Elemental Abundance variations of the Suprathermal Heavy Ion Population over solar cycle 23

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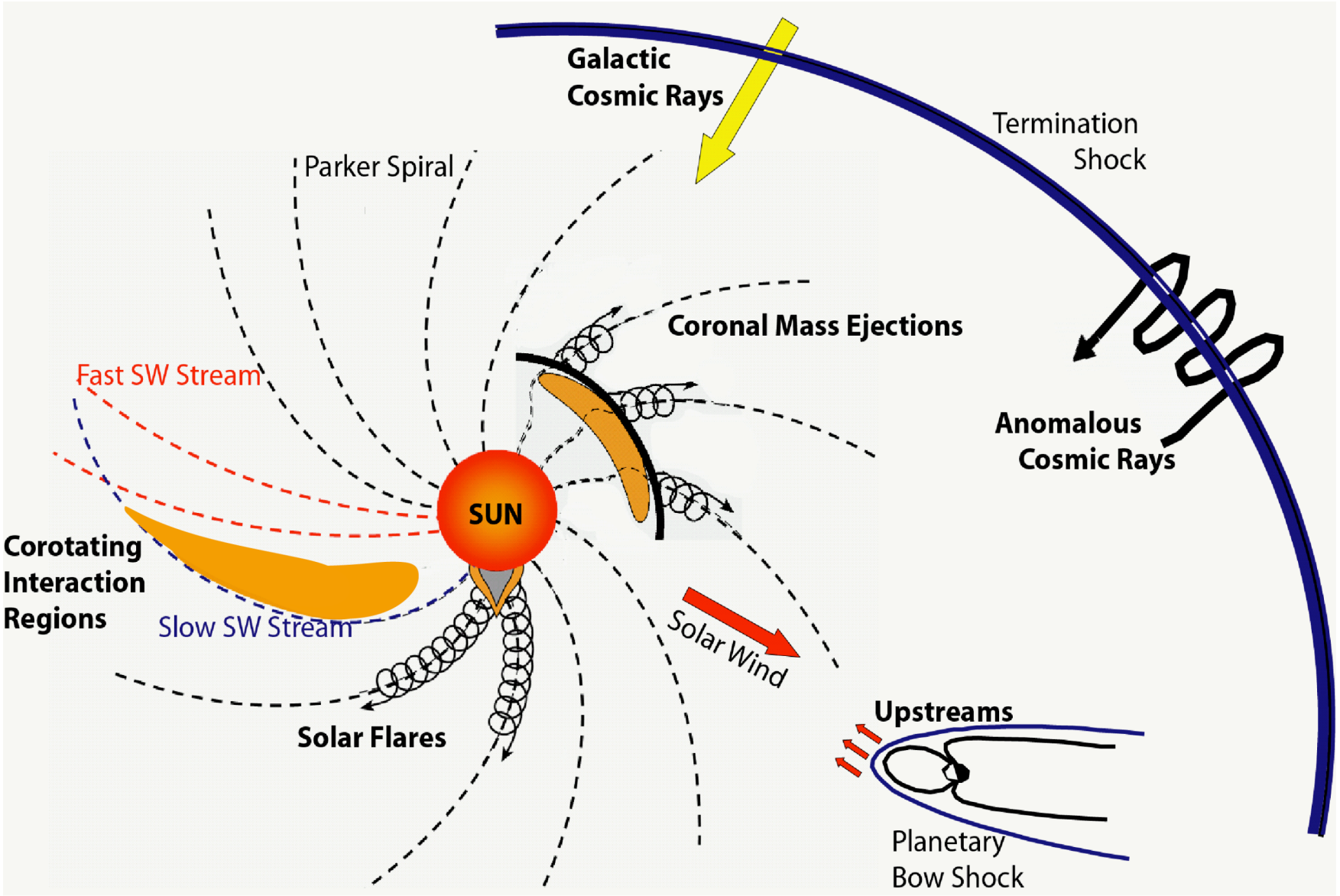
SHINE Workshop, Zermatt, Utah **July 30, 2006**

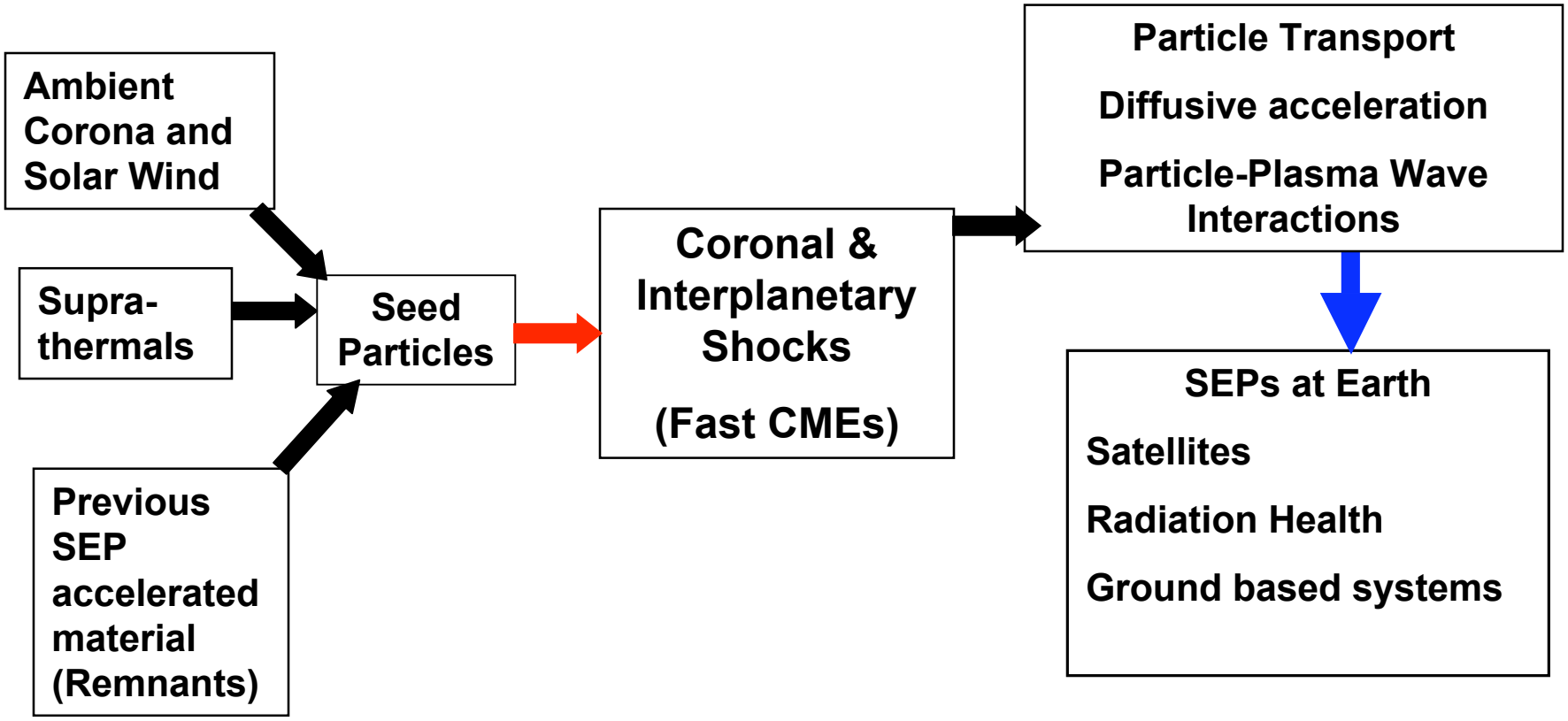


Energetic particle populations in the heliosphere

Solar Energetic Particle (SEP) Events

Impulsive SEP events		Gradual SEP events
"Small"	Event Spatial Size	"Big"
~hours	Duration	~days
~1000 / year over the whole Sun	Frequency at Solar Max	~10 / year
Restricted to magnetically-connected longitudes, ~W30-W80	Source Location	Over the whole Sun
~1.0	Event-Integrated Fe/O	~0.1
100x – 1000x enhancements	*Trans-Fe (30 $\leq$ Z $\leq$ 82)	Nominal coronal values
~16-20	Fe Charge States	~10-14
~ 1	3He/4He	~ 0.0001
Resonant wave-particle interactions at Flare/Reconnection Site	Acceleration Mechanism	Shock, driven by fast CME

Statement of the problem



Complicated recipe: Mixed ingredients

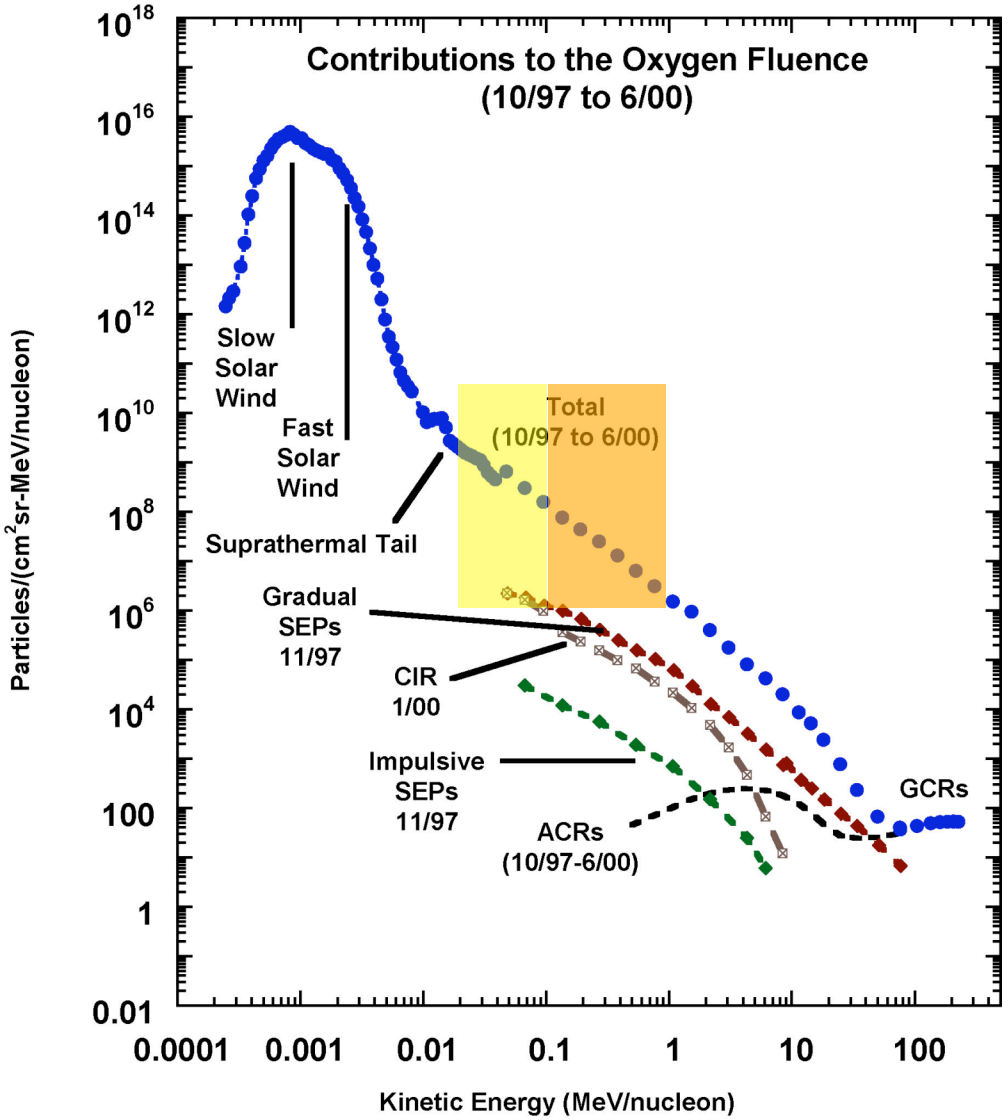
More complications:

- Large elemental abundance variability within Gradual events.
- A zoo of energy spectra (spectral breaks!).

Big Questions still not answered:

- Acceleration mechanisms?
  [shocks, flares]
- Transport effects?
  [elemental abundances/spectra]
- Accelerated material?
  [Coronal/SW, Flare]

Seed particles?



(Mewaldt et al., 2001 AIP conference Proceedings 598, 165)

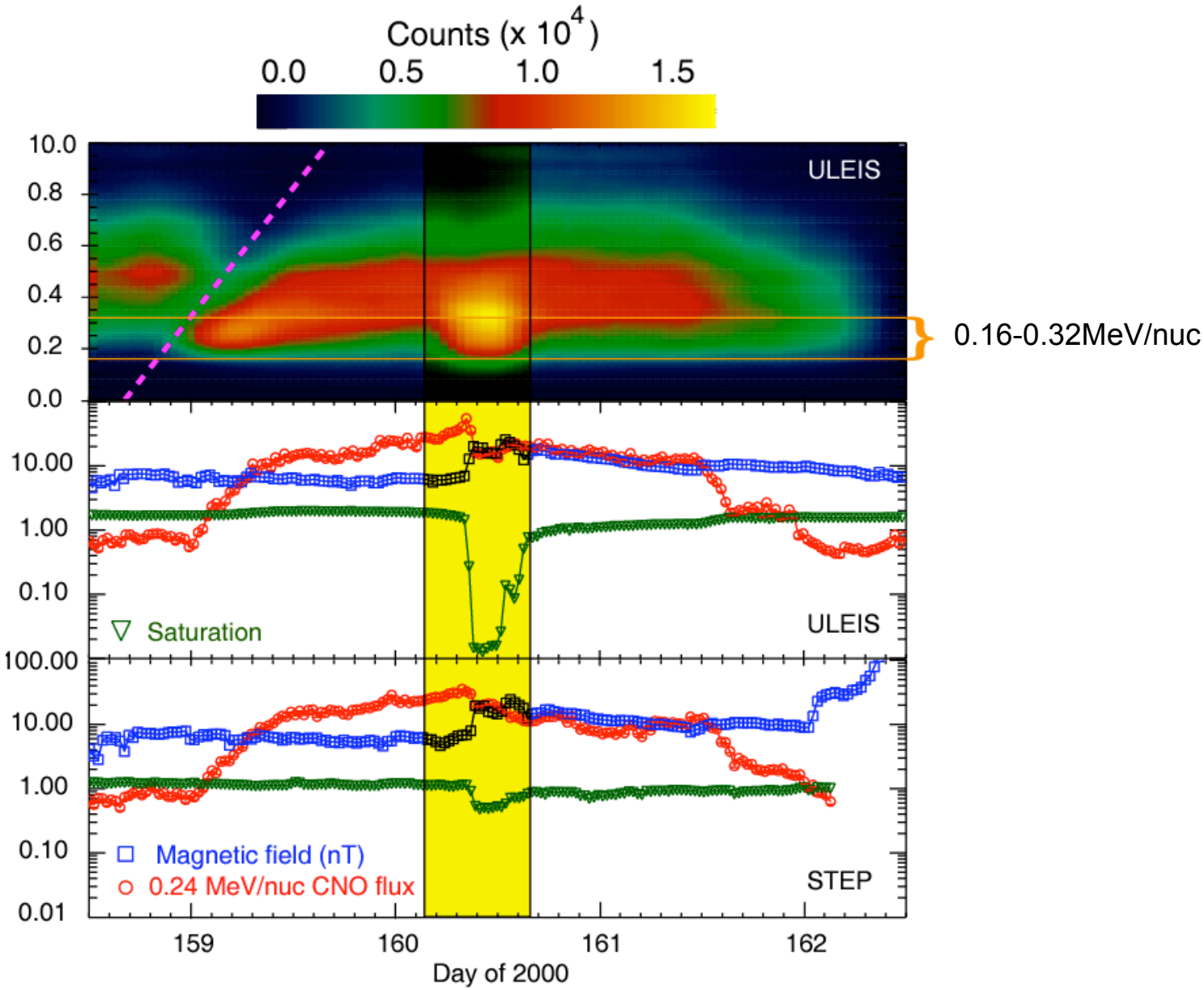
Instrumentation

Ultra Low Energy Isotope Spectrometer (ULEIS):

Launched onboard ACE on August 25, 1997
Time of Flight Mass Spectrometer
Measured species: Protons to Gold
Energy range: 45 keV to few MeV/nuc
Instrument geometrical factor: ~1.3 cm^2 sr

Supra Thermal Energetic Particle Telescope (STEP):

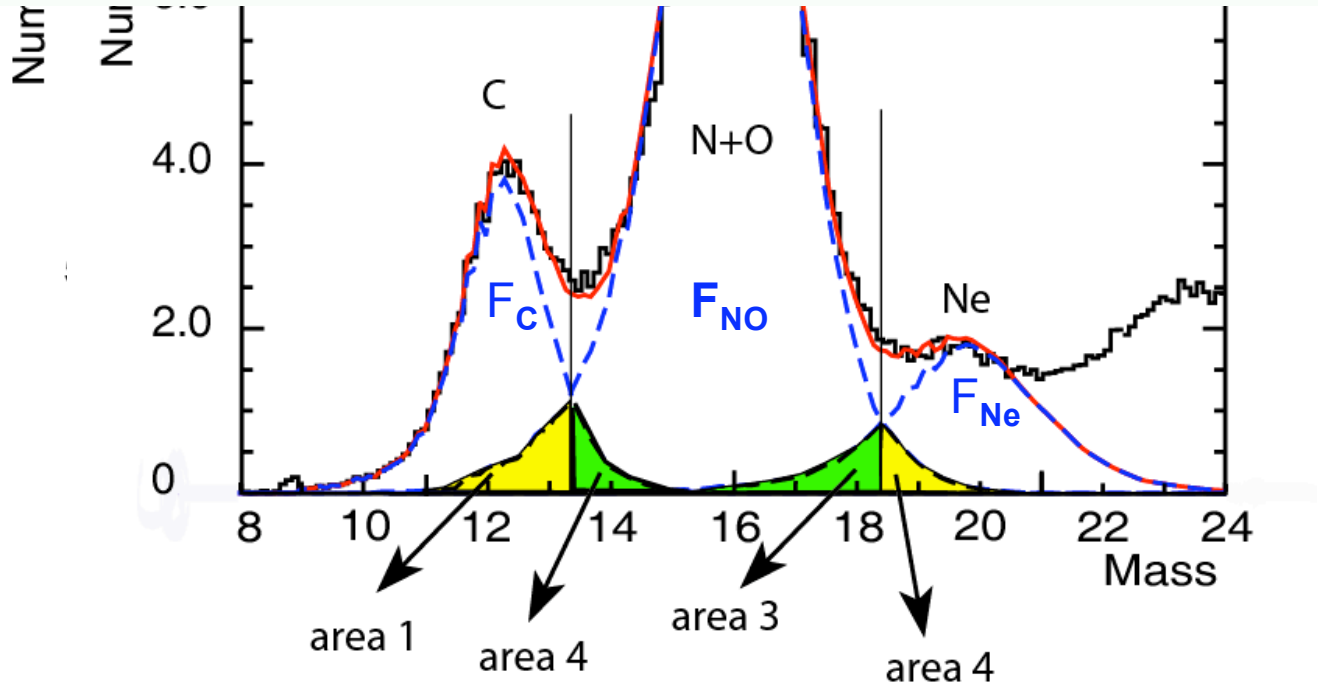
Launched onboard Wind on November 1, 1994
Time of Flight Mass Spectrometer
Measured species: Protons to Fe
Energy range: ~30 keV to ~2 MeV/nuc
Instrument geometrical factor: 2 x 0.4 cm^2 sr


Counts (x 10^4)
0.0
0.5
1.0
1.5
10.0
0.8
0.6
0.4
0.2
0.0
ULEIS
0.16-0.32MeV/nuc
10.00
1.00
0.10
Saturation
ULEIS
100.00
10.00
1.00
0.10
0.01
Magnetic field (nT)
0.24 MeV/nuc CNO flux
STEP
159
160
161
162
Day of 2000

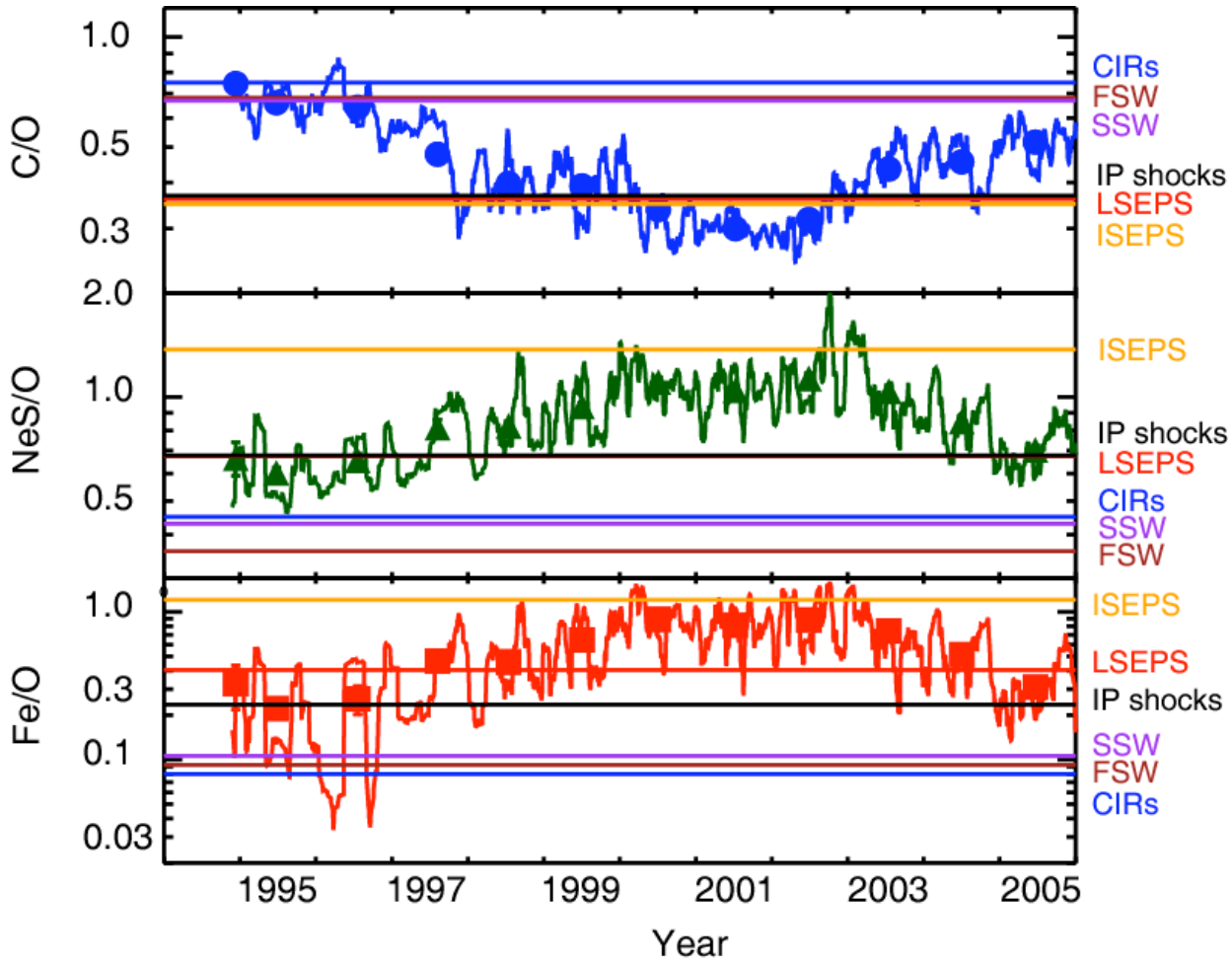
C/O at low energies:

Correction Matrix

$$\begin{pmatrix} C \\ NO \\ Ne \end{pmatrix}_{True} = \begin{pmatrix} 1+\frac{area2}{F_C} & -\frac{area1}{F_{NO}} & 0 \\ -\frac{area2}{F_C} & \frac{area1}{F_{NO}}+1+\frac{area4}{F_{NO}} & -\frac{area3}{F_{Ne}} \\ 0 & -\frac{area4}{F_{NO}} & 1+\frac{area3}{F_{Ne}} \end{pmatrix} \times \begin{pmatrix} C \\ NO \\ Ne \end{pmatrix}_{Measured}$$



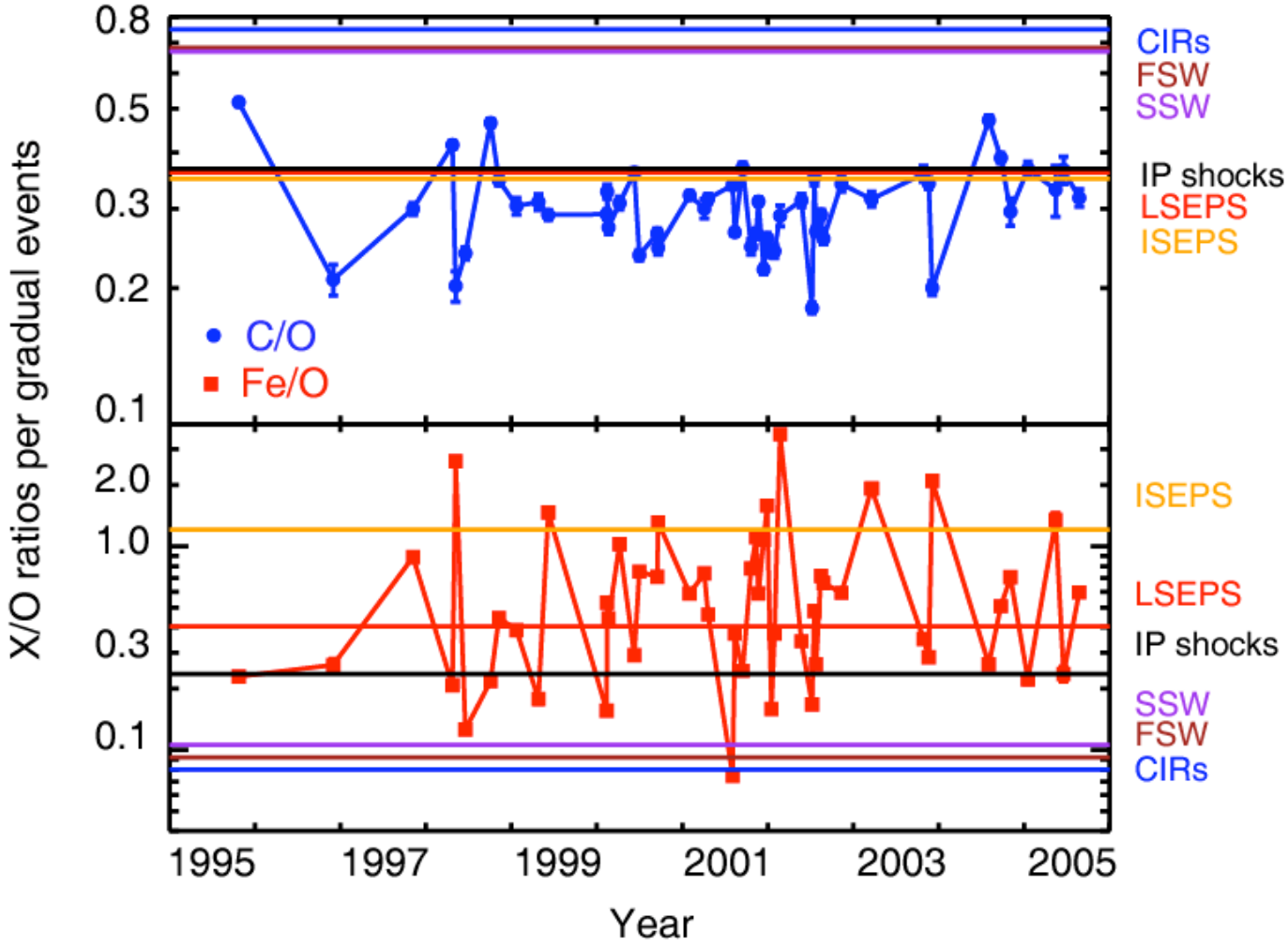
Solar Cycle variation of C/O, NeS/O, and Fe/O at 0.08-0.16 MeV/nuc



Solid plot: 27-day running average
Symbols: Annual averages

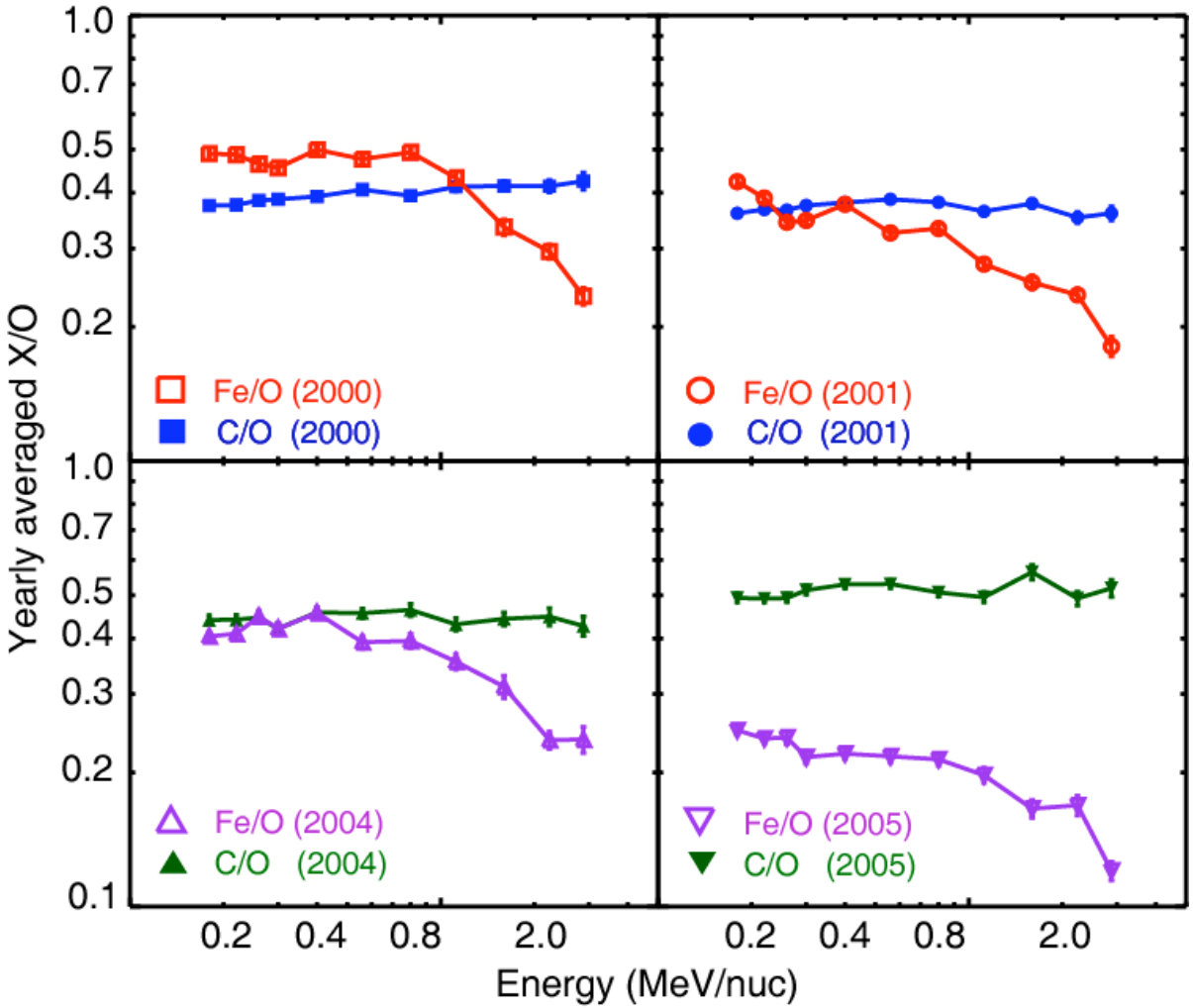
➔ Clear dependence on the solar cycle

Solar Cycle Compositional Variation in SEP events



➔ No dependence on the solar cycle
➔ Large event-to-event fluctuations
➔ Remnant flare signature

C/O and Fe/O Energy dependence

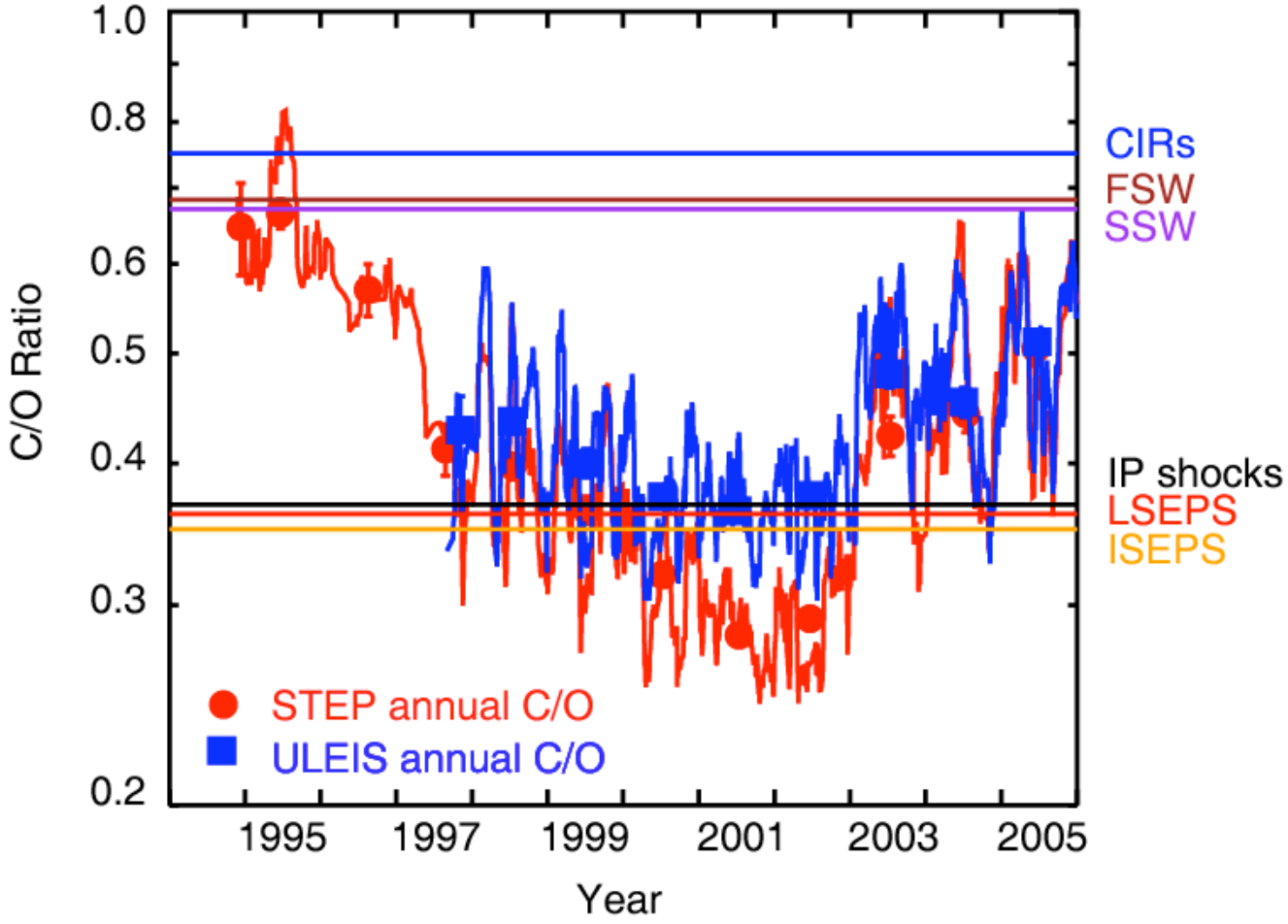


➔ constant C/O

➔ Fe/O decreases with increasing energy

➔ Rigidity effect

Case study: STEP and ULEIS C/O data at 0.16-0.32 MeV/nuc



➔ Why such a large difference ?

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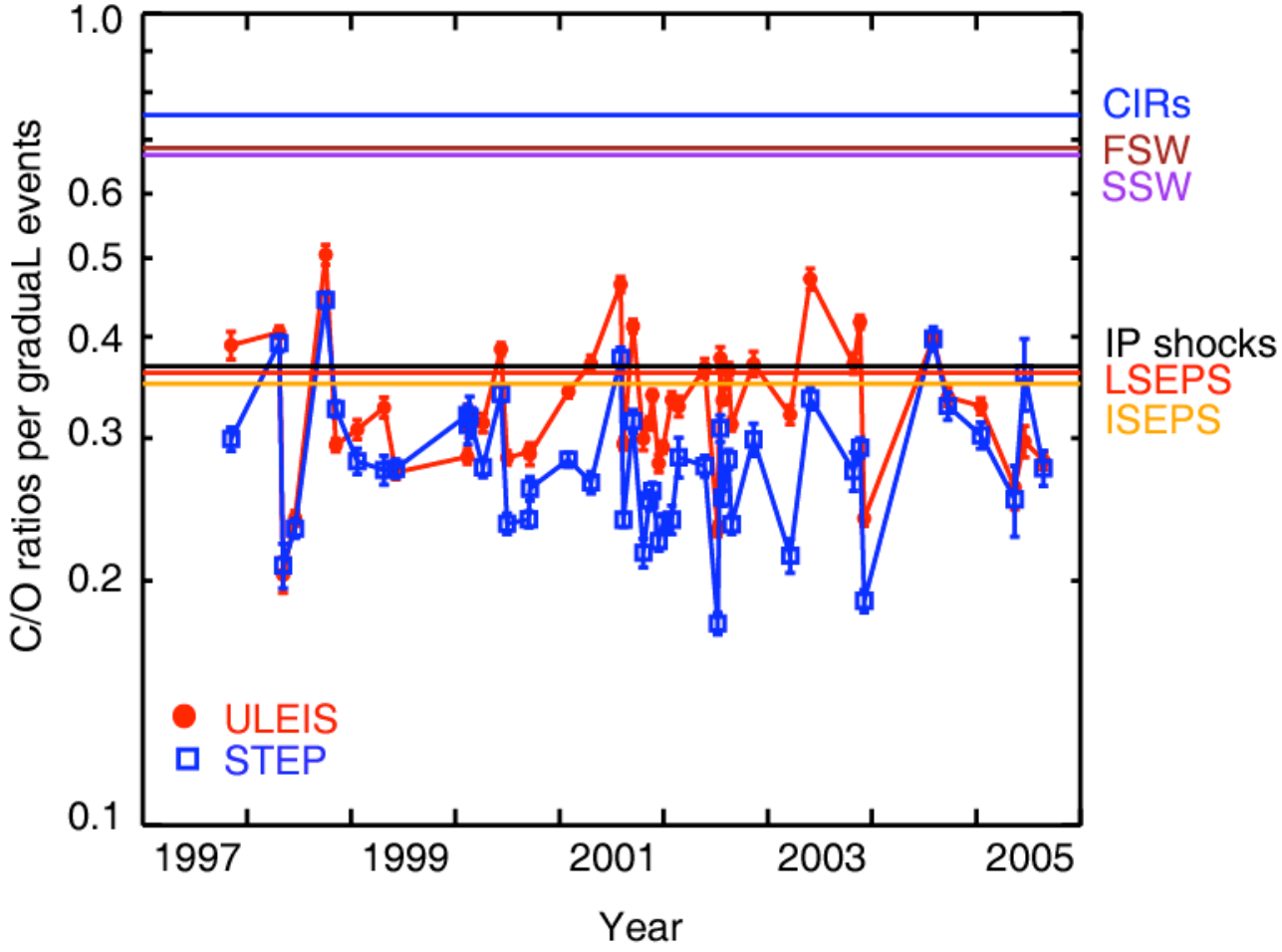

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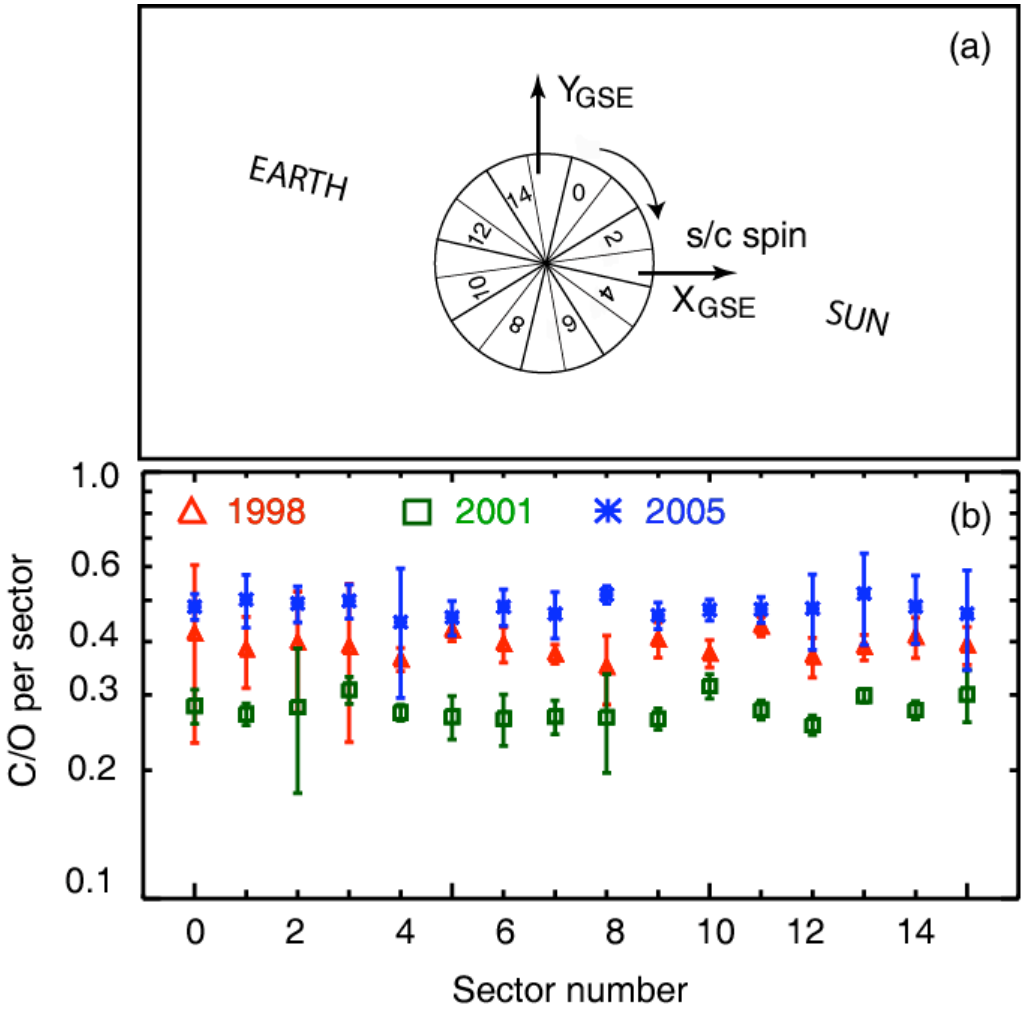

➔ Not an azimuthal effect
➔ Efficiency check?

Summary

1. C/O, NeS/O, and Fe/O daily variations show solar cycle dependence at low energies (0.08 MeV/nuc to 0.32 MeV/nuc).

2. LSEPs C/O and Fe/O ratios show large event-to-event fluctuations and no dependence on the solar cycle or solar longitude.

3. At solar maximum, ACE\ULEIS measures a high C/O values compared to Wind\STEP; the difference is on the order of 30%. This difference does not appear to be an azimuthal sampling or instrumental effect; more investigation will be done in the near future.

4. C/O stays constant with increasing energy while Fe/O decreases. We suggest that this behavior is due to acceleration preference based on rigidity effects where the higher the rigidity (Fe), the lower the acceleration efficiency.

Thank you