SEP "Campaign Events" for SHINE 2003

A.J. Tylka, NRL

allan.tylka@nrl.navy.mil; 202-767-2200

***Question**: Can we identify solar/interplanetary factors that drive SEP spectral and compositional variability at high energies?*

Two possible events for addressing this question:

21 April 2002 and 24 August 2002

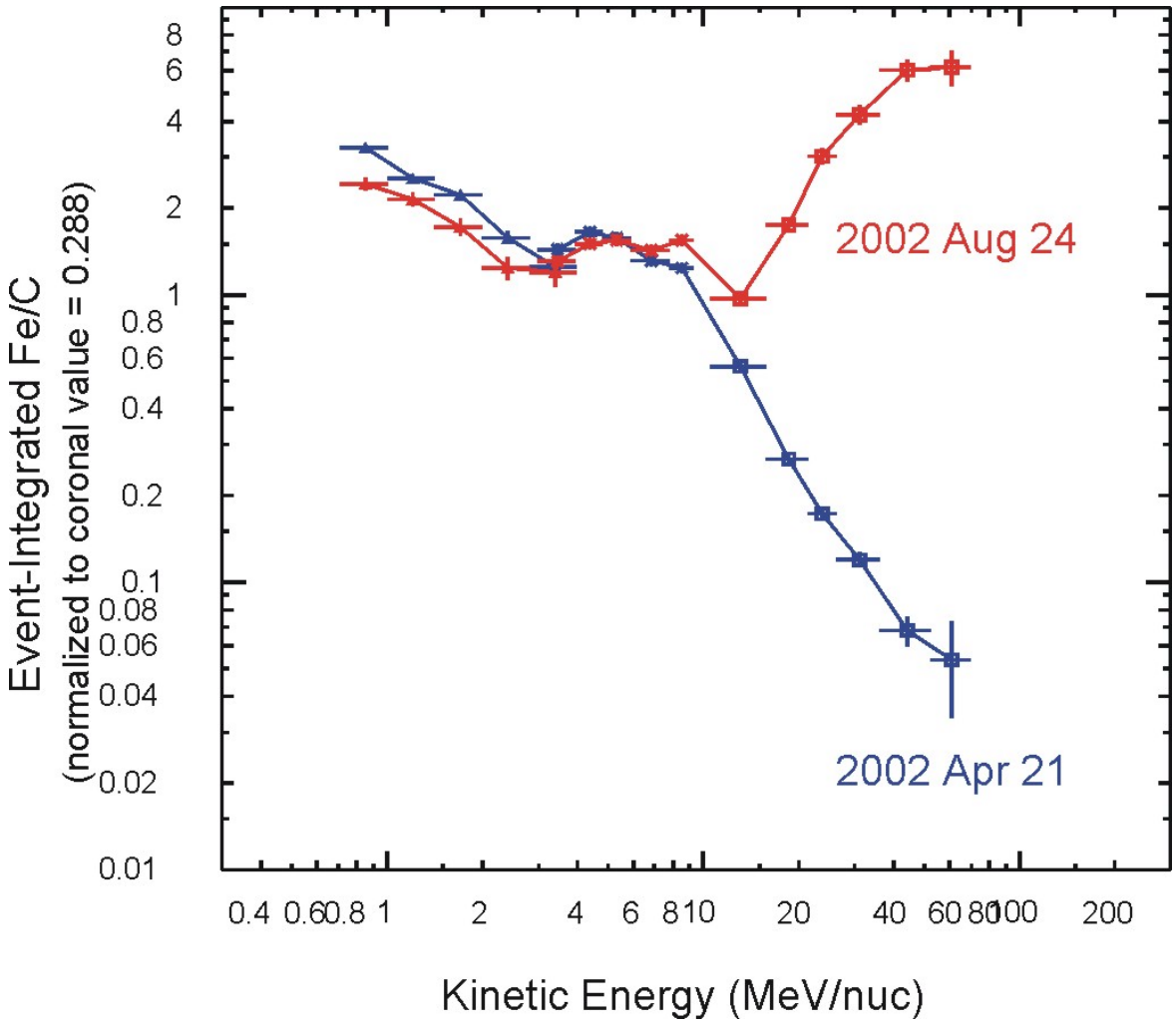
(the largest SEP event of 2002)

(the only ground-level event of 2002)

-- Ostensibly very similar flare/CME characteristics

-- But very different SEP composition & spectra at high energies.

Compare SEP Fe/C vs. Energy



Fe/C nearly identical at ~0.5 - 10 MeV/nuc

But the two events diverge dramatically at higher energies

-- Fe/C differ by a factor of ~100 at 50 MeV/nuc.

The origin of this behavior is perhaps the biggest puzzle to have emerged from Cycle 23 SEP observations.

Data from ACE/EPAM, Wind/LEMT, ACE/SIS

Compare Solar Activity & Interplanetary Conditions

	21 Apr 2002	24 Aug 2002
CME Characteristics (S. Yashiro)		
Speed (km/s)	2400	1900
Width (deg)	240	360
Position Angle (deg)	260	Halo
Flare Characteristics (NOAA/SGD)		
Size	X1.5 / 1F	X3.1 / 1F
Location	S14W84	S02W81
Duration: Start to Maximum/e (min)	115	42
SW Speed at 1 AU (km/s), averaged over the first 6 hours (CDAWeb)	~475	~385
Associated Shock (C.W. Smith)		
Transit Time to 1 AU (hours)	51	58
Velocity Jump (km/s)	~200	~100

What might we learn from these two events?

These two SEP events show significant differences in terms of:

- ***Elemental Composition (esp. Fe/C above ~10 MeV/nuc)***
- ***Spectral Shape***
- ***Size***
- ***Temporal Structure***

However, the CMEs, flares, and interplanetary conditions associated with these two events are remarkably similar.

Thus, these two events provide an opportunity to examine the origins of SEP variability under nearly "controlled conditions".

Comparisons between these events can help us isolate and model the drivers of SEP variability.

Advantages/Disadvantages as Campaign Events

Advantages:

1. ***Overall, both events are well measured.***
2. ***Lots of interest already in 21 April 2002.***
3. ***This study will educate the SHINE community on "our SEP puzzles".***
4. ***Lots of other events show characteristics similar to these two events – plenty of data for testing new hypotheses.***
5. ***A tremendous success, if we can figure this out.***

Disadvantages:

1. ***We might not figure it out.***
2. ***Unfortunate datagaps in RHESSI (esp. 24 August).***
3. ***These are weak shocks by the time they get to 1 AU. (That is, they are no longer accelerating ions beyond ~0.5 MeV/nuc or less.)***

Additional Comparisons

FYI: The following pages offer comparisons of:

GOES Proton Timelines

Ion Timelines, Spectra, & Composition from Wind & ACE

LASCO CME Measurements

GOES X-Ray Timelines

RHESSI Observations

Wind/Waves Radio Emission

Solar Wind Parameters, as reported by Wind

GOES Protons – preceding 6 days

GOES X-Rays – preceding 6 days

Wind Waves Radio Emission – preceding 3 days

CME Interactions – a la Gopalswamy et al.

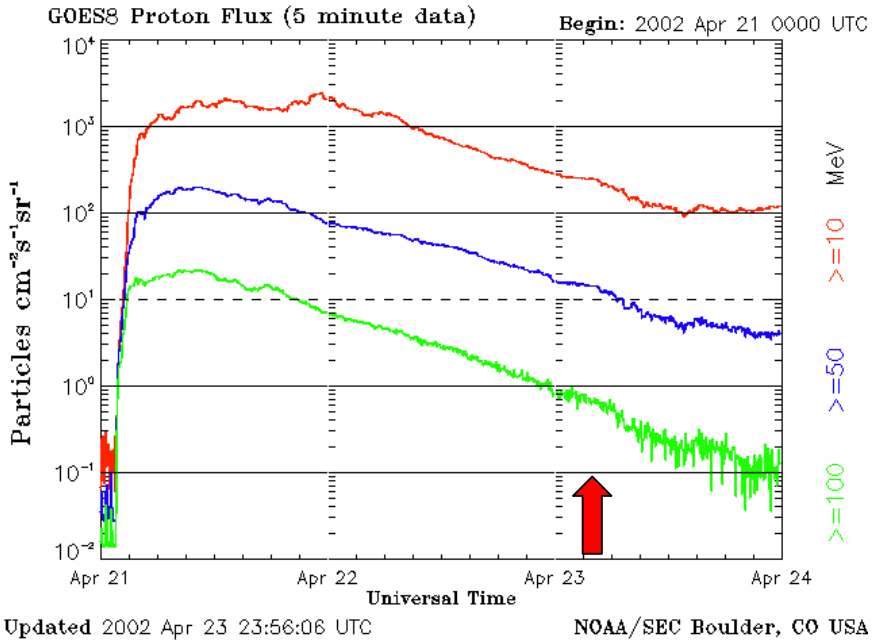
Time-Dependent Spectra & Composition

(Maybe you'll spot the answers here!!)

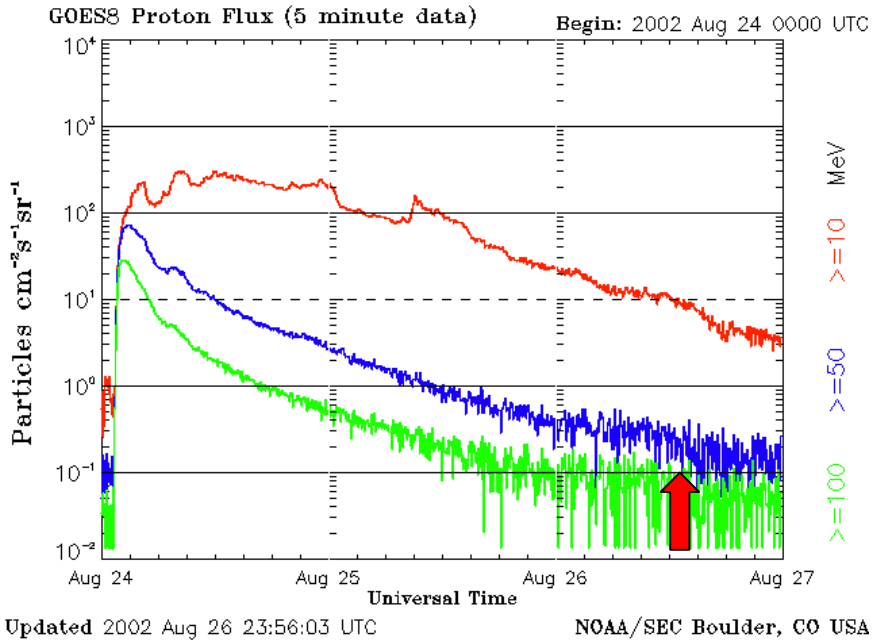
GOES Protons

>10 MeV, >50 MeV, >100 MeV

21 April 2002



24 August 2002



>10 MeV profiles very similar, except for normalization. But >50, >100 MeV profiles have different shapes in the two events.

No increase in high-energy particles at the time of shock arrival at the Earth (arrows).

Thus, in both events, the high-energy particles are produced predominantly while the shock is still far from 1 AU.

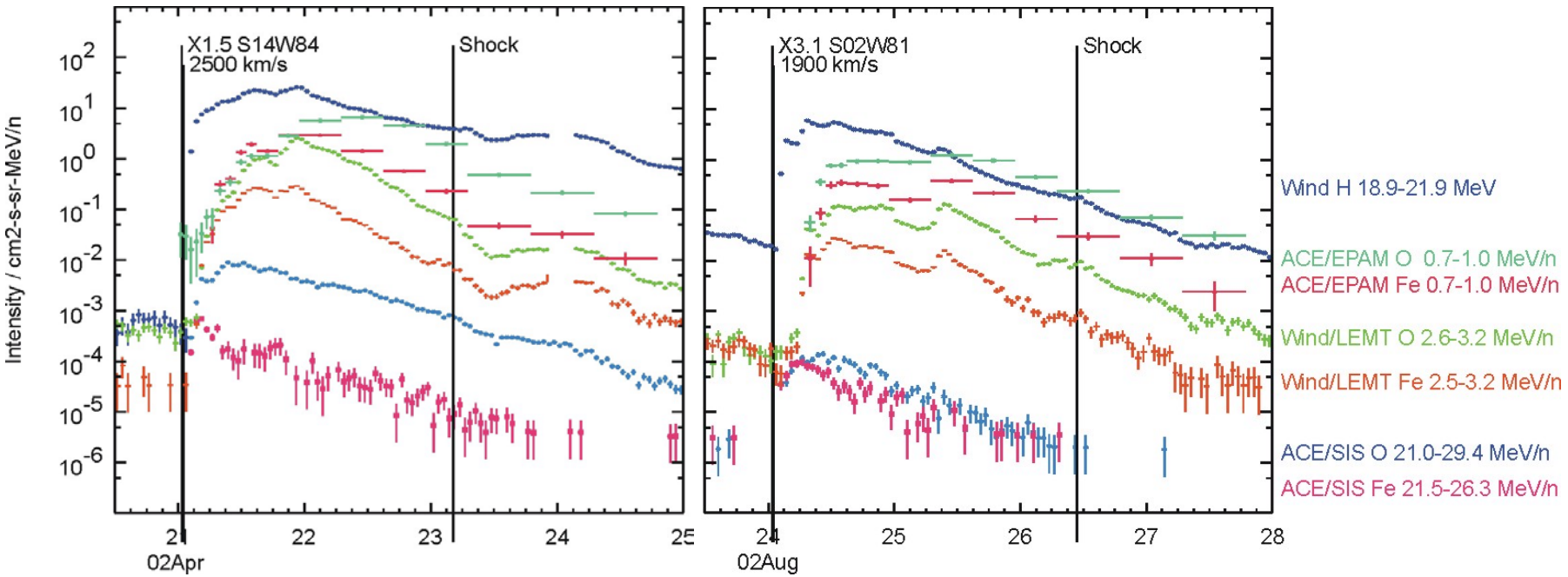
But the apparent duration of >50 MeV proton production is longer in the April event.

Why? And how does this relate to the differences in ionic composition & spectra ? (See below.)

Ion Timelines (from Wind & ACE)

21 April 2002

24 August 2002

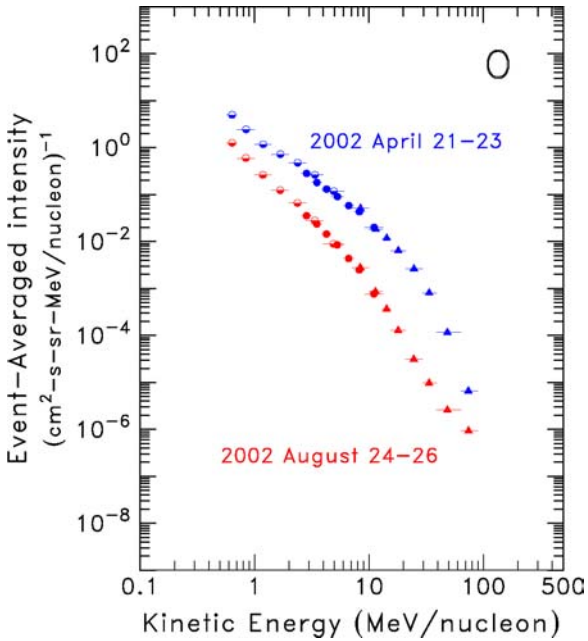


Timelines are similar, except for

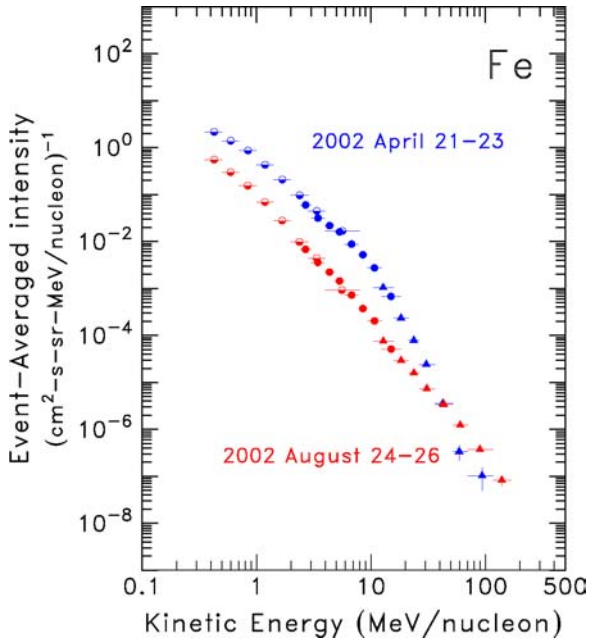
- *Larger intensities in the April event*
- *Higher Fe/O ratio at ACE/SIS energies in the August event. (Compare bottom two traces in the two plots.)*

Ion Spectral Shapes (event-integrated)

Oxygen



Iron



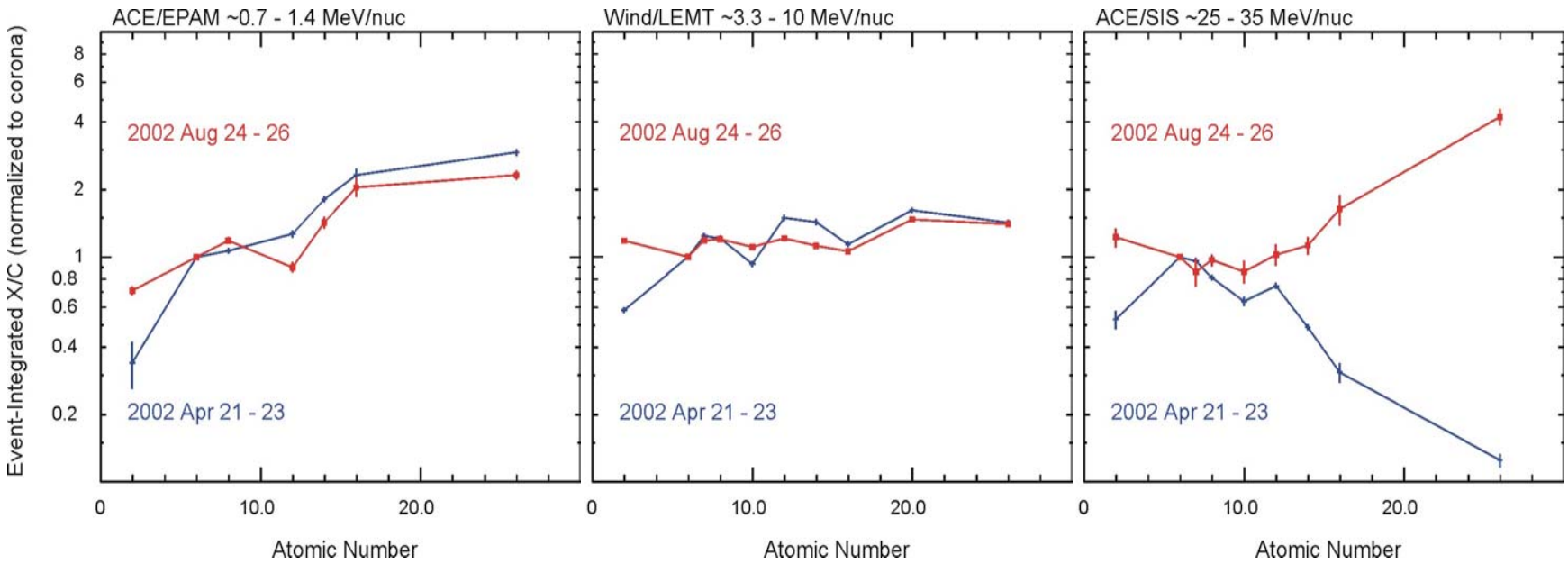
Spectra have more pronounced "exponential rollovers" in the April event.

Spectra closer to power-laws (especially Fe) in the August event.

Data from ACE/EPAM, Wind/LEMT, ACE/SIS

Elemental Composition (event-integrated)

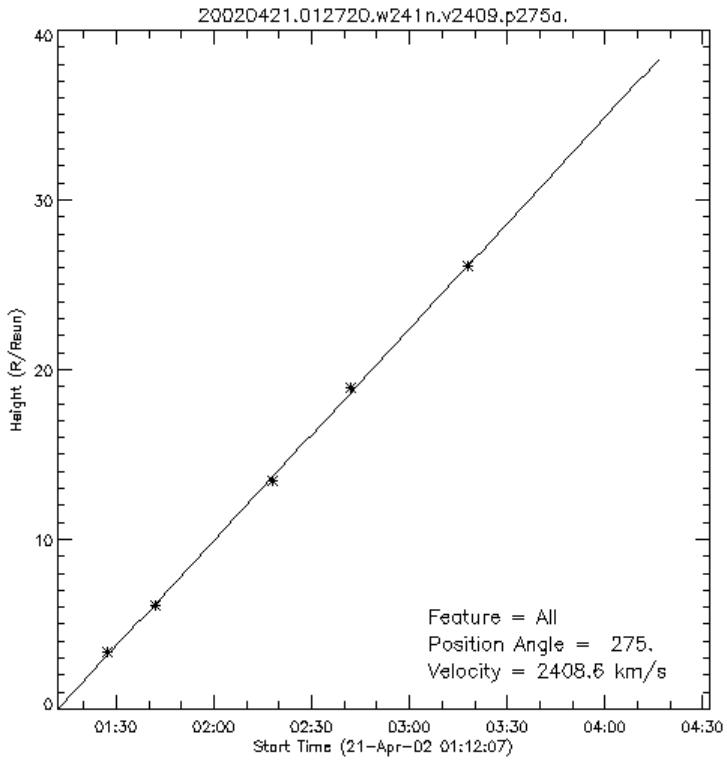
ACE/EPAM ~1 MeV/nuc ***Wind/LEMT ~5 MeV/nuc*** ***ACE/SIS ~30 MeV/nuc***



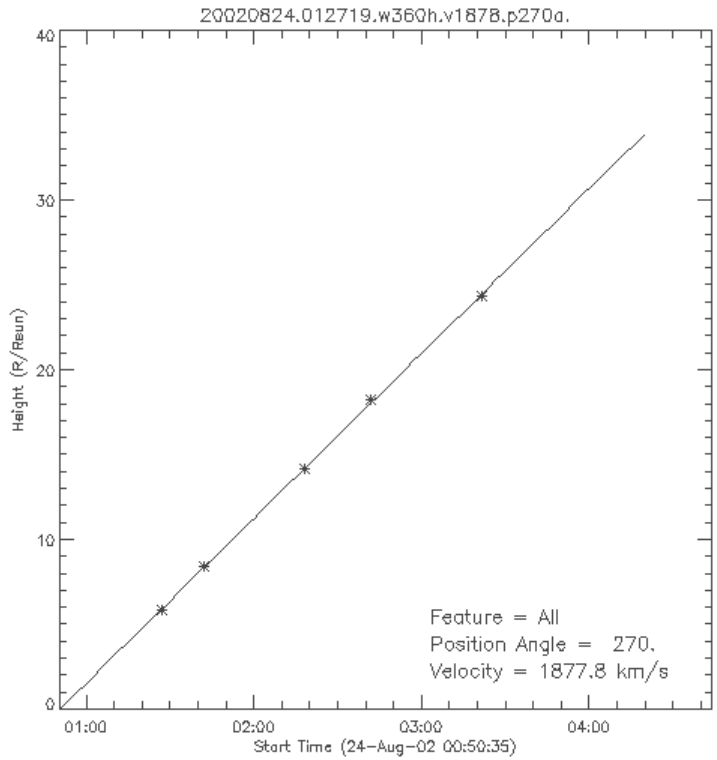
X/C, normalized to corona, for He - Fe

LASCO CMEs
-- 1 parameter fits

21 April 2002



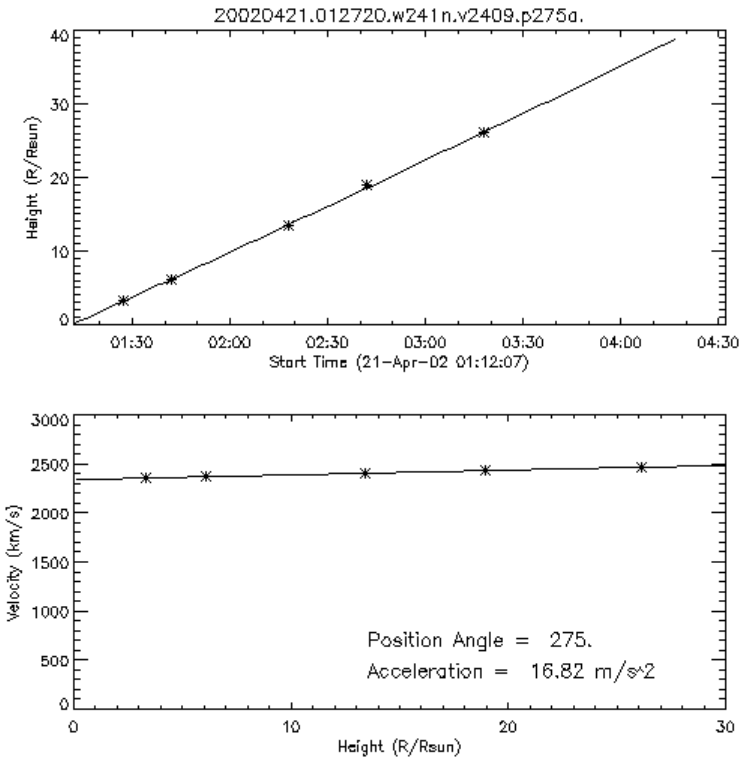
24 August 2002



**from Seijo Yashiro.*

LASCO CMEs
-- 2 parameter fits

21 April 2002



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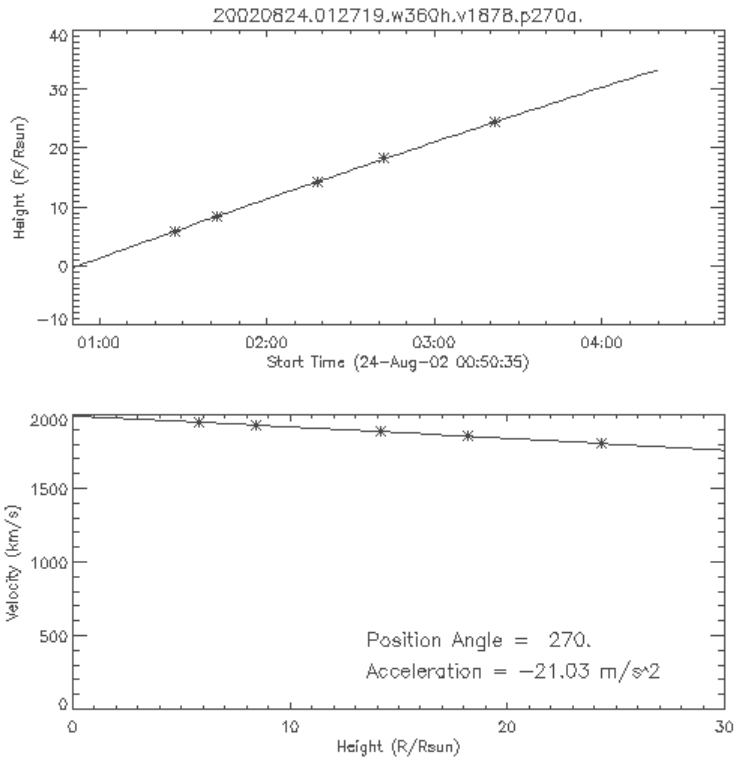
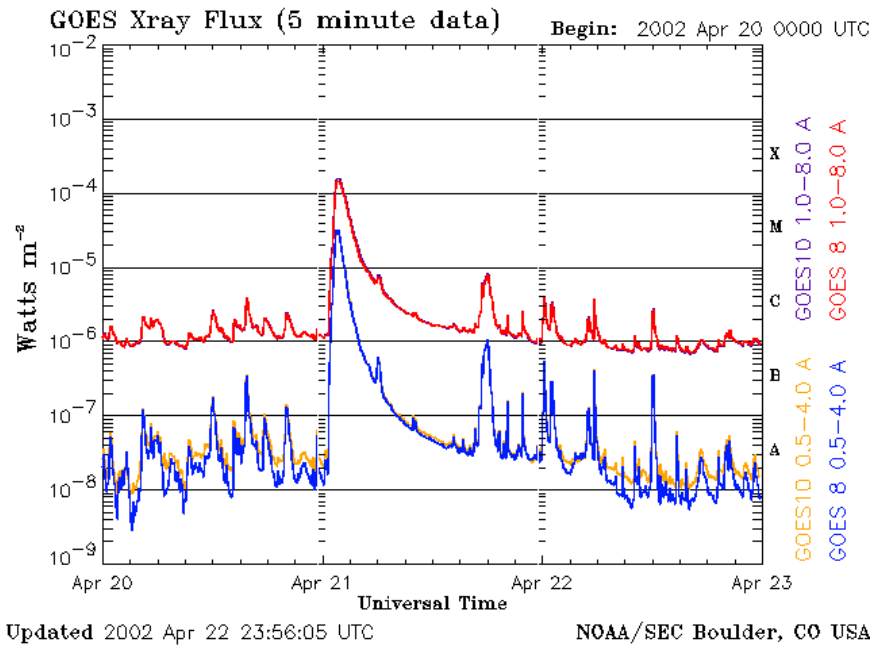


*from Seijo Yashiro.

GOES X-rays

21 April 2002



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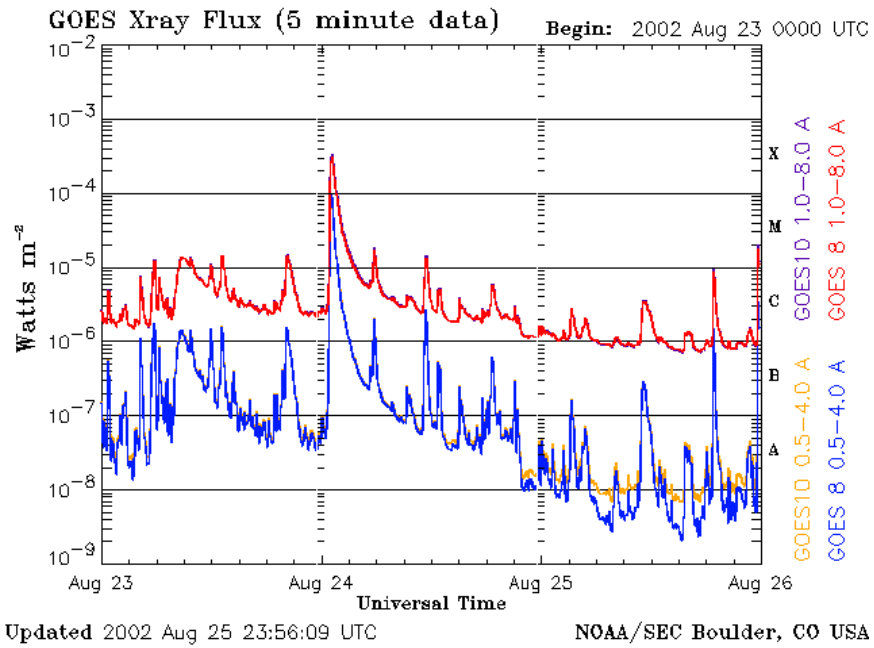


X1.5 at S14W84,

115-minutes duration*

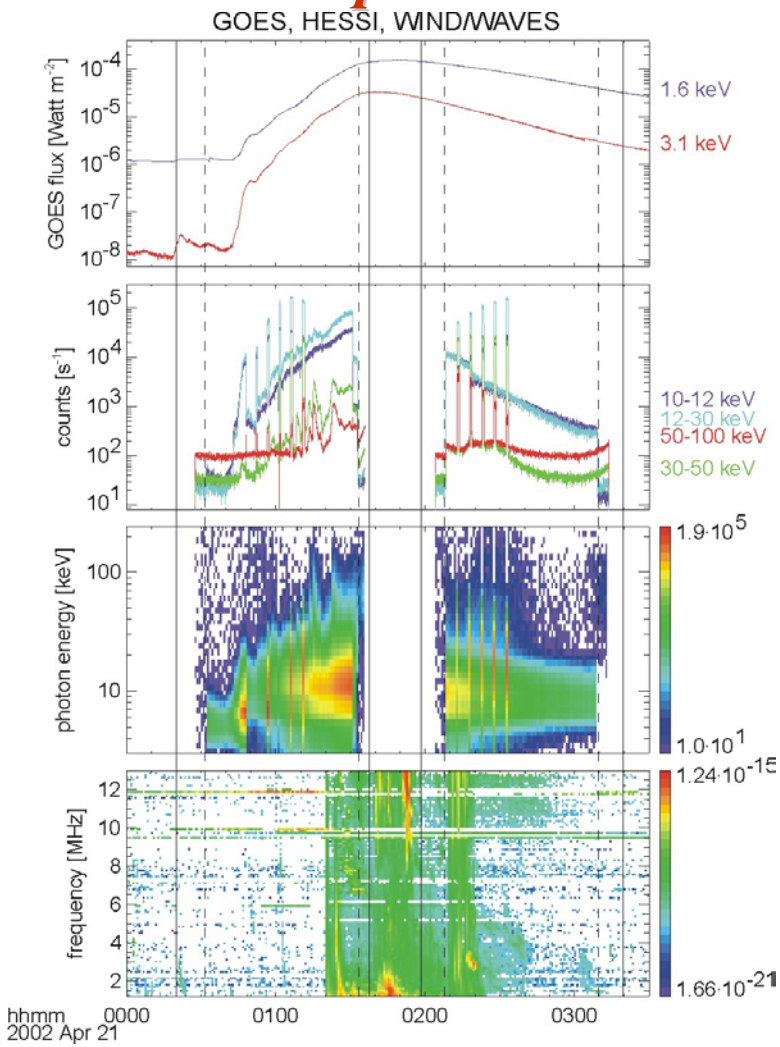
X3.1 at S02W81,

42-minutes duration*

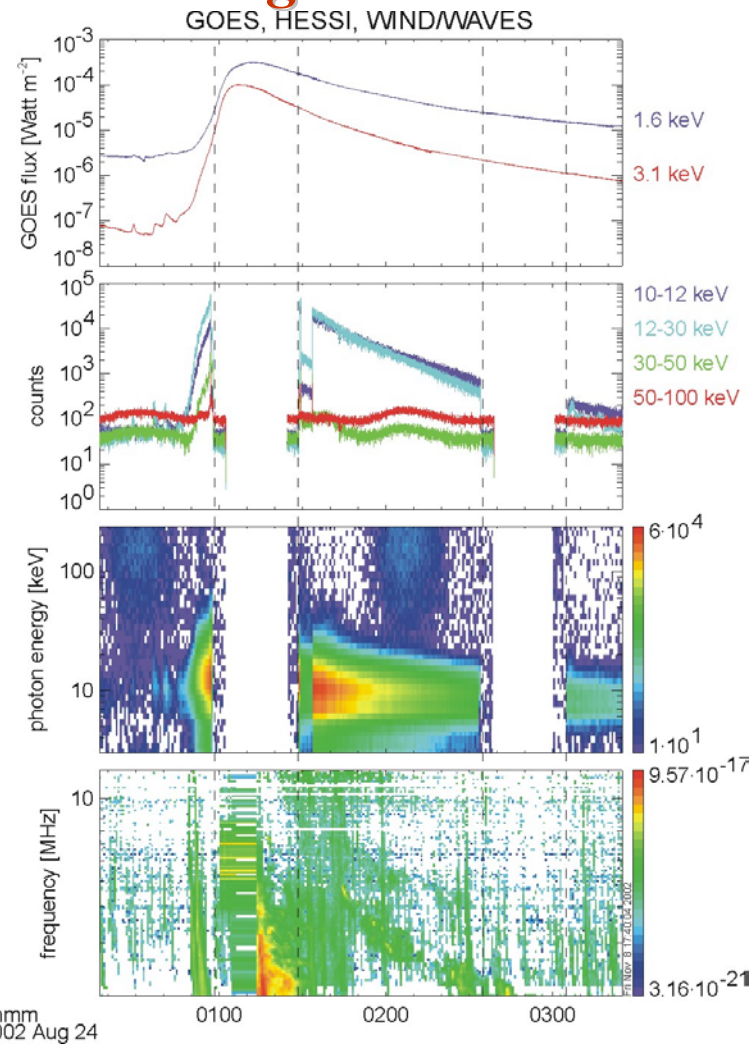
****As defined by GOES: from start until maximum has decreased by 1/e.***

RHESSI Observations

21 April 2002



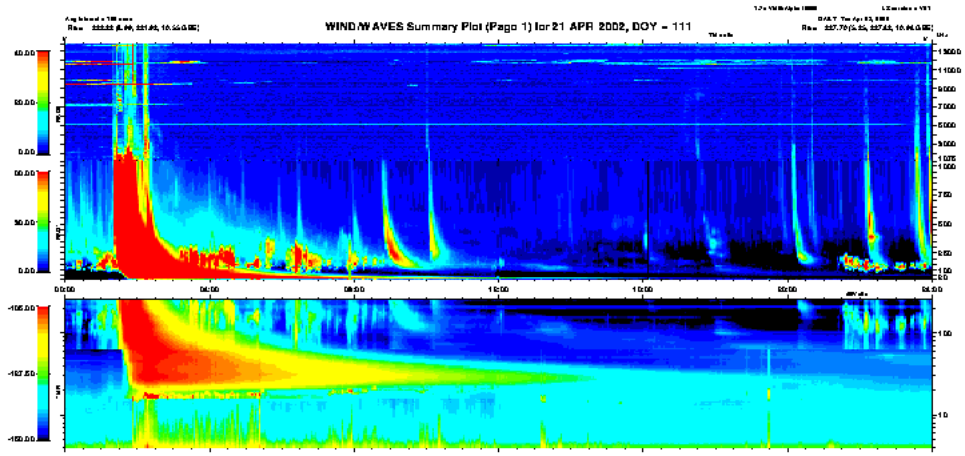
24 August 2002



Provided by Säm Krucker

Wind/Waves Radio Emissions

21 April 2002



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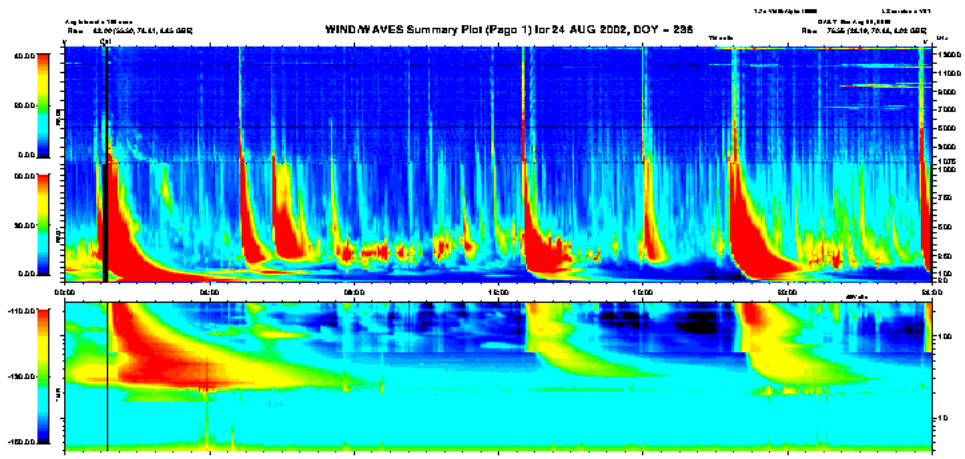
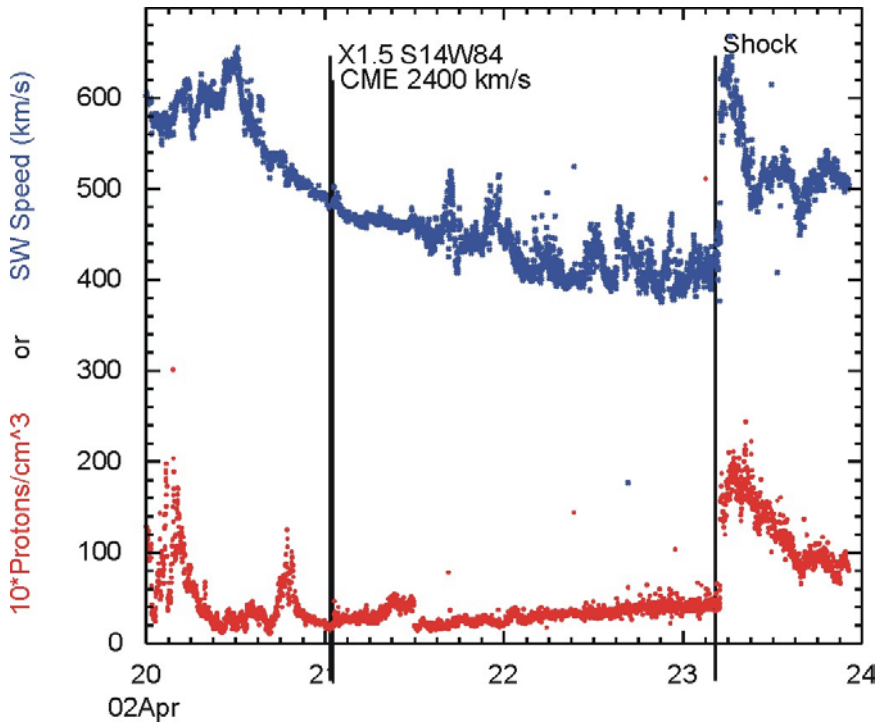


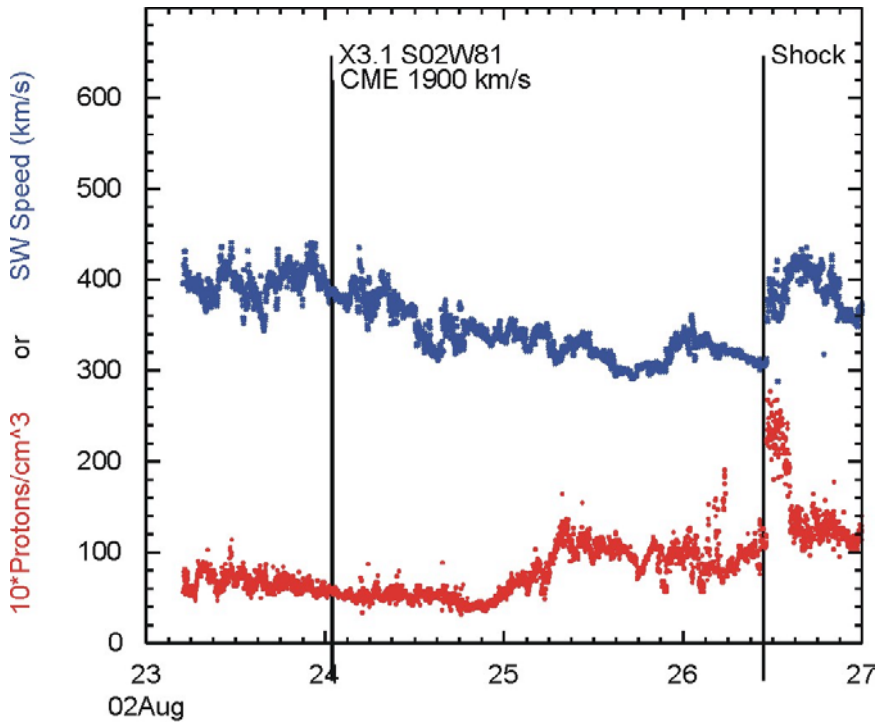
From http://lep694.gsfc.nasa.gov/waves/waves.html

Solar Wind Parameters from Wind

20-24 April 2002



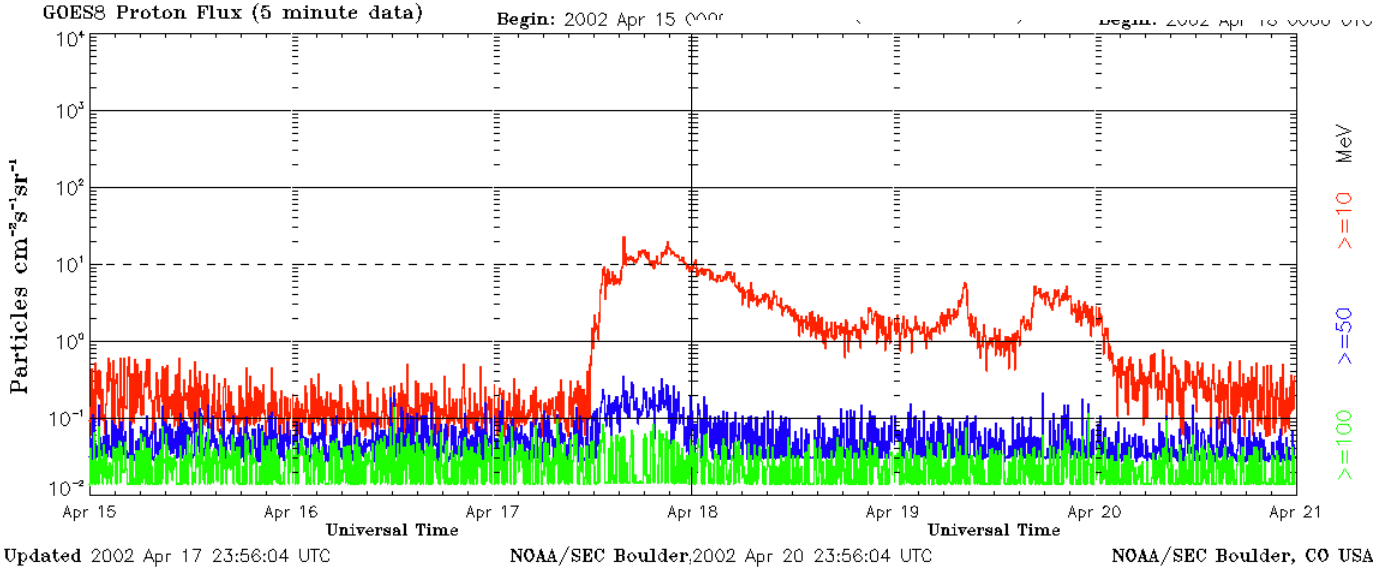
23-27 August 2002



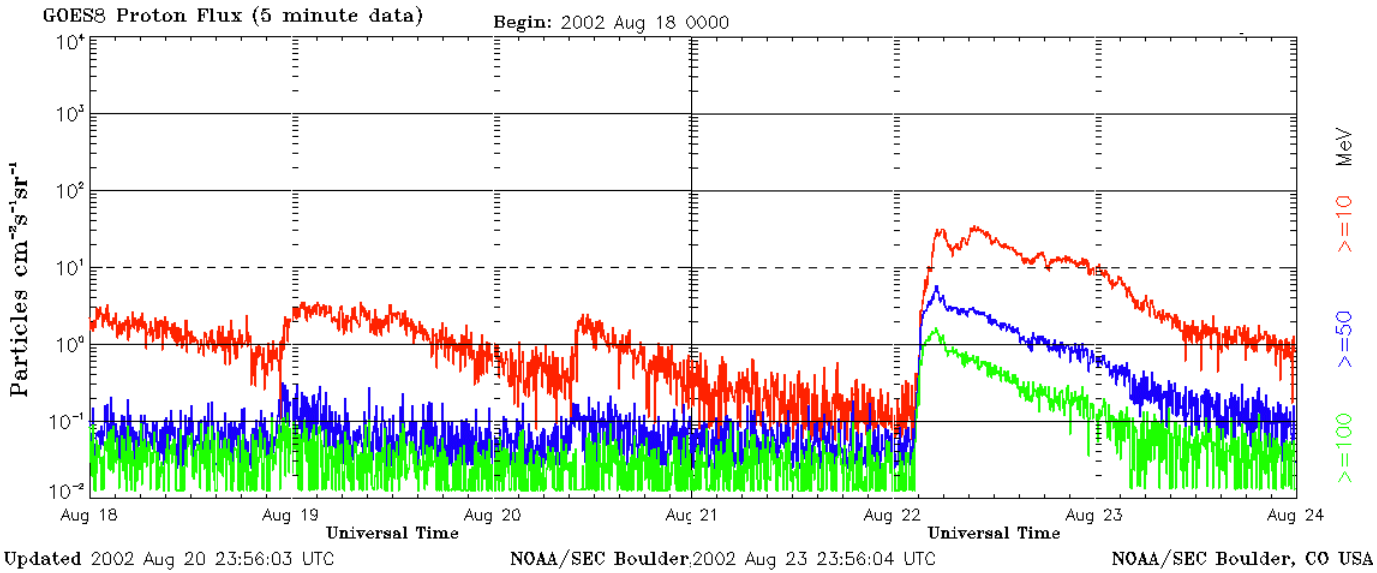
Provided by K. Olgilvie, via NSSDC's CDAWeb

GOES Protons – Previous 6 Days

15-20 April 2002

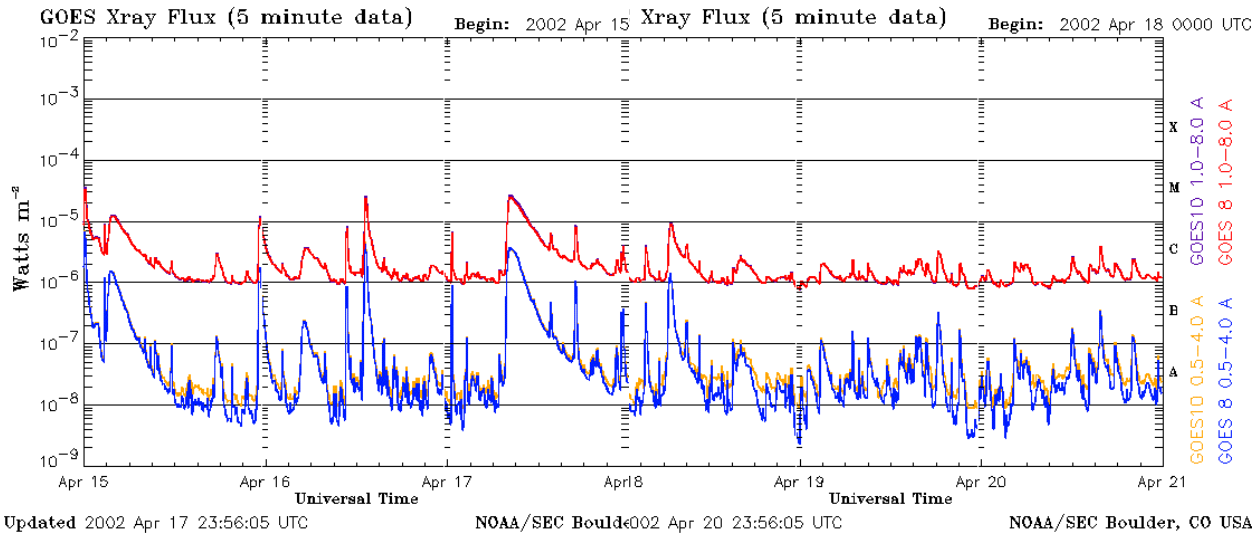


18-23 August 2002



GOES X-Rays – Previous 6 Days

15-20 April 2002



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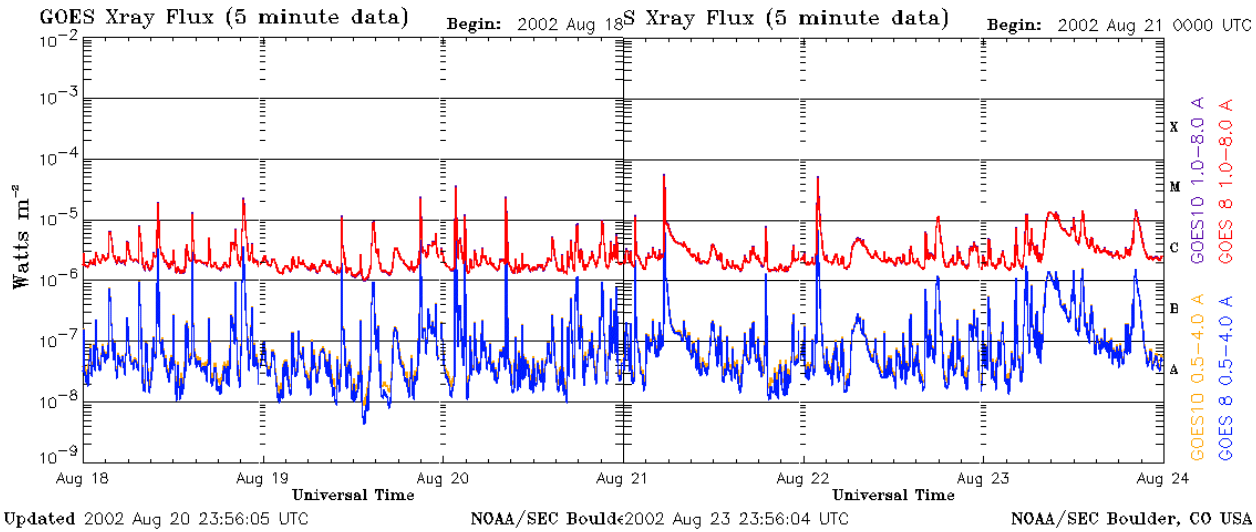
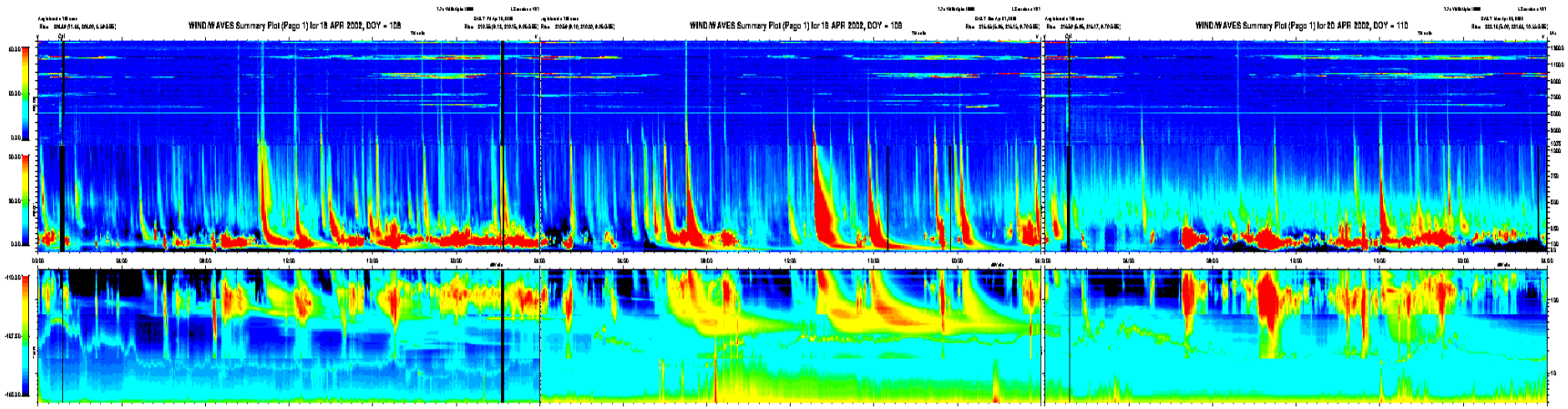
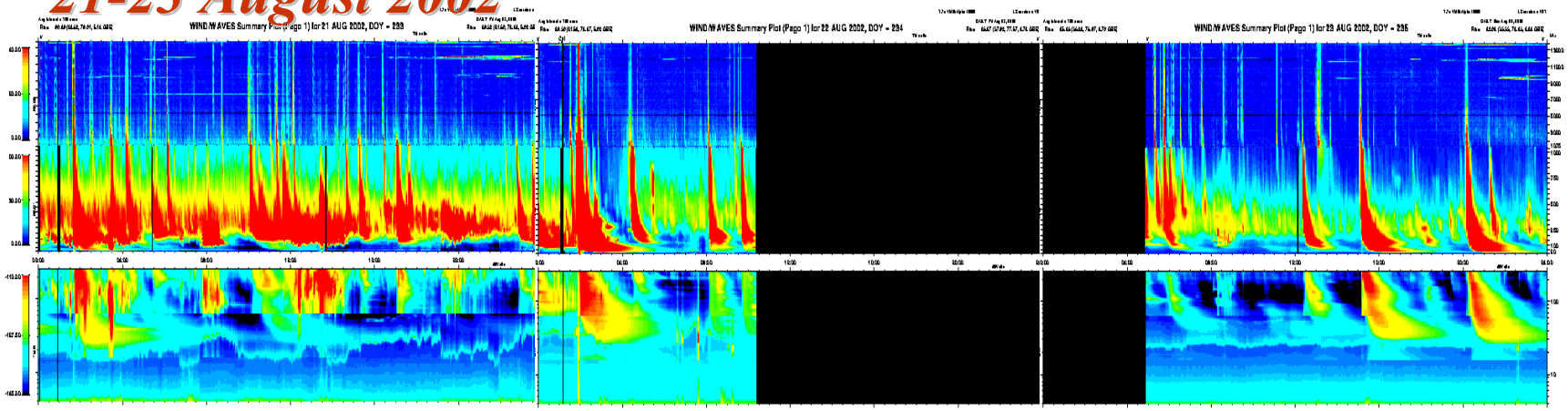


Wind/Waves Radio – Previous 3 Days

18-20 April 2002



21-23 August 2002



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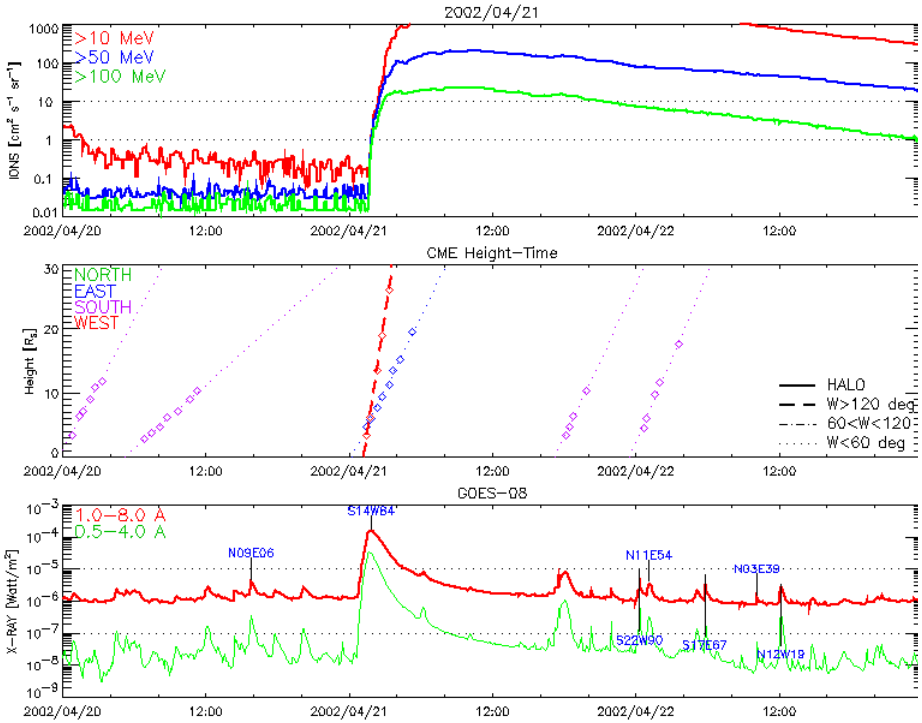
CME Interactions

21 April 2002



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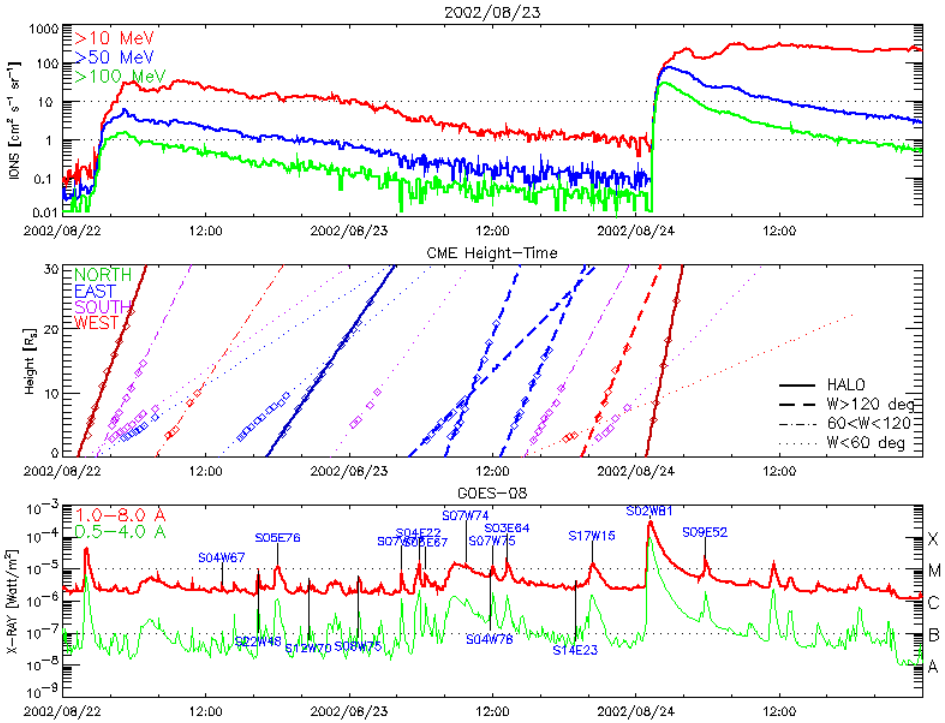


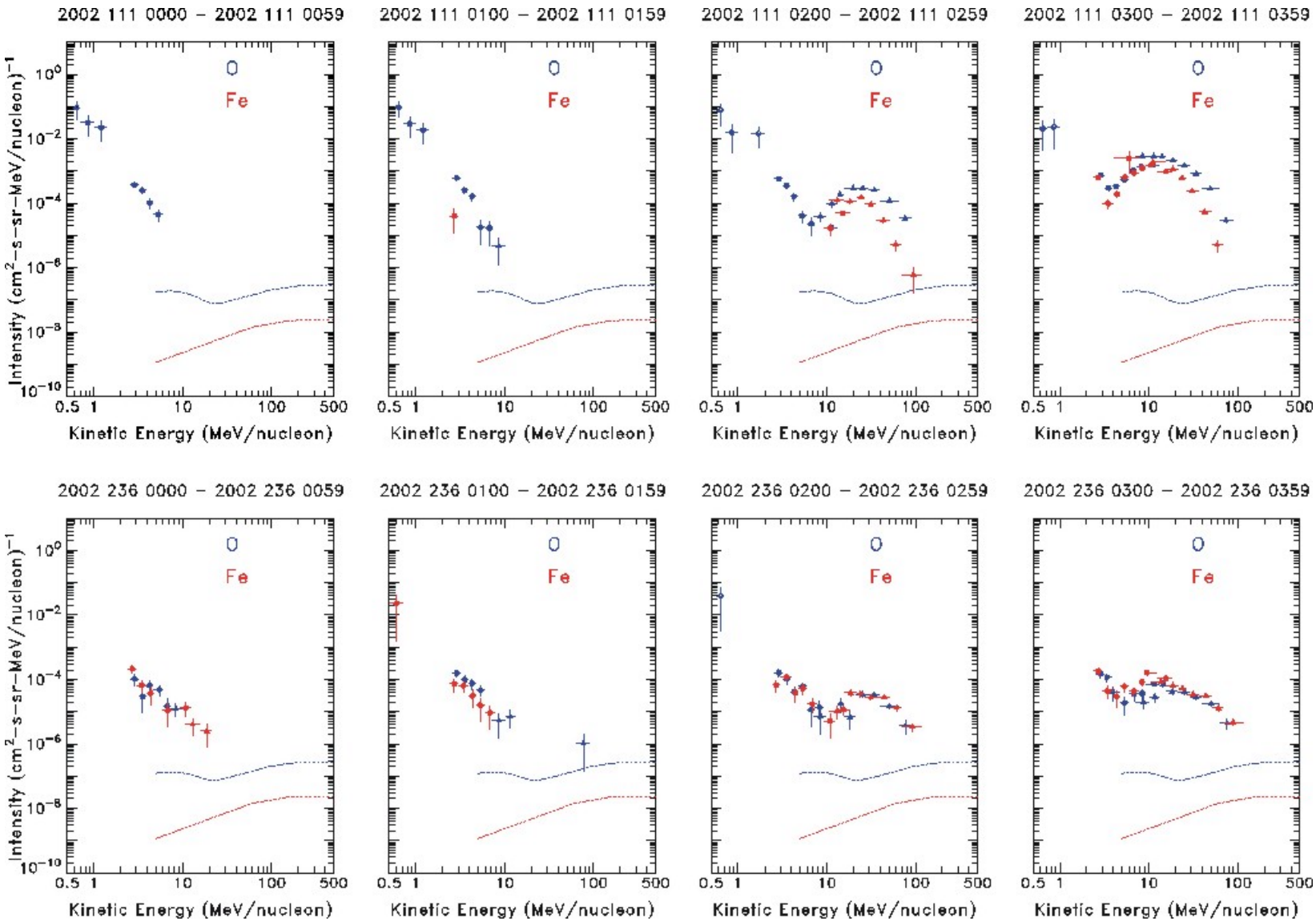
Provided by Seiji Yashiro & Nat Gopalswamy

Time-Dependent Spectra & Composition

- ***Event-Integrated spectra & composition can provide only a first hint.***
- ***Time-dependent spectra & composition needed for detailed modeling.***
- ***Data below provided by:***
  - ***ACE/SIS (from the ACE Science Center, courtesy of the SIS team)***
  - ***Wind/LEMT (from Don Reames)***
  - ***ACE/EPAM (from Carol Maclennan, on behalf of the EPAM team)***
  - ***Plots will be updated as additional data become available.***

Time-Dependent O & Fe Spectra (Hours 0.0 – 3.0)

	Pre-Event Bgrd	Hours 0.0 – 1.0	Hours 1.0 – 2.0	Hours 2.0 – 3.0
21 April 2002	2002 111 0000 – 2002 111 0059	2002 111 0100 – 2002 111 0159	2002 111 0200 – 2002 111 0259	2002 111 0300 – 2002 111 0359
24 August 2002	2002 236 0000 – 2002 236 0059	2002 236 0100 – 2002 236 0159	2002 236 0200 – 2002 236 0259	2002 236 0300 – 2002 236 0359



Time-Dependent O & Fe Spectra (Hours 3.0 – 8.0)

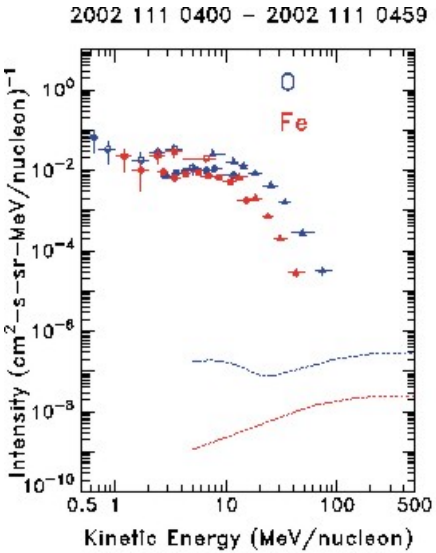
Hours 3.0 – 4.0

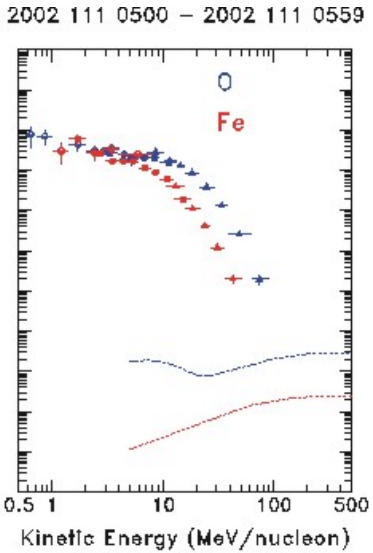
Hours 4.0 – 5.0

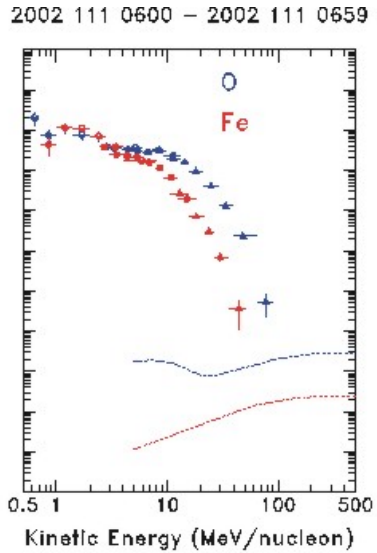
Hours 5.0 – 6.0

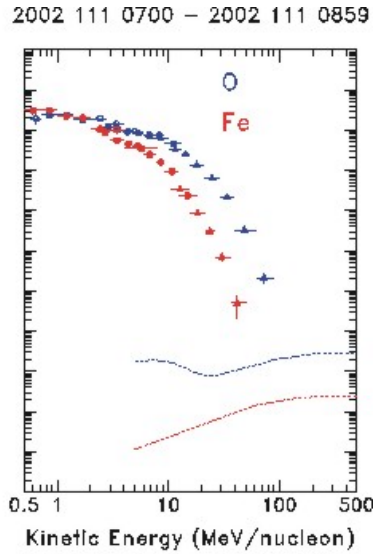
Hours 6.0 – 8.0

21 April 2002

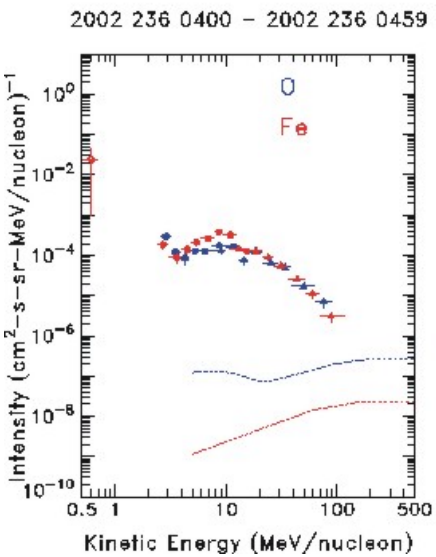


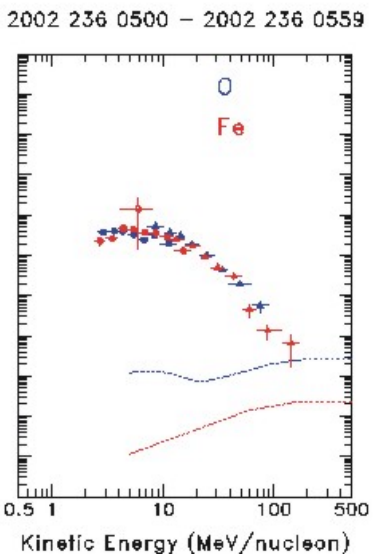


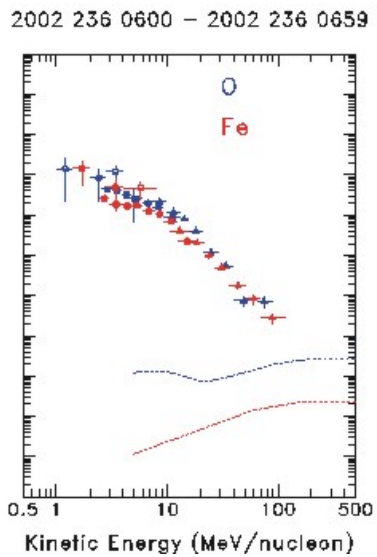


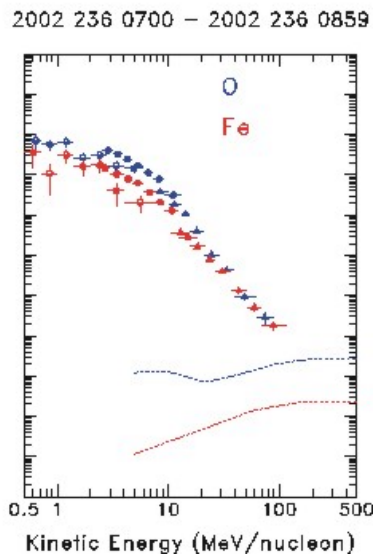


24 August 2002









Time-Dependent O & Fe Spectra (Hours 8.0 – 18.0)

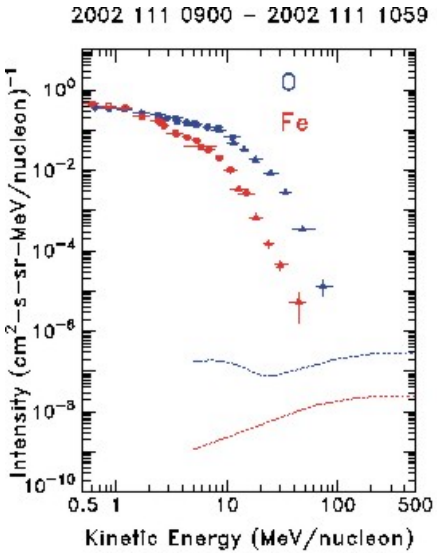
Hours 8.0 – 10.0

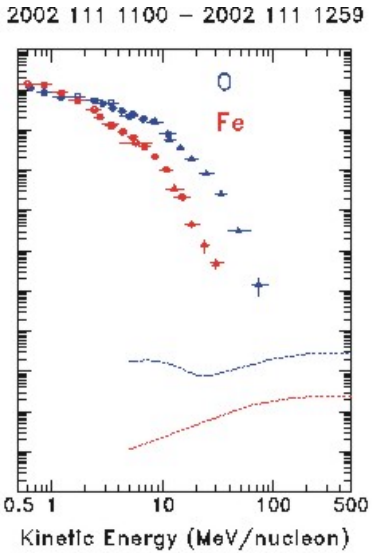
Hours 10.0 –12.0

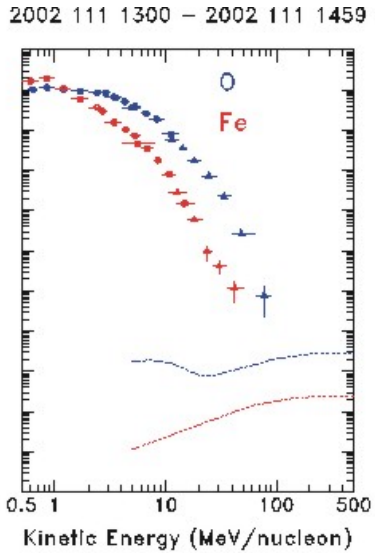
Hours 12.0-14.0

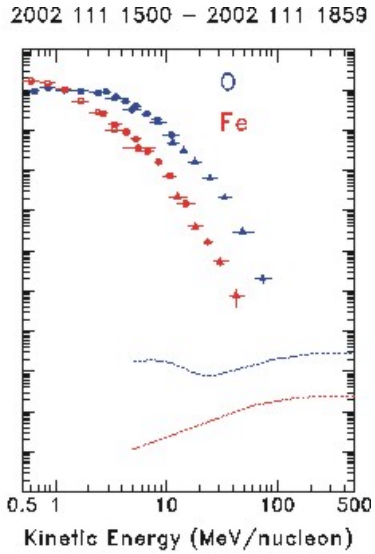
Hours 14.0-18.0

21 April 2002

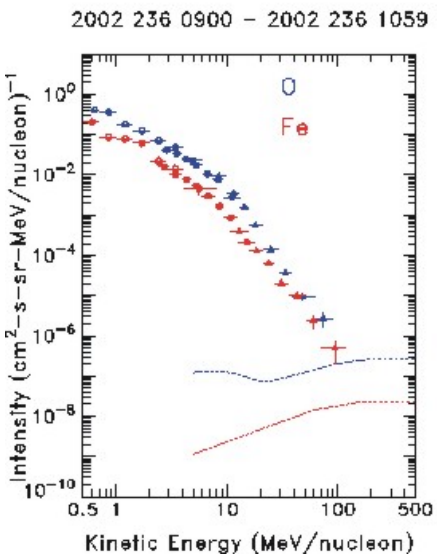


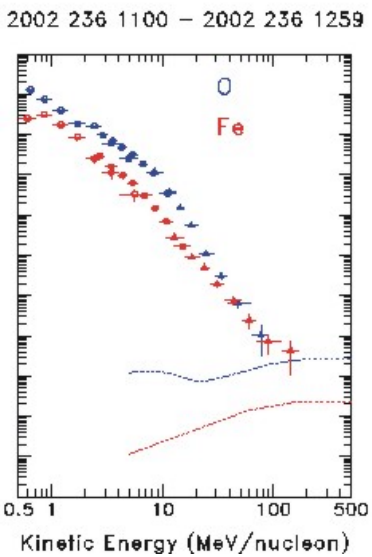


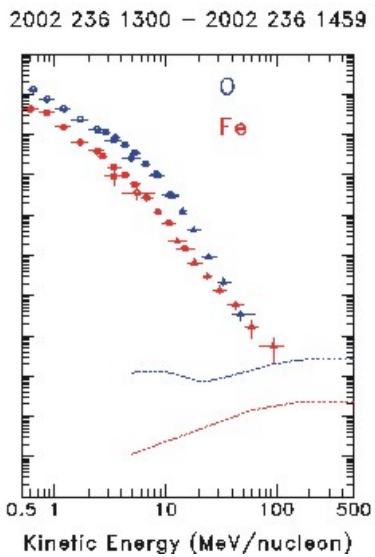


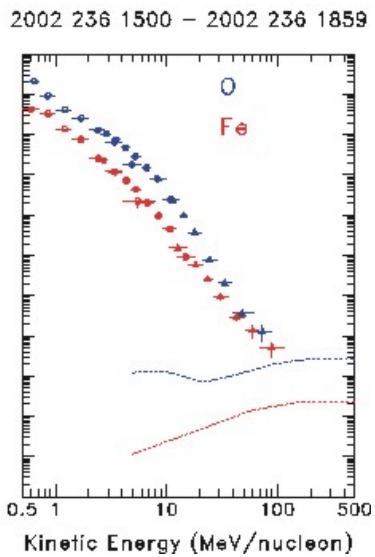


24 August 2002









Time-Dependent O & Fe Spectra (Hours 18.0-46.0)

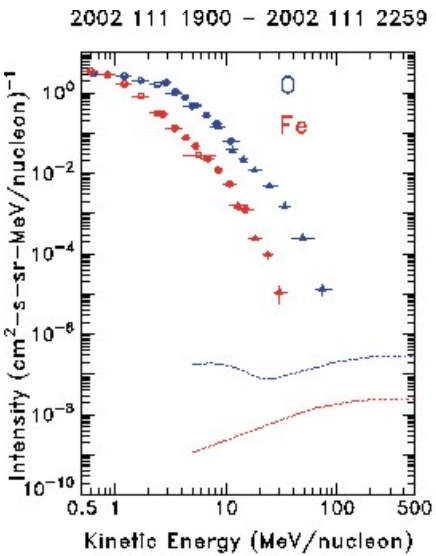
Hours 18.0 – 22.0

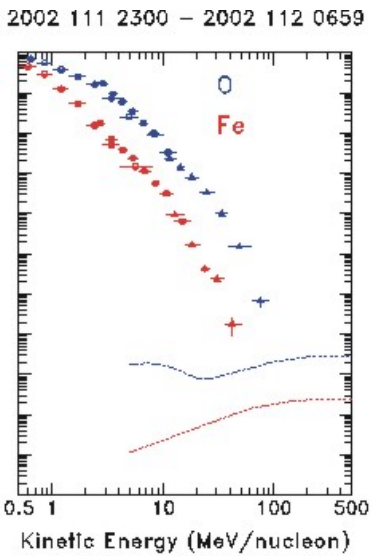
Hours 22.0 – 30.0

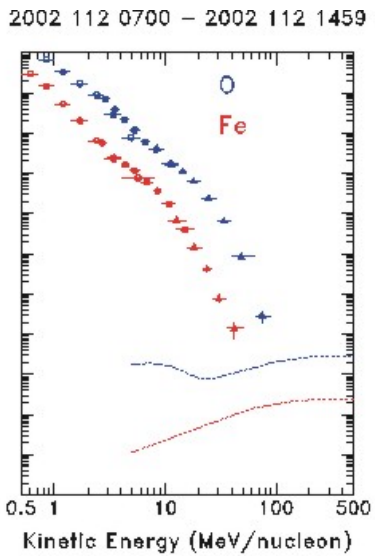
Hours 30.0 - 38.0

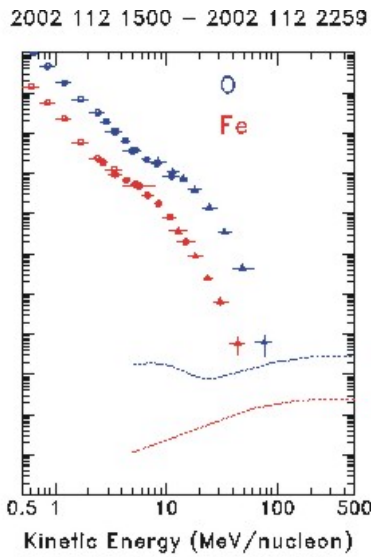
Hours 38.0 - 46.0

21 April 2002









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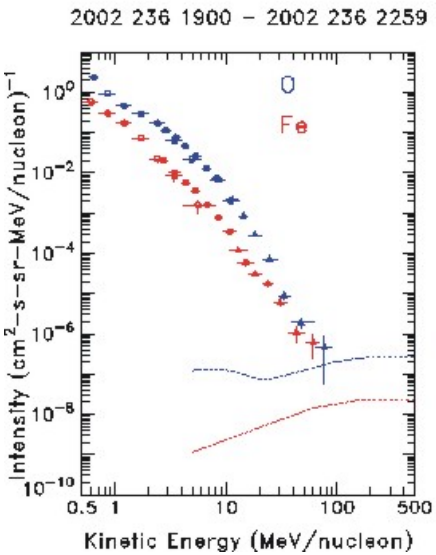
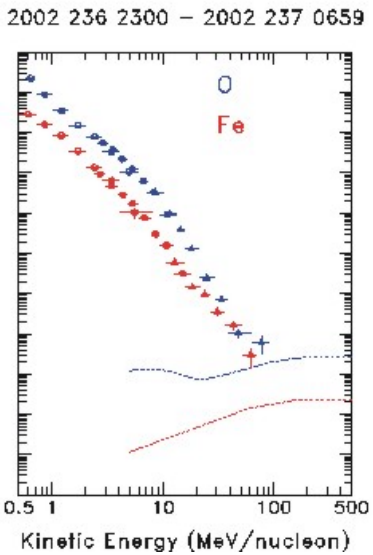
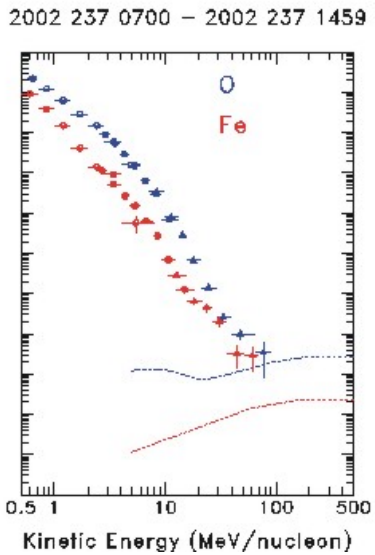
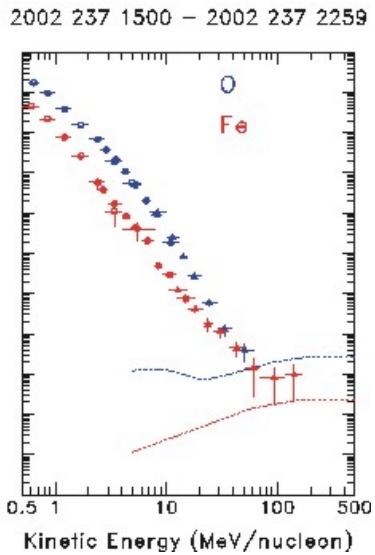








Time-Dependent O & Fe Spectra (Hours 46.0 – 90.0)

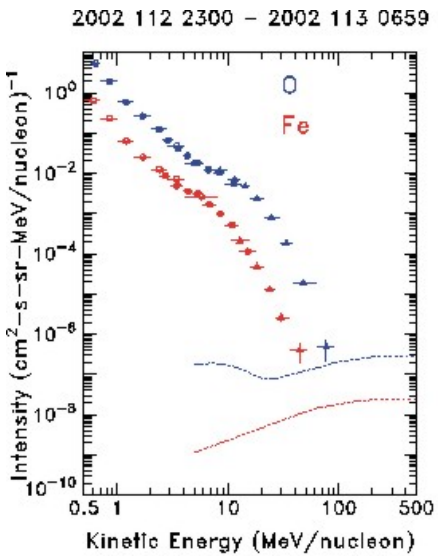
Hours 46.0 - 54.0

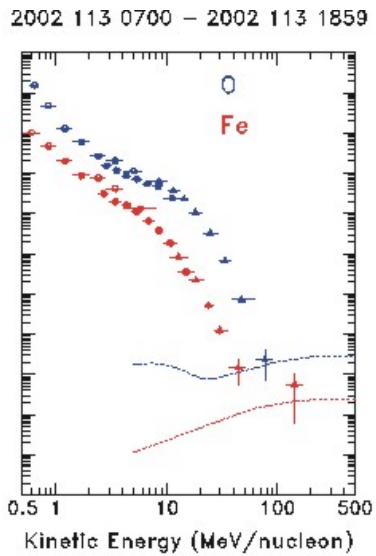
Hours 54.0 - 66.0

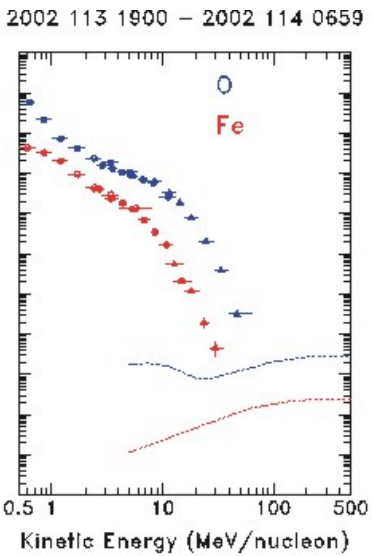
Hours 66.0 - 78.0

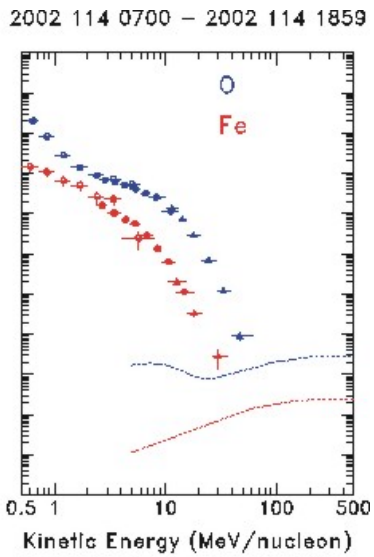
Hours 78.0 – 90.0

21 April 2002

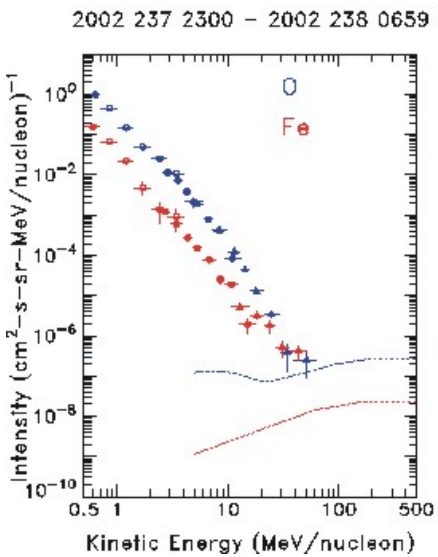


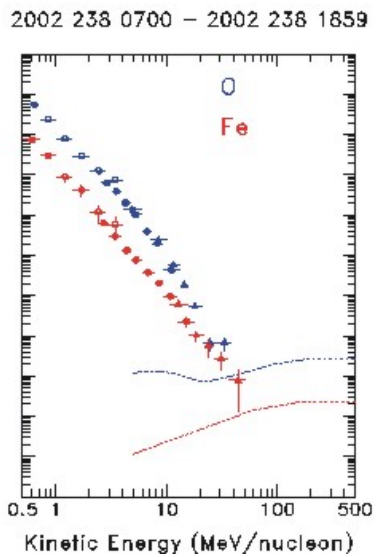


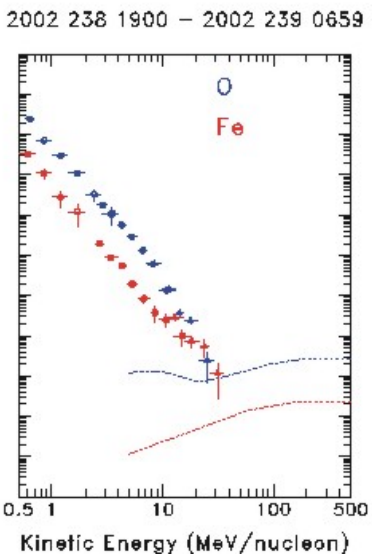


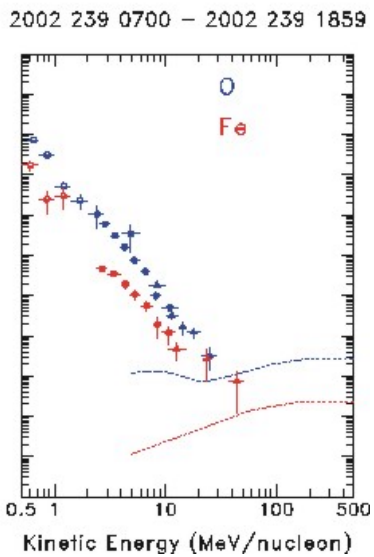


24 August 2002





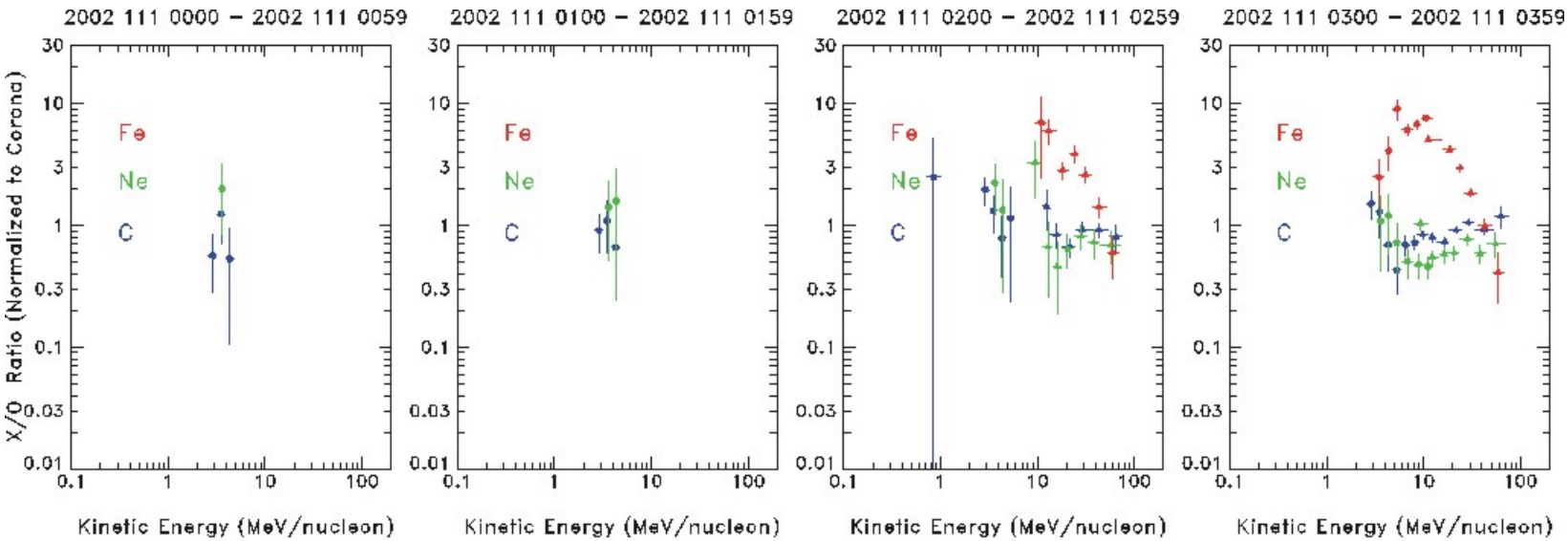




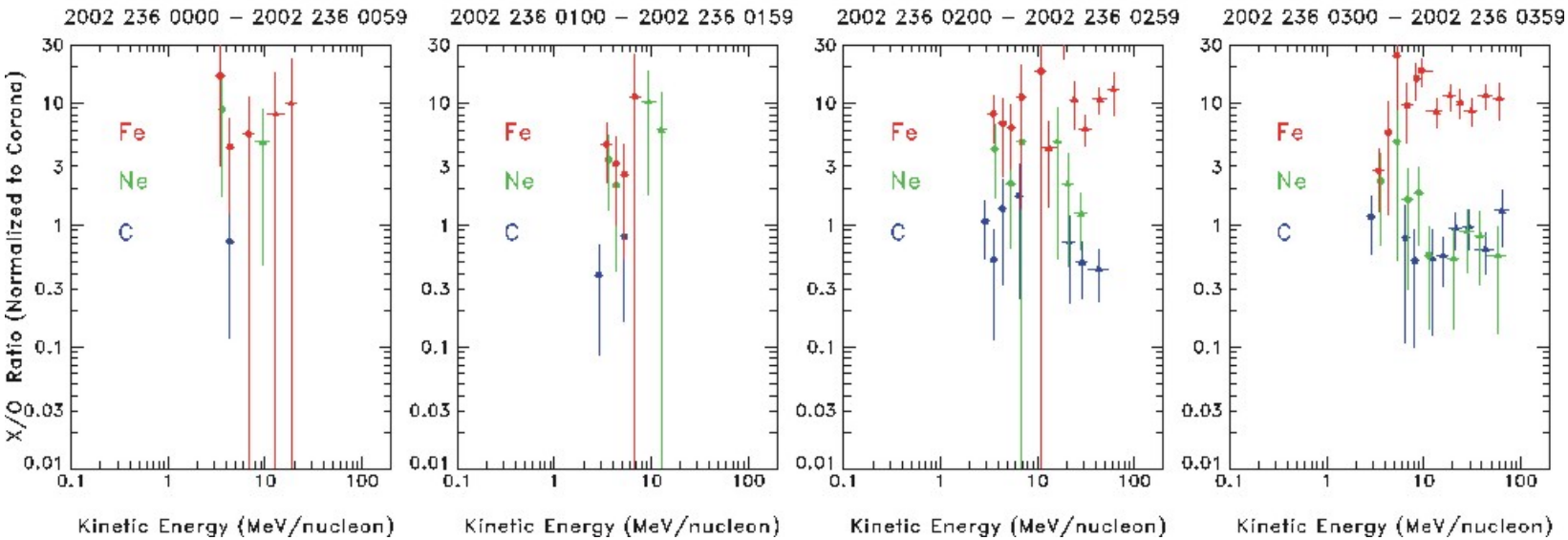
Time-Dependent C/O, Ne/O, Fe/O (Hours 0.0 – 3.0)

Pre-Event Bgrd | **Hours 0.0 – 1.0** | **Hours 1.0 – 2.0** | **Hours 2.0 – 3.0**

21 April 2002



24 August 2002



Time-Dependent C/O, Ne/O, Fe/O (Hours 3.0 – 8.0)

Hours 3.0 – 4.0

Hours 4.0 – 5.0

Hours 5.0 – 6.0

Hours 6.0 – 8.0

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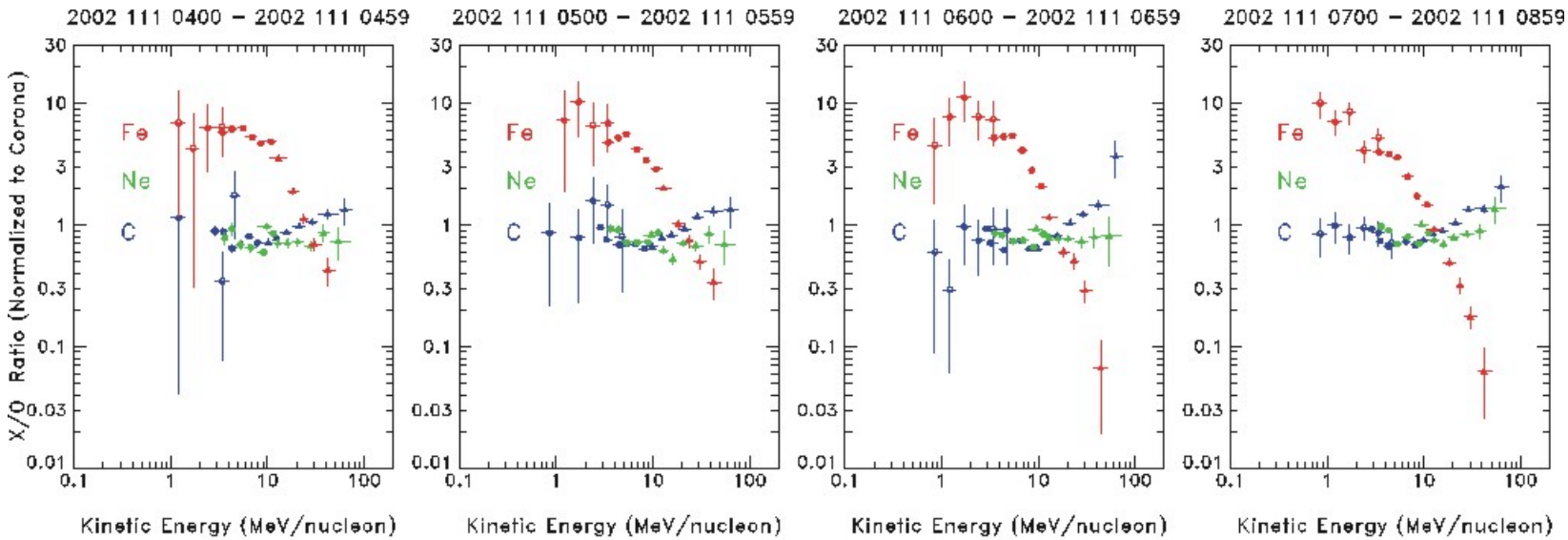
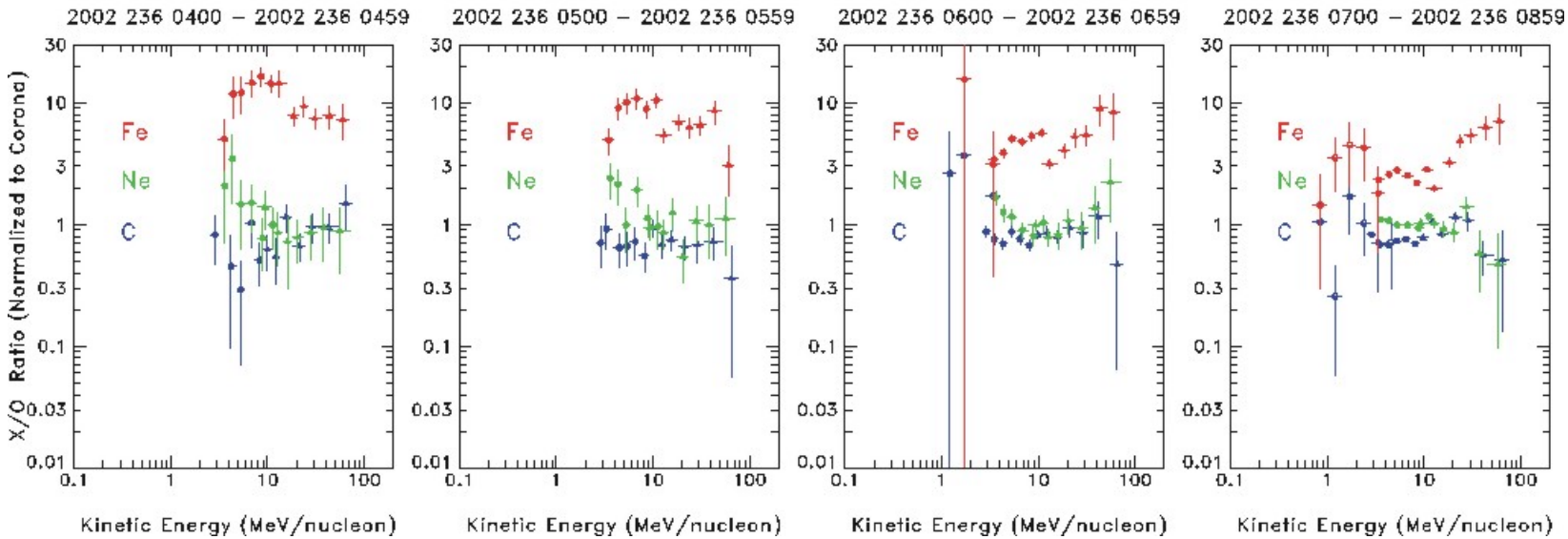


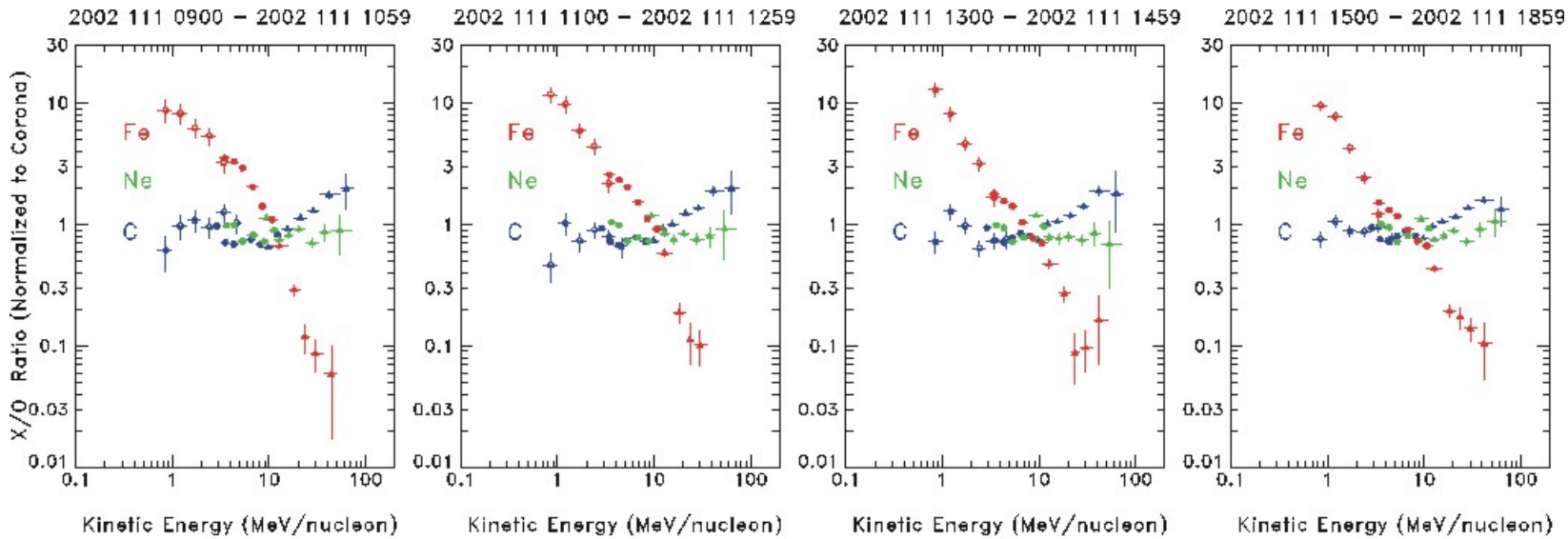
24 August 2002



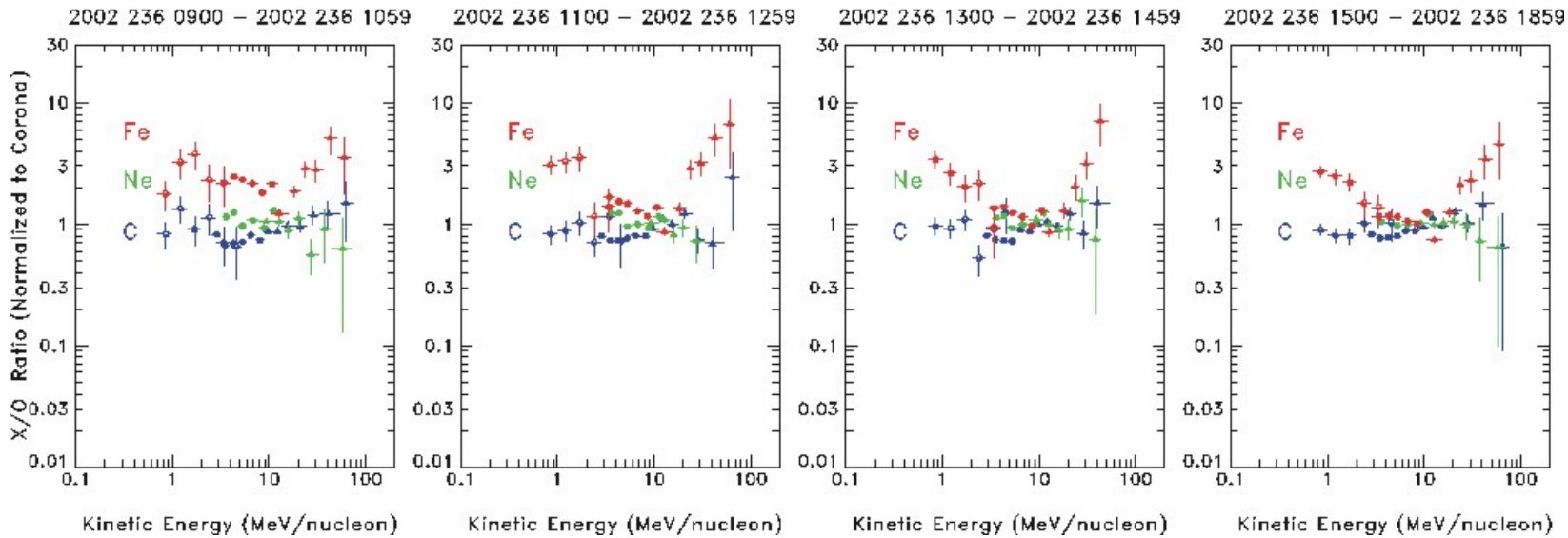
Time-Dependent C/O, Ne/O, Fe/O (Hours 8.0 – 18.0)

Hours 8.0 – 10.0 | Hours 10.0 –12.0 | Hours 12.0-14.0 | Hours 14.0-18.0

21 April 2002



24 August 2002



Time-Dependent C/O, Ne/O, Fe/O (Hours 18.0-46.0)

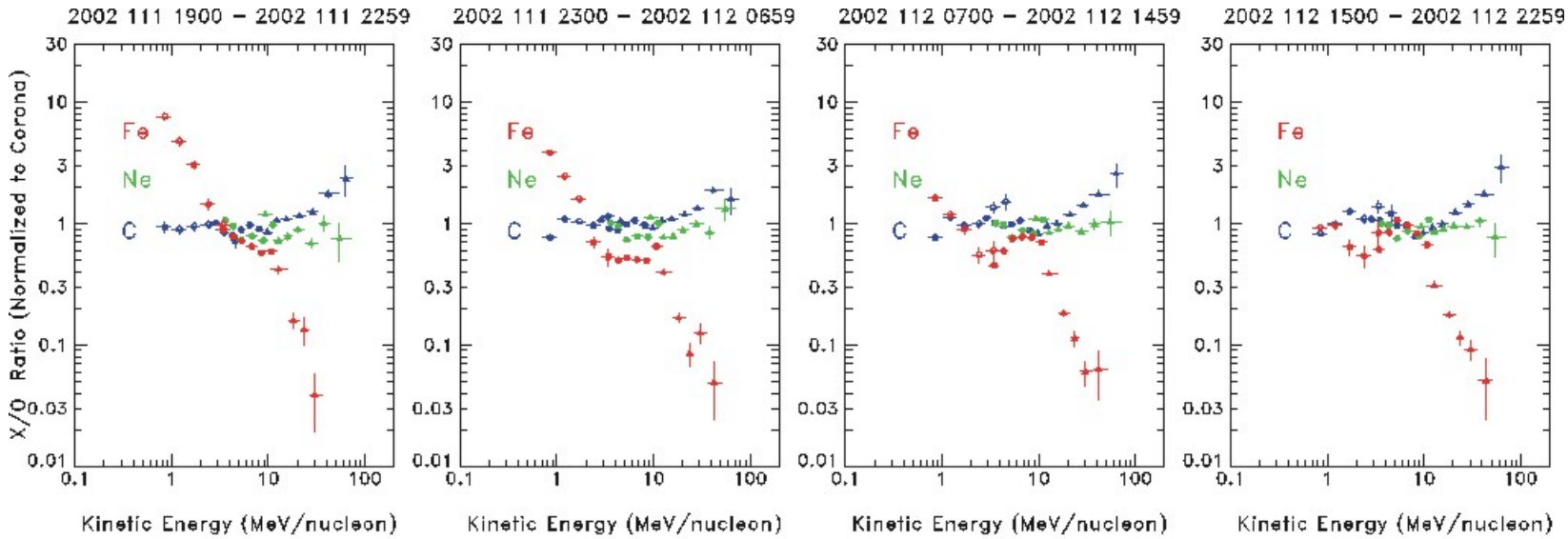
Hours 18.0 – 22.0

Hours 22.0 – 30.0

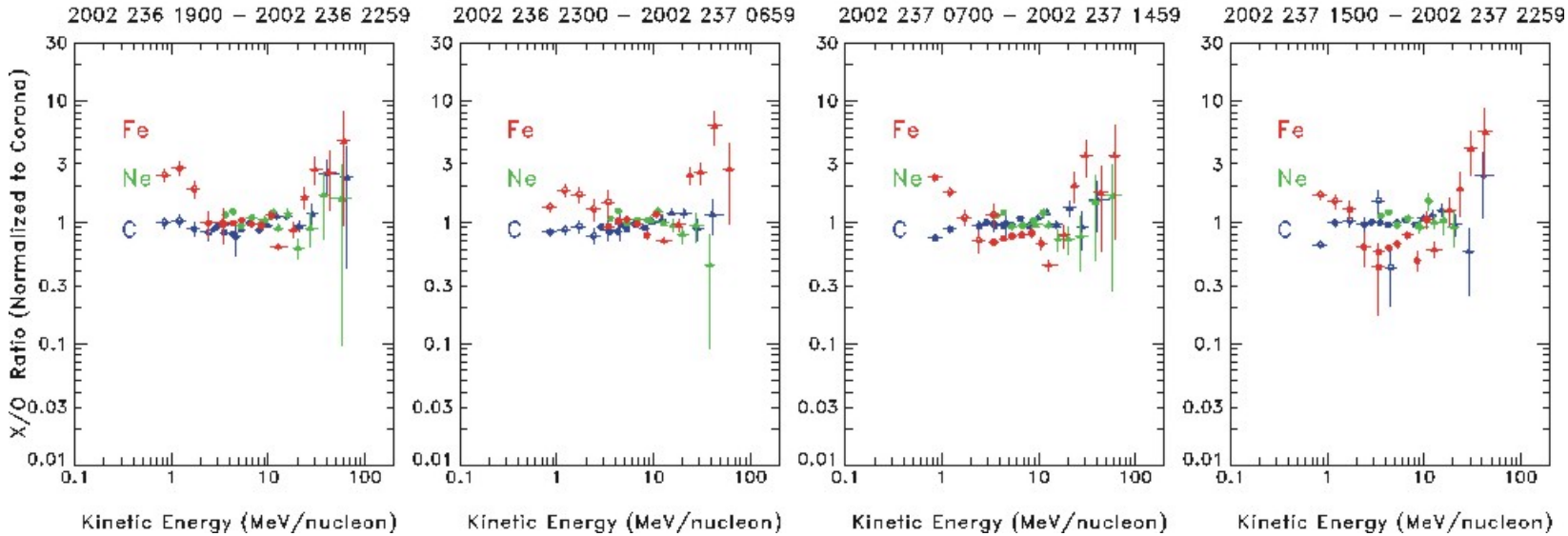
Hours 30.0 - 38.0

Hours 38.0 - 46.0

21 April 2002



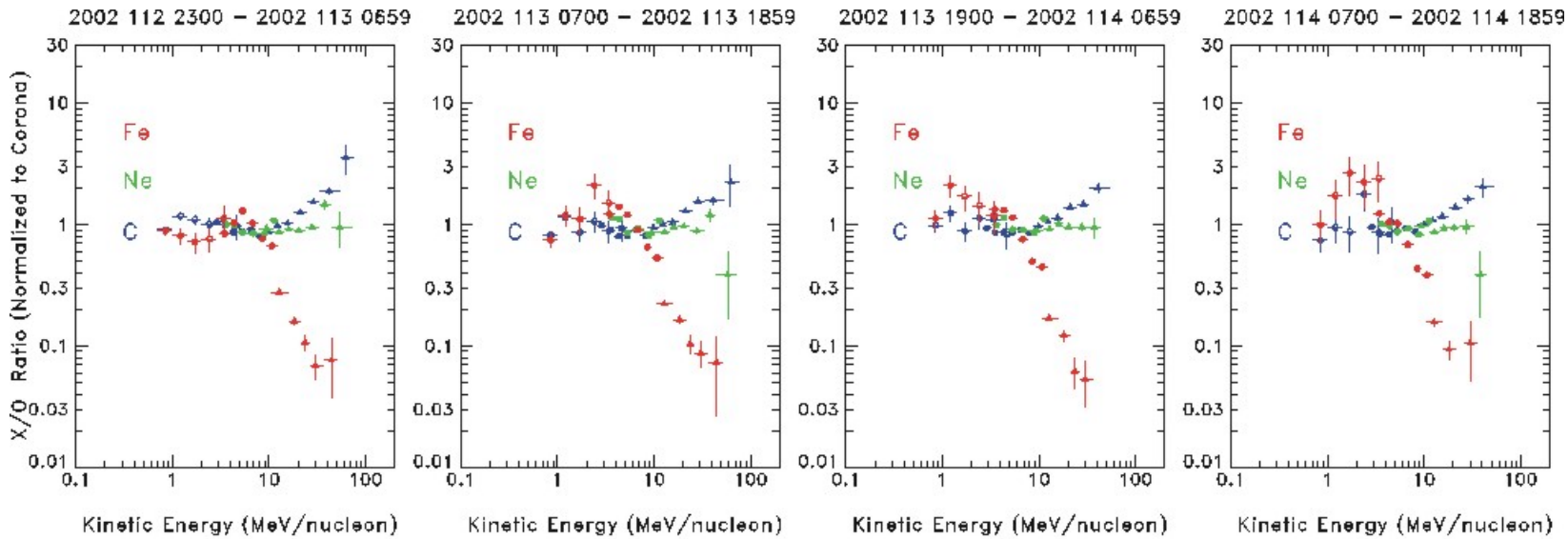
24 August 2002



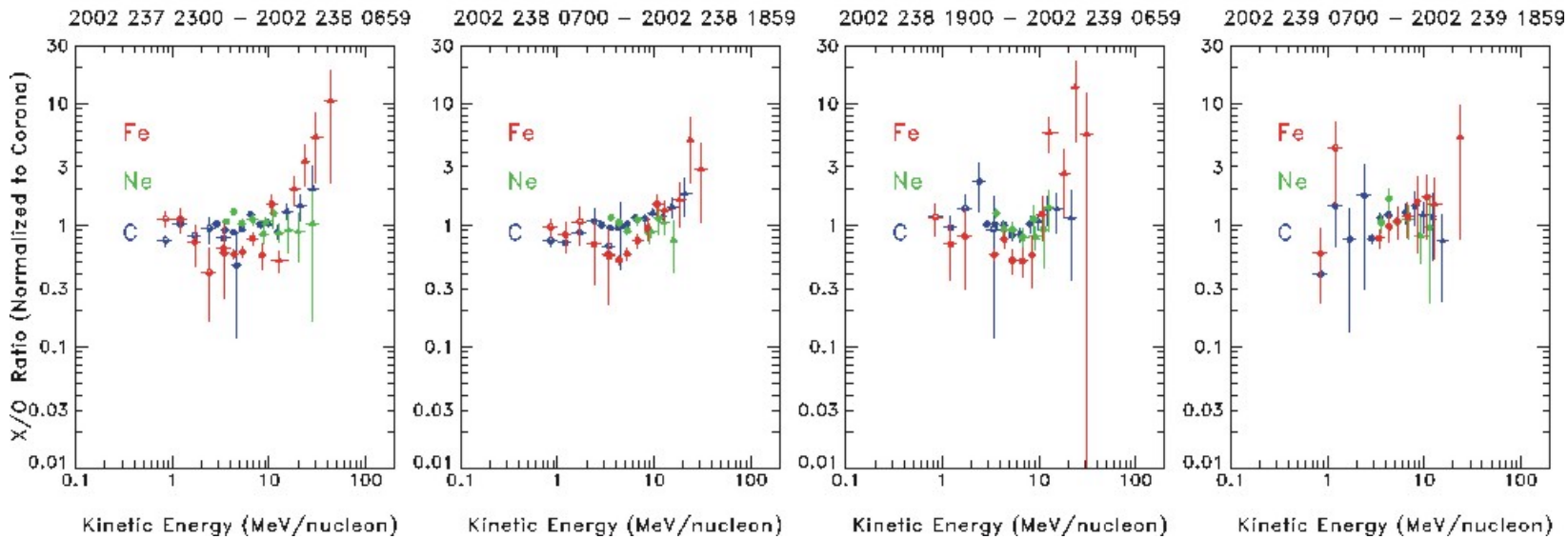
Time-Dependent C/O, Ne/O, Fe/O (Hours 46.0 – 90.0)

Hours 46.0 - 54.0 | Hours 54.0 - 66.0 | Hours 66.0 - 78.0 | Hours 78.0 – 90.0

21 April 2002



24 August 2002



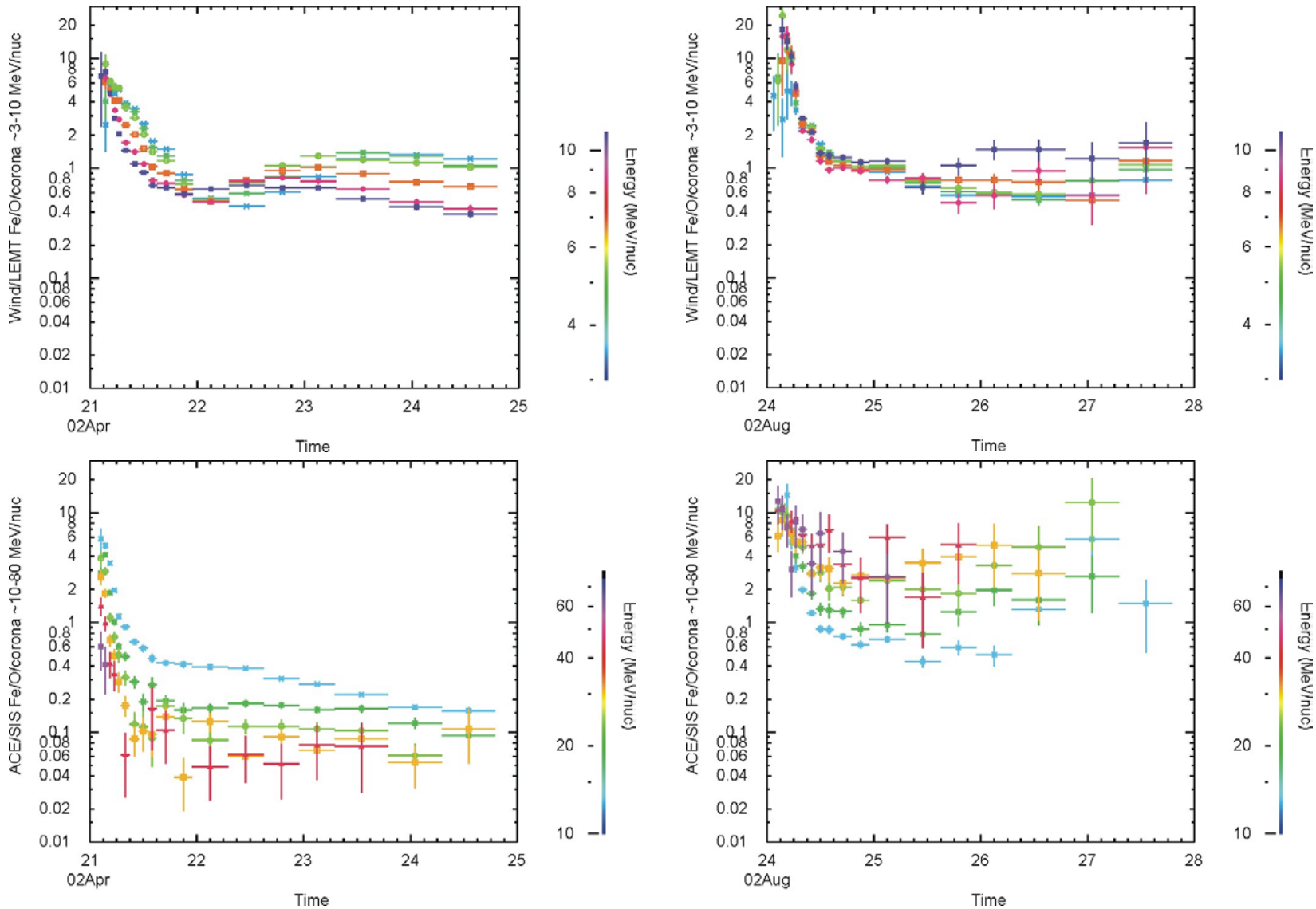
Time & Energy Dependent Fe/O

21 April 2002

24 August 2002

Wind/LEMT ~3-10 MeV/nuc

ACE/SIS ~10-80 MeV/nuc



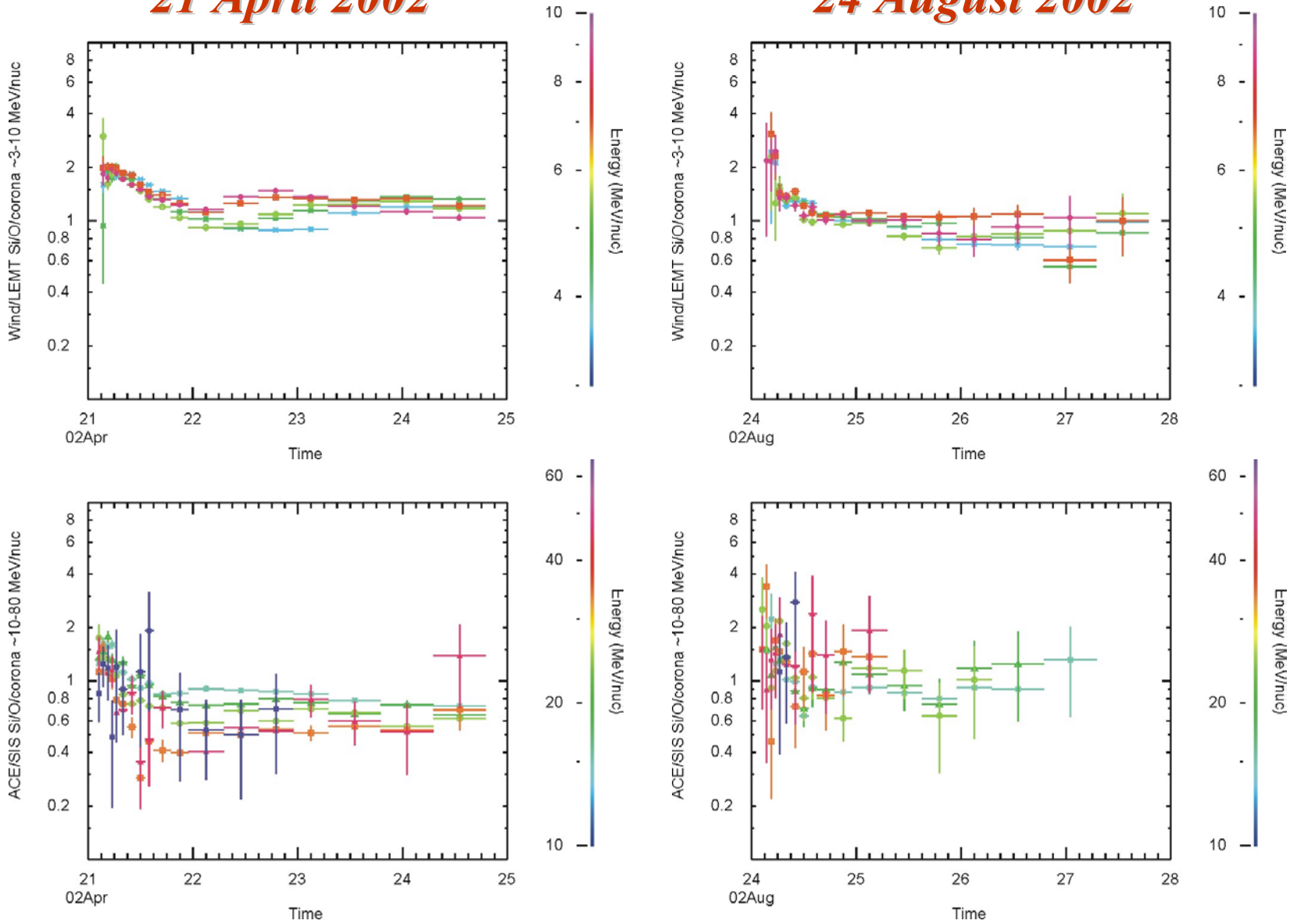
Time & Energy Dependent Si/O

21 April 2002

24 August 2002

Wind/LEMT ~3-10 MeV/nuc

ACE/SIS ~10-80 MeV/nuc



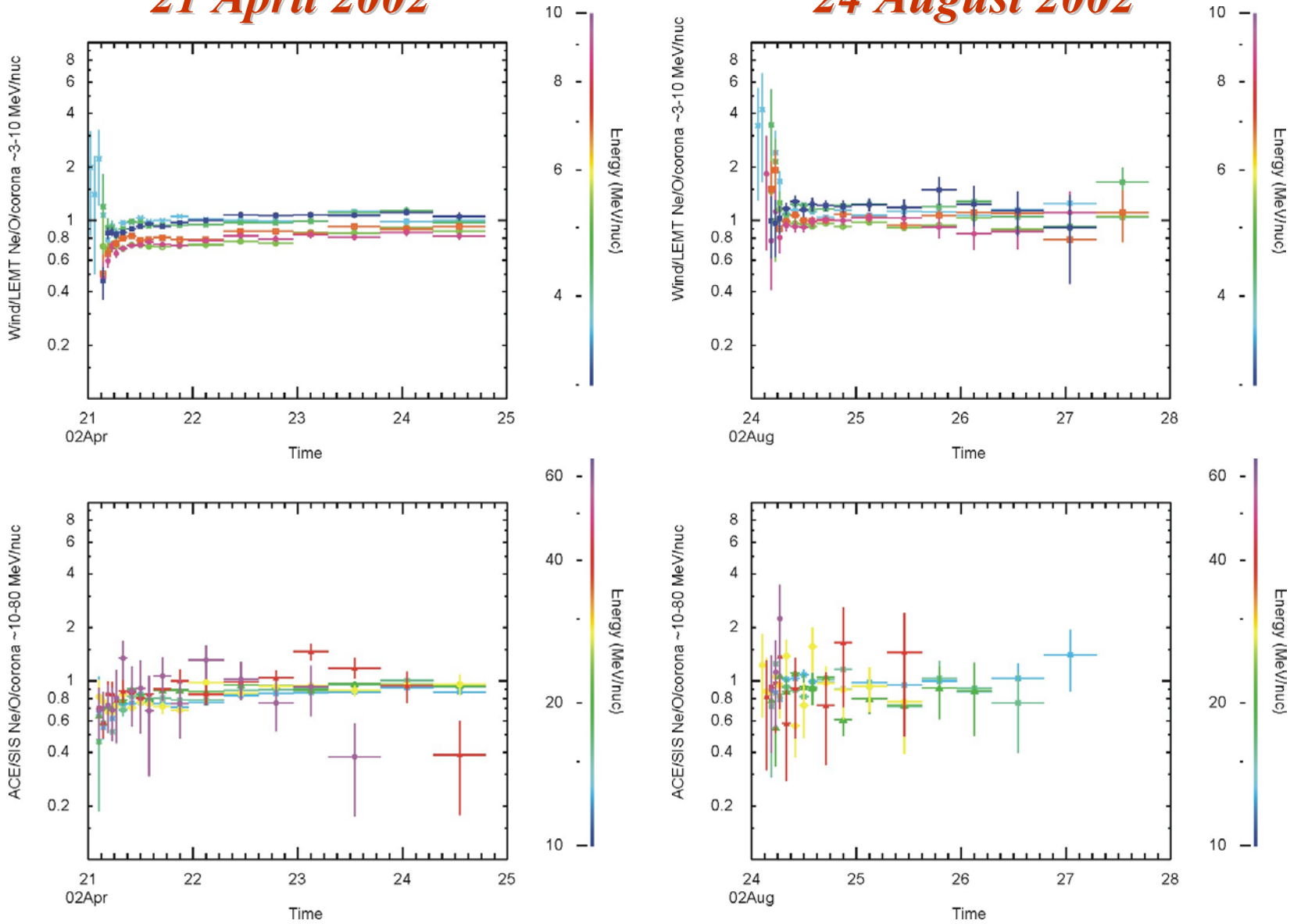
Time & Energy Dependent Ne/O

21 April 2002

24 August 2002

Wind/LEMT ~3-10 MeV/nuc

ACE/SIS ~10-80 MeV/nuc



Time & Energy Dependent C/O

21 April 2002

24 August 2002

Wind/LEMT ~3-10 MeV/nuc

ACE/SIS ~10-80 MeV/nuc