In-situ Observations of CIRs on STEREO and ACE during 2007-2008

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STEREO SWG #19
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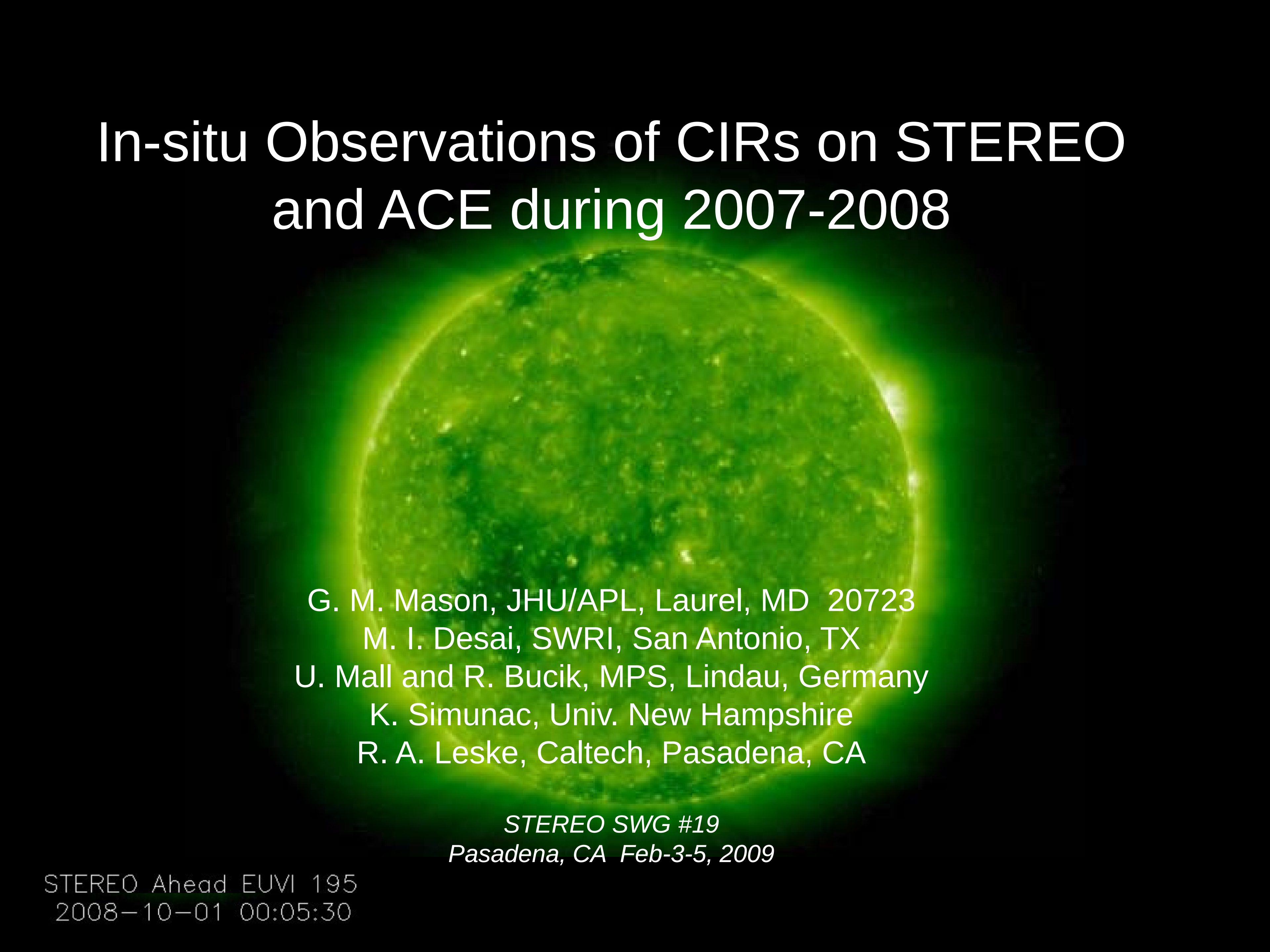
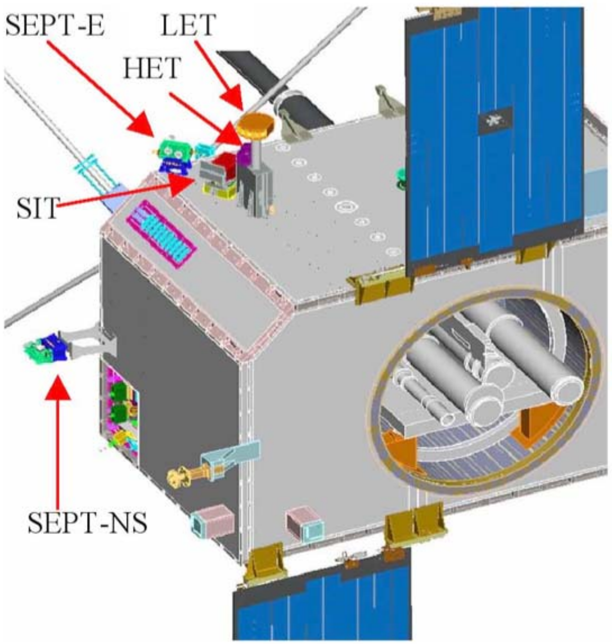
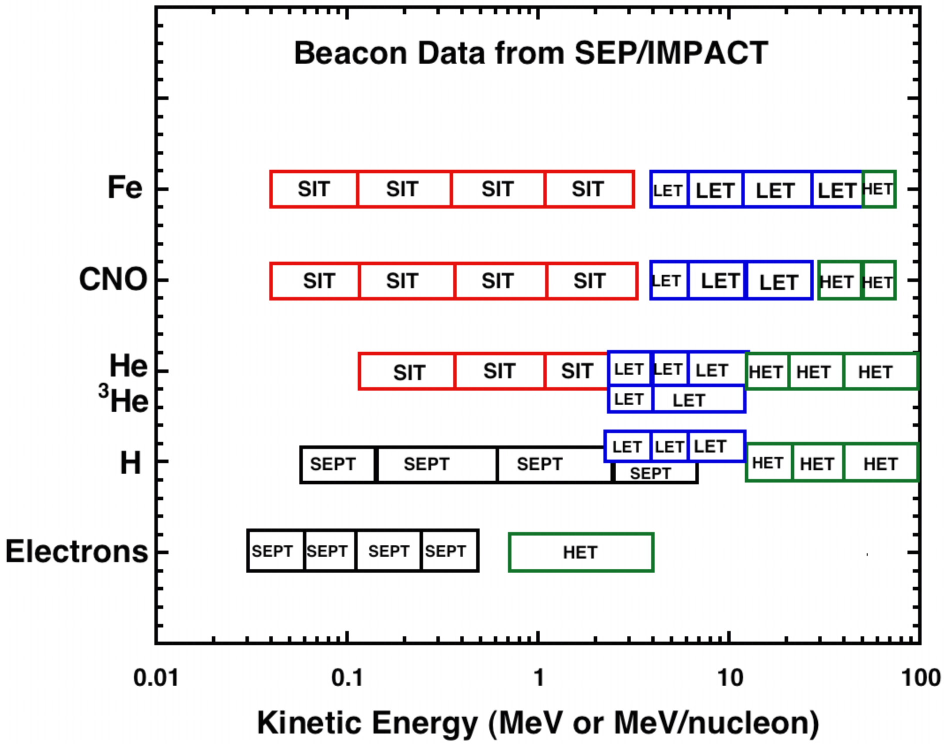


Solar Enegetic Particle (SEP) package -

(Part of the IMPACT suite, J. Luhmann, PI)

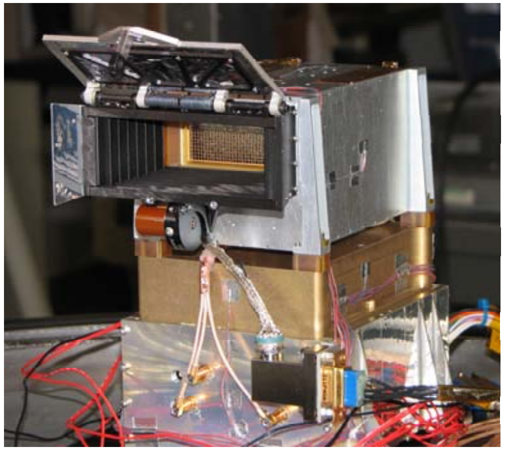


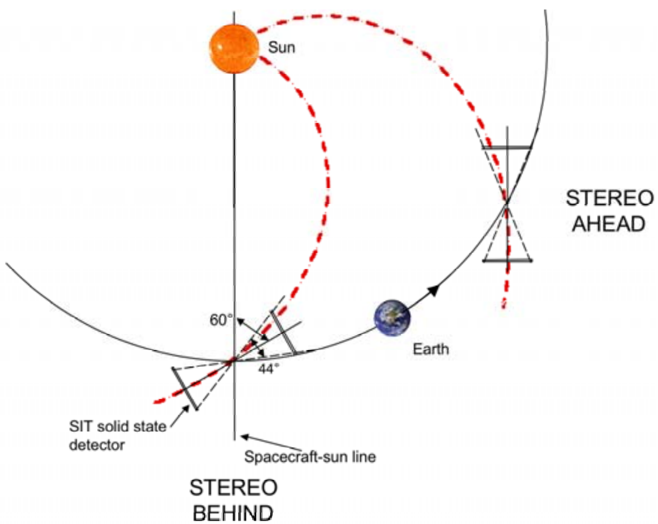
(SEP package on STEREO-A)

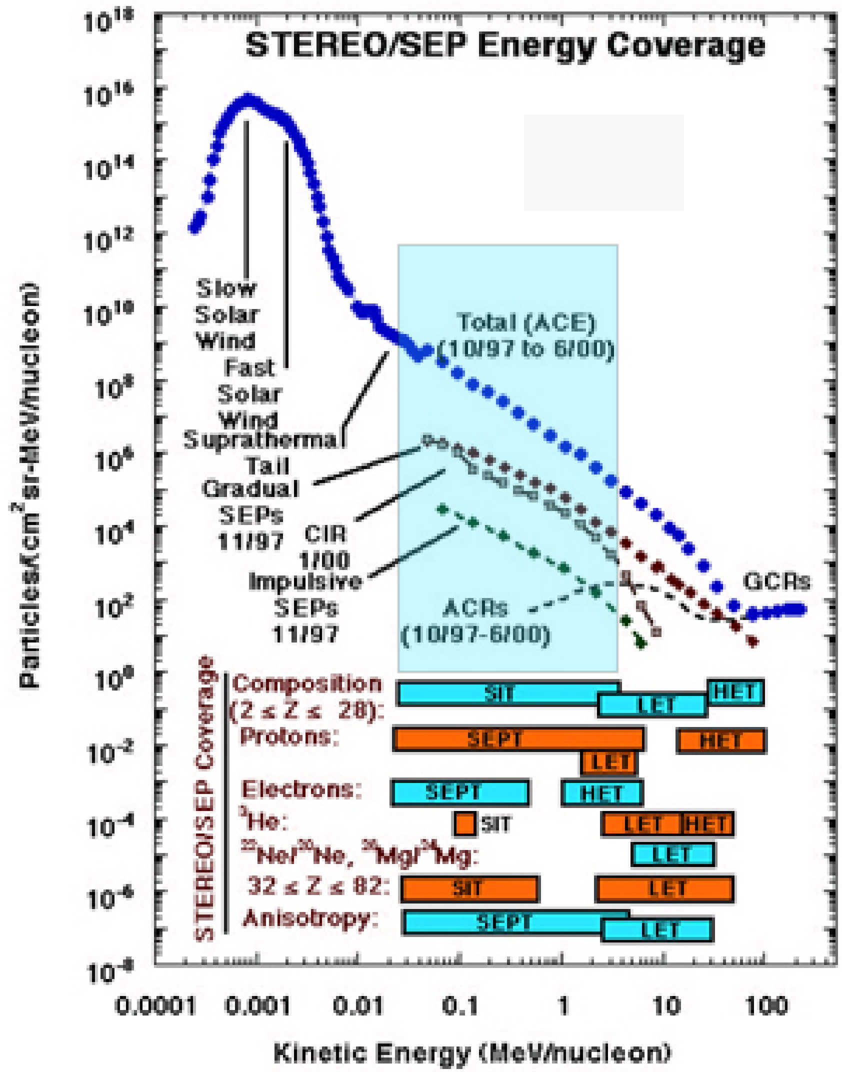


figures from Mewaldt et al., SSR, 136, 285, 2008

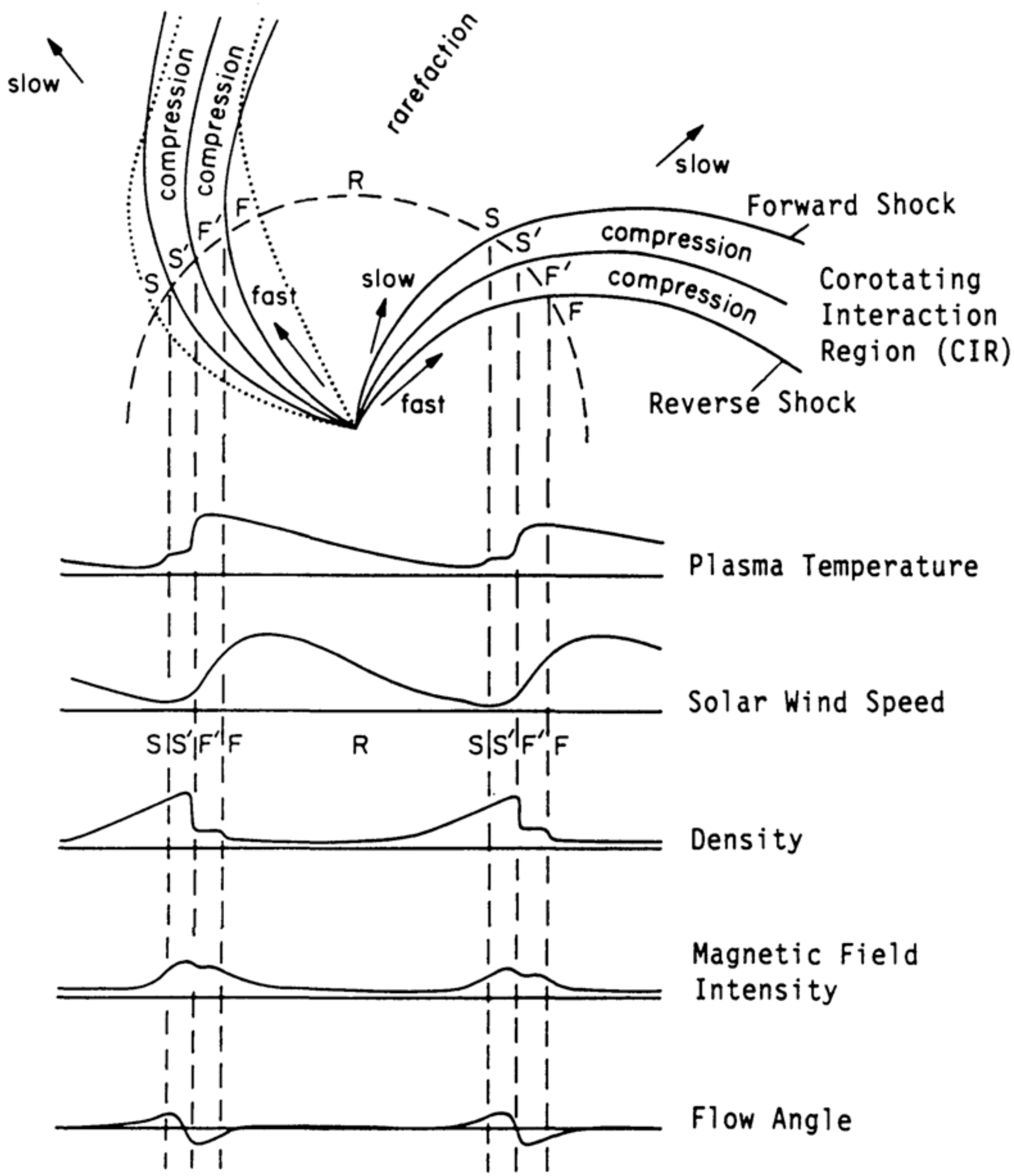
Suprathermal Ion Telescope - SIT:







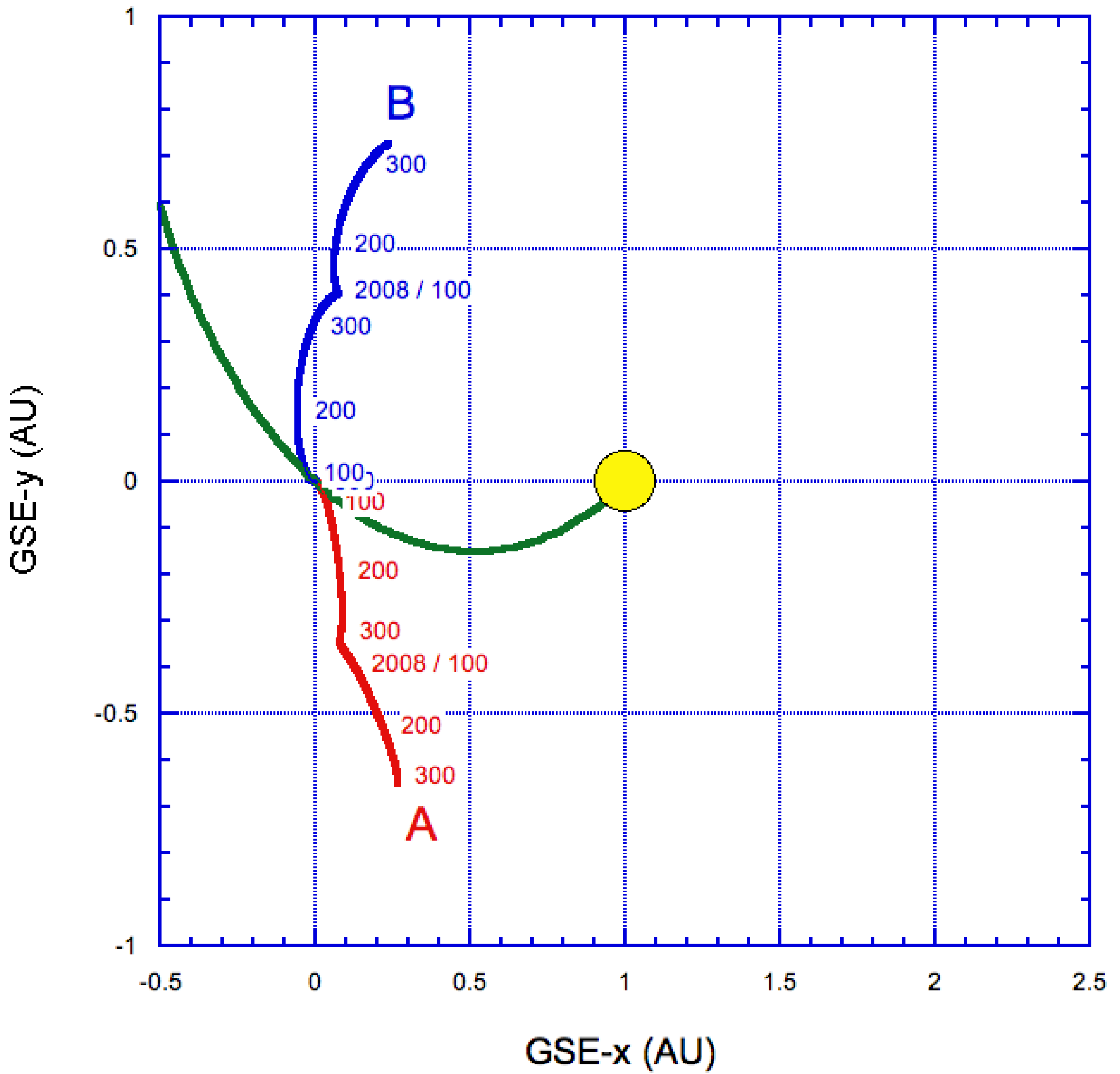
instrument description: Mason et al., SSR, 136, 257, 2008.

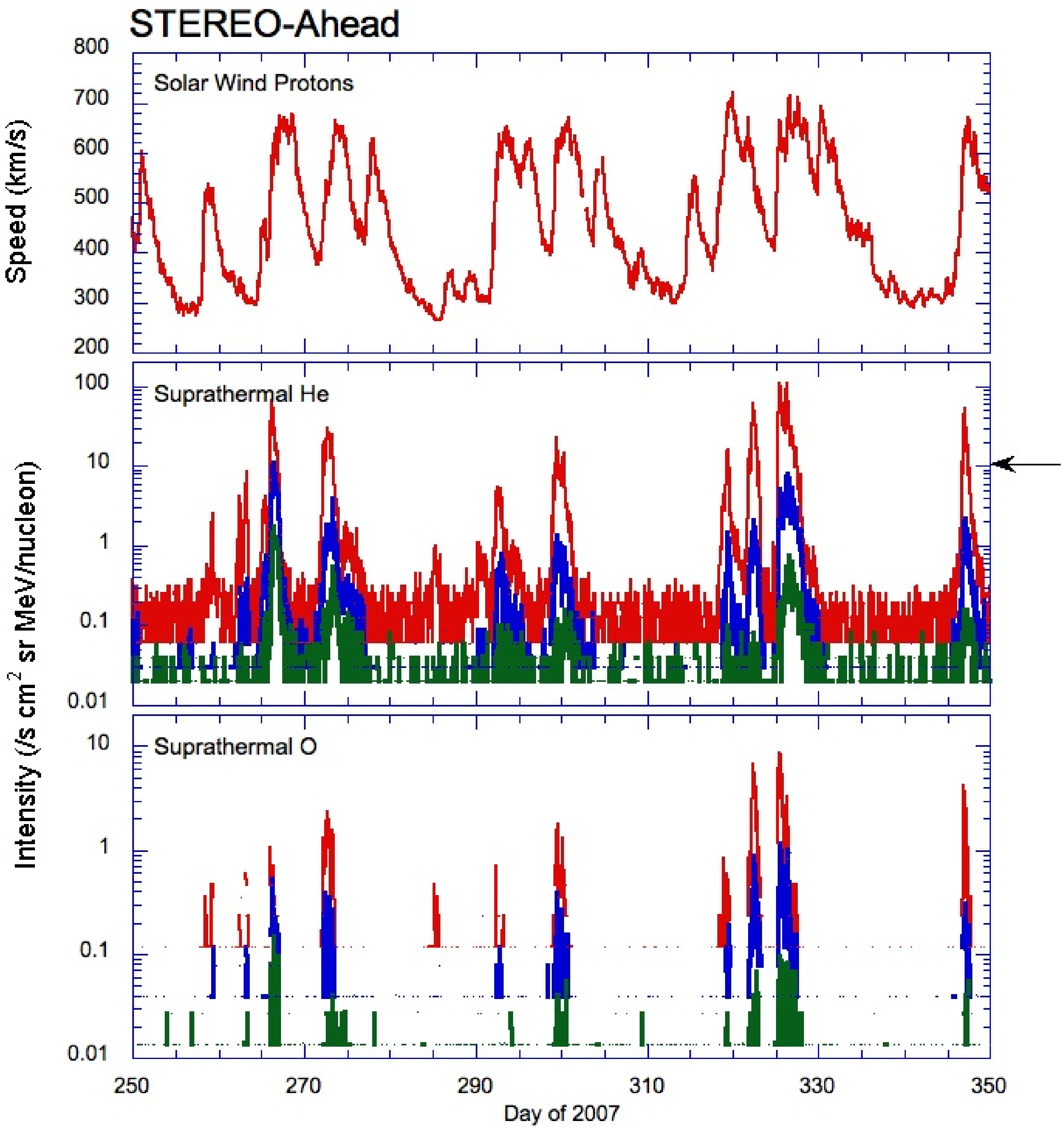


Solar wind and magnetic field signatures of CIRs

Richardson et al. 1993, after Belcher & Davis 1971

STEREO positions through 2008/343
with 650 km/s spiral field line





top panel: plastic sw proton speed

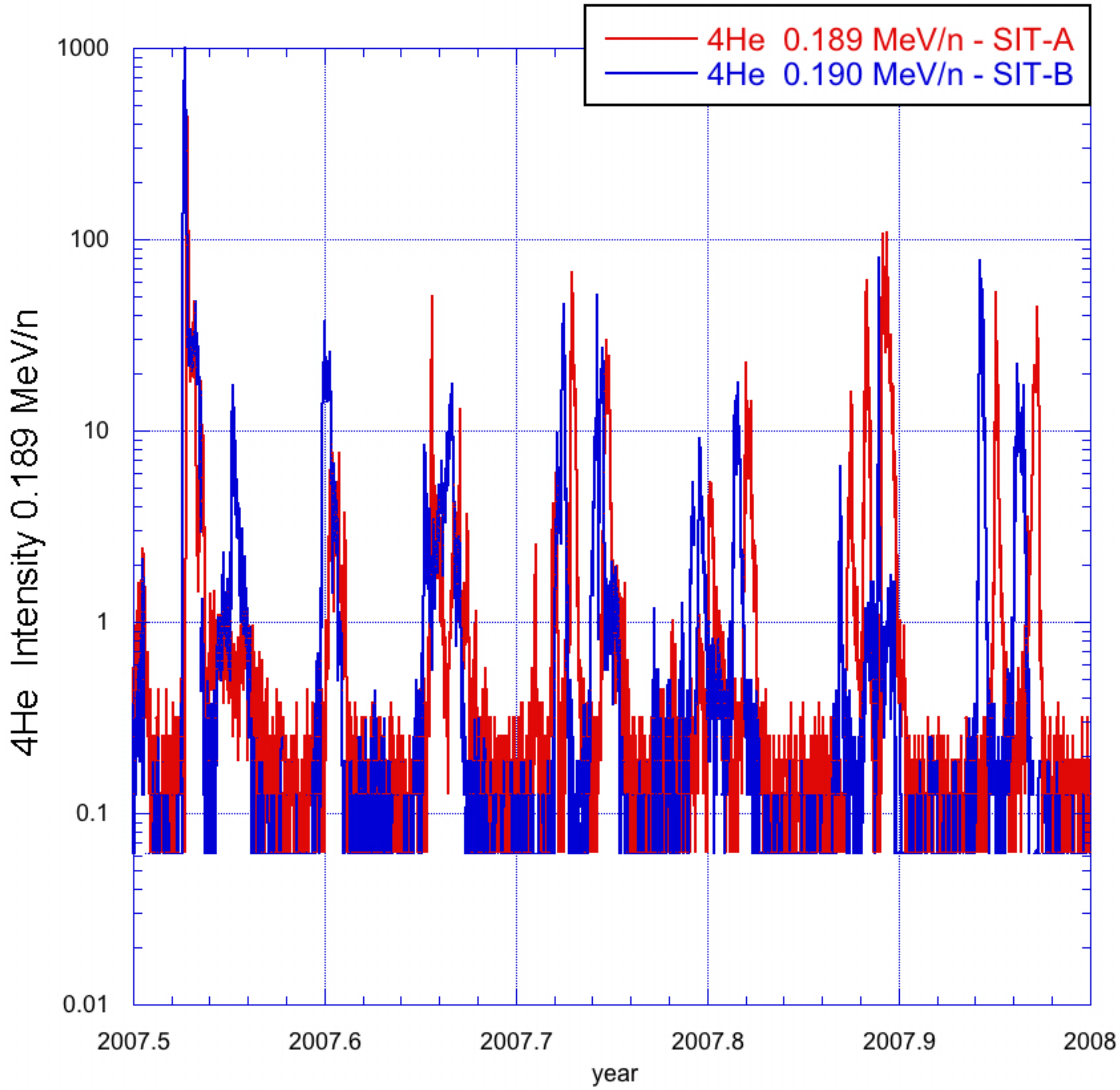
middle panel: SIT He, for 189, 384, and 787 keV/nucleon

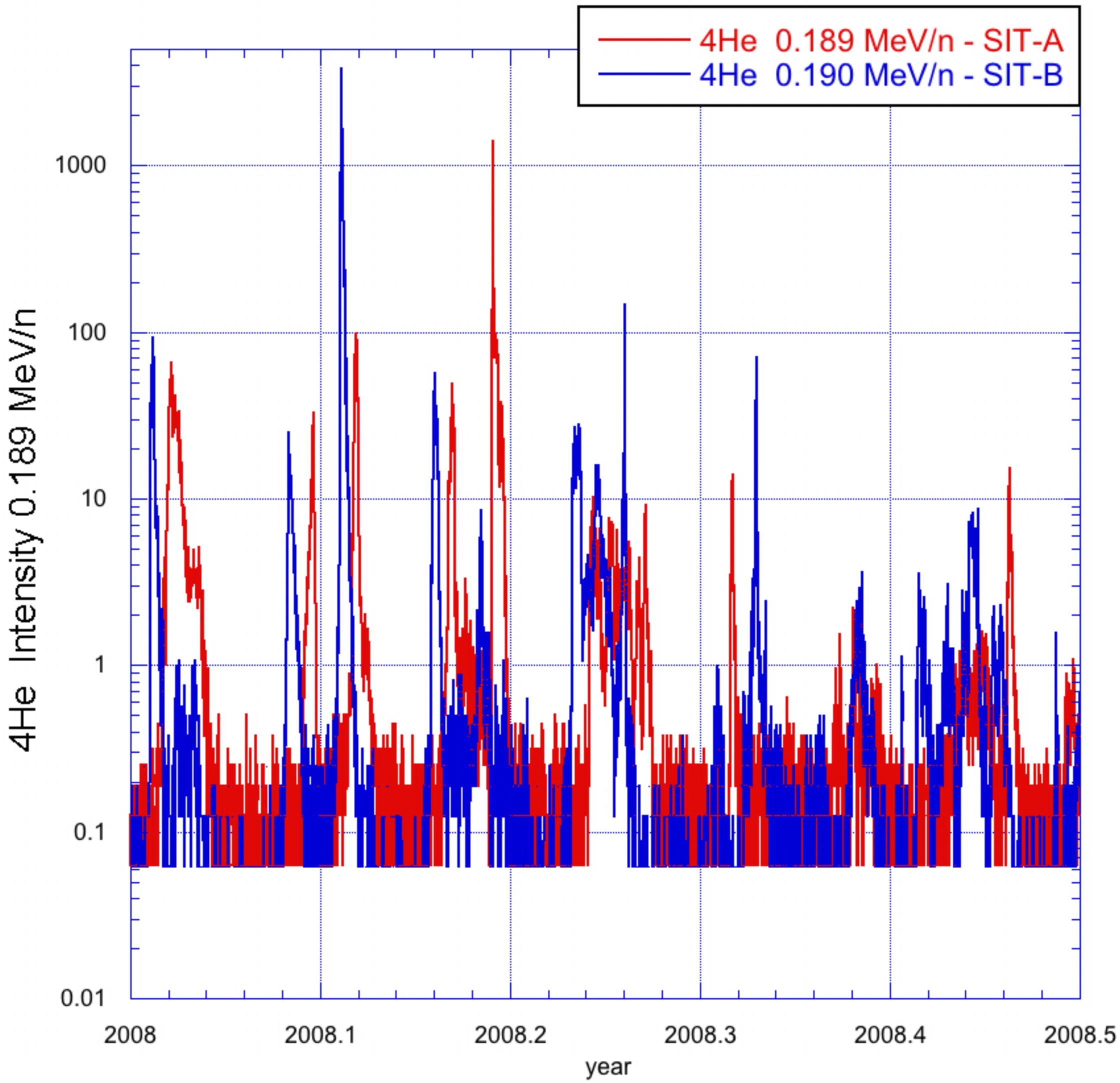
arrow marks selection threshold

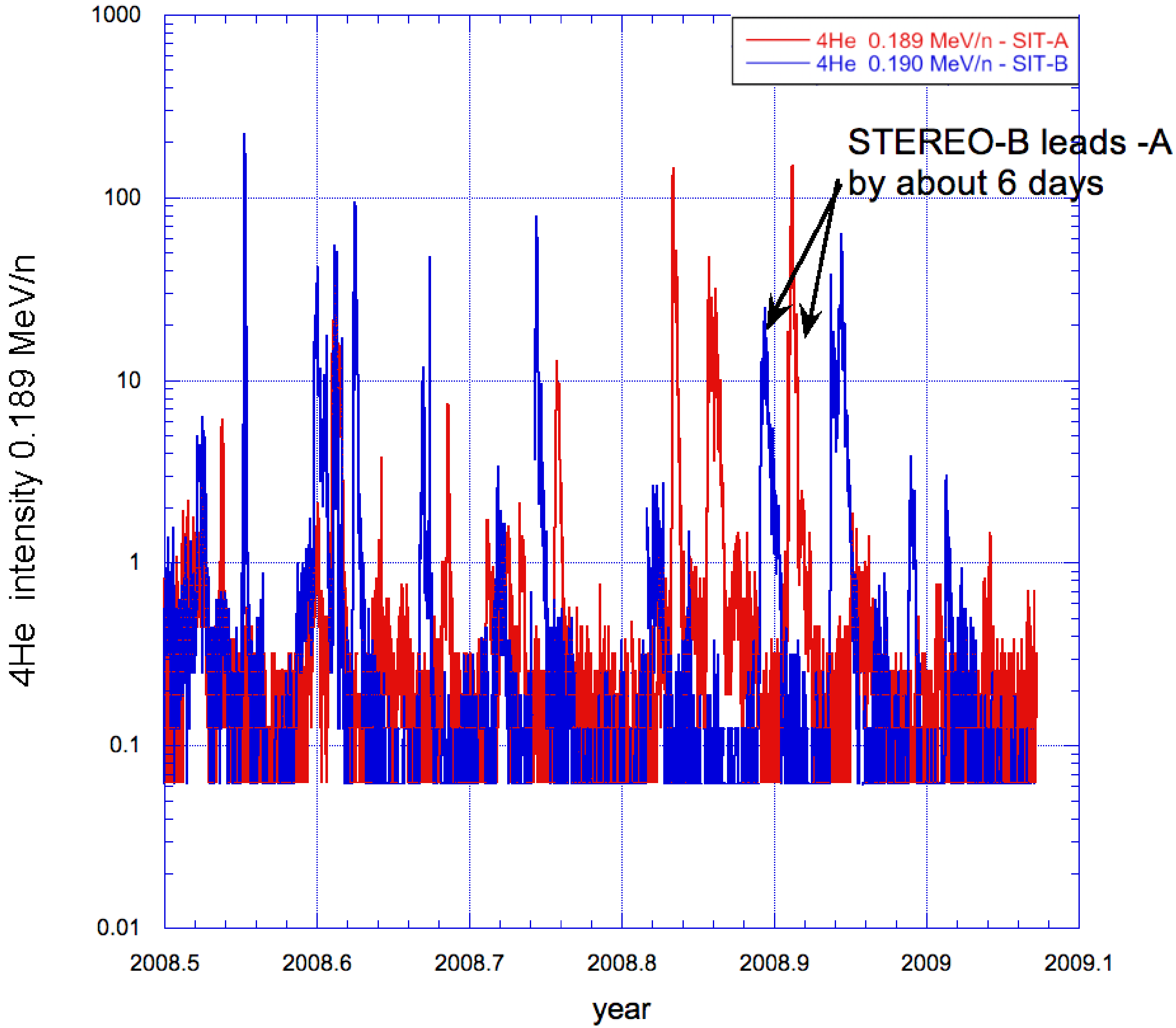
figure shows events 15-21 in Table 1. Note increases starting on days 258, 261,284 and 291 are below the selection threshold and so are not in the table

bottom panel: SIT O for 67, 136, and 266 keV/nucleon

note high speed streams with no suprathermals around day 305, 315, and 330


4He 0.189 MeV/n - SIT-A
4He 0.190 MeV/n - SIT-B
4He Intensity 0.189 MeV/n
1000
100
10
1
0.1
0.01
2007.5
2007.6
2007.7
2007.8
2007.9
2008
year

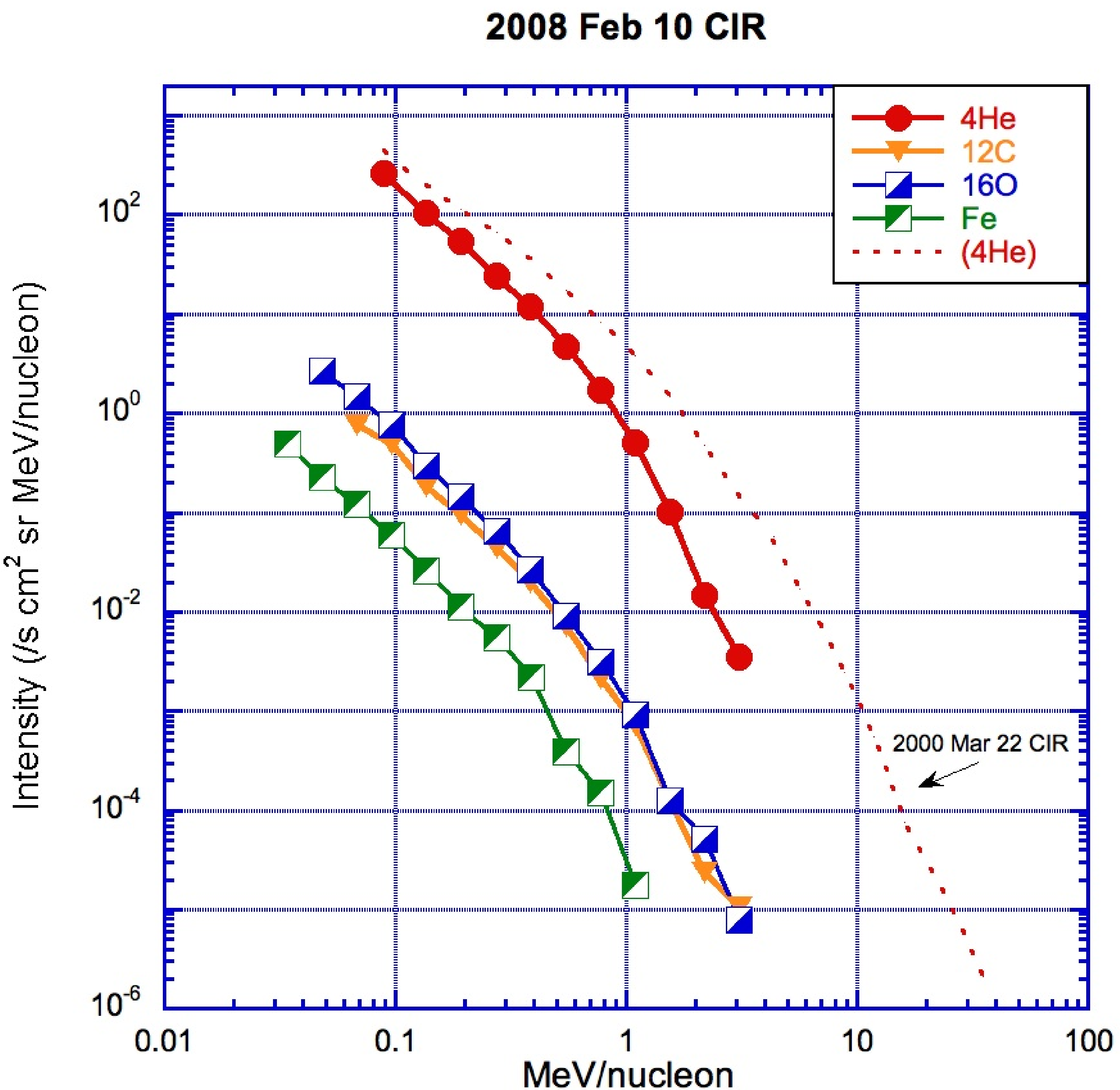

4He 0.189 MeV/n - SIT-A
4He 0.190 MeV/n - SIT-B
4He Intensity 0.189 MeV/n
1000
100
10
1
0.1
0.01
2008
2008.1
2008.2
2008.3
2008.4
2008.5
year



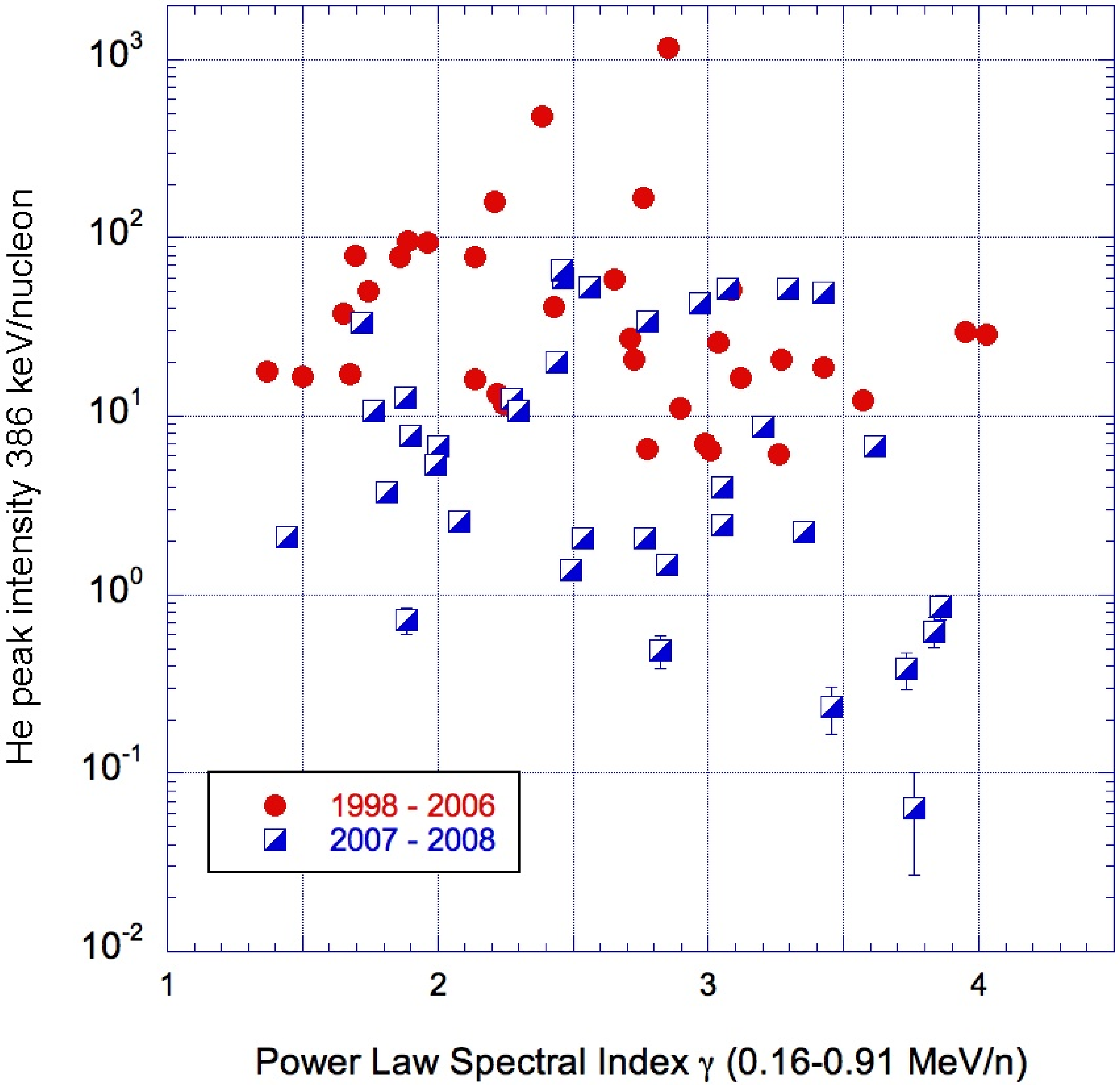
4He 0.189 MeV/n - SIT-A
4He 0.190 MeV/n - SIT-B
STEREO-B leads -A
by about 6 days
4He intensity 0.189 MeV/n
1000
100
10
1
0.1
0.01
2008.5
2008.6
2008.7
2008.8
2008.9
2009
2009.1
year

CIR #	Angle ¡ (a)	SIT-A StartÉ Stop Day of year	ULEIS StartÉ Stop Day of year	SIT-B StartÉ Stop Day of year	ULEIS peak intensity (b)	ULEIS spectral index (c)	Notes
2007							
1	0.6	29.0É31.0	29.5É31.5	29.0É31.0	5.3E+1±1.9E+0	2.56±0.01	d,e
2	0.8	44.0É46.0	44.0É46.0	44.0É46.0	1.3E+1±5.3E-1	2.28±0.01	d,e
3	1.2	58.5É61.0	58.5É61.0	58.5É61.0	2.0E+1±6.8E-1	2.44±0.01	d,e
4	1.8	72.0É75.0	72.0É75.0	72.0É75.0	3.3E+1±9.1E-1	1.72±0.01	d,e
5	3.2	91.0É94.0	91.0É94.0	91.0É94.0	2.2E+0±2.2E-1	3.36±0.03	
6	3.9	98.5É104.0	98.5É104.0	98.5É104.0	2.1E+0±2.1E-1	2.77±0.02	
7	7.4	127.5É1 33.0	127.5É1 33.0	127.5É1 33.0	5.9E+1±1.8E+0	2.46±0.01	d
8	8.8	138.0É1 42.0	138.0É1 42.0	138.0É1 42.0	6.7E+0±3.8E-1	2.00±0.01	d
9	9.7	144.0É1 47.0	144.0É1 47.0	144.0É1 47.0	3.4E+1±1.4E+0	2.77±0.01	
10	11.5	154.0É1 59.0	154.0É1 59.0	154.0É1 59.0	8.7E+0±4.4E-1	3.20±0.02	
11	18.6	192.0É1 95.0	192.0É1 95.0	191.5É1 95.5	5.2E+1±2.1E+0	3.07±0.01	
12	20.7	202.0É2 06.0	202.0É2 06.0	201.0É2 05.0	3.8E-1±9.0E-2	3.73±0.08	f
13	24.0	219.0É2 22.0	219.0É2 22.0	218.0É2 21.0	2.1E+0±2.1E-1	2.54±0.02	
14	28.3	239.0É2 47.0	238.0É2 46.0	237.5É2 46.0	2.1E+0±2.2E-1	1.44±0.03	
15	32.5	264.0É2 68.0	264.0É2 67.0	262.0É2 66.0	1.1E+1±4.8E-1	2.30±0.02	
16	33.7	271.5É2 74.0	270.5É2 74.0	269.5É2 72.0	2.6E+0±2.4E-1	2.08±0.02	
17	37.6	298.5É3 02.0	298.0É3 01.0	297.5É3 00.0	6.8E+0±4.1E-1	3.62±0.02	
18	39.9	318.0É 321.0	317.0É3 21.0	316.5É3 19.0	8.5E-1±1.3E-1	3.86±0.06	
19	40.2	321.5É3 23.5	321.5É3 23.5	320.5É3 24.0	6.4E-2±3.7E-2	3.76±0.34	
20	40.5	325.0É3 28.0	324.0É3 27.0	324.0É3 28.0	5.2E+1±2.4E+0	3.30±0.01	
21	42.1	346.0É3 49.0	344.0É3 47.0	343.0É3 46.0	4.0E+0±2.9E-1	3.05±0.02	
22	42.6	353.0É3 56.0	351.0É3 55.0	350.0É3 54.0	4.3E+1±1.8E+0	2.97±0.01	
2008							
23	43.7	6.0É15.0	4.5É15.0	3.5É13.0	1.3E+1±5.3E-1	1.88±0.01	
24	44.6	33.0É36.0	31.5É35.0	29.5É33.5	3.7E+0±2.8E-1	1.81±0.02	
25	45.0	42.5É45.0	41.0É45.0	40.0É43.0	6.6E+1±2.1E+0	2.46±0.01	
26	45.7	61.0É63.0	58.0É62.0	57.5É60.0	7.7E+0±4.1E-1	1.90±0.02	
27	46.1	69.5É73.0	69.0É71.0	67.0É70.0	2.4E+0±2.3E-1	3.05±0.04	
28	47.2	88.0É91.5	86.0É90.0	85.0É87.0	5.4E+0±3.5E-1	1.99±0.02	
29	48.0	98.0É101.0	96.0É99.5	94.0É97.0	1.5E+0±1.8E-1	2.85±0.04	
30	49.5	115.5É1 17.4	113.5É1 15.5	112.0É1 14.5	6.2E-1±1.2E-1	3.84±0.08	g
31	57.1	168.5É1 71.0	167.0É1 71.0	165.5É1 69.0	7.2E-1±1.2E-1	1.89±0.05	
32	67.2	224.0É2 28.0	222.0É2 26.0	220.0É2 24.0	4.9E+1±2.1E+0	3.43±0.01	
33	69.1	234.0É2 38.0	231.0É2 37.0	229.0É2 32.0	2.4E-1±7.1E-2	3.45±0.08	h
34	71.9	250.5É2 54.0	247.5É2 50.5	245.5É2 49.0	4.9E-1±1.0E-1	2.82±0.07	
35	76.7	277.5É2 82.0	275.0É2 80.0	272.0É2 77.0	1.1E+1±4.9E-1	1.76±0.01	
36	80.6	305.5É3 09.0	302.5É3 05.	299.0É3 05.0	1.4E+0±1.7E-1	2.49±0.04	

Spectral forms: broken power law--

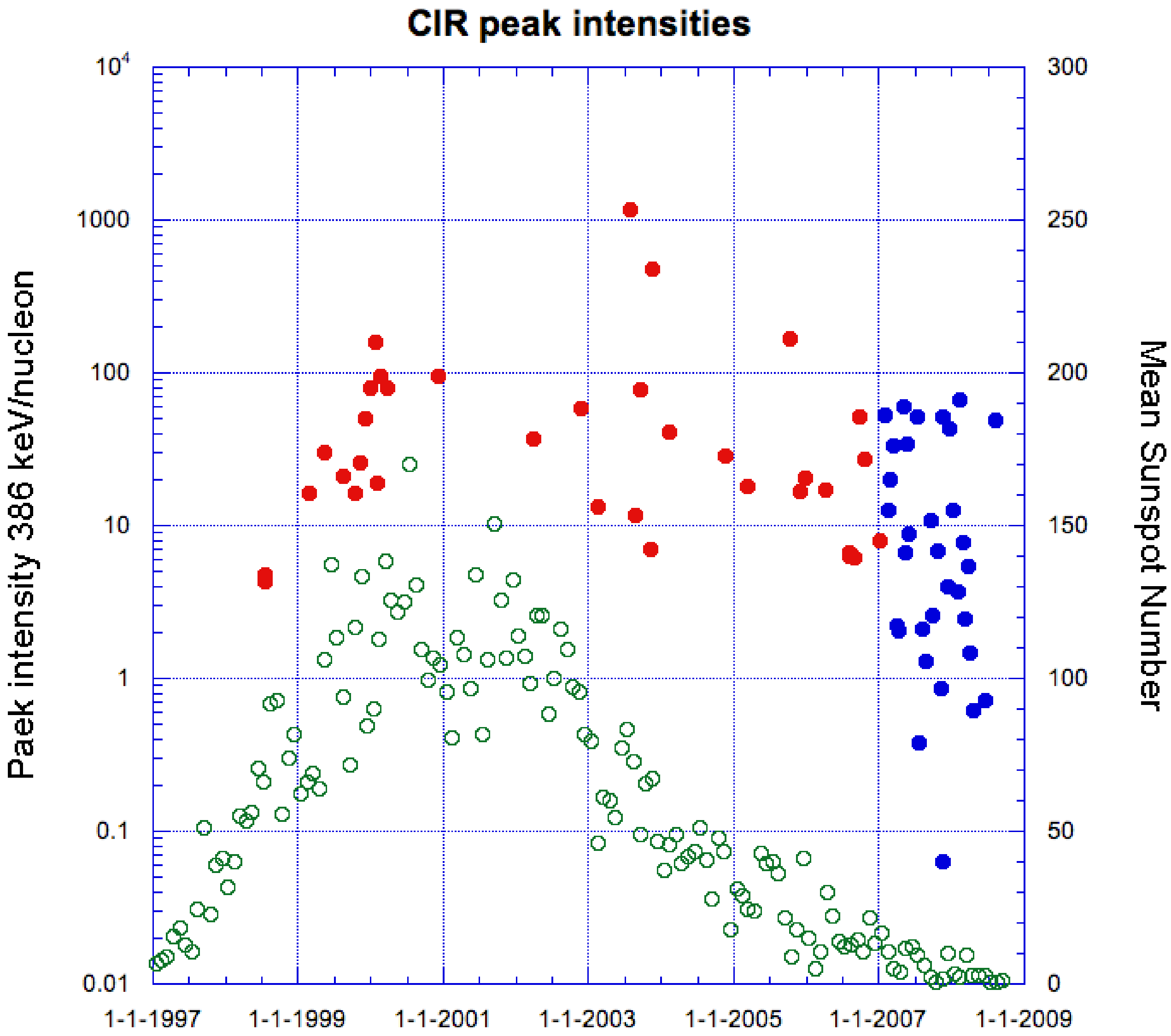


SIT-B



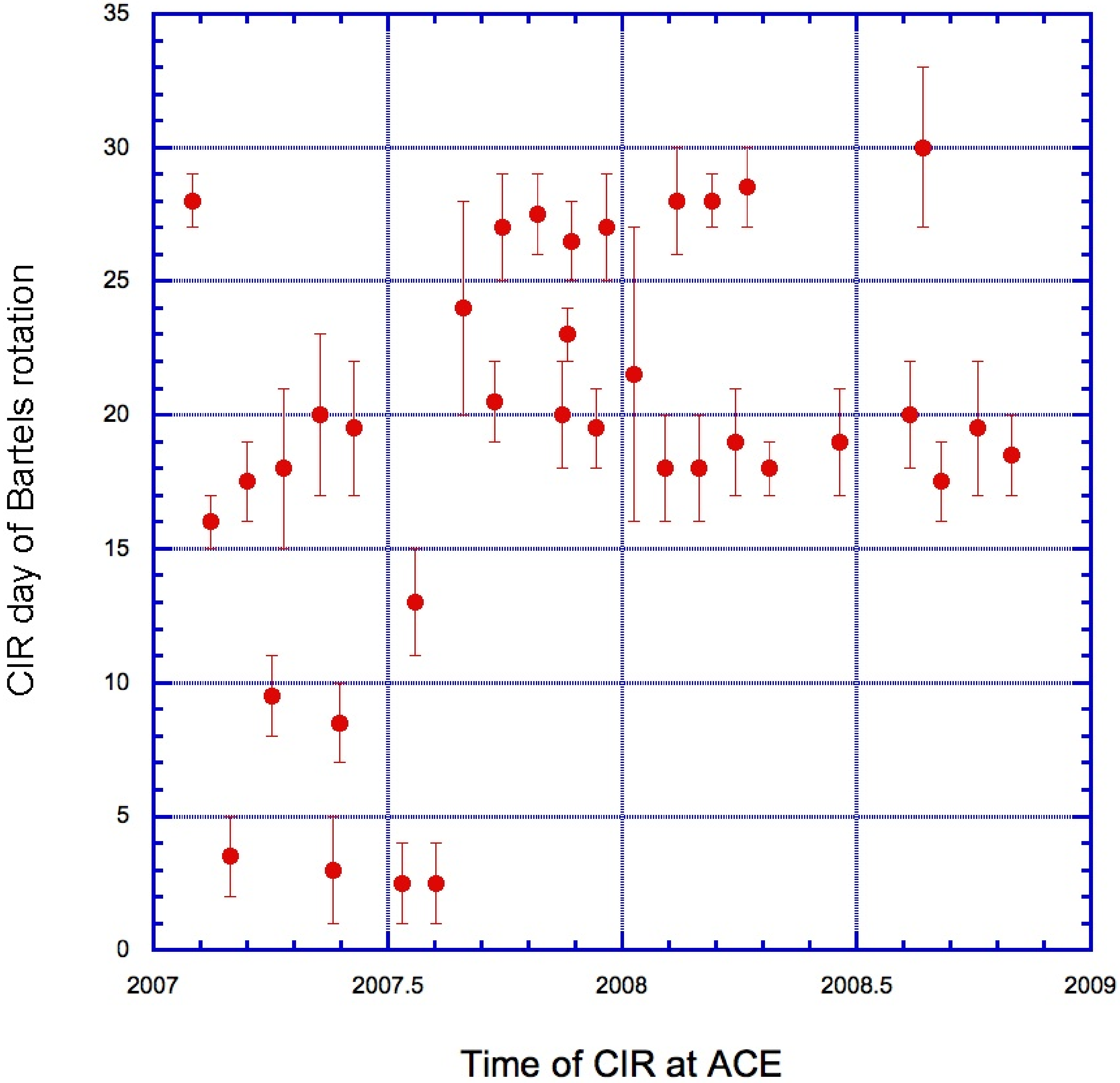
Peak intensity:

- *during ACE survey over recent solar maximum, peak He intensities (386 kev/n) did not correlate with the 160-910 keV/n spectral index*



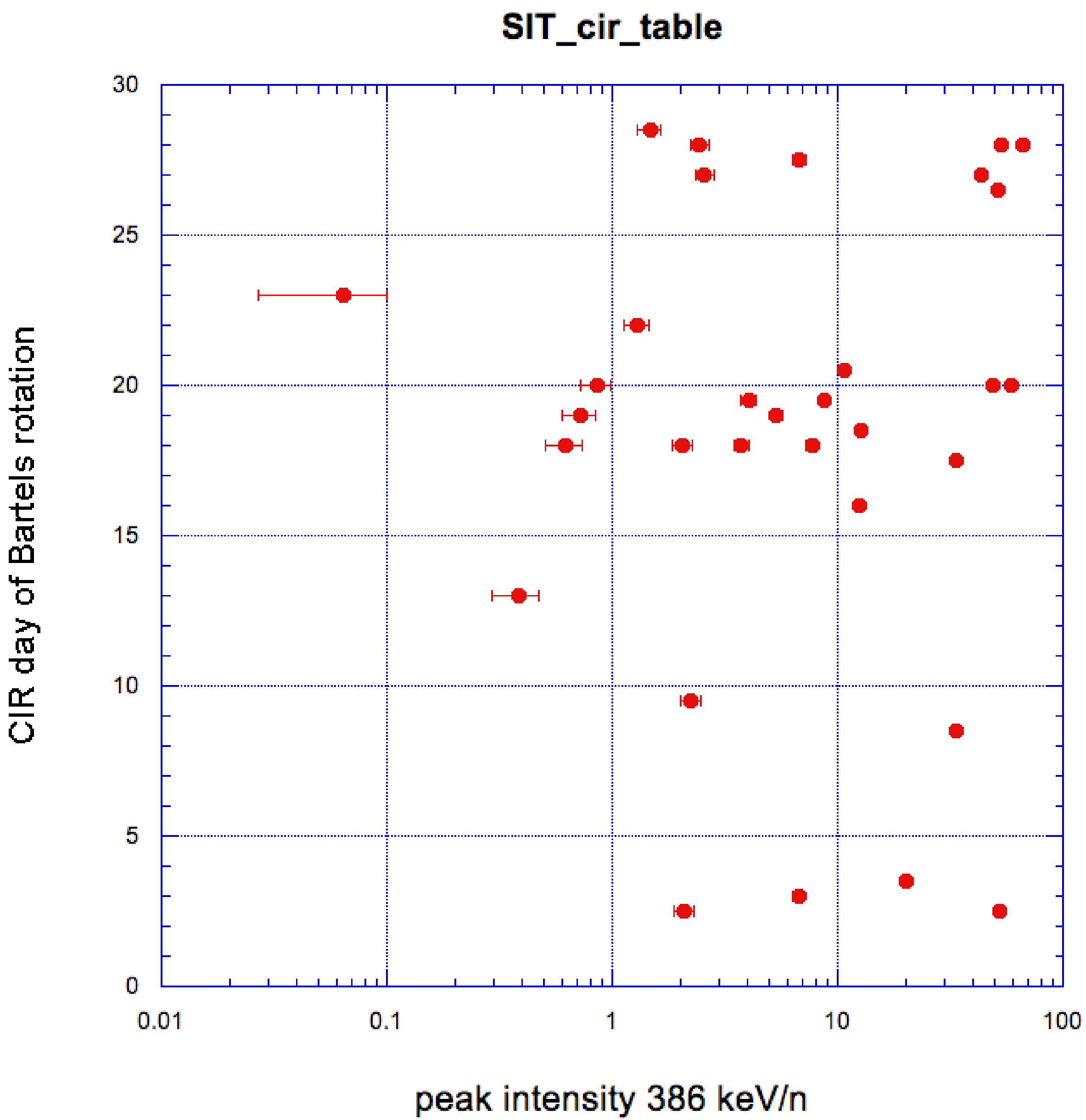
Event sizes:

- *largest ones during 2007-08 as large as all but a few during recent solar activity maximum*
- *smaller events included in present survey might not have been seen earlier due to other activity*



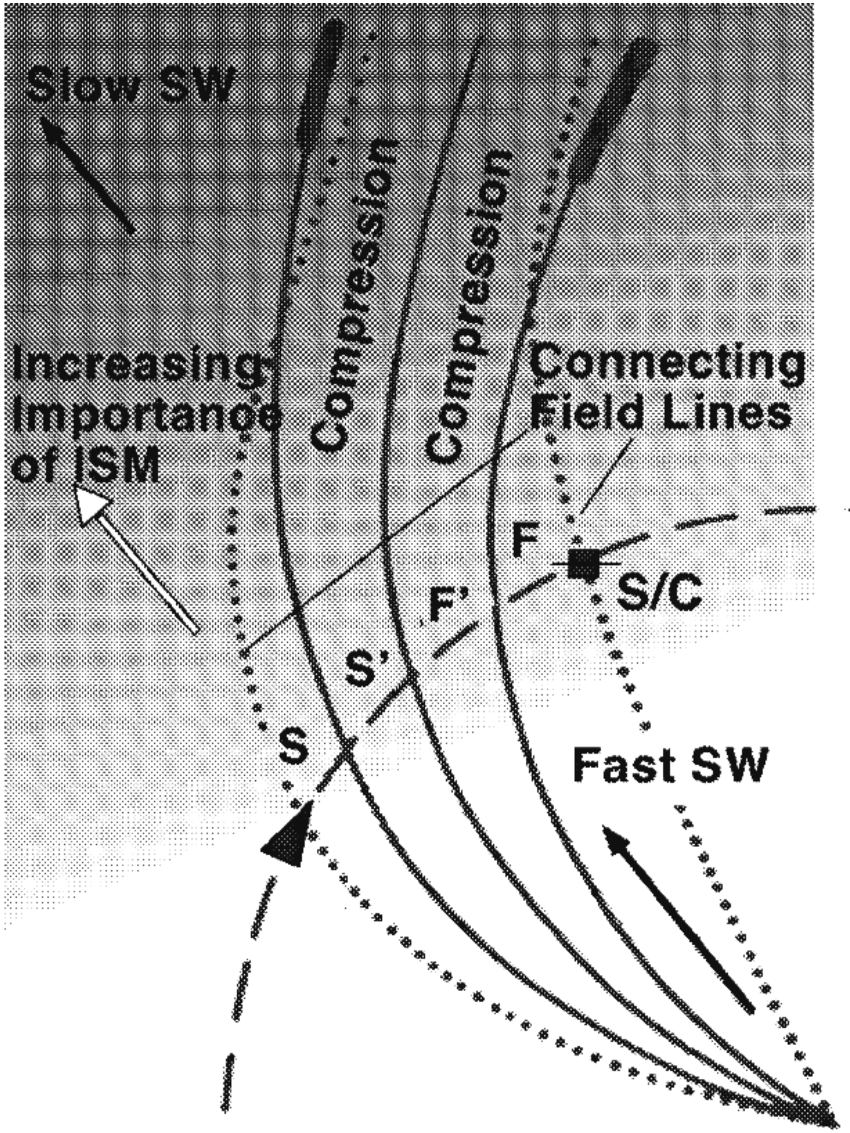
Phase of CIR:

- *recurrent CIRs show origin at same or nearby coronal holes*
- *more complex pattern in early 2007*
- *gives way to 2 steam per rotation pattern from later 2007 through the first prt of 2008*
- *single feature seen in more recent data*



Peak intensity:

- *for 2007-2008 period the peak intensity does not depend on the solar longitude of the source regions -- see widely different intensities from each region*
- *suggests that connection details are important even if the regions are fairly stable in production of energetic particles*

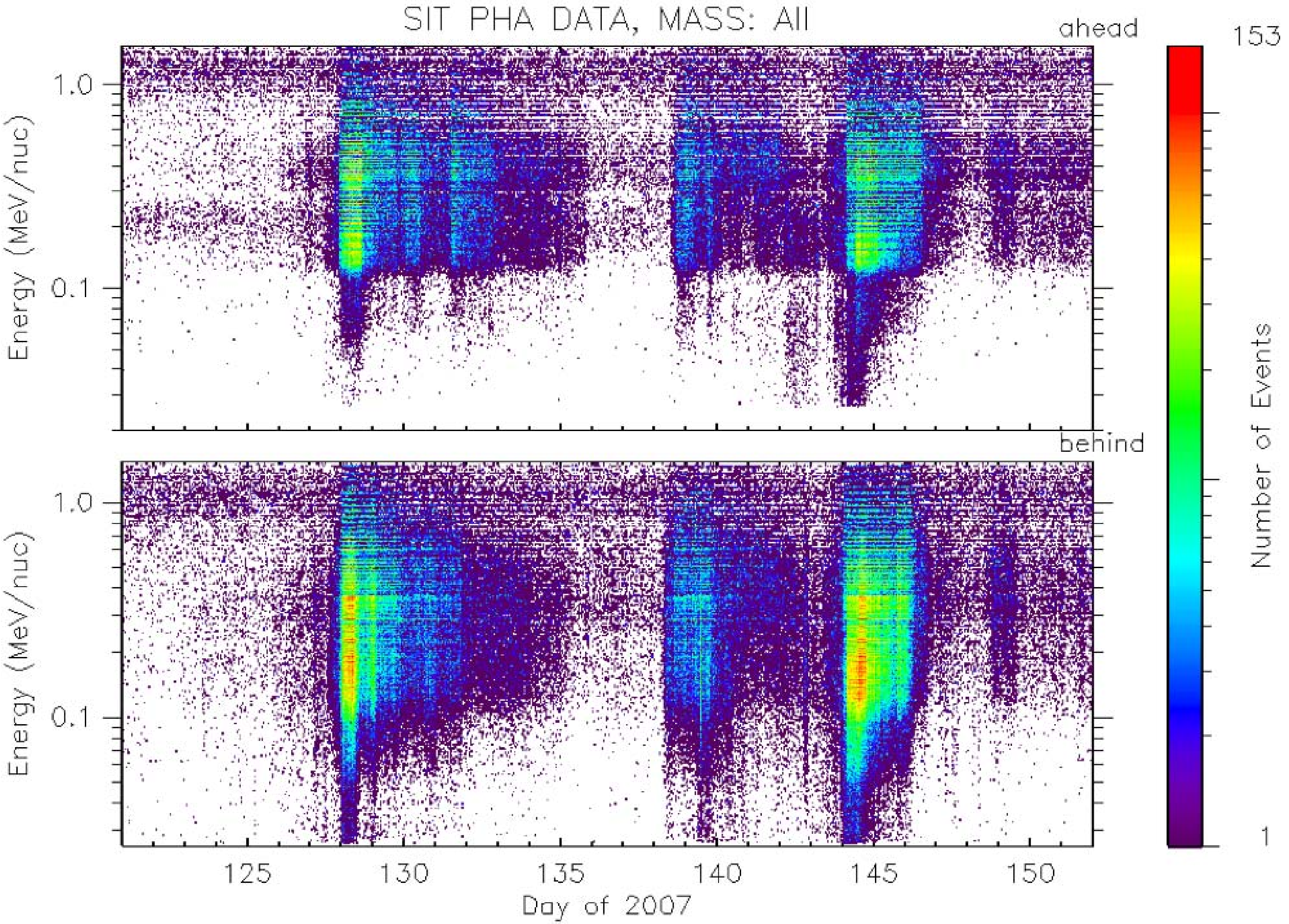


Connection to CIRs:

- *with source of particles beyond 1 AU, region of connection of spacecraft to outer region depends on solar wind speed*
- *simple corotating picture sometimes works, but often is more complex*

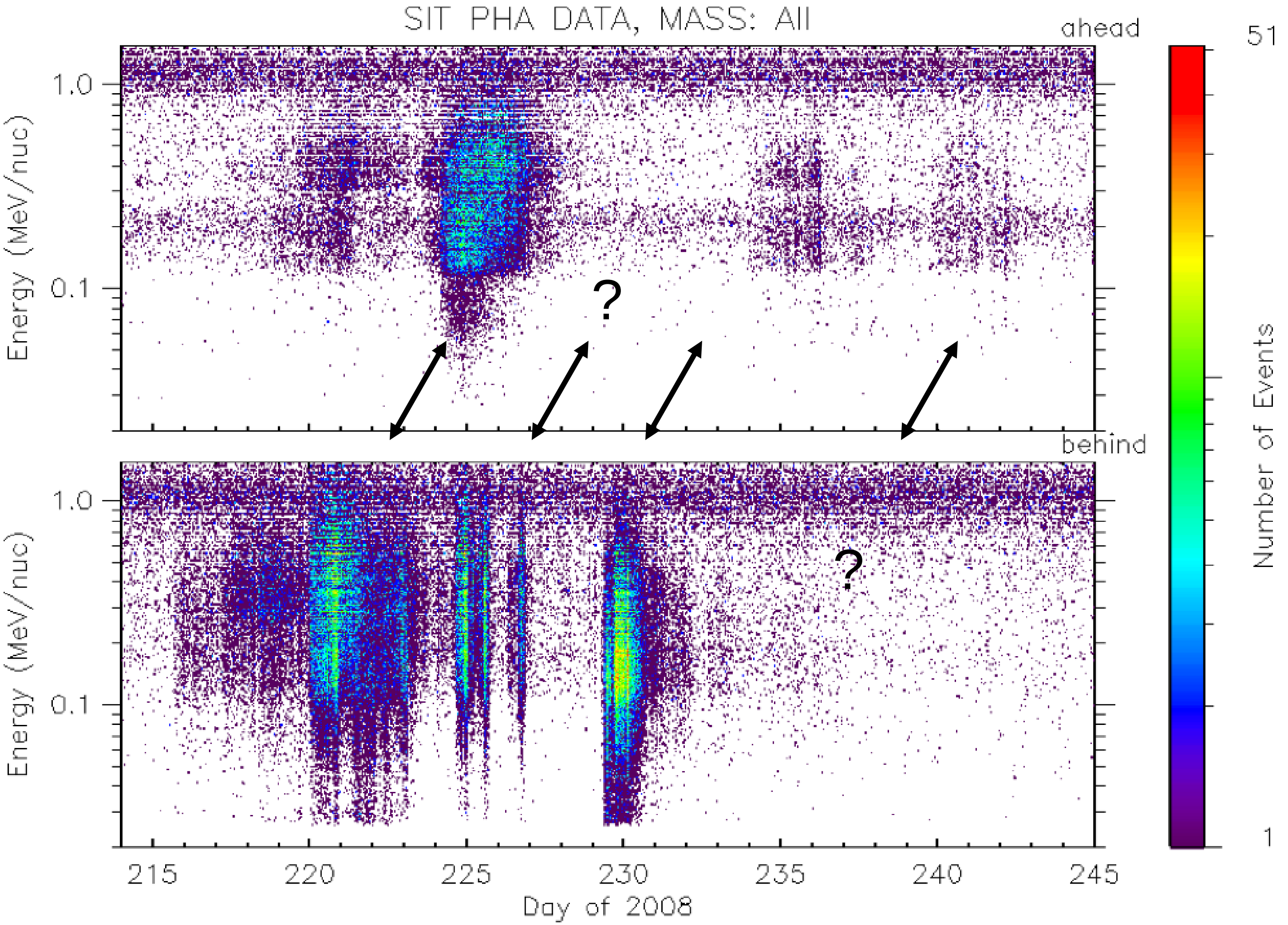
Morris et al., API CP598, 2001

Spectograms from -A and -B in spring 2007...quite similar

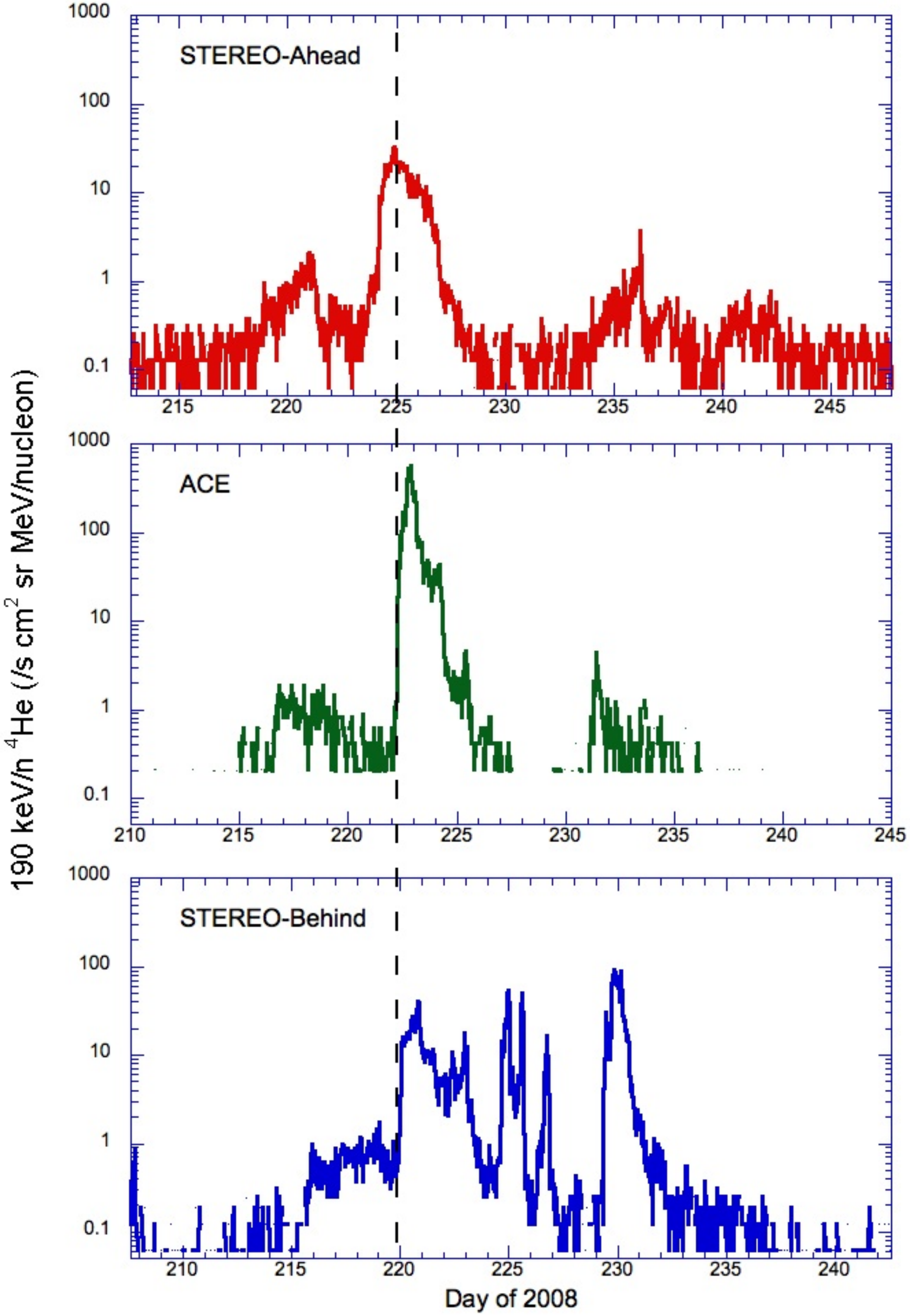


plot from R. Bucik, MPS

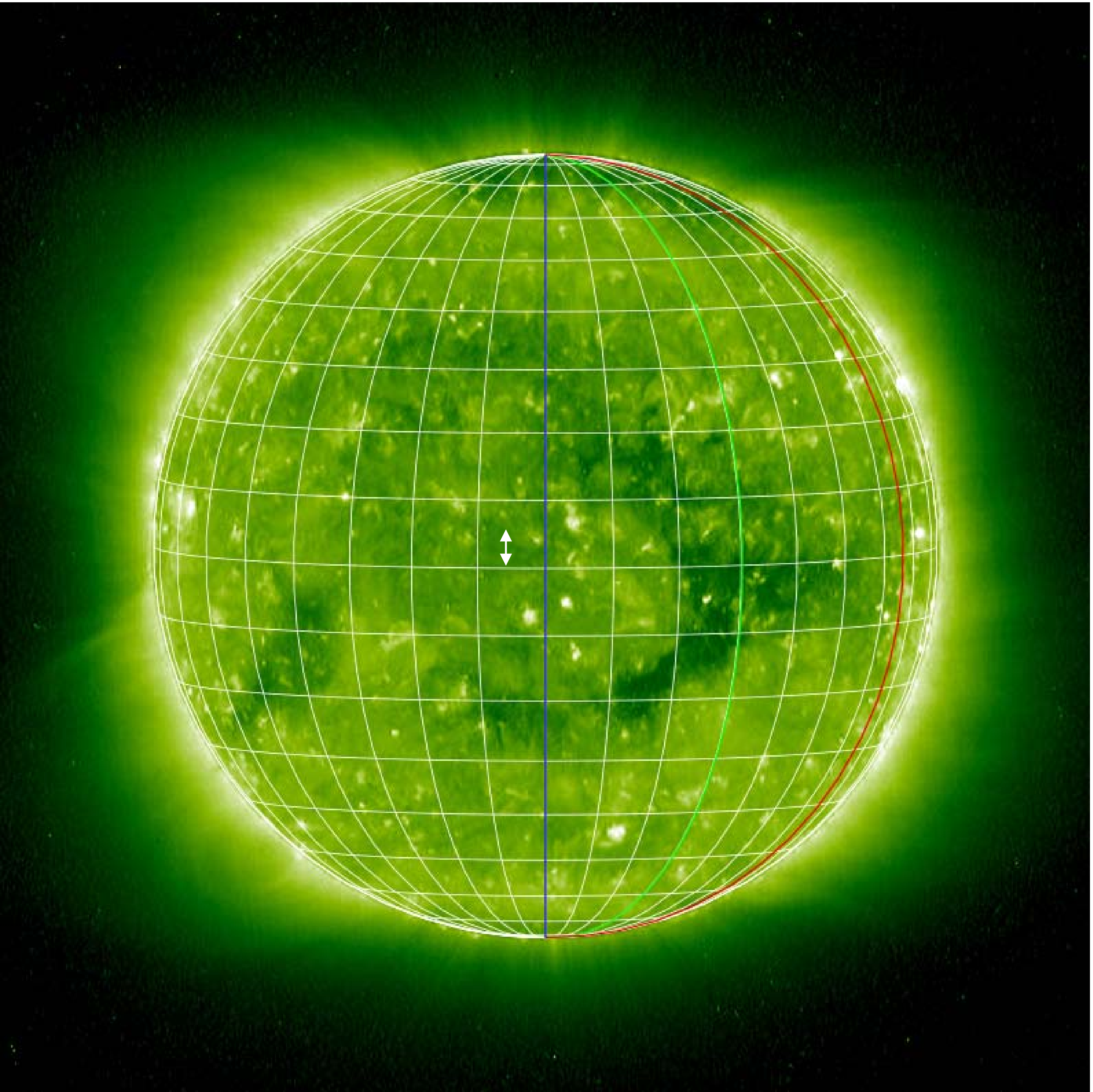
Aug. 2008 spectograms (~5 days corotation) ... some features shifted as expected, others not seen on both S/C



plot from R. Bucik, MPS



STEREO-Ahead
ACE
STEREO-Behind
190 keV/n ^{4}He (/s cm^2 sr MeV/nucleon)
Day of 2008
1000
100
10
1
0.1
210
215
220
225
230
235
240
245



Stereo-B SECCHI
19.5nm image

Aug 7, 2007
00:06:32

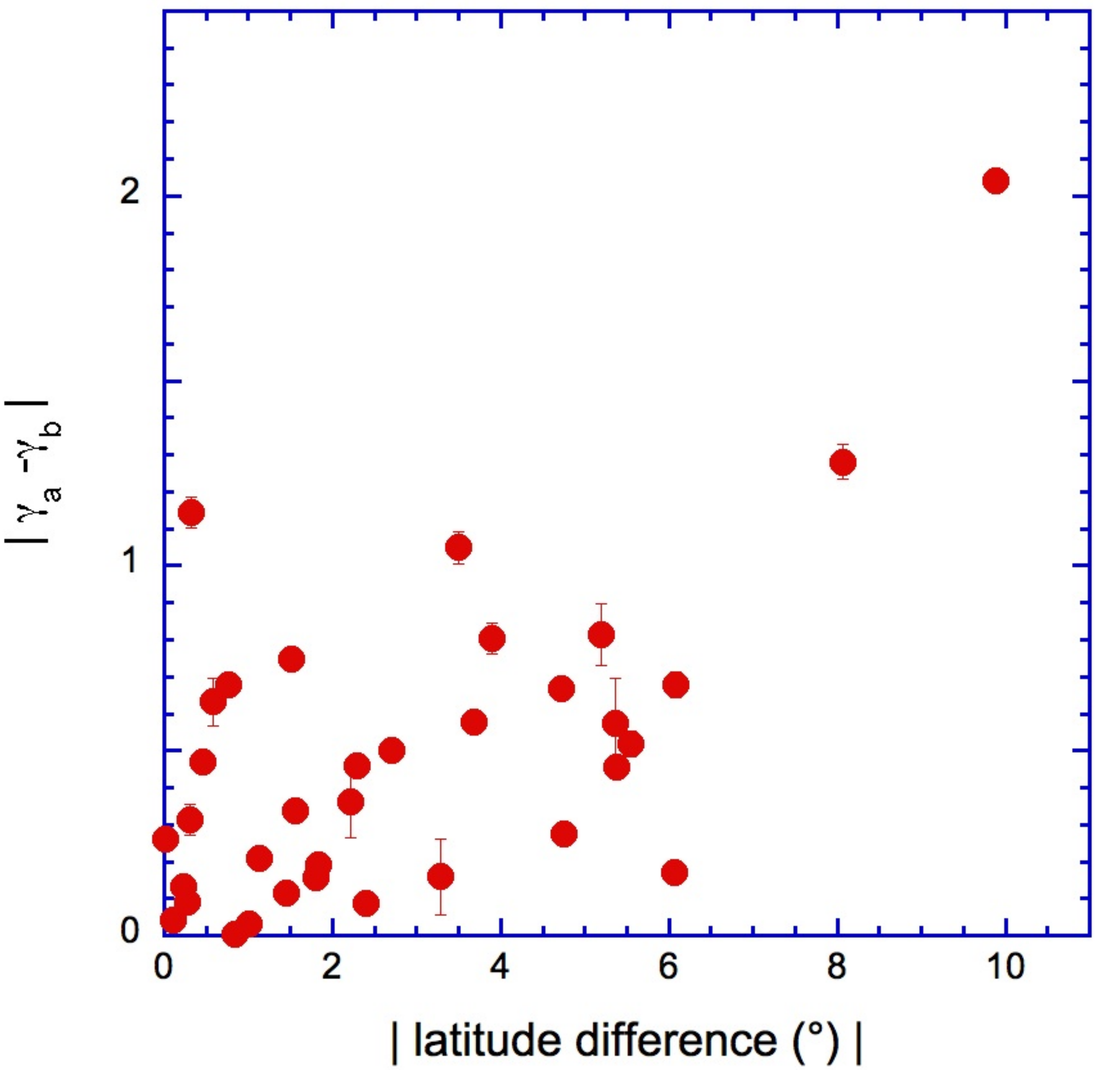
(day 220)

10 degree heliographic grid overlay as seen from STEREO-B

Central meridian seen from STEREO-B is in blue; green as seen from Earth; red as seen from STEREO-A

Solar Weather Browser image

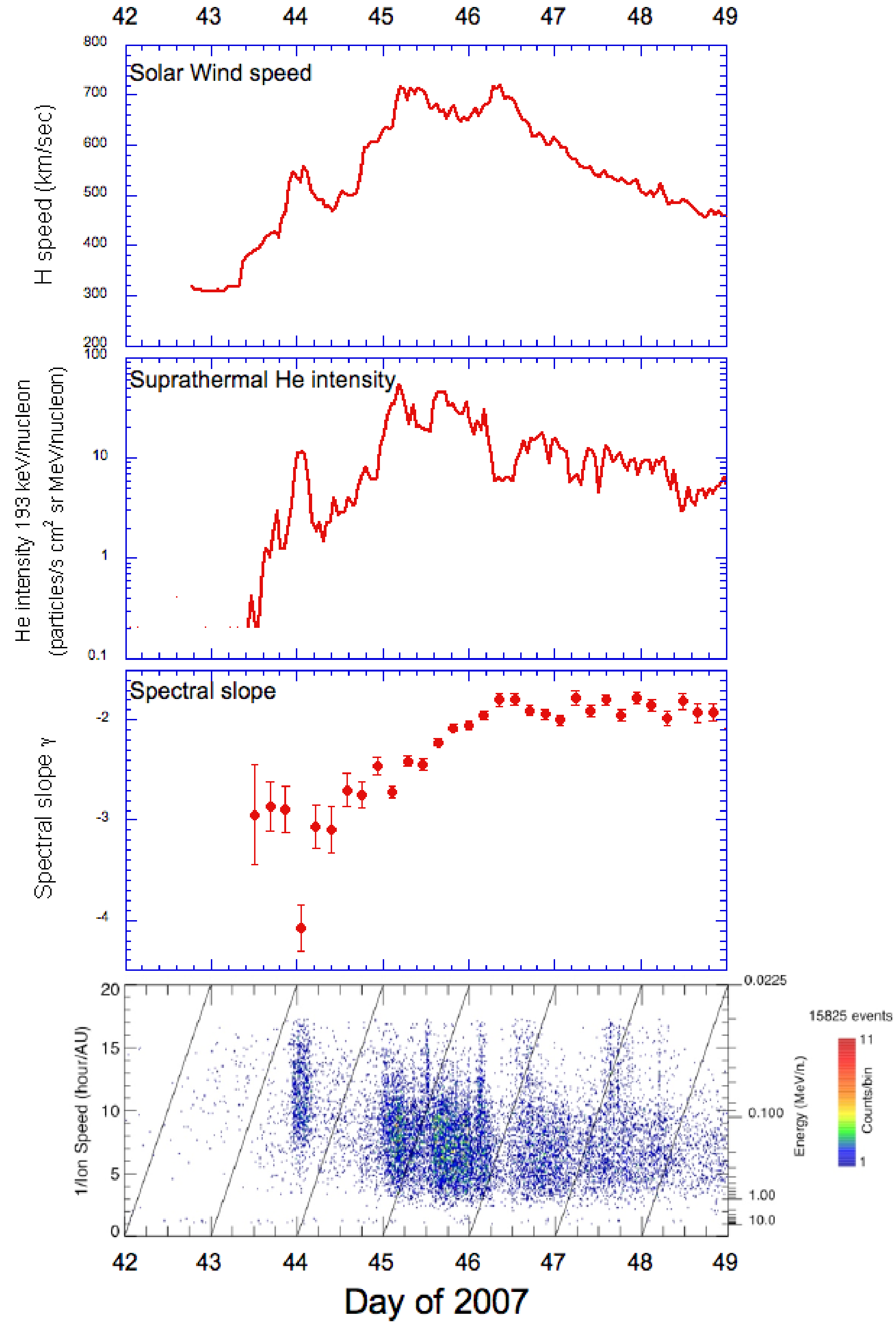
Stereo A is at 8.98° latitude; B at 3.78° ; so the 5.2° difference is about one-half of a grid spacings. The hole at about E45 is probably the one seen by STEREO-B on day 224-26, and was probably missed by STEREO-A since it's trace is about 5° , north of B, a size shown by the double headed arrow at E5



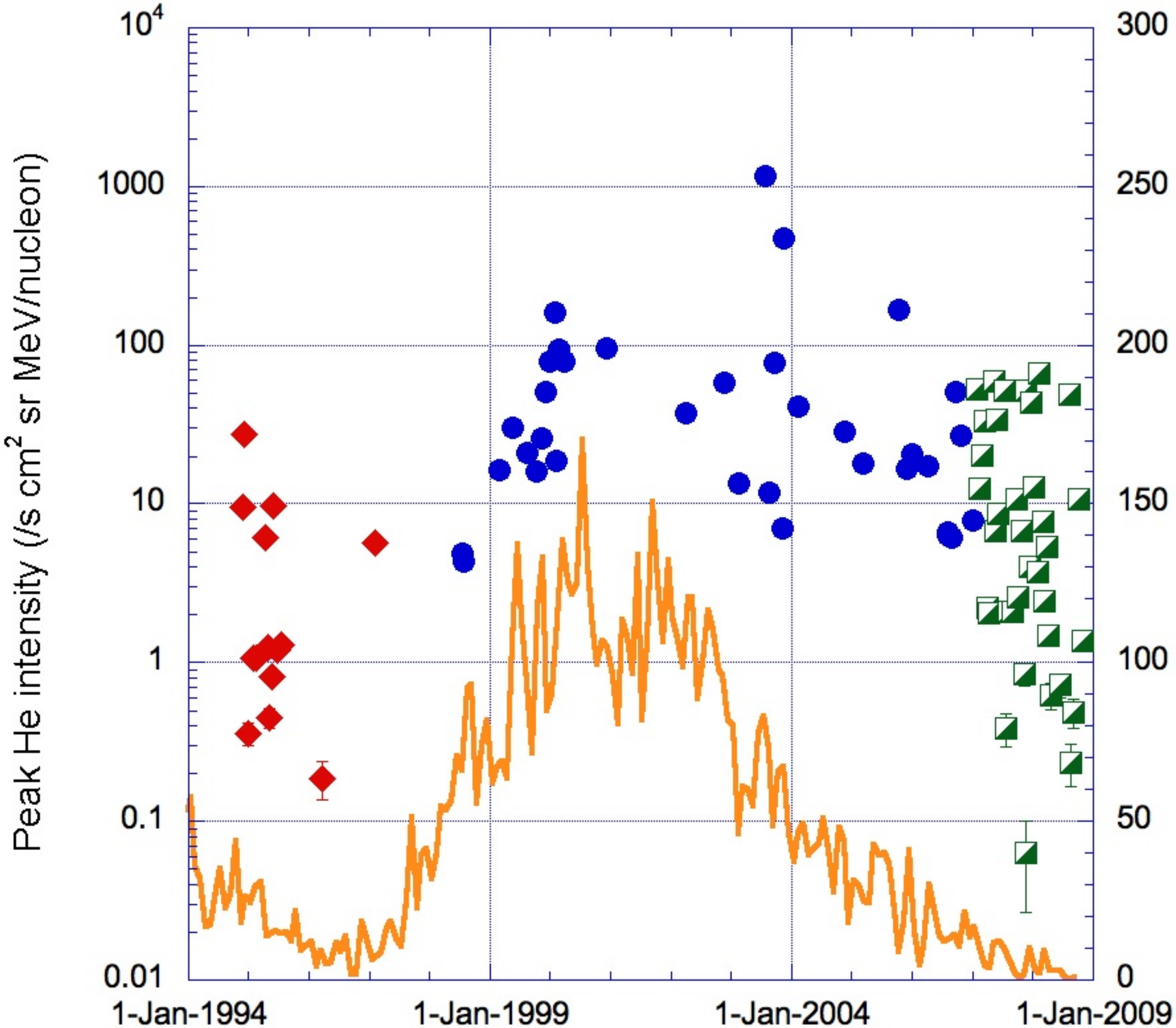
Difference between SIT-A and SIT-B spectral index for He vs. heliographic latitude difference between the two spacecraft. The correlation coefficient between the two quantities is 0.62, which has a <0.1% chance of arising from unrelated variables (n=36).

“Dropout events” --

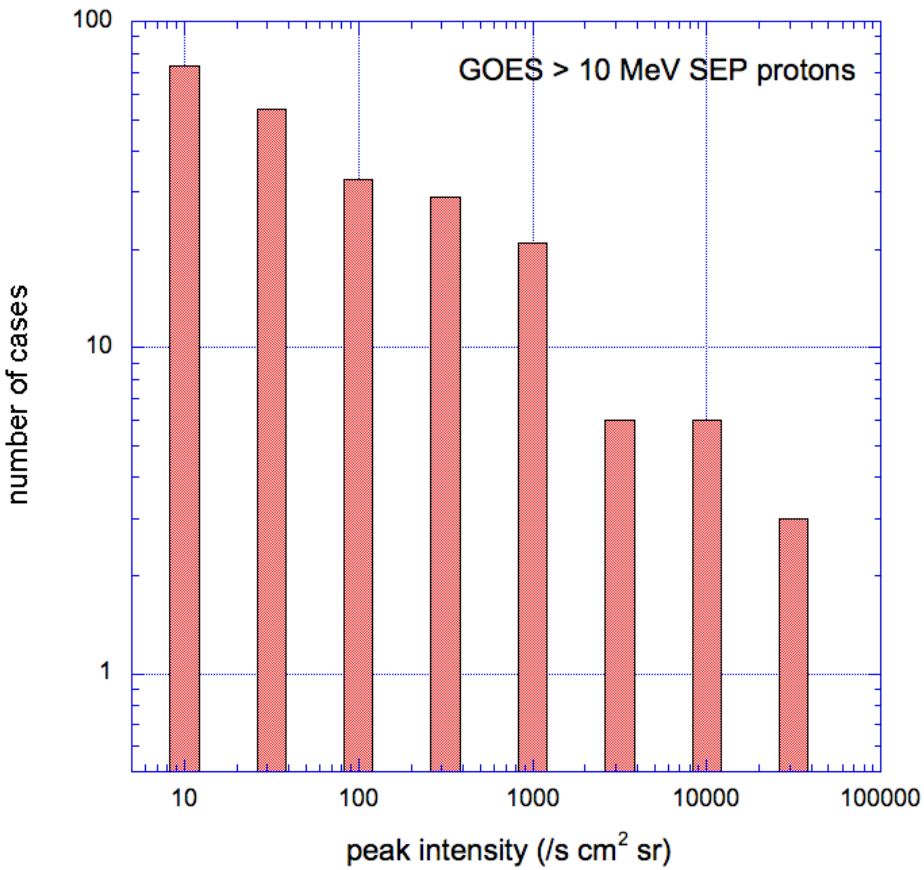
- *in several CIRs, particle intensity increases show a decrease at all energies, followed by a recovery that is also independent of energy*
- *these decreases correlate reasonably well with changes in solar wind speed*
- *particle energy spectra are similar before and after the droput, although intensities may change*
- *these features suggest that connection to the acceleration region beyond 1 AU is responsible for the dropouts -- not temporal changes in the CIRs*


Solar Wind speed
H speed (km/sec)
Suprathermal He intensity
He intensity 193 keV/nucleon
(particles/s cm^2 sr MeV/nucleon)
Spectral slope
Spectral slope γ
1/Ion Speed (hour/AU)
Energy (MeV/n.)
15825 events
Counts/bin
Day of 2007

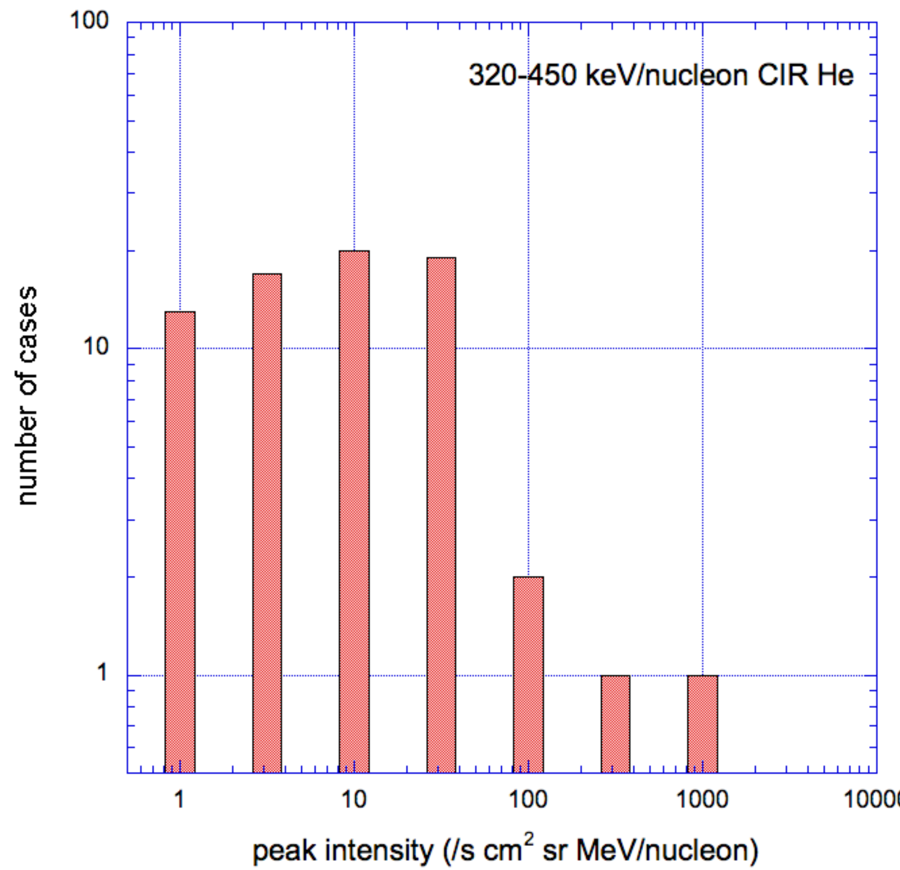
Comparison of 2008-2008 with 1996-1997 solar minimum period



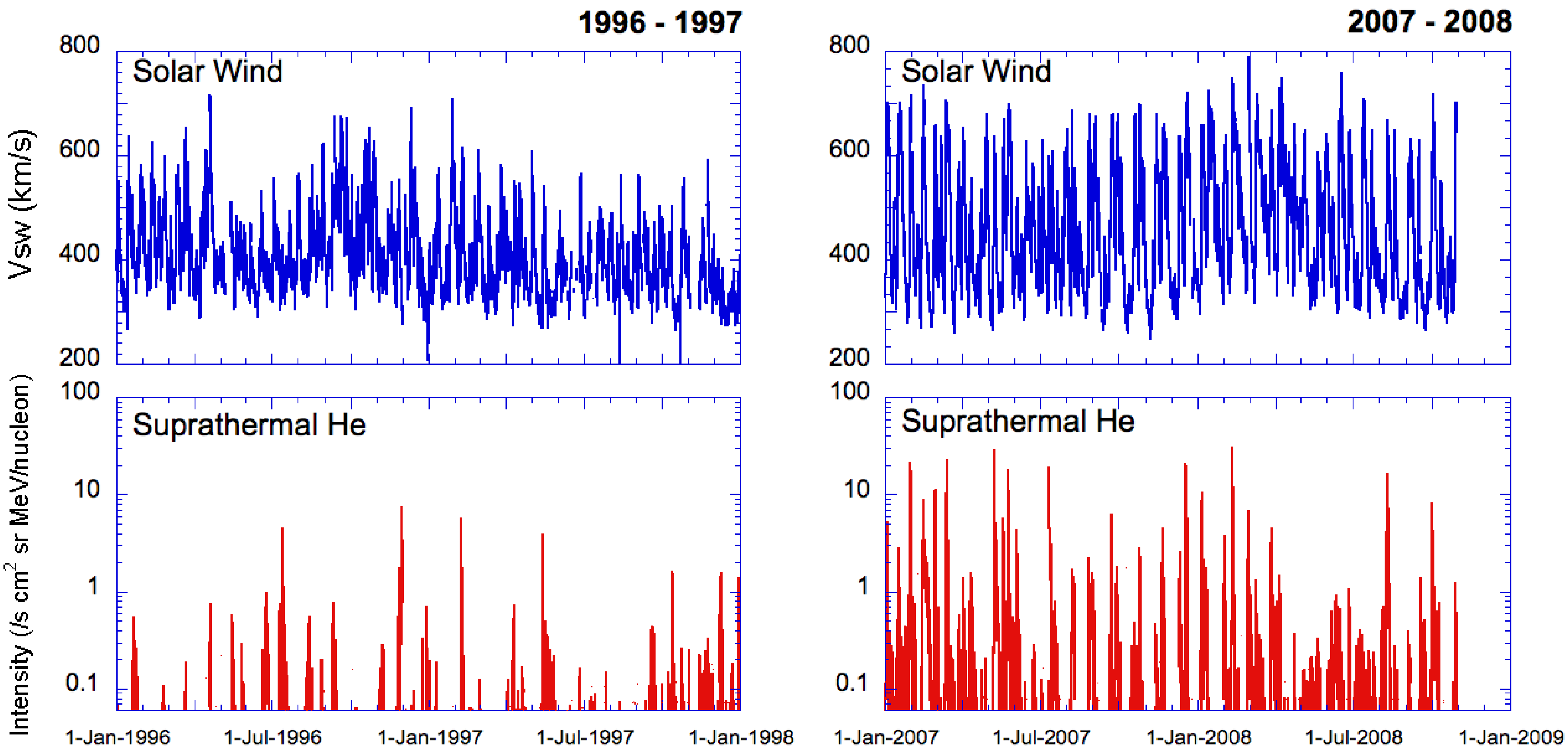
10^4
1000
100
10
1
0.1
0.01
Peak He intensity (/s cm^2 sr MeV/nucleon)
300
250
200
150
100
50
0
Mean Sunspot Number
1-Jan-1994
1-Jan-1999
1-Jan-2004
1-Jan-2009



GOES > 10 MeV SEP protons
number of cases
100
10
1
10
100
1000
10000
100000
peak intensity (/s cm^2 sr)



320-450 keV/nucleon CIR He
number of cases
100
10
1
1
10
100
1000
10000
peak intensity (/s cm^2 sr MeV/nucleon)



Wind SWE proton speed (blue) from kp data; STEP He5/1.6 -- division by 1.6 to adjust energy window to correpond approximately (20%) to ACE 386 keV/n channel;
Wind data blanked out for R<25Re; for solar activity days 1997/308.0-318.0, and for interplanetary shock event on 1997/326 (ACE disturbance list)

Summary --

- *many fast solar wind streams and CIRs observed in 2007-2008, but not all streams produced CIRs*

- *spectral forms similar to earlier surveys; much lower intensities at ~few MeV/n compared to active period*

- *CIRs observed sequentially from -B to -A, but not always seen; energetic particle intensity pattern did not corotate rigidly, probably due to magnetic connection effects to the CIR beyond 1 AU*

- *for 1994-2008 the most intense CIRs were during solar active periods, but cannot pinpoint simple cause for this*

- *2007-2008 period had much better defined high speed solar wind streams than prior solar minimum in 1996-1997, and many more CIRs*

- *size distribution of CIRs shows a much sharper cutoff than 10 MeV SEP protons from GOES*

- *about 25% of CIRs show "dropouts" for a day or so apparently when connection to acceleration region beyond 1 AU changes*

- *some of the complex features of the CIRs appear to be due to relatively small coronal hole solar sources, wherein the different heliolatitude traces of STEREO-B, -A, and ACE played a significant role*

(survey submitted to Solar Physics STEREO special issue)