



Suprathermal Particles in Magnetic Clouds (and elsewhere)

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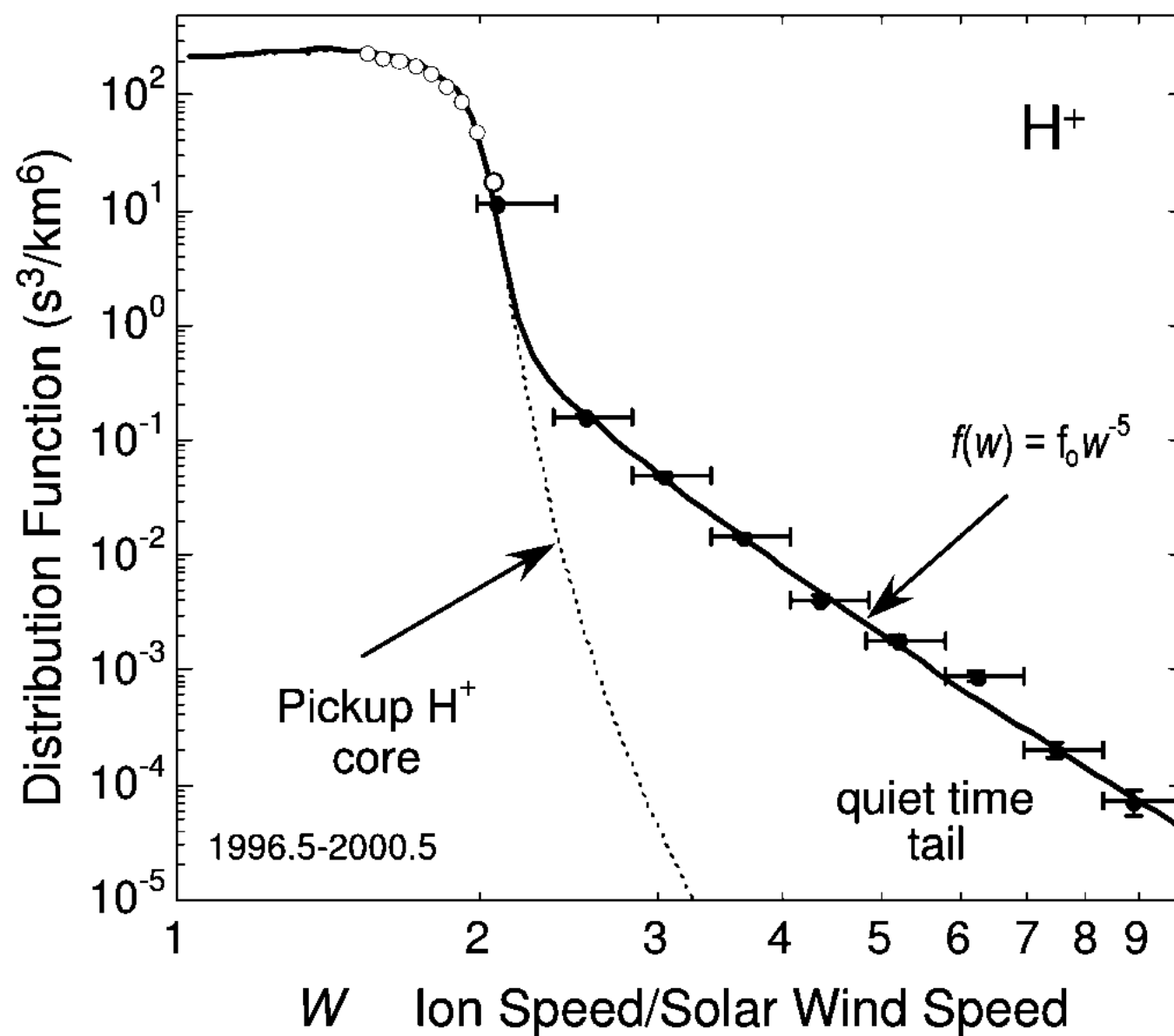
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& Dept. of Physics, Univ. Maryland, College Park, USA



Observations with SWICS on Ulysses and others have

SWICS Ulysses

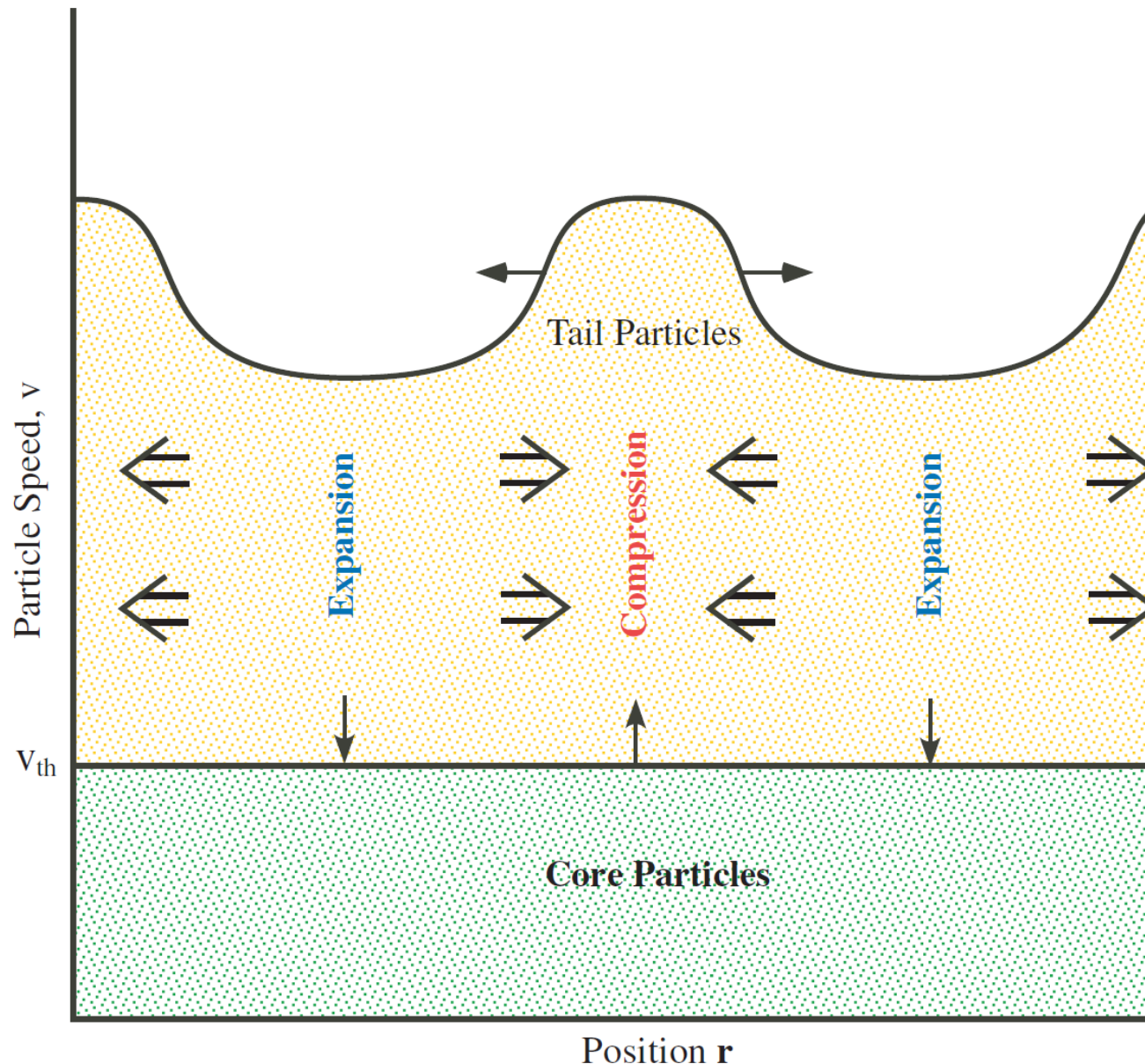
shown that there is a population of suprathermal particles which exhibits a w^{-5} power-law behavior.



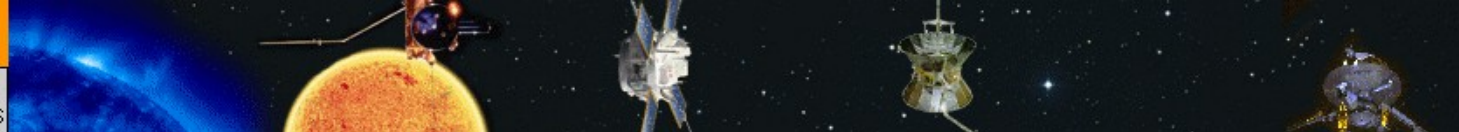
This talk uses ACE/SWICS to further study these particles.



Fisk et al., 2010, explain the formation of these STP tails as a consequence of successions of compressions and expansions. This adiabatic pumping leads to STP tails.

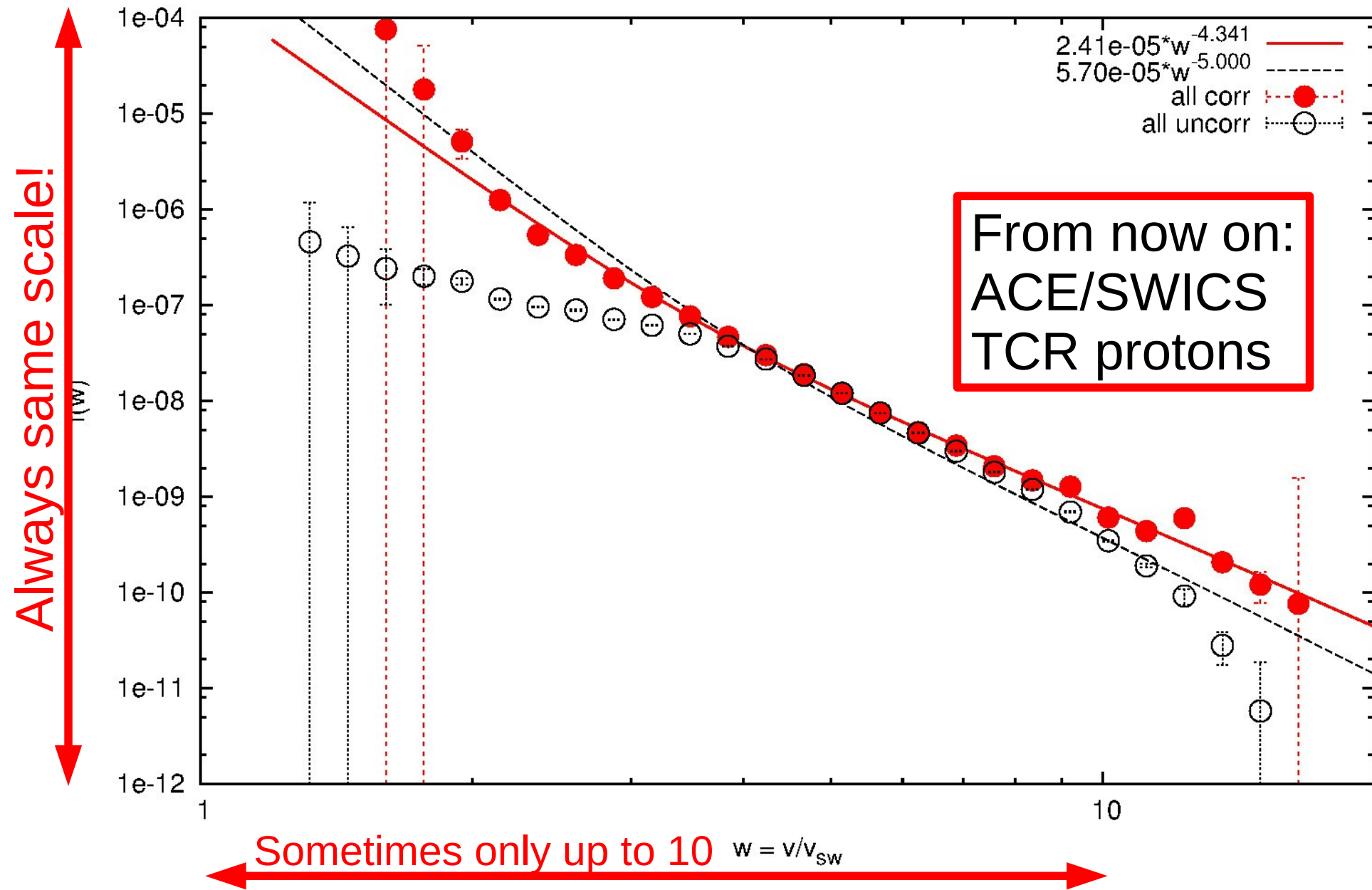


Schwadron et al. (2010) show that also suitable averaging gives such tails. Jokipii&Lee (2010) posit remnant CIR and/or SEP STPs as the source.



Long-term average of suprathermal particles (STPs)

plots/w-spec-20011-2009100-200.eps





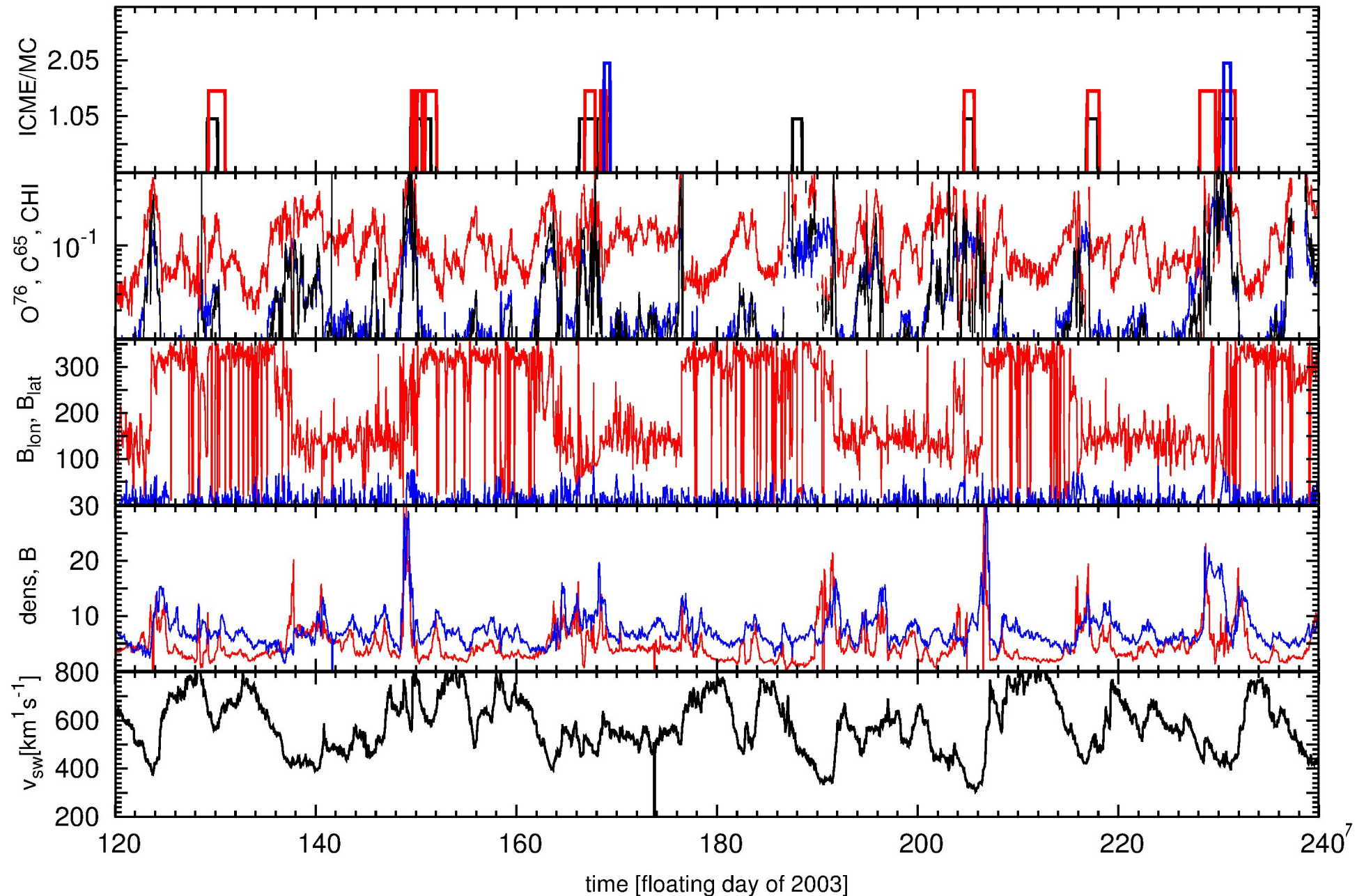
But there's more to life than long-term averages!





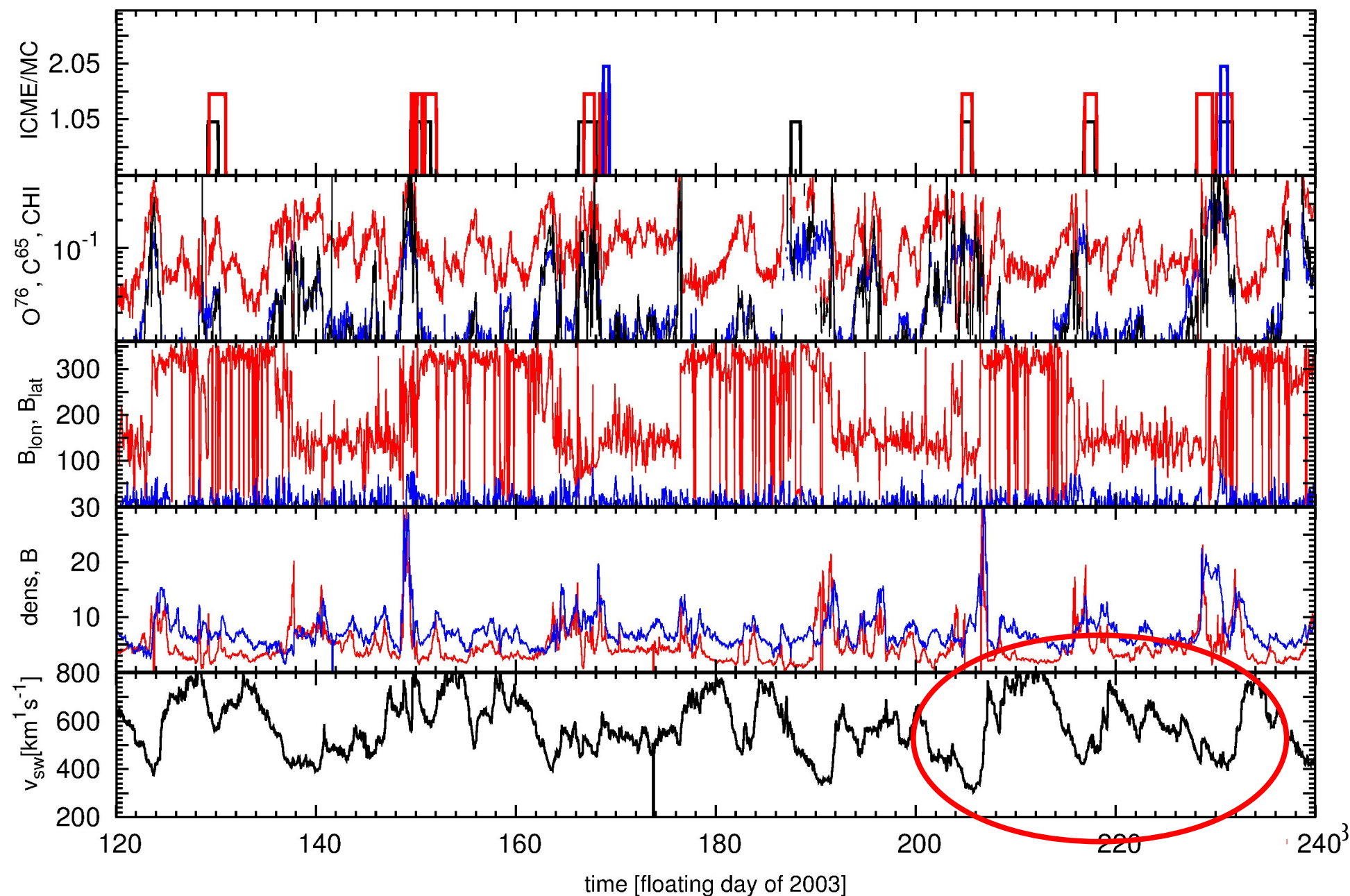


Past solar activity cycle was a good source for STPs



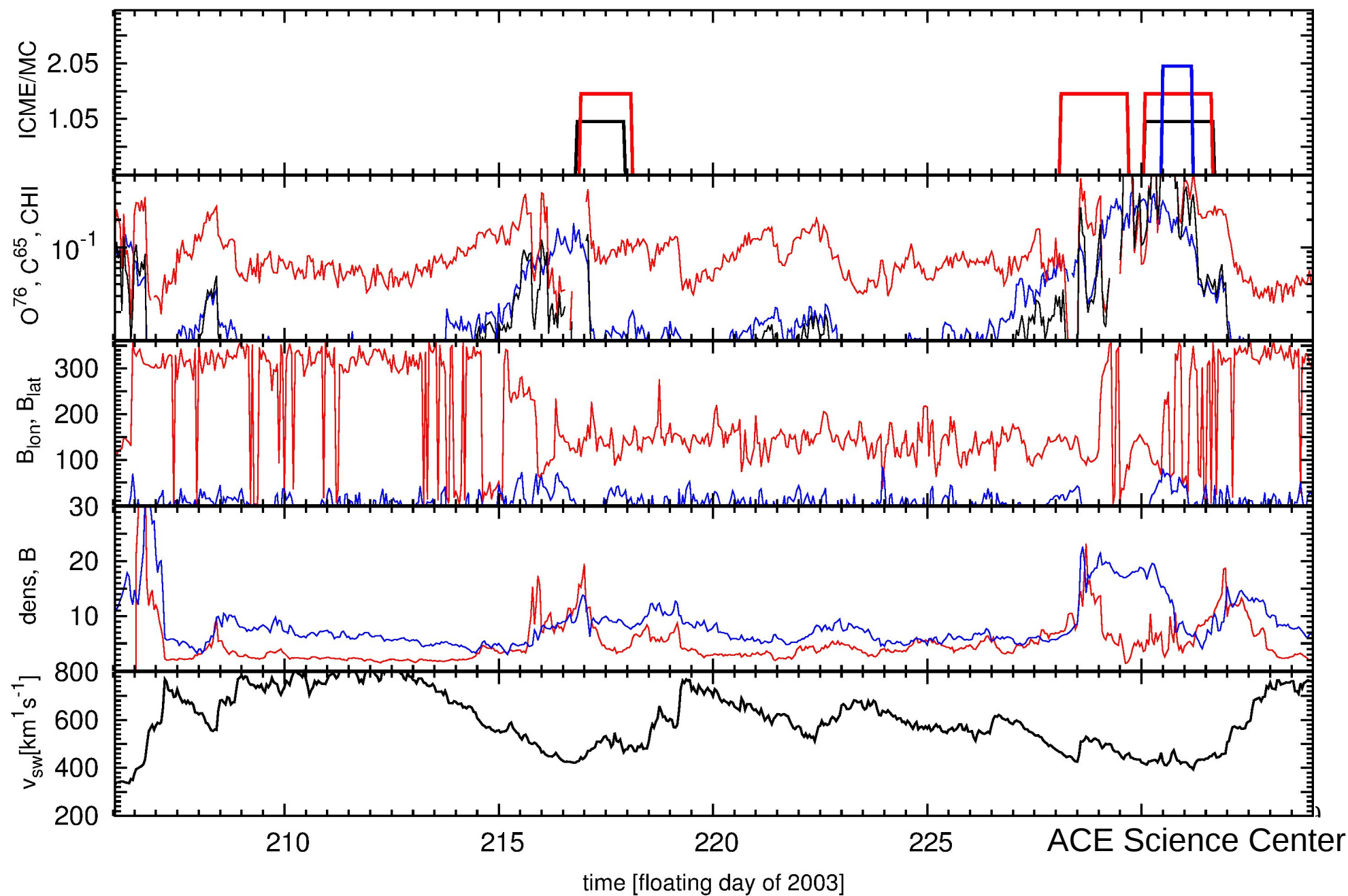


Past solar activity cycle was a good source for STPs





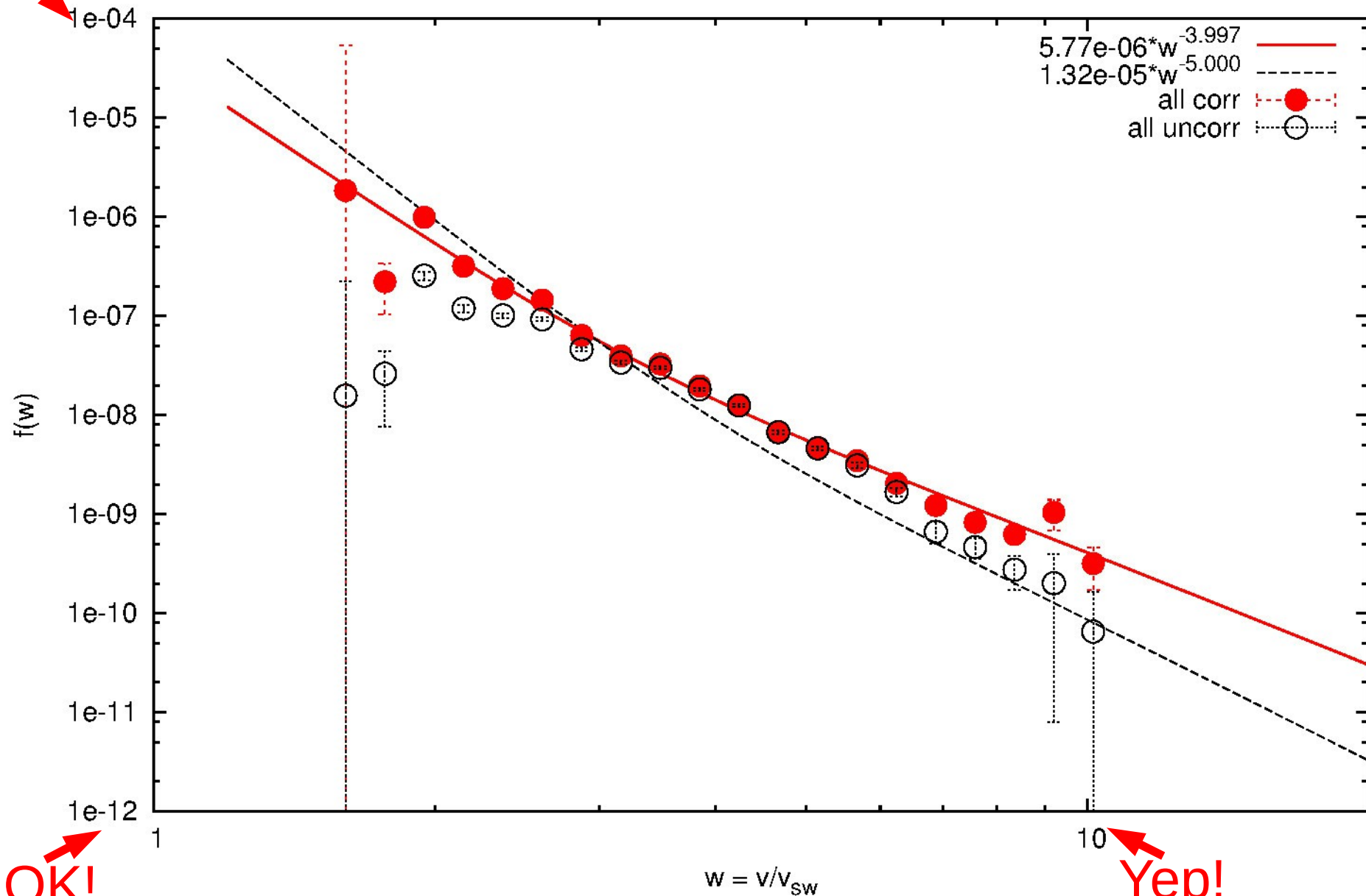
A closer look at shorter-term properties





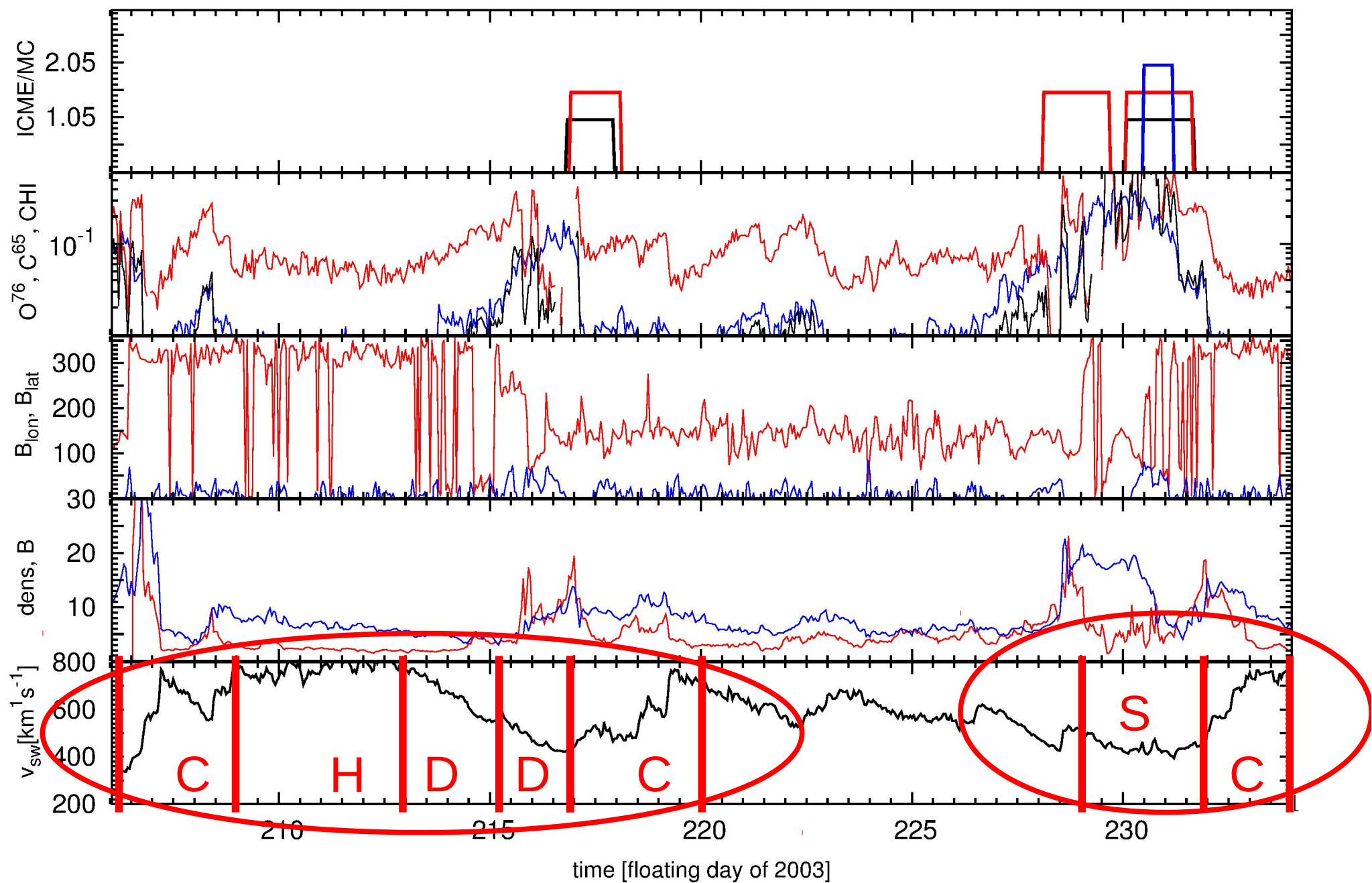
STPs are present, extending to large values in $w = v/v_{\text{bulk}}$

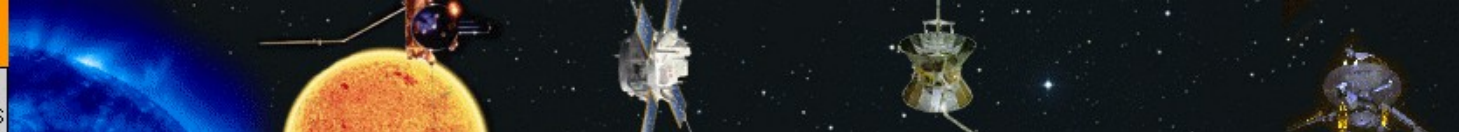
plots/w-spec-003203-2003234-200.eps



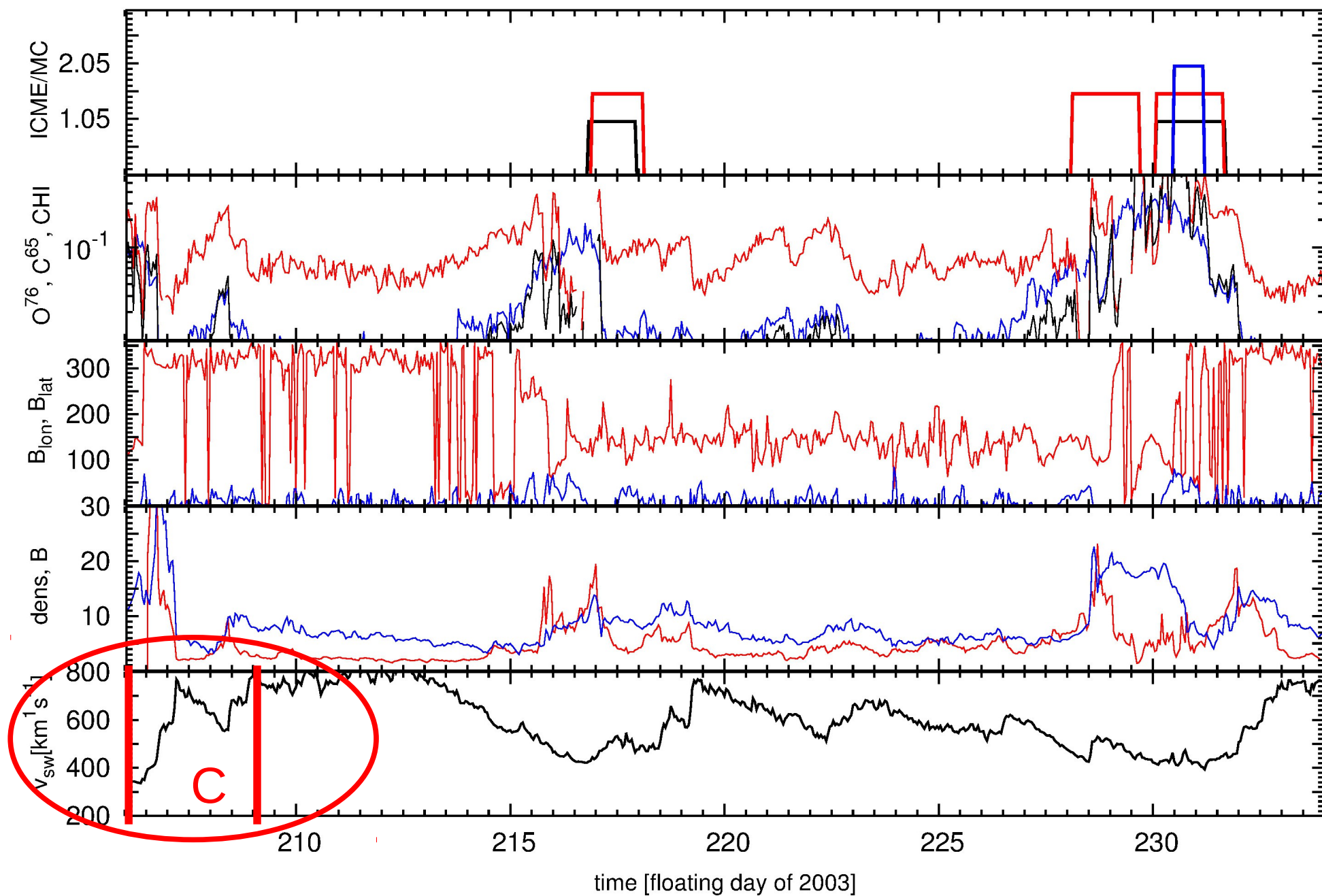


But there's more to the solar wind than 'on the average'





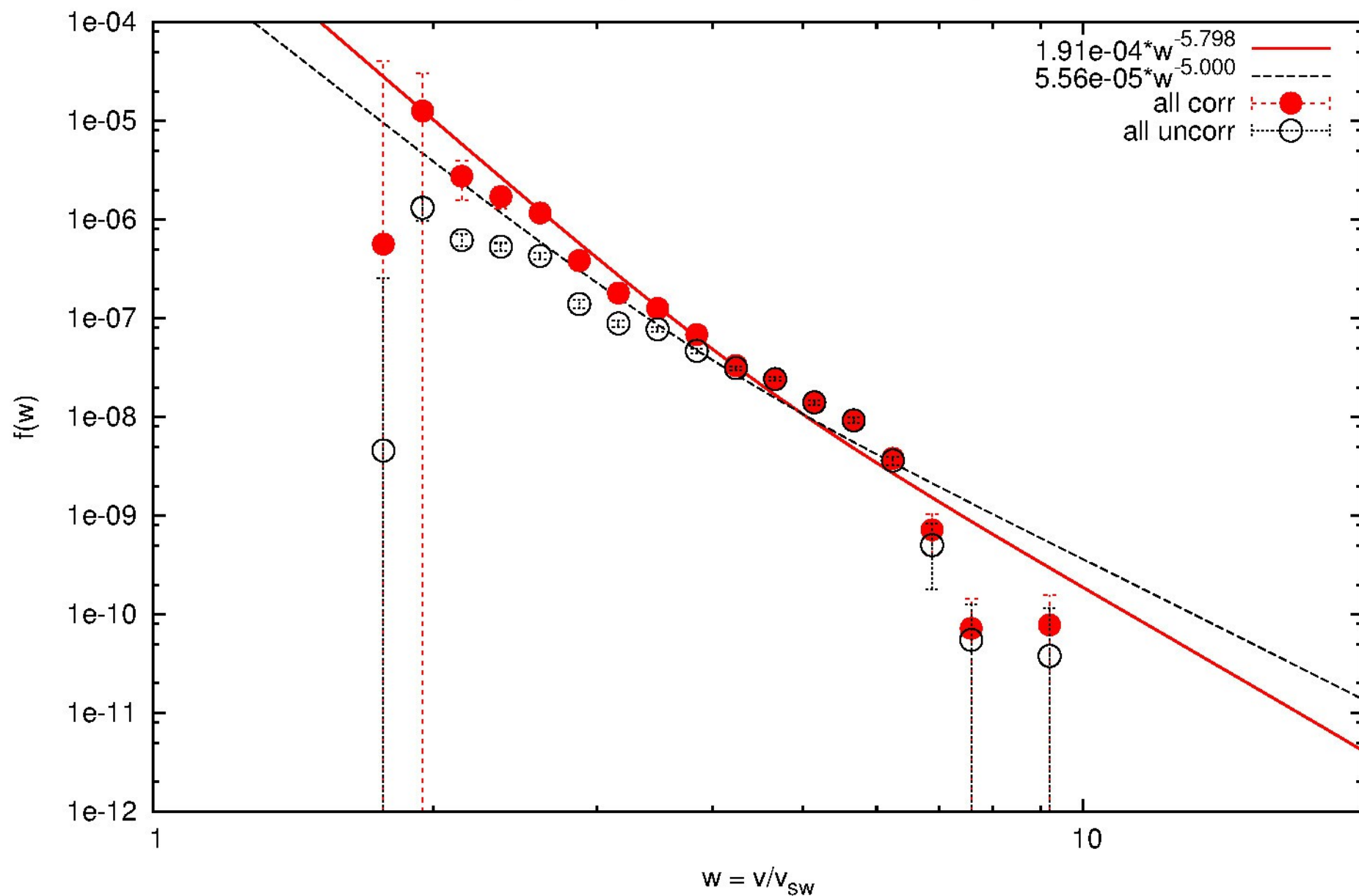
Compression regions should be a source of STPs I

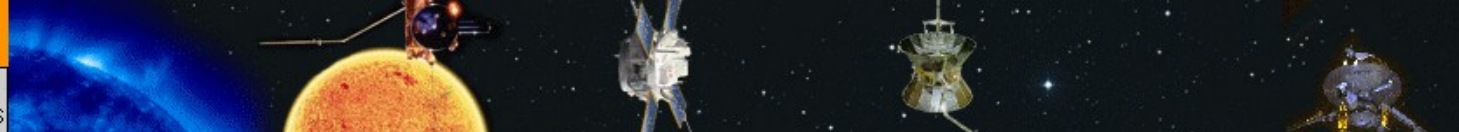




Yes, indeed. Power law with index -5.8 in $w=v/v_{\text{bulk}}$

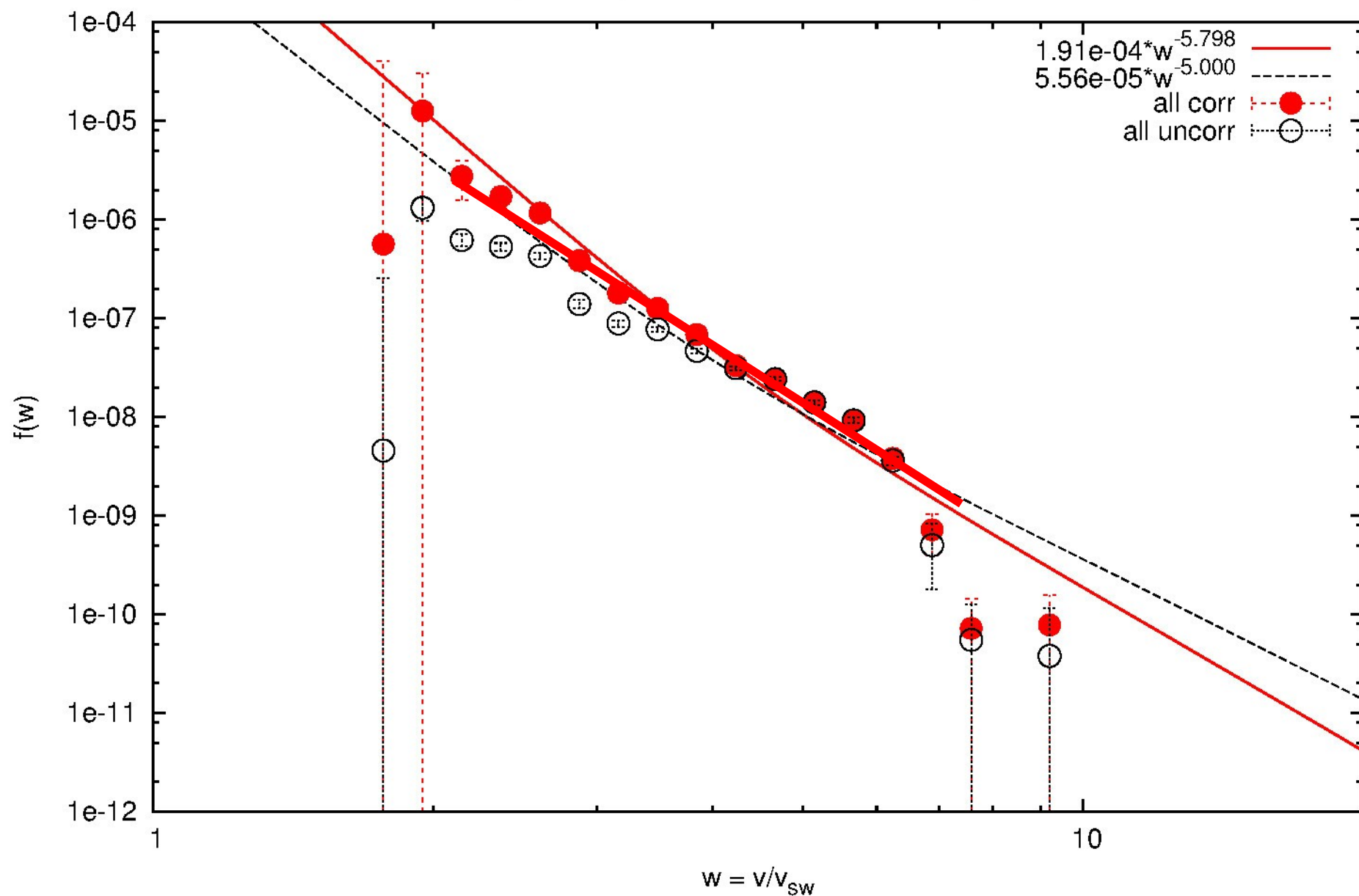
plots/w-spec-2003203-2003209-200.eps





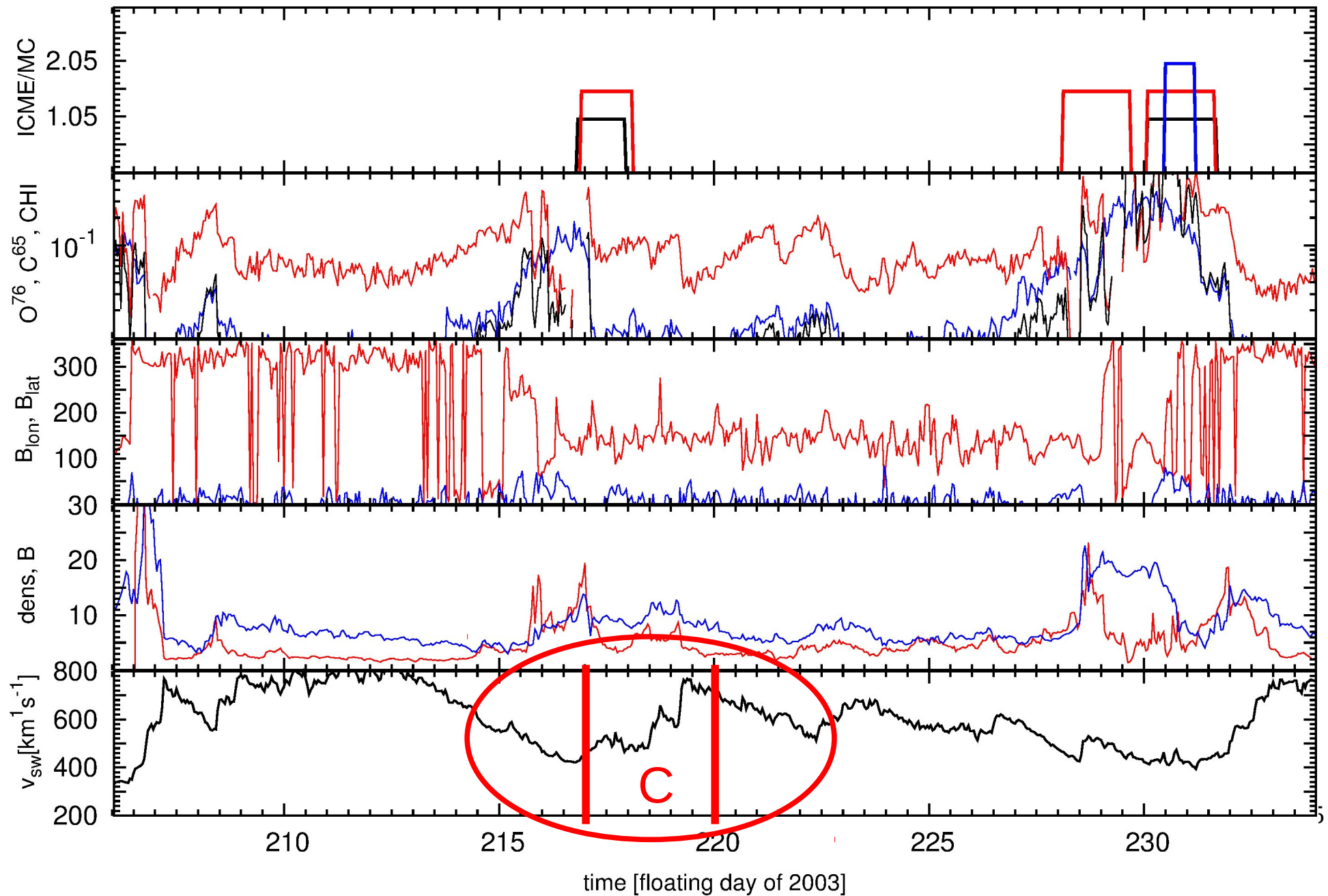
Yes, indeed. Power law index could also be -5

plots/w-spec-2003203-2003209-200.eps





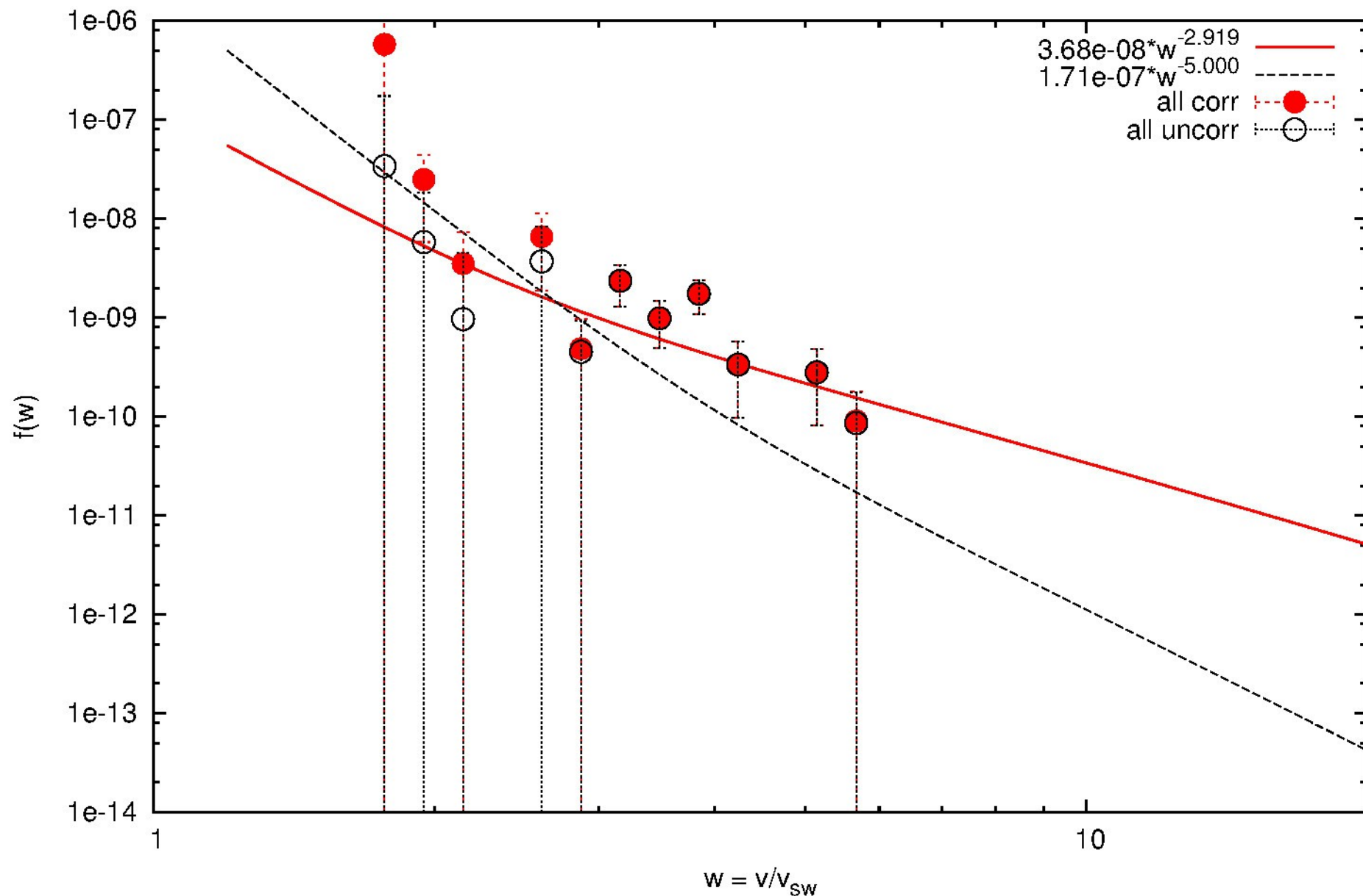
Compression regions should be source of STPs II

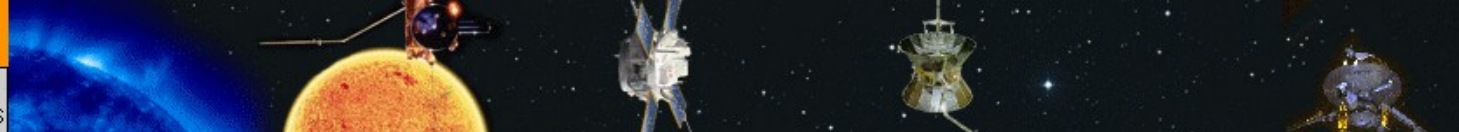




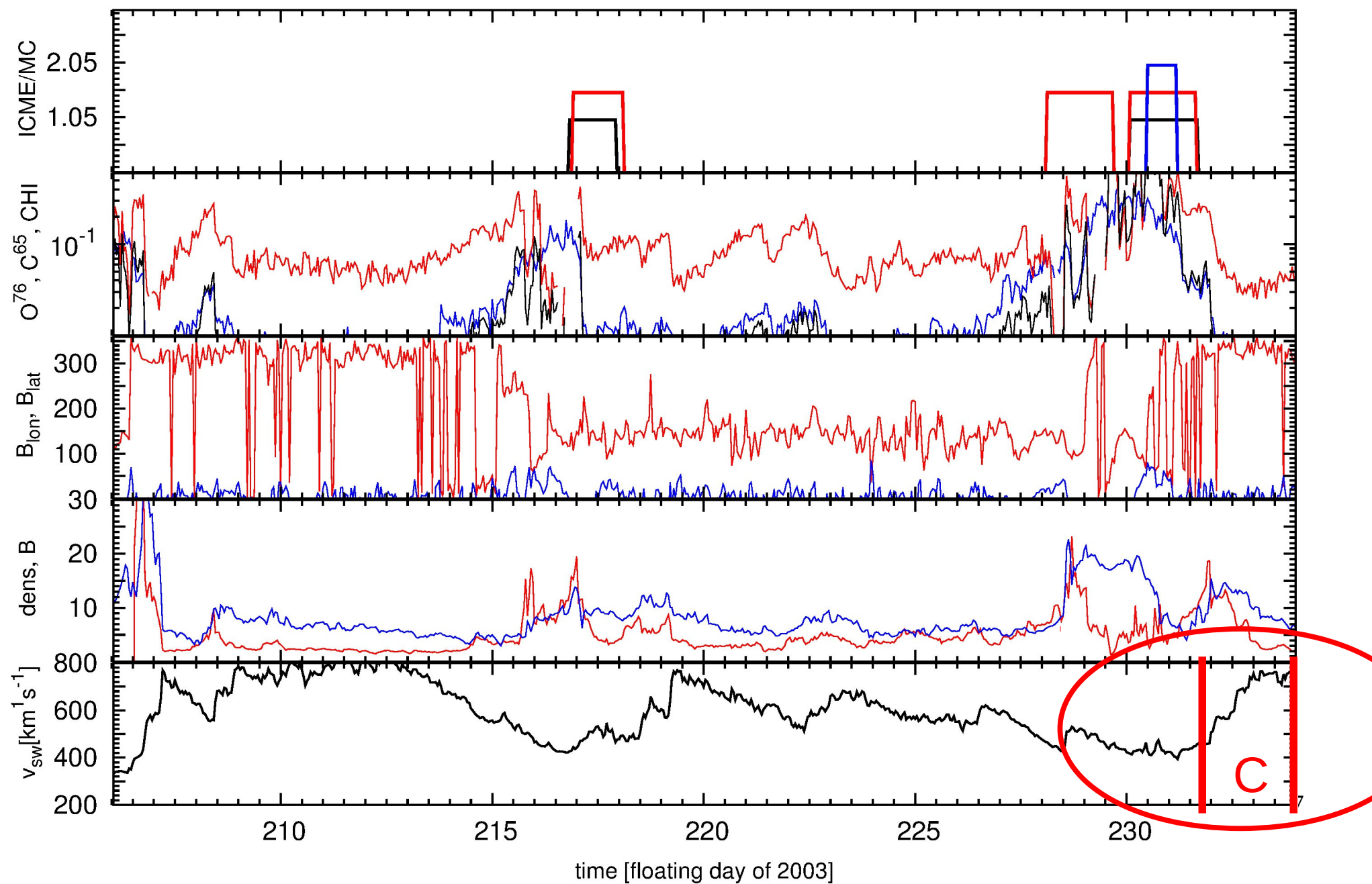
And obviously, they are. Hard spectrum!

plots/w-spec-2003217-2003220-200.eps





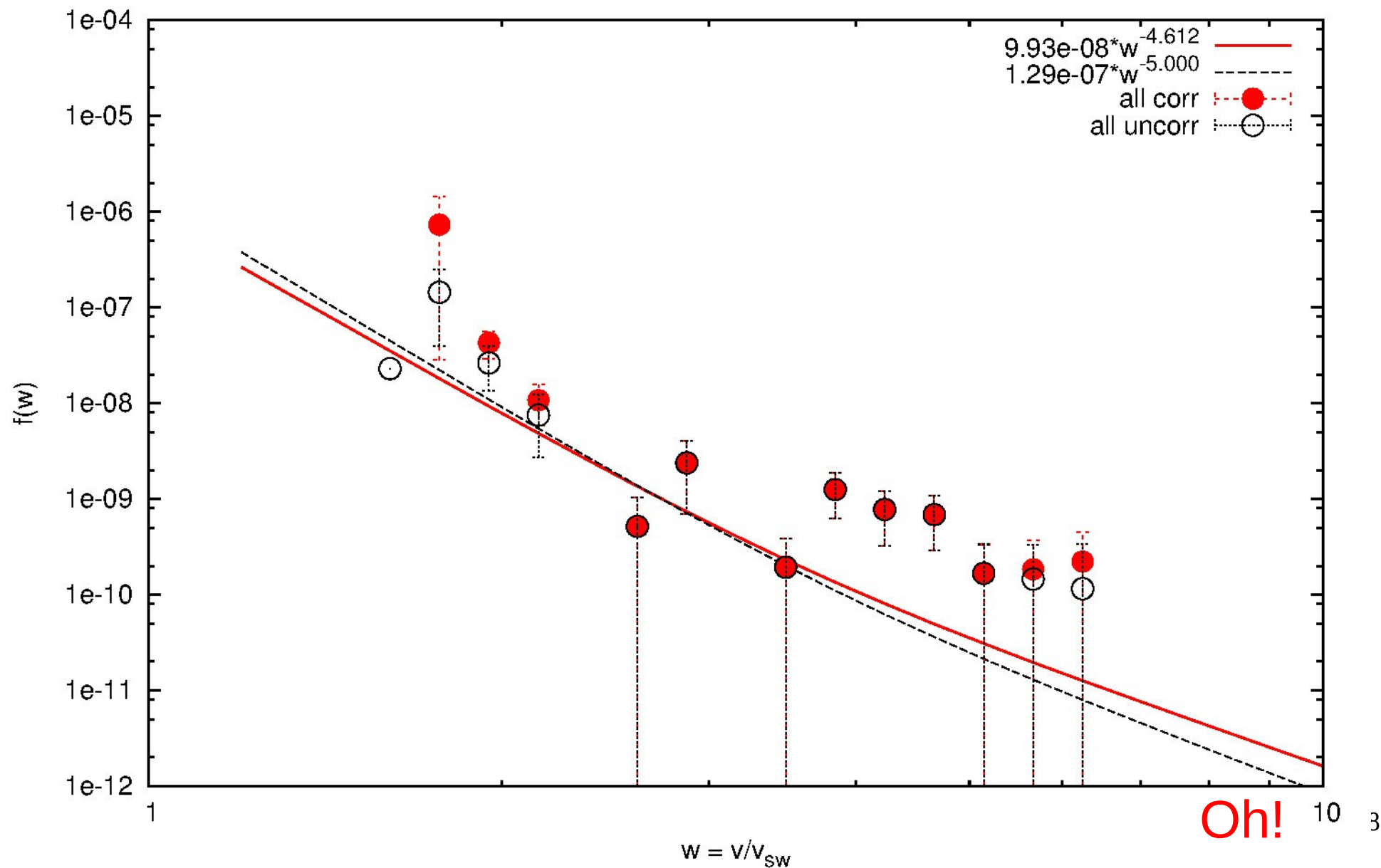
Compression regions should be source of STPs III





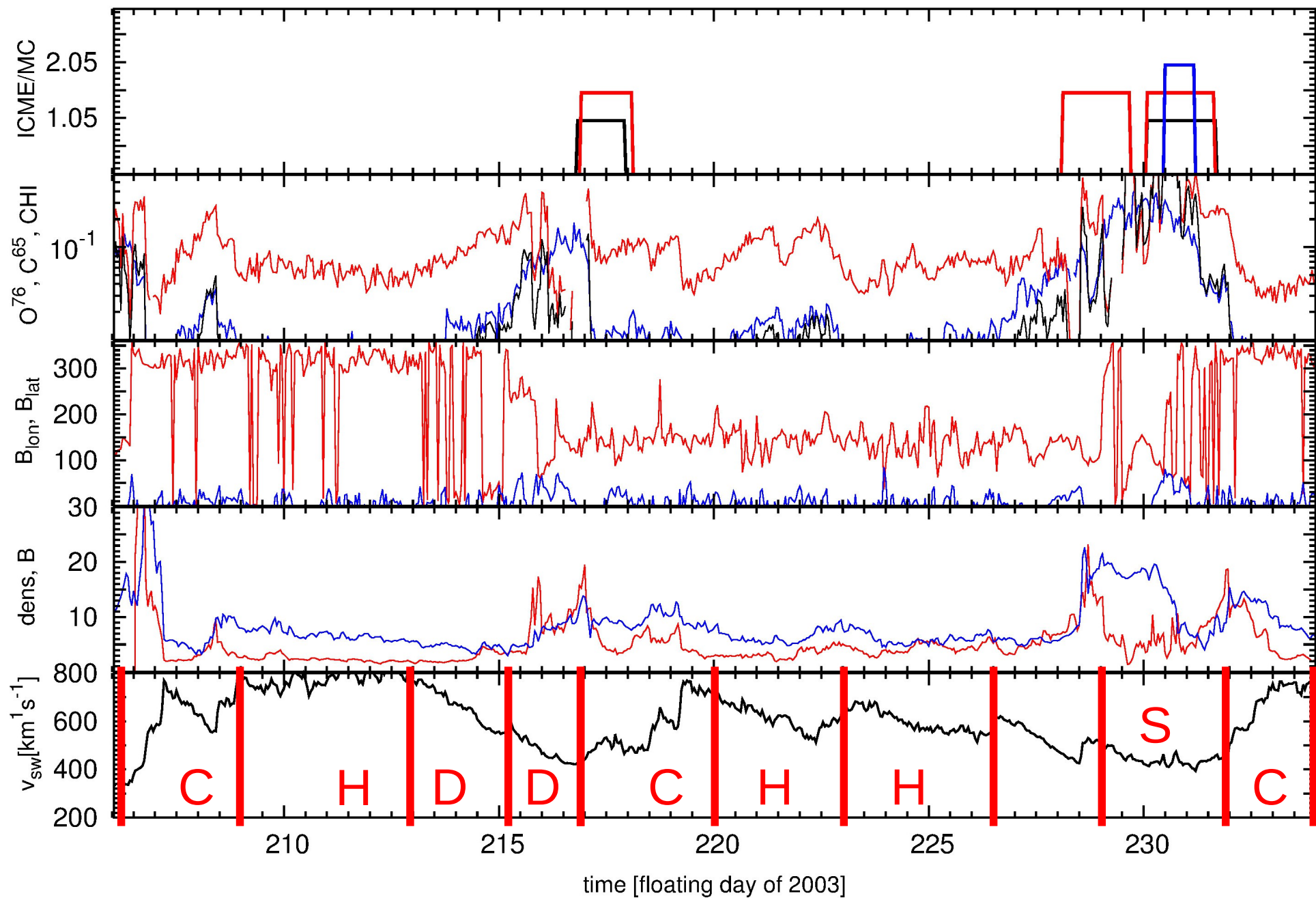
Again power law, index ~ -5 (-4.6 , but not very good fit)

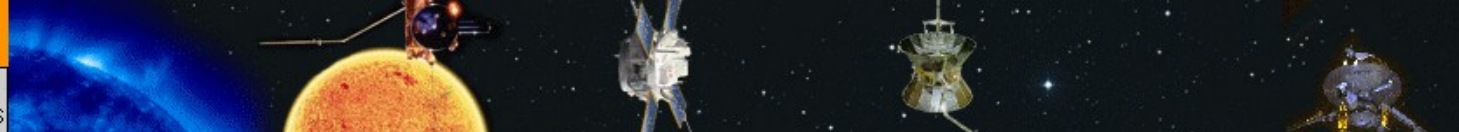
plots/w-spec-2003232-2003234-200.eps



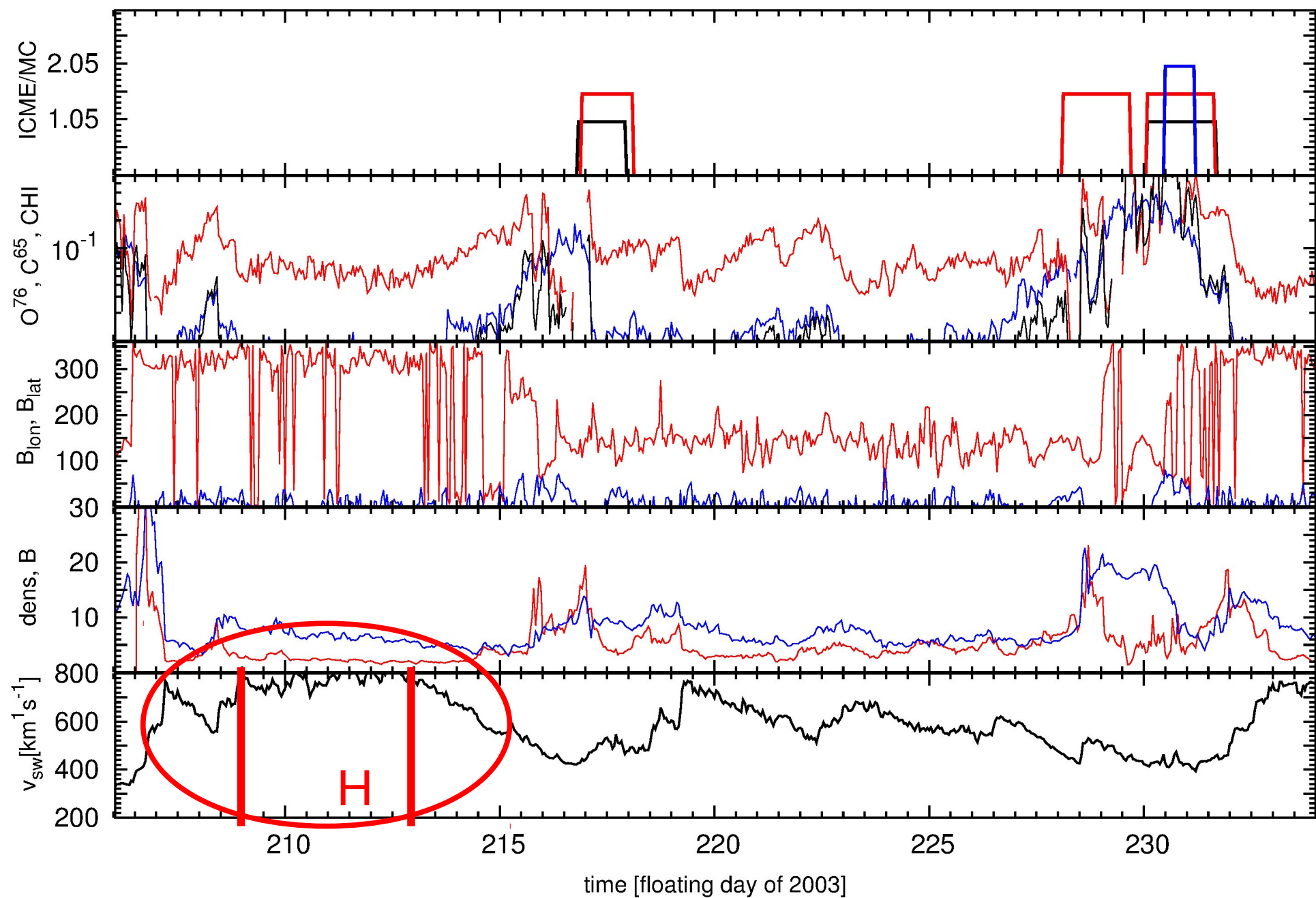


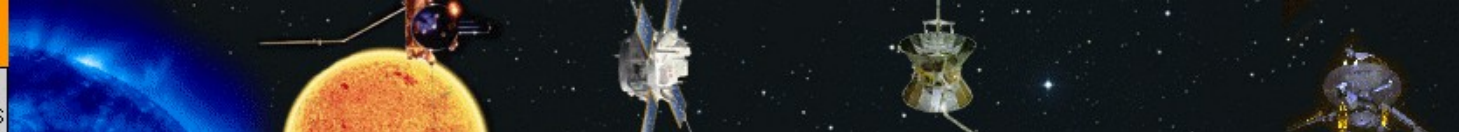
But there's more to the solar wind than compression!





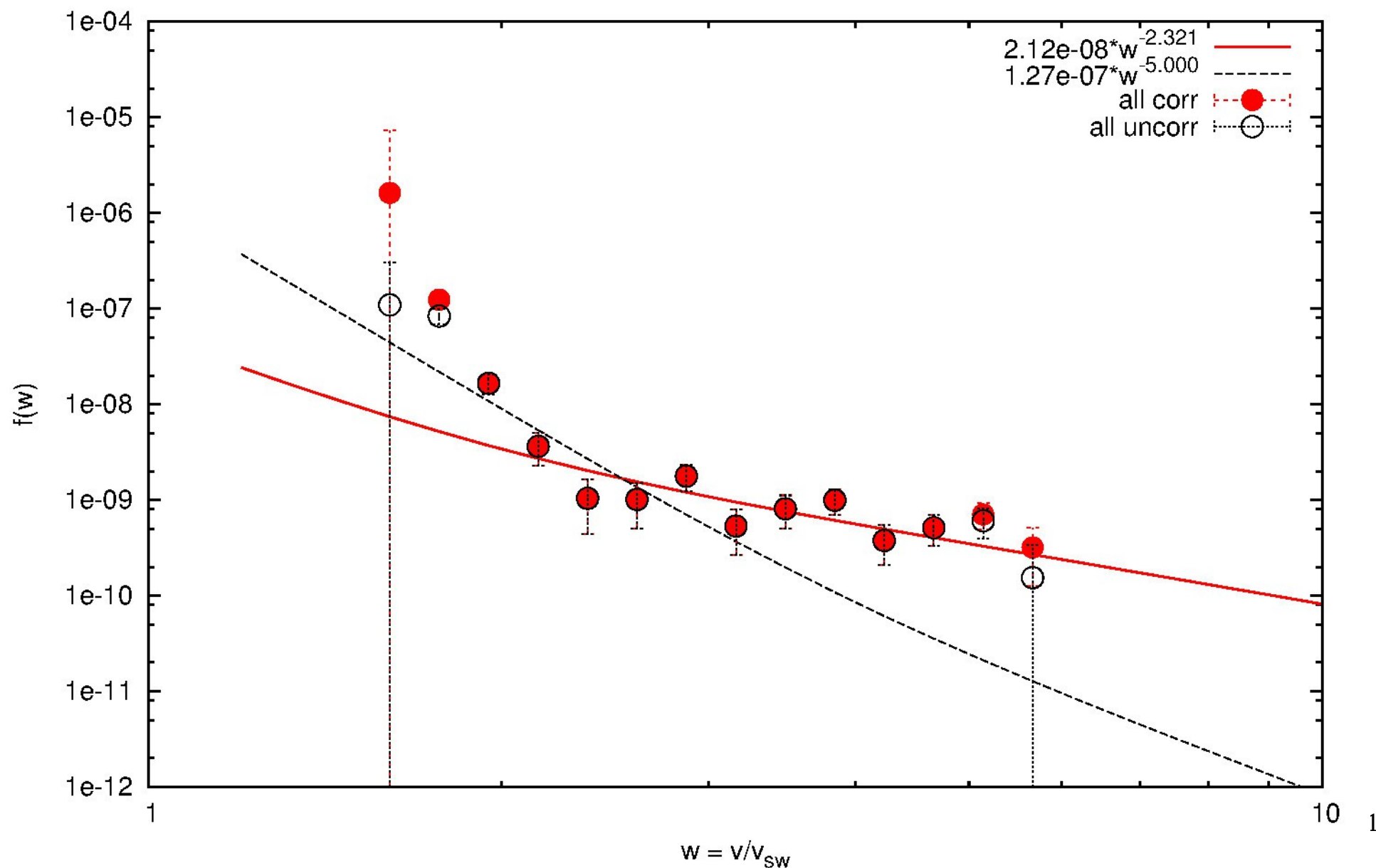
Try pure coronal hole flow, long-lasting high-speed stream





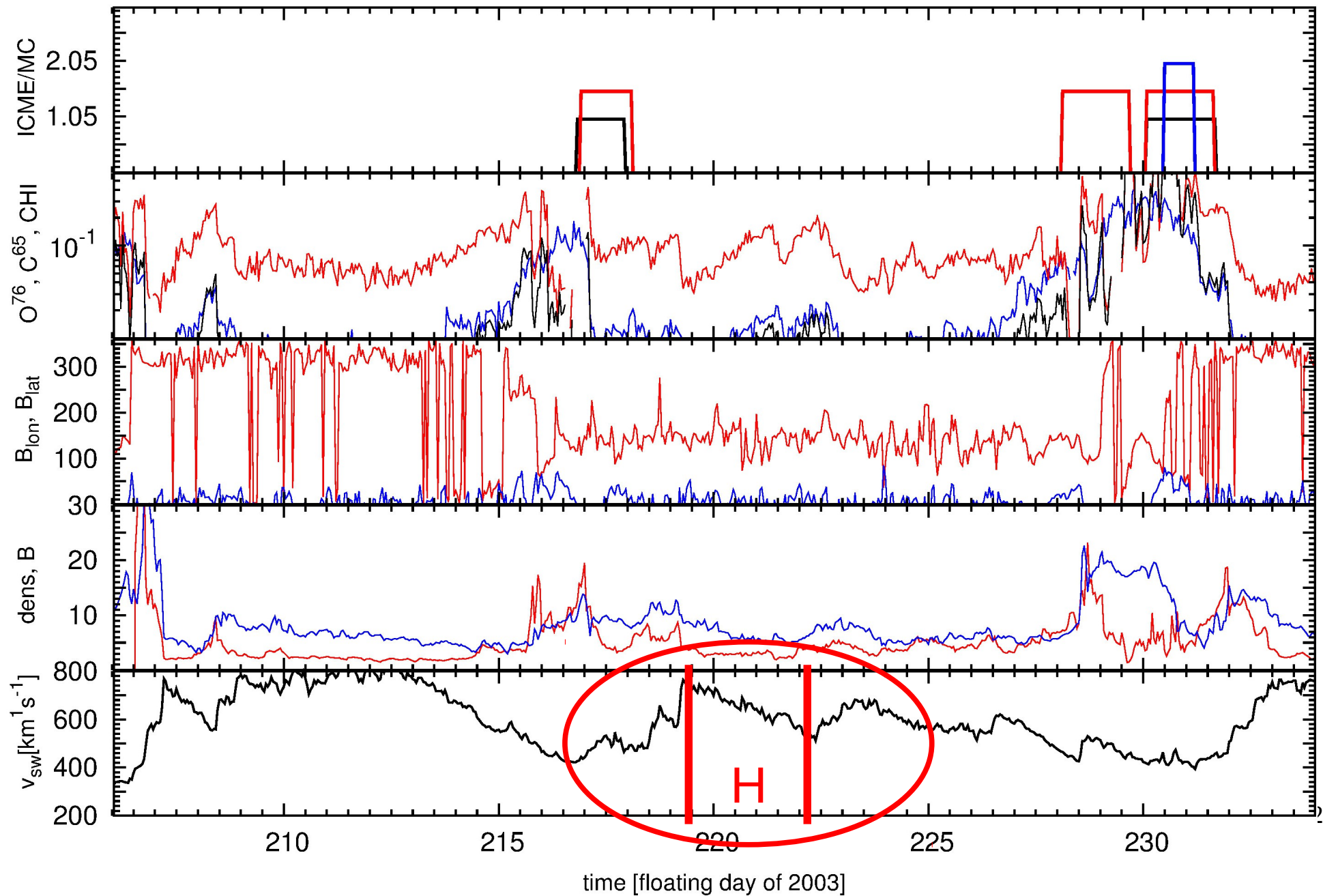
STPs in pure this coronal-hole flow show hard spectrum

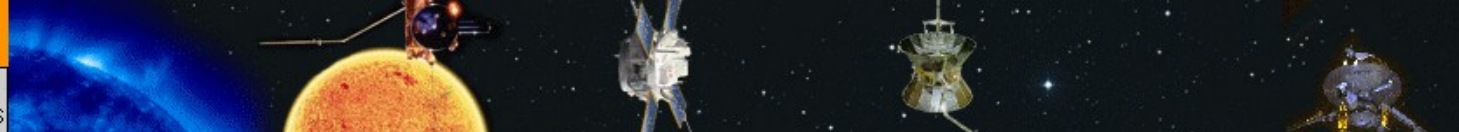
plots/w-spec-2003209-2003213-200.eps





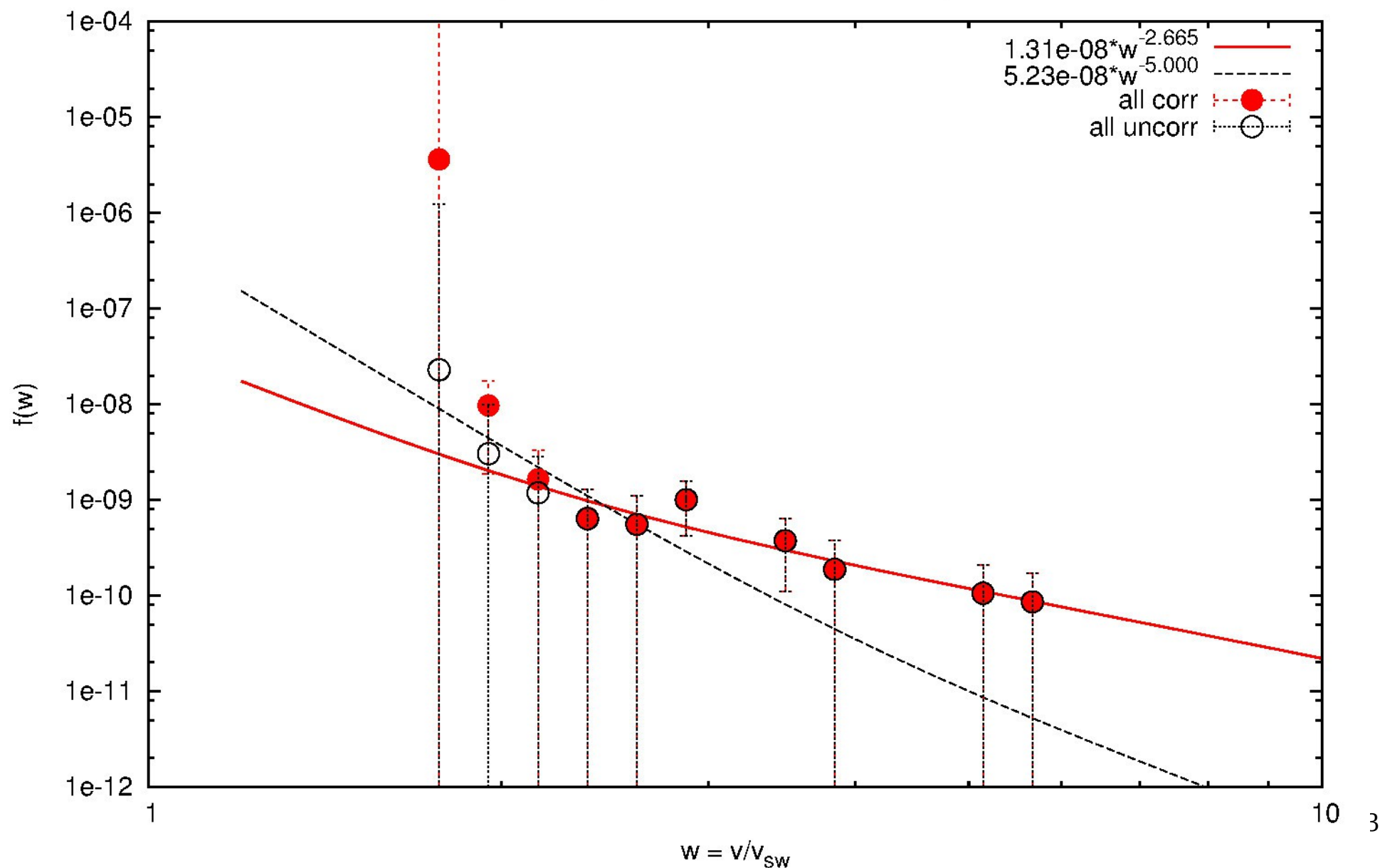
Try another long-lasting high-speed stream





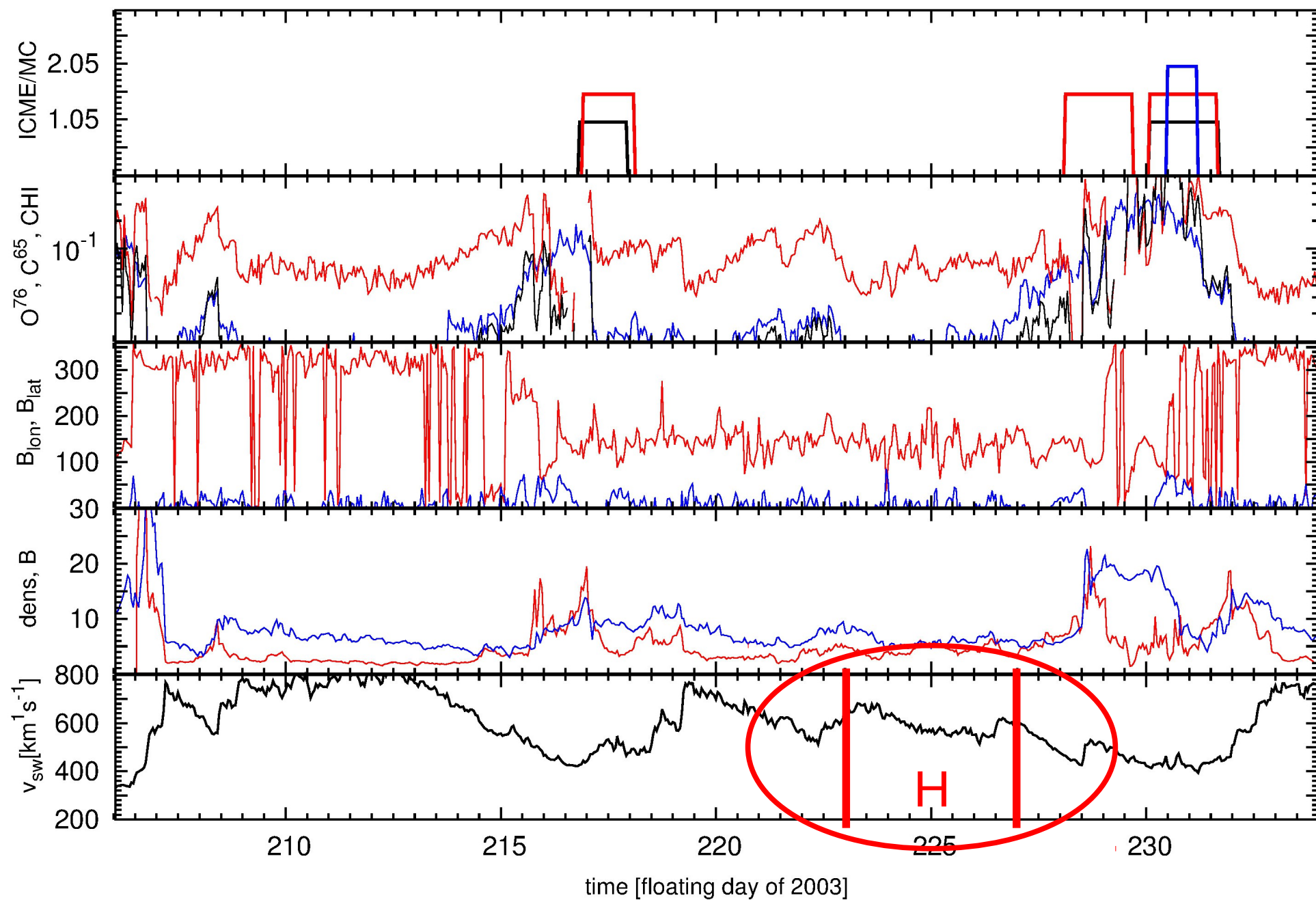
STPs in this coronal-hole flow also show hard spectrum

plots/w-spec-2003219-2003222-200.eps





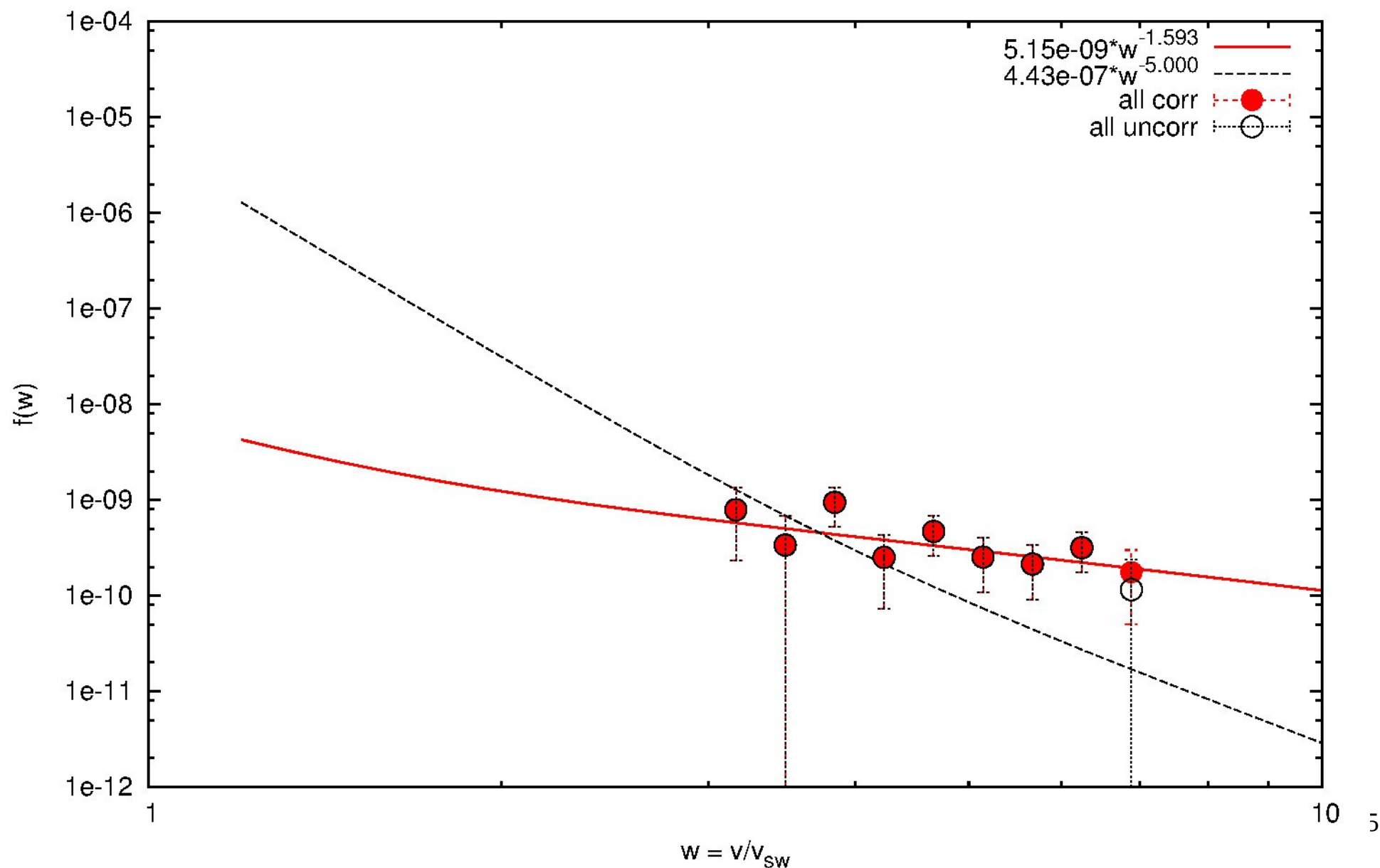
Try another long-lasting high-speed stream





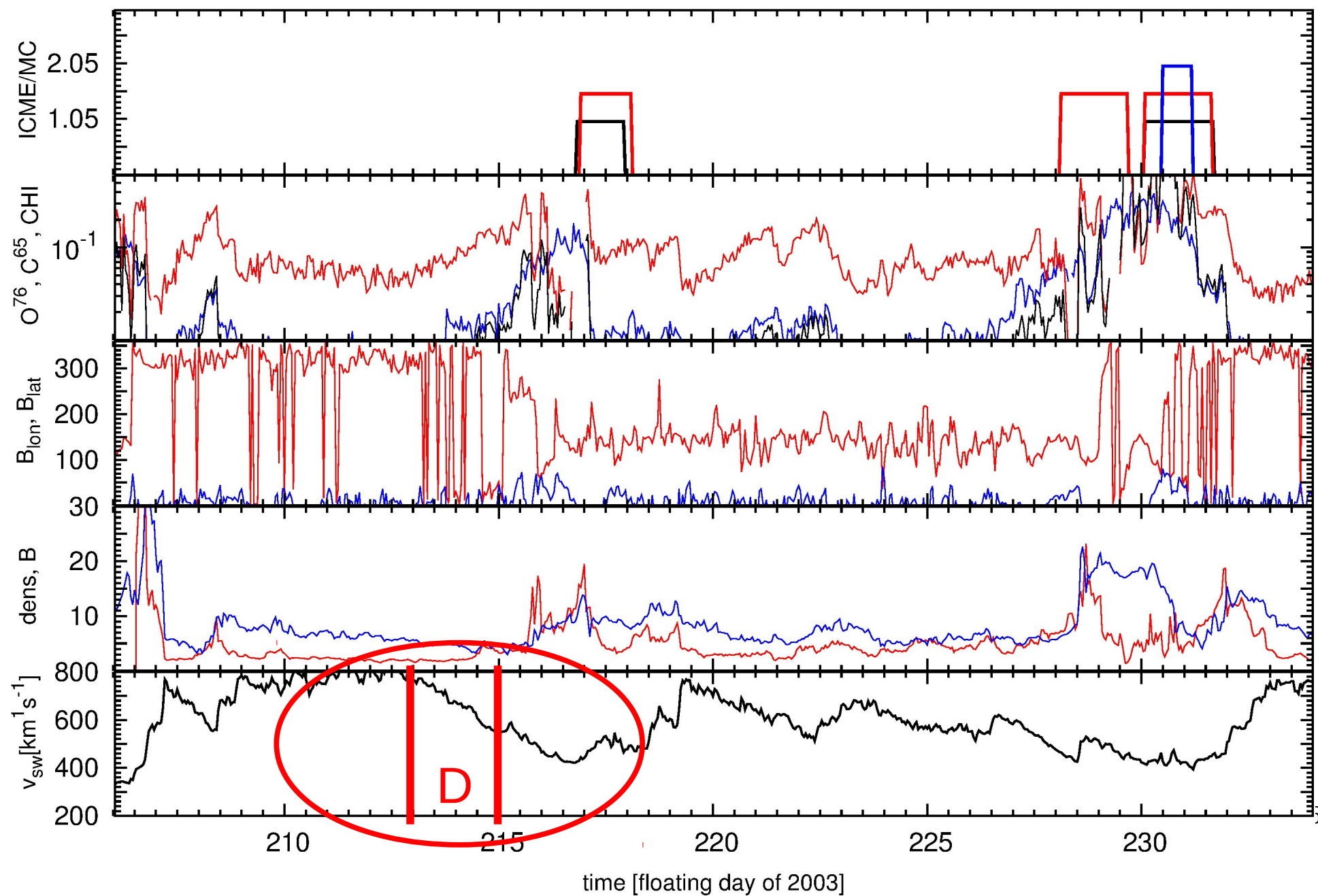
STPs in this coronal-hole flow show hard spectrum too

plots/w-spec-2003223-2003227-200.eps





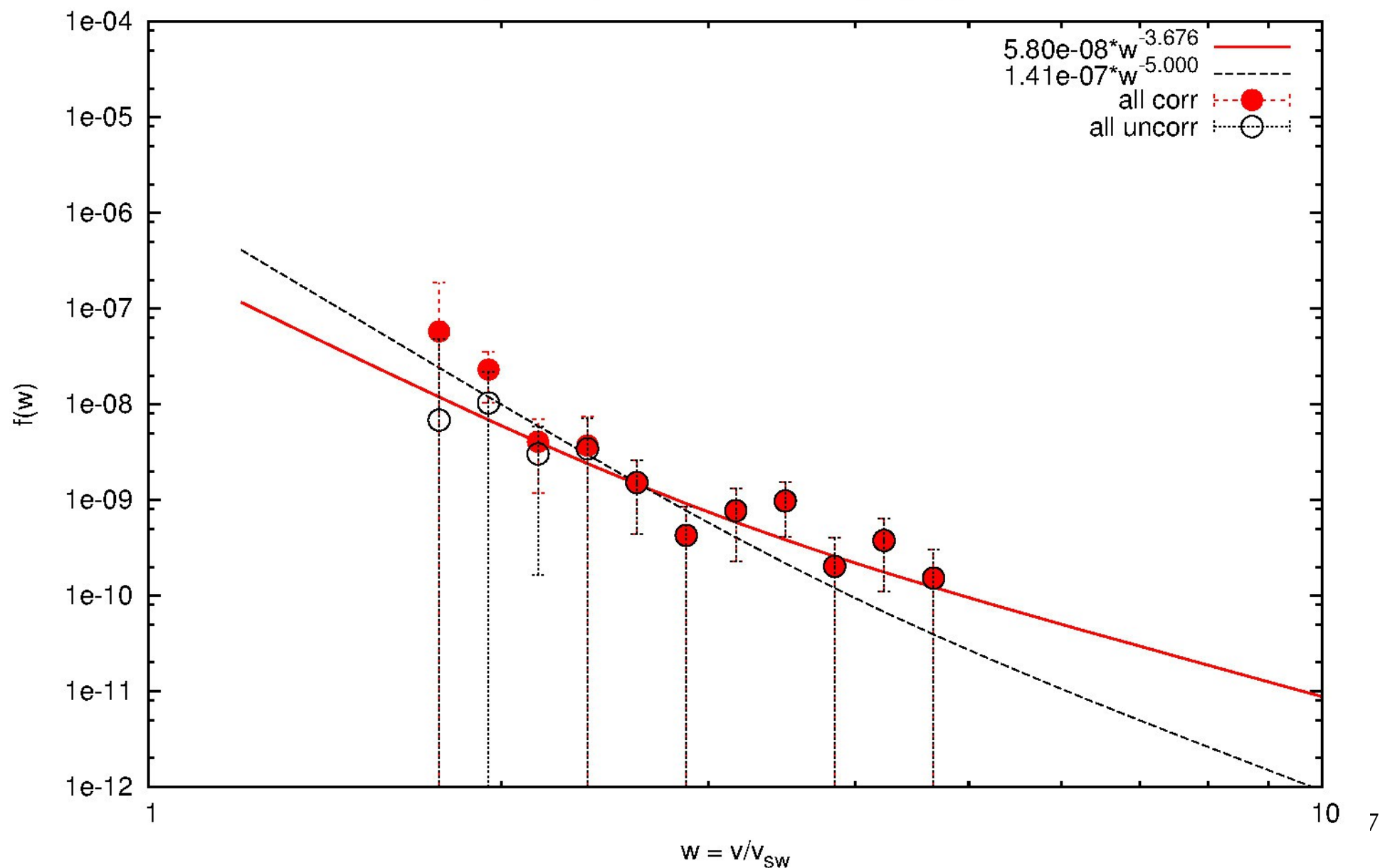
Solar wind 'dwells' are regions of predominant expansion





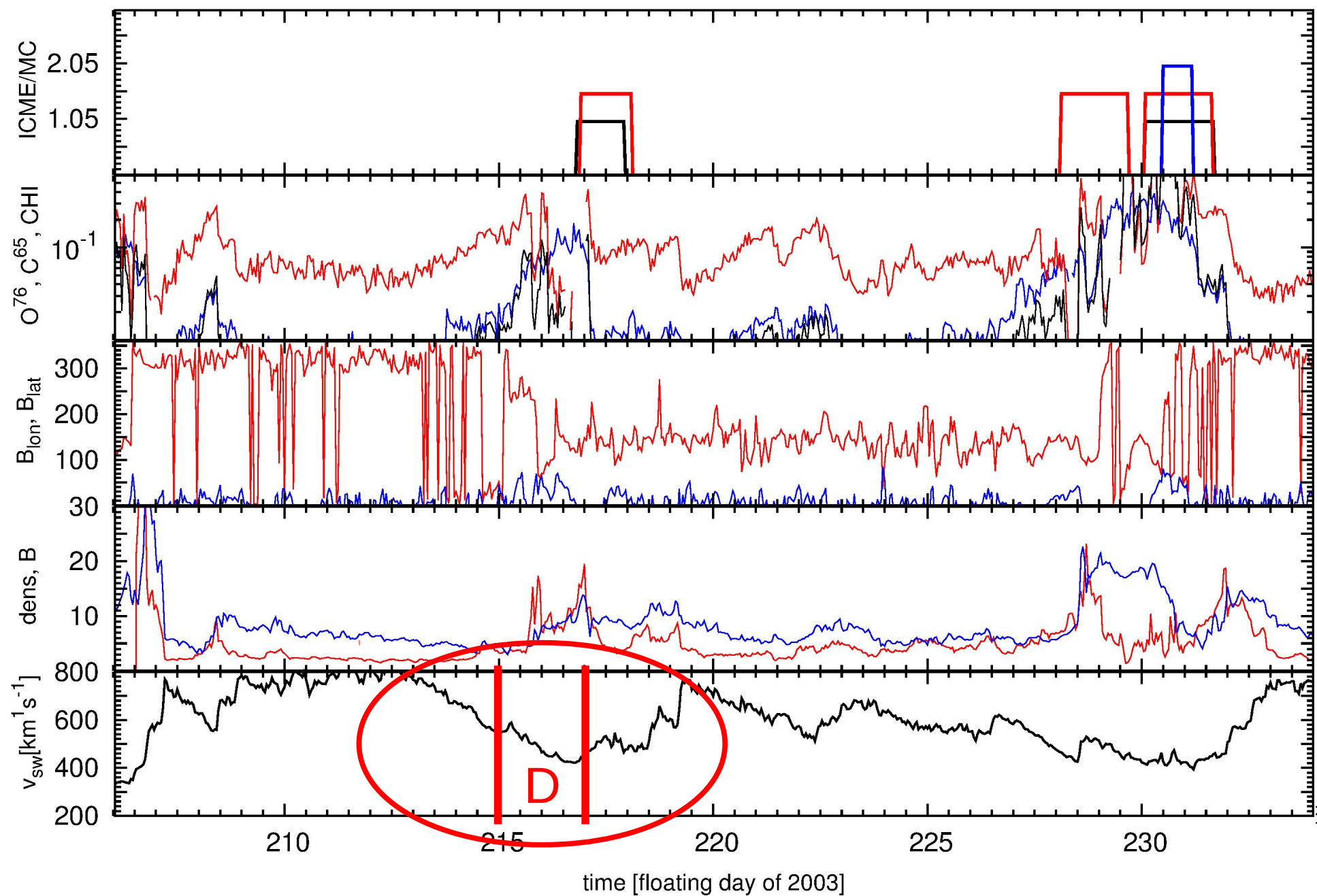
STPs are still present, clearly with power law in $w=v/v_{\text{bulk}}$

plots/w-spec-2003213-2003215_2001.2.eps





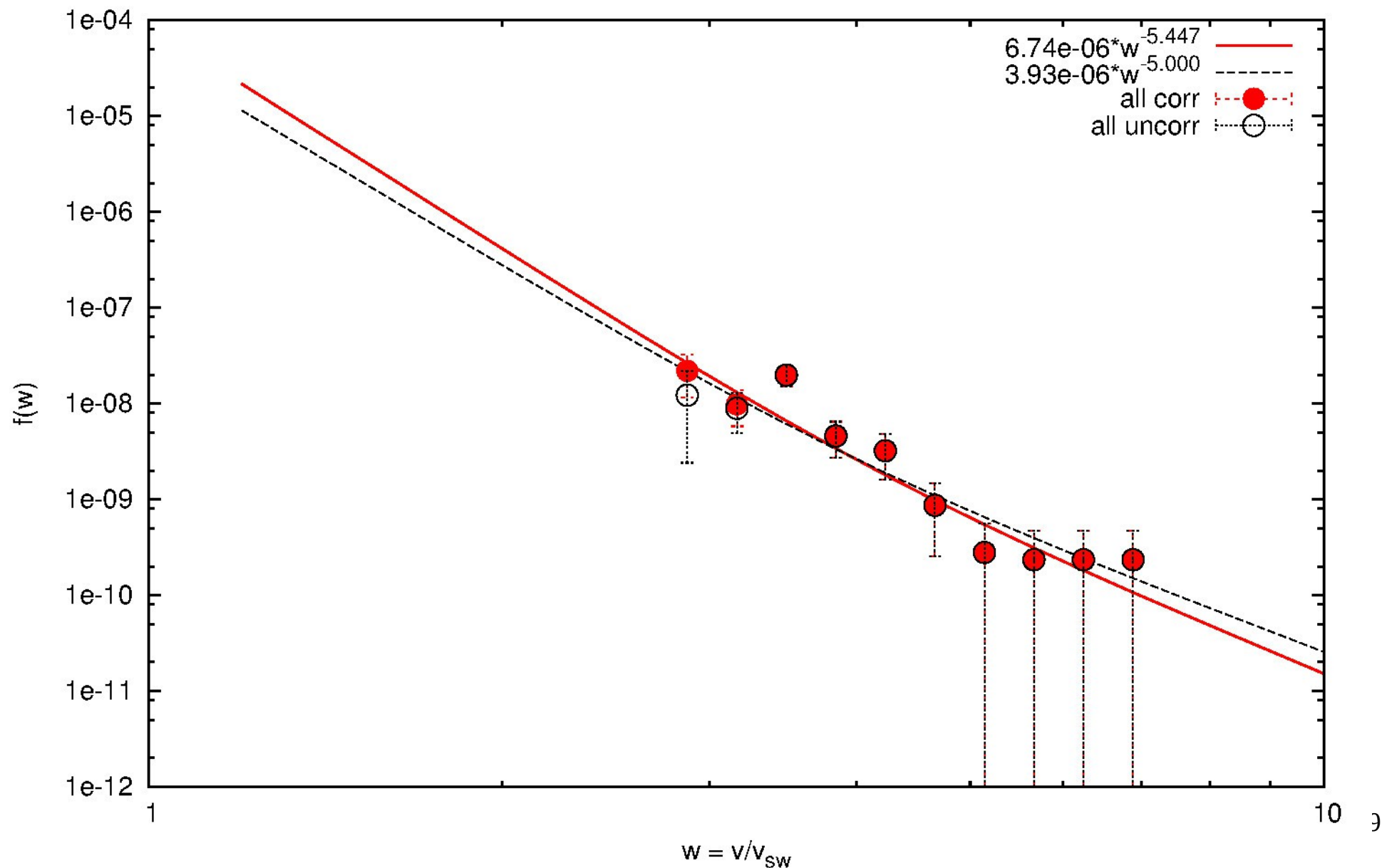
Solar wind 'dwells' are regions of predominant expansion





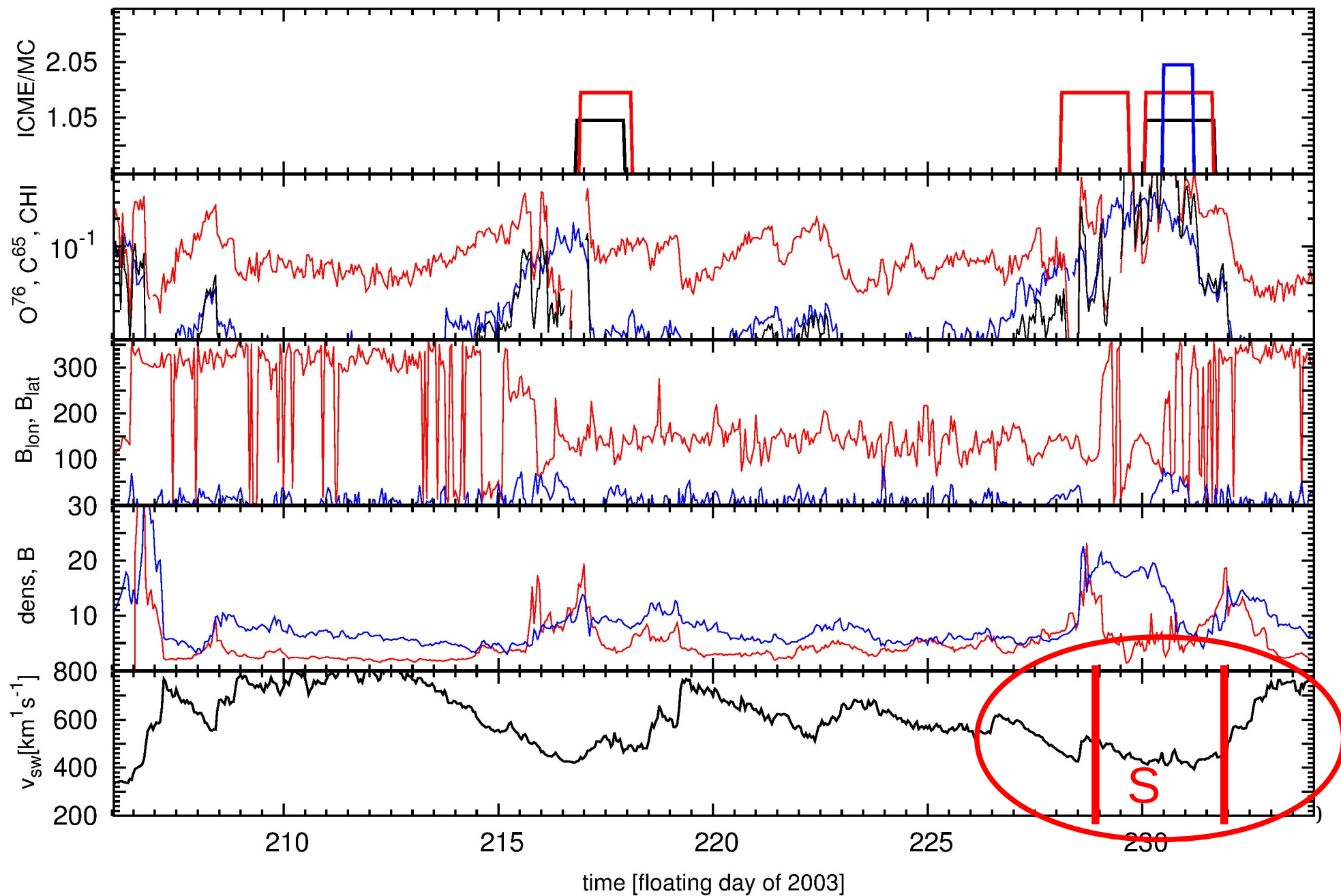
STPs are still present, clearly with power law in $w=v/v_{\text{bulk}}$

plots/w-spec-2003215-2003217-200.eps





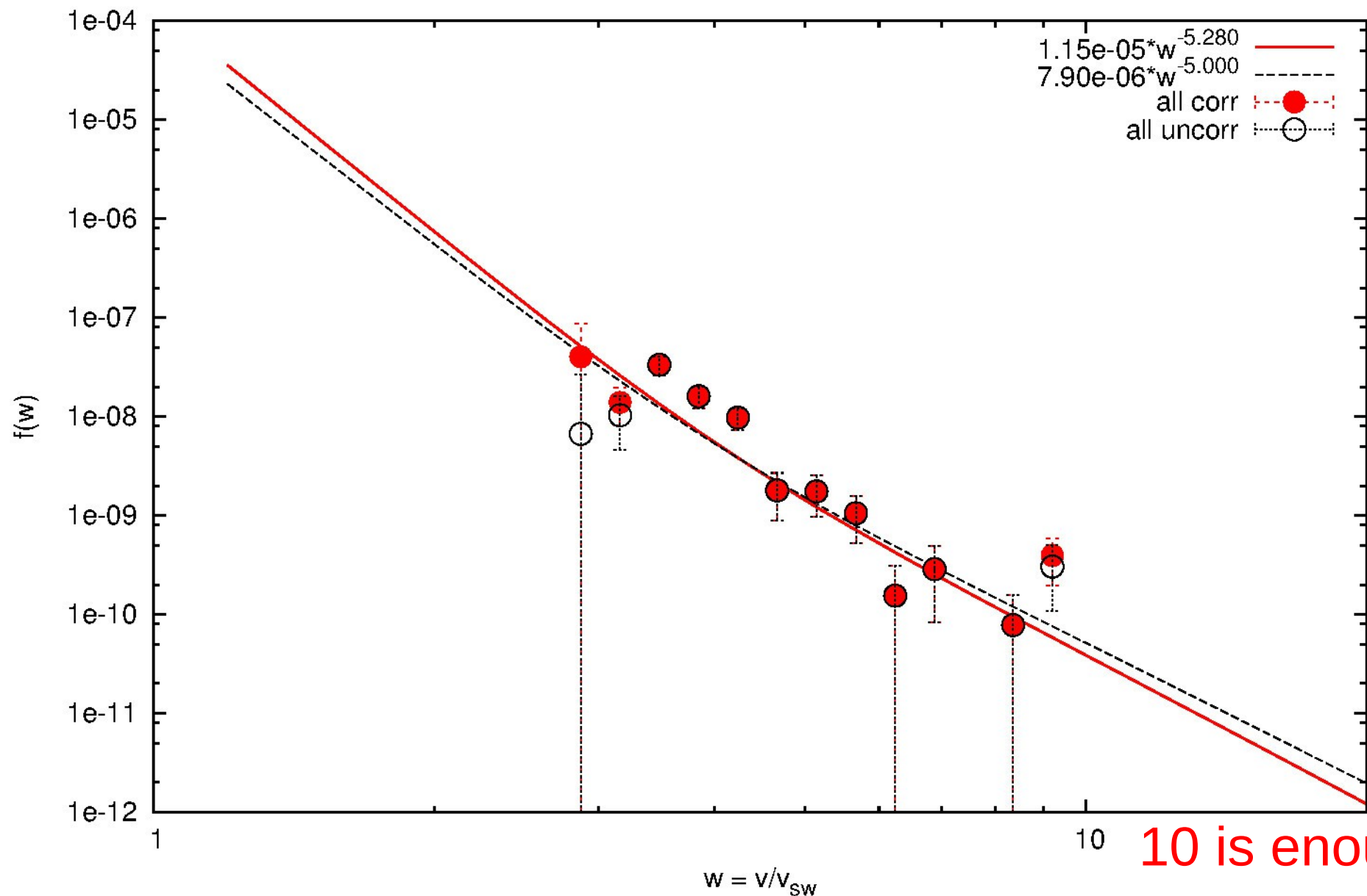
And now the slow wind





STPs also present in the slow wind, soft spectrum

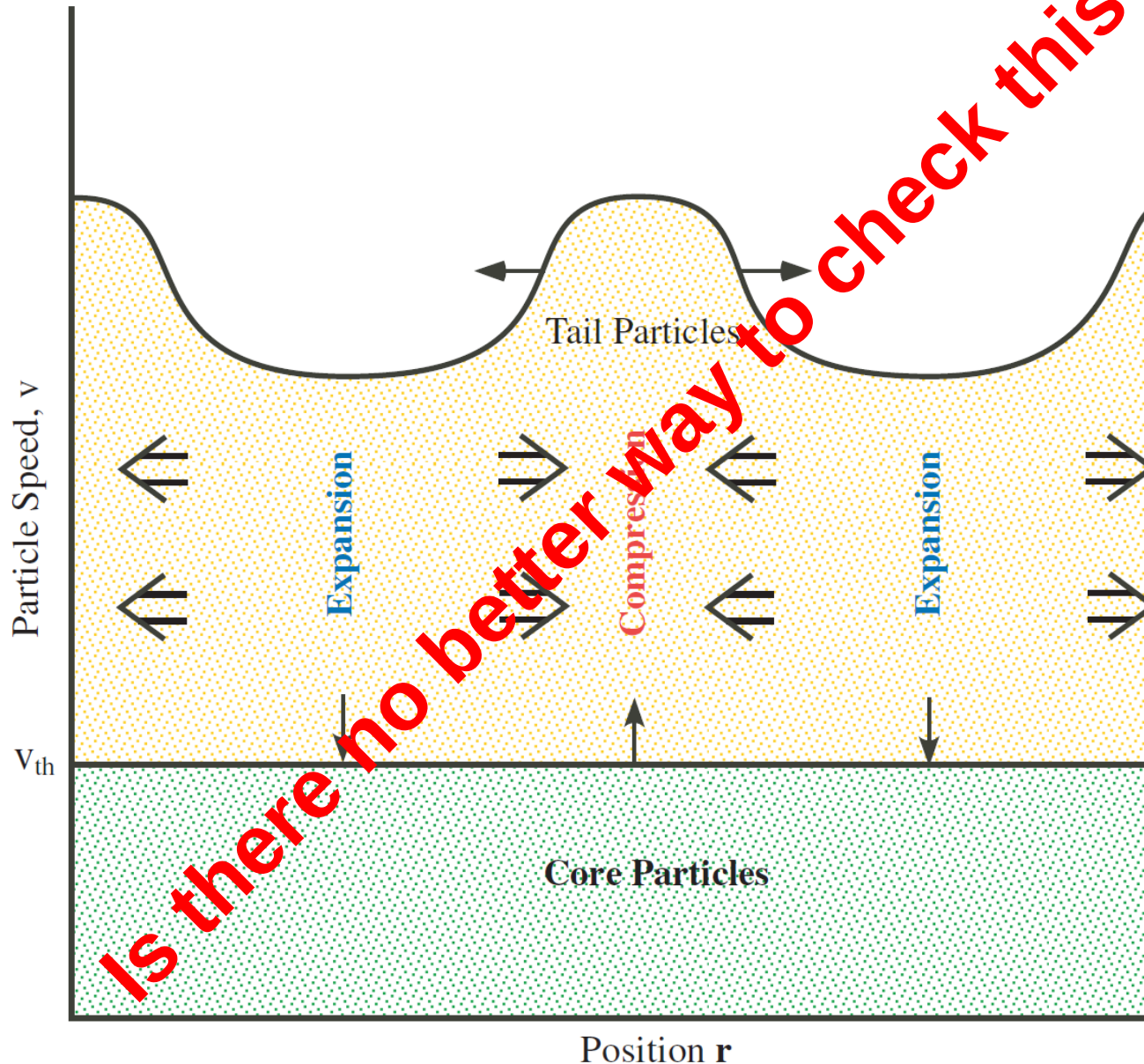
plots/w-spec-2003229-2003232-200.eps



10 is enough!



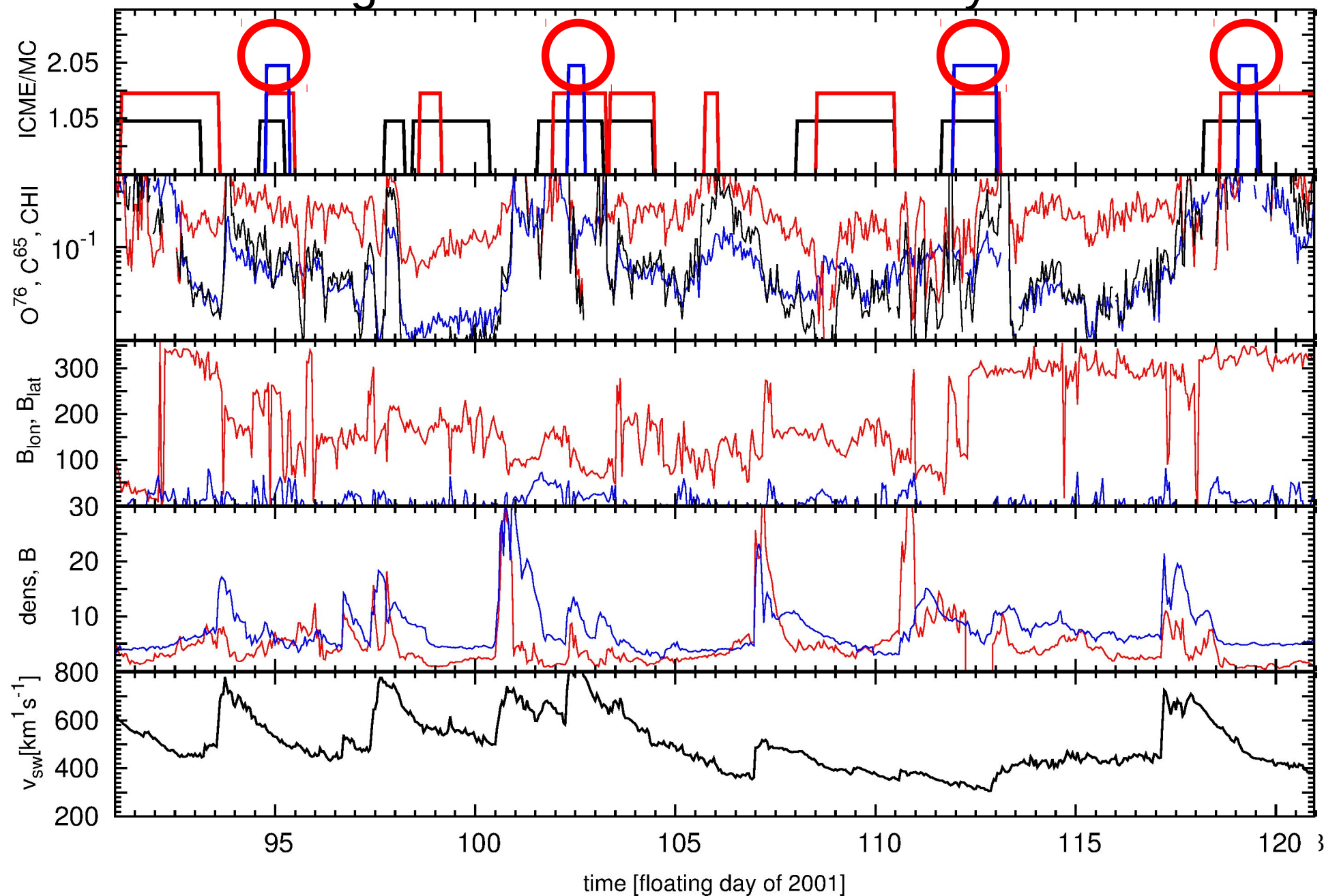
Fisk et al., 2010, explain the formation of these STP tails as a consequence of successions of compressions and expansions. This adiabatic pumping leads to STP tails.



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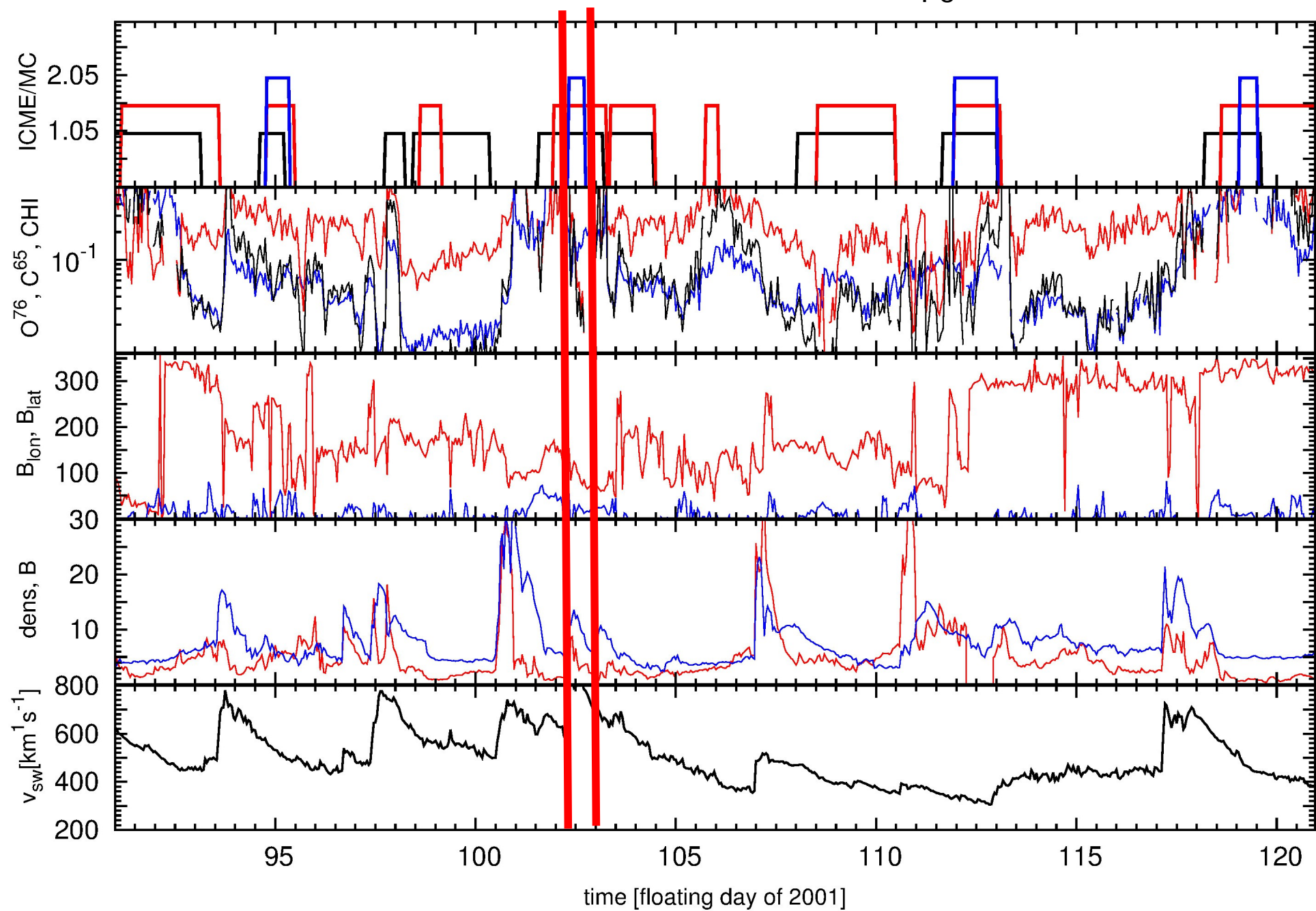


Consider magnetic clouds: What will they show?





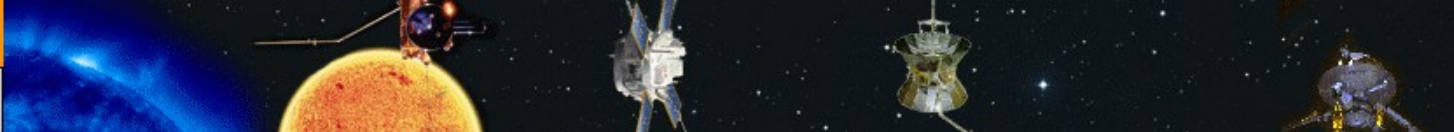
April 12, 2001 magnetic cloud: High Q_{Fe} , BDE, 'classical'





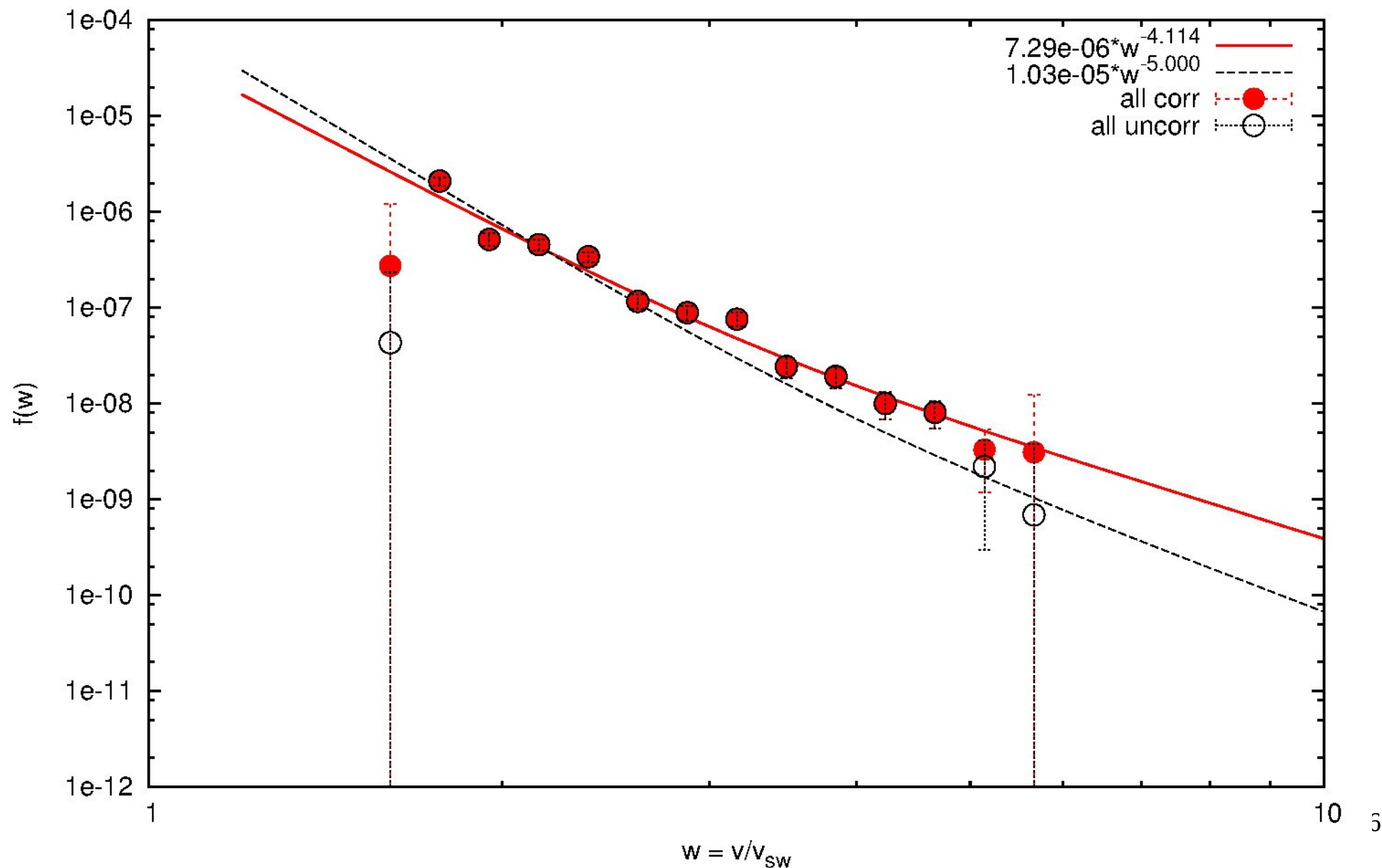
The April 12, 2001 magnetic cloud

- 08:00 – 18:00, as given in Richardson & Cane list (ASC)
- High iron, oxygen, and carbon charge states
- 'normal' He/H ratio
- Average $B = 11.5$ nT
- Average proton gyroradius ~ 3000 km
- Average speed ~ 720 km/s (allows to measure low w_s)
- Convected by ACE in ~ 4 s
- If we see STPs, they can't be from shocked sheath



STPs are even present in magnetic clouds!

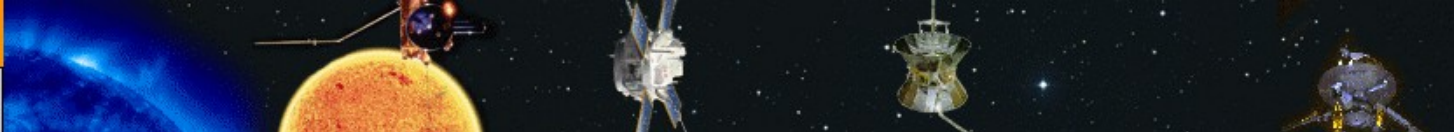
plots/w-spec-2001102-2001102-200.eps





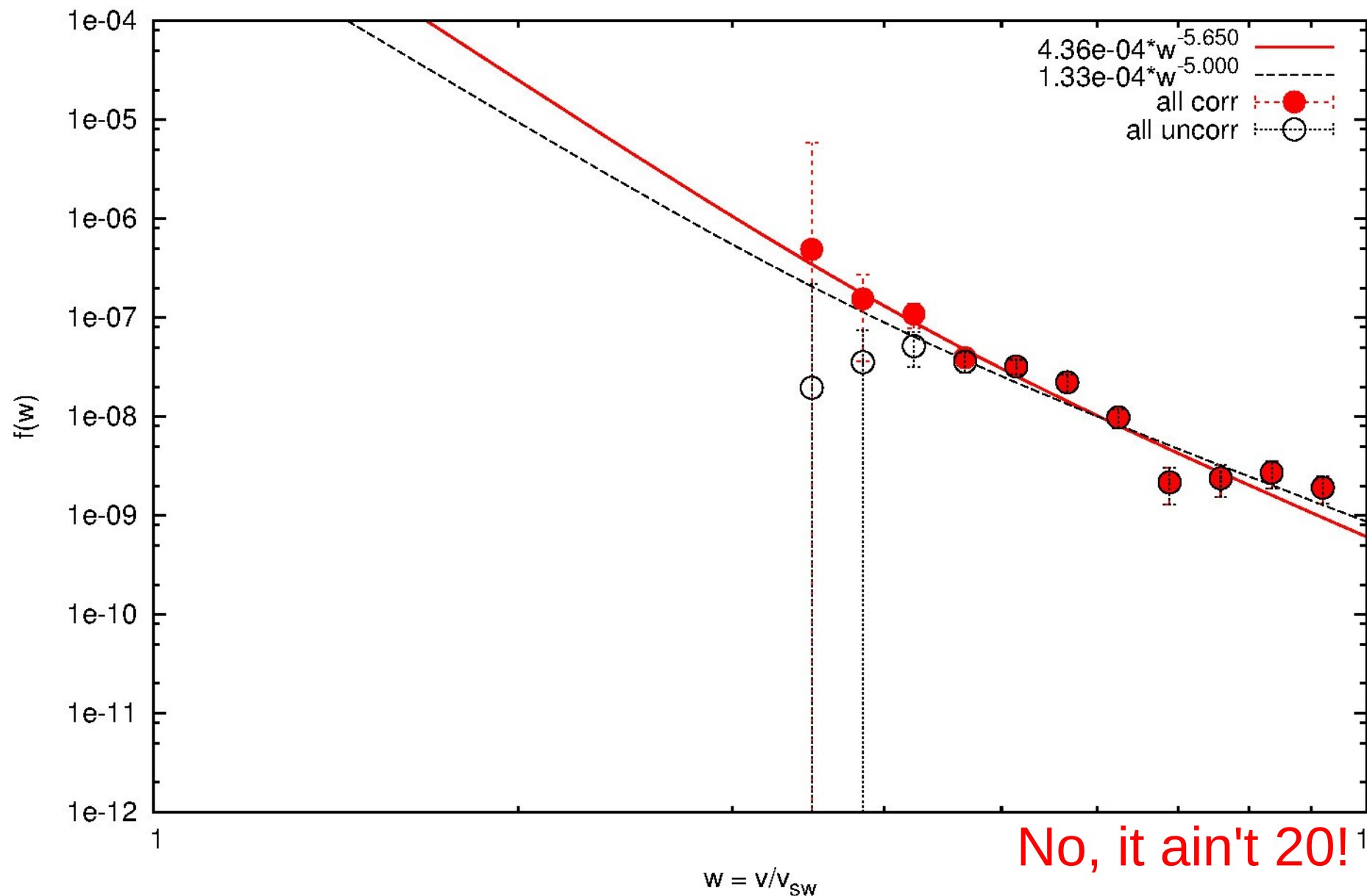
The March 19-21, 2001 magnetic cloud

- as given in Richardson & Cane list (ASC)
- Slightly enhanced iron charge states
- flare-associated
- Elevated B (15 nT)
- Clear BDE, indicating good connection to Sun
- Slow (average 380 km/s, allows to measure high w_s)

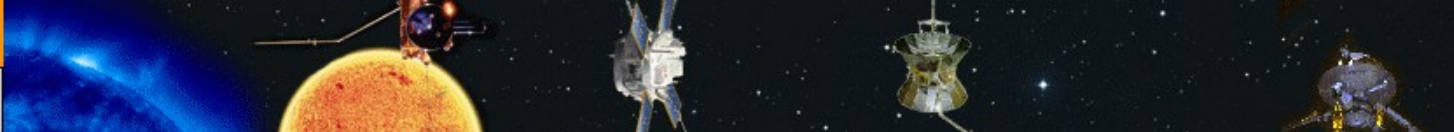


Power law extends out to high ws...

plots/w-spec-200178-200181-200.eps

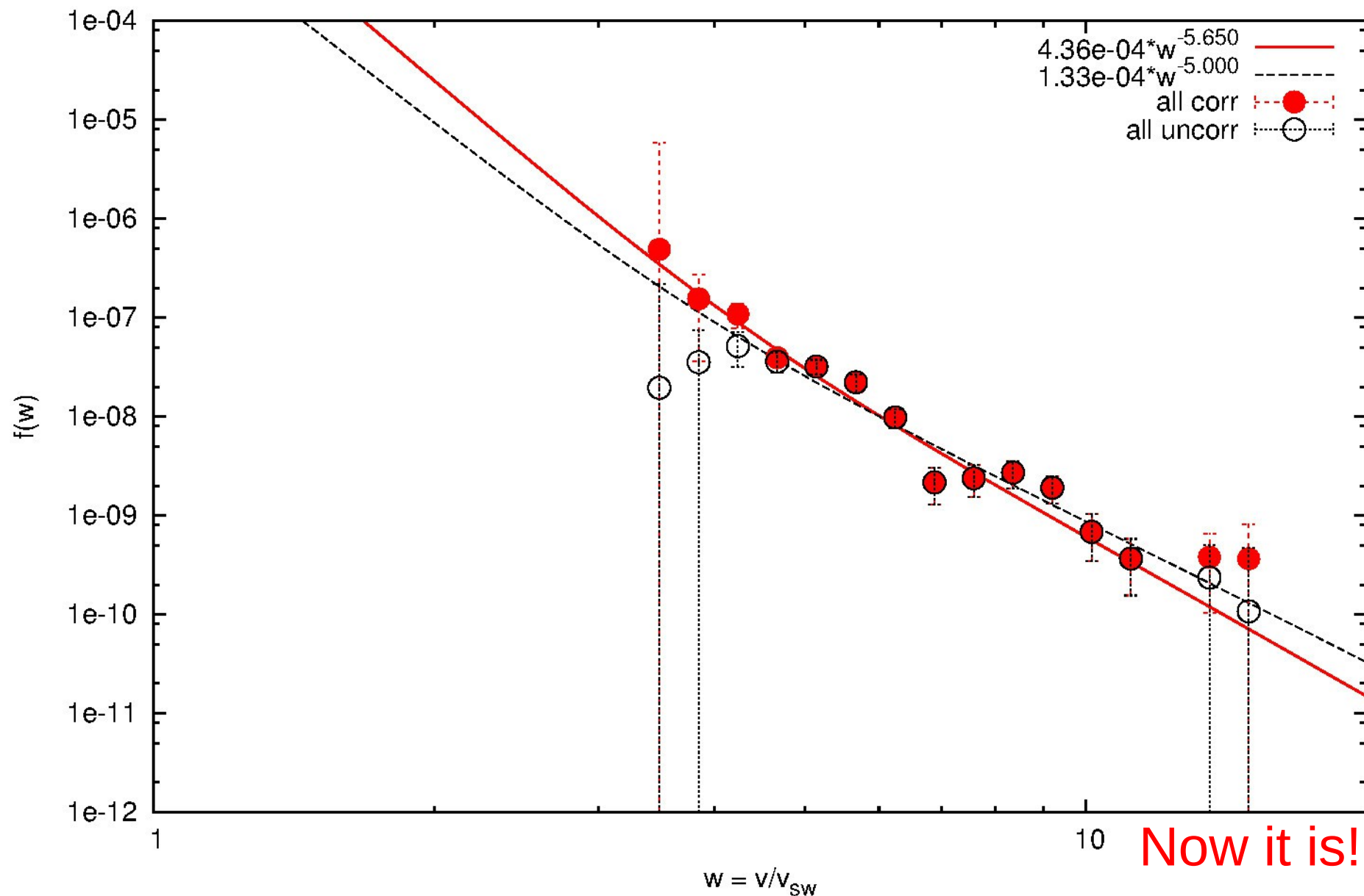


No, it ain't 20! ¹⁰ 3



Power law extends out to high ws...

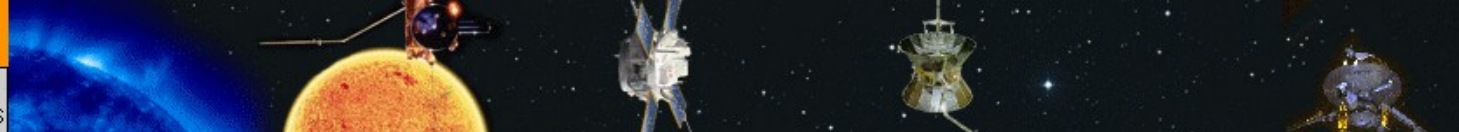
plots/w-spec-200178-200181-200.eps





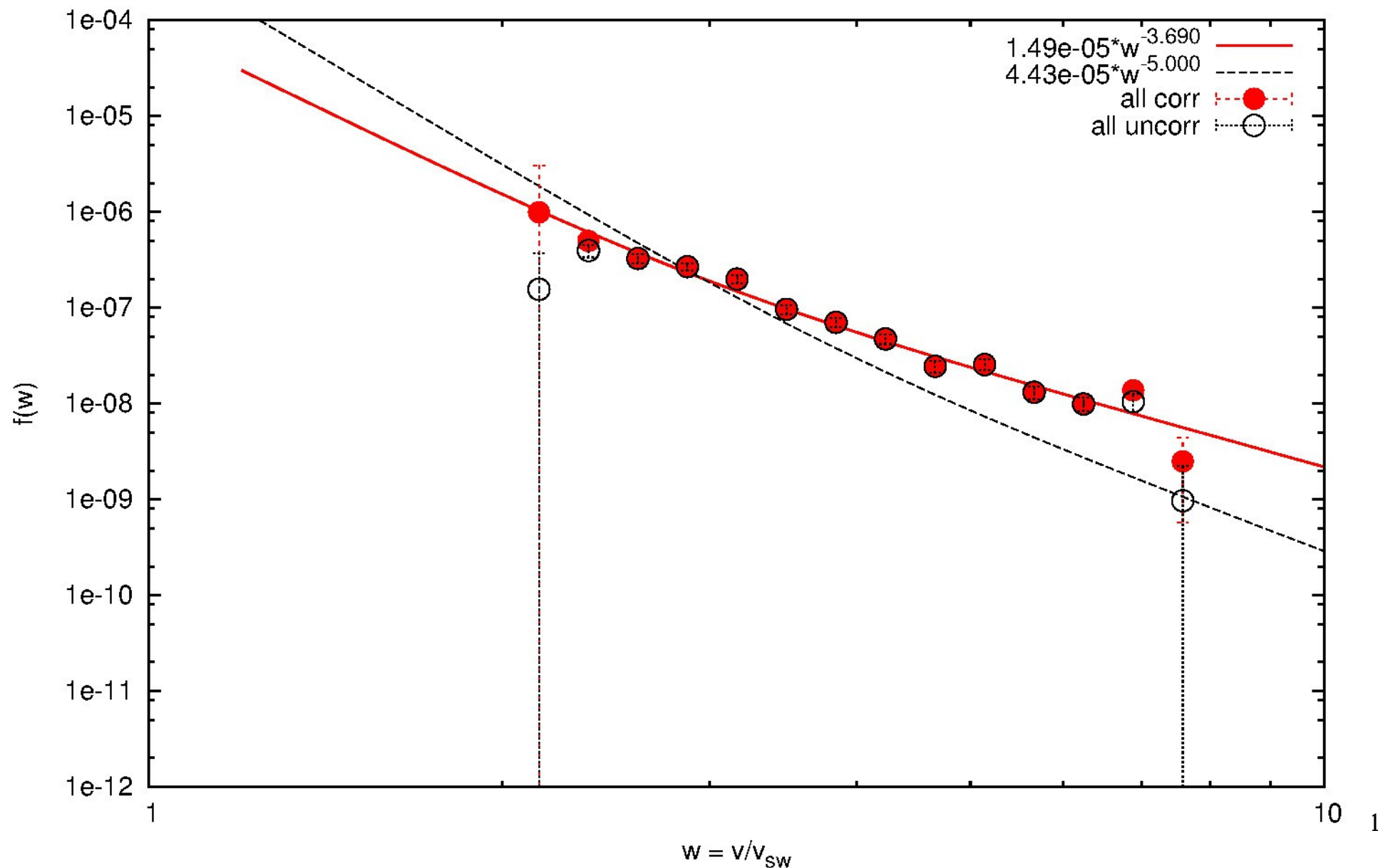
The November 24-25, 2001 magnetic cloud

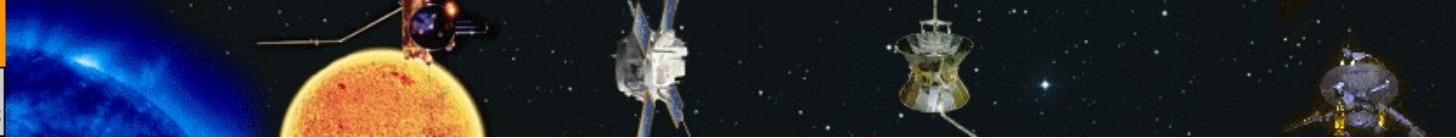
- as given in Richardson & Cane list (ASC)
- Slightly enhanced iron charge states
- Associated with central-meridan flare
- High B (27 nT)
- Fast (average 710 km/s, allows to measure low w_s)



November 24/25, 2001, rather hard spectrum

plots/w-spec-2001328-2001329-200.eps





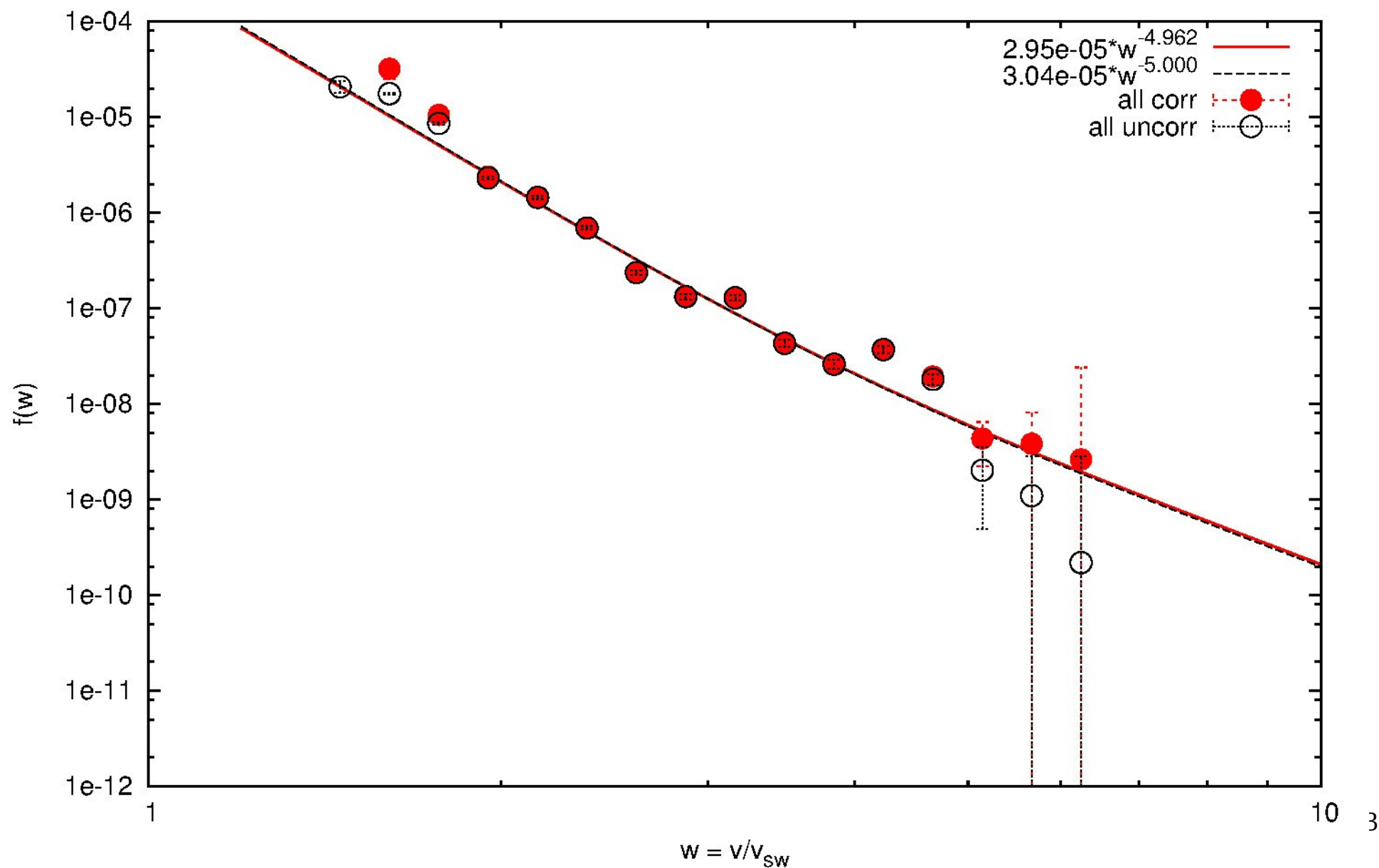
The May 15, 2005 magnetic cloud

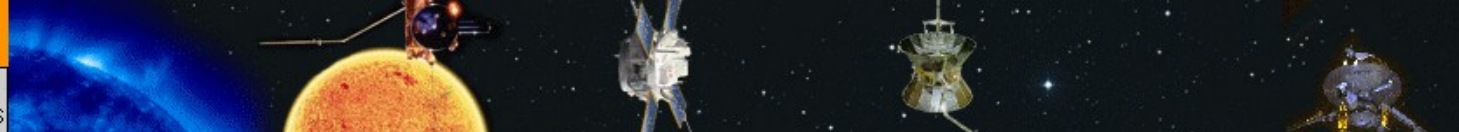
- as given in Richardson & Cane list (ASC)
- Enhanced iron charge states
- Associated with central-meridan flare
- Highest B (49 nT) seen
- Globally expanding
- Fast (average 820 km/s, allows to measure low *ws*)



May 15, 2005, 'perfect' $w \sim -5$ spectrum

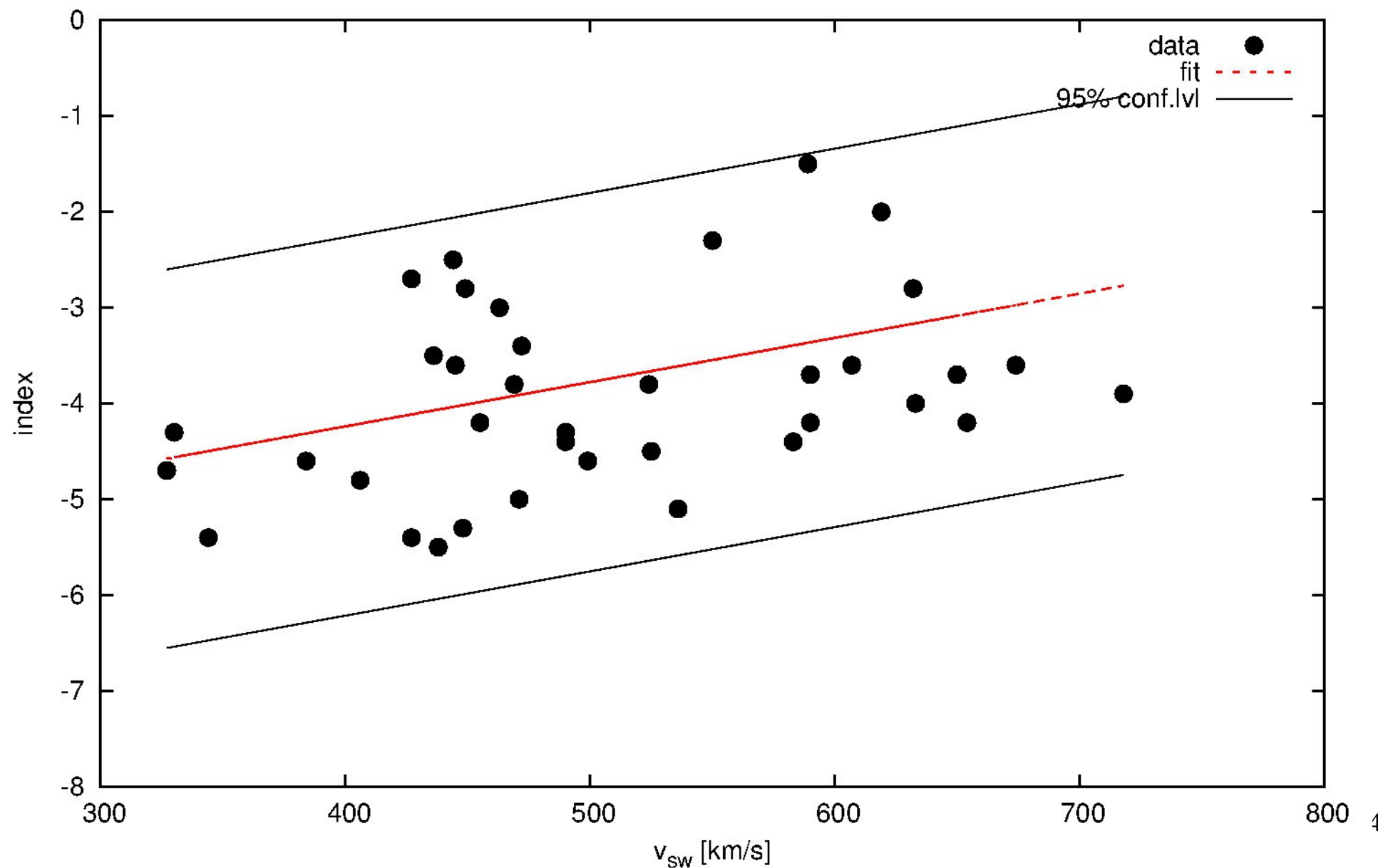
plots/w-spec-2005134-2005135-200.eps





Does power-law index depend on time available?

Pearson's $r = 0.352$, $p = 0.03262$; Spearman's $r = 0.354$, $p = 0.03178$





Summary, Conclusions, and Outlook

- Have investigated STP tails with SWICS on ACE
- STP seen in all types of solar wind, even in MCs!
- Not only long-term power laws, but also short term!
- Different power laws in high-speed streams than in slow wind or dwells. Hardest spectra in high-speed streams.
- Possibly wave related – but then why in MCs?
- Do ***systematic*** study in different solar winds (waves)

Mahalo!

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