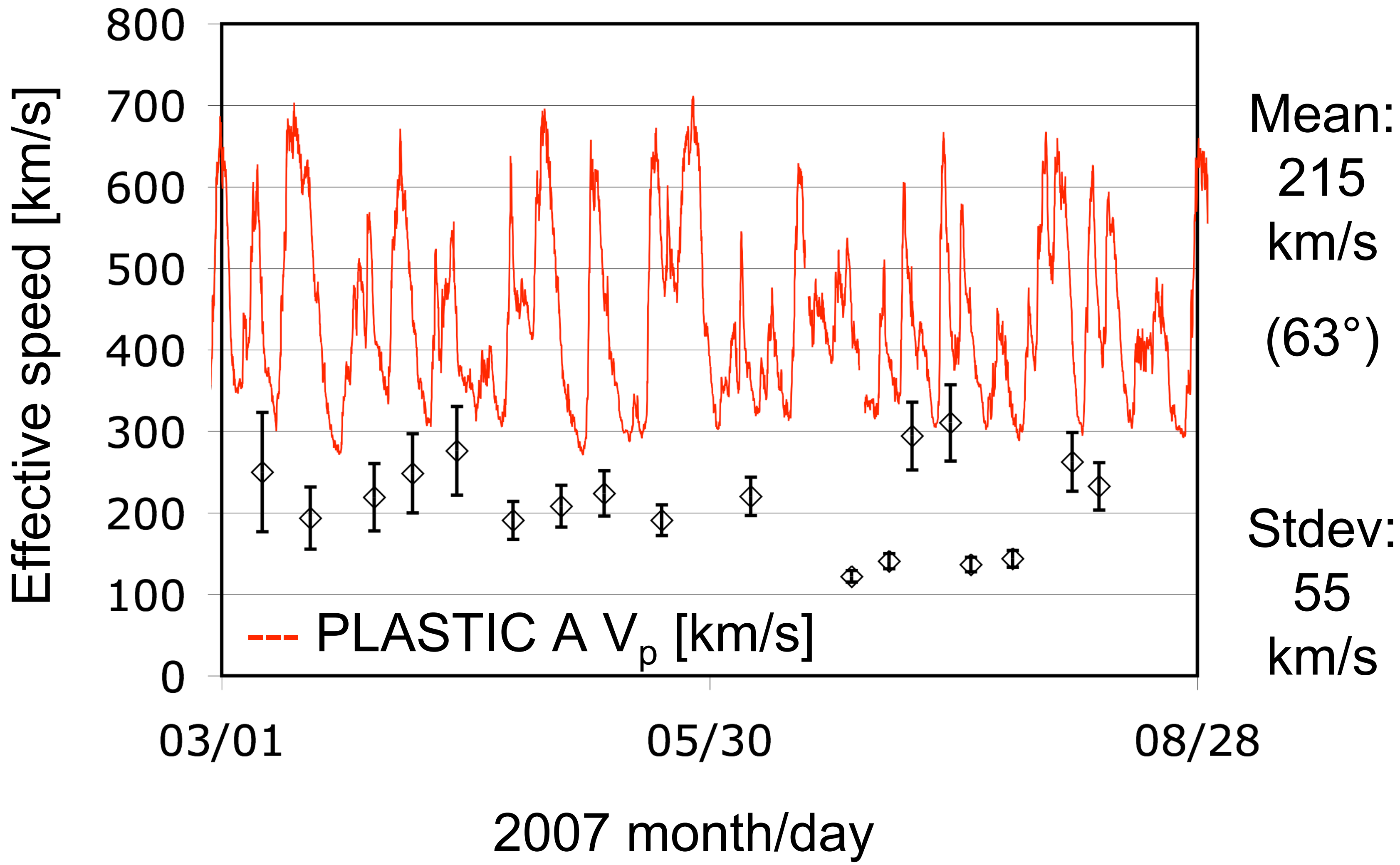
Mean: 330 km/s

(53°)

Stdev: 91 km/s

*Error bars assume uncertainty of ± 30 minutes.

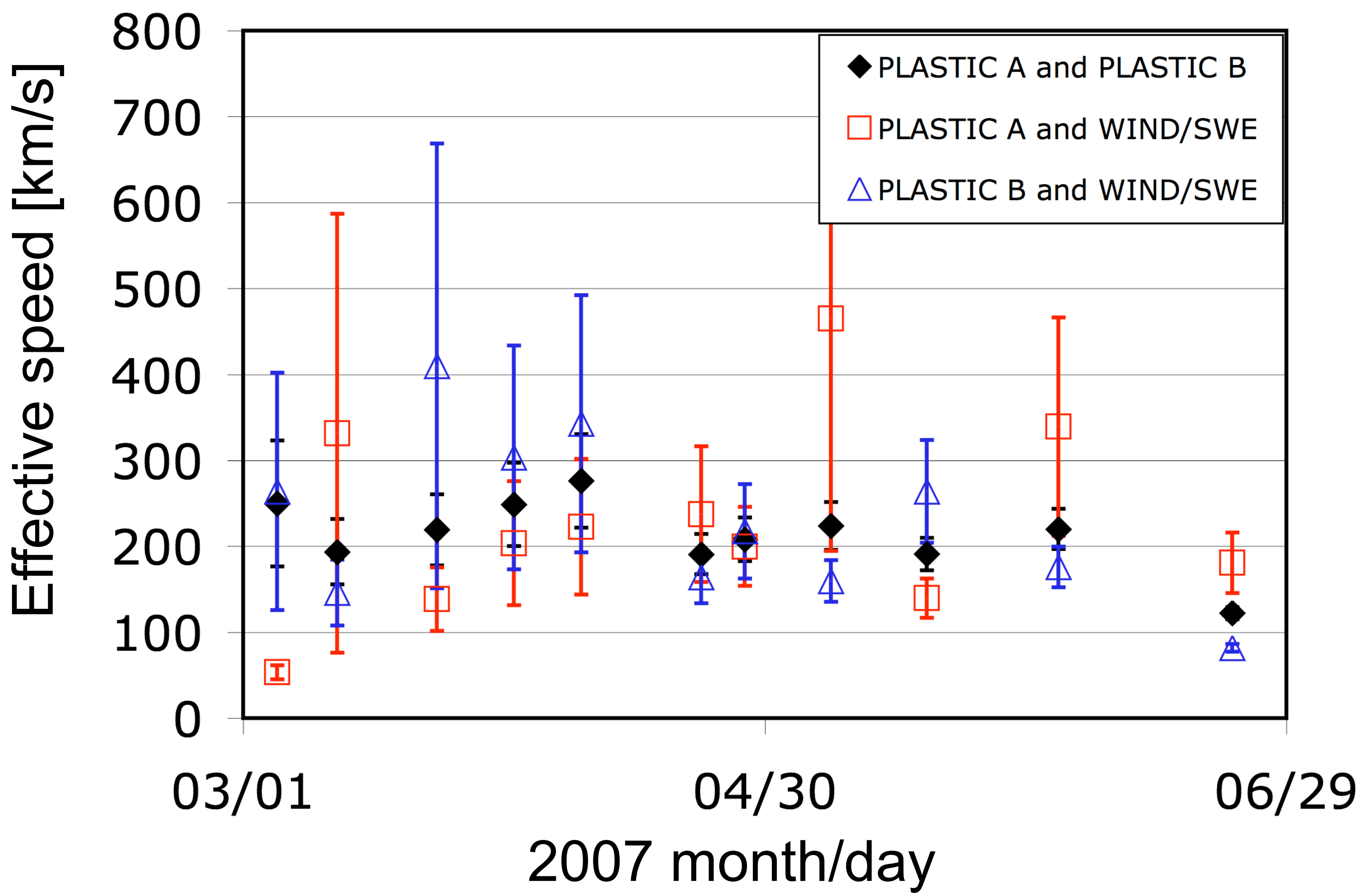
Fast-to-Slow Transition Effective Speeds (Entropy Drop)



*Error bars assume uncertainty of ± 6 hours.

Fast-to-Slow Effective Speeds with WIND/SWE

data courtesy of K.W. Ogilvie, A.J. Lazarus, and M.R. Aellig

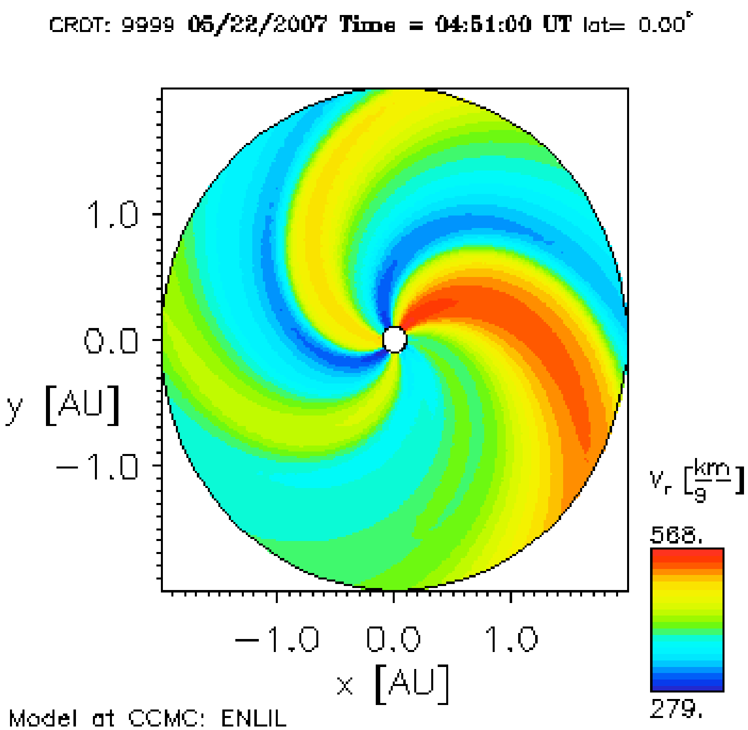


*Error bars assume uncertainty of ± 2 hours.

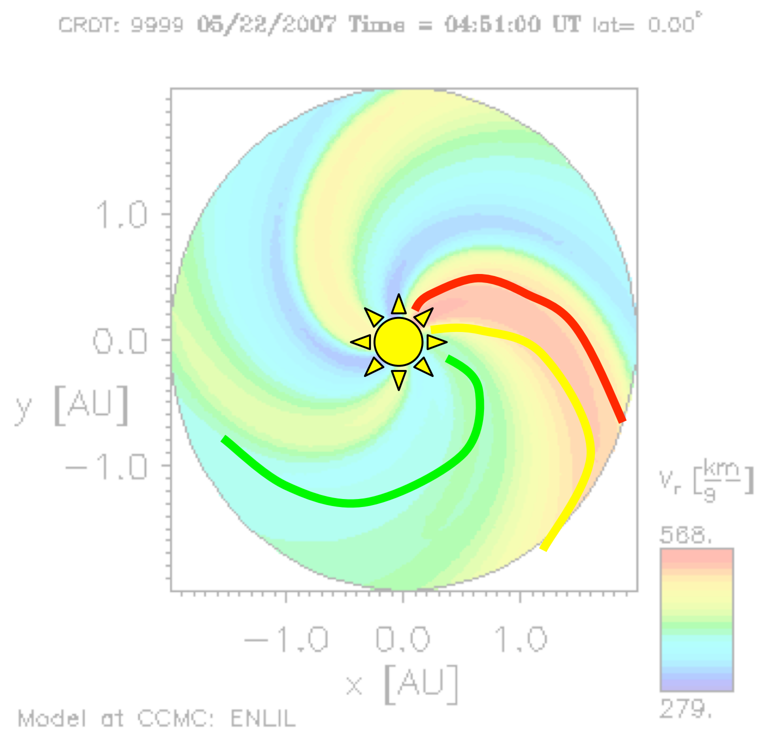
Summary

- The average slow-to-fast SI effective propagation speed is 330 km/s -- or 53°garden hose angle at 1 AU.
- The effective speed of the slow-to-fast SI is sometimes LESS than the local minimum speed -- this was NOT expected!
- The average fast-to-slow interface effective speed is 215 km/s -- or 63°garden hose angle at 1 AU.
- In most cases, effective propagation speed of the entropy drop agrees (within the error bars) between the two STEREO observatories and WIND/SWE.

ENLIL Model versus A Rough Sketch of My Results



ENLIL CR #2056

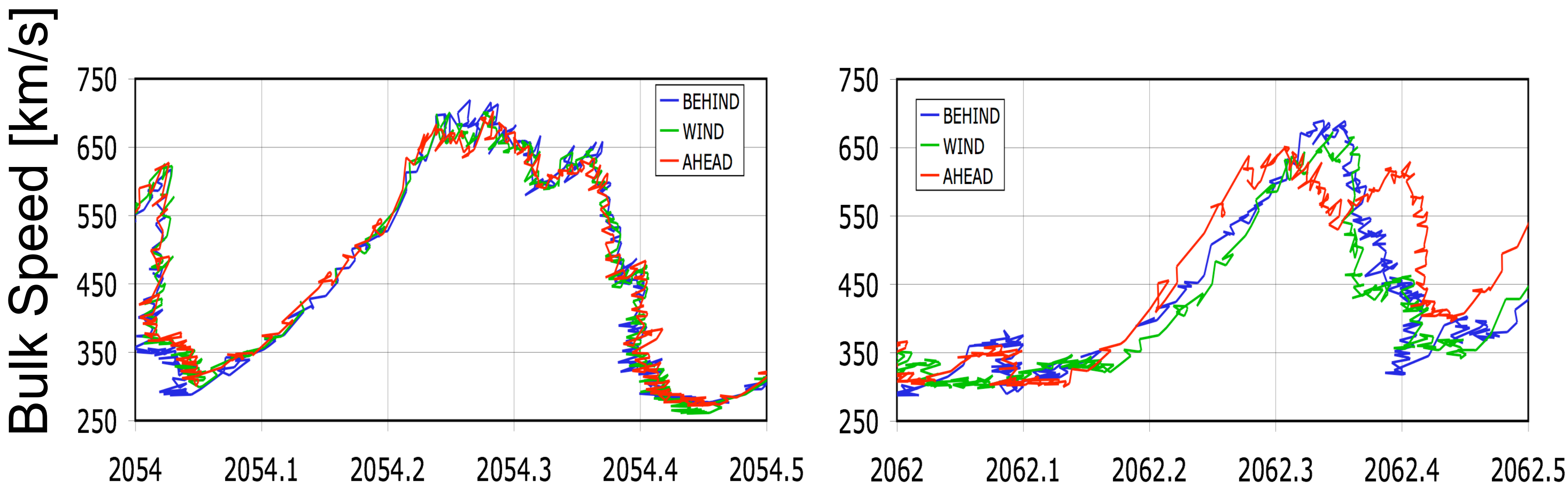


My Result CR #2056

On-going Work

- Extending study to cover more entropy transitions.
- Back-mapping of streams to see if slower than expected stream interface propagation speed makes sense.

Ballistic Back-mapping



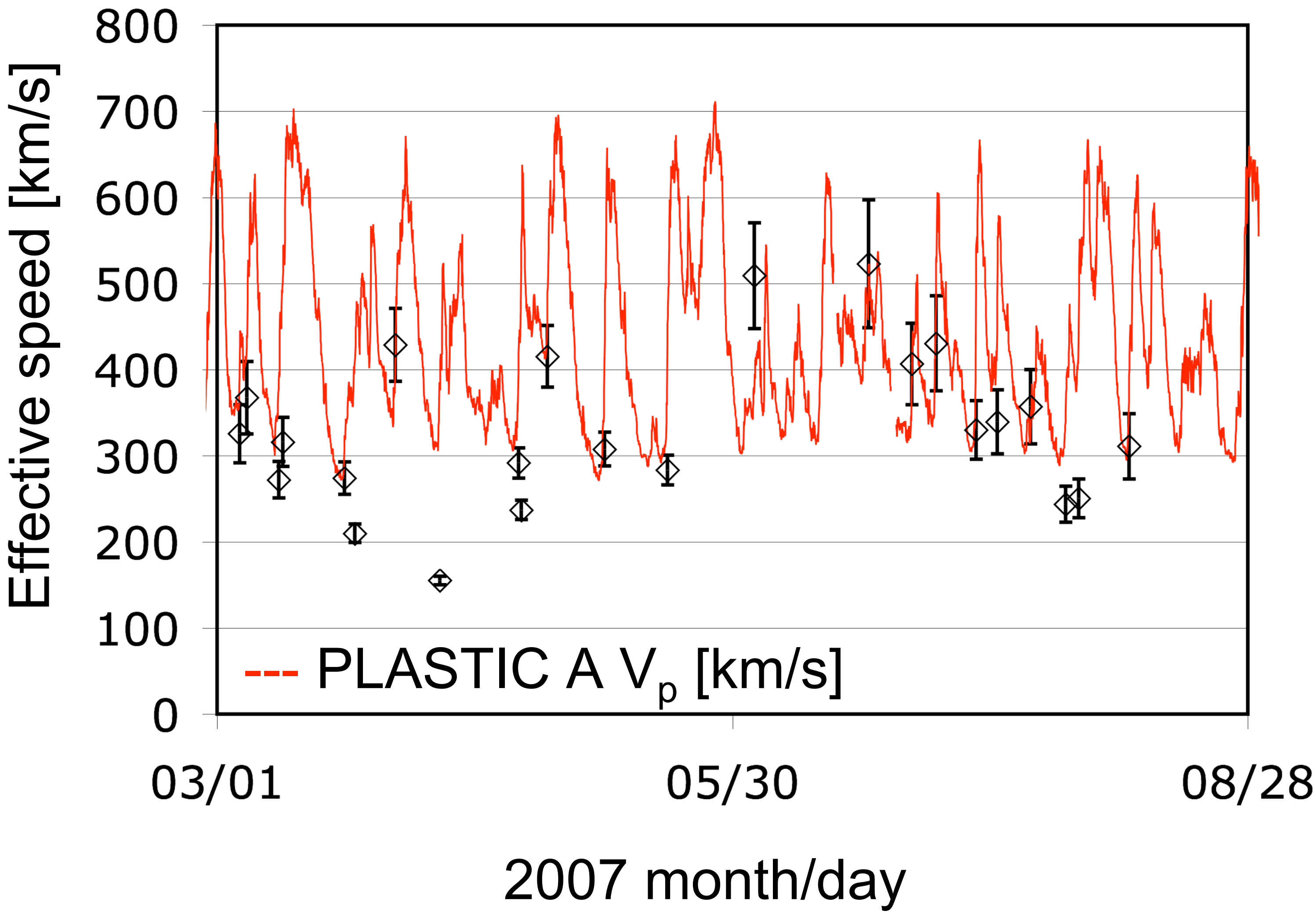
Mapped Carrington Number

(March 2007)

Mapped Carrington Number

(October 2007)

Slow-to-Fast Stream Interface Effective Speeds (Entropy Increase)



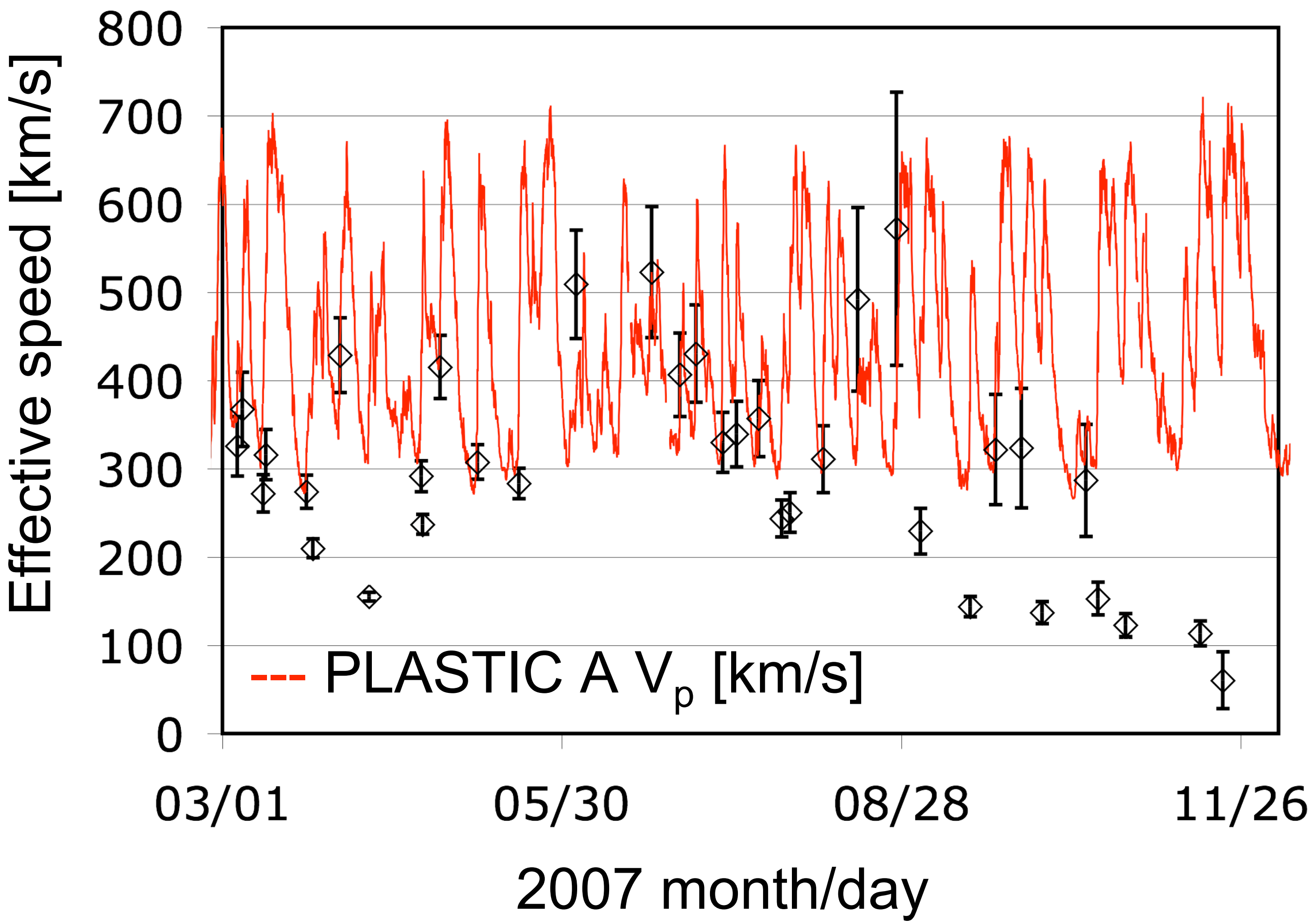
Mean: 330 km/s

(53°)

Stdev: 91 km/s

*Error bars assume uncertainty of ± 30 minutes.

Slow-to-Fast Interface Effective Speeds (Extended)



Mean: 301 km/s

(54°)

Stdev: 123 km/s

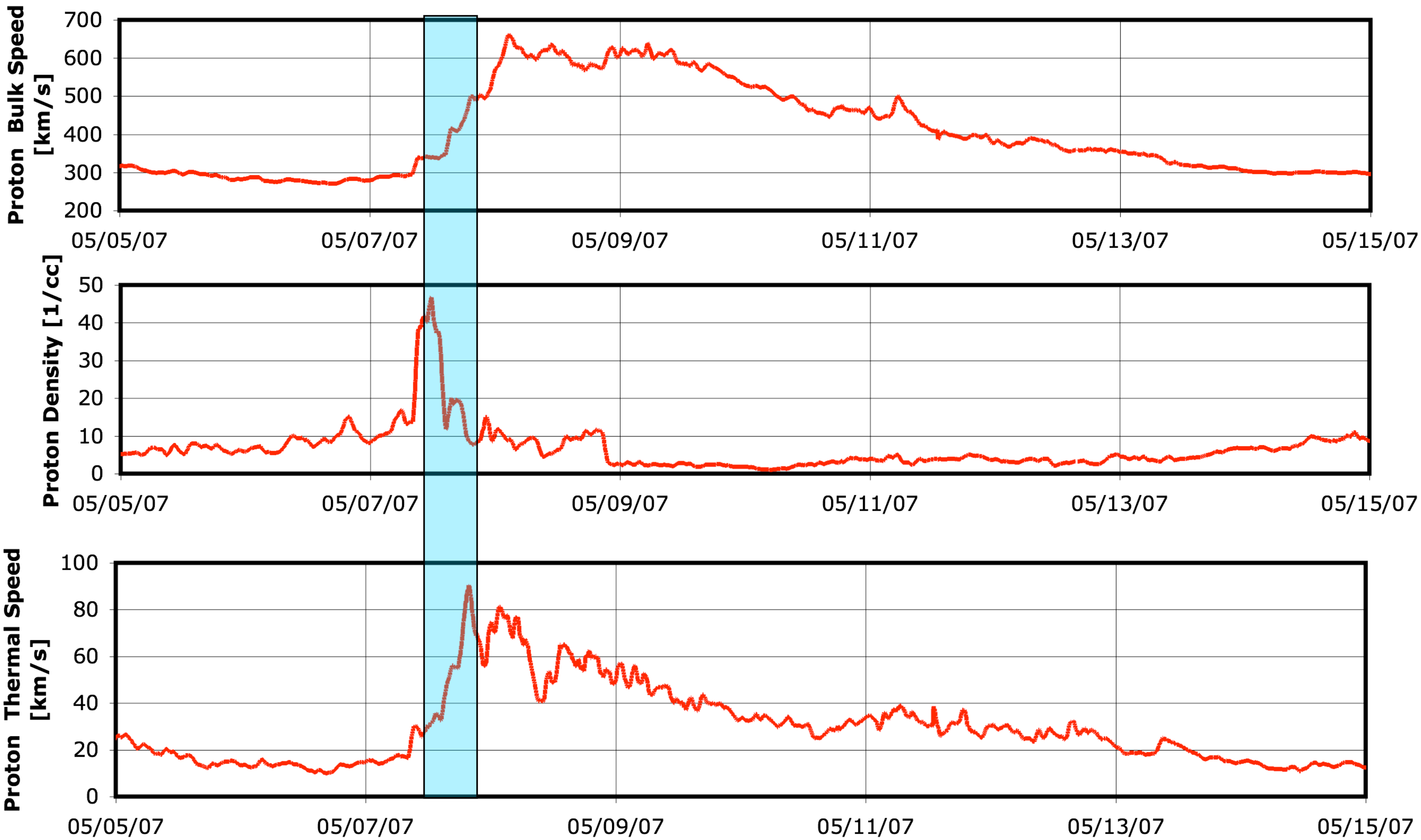
*Error bars assume uncertainty of ± 30 minutes.

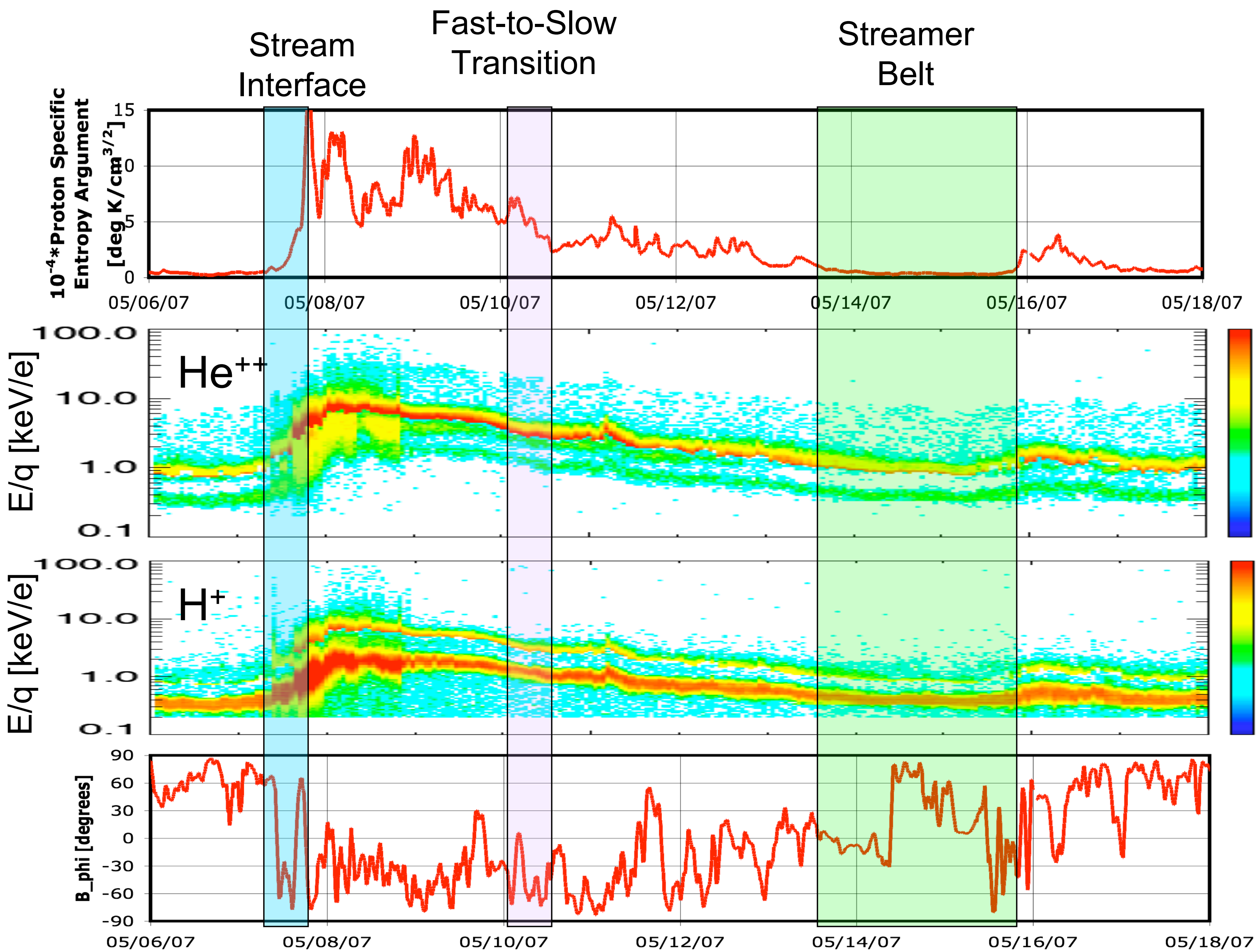
Thank You

The STEREO PLASTIC Team

- University of New Hampshire
- University of Bern, Switzerland
- Max Planck Institute for Extraterrestrial Physics, Garching, Germany
- University of Kiel, Germany
- Goddard Space Flight Center

Stream Interface:
Slow to Fast Transition





Stream Interface
Fast-to-Slow Transition
Streamer Belt
10^-4*Proton Specific Entropy Argument [deg K/cm^3/2]
15
10
5
0
05/06/07
05/08/07
05/10/07
05/12/07
05/14/07
05/16/07
05/18/07
He++
E/q [keV/e]
100.0
10.0
1.0
0.1
1000
0.1
counts
H+
E/q [keV/e]
100.0
10.0
1.0
0.1
1000
0.1
counts
B_phi [degrees]
90
60
30
0
-30
-60
-90
05/06/07
05/08/07
05/10/07
05/12/07
05/14/07
05/16/07
05/18/07