Recent Voyager data and unexpected properties of the heliospheric termination shock

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Voyager-2 crossed the SW termination shock late in August 2007, just 10 days after celebrating its 30-years birthday!

V-1 has been exploring the Heliosheath since mid-December 2004.

Major significance of the V-2 TS crossing(s):

1. **Observing SW plasma parameter changes for the first time**
2. **Observing multiple shock transits in fine time resolution**
3. **Recognition of the dynamic importance of suprathermals**
4. **Indications for an asymmetric („squashed") Heliosphere**

Just as the Sun is the most accessible star, our Heliosphere is the most accessible **astrosphere**. The TS is expected to be an acceleration site, and *in situ* data from that region may have major impact on our understanding of **cosmic shocks**.

Discovery papers
on the Voyager-2 termination shock crossings

SOLAR SYSTEM

A shock for Voyager 2

J. R. Jokipii

NATURE|Vol 454|3 July 2008

An asymmetric solar wind termination shock

Edward C. Stone[1], Alan C. Cummings[1], Frank B. McDonald[2], Bryant C. Heikkila[3], Nand Lal[3] & William R. Webber[4]

Magnetic fields at the solar wind termination shock

L. F. Burlaga[1], N. F. Ness[2], M. H. Acuña[1], R. P. Lepping[1], J. E. P. Connerney[1] & J. D. Richardson[3]

Intense plasma waves at and near the solar wind termination shock

D. A. Gurnett[1] & W. S. Kurth[1]

Discovery papers (continued)

Cool heliosheath plasma and deceleration of the upstream solar wind at the termination shock

John D. Richardson[1,2], Justin C. Kasper[3], Chi Wang[2], John W. Belcher[1] & Alan J. Lazarus[1]

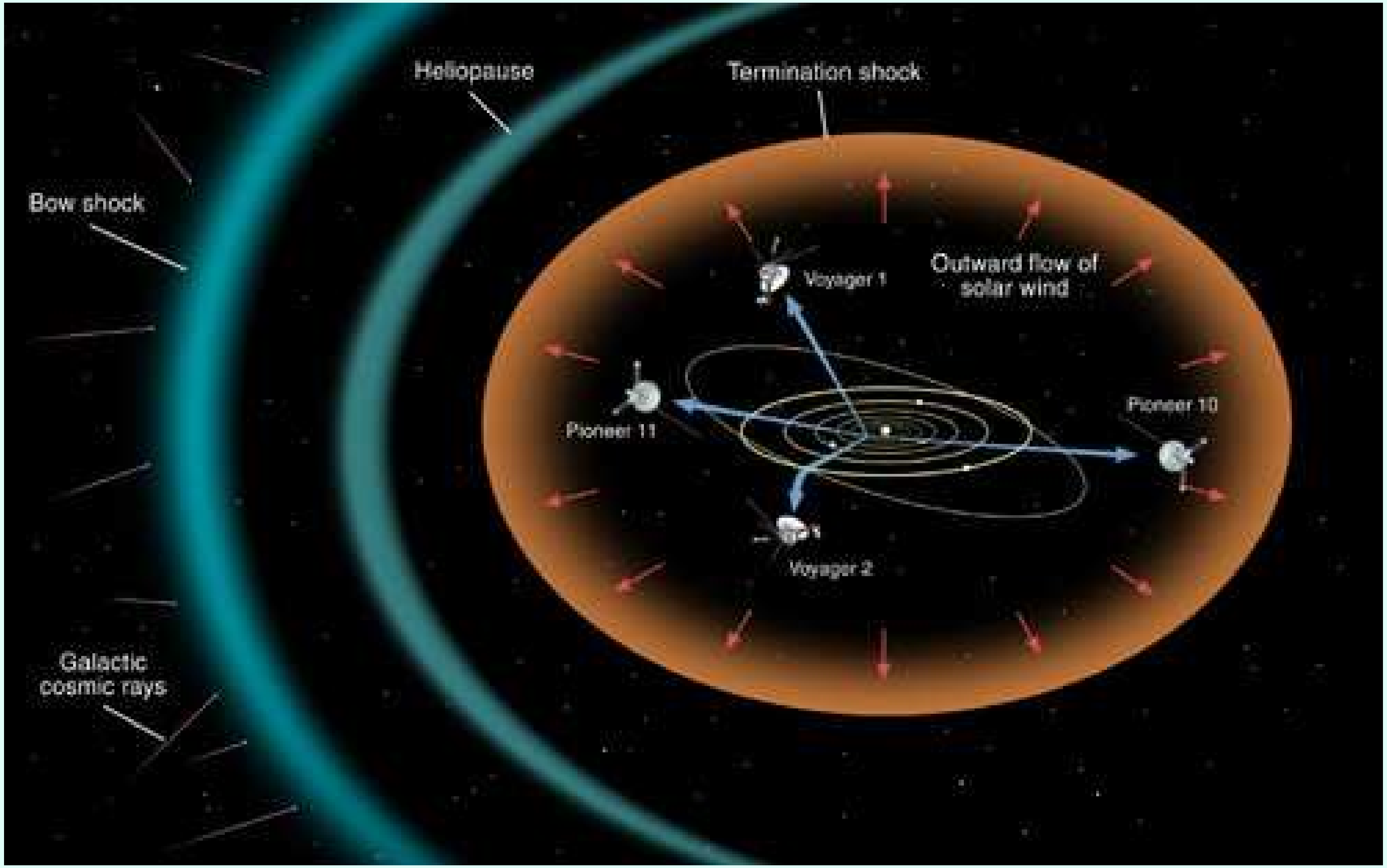
Mediation of the solar wind termination shock by non-thermal ions

R. B. Decker[1], S. M. Krimigis[1,2], E. C. Roelof[1], M. E. Hill[1], T. P. Armstrong[3], G. Gloeckler[4], D. C. Hamilton[5] & L. J. Lanzerotti[6,7]

Domination of heliosheath pressure by shock-accelerated pickup ions from observations of neutral atoms

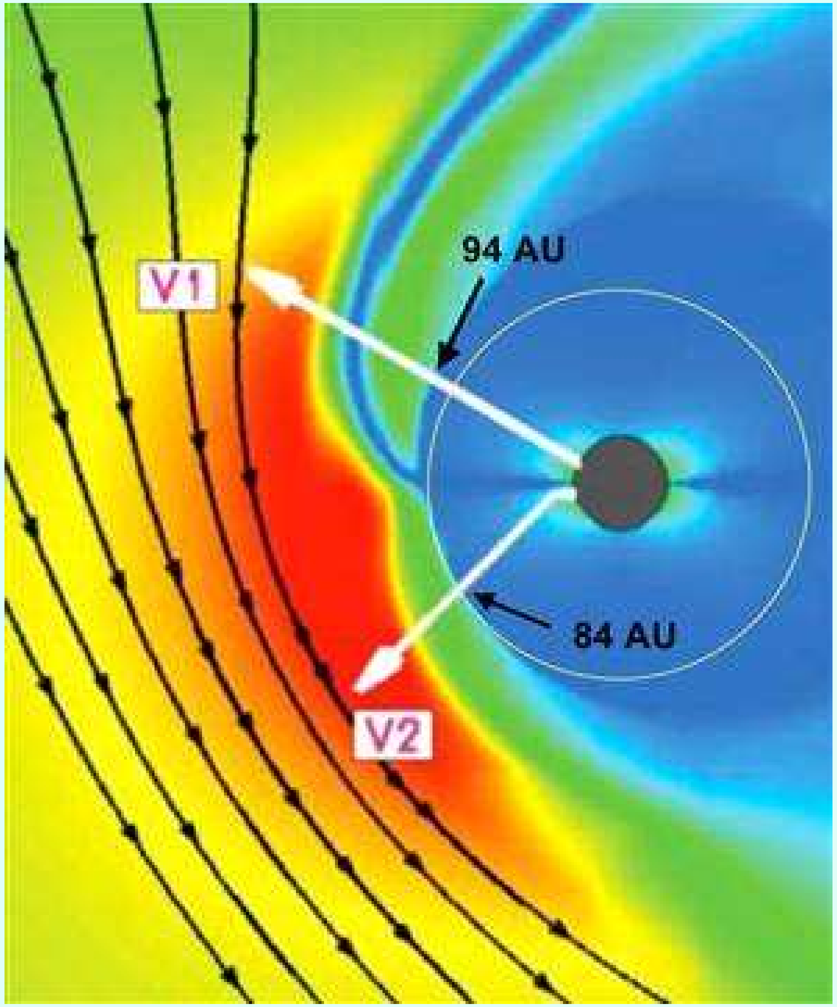
Linghua Wang[1,2], Robert P. Lin[1,2], Davin E. Larson[2] & Janet G. Luhmann[2]

Old picture of the heliospheric boundary region, with Pioneers still alive



Ian Axford's solar wind termination shock model and how it looks in my kitchen sink

(That simple visualization is now widely used without reference to the originator.)

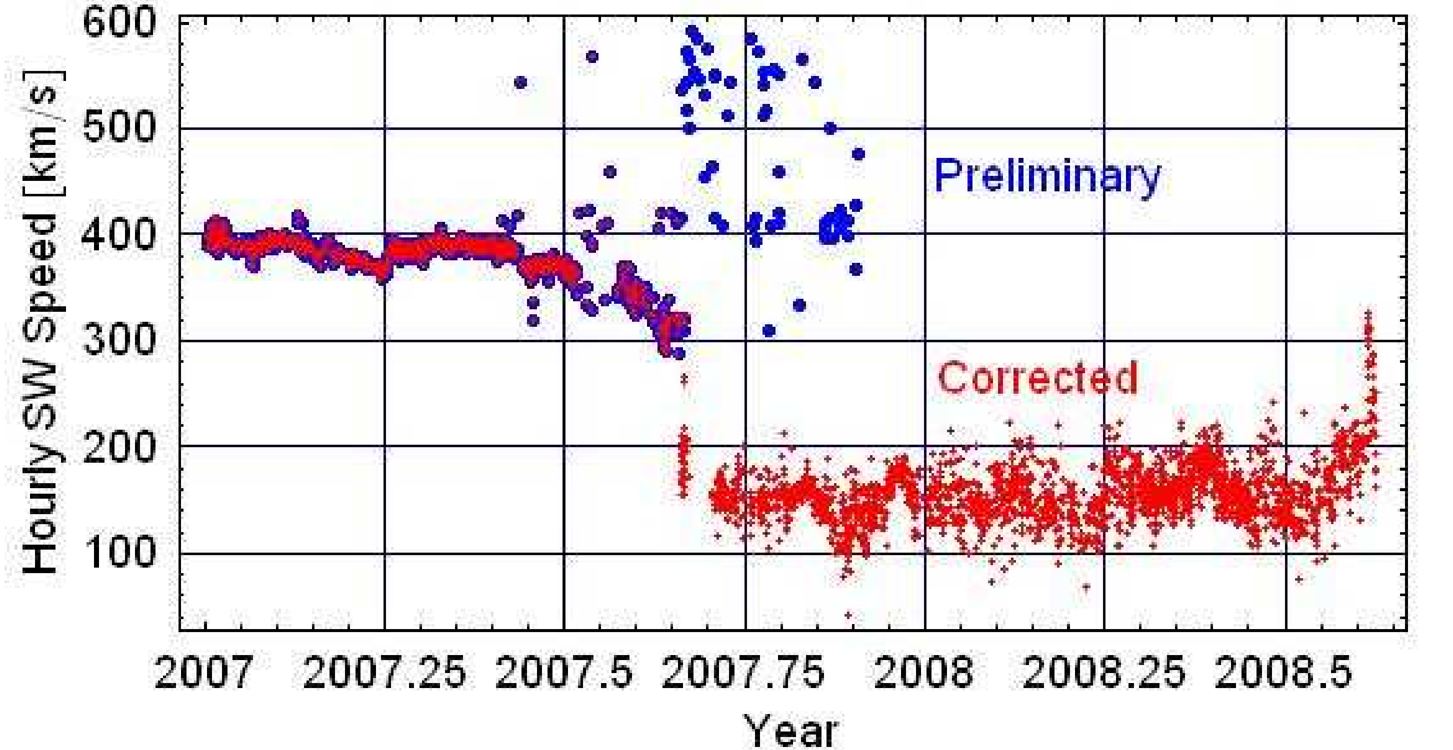


Artist's impression of a squashed heliosphere, with present positions of Voyager-1 and -2.

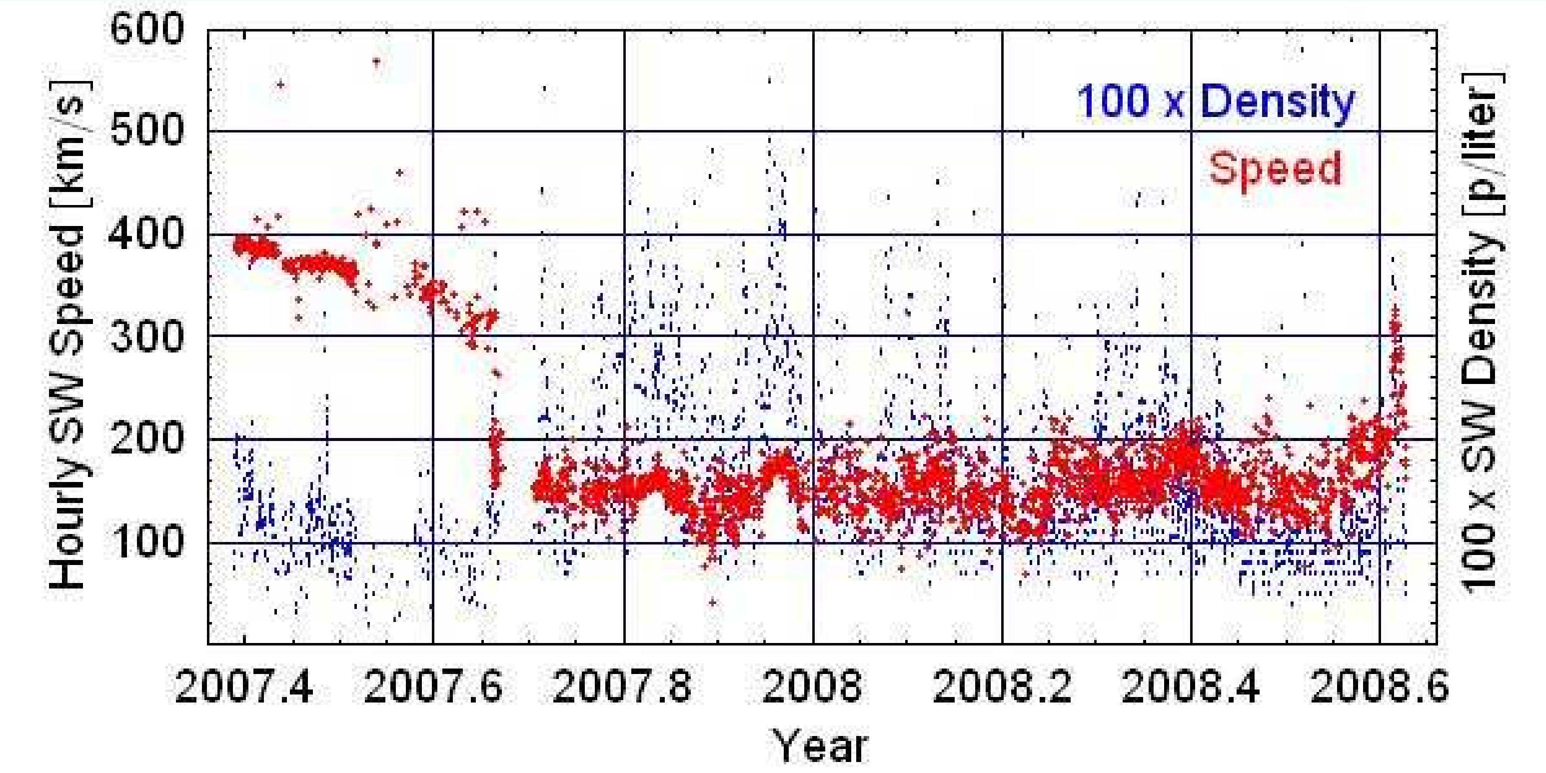
If magnetic reconnection is the cause of asymmetry, then for subsequent solar cycles its sense might be reversed.

Solar Wind Parameter Changes

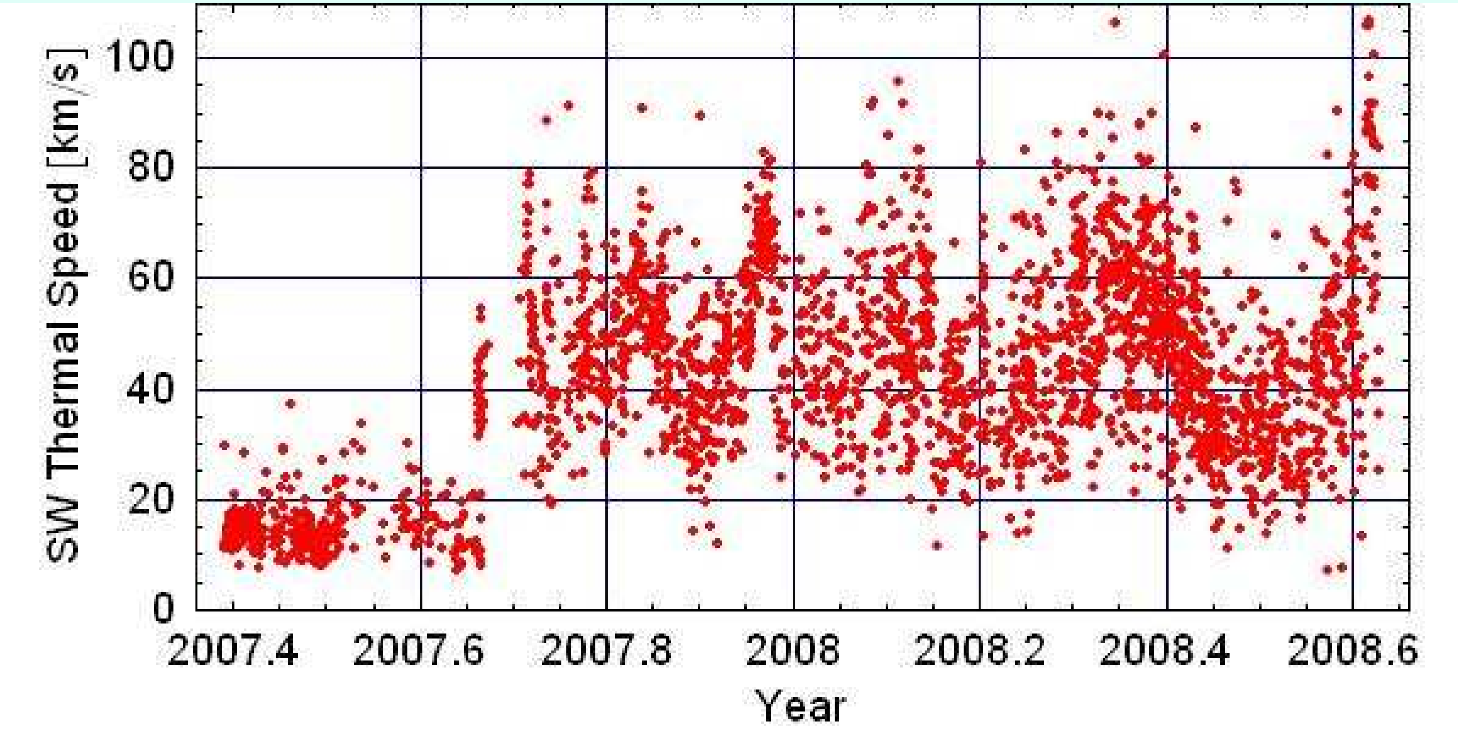
Preliminary (up to „shock crossing announcement”) and final hourly SW speed data, before and after the V-2 TS crossing



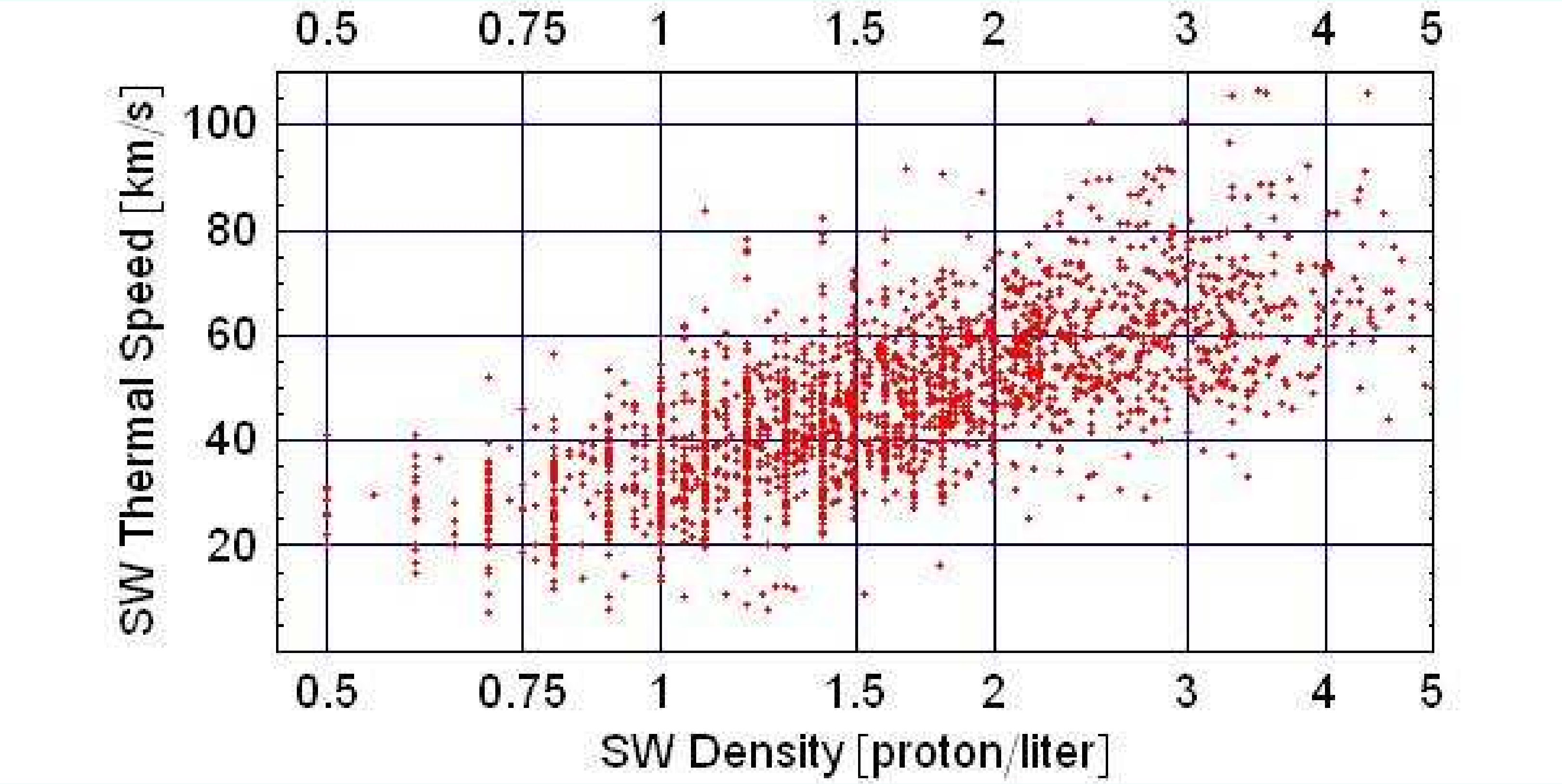
Solar wind hourly speed and density data



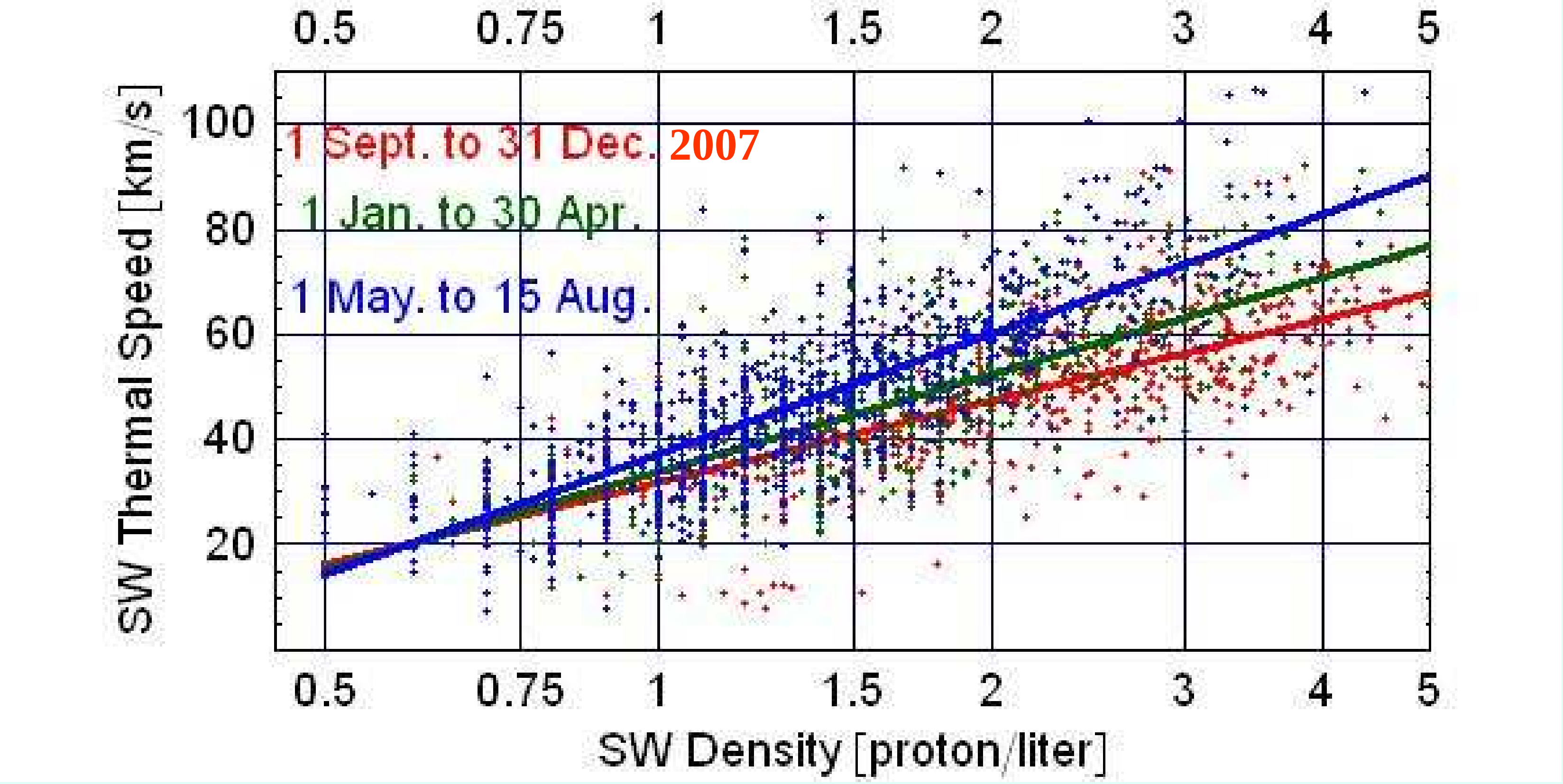
Solar wind hourly thermal speed data



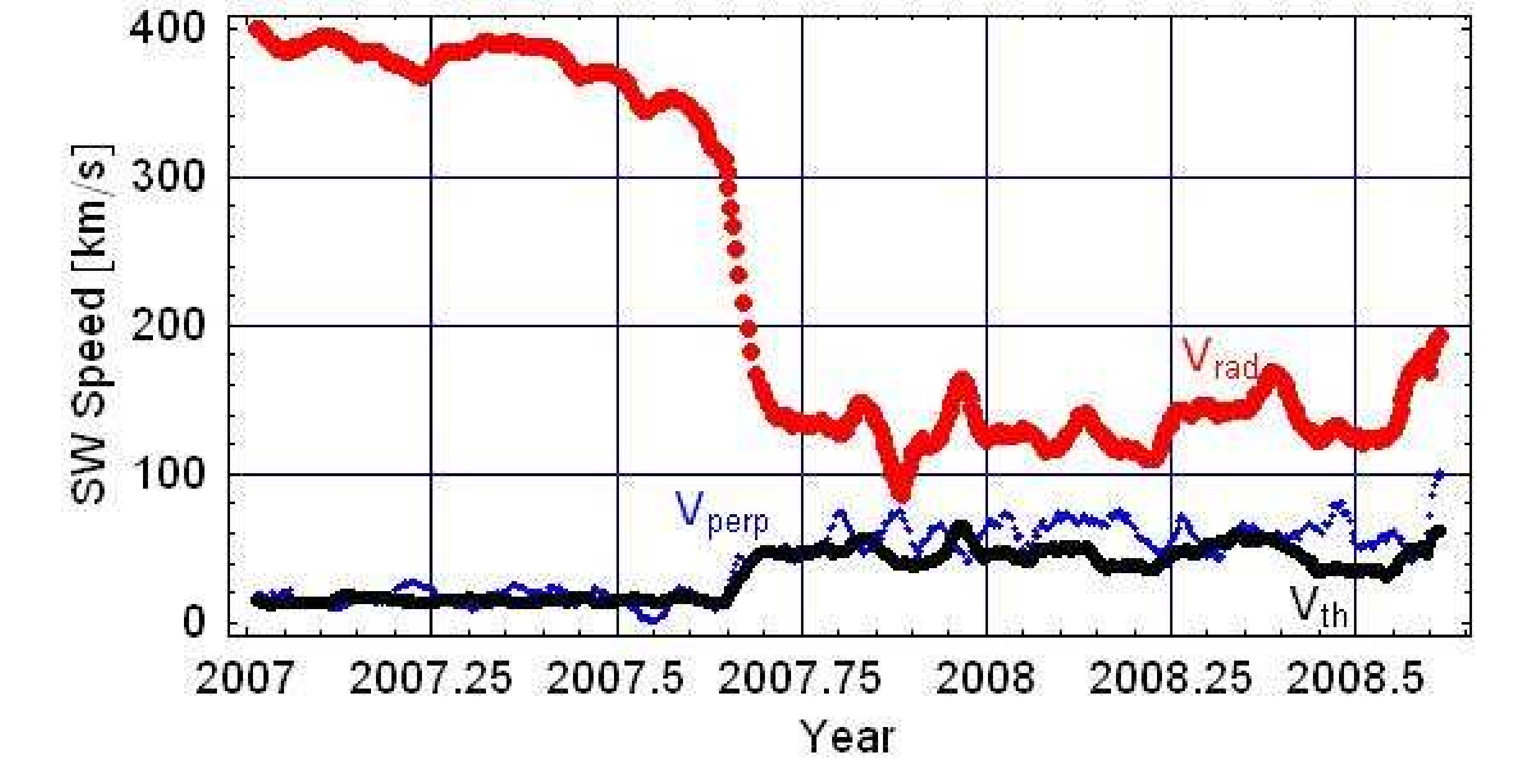
Scatter plot of hourly SW density and thermal speed data for the period subsequent to the shock crossing of V-2



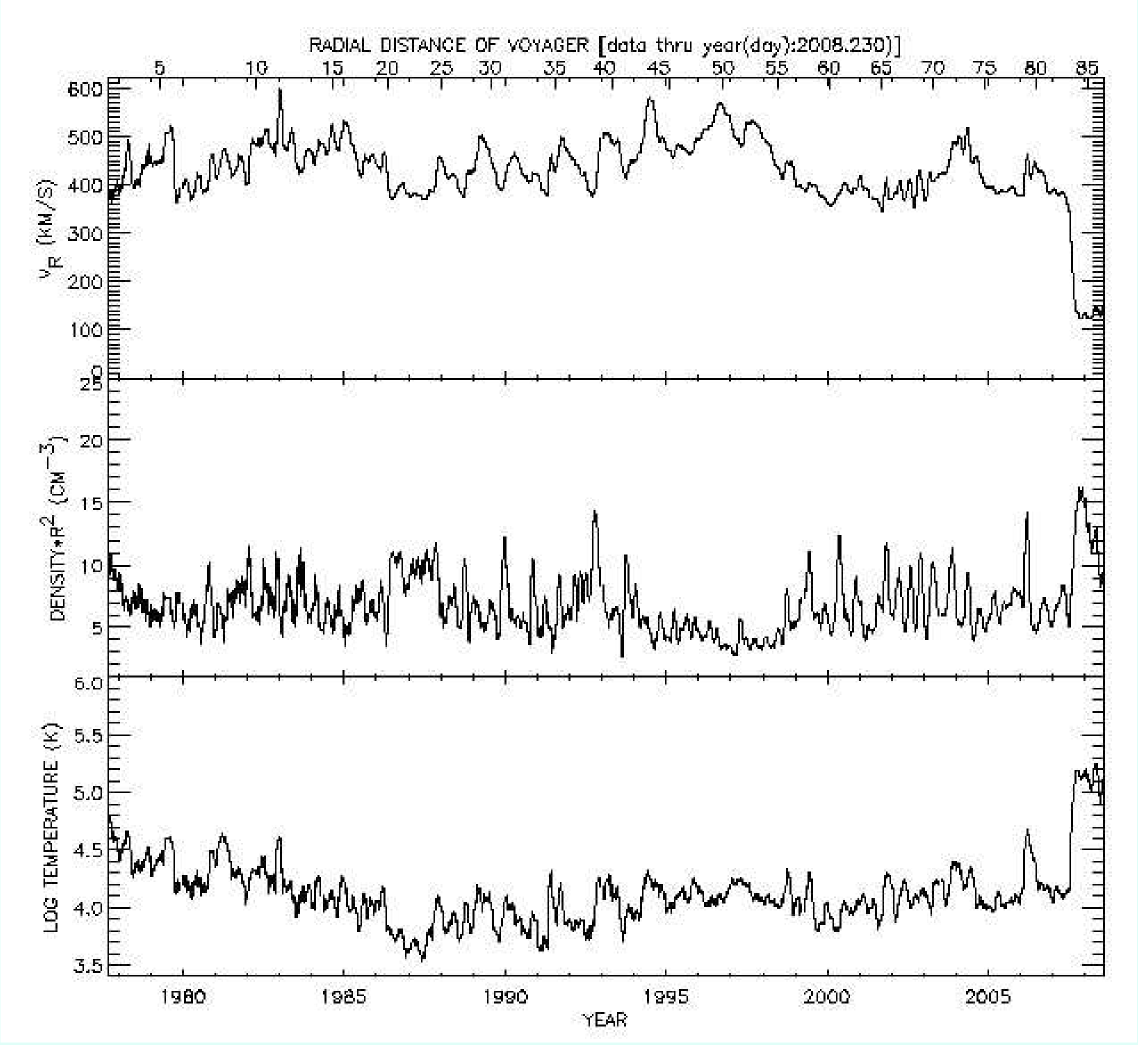
As before, but for three different time periods



Smoothed daily means of SW radial, perpendicular and thermal speed data



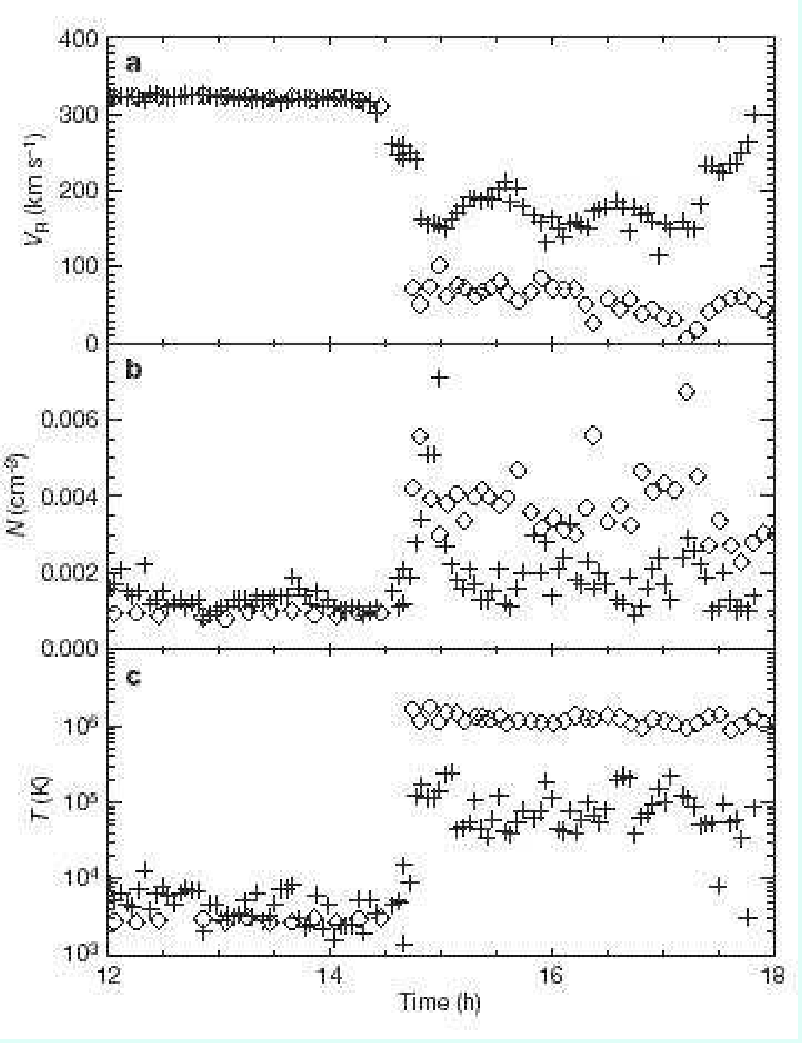
Overview of SW plasma parameters
(John Richardson)



Radial Speed

Density x R^2

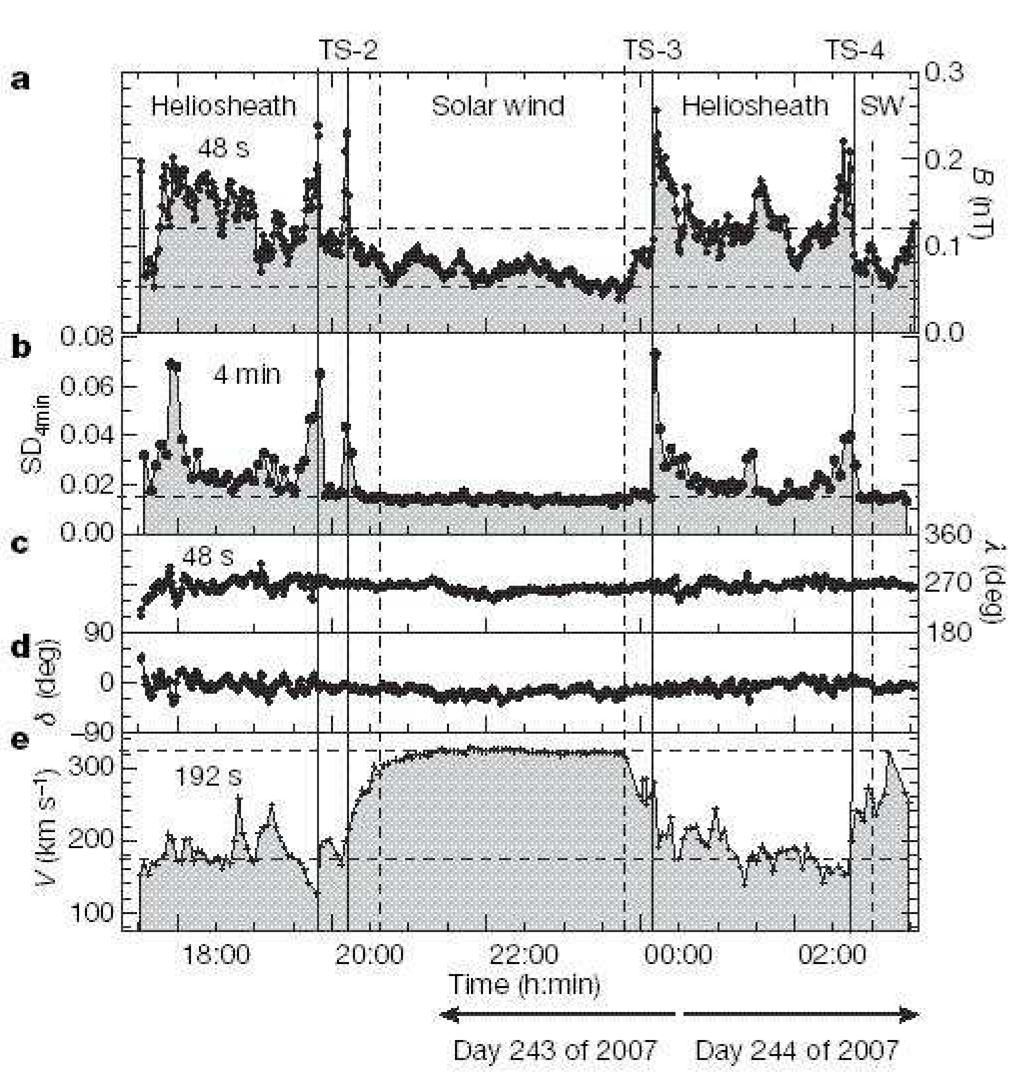
Log Temperature



Upstream to downstream jumps of SW parameters for the Neptune bow shock (crosses) and for the TS (diamonds).

Upstream parameters were normalized to the same values.

(Nature paper, John Richardson et al., as quoted above)

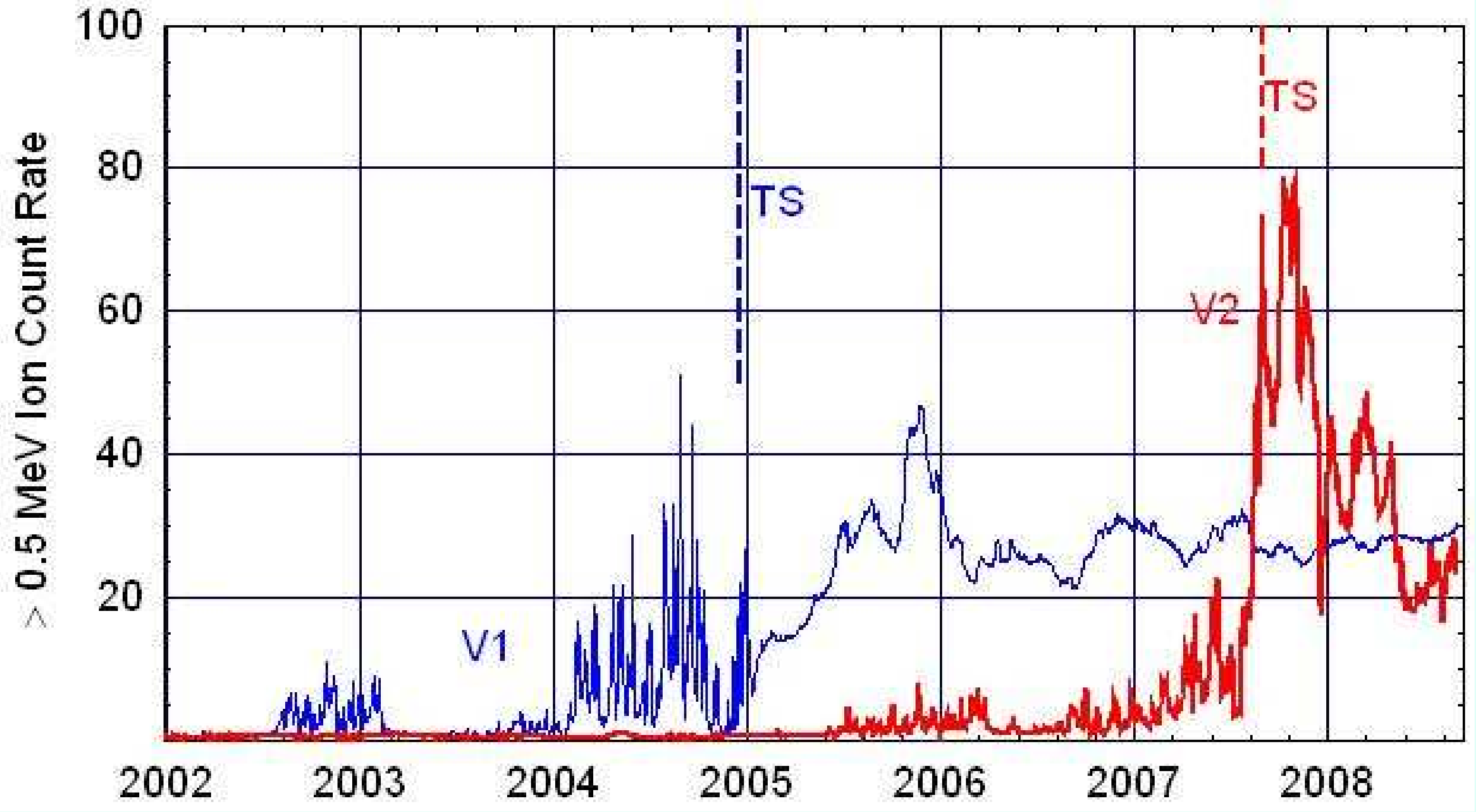


LECP data for 3 of the 5 shock transits presumed by the Voyager teams.

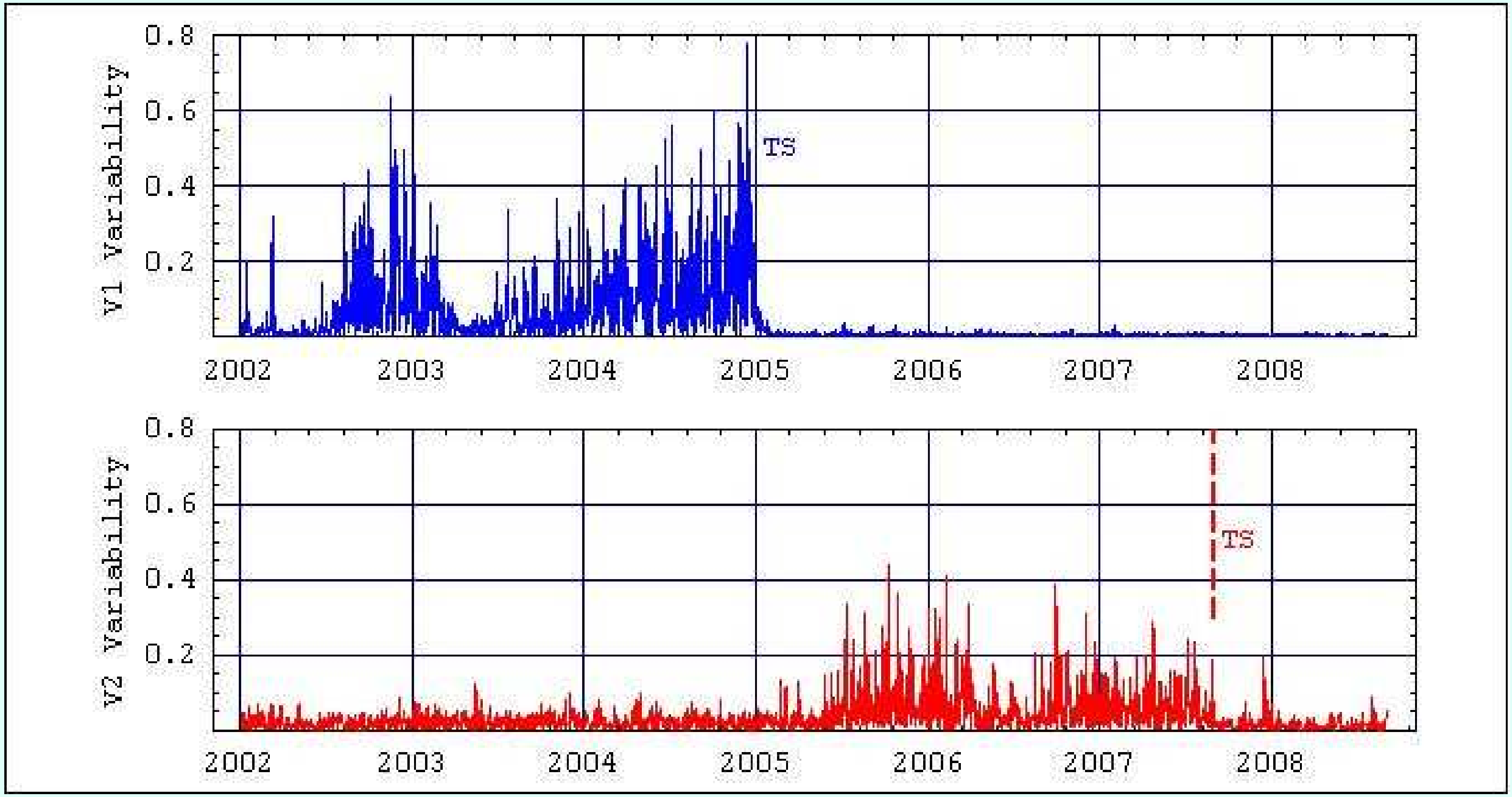
A return to the fast SW for almost 4 hours is clearly seen.

Low and High Energy Ion Count Rates

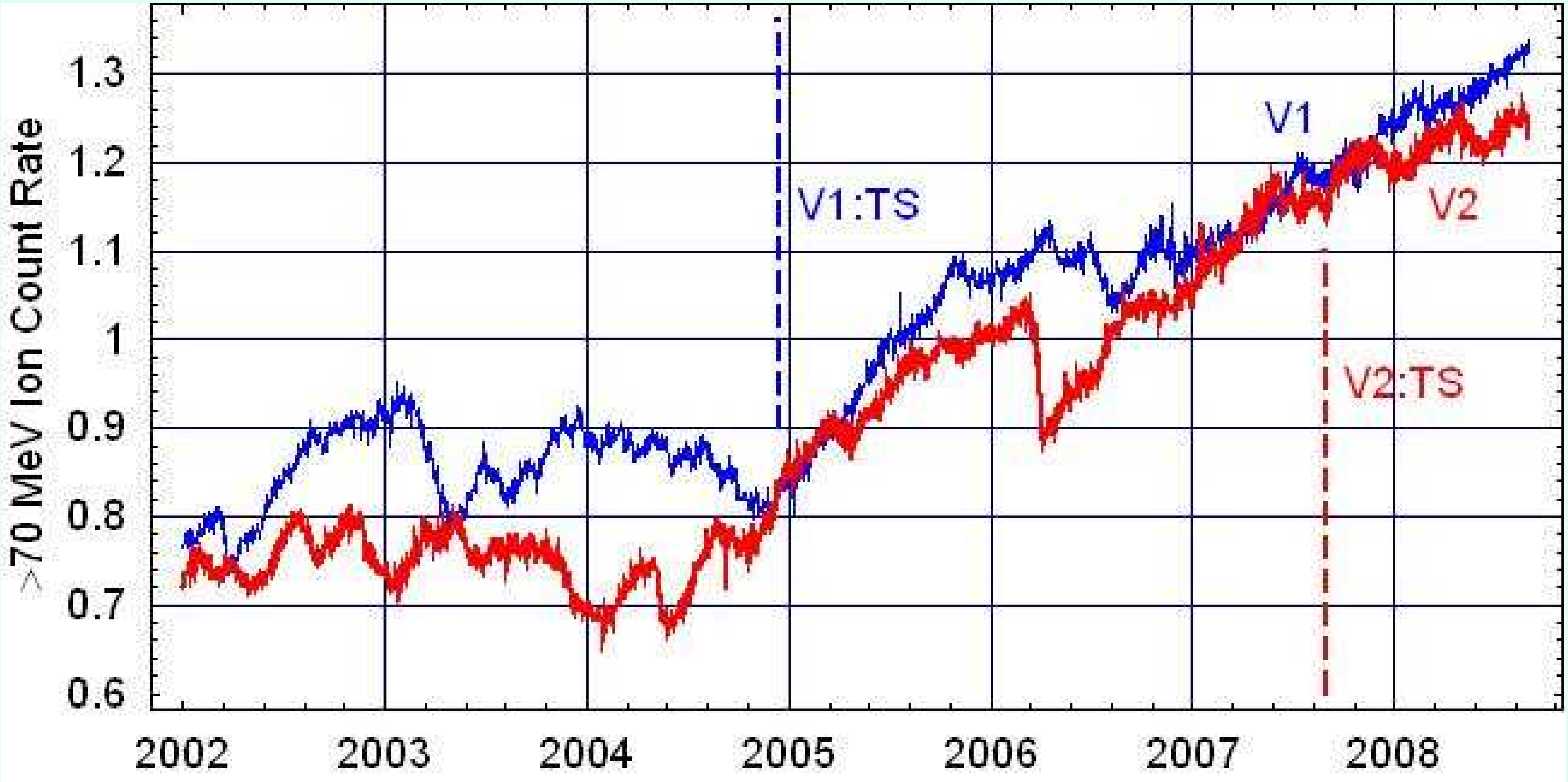
Low-energy ion count rate variation for V-1 and V-2



„Day-to-day variability”, i.e. the absolute value of the Log of the low-energy flux ratio for subsequent days

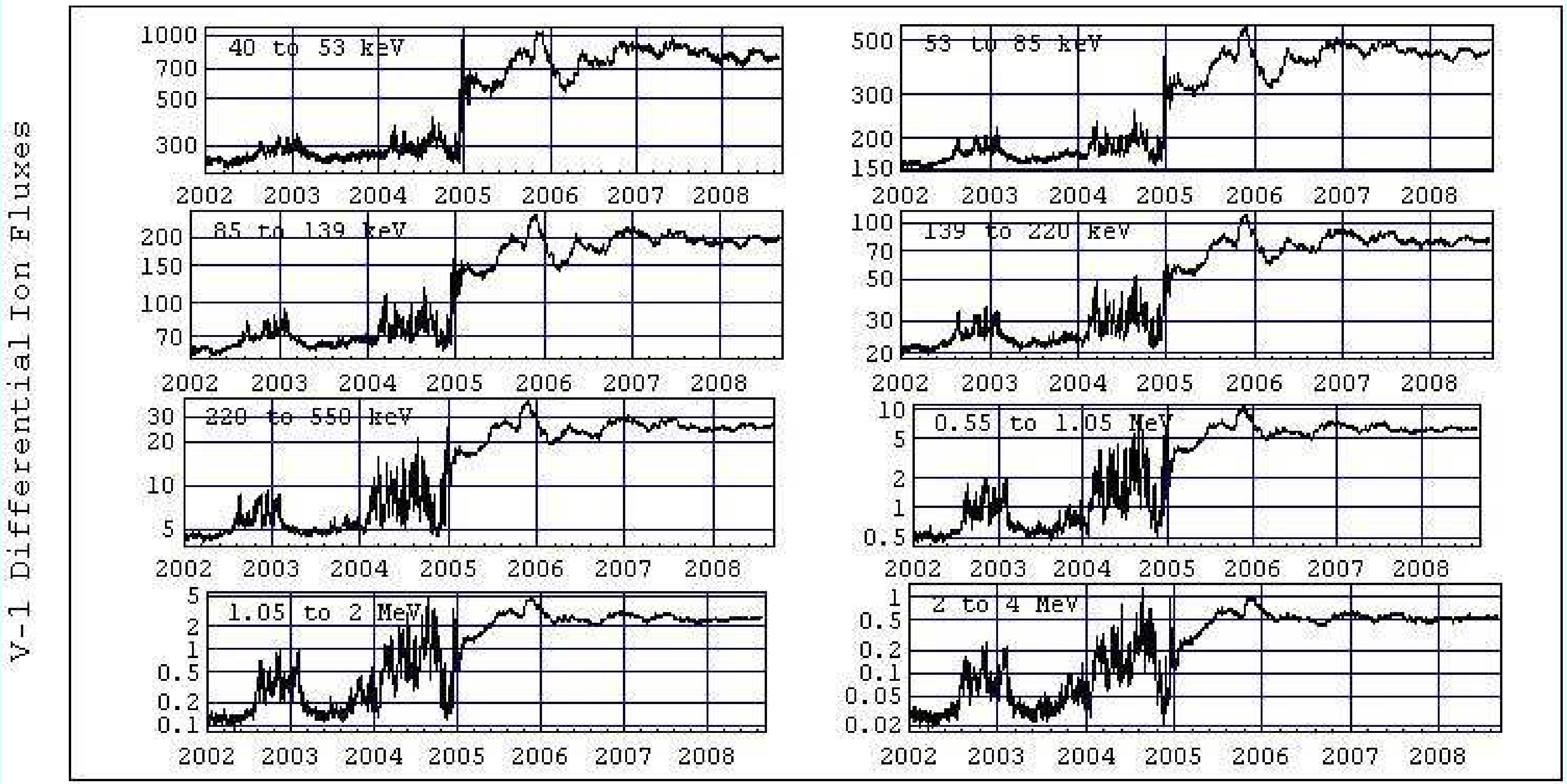


Variation of „cosmic ray" count rates for V-1 and V-2

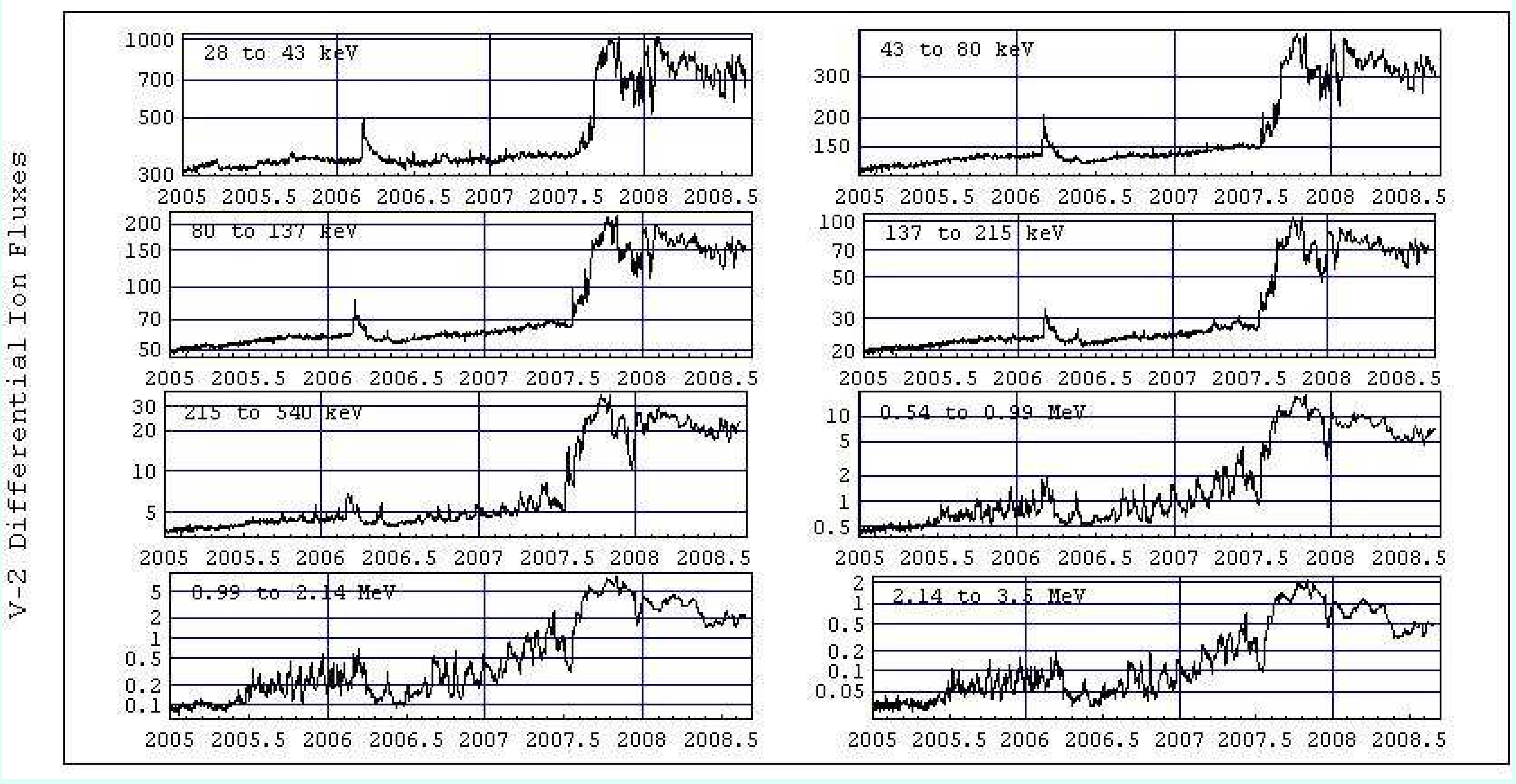


Energetic Particle Fluxes and Directional Distributions

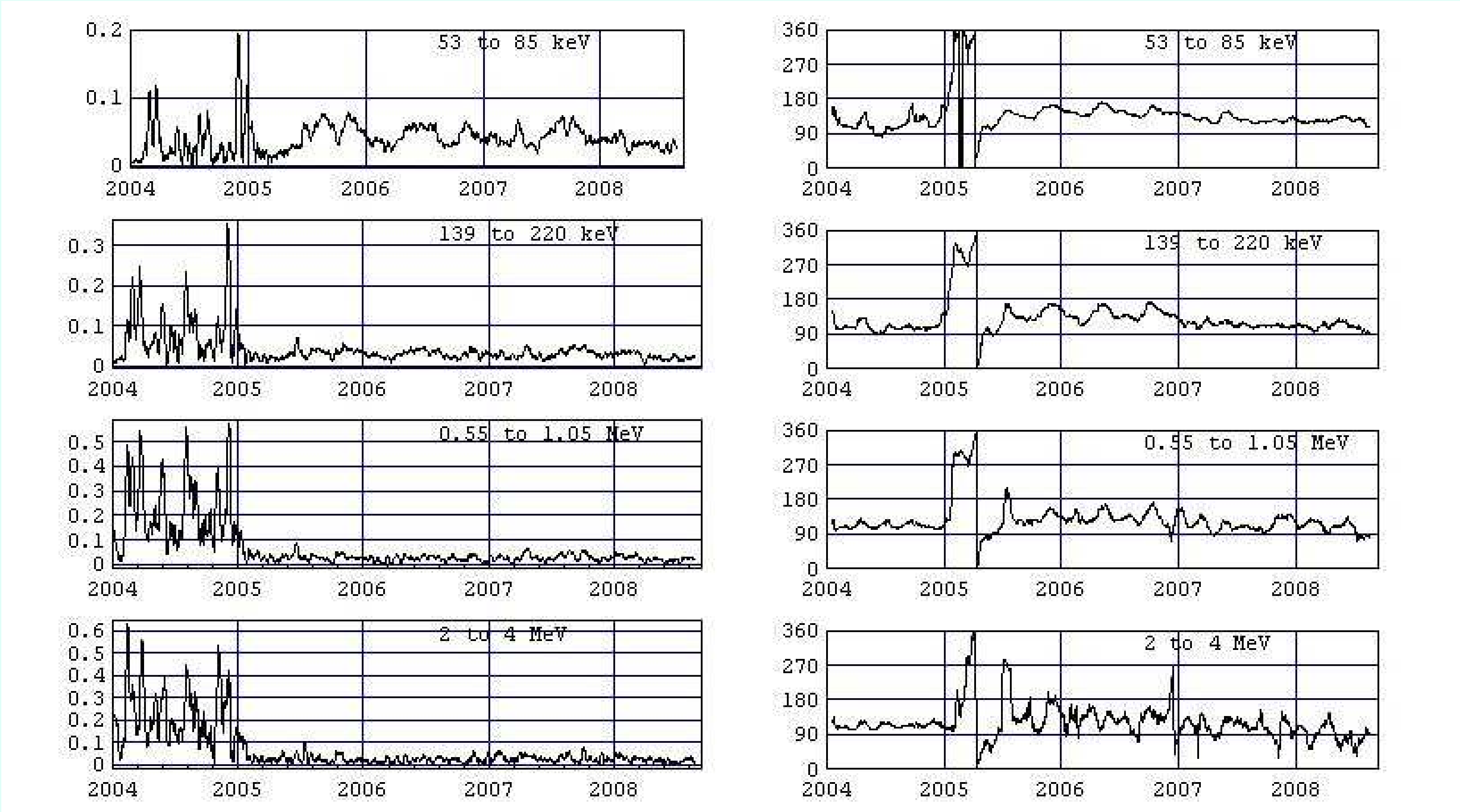
LECP energetic ion flux variation for 8 energies at V-1



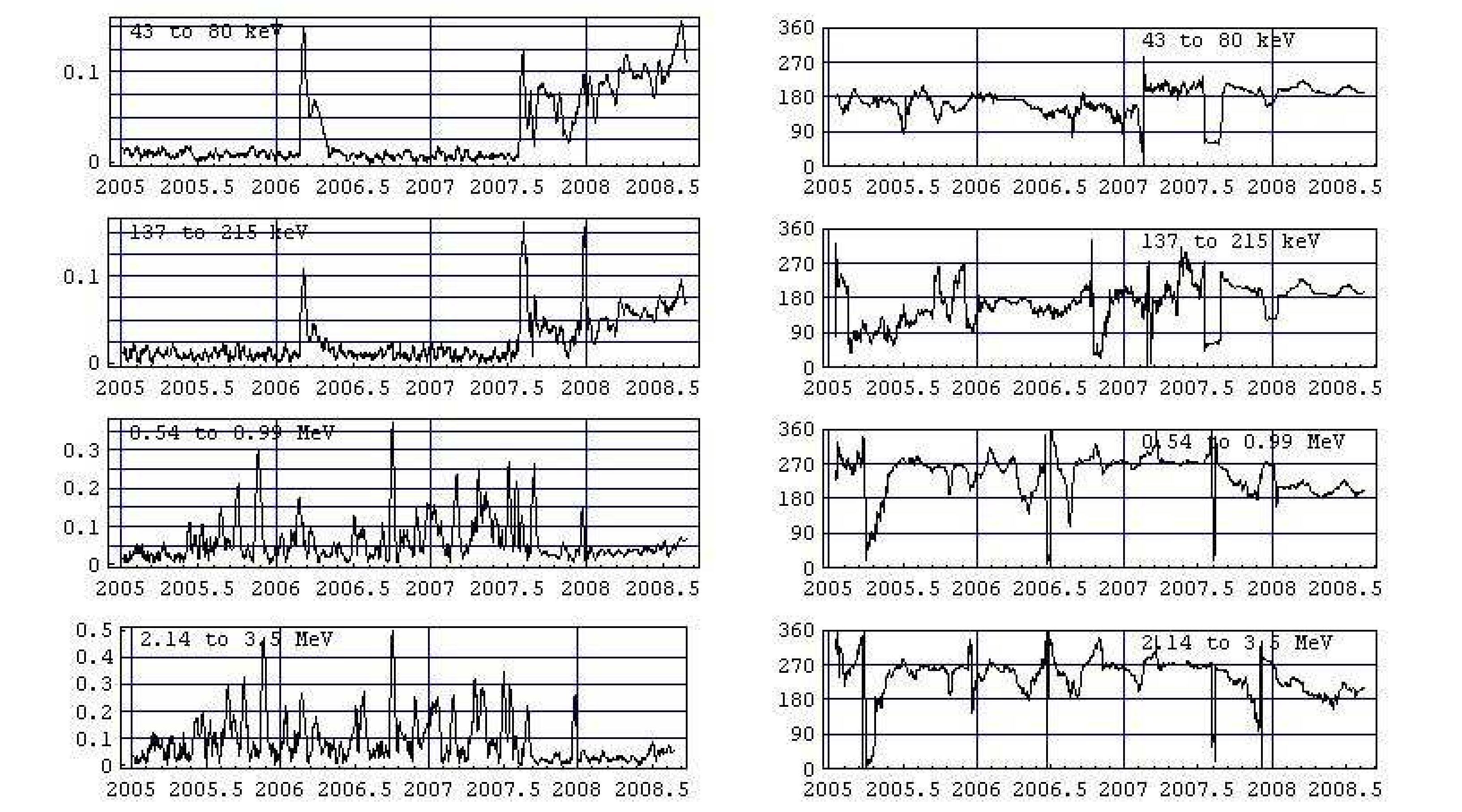
LECP energetic ion flux variation for 8 energies at V-2



Anisotropy amplitudes (left) and directions (right) at V-1



Anisotropy amplitudes (left) and directions (right) at V-2



Conclusions

1. Voyager-2 crossed and re-crossed the termination shock at least 3 times at the end of August 2007. Before crossing, intermittent anisotropic flux increases lasted for more than two years.
2. Changes in some solar wind parameters were rather sudden and differed from expectations. A possibly predominant fraction of the SW kinetic energy appears to have gone into suprathermals, instead of heating.
3. Downstream of the shock, both the energetic particle variability and anisotropy decreased less than for V1. The streaming direction changed from the inward spiral (with some reversal near the shock) towards outward radial.
4. The shock crossing occurred at 84 AU, i.e. 10 AU closer to the Sun than for V-1. That might reflect the effect of galactic magnetic fields.