

Suprathermal Heavy Ions in Quiet Time near 1 AU during Solar Cycles 23 & 24

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SPACE SCIENCE & ENGINEERING

Introduction – Suprathermal ions (ST)

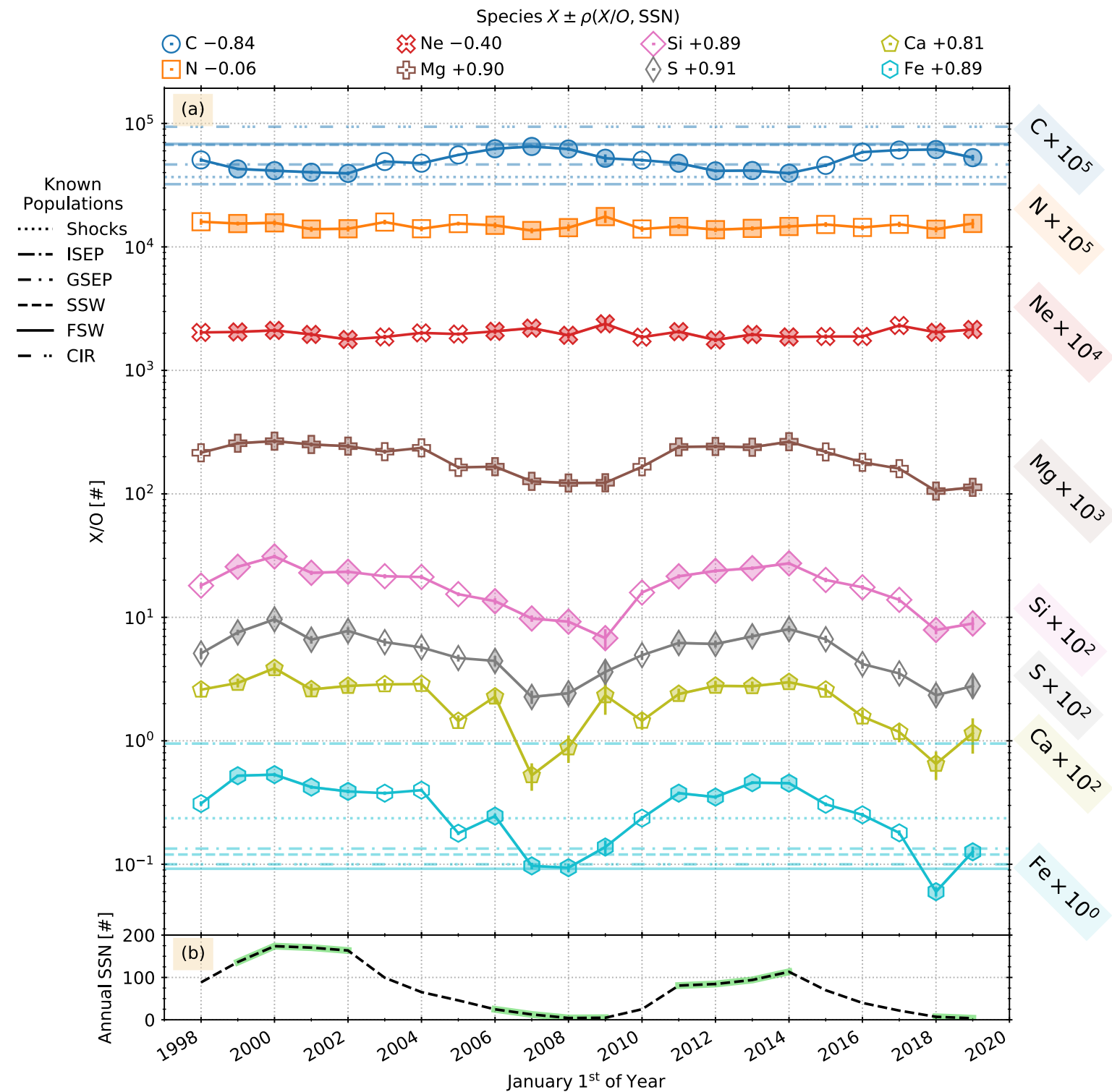
- A potential energetic particle seed population
- Energies of a few keV to several MeV
- Acceleration mechanism unknown
 - Impulsive events: CMEs, CIRs, and/or flares
 - Continuously: turbulence, velocity fluctuations, and/or magnetic reconnection
- Most sensors optimized for solar wind or energetic particles, so STs are difficult to detect
- Two key open questions:
 - Where do STs come from?
 - What accelerates them?

Introduction – This Work

- 23 years of ACE/ULEIS measurements
 - C, N, O, Ne, Mg, Si, S, Ca, & Fe
 - 0.11 MeV/nuc to 1.29 MeV/nuc for quiet time selection
 - 0.3 MeV/nuc to 1.29 MeV/nuc for detailed analysis
- Derive a quiet time threshold that includes an uncertainty metric
 - Quiet times
 - Accelerating phenomena are not present/active
 - Uncertainty metric
 - Study the sensitivity of our results to quiet time selection
- We promised abundances and spectra
 - Too much for 5 minutes
 - Stick with abundances
 - Compare abundances across solar cycle extrema
 - Study ST fractionation vs M/Q
 - Come back next year for spectra

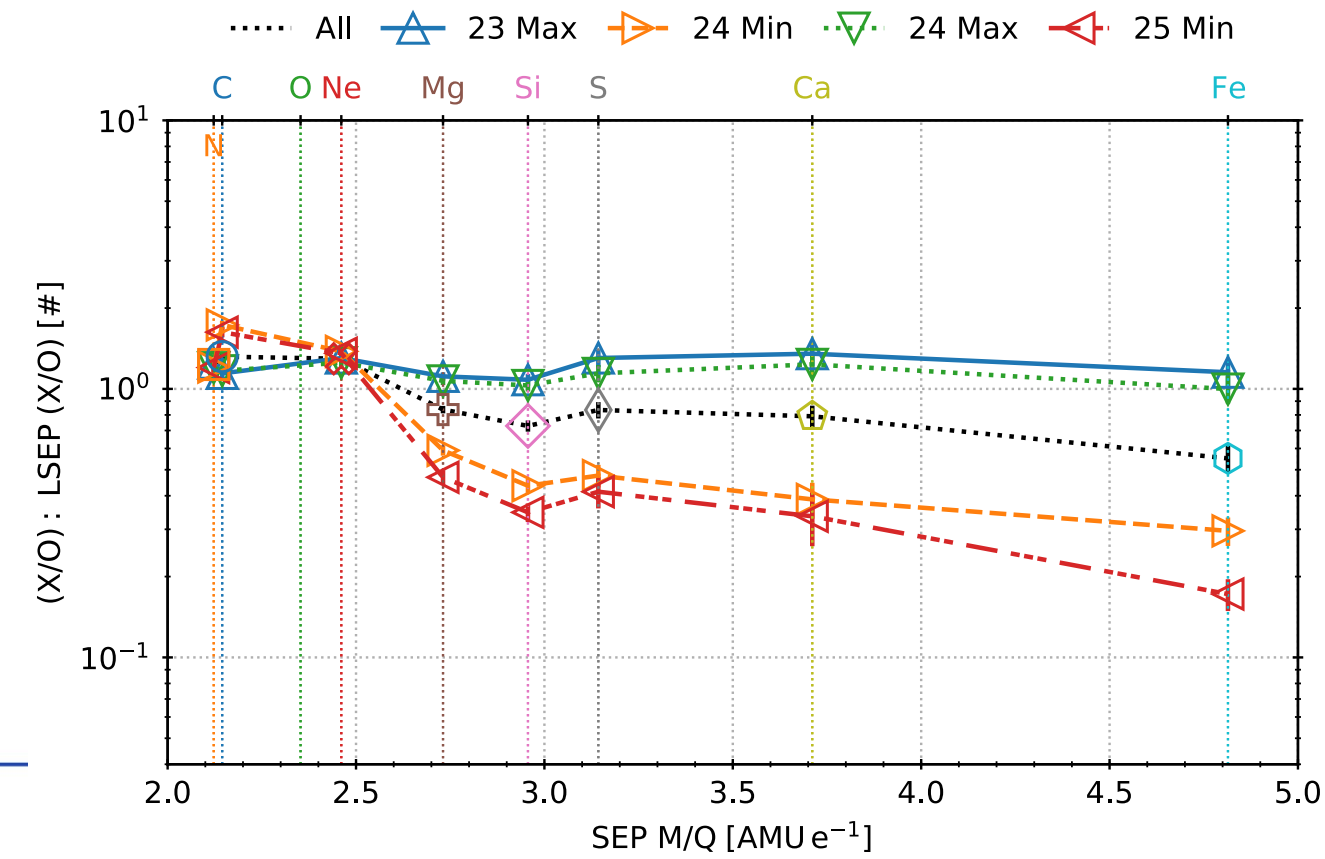
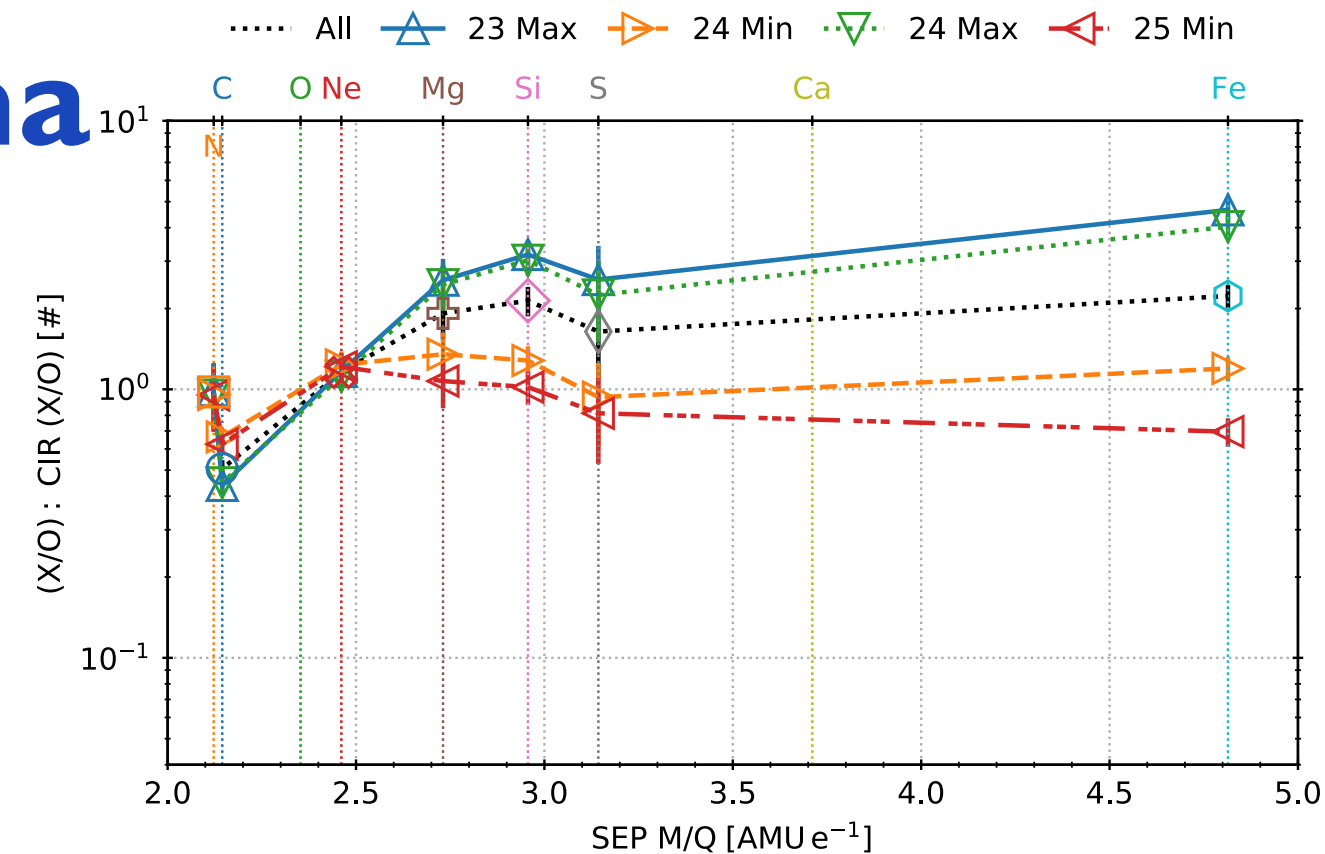
Annual X/O

- C, N, Ne, Mg, Si, S, Ca, & Fe
- Normalized to Oxygen
- Abundances scaled vertically by the value indicated on the right
- Filled markers indicate solar cycle extrema
- Marker style and color consistent across all figures
- Legend indicates Pearson cross-correlation coefficient with SSN



Annual X/O in SSN Extrema

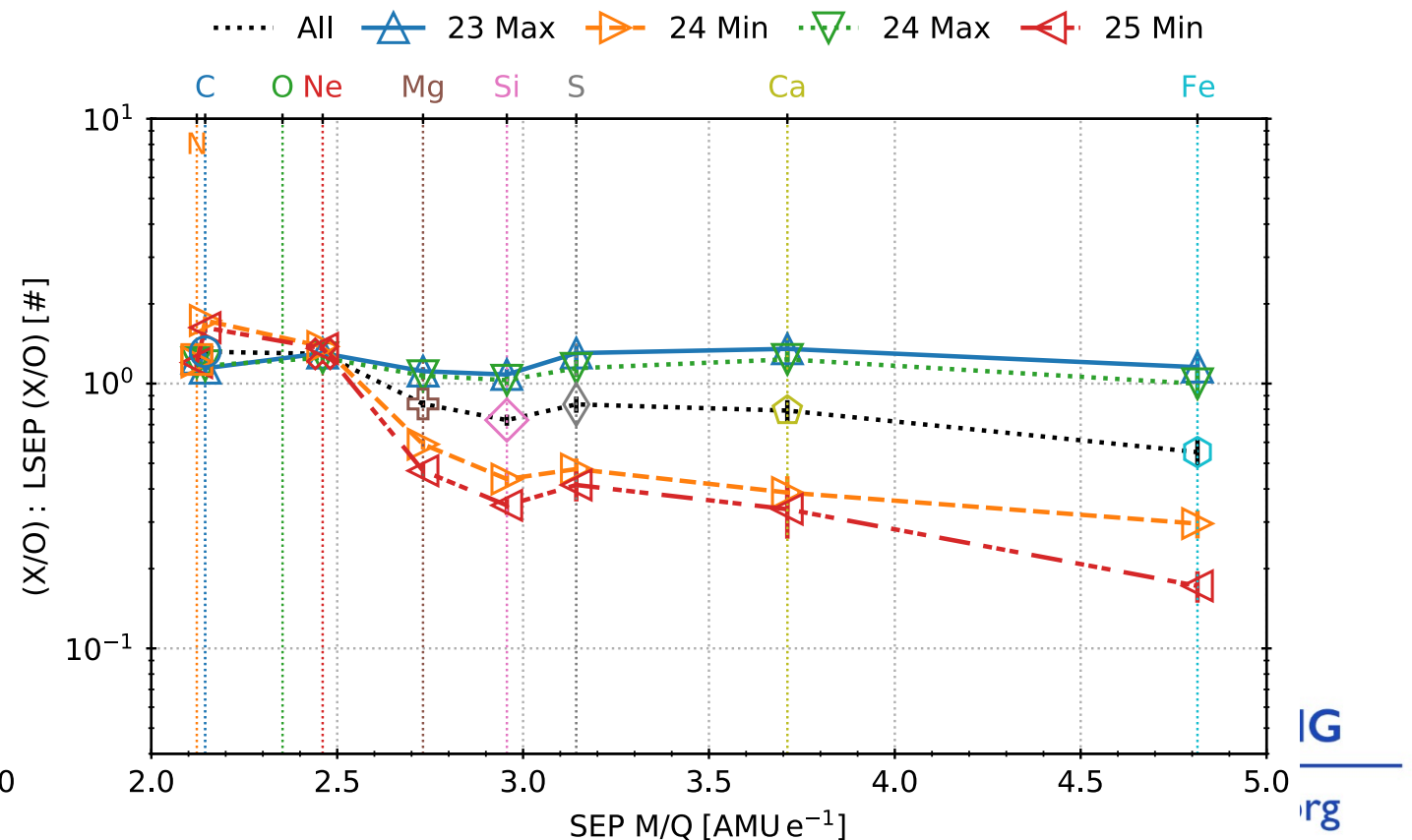
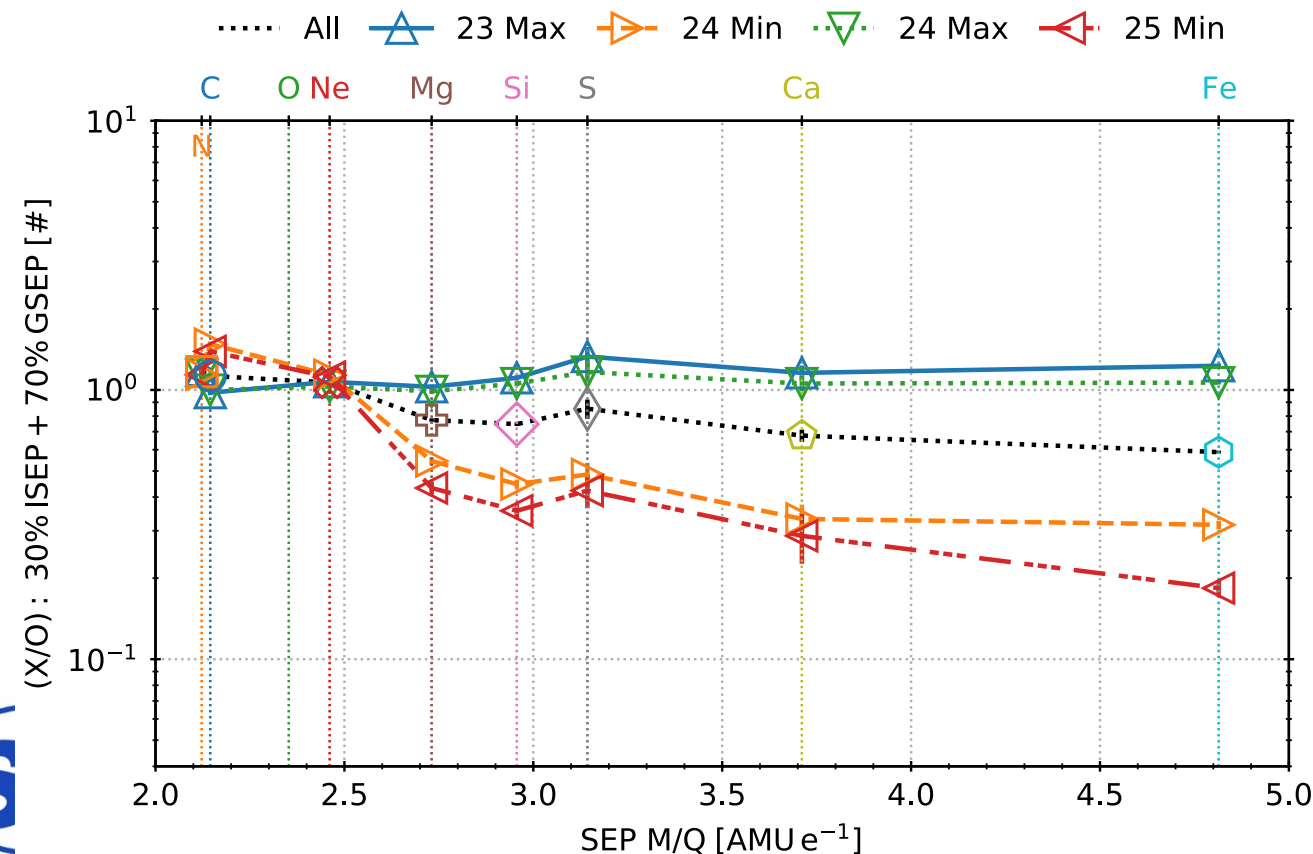
- Compared X/O to multiple known populations
 - GSEP, ISEP, LSEP, CIR, Corona, Photosphere, FSW, SSW, Shocks, etc.
- Top
 - X/O ST: CIR
 - Normalizes out trend during solar minima
- Bottom
 - X/O ST: LSEP
 - Normalizes out trend during solar maxima



ST Pool during SSN Maxima

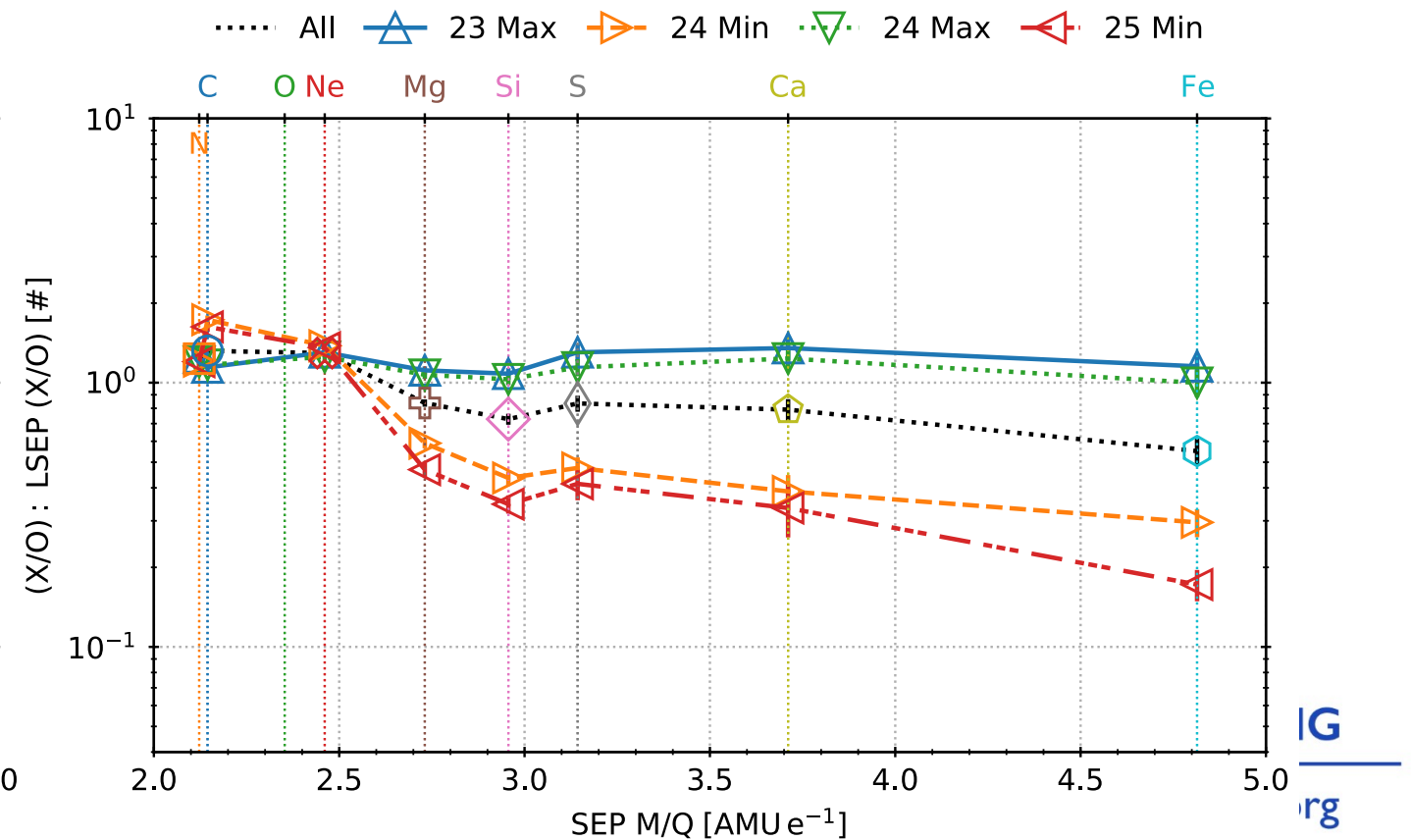
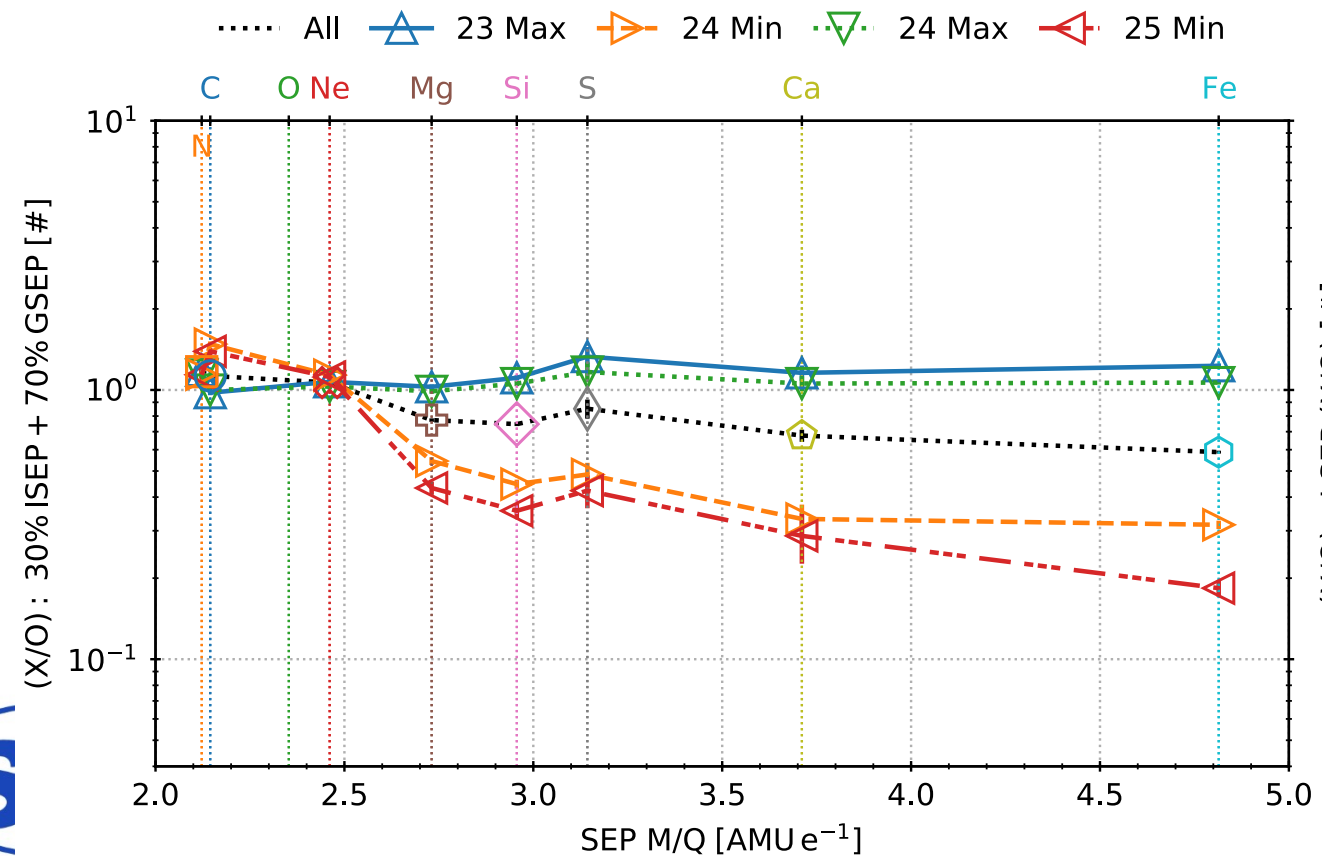
- Desai+ '03 study 72 IP shocks
 - ACE/ULEIS
 - Composition of accelerated particles is
 - 70% prior CME accelerated
 - 30% flare-accelerated

- Desai+ '06 study 64 LSEP events
 - ACE/ULEIS
 - Ions the CME-associated events accelerate come from ST pool



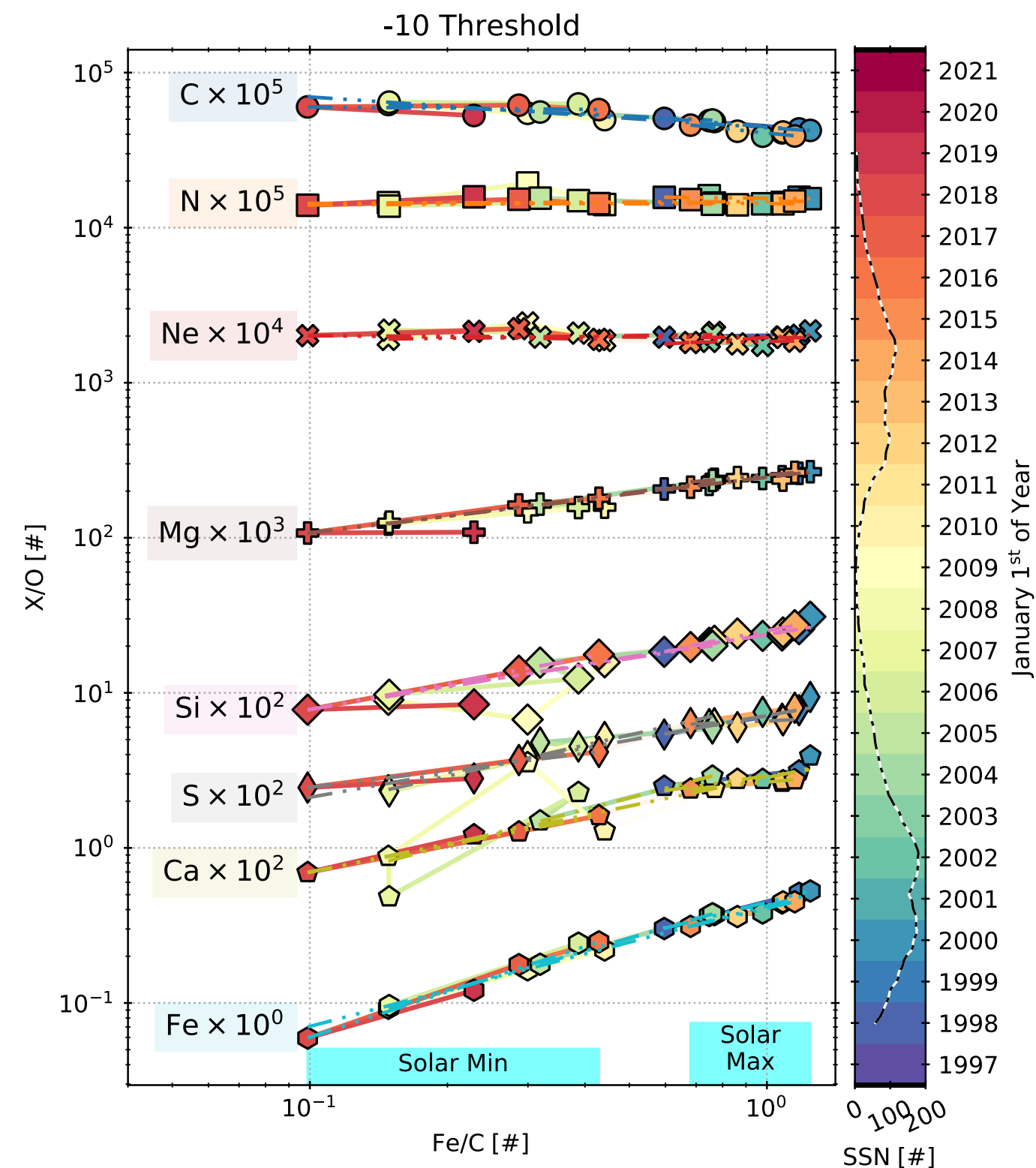
ST Pool during SSN Maxima

- Left
 - X/O ST : 70% GSEP + 30% ISEP
- Right
 - X/O ST : LSEP
- Both cases normalize out the M/Q dependence
- Strong relationship between ST ions and particles accelerated in prior CME-driven shocks and flares during solar maxima



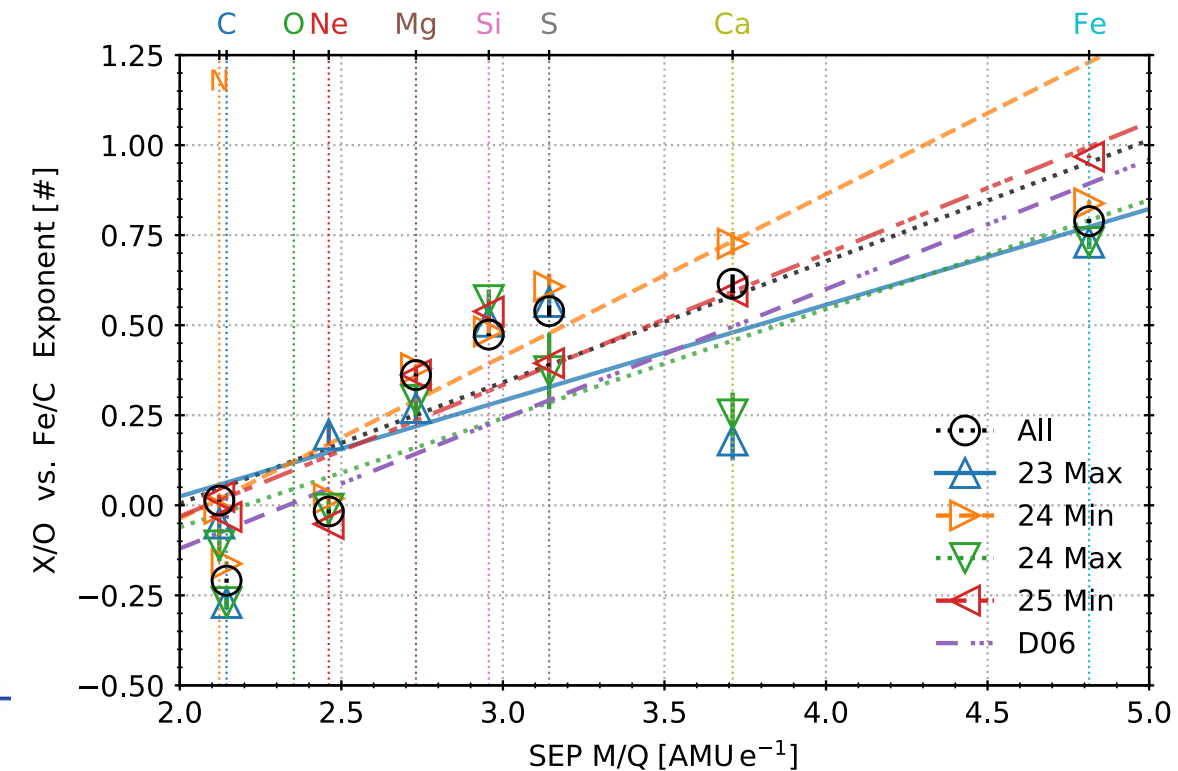
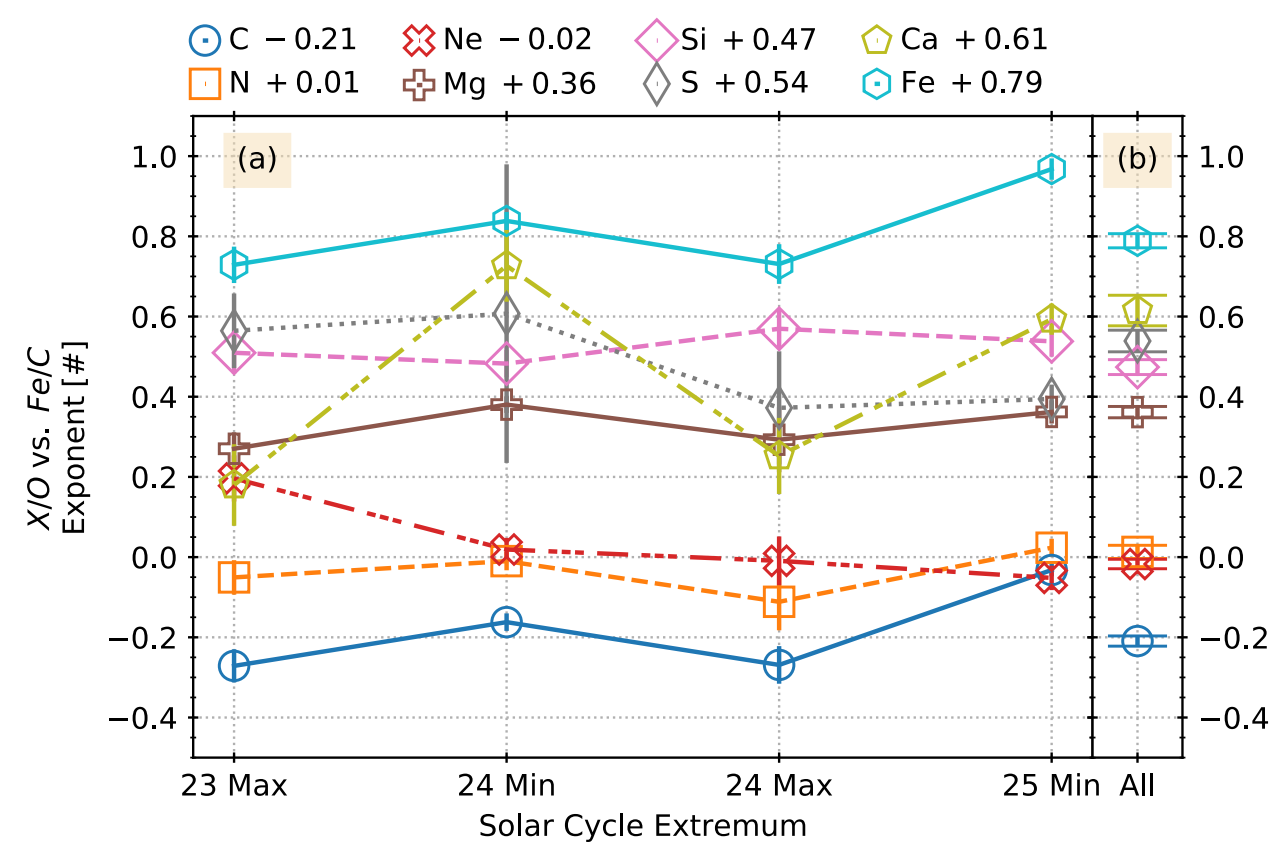
X/O vs Fe/C

- Study fractionation
- Plotted each abundance scaled vertically by the value indicated on the left
- In general, a decreasing power law exponent with increasing mass
 - Next slide examines these trends with solar activity and ion properties



X/O vs Fe/C

- Top
 - Exponents vs Solar Cycle Extrema
 - Right is average across cycle extrema
 - With the exception of Fe and maybe Ca, no meaningful correlation
 - Ca has the most uncertainty due to instrument considerations
- Bottom:
 - Exponents vs SEP M/Q
 - Monotonically increasing trend
 - Matches Desai+ '06 trend from LSEP events, especially during solar maxima



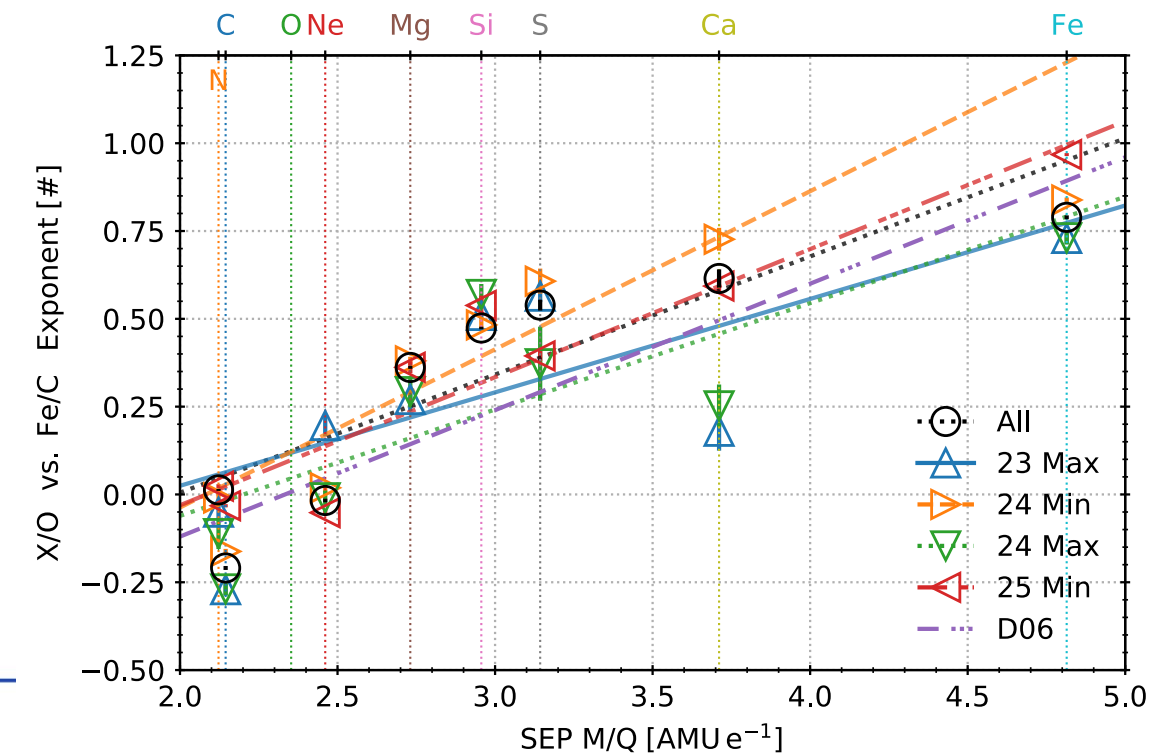
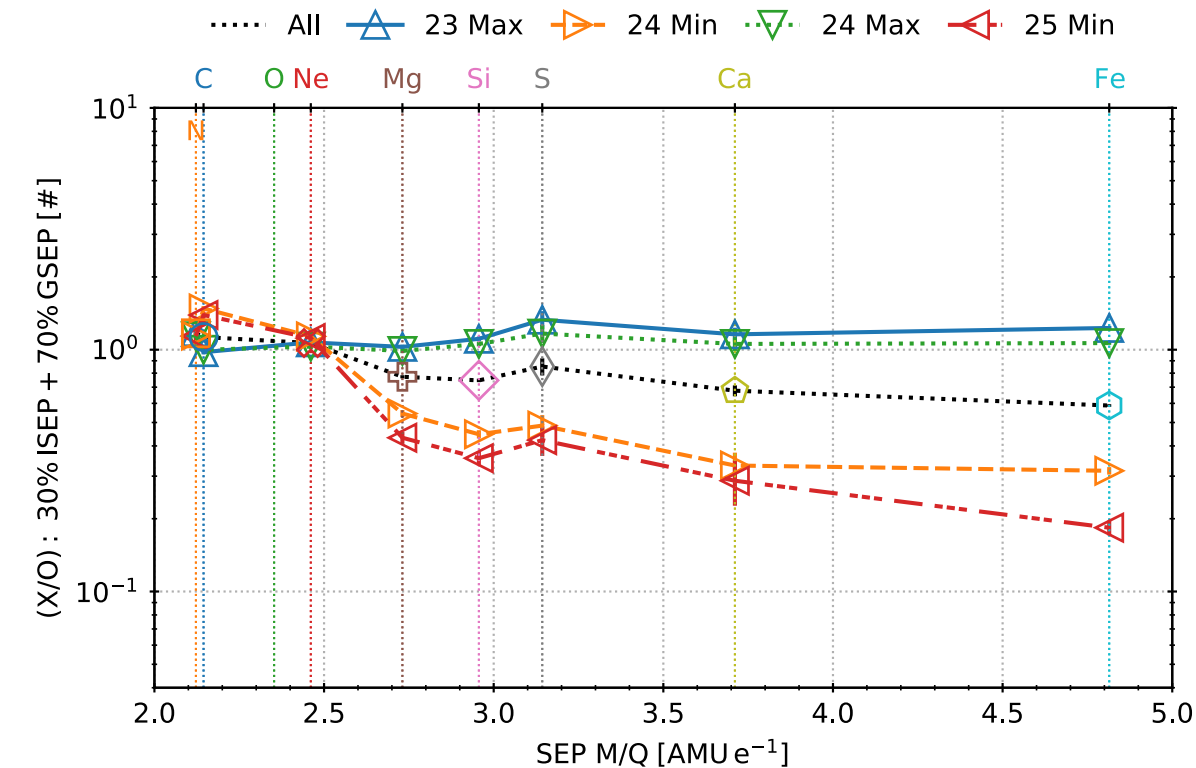
ST Pool during SSN Maxima

■ Top:

- X/O : Known X/O vs M/Q
- ST pool likely composed of 30% ISEP + 70% GSEP originating ions

■ Bottom:

- X/O vs Fe/C exponents vs M/Q
- Common M/Q fractionation mechanism for in ST and LSEP events suggests LSEP events accelerate ions out of ST pool



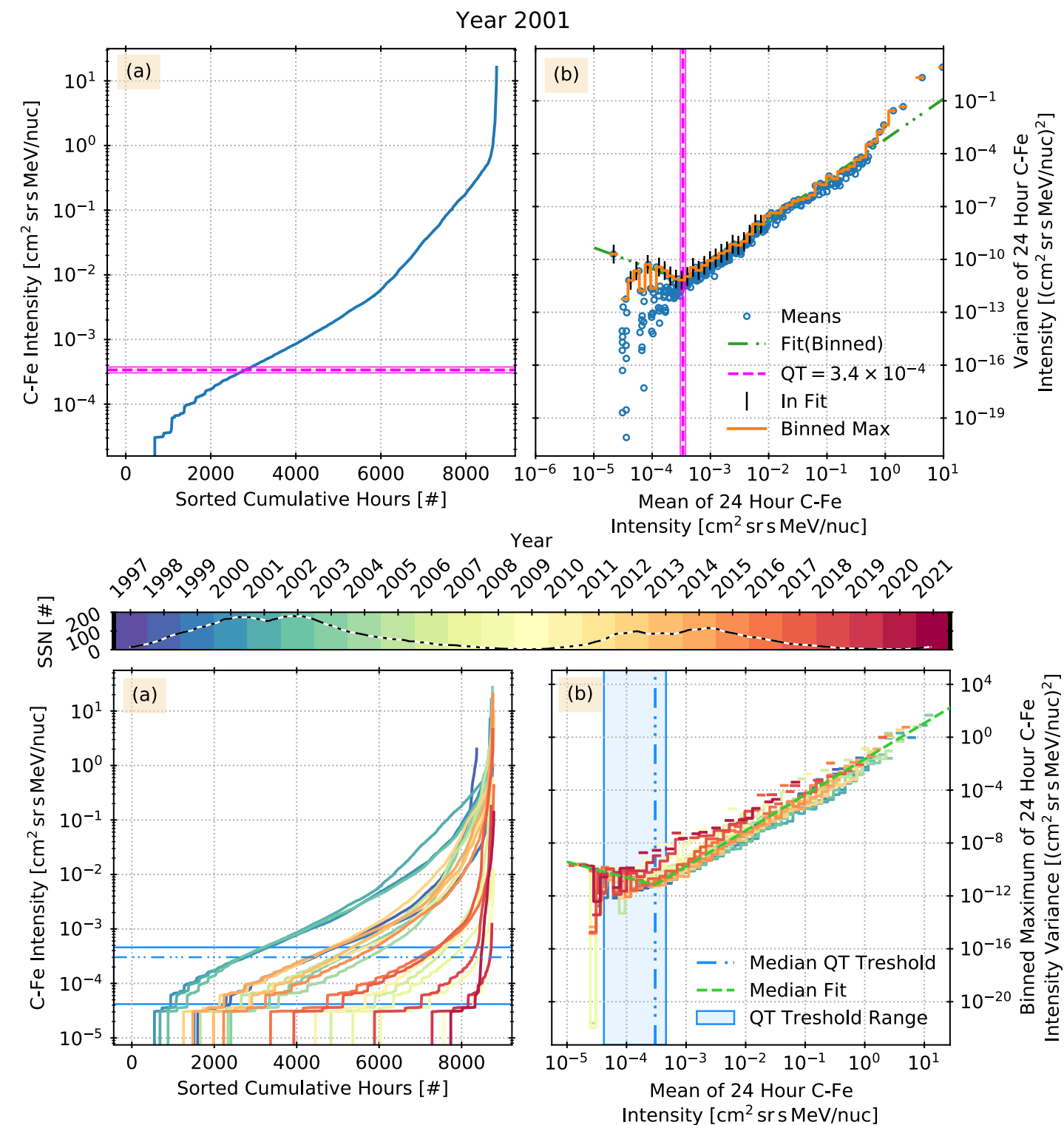
Thank You

Questions?



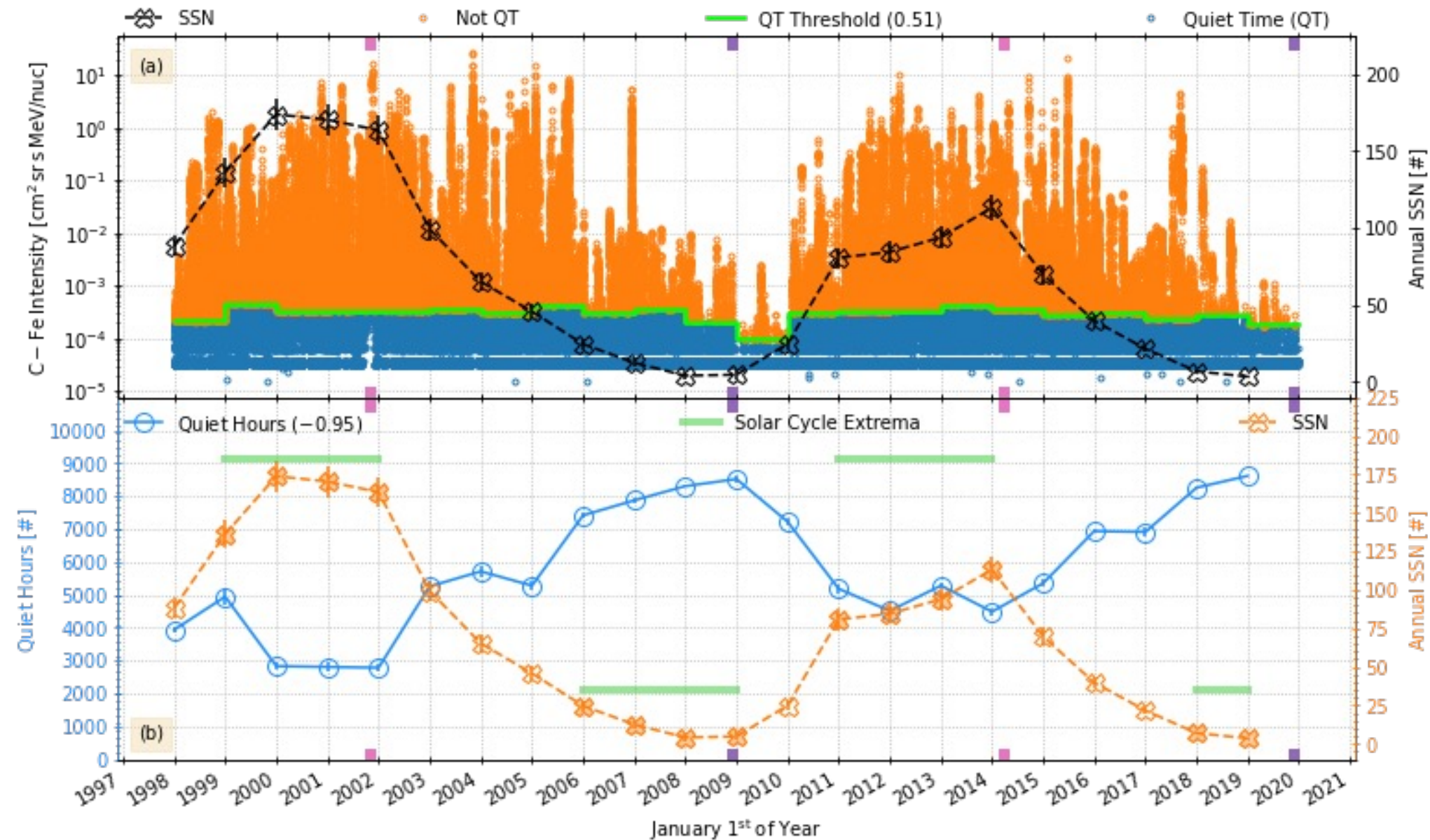
Quiet Time Selection

- Top – Selection Example
 - Inflection in the variability of the sorted cumulative C-Fe intensity
 - Fit the inflection to identify
 - Fit uncertainty is our uncertainty metric
- Bottom:
 - Summary of all selections



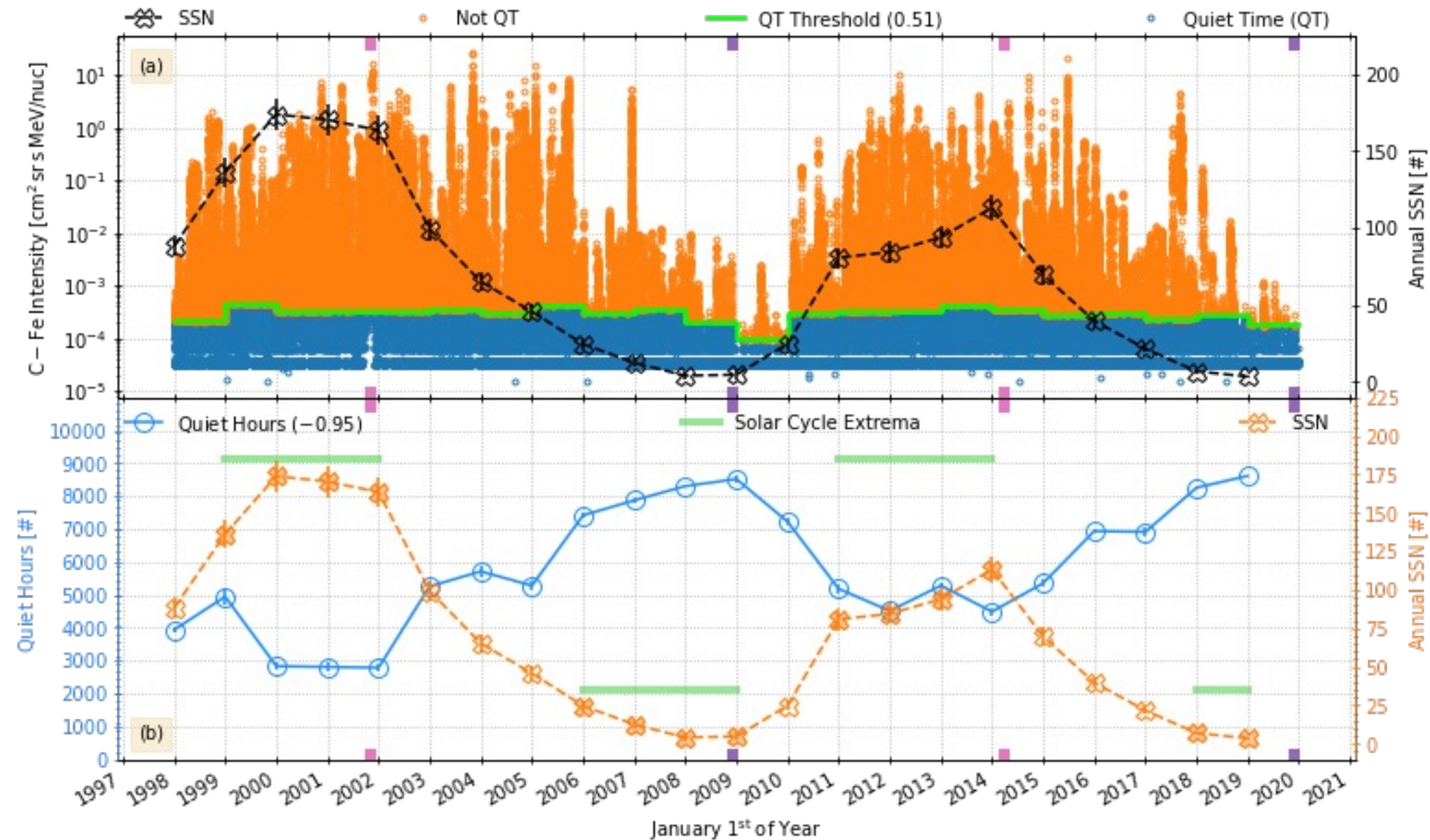
Annual Quiet Time Threshold and Hours

- Top:
 - Hourly C-Fe intensity
 - Quiet Time Threshold
 - SSN
- Bottom
 - Number of Quiet Hours
 - SSN



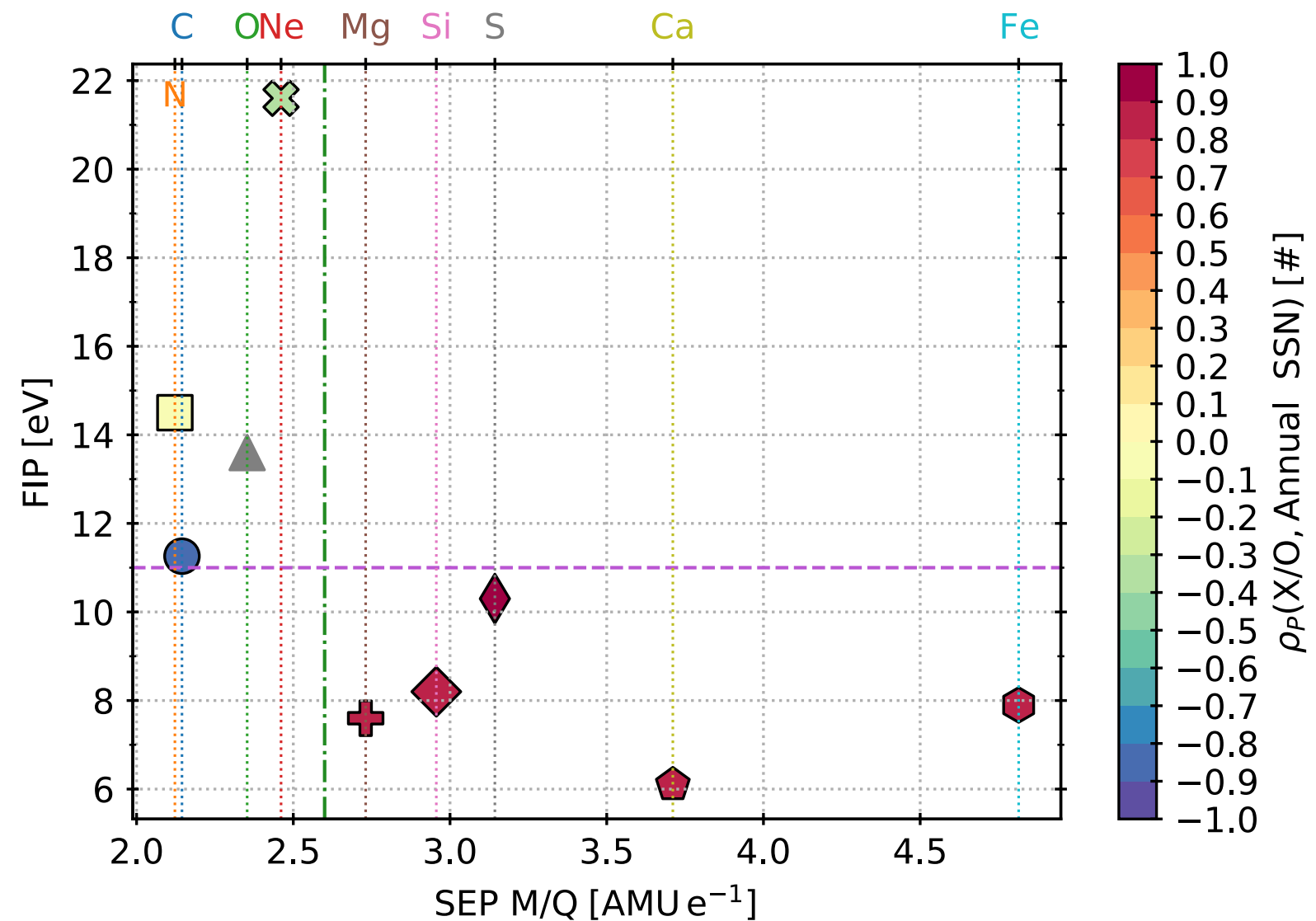
Annual Quiet Time Threshold and Hours

- Number of Quiet Hours varies with SSN
 - Expected from prior work
 - Quiet Hour error bars
 - Averaging over the range of values used to study sensitivity



Sulfur is Low FIP

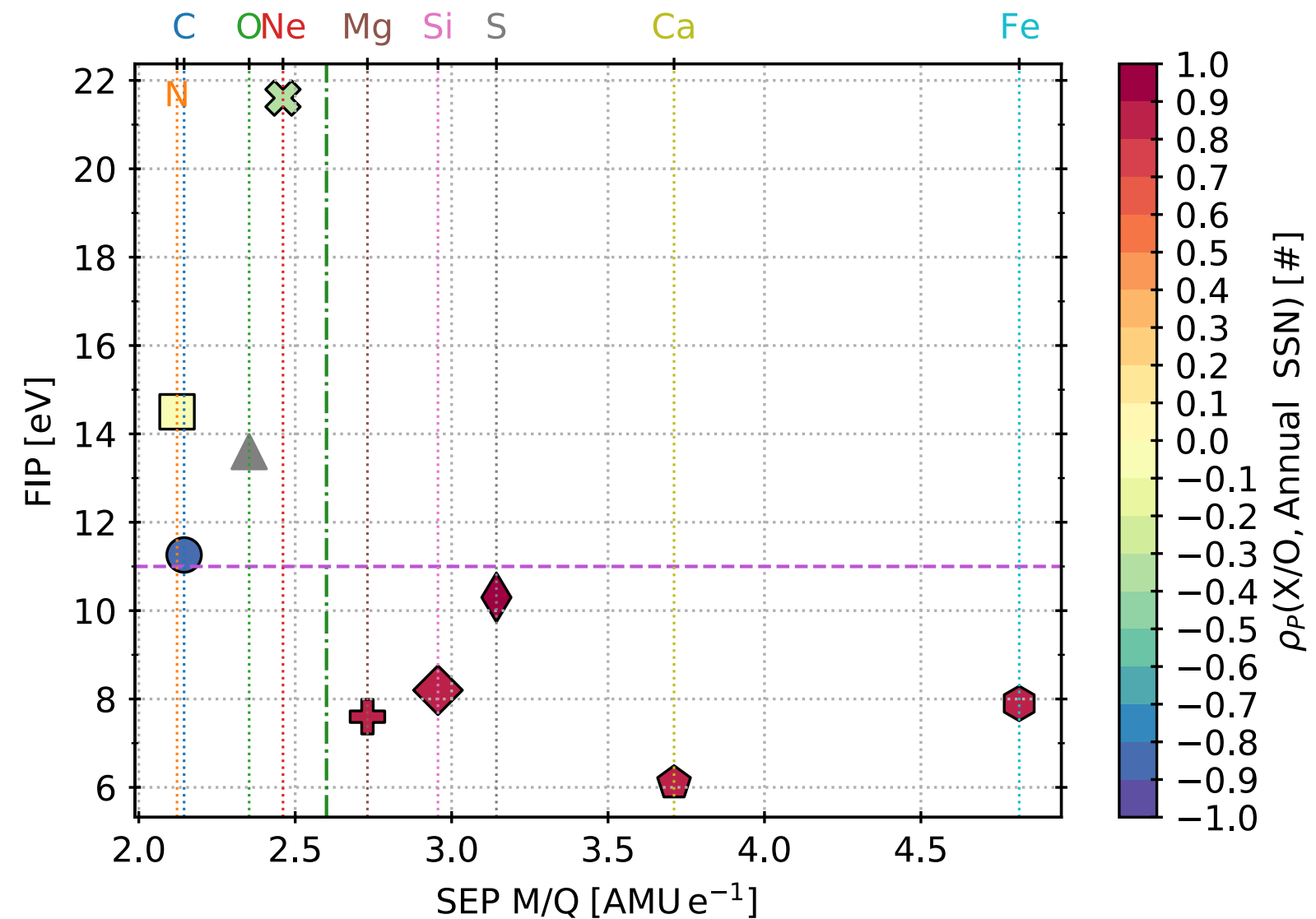
- ST ions are tracers of energetic particle processes
- Inferences can be drawn about
 - Acceleration processes can be from M/Q dependence
 - Solar sources from FIP dependence
- Cross-correlation (ρ) between X/O and SSN provides insight about long-term behavior



- ρ depends on element identity
 - Is this a signature of FIP or M/Q ?

Sulfur is Low FIP

- Assume M/Q
 - M/Q depends on the accelerating phenomenon
 - The occurrence rate of, e.g., CIRs, flares (ISEP), and CMEs (GSEP) events change with solar activity



- Assume FIP