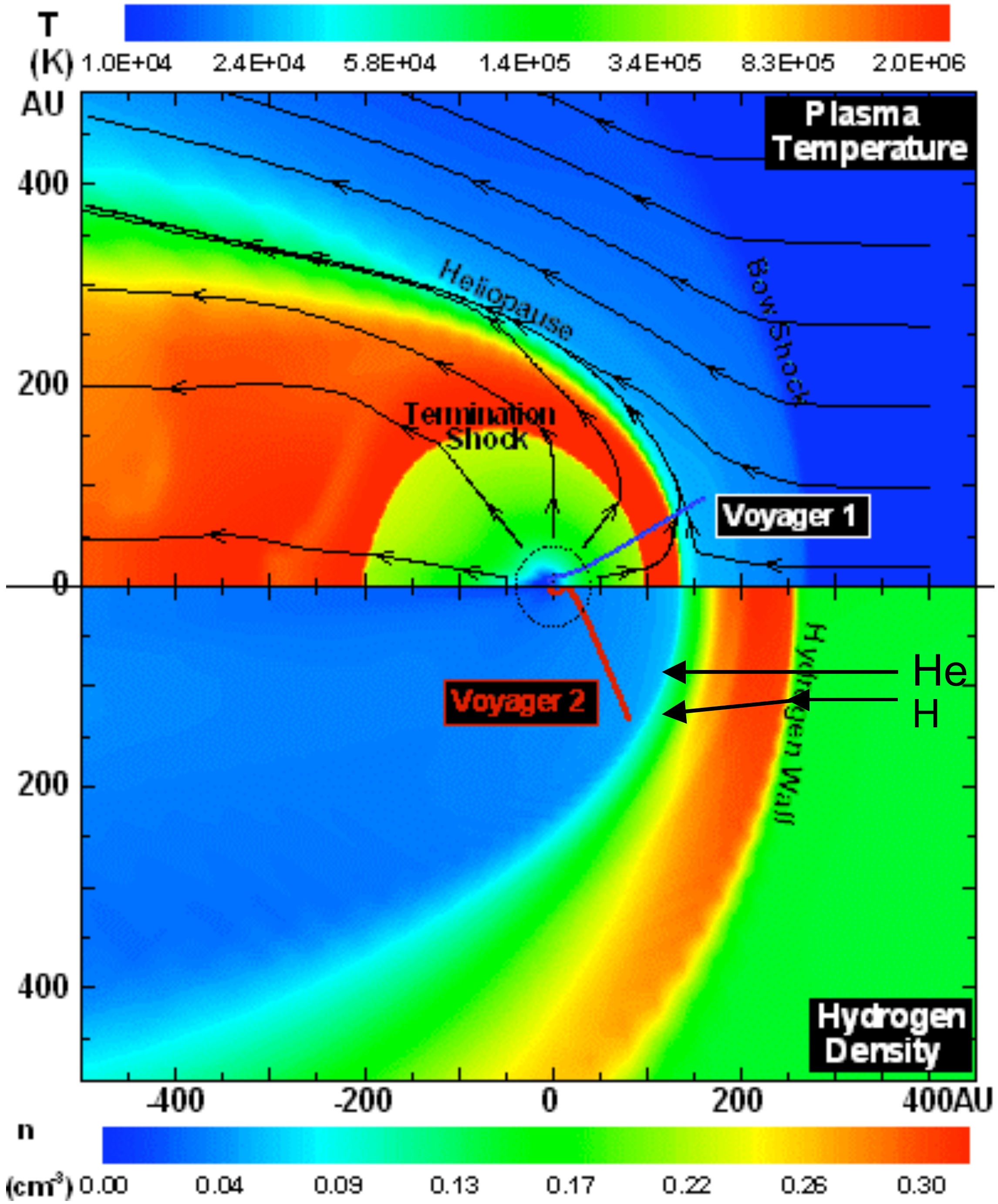
Voyager Plasma and Magnetic Field Data

John Richardson
M.I.T.

Thanks to Len Burlaga for MAG data

Outline

- Overview
- Heliosheath variability
- CR-B relation
- V2 HSH evolution
- V1/V2 speed difference



Heliosphere Overview

Asymmetric.

Thermal pressure dominated by pickup ions.

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

Mueller et al.

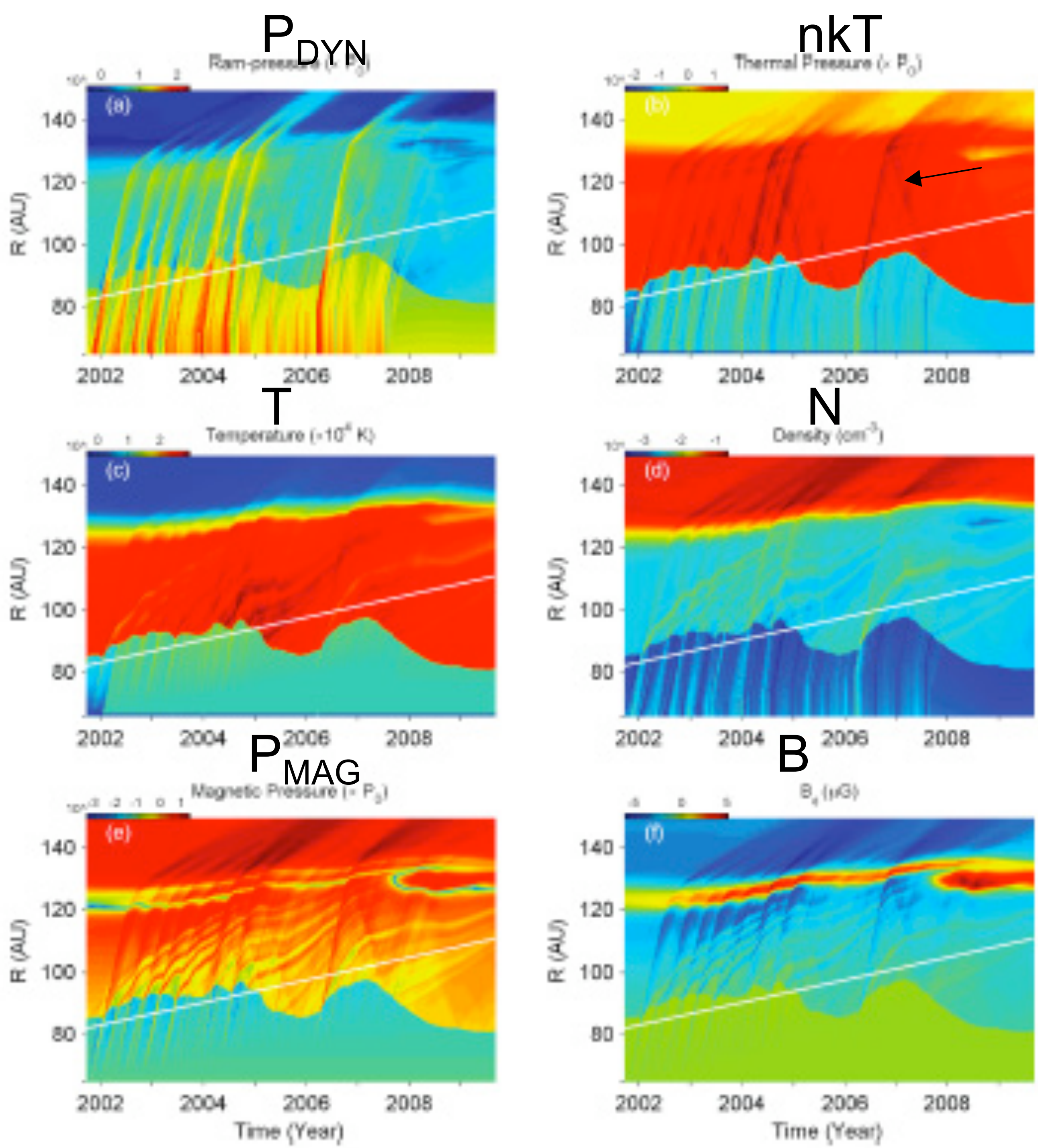
Model Prediction:
(Washimi et al.)

3-D MHD with
observed daily
average plasma
data as imput.

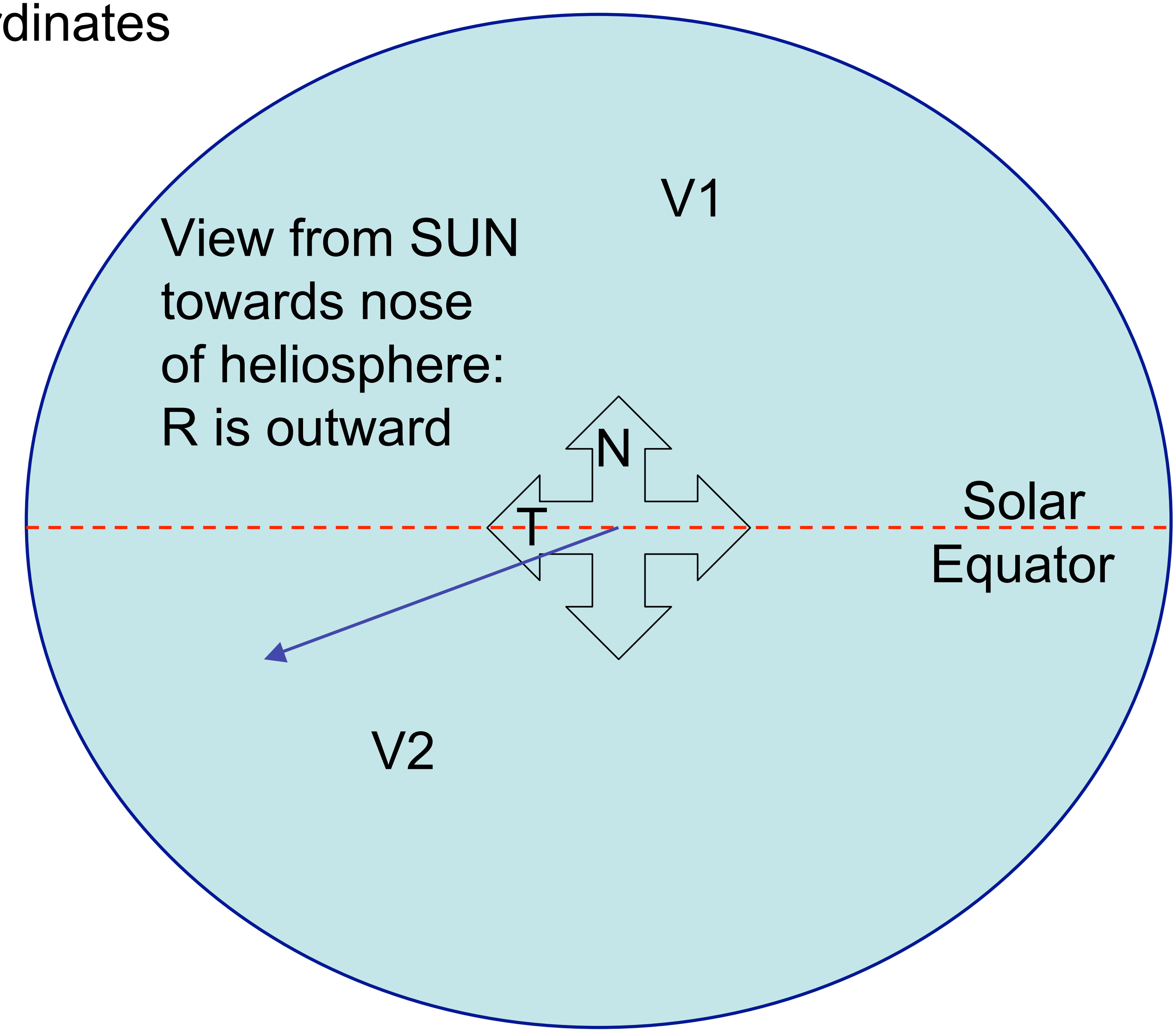
Quasi-periodic
SW pressure
pulses observed,
then propagate
through HSH.

Waves bounce
between TS and
HP.

TS motions
produce vortices



RTN coordinates



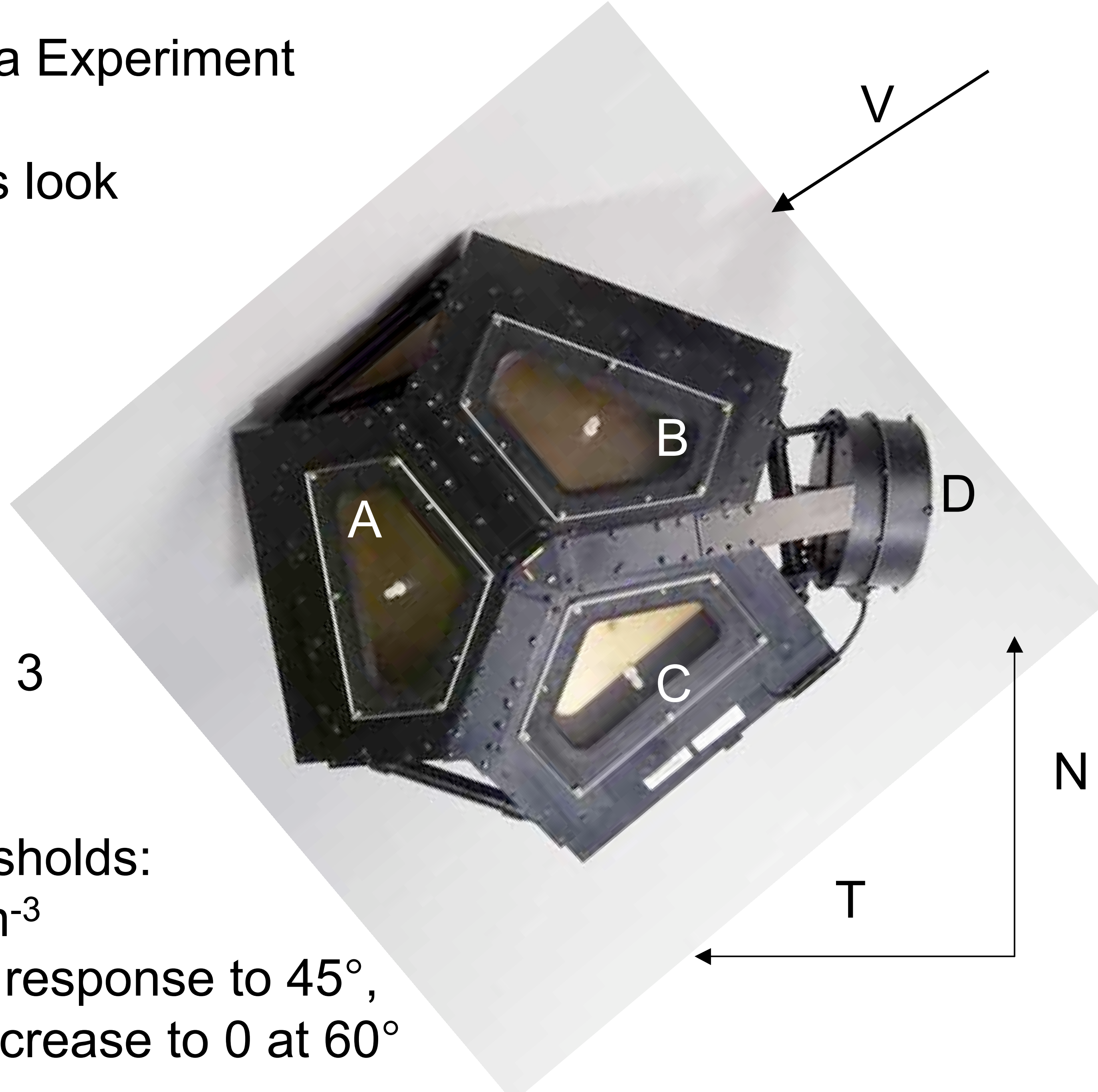
Voyager Plasma Experiment

3 Faraday Cups look sunward.

Flow is now in +R, +T, and -N direction.

Need data in all 3 Cups to fit V

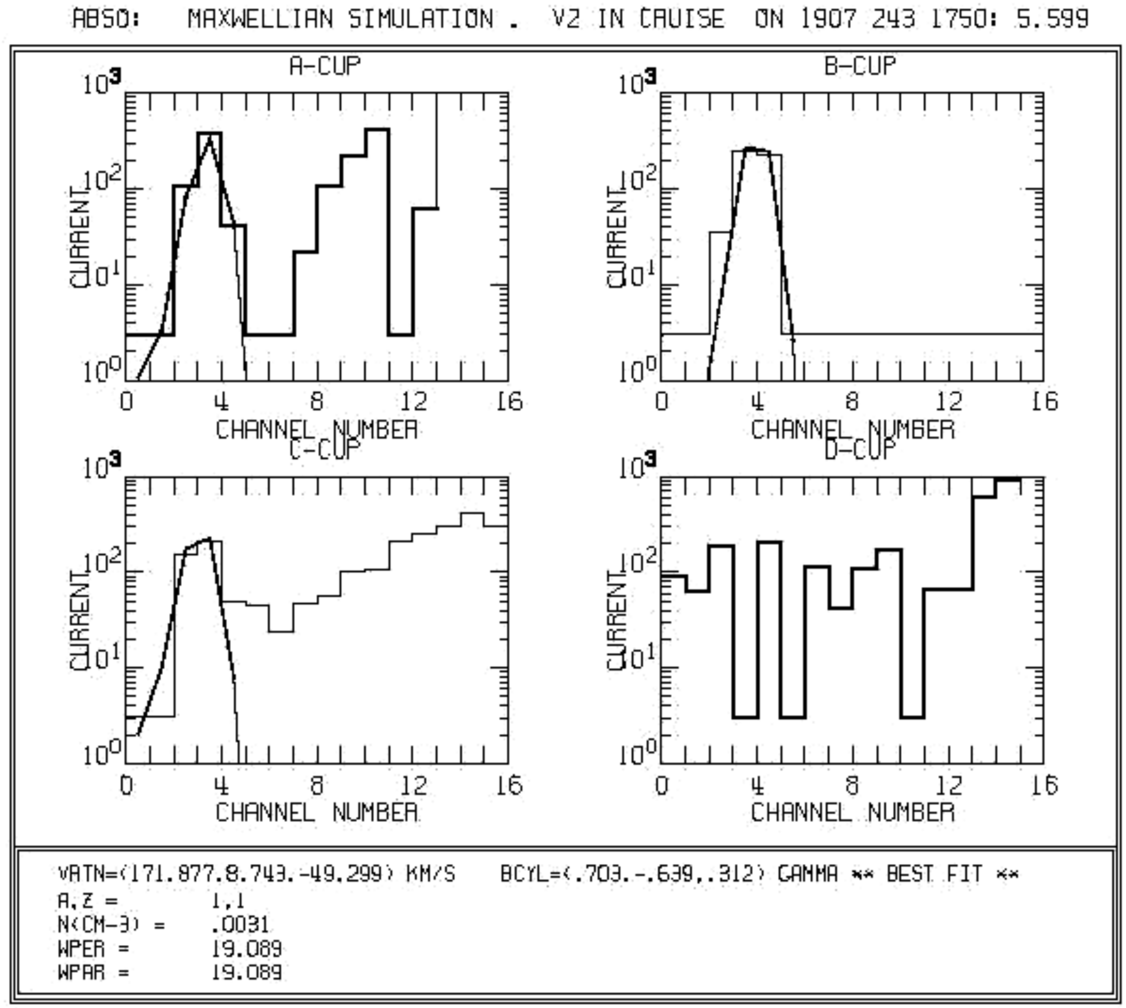
Instrument thresholds:
N > ~0.0003 cm^{-3}
Flow angle: flat response to 45°, then linear decrease to 0 at 60°



- HSH spectra
- Data in 3 cups
- Noise at higher energies
- Spectra every 192 sec.
- V(R,T,N) =

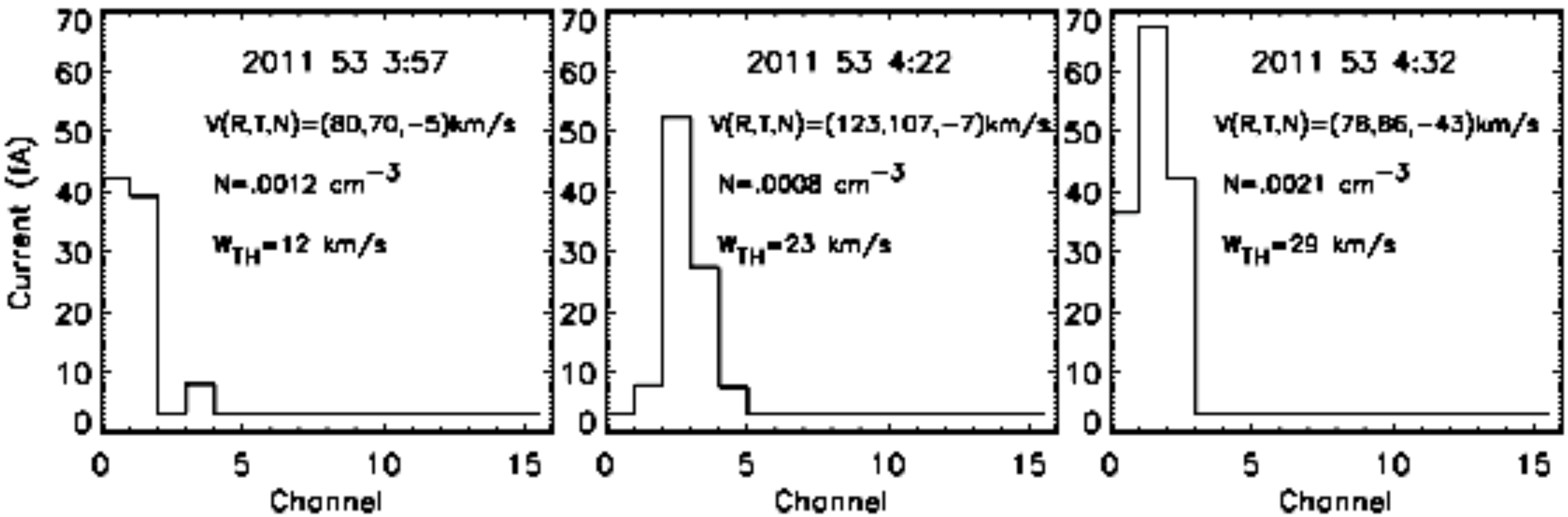
172, 9, -49 km/s

- N = 0.003 /cc
- W_{TH} = 19.1 km/s

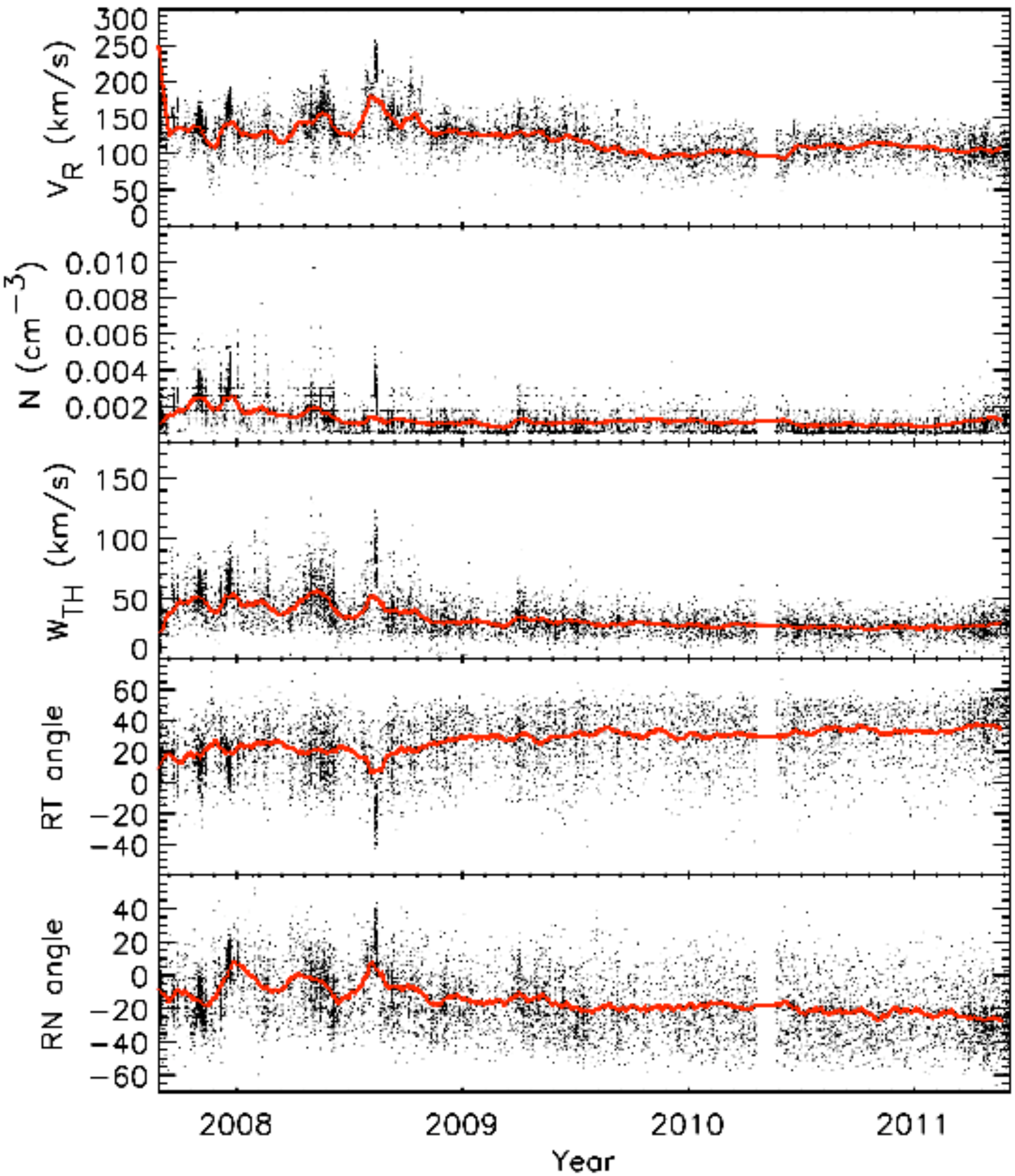


Current vs log E (10 - 5950 eV)

Plasma variability: Three spectra from within 35 minutes from B detector showing significant changes.



Current vs. log energy

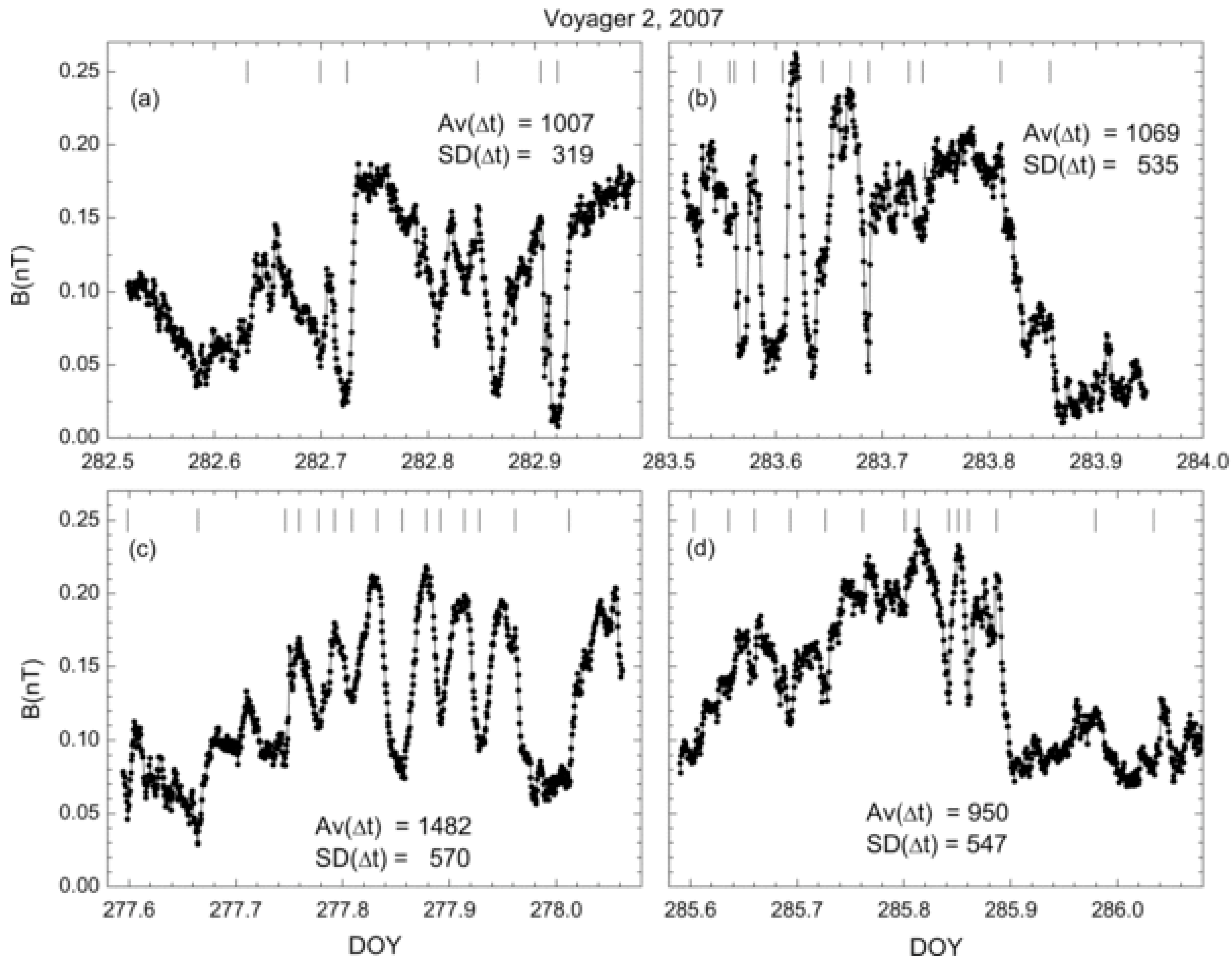


Lots of variation on short (tens of minute) time scales.

Can quantify the variability by looking at the distributions.

Distributions are generally fit well by Gaussians.

RT angle chopped off due to instrument response



B variation on short time scales (48 s data, Burlaga et al., 2009)

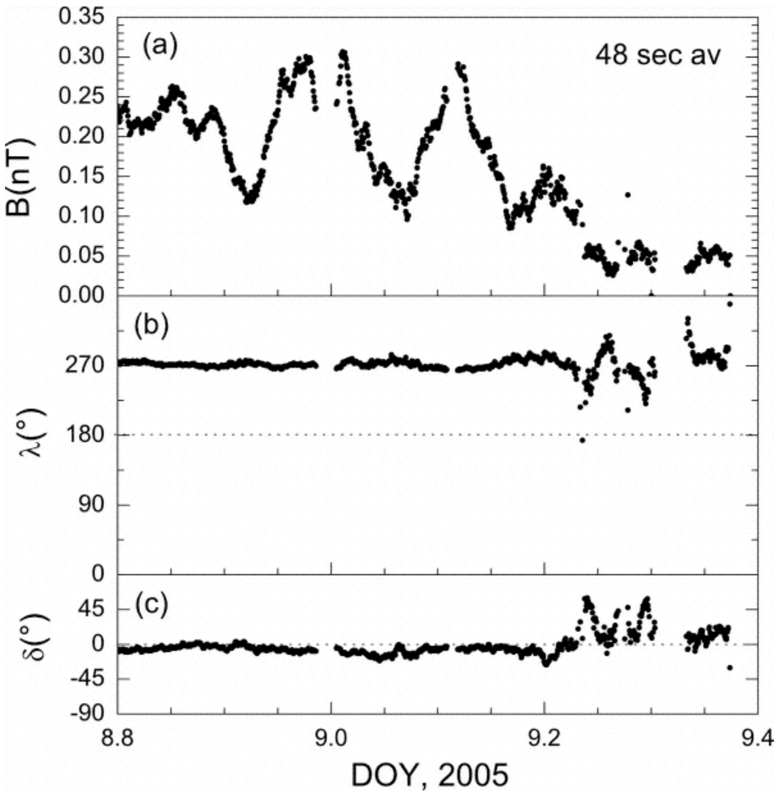
1 keV: pui rl = 30,000 km 5 minutes to pass V2

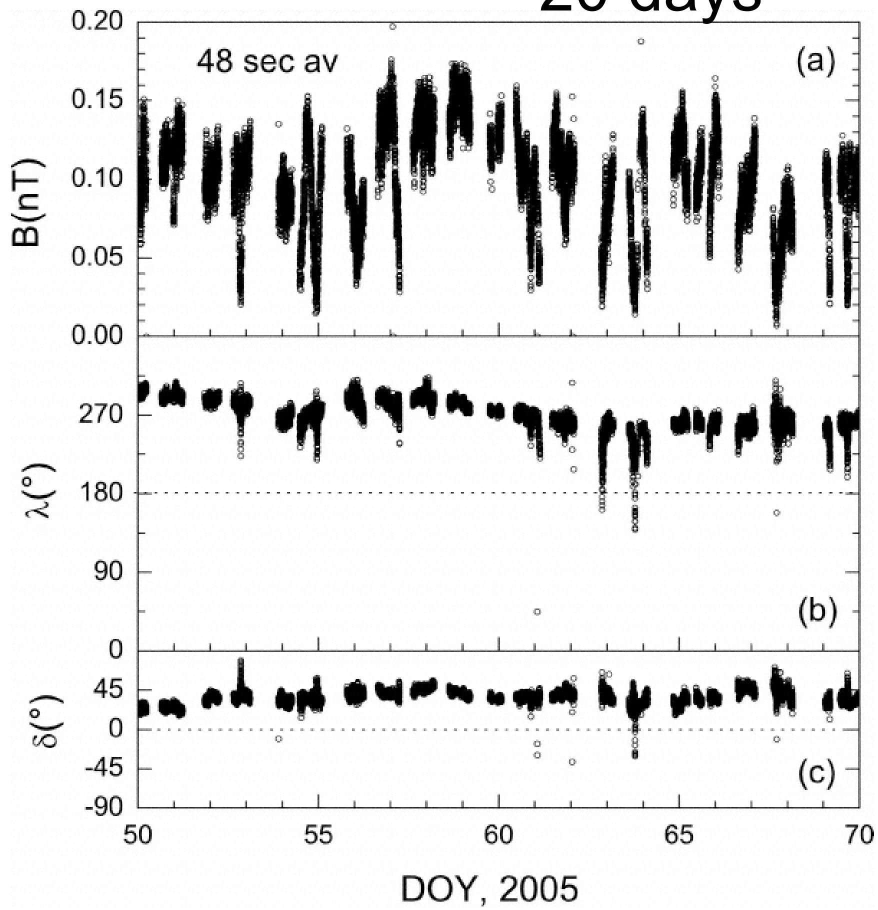
4 keV 60,000 km 10 minutes

6 hours

Magnetic field

20 days





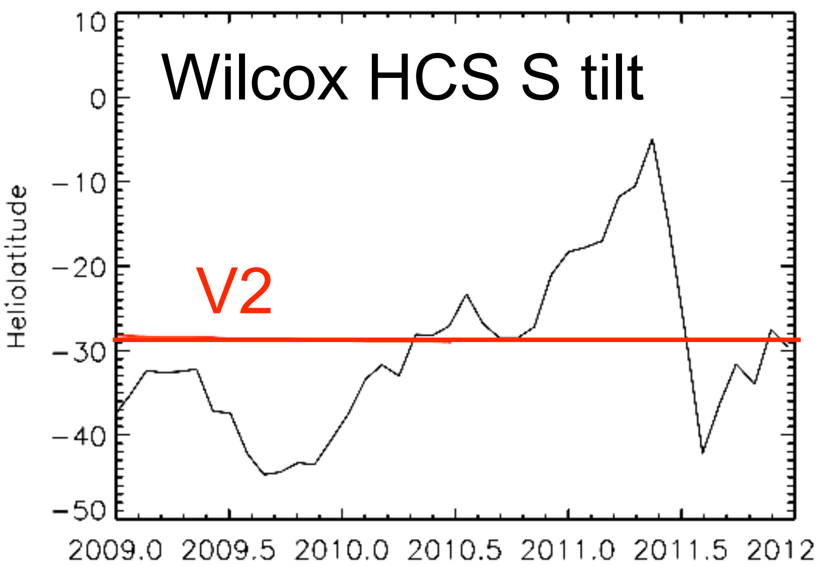
Heliosheath variability

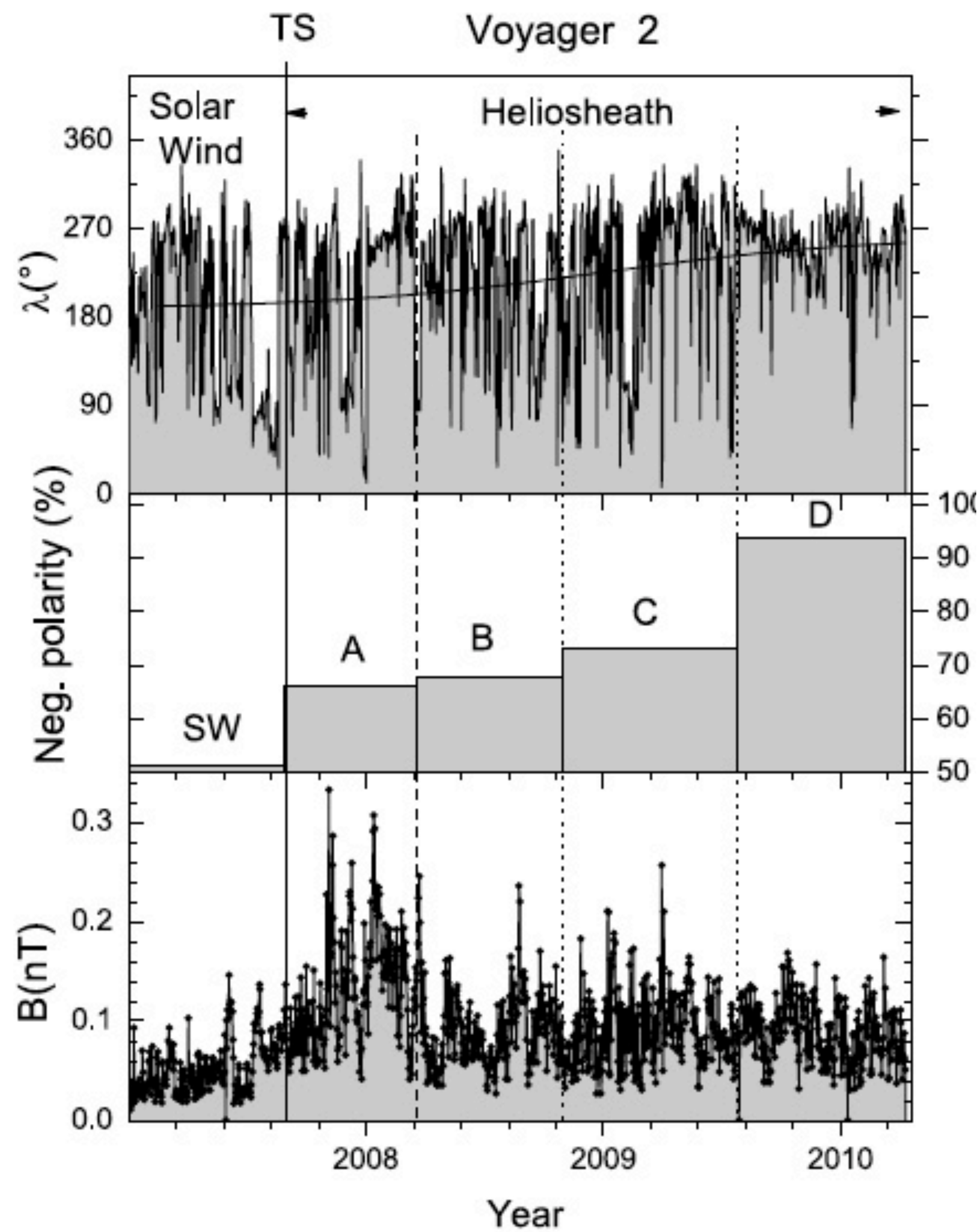
|B| highly variable

Direction ~ constant

Flow is compressive

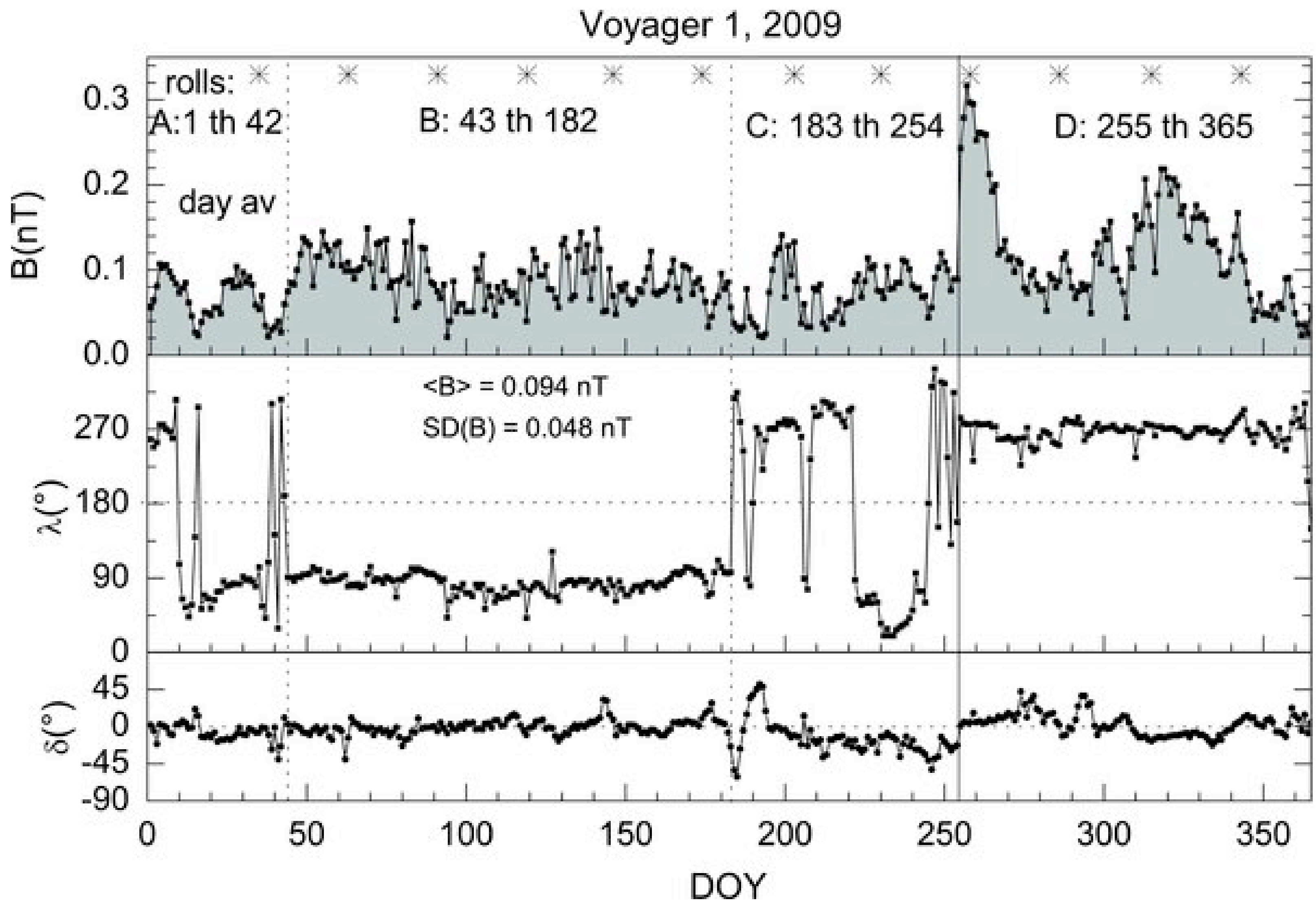
Burlaga et al., 2008





V2 almost above HCS in 2010. HCS tilt is now increasing at Sun.

Factor of 2 changes in B from day to day common.

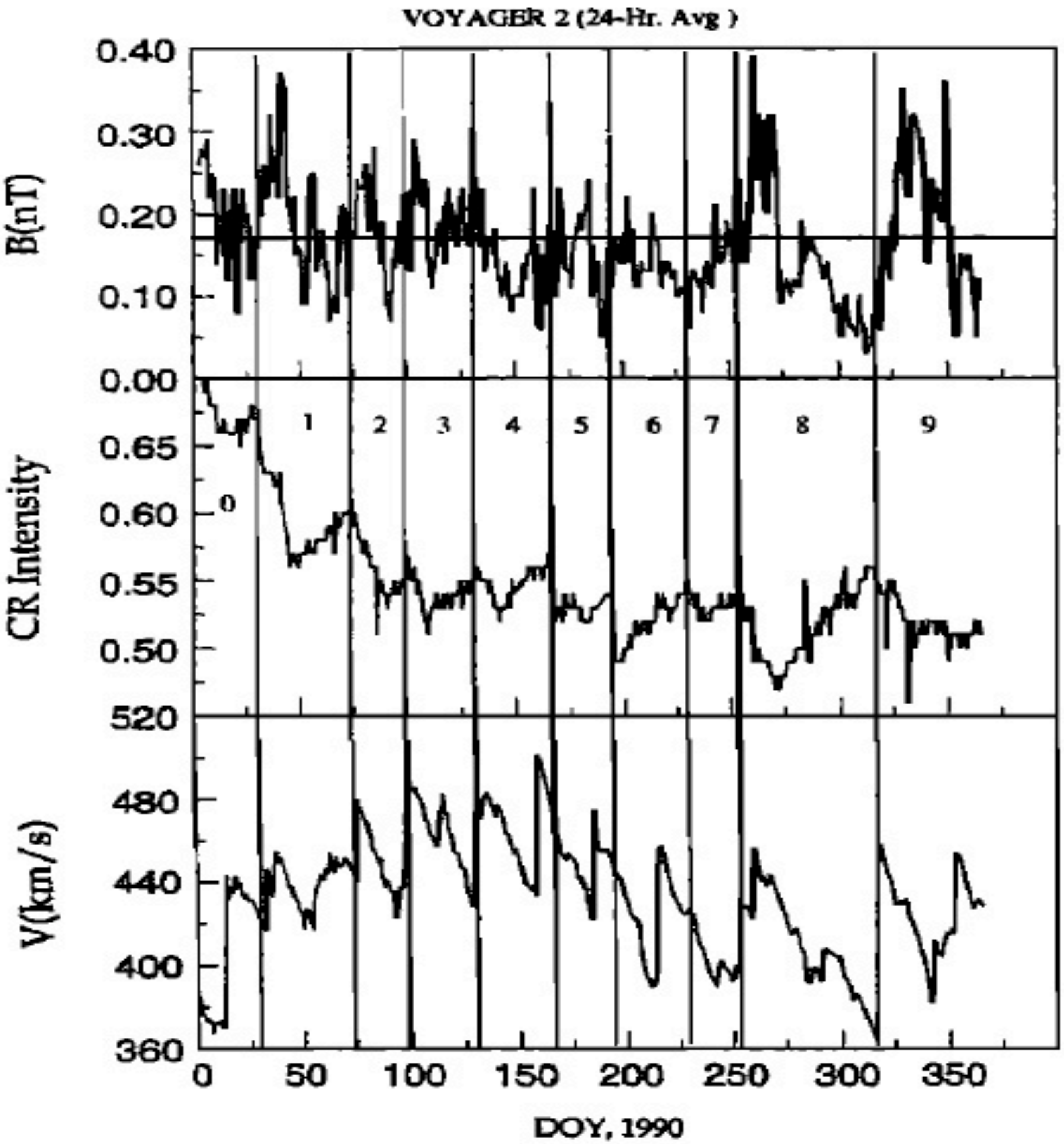


V1 still crossed HCS in 2009:
low speeds = long time in sector

CR-B relation
(Burlaga et al.)

When B is high
CRs decrease.

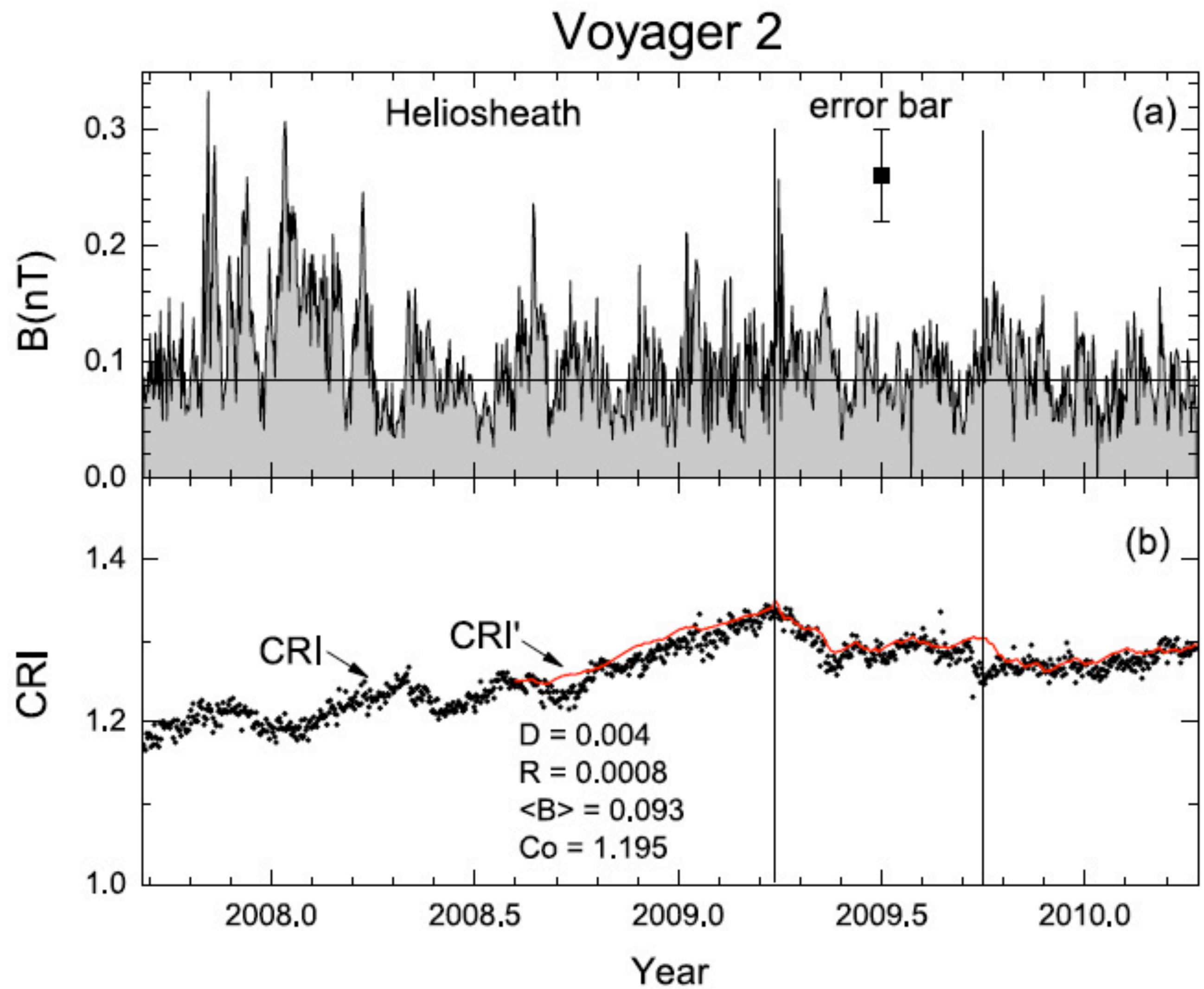
When B is low
CRs increase.



CR-B fails near TS.

Starts to work again about one year after TS.

(Both at V1 and V2)

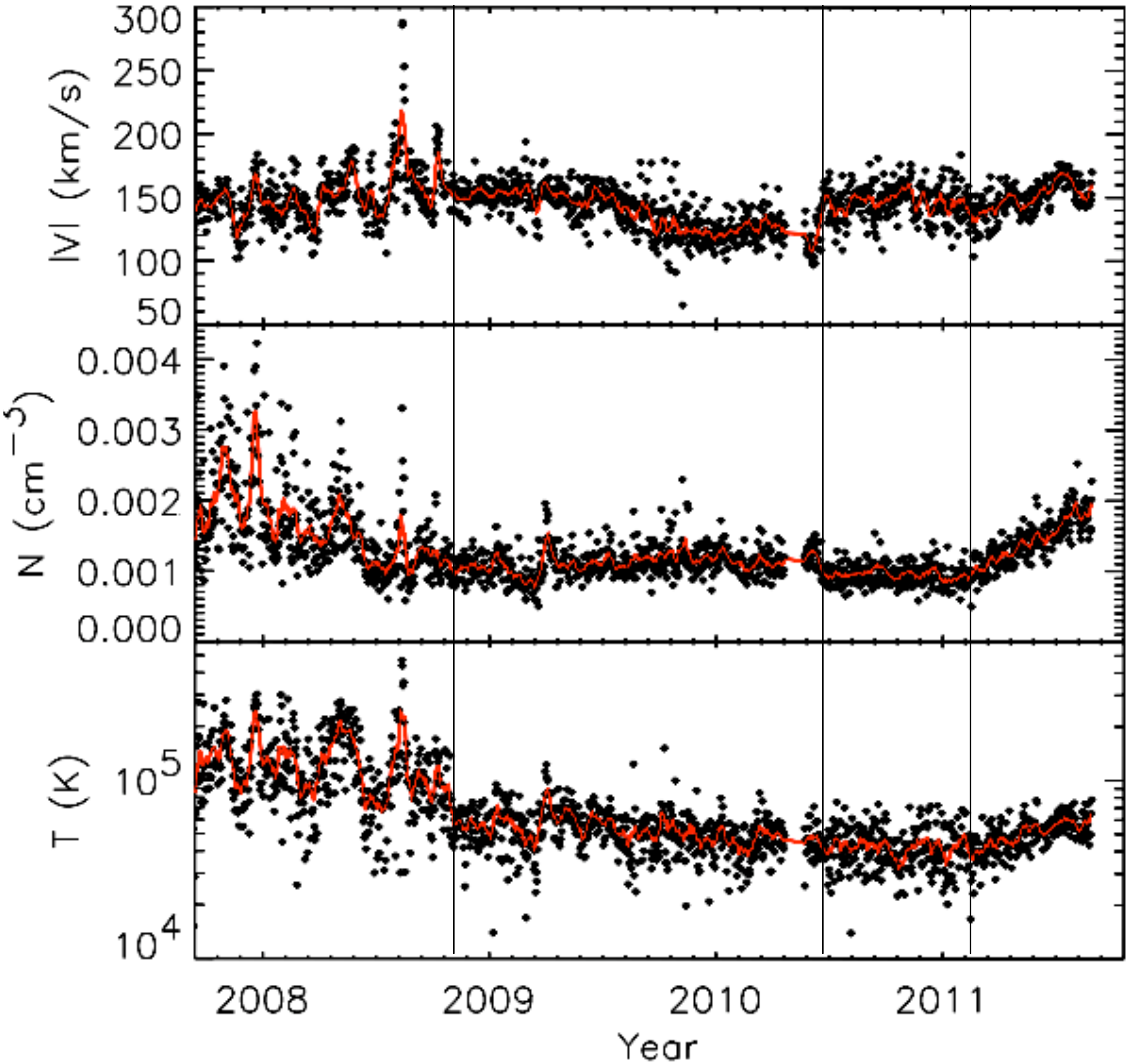


Plasma data (1 and 11-day averages)

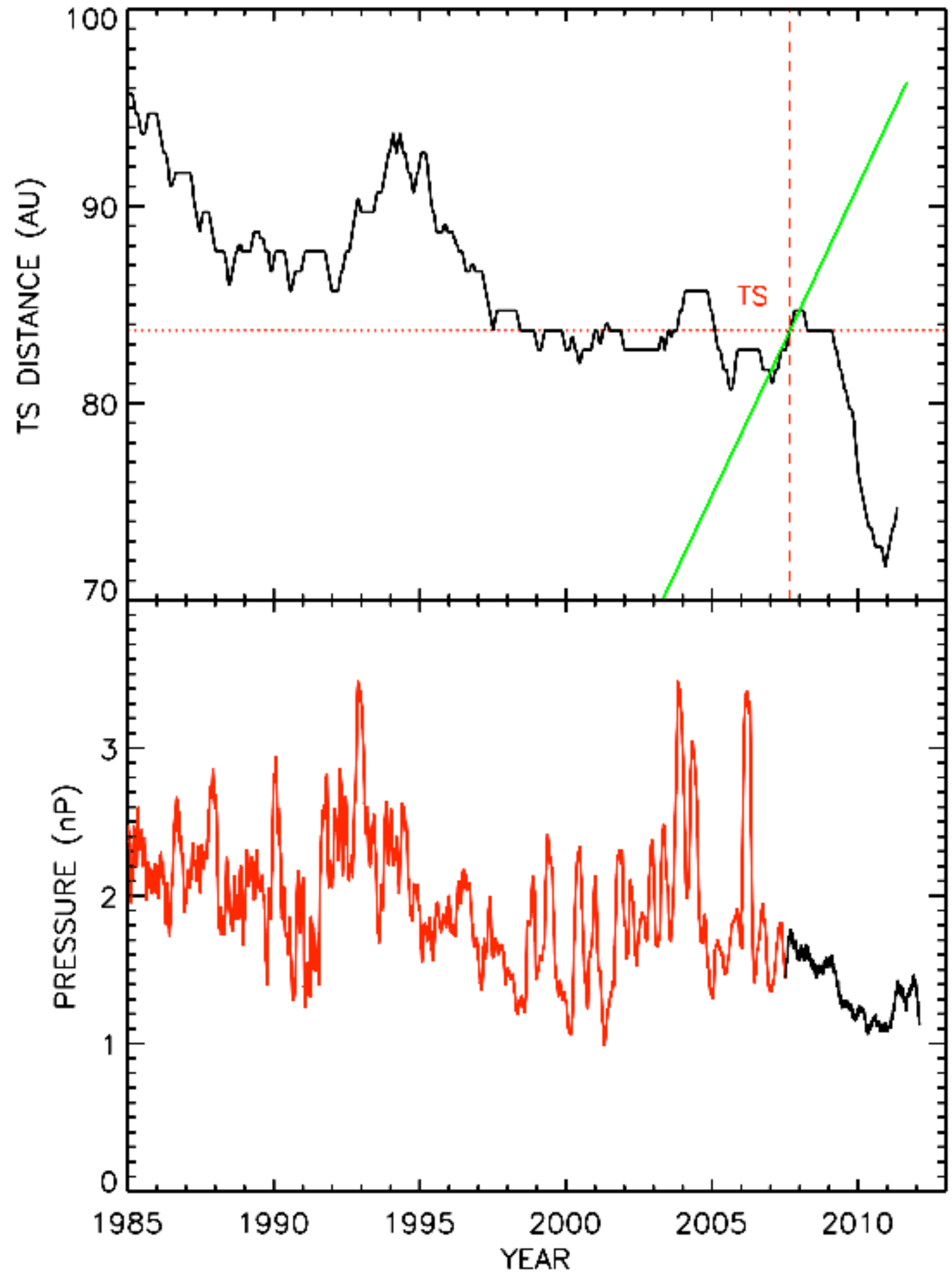
|V| ~ constant

N decrease after TS, now increasing

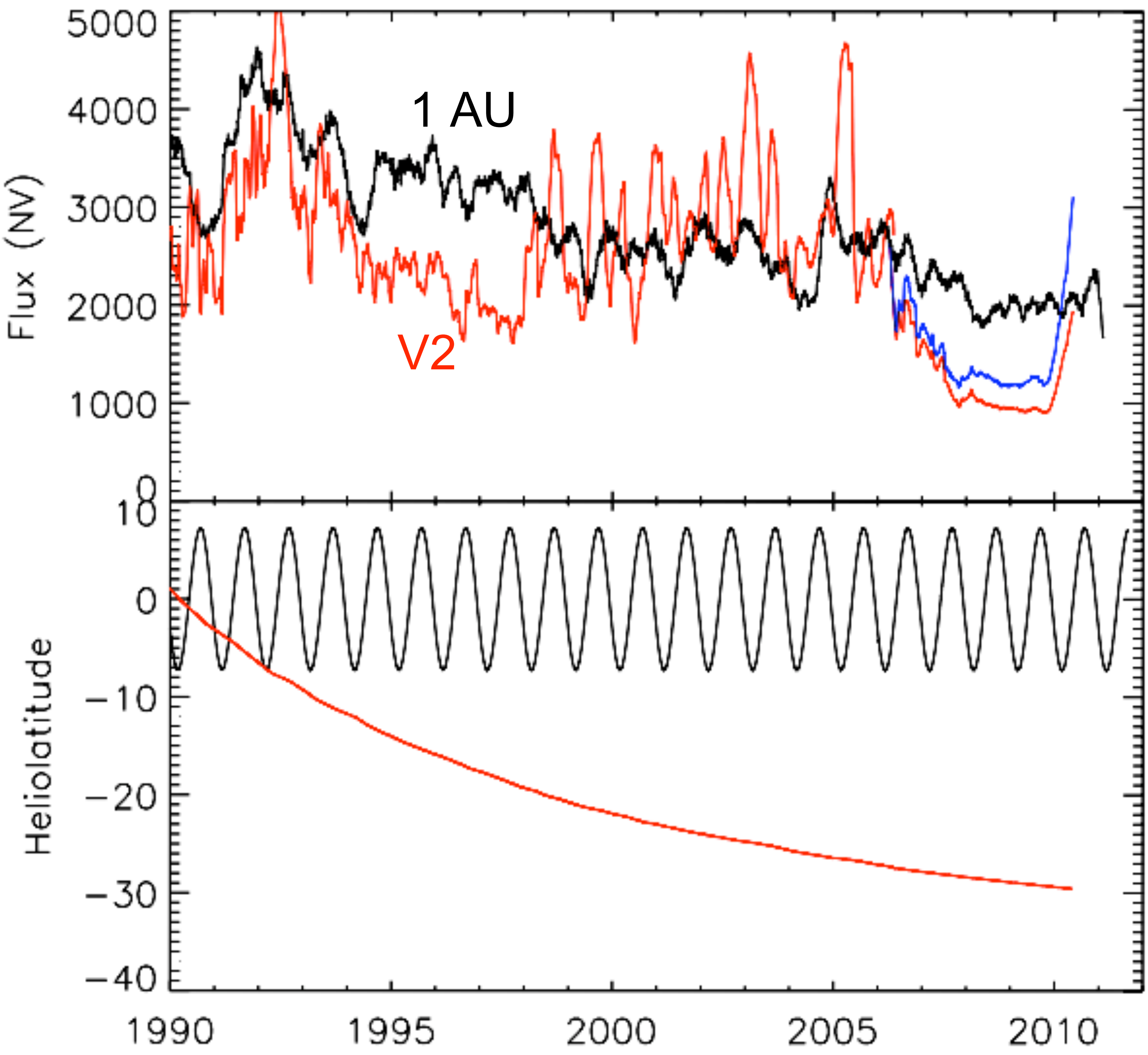
T decreased by factor of three, now increasing



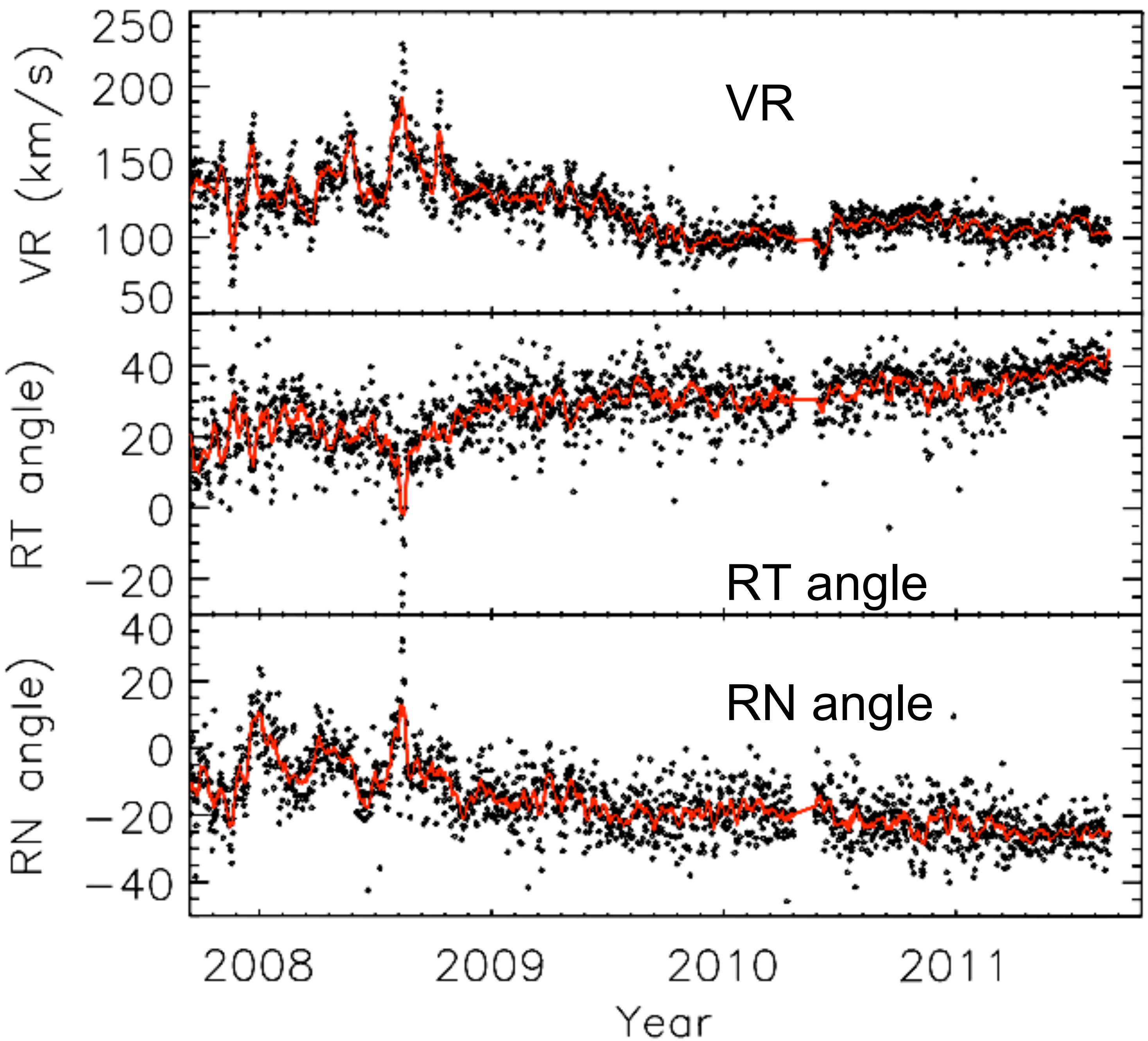
2-D HD model
with pickup
ions (Wang et al.).
V2 and 1 AU data used
as input

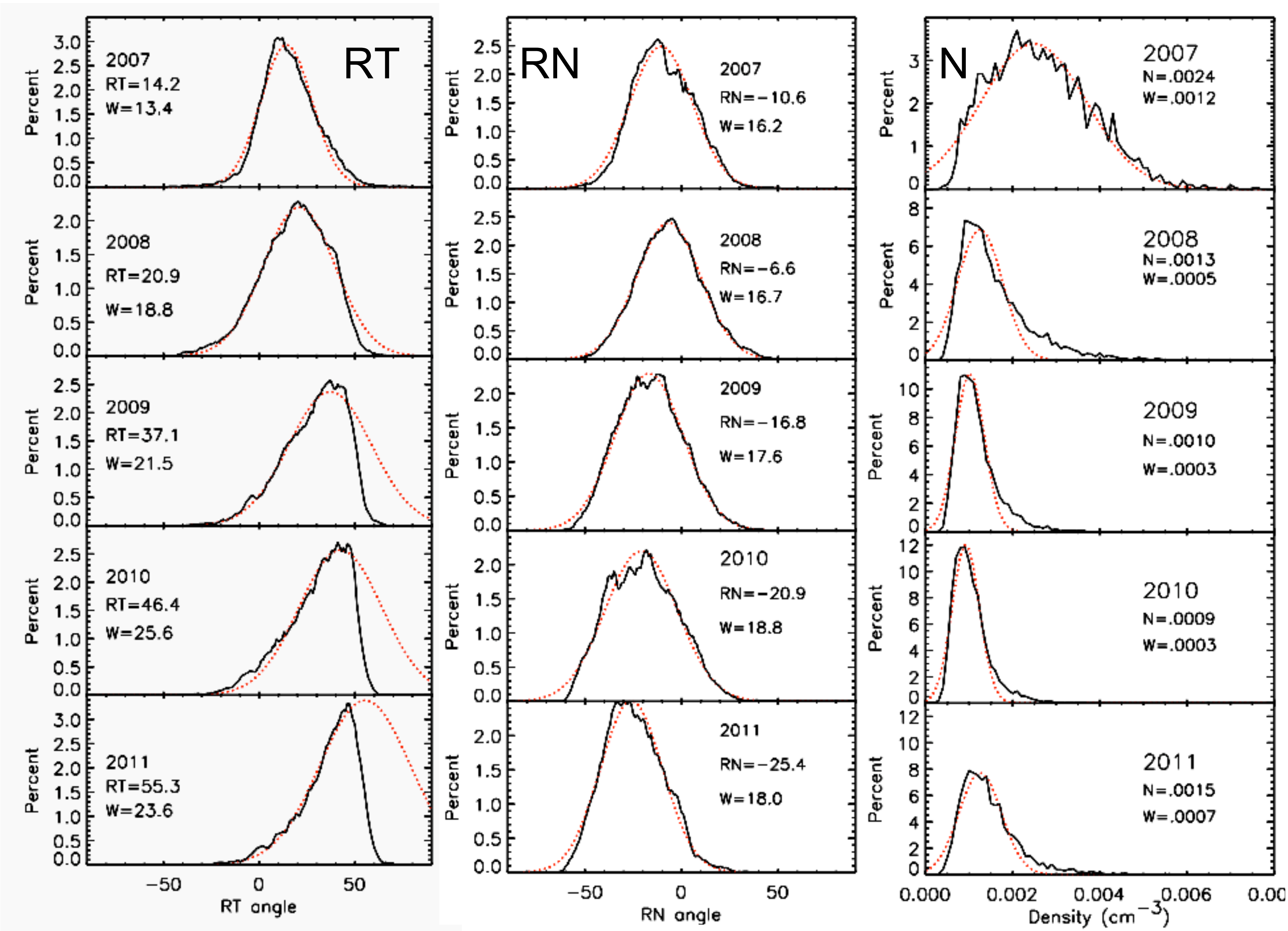


Lower
flux at
higher
latitudes
at solar
minimum

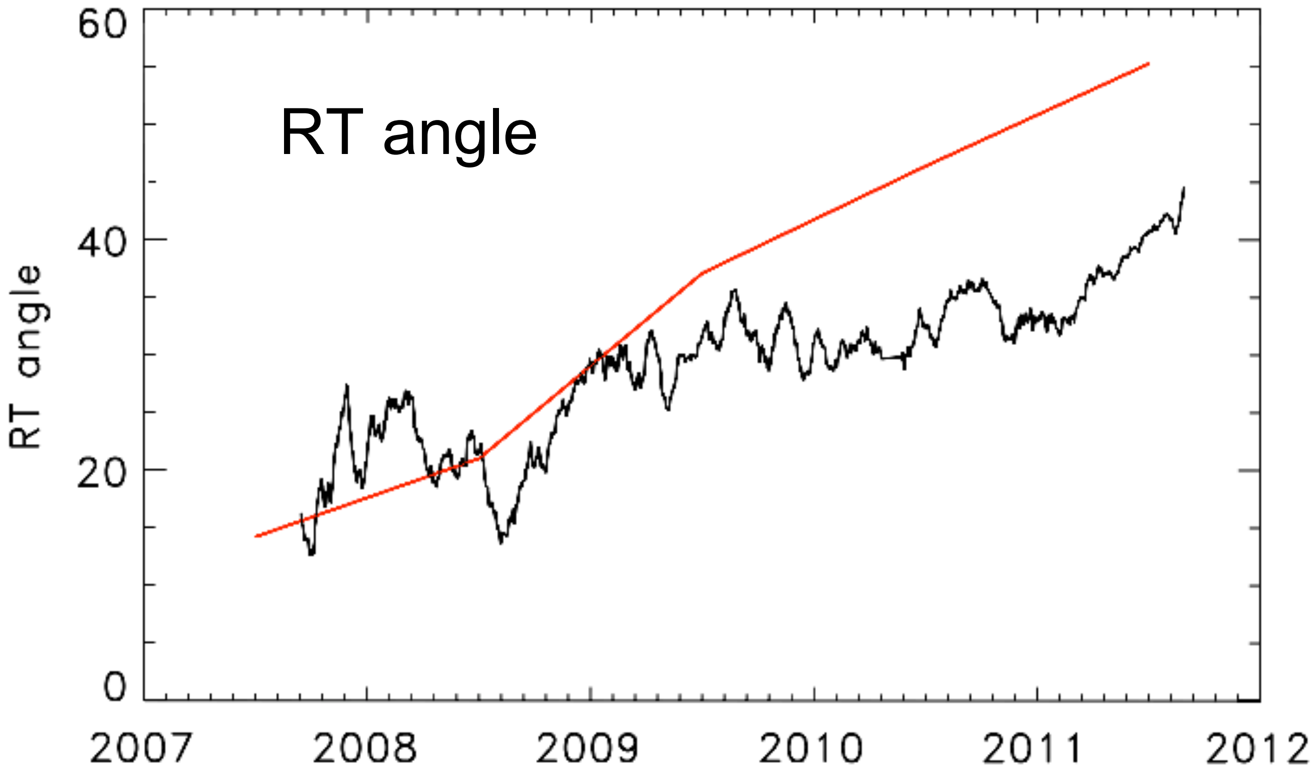


V2 1-day
And 11-day
averages

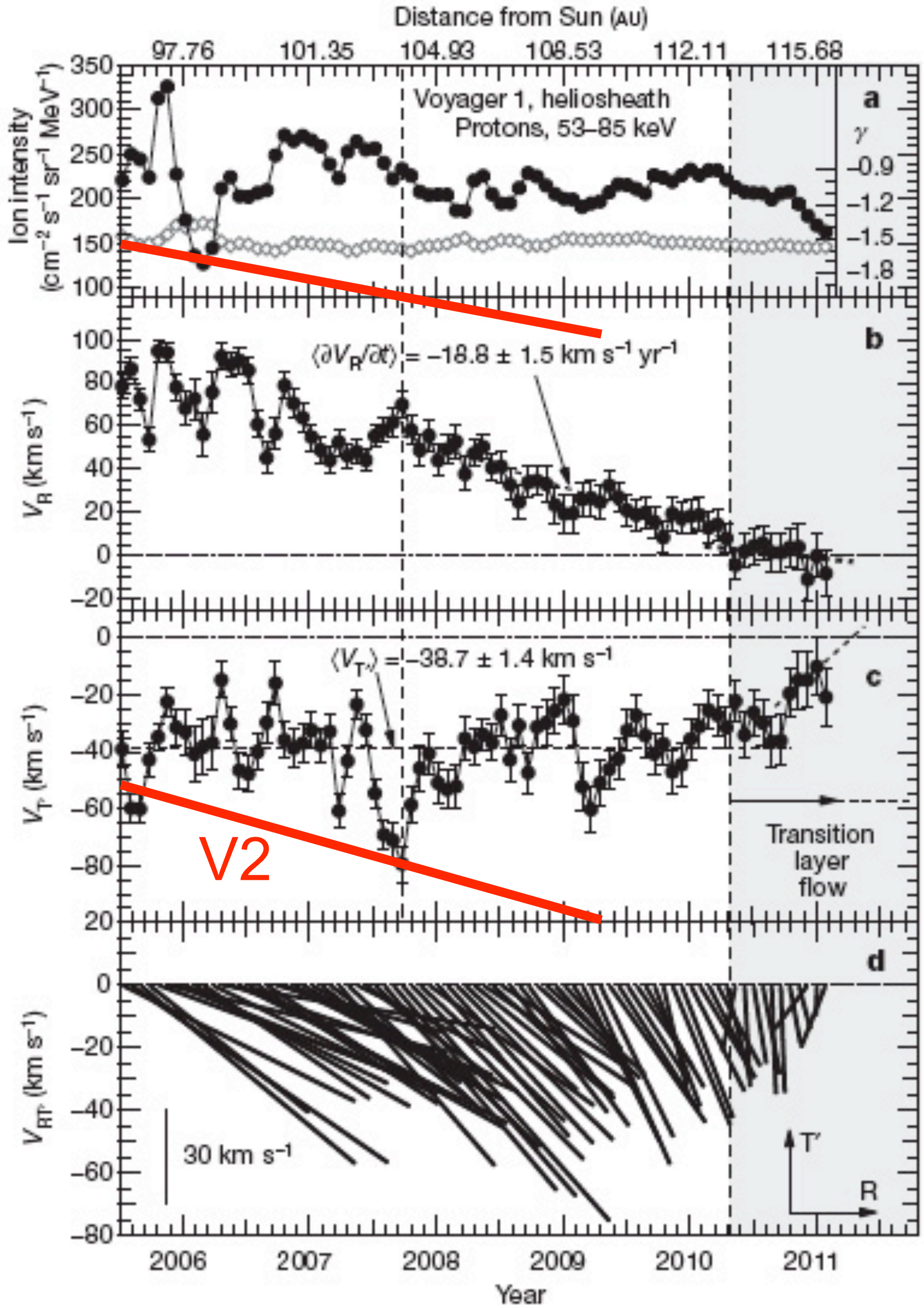




RT
2007
RT=14.2
W=13.4
2008
RT=20.9
W=18.8
2009
RT=37.1
W=21.5
2010
RT=46.4
W=25.6
2011
RT=55.3
W=23.6
Percent
RT angle
RN
2007
RN=−10.6
W=16.2
2008
RN=−6.6
W=16.7
2009
RN=−16.8
W=17.6
2010
RN=−20.9
W=18.8
2011
RN=−25.4
W=18.0
RN angle
N
2007
N=.0024
W=.0012
2008
N=.0013
W=.0005
2009
N=.0010
W=.0003
2010
N=.0009
W=.0003
2011
N=.0015
W=.0007
Density (cm^{-3})



10 deg/year

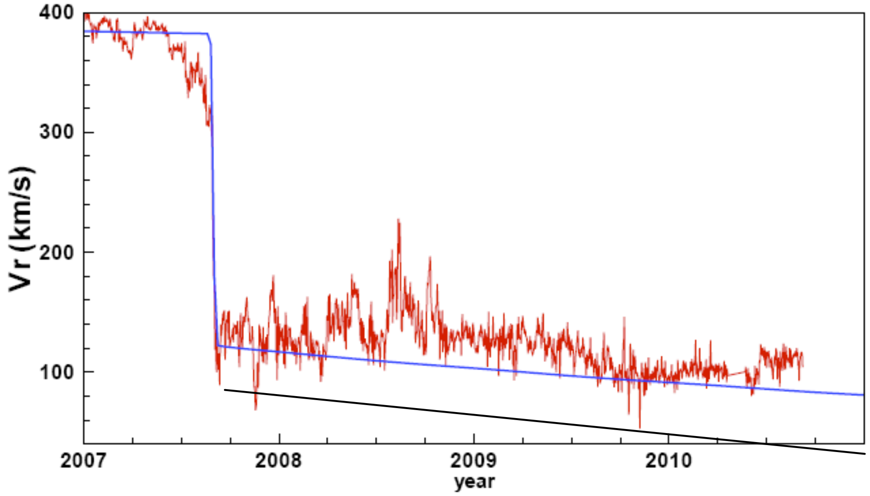


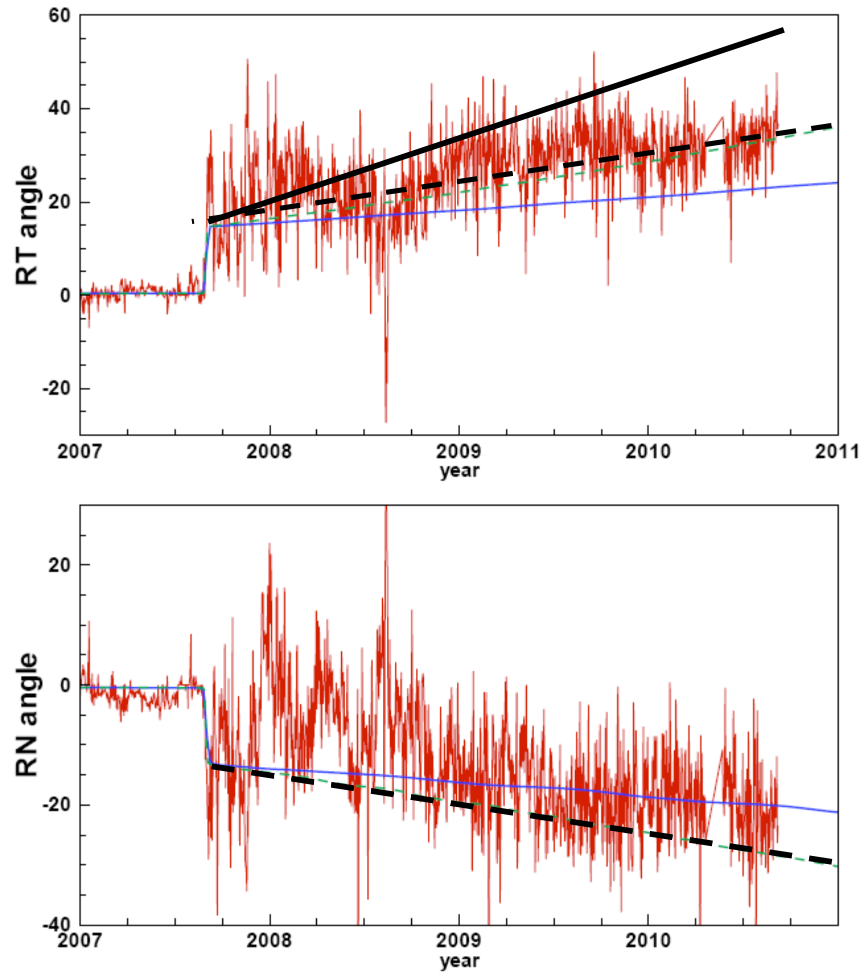
Krimigis et al., Nature, 2011

V1 now at 117 AU
(V2 at 96 AU)
V1: No plasma data.
Speeds determined from Compton-Getting effect.
V_R has gone to 0.
V_T is decreasing.
LECP does not measure V_N
Stone et al. (2011) show V_N also decreasing.
Ion intensity decreasing.
B not changing yet.

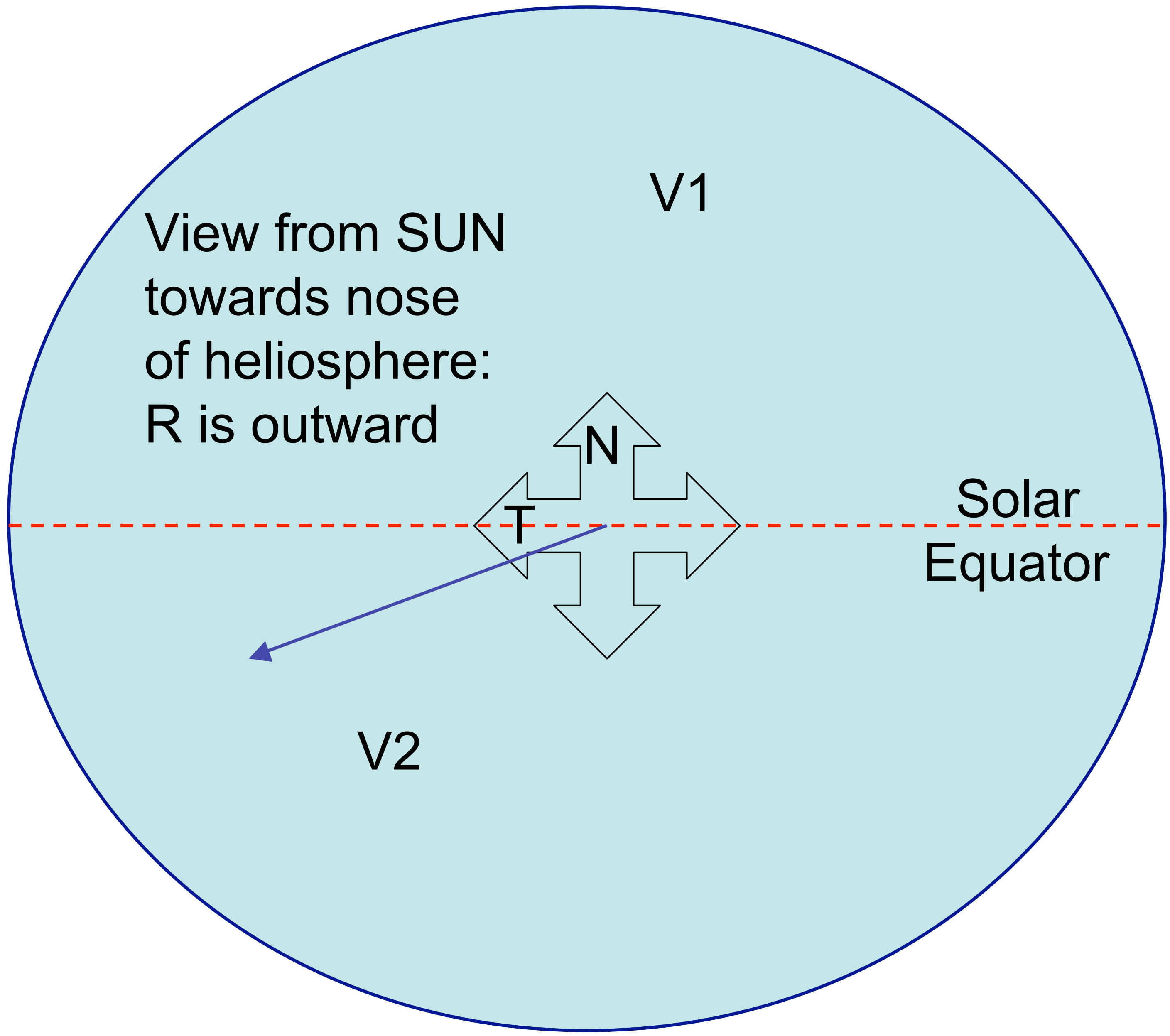
Heliopause not a sharp boundary, but characterized by a transition layer?

Comparison of numerical results with the Voyager 2 observations





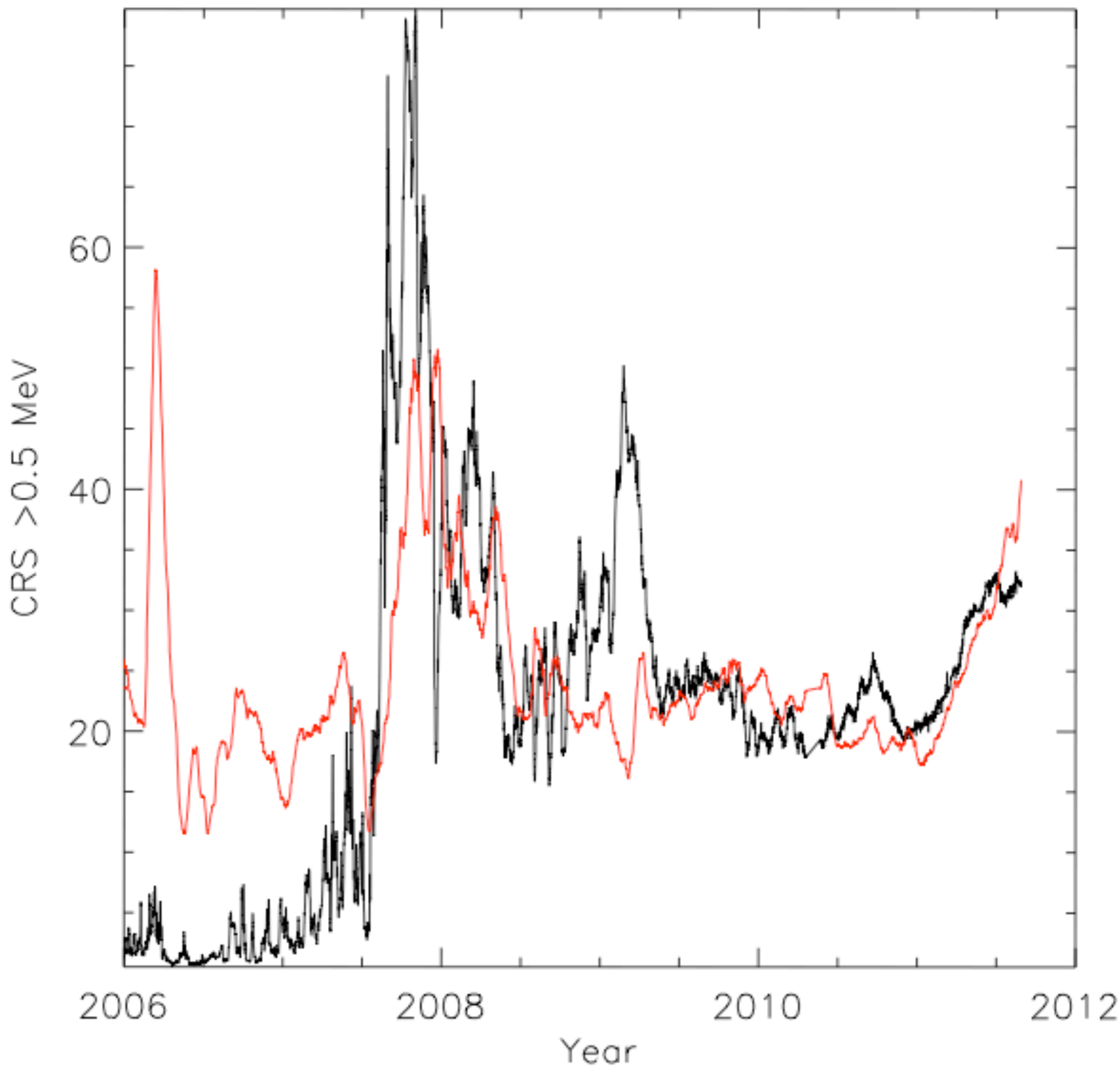
From Borovikov et al. (2011)

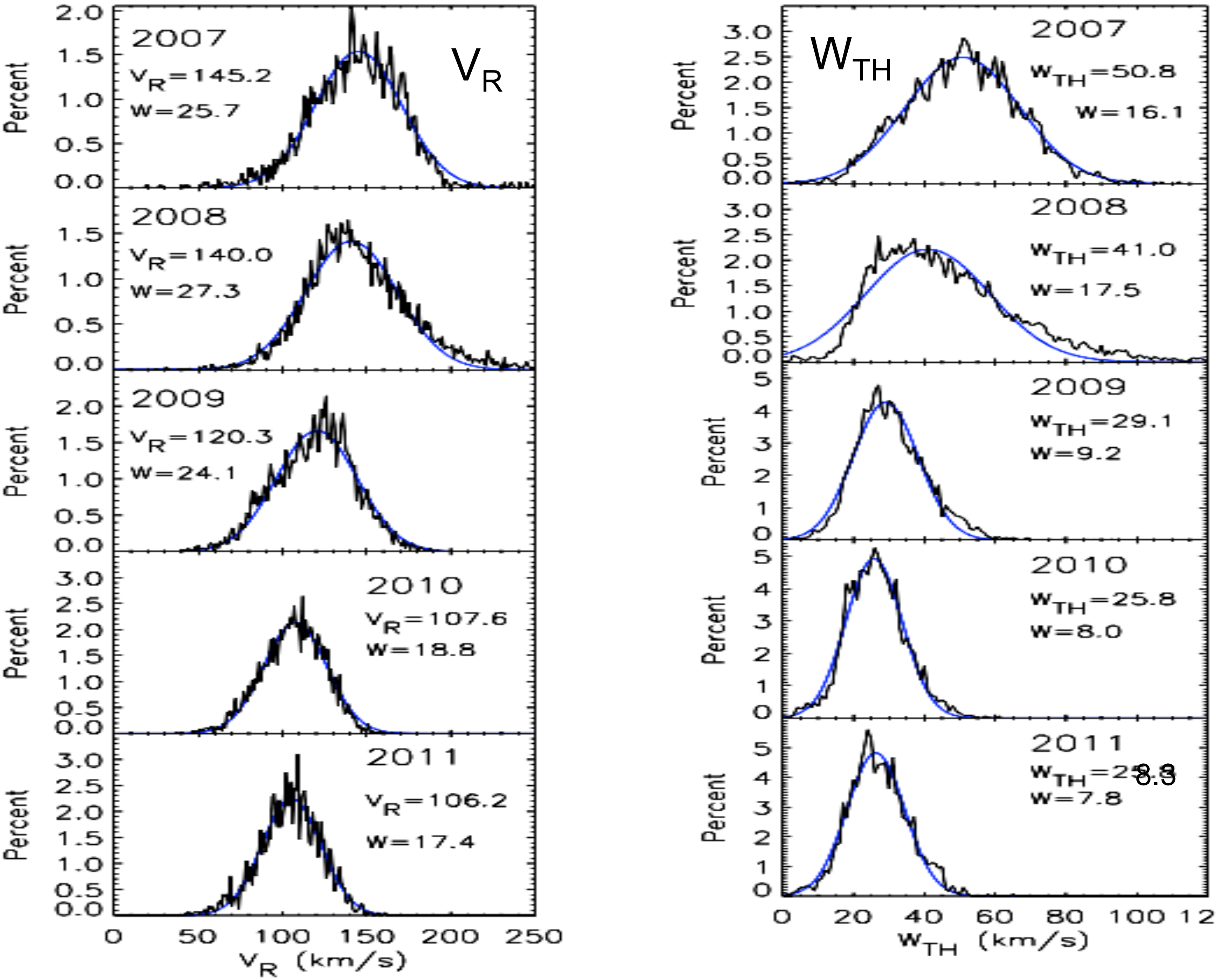

V1
View from SUN
towards nose
of heliosphere:
R is outward
N
T
Solar
Equator
V2

Summary

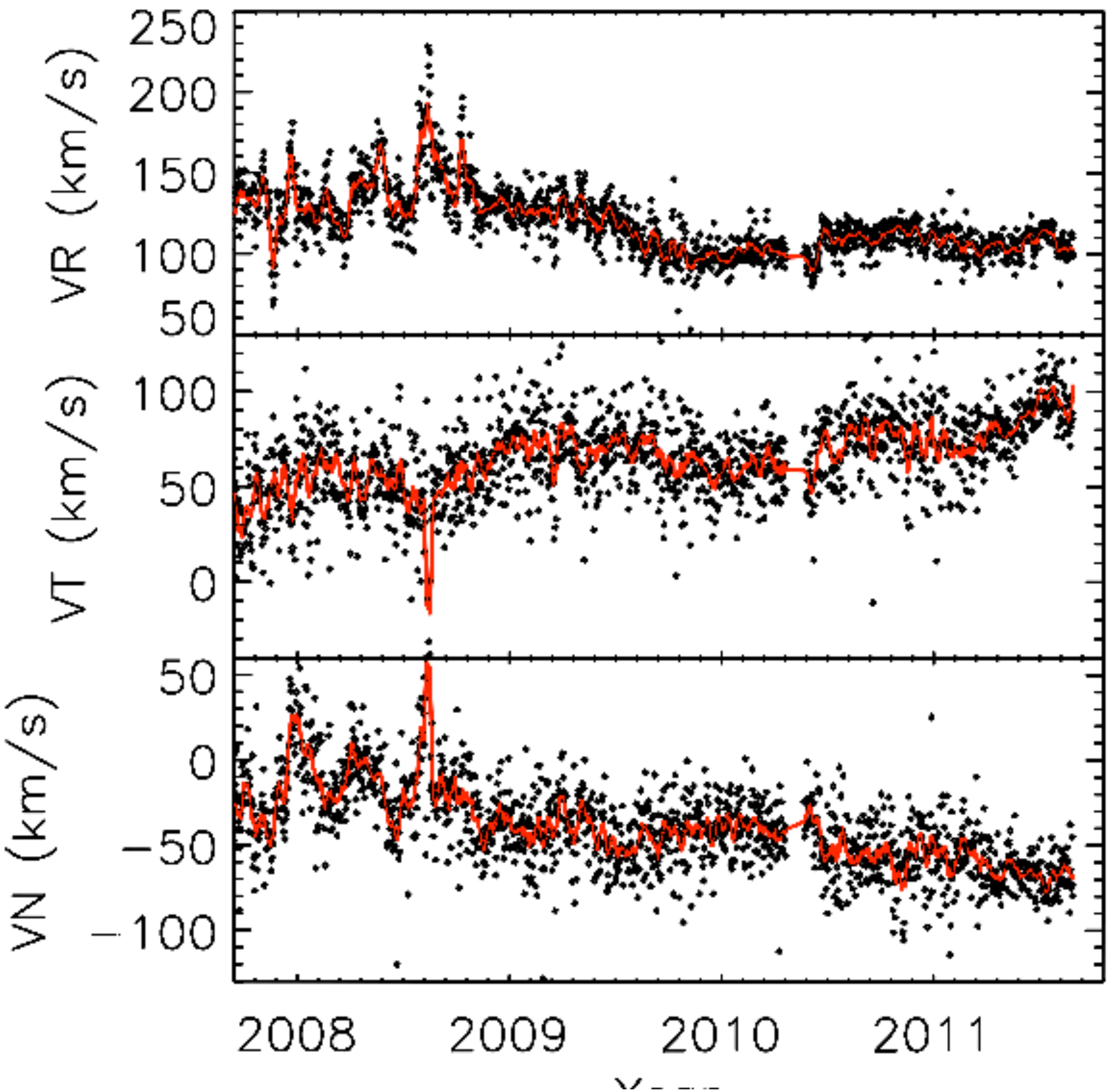
1) HSH highly variable on time scales of tens of minutes.
2) Long (days) averages show coherent changes.
3) Recent increase in N and T
4) More flow deflection than model prediction

Thermal H+ and >0.5 MeV/nuc profiles similar.





V_R
W_{TH}
2007
V_R=145.2
W=25.7
2008
V_R=140.0
W=27.3
2009
V_R=120.3
W=24.1
2010
V_R=107.6
W=18.8
2011
V_R=106.2
W=17.4
2007
W_{TH}=50.8
W=16.1
2008
W_{TH}=41.0
W=17.5
2009
W_{TH}=29.1
W=9.2
2010
W_{TH}=25.8
W=8.0
2011
W_{TH}=2
8.3
W=7.8
Percent
0 50 100 150 200 250
V_R (km/s)
0 20 40 60 80 100 120
W_{TH} (km/s)



250
200
150
100
50
VR (km/s)
100
50
0
VT (km/s)
50
0
−50
−100
VN (km/s)
2008
2009
2010
2011