Energetic Particles from Corotating Interaction Regions as Observed by STEREO and ACE

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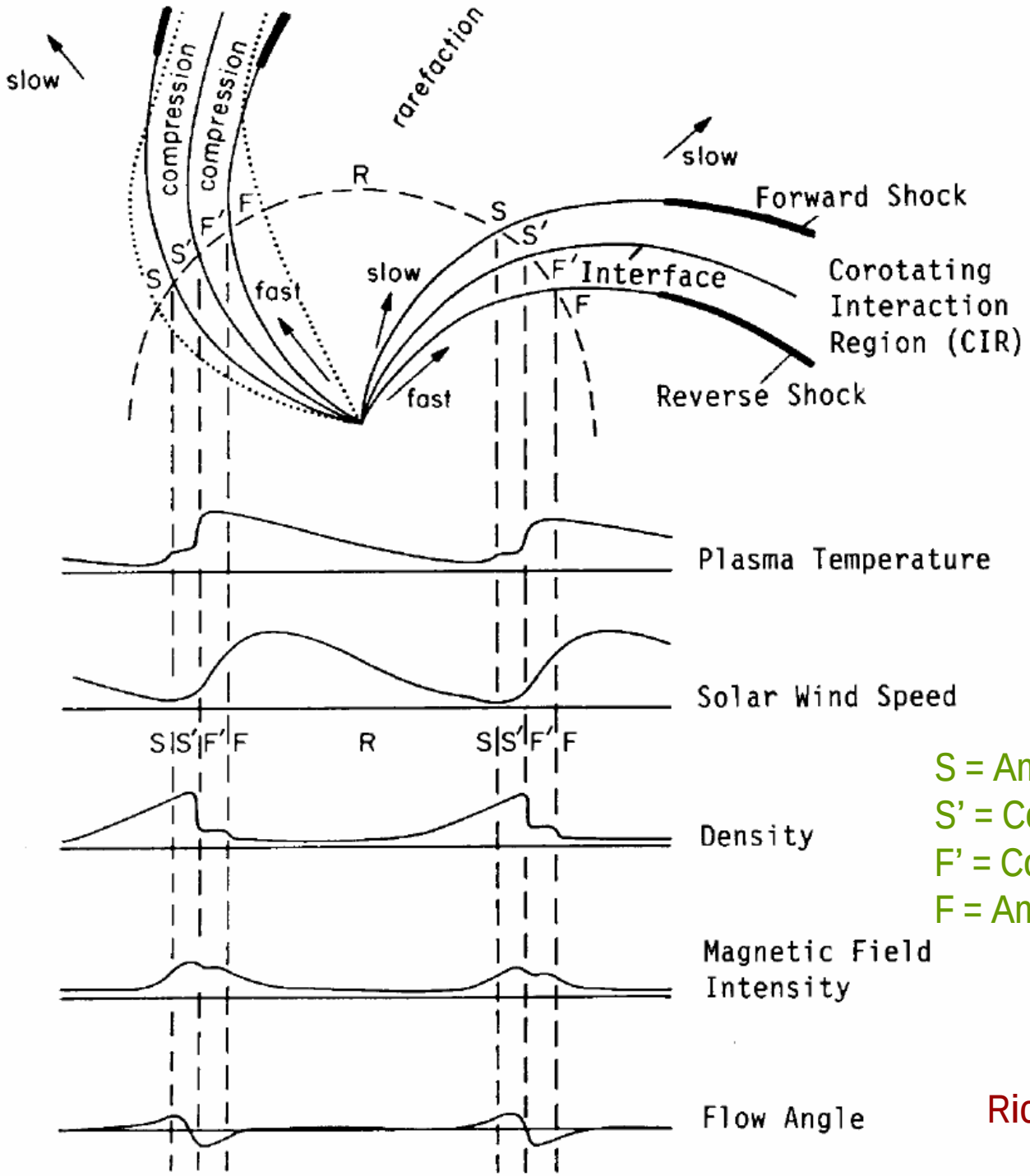
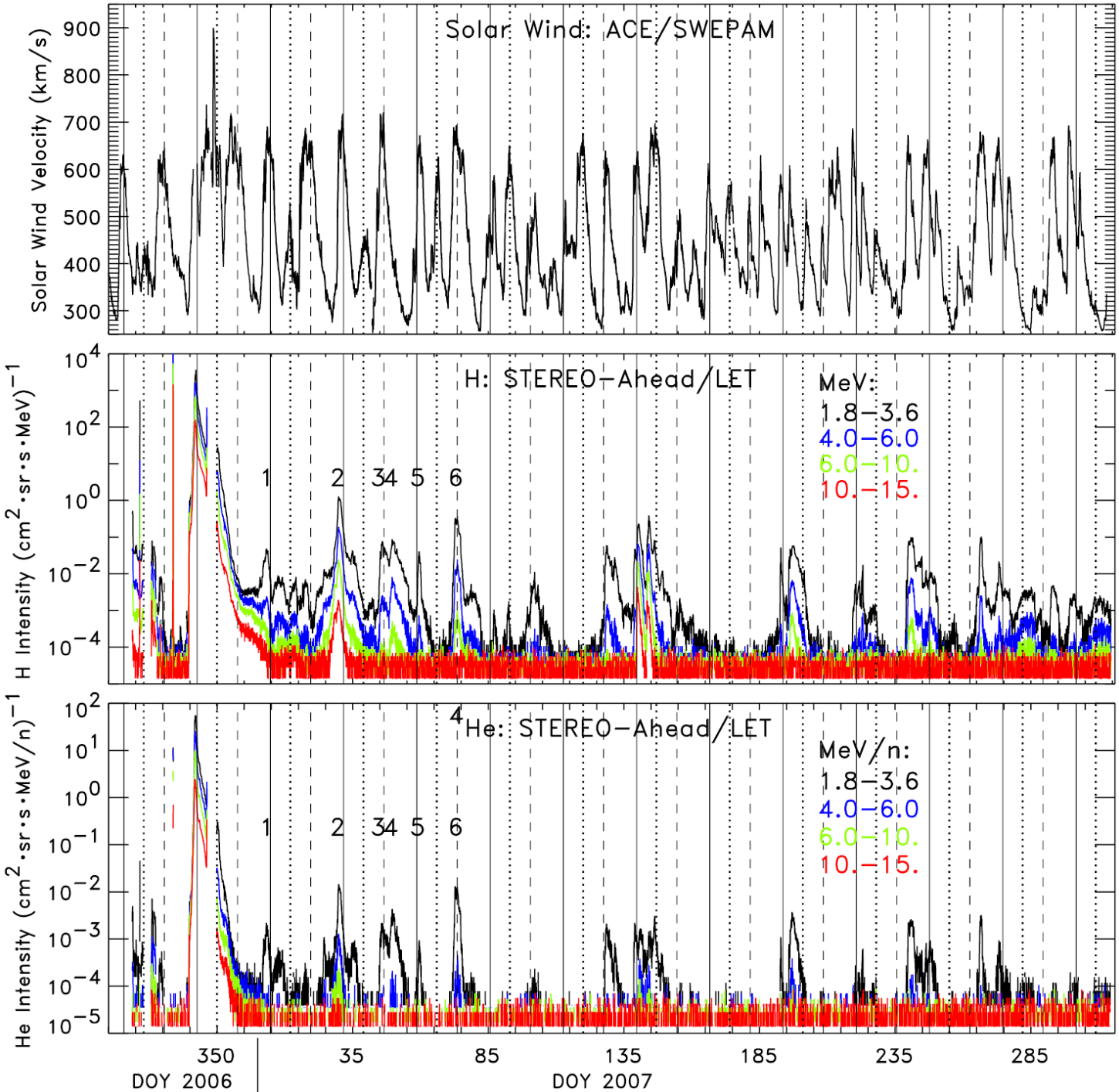


Corotating Interaction Regions (CIRs) form when a high-speed solar wind stream overtakes and interacts with a slower speed stream.

S = Ambient, slow solar wind
S' = Compressed, accelerated slow SW
F' = Compressed, decelerated fast SW
F = Ambient, undisturbed fast SW

Richardson 2004

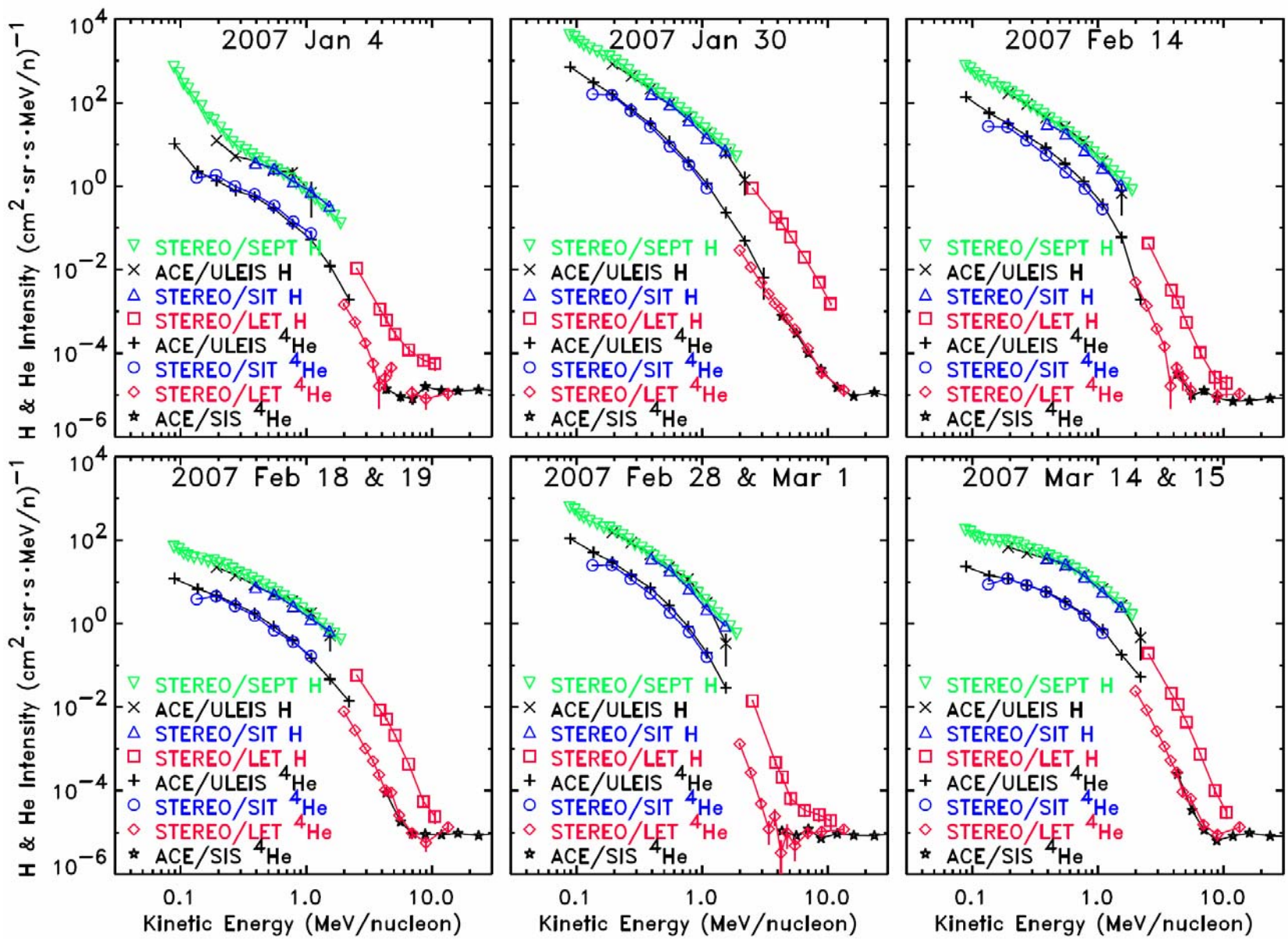


LET is seeing recurrent CIR particle increases.

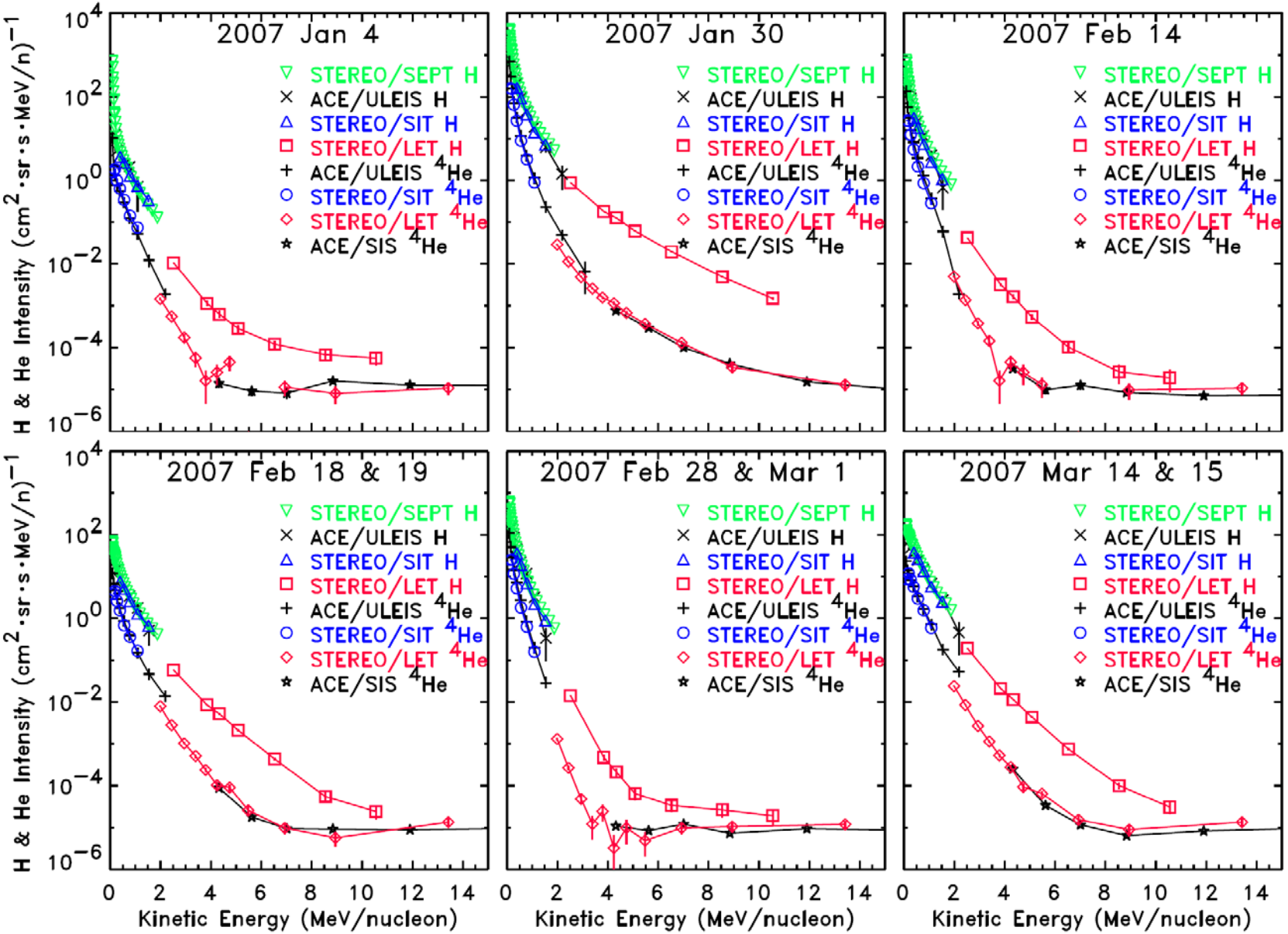
At first high speed streams from 3 different longitudes were responsible, but recently a new stream pattern seems to have appeared.

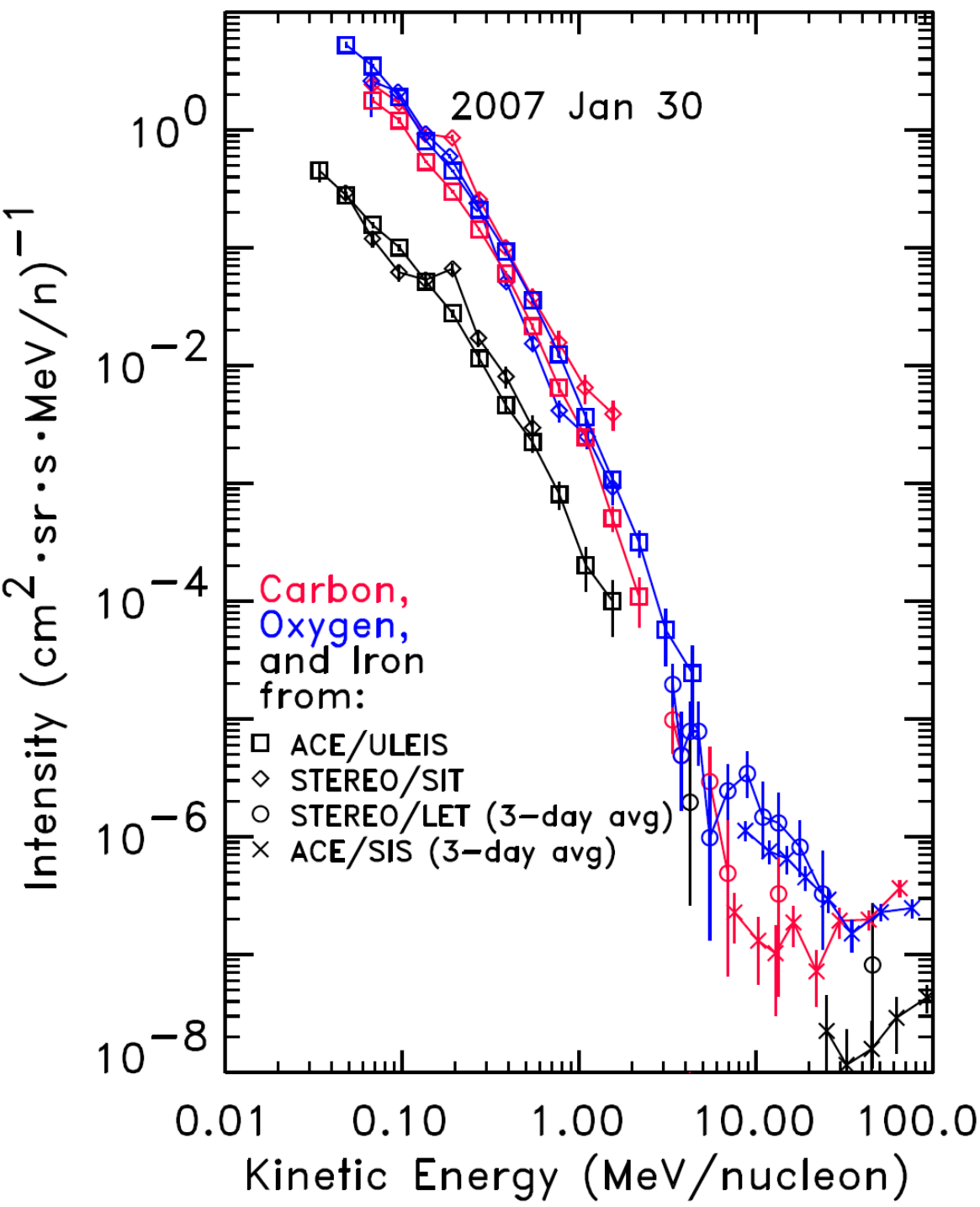
Not all of the high speed streams are generating particles at MeV energies.

CIR H and He spectra from LET, SIT, and SEPT on STEREO as well as ULEIS and SIS on ACE agree reasonably well with each other.



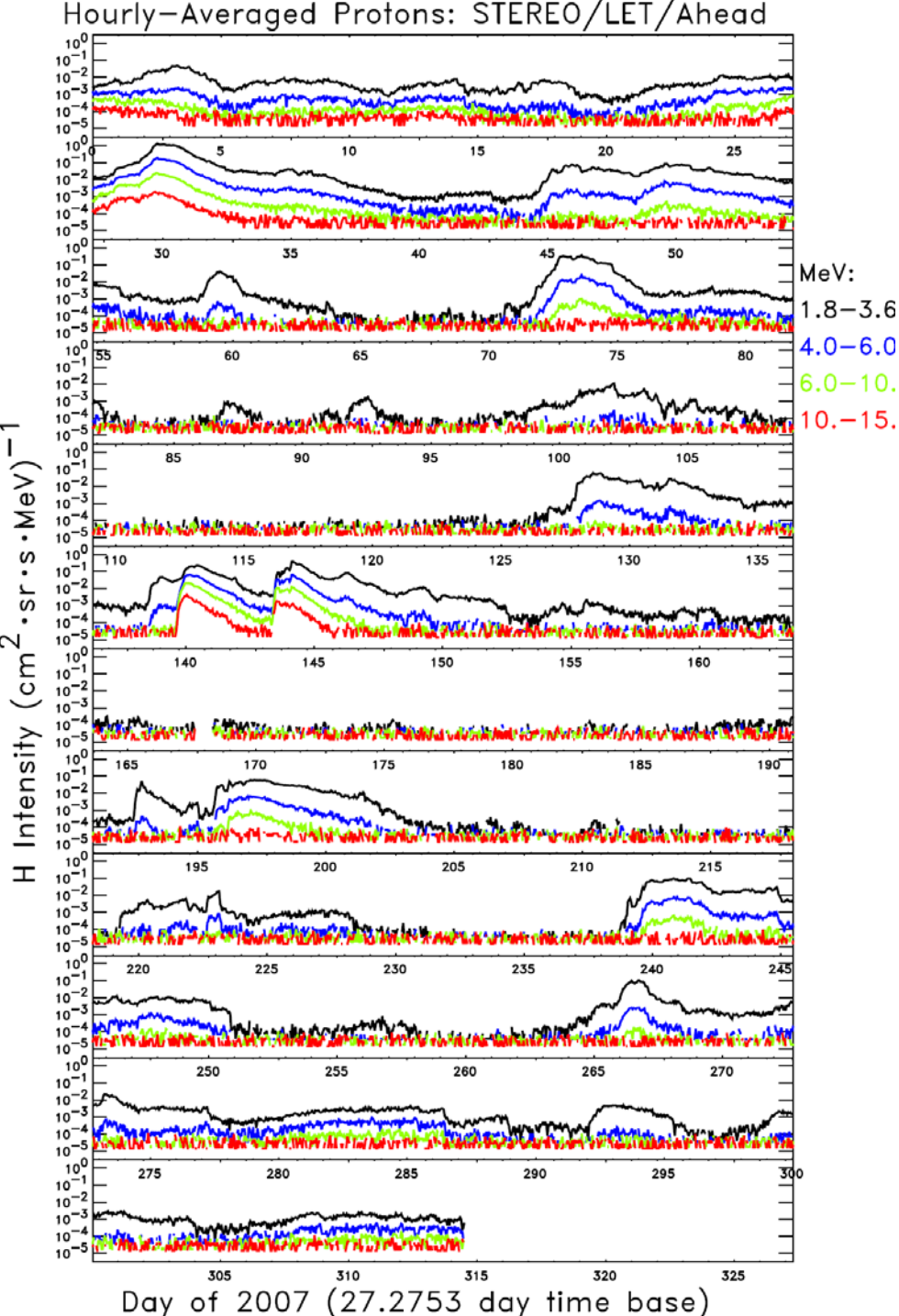
All of the spectra fall off rapidly at higher energies; several appear to be nearly exponential above ~0.5 MeV. He seems to be falling more rapidly than H.



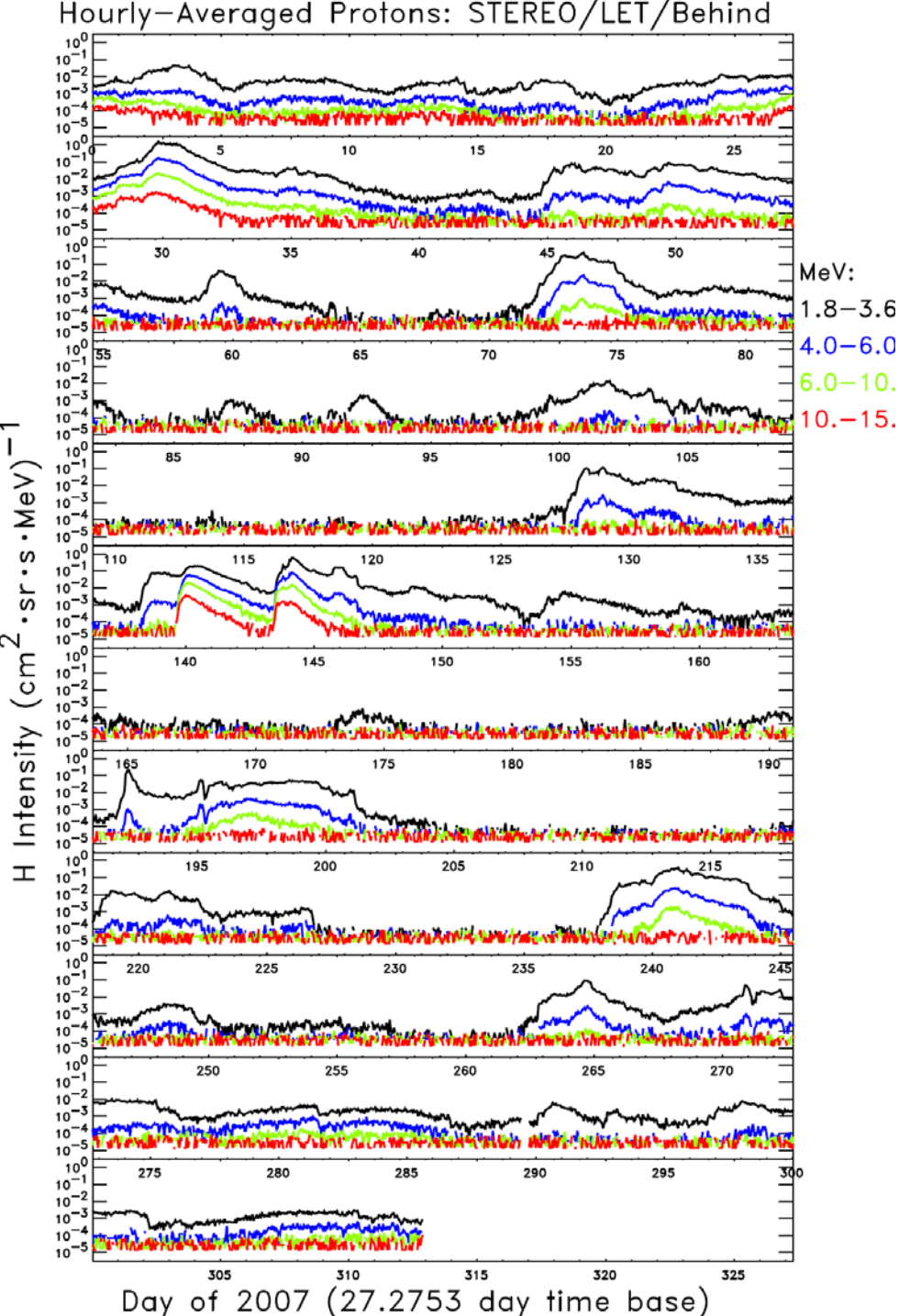


Carbon, Oxygen, and Iron spectra in the 30 Jan CIR event are shown here.

The agreement between STEREO/LET and SIT and ACE/SIS and ULEIS seems fairly good, but statistical accuracy is rather limited at high energies, which are dominated by GCRs and ACRs.



Early in the mission, the CIR time profiles as observed on Ahead and Behind agreed well with each other, but differences are becoming more apparent as the spacecraft move farther apart.



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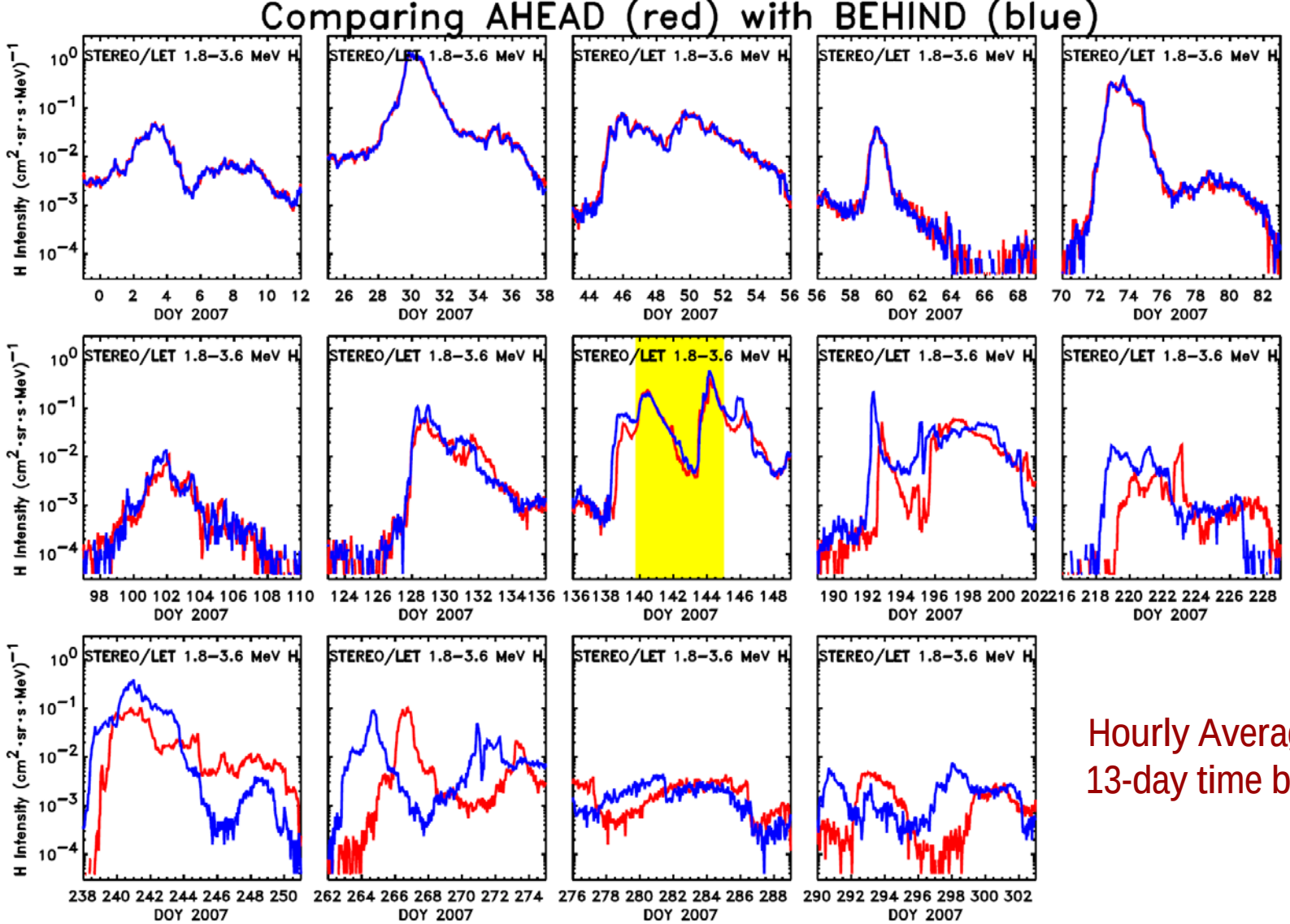
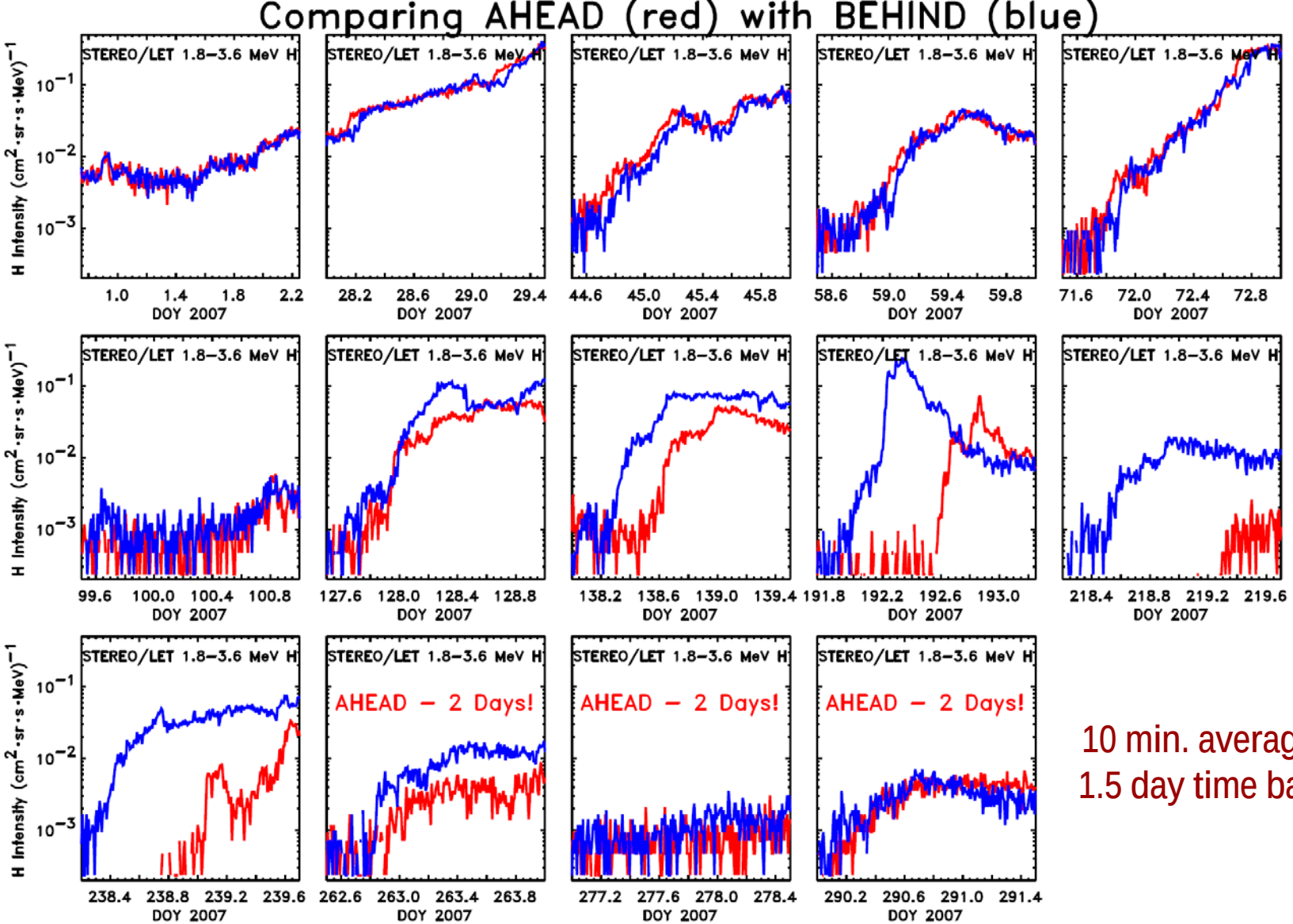


Hourly Averages
13-day time base

Early in the mission, the CIR time profiles as observed on Ahead and Behind agreed well with each other, but differences are becoming more apparent as the spacecraft move farther apart.

Sometimes the Behind-to-Ahead time differences at the start of the CIR event are different than those at the end of the event!

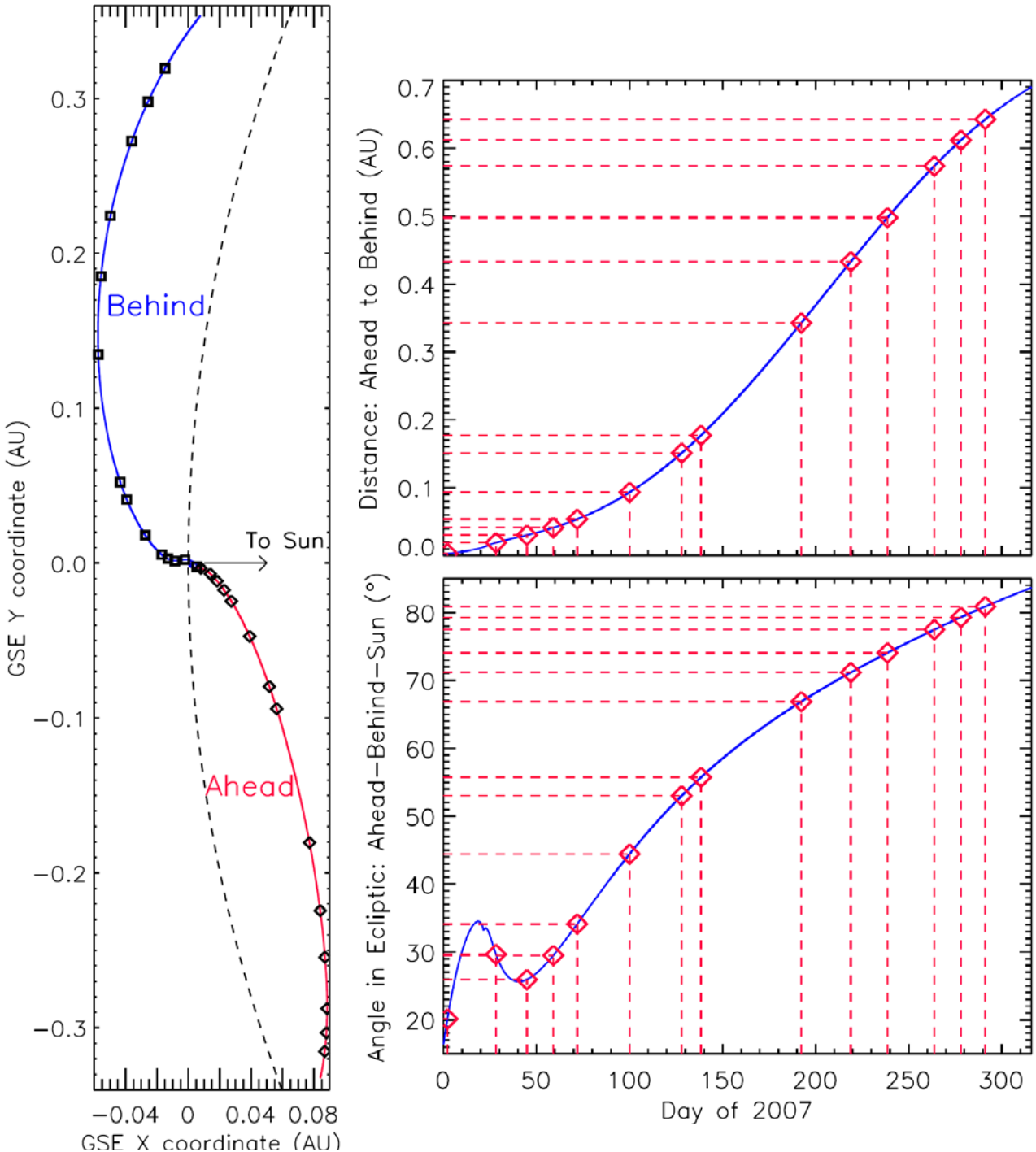
Individual features are becoming difficult to match up between the two spacecraft.



10 min. averages
1.5 day time base

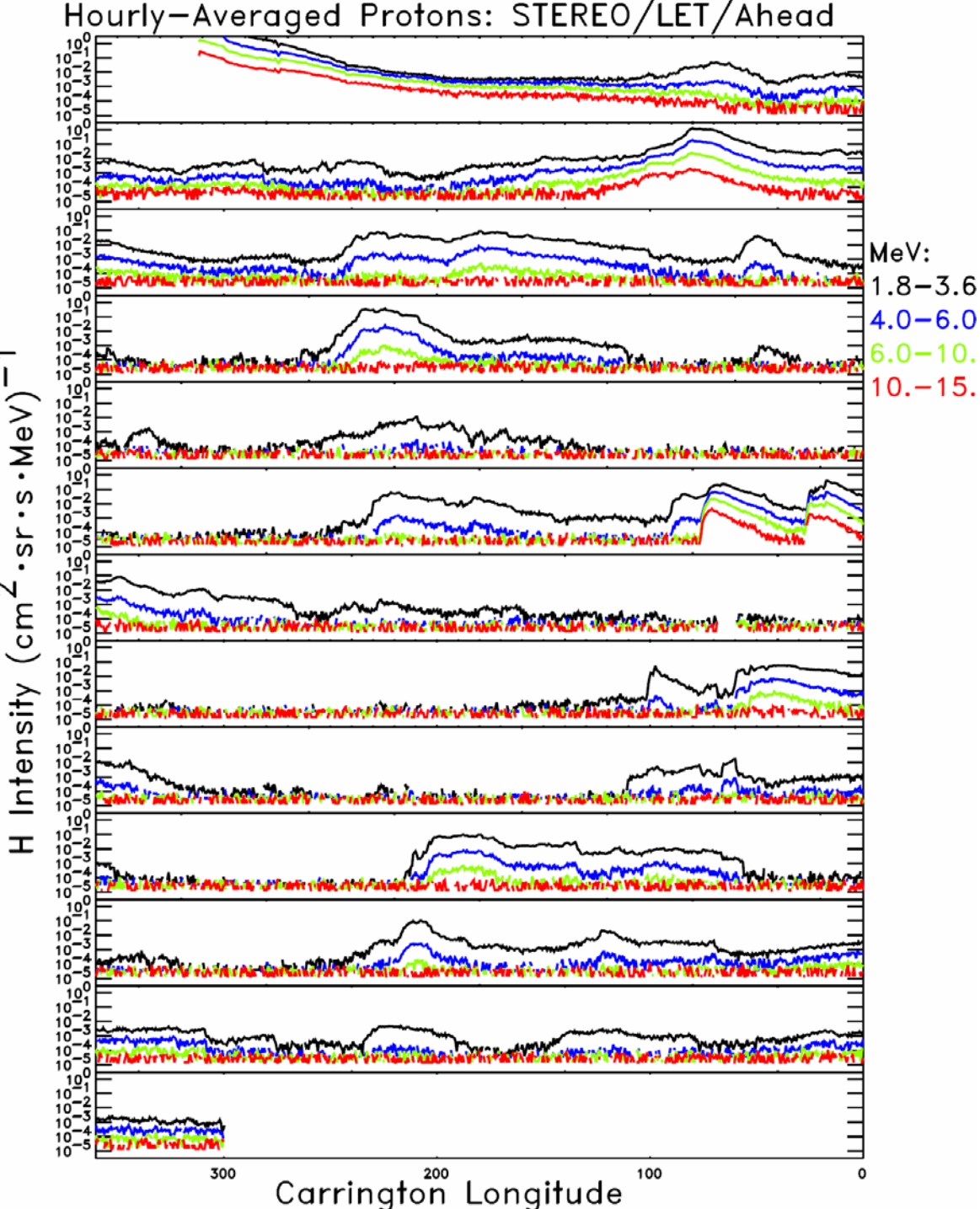
Zooming in on the CIR onsets, we see that in several of the early events particles arrived at Ahead as much as a couple of hours before being seen at Behind.

More recently, Behind is always first, sometimes by more than 2 days.



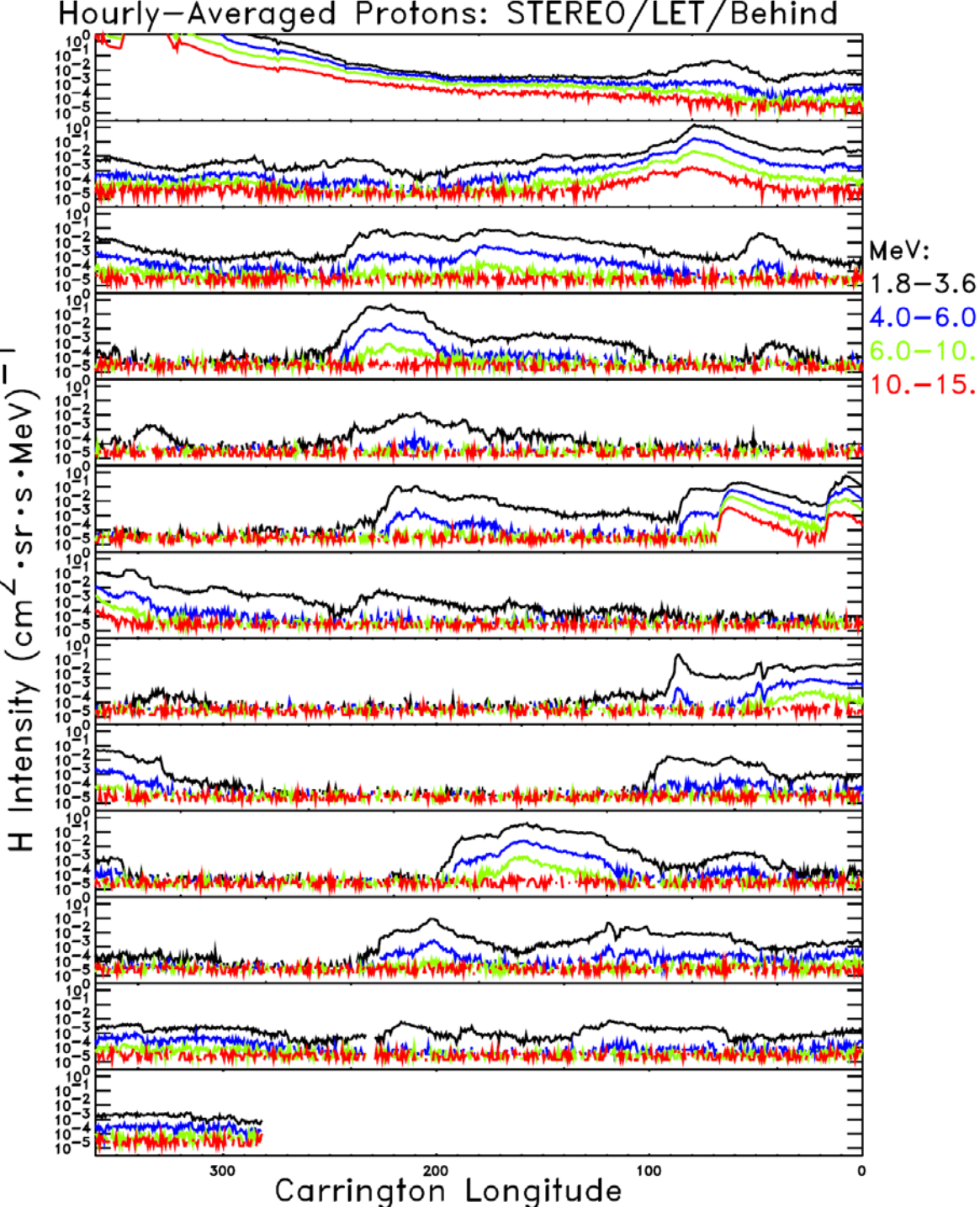
The spacecraft positions and separation for each of the 14 CIR events are shown here.

For the 1st 5 or 6 events, the Ahead-Behind-Sun angle was less than the nominal Parker spiral, so one might expect a field line to contact Ahead first (by a bit; the S/C were not far apart at this time), as observed. As the angle grows larger Behind is favored to be first.



If the spacecraft were at the same radial distance from the Sun, one might expect features to line up between the two when plotted vs. Carrington longitude.

This does NOT work, since the radial separation is significant (~0.1 AU). One should map the field lines back to the Sun and plot vs. the field line footpoint longitude.



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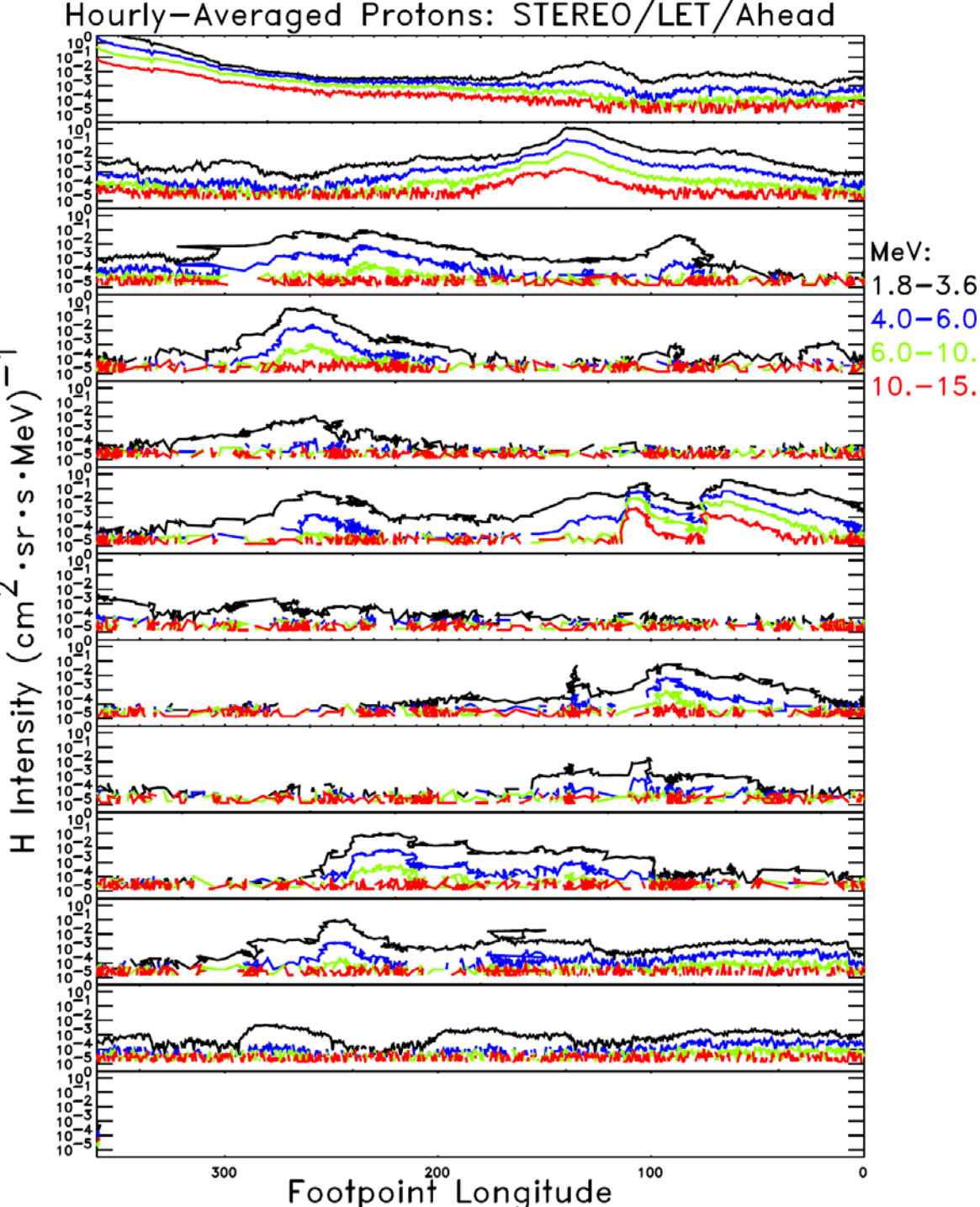
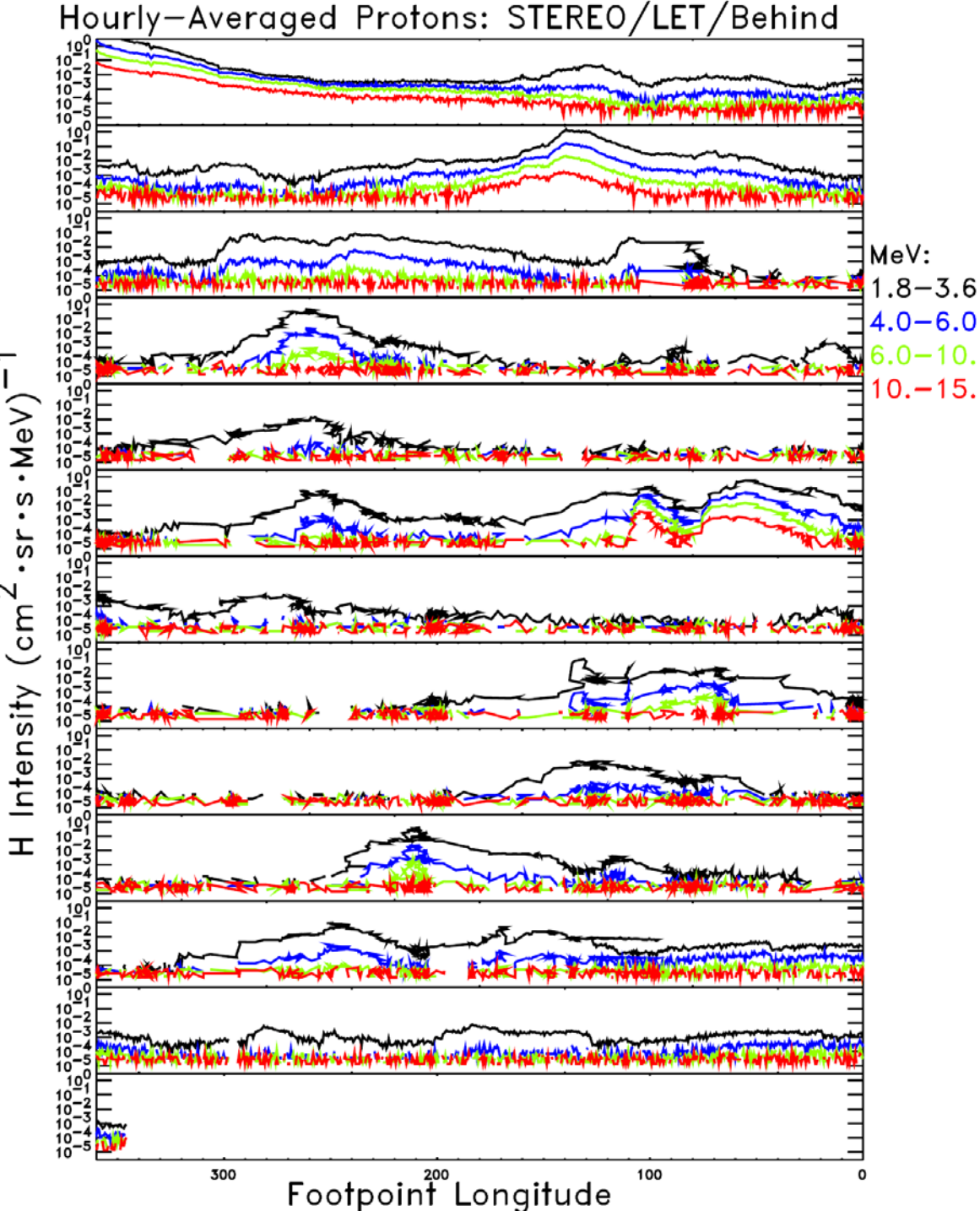


I've used solar wind velocities from STEREO/PLASTIC to calculate the footpoint longitude. However, the distortion of the time profiles is so great that it's difficult to tell if this helps or not.



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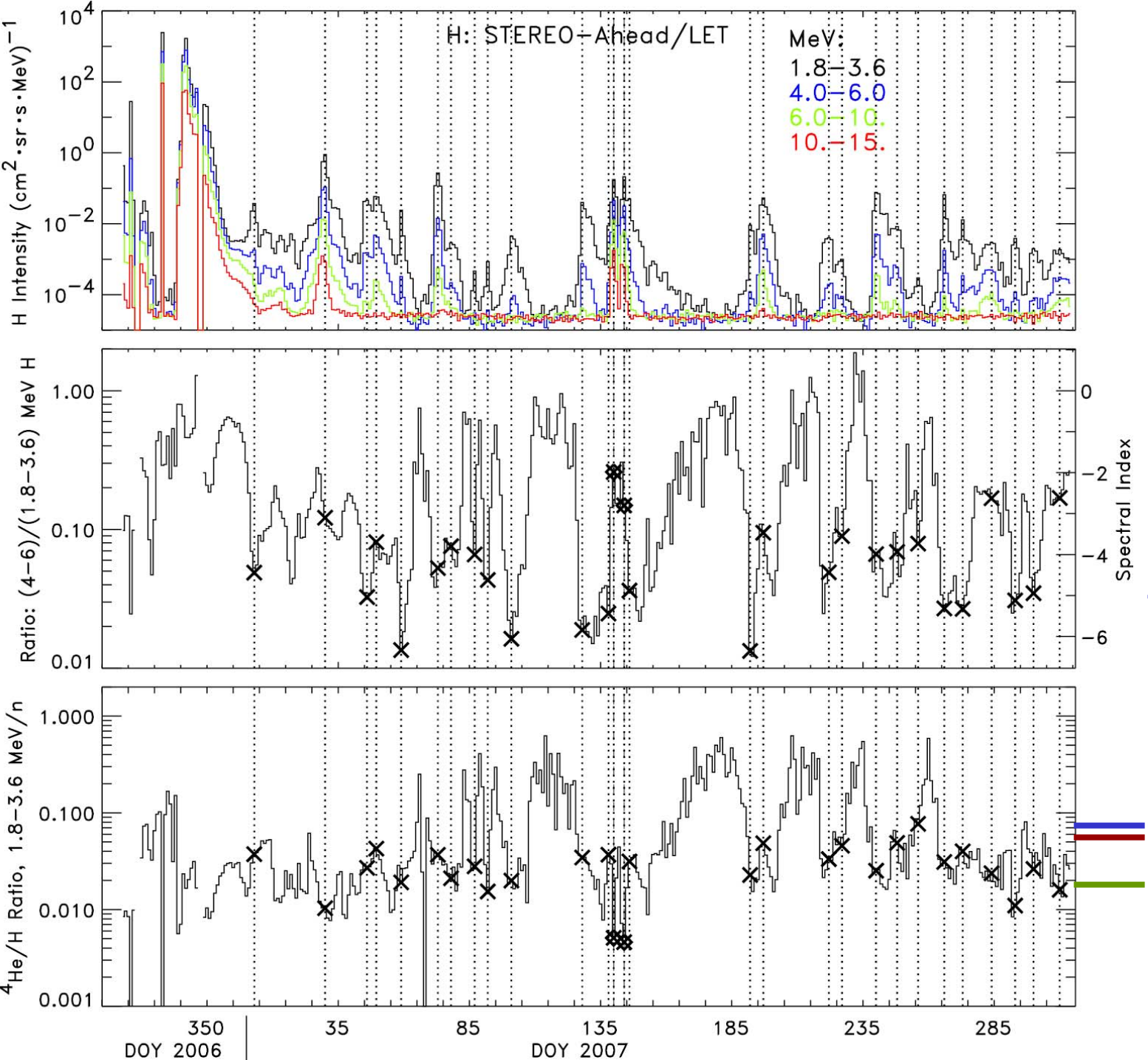
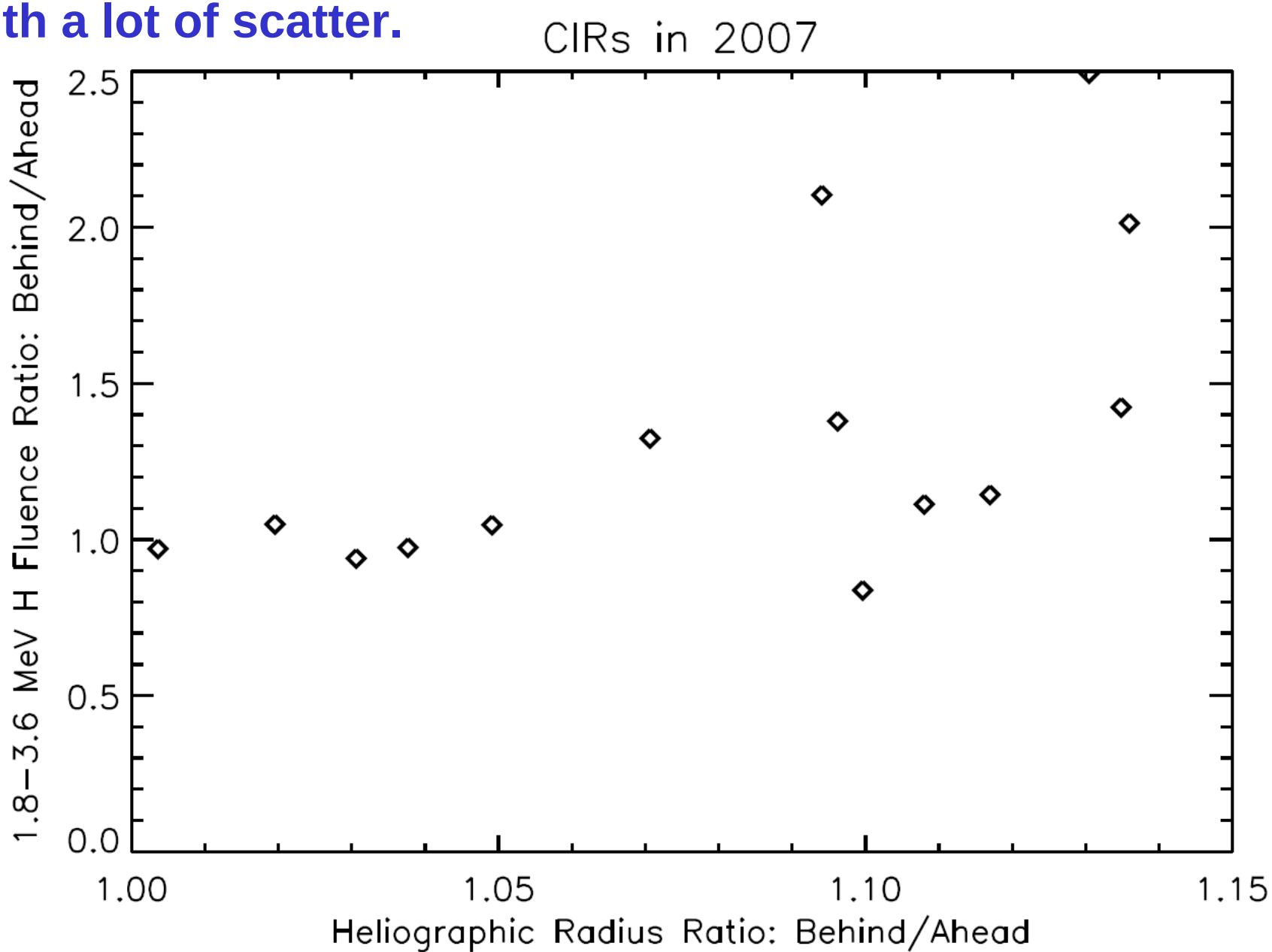


Using daily averaged LET rates, we can obtain preliminary estimates of the spectral hardness and He/H ratio.

CIRs
SW
SEPs
(from Richardson 2004)

A preliminary comparison of the Behind/Ahead CIR fluence ratios shows some indication of a positive radial gradient, with a lot of scatter.



Summary/Conclusions

- **CIRs are a regular occurrence now at solar minimum.**
- **LET and SIT on STEREO are functioning well.**
  - **Some calibration issues remain to be worked out, but preliminary results are in good agreement with each other, with SEPT, and with similar instruments on ACE.**
- **Differences in the particle environments at Ahead and Behind are very apparent, now that the spacecraft are ~0.7 AU (or 40 degrees) apart.**
- **Clear timing differences between Ahead and Behind are now routinely seen in the onsets of CIRs, but other details of the time profiles are already difficult to compare in the two locations.**
  - **The time differences expected from the S/C positions and B-field angles sometimes agree (at least in sign) with those observed, but large variations in the B-field direction and the great sensitivity of the time differences to this direction make quantitative predictions of the time lags problematic.**
- ***Preliminary looks at spectral hardness, He/H composition, and radial gradients show:***
  - ***The index from 1.8-6 MeV (for H) is very soft, ~-4 to -6***
  - ***He/H is perhaps lower than expected, but this may be energy-dependent***
  - ***Intensities tend to be higher at Behind, which is farther from the Sun than Ahead***