

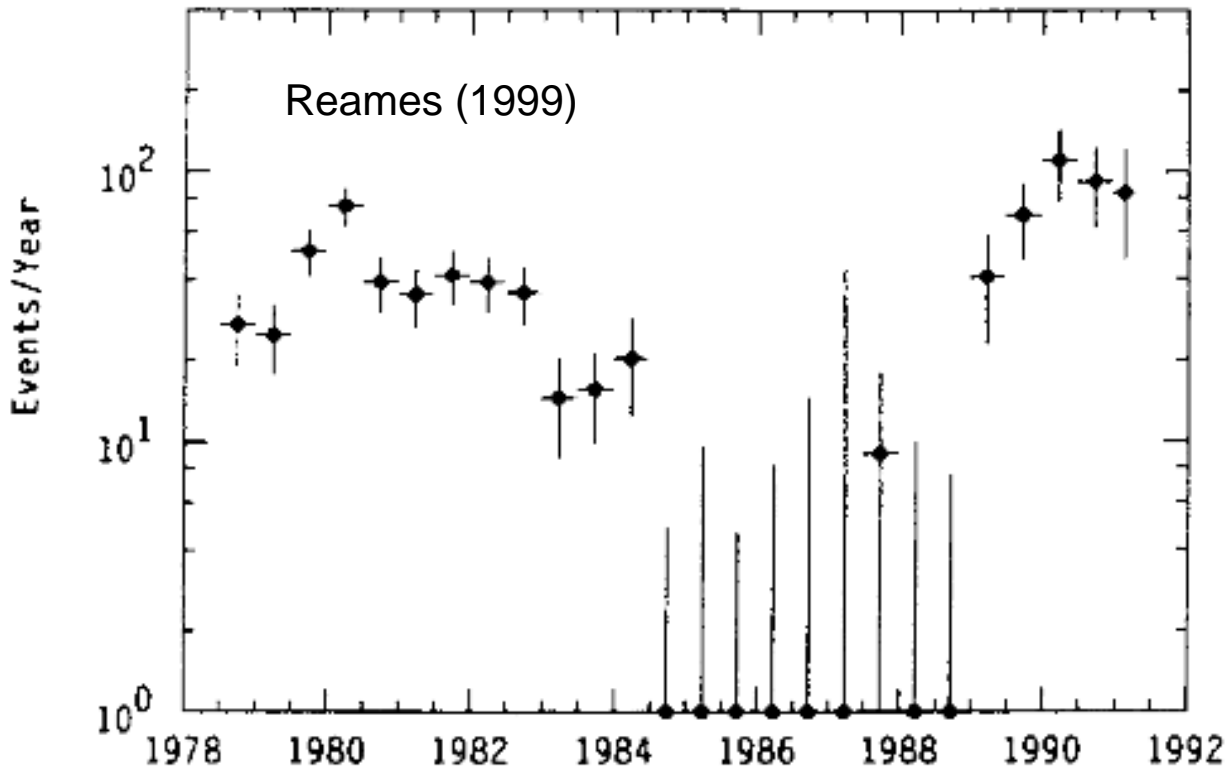
# A Search for $^3\text{He}$ -rich Solar Energetic Particle Events at Solar Minimum using the STEREO/LET Instruments

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with contributions from  
STEREO/LET, SEPT and SIT  
and from ACE/SIS, ULEIS and EPAM

## Rate of Occurrence of $^3\text{He}$ -rich SEP Events over the Solar Cycle

- investigated by Reames and collaborators using data from ISEE-3
- energies in the few MeV/nuc energy range
- found up to  $\sim 100$  events per year at solar maximum
- taking into account the limited range of longitudes ( $\sim 20^\circ$  rms longitude spread about Parker spiral field line connecting to the source region), infer  $\sim 1000$  events/yr on the visible face of the Sun at solar maximum



### What about solar min?

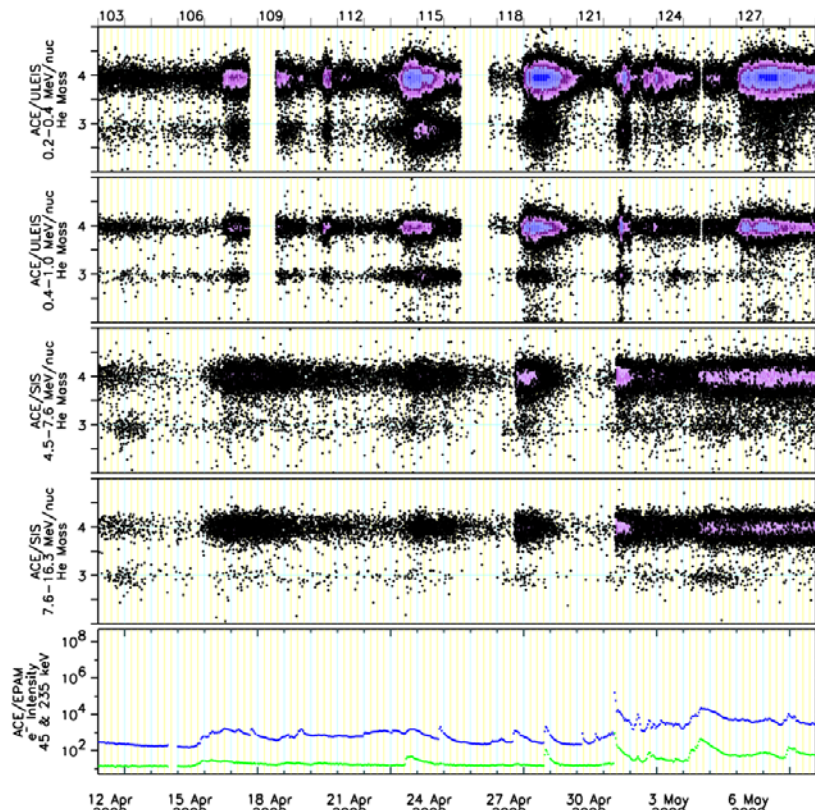
- ISEE-3 coverage during 1985-88 solar min was rather limited
- some  $^3\text{He}$ -rich events were detected, but inferred event rates had large uncertainties
- should be able to improve the determination of the solar minimum rate using STEREO/LET data in the present solar minimum

# $^3\text{He}$ Observed with ACE: Solar Minimum-Solar Maximum Comparison

- at solar maximum  $^3\text{He}$  from impulsive SEP events observed a large fraction of the time
- $^3\text{He}$  can be present for extended periods, probably to a series of unresolved events
- at solar minimum many solar rotations with no detectable  $^3\text{He}$ -rich SEP with present instrument sensitivity

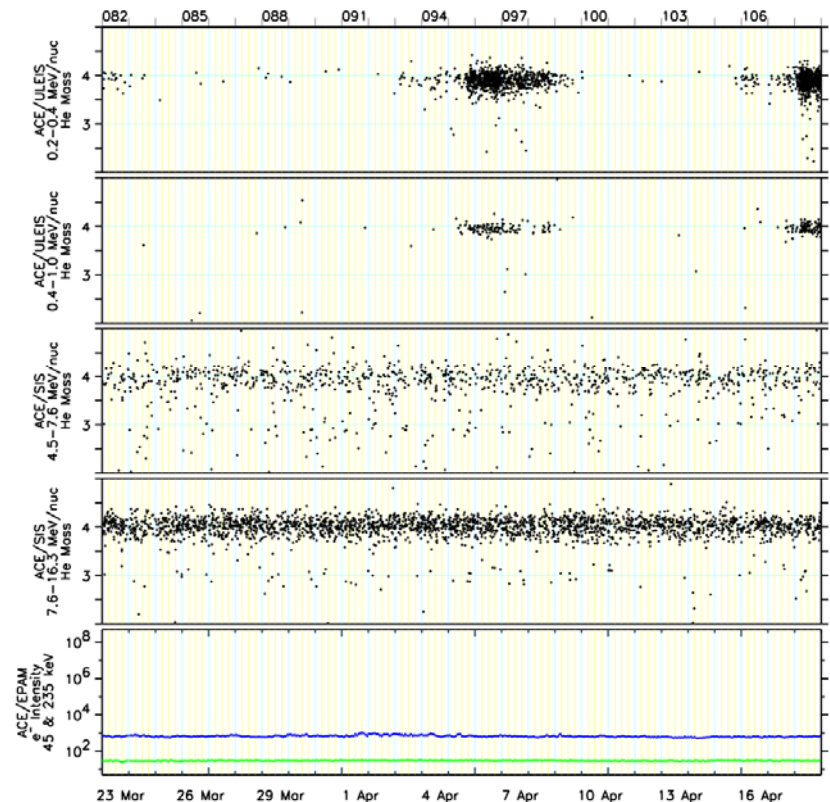
## Solar Maximum

Bartels Rotation 2276 12 Apr 2000 through 8 May 2000 2000:103–2000:129



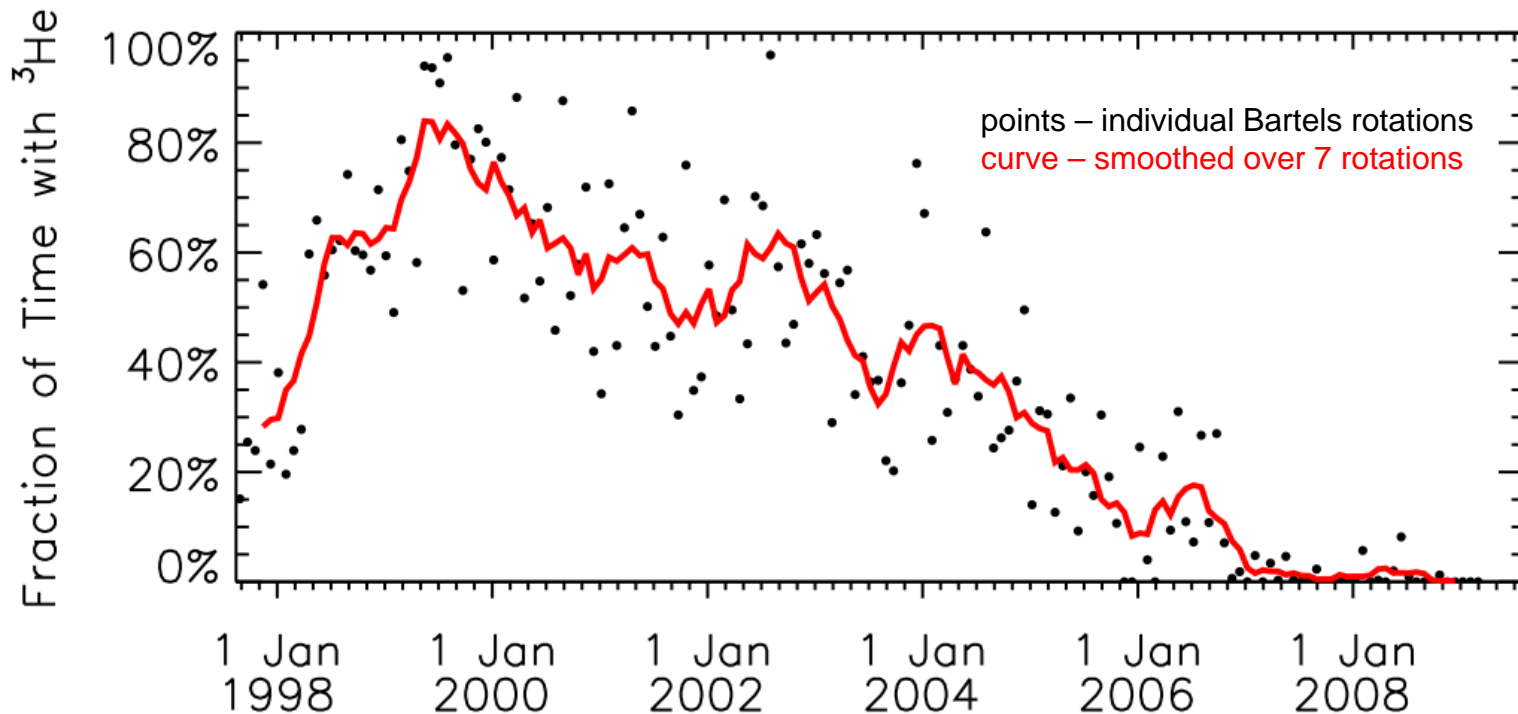
## Solar Minimum

Bartels Rotation 2397 23 Mar 2009 through 18 Apr 2009 2009:082–2009:108



## Time Variation of the Fraction of Time with $^3\text{He}$ Observed at ACE

- fraction determined for each Bartels rotation over the past ~12 years
- from >80% of the time at solar maximum, the fraction has dropped to at most a few % over the past 2 years
- if one assumes a  $^3\text{He}$ -rich event duration of ~1 to 1½ days, ~200--300 events per year would be needed to account for the observed fraction

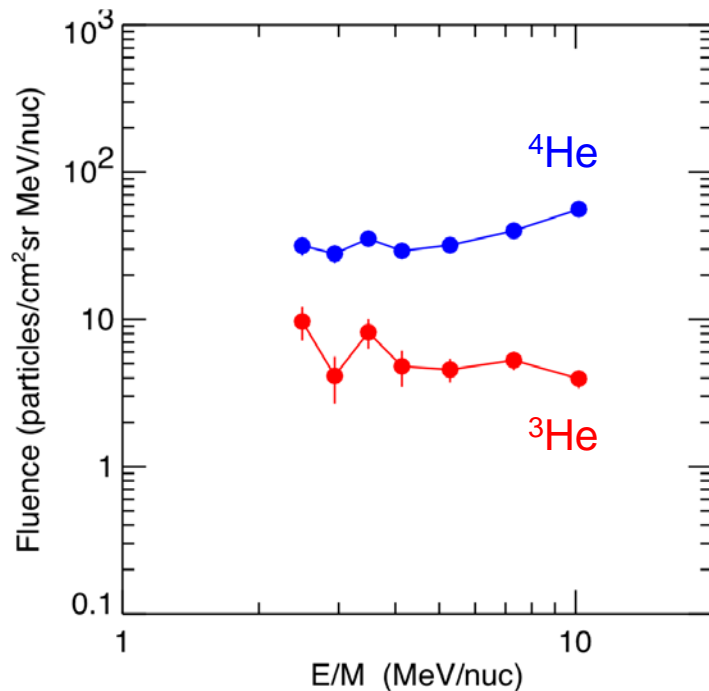


## “Quite Time” Background

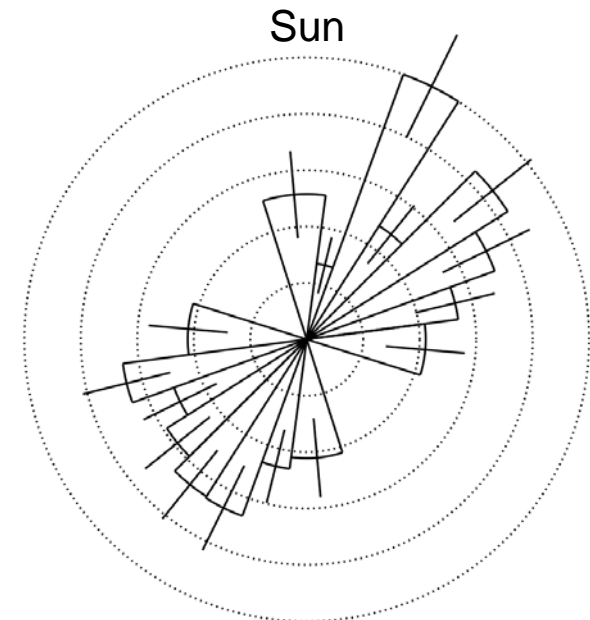
Example: Bartels Rotation 2399 (16 May through 11 June 2009) STEREO-A LET

- energy spectra flat or rising with increasing E/M
- significant contribution to  $^4\text{He}$  from anomalous cosmic rays (ACRs) plus some modulated galactic cosmic rays (GCRs) [have selected times without CIRs]
- $^3\text{He}$  background from modulated GCRs and from spill-over from  $^4\text{He}$

### He Isotope Energy Spectra



### Angular Distribution 2.3 - 3.8 MeV/nuc He

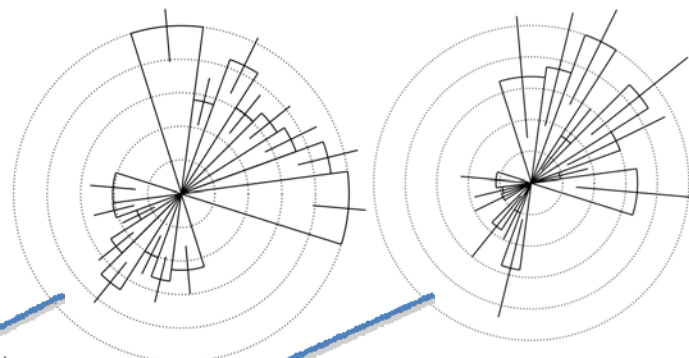
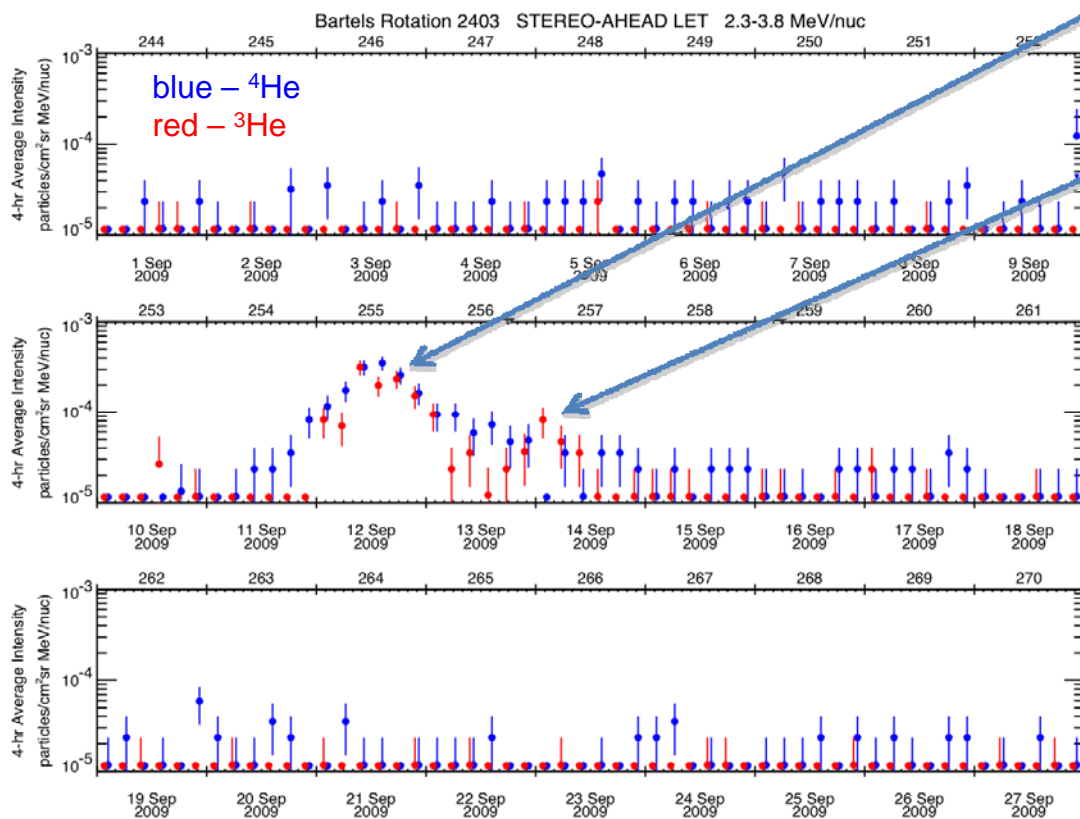


## Search for candidate $^3\text{He}$ -rich events

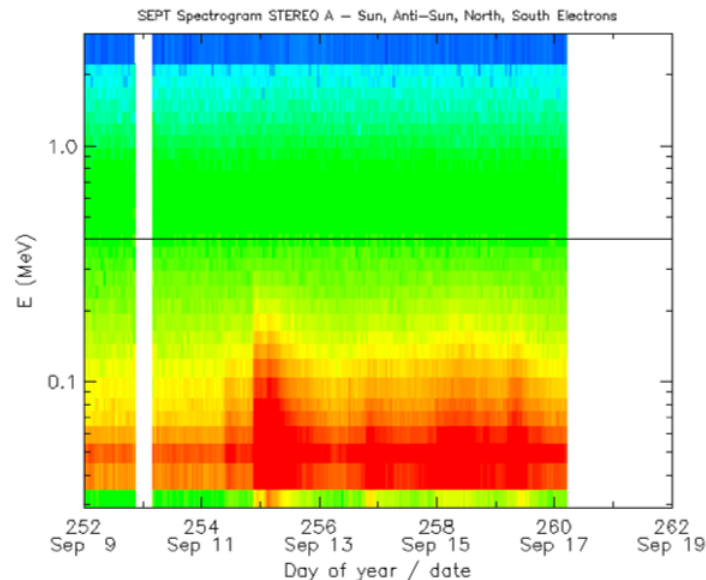
by looking for:

- $^3\text{He}$  intensity increase at low energies
- $^3\text{He}$  intensity falling with increasing E/M (next slide)
- significant abundance of  $^3\text{He}$  relative to  $^4\text{He}$
- significant anisotropy
- accompanying electron event

LET He isotopes – 2.3—3.8 MeV/nuc



SEPT electrons



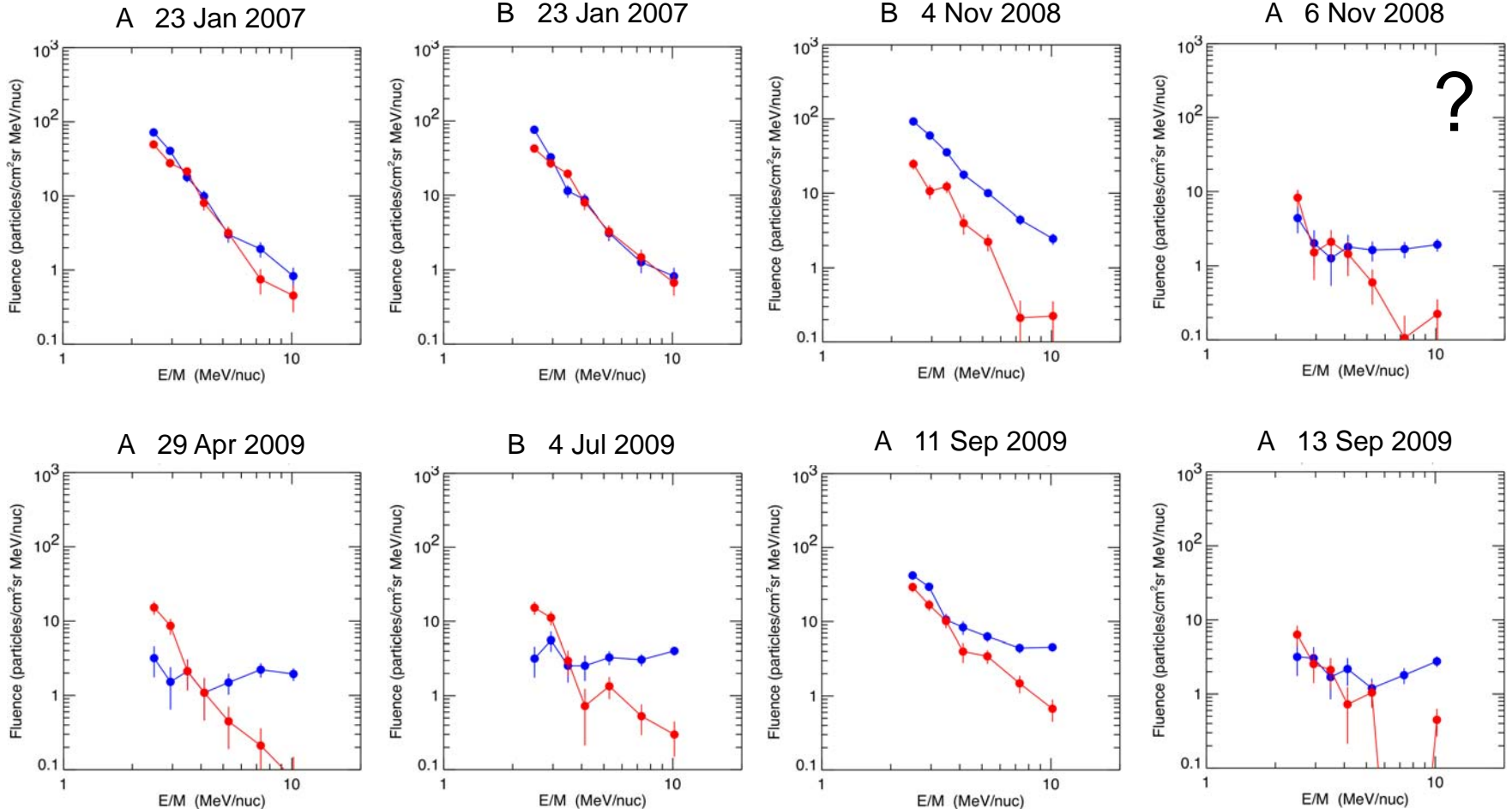
26-28 Oct 2009

STEREO SWG, Meredith, NH

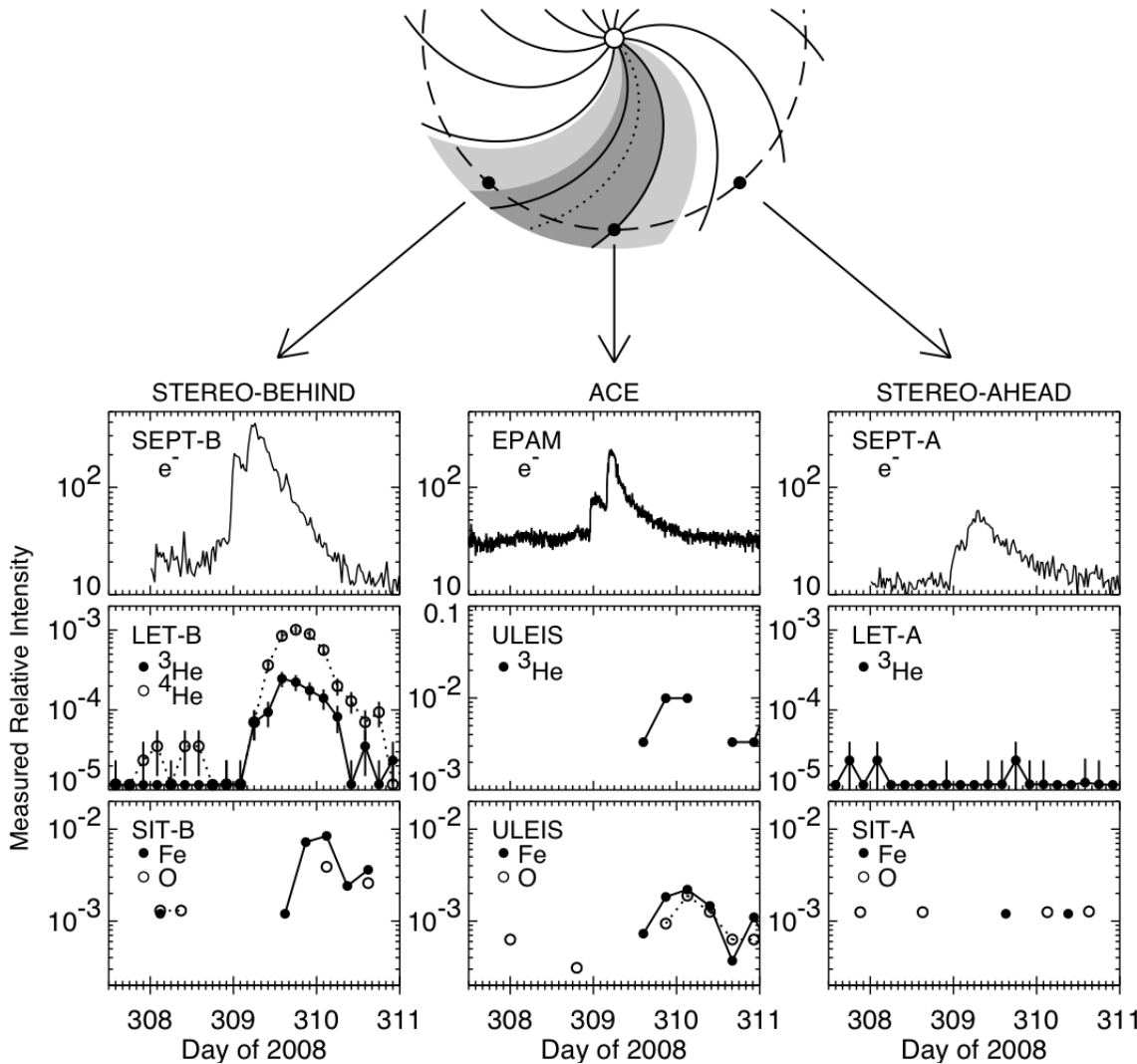
# Fluence Spectra for Best Candidate $^3\text{He}$ -rich SEP Events Seen with STEREO/LET

- January 2007 through September 2009
- restrict initial analysis to events with enhanced  $^3\text{He}$  and falling  $^3\text{He}$  energy spectrum

$^3\text{He}$   $^4\text{He}$



# One Event Observed over a Wide Range of Heliographic Longitudes



## 3-4 Nov 2008 event

- STEREOs located  $\pm 41^\circ$  from ACE
- electrons observed at all three spacecraft using SEPT and EPAM
- $^3\text{He}$  and heavy ions with enhanced Fe/O observed at STEREO-B and ACE
- lack of ion detection at STEREO-A might be due to sensitivity limitations
- results are discussed in a paper to appear in the Solar Wind 12 proceedings



## Comments

- ~6--7  $^3\text{He}$ -rich events have been observed at the two STEREOs over 33 months
- single-spacecraft rate of ~1 per year at solar minimum inferred
- compare with rough estimate of ~200 to 300 per year at solar maximum from the ACE study
- results are consistent those from ISEE-3, but solar minimum rate is a factor ~5-10 below the ISEE-3 upper limits
- STEREO/LET has also been detecting small SEP events having  $^4\text{He}$  but no clear enhancement of  $^3\text{He}$ . The number of such events is comparable to that of the  $^3\text{He}$ -rich events we have shown. These events require further examination—they could be impulsive events in which the LET sensitivity is not sufficient to detect the  $^3\text{He}$ .
- quantitative comparison of results between different instrument types should take into account difference in energy ranges, flux sensitivity, isotope resolution, etc.
- tracking the  $^3\text{He}$  event rate as solar activity increases should provide a determination of the solar cycle variation with a single instrument type