

DECEMBER 2006 SEP EVENTS: Ulysses, STEREO & ACE OBSERVATIONS

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Collaborators:

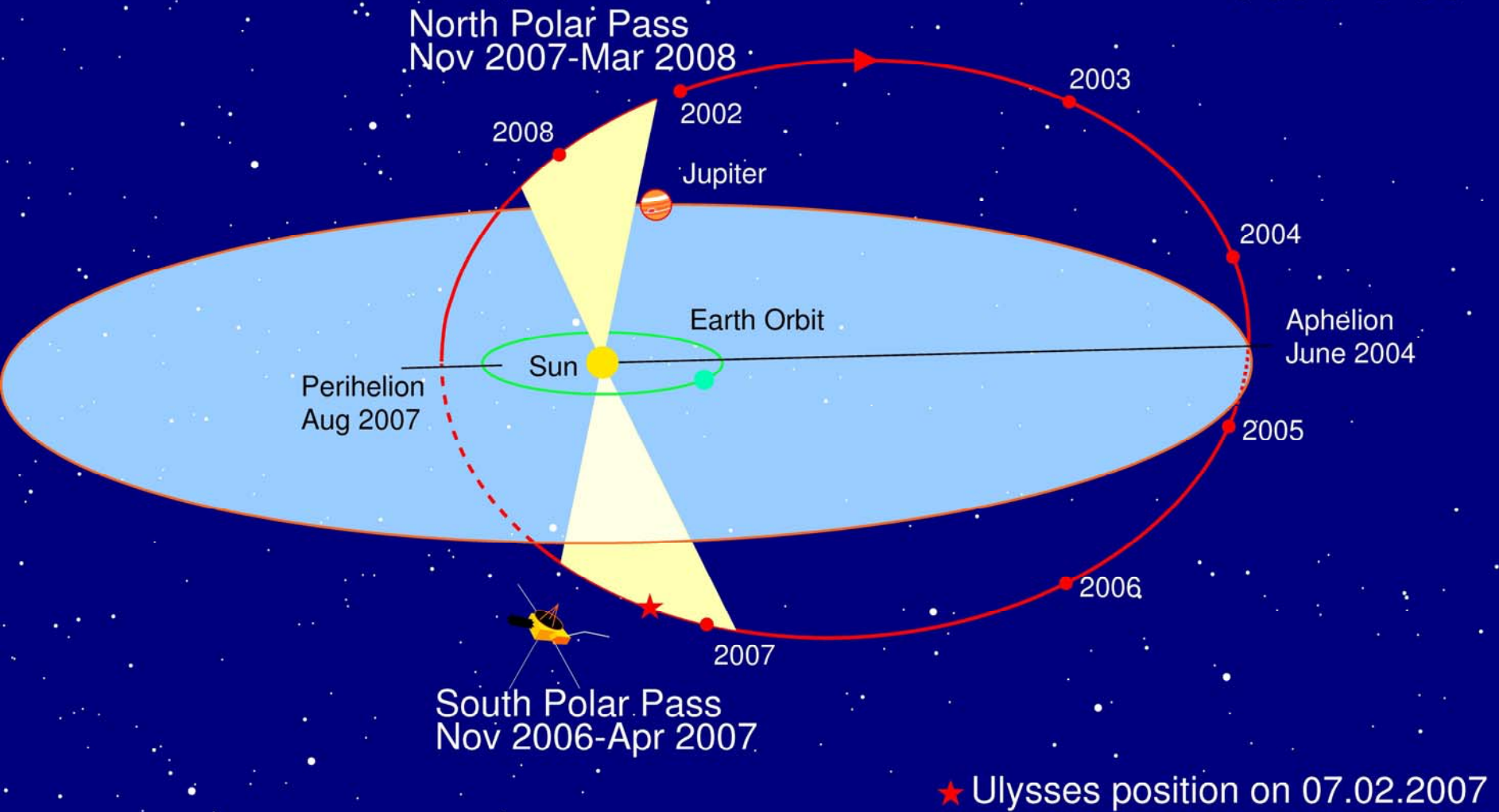
R. Marsden, C. Tranquille, ESTEC/ESA, The Netherlands,
D. Lario, APL/JHU, USA,
B. Heber, CAU, Kiel, Germany, R. A. Mewaldt, C. M. S. Cohen, SRL,
Caltech, USA, L. J. Lanzerotti, NJIT, USA, R. B. Forsyth, IC, UK,
H. A. Elliott, SRI, USA, A. Geranios, UOA, Greece

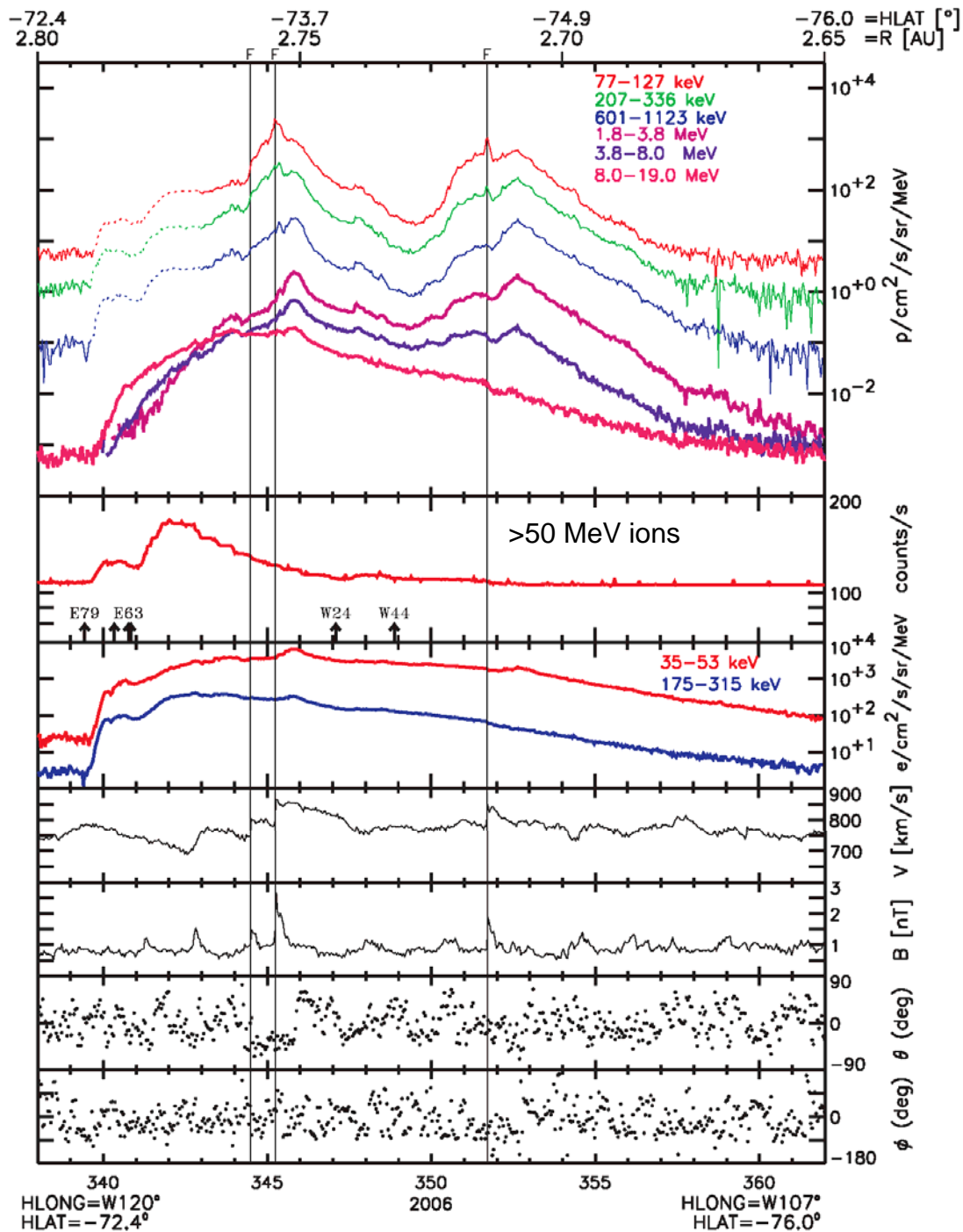
Objective

- Present unique energetic particle observations by Ulysses $> 70^\circ\text{S}$ during intense solar activity in December 2006
- Compare with previous high latitude measurements obtained close to solar max
- Compare with simultaneous in ecliptic observations by STEREO, ACE at 1 AU

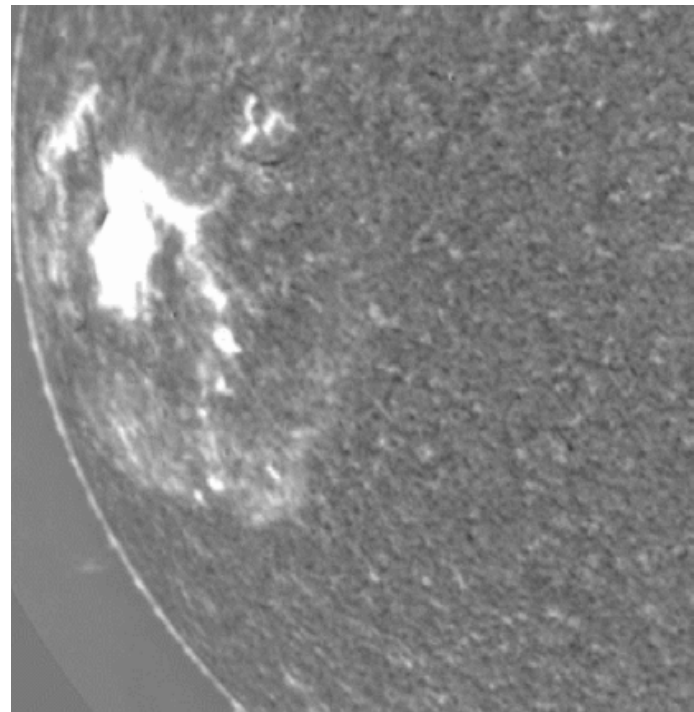
Ulysses

Third Solar Orbit





Unique Events of December 2006

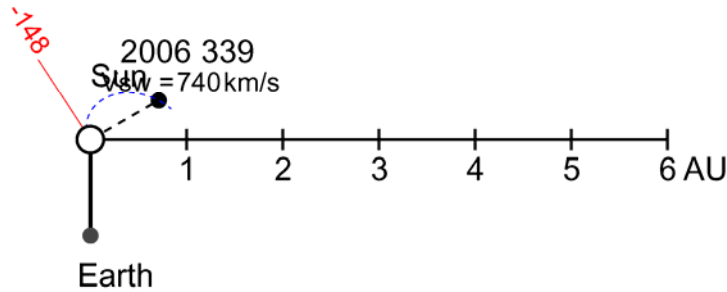


Credit: NSO/Optical Solar
Patrol Network Telescope

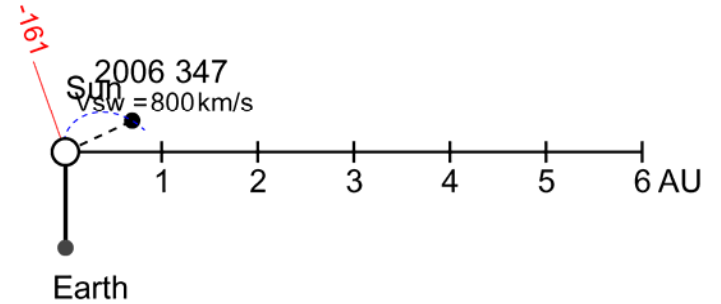
All x-ray events associated with
intense, metric type-II radio bursts,
indicative of coronal shocks

View from top

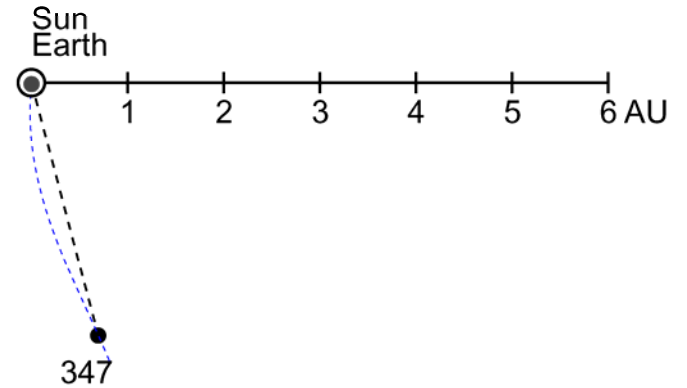
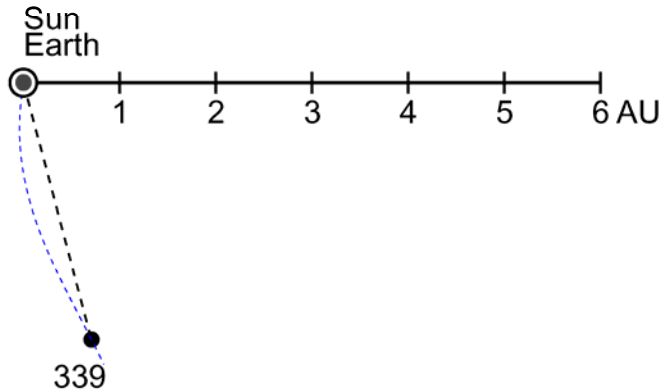
5 Dec



13 Dec



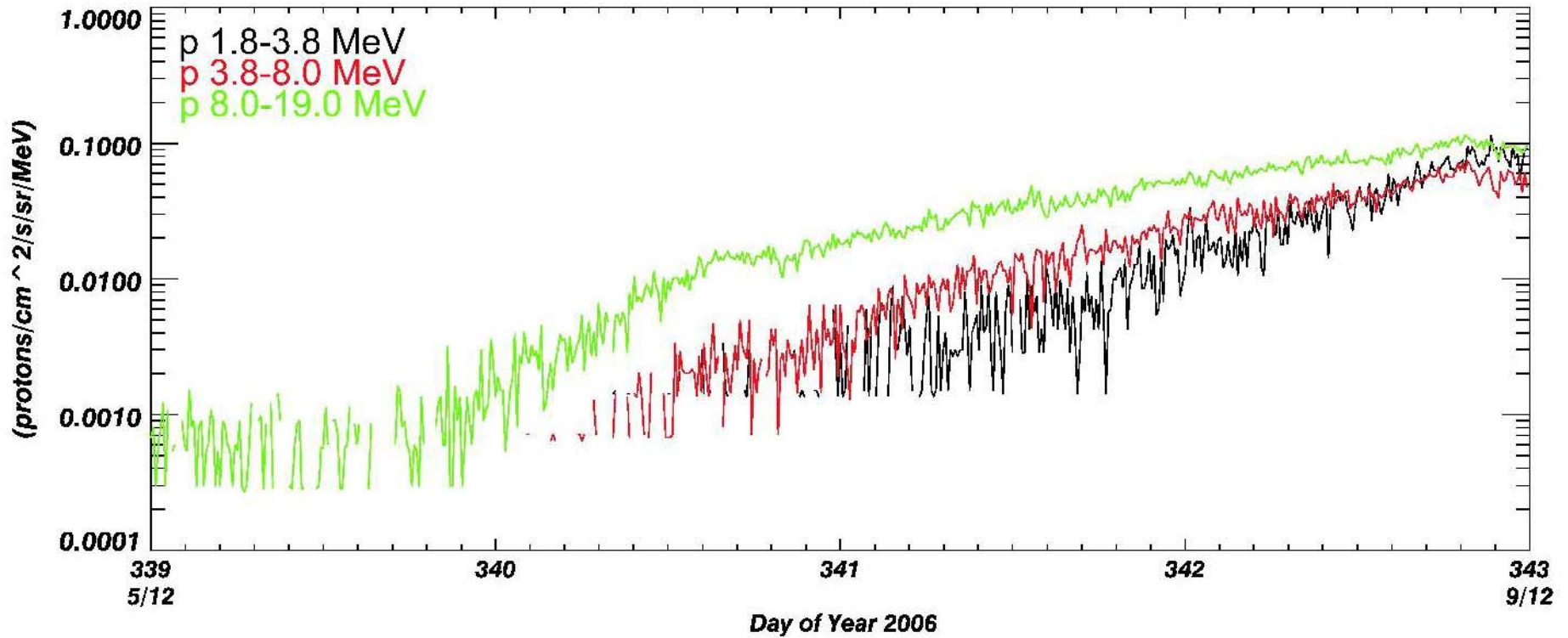
View from side



Angular separation with X9.0 flare location

Ulysses footpoint : 70 deg

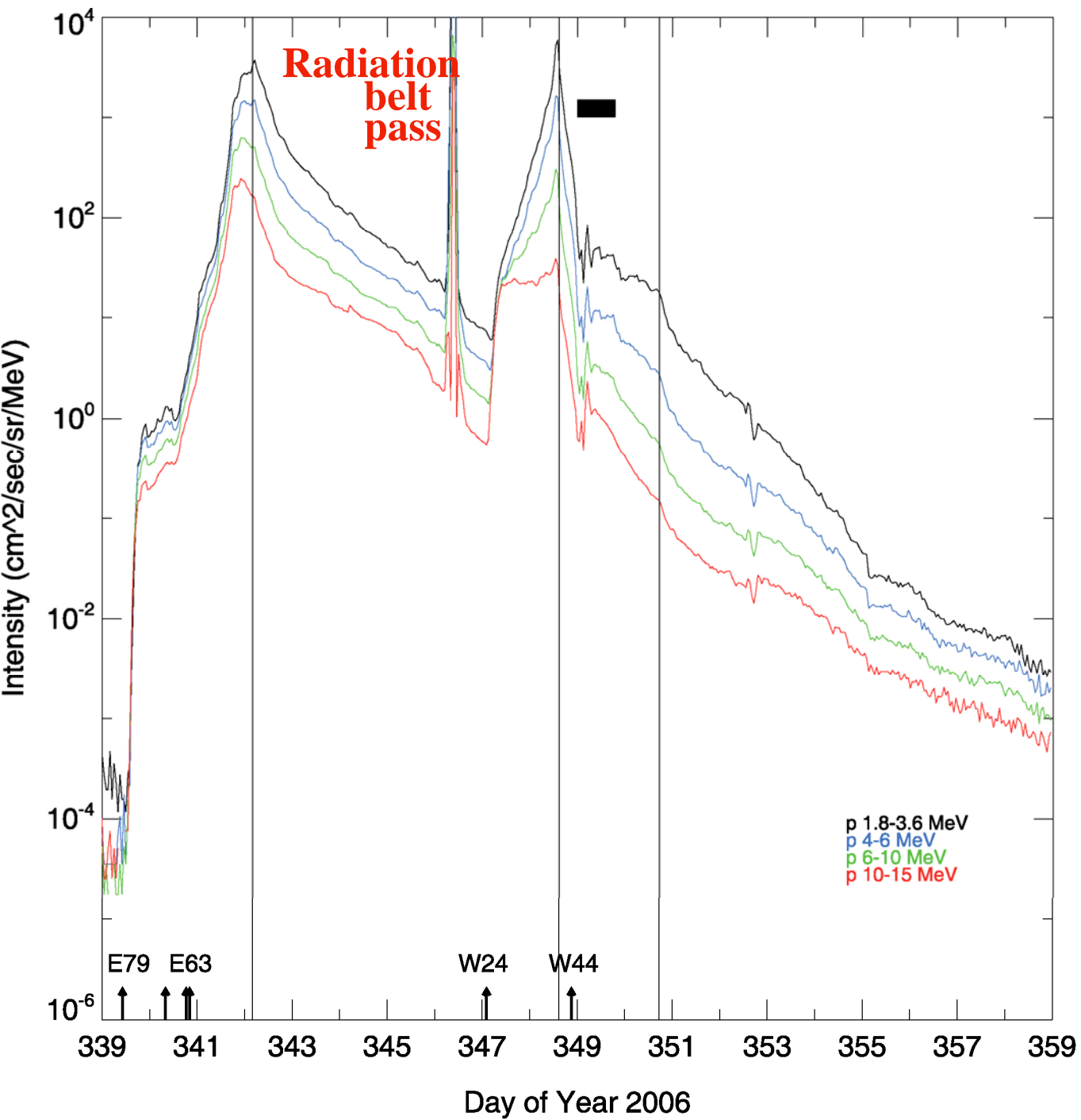
ACE footpoint : 135 deg



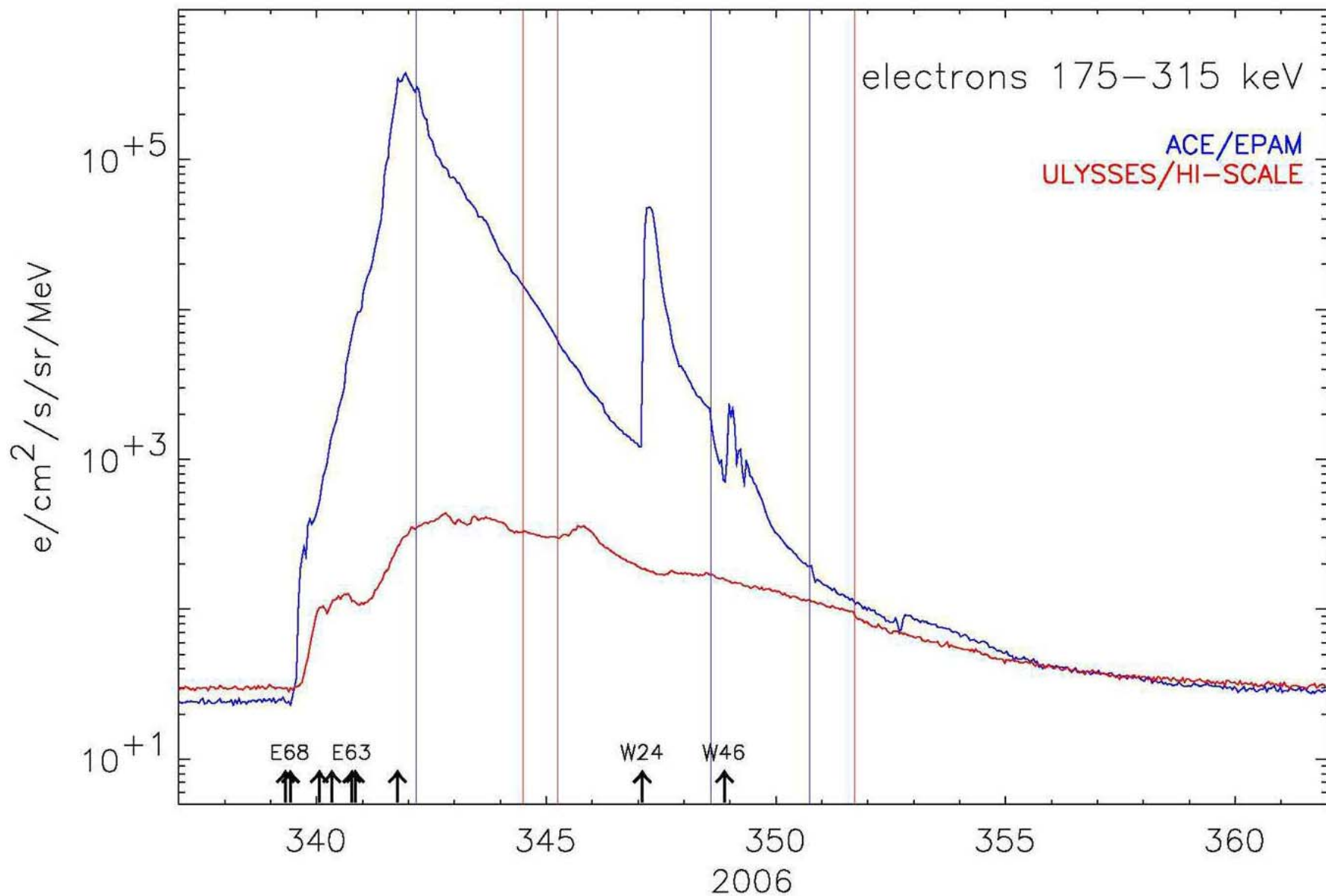
Velocity dispersion at Ulysses



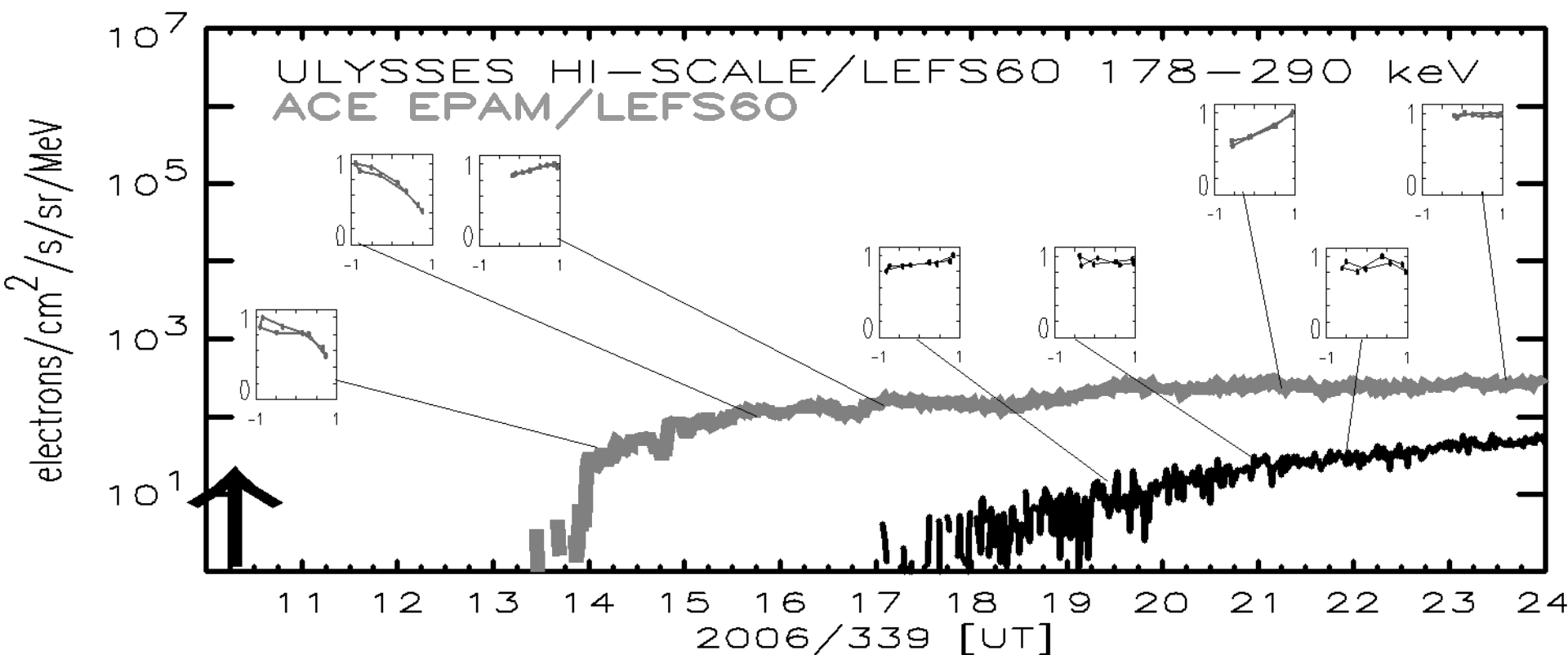
STEREO-B



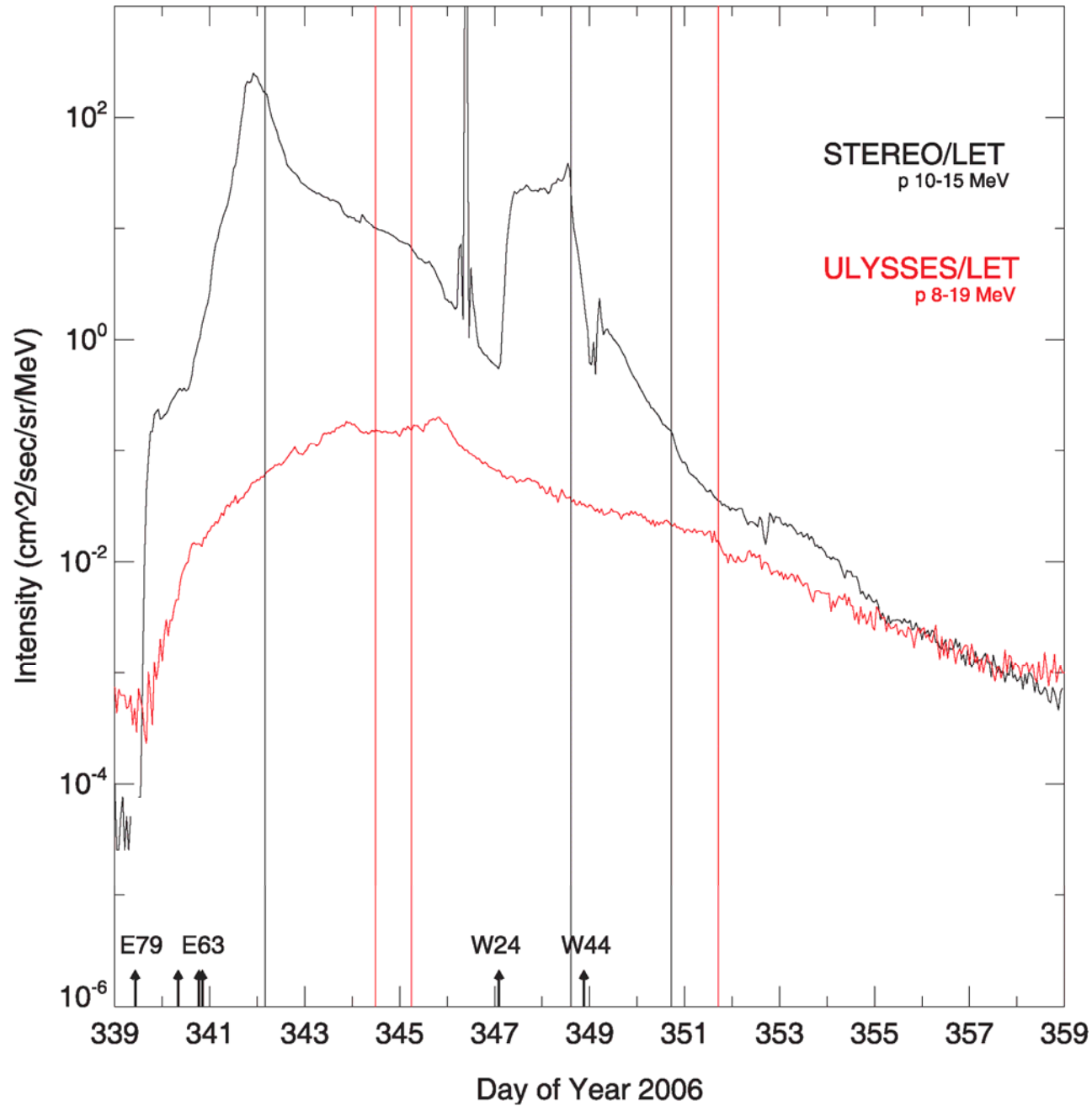
ULYSSES/ACE OBSERVATIONS



Near-isotropic angular distributions at the onset (*Ulysses*)

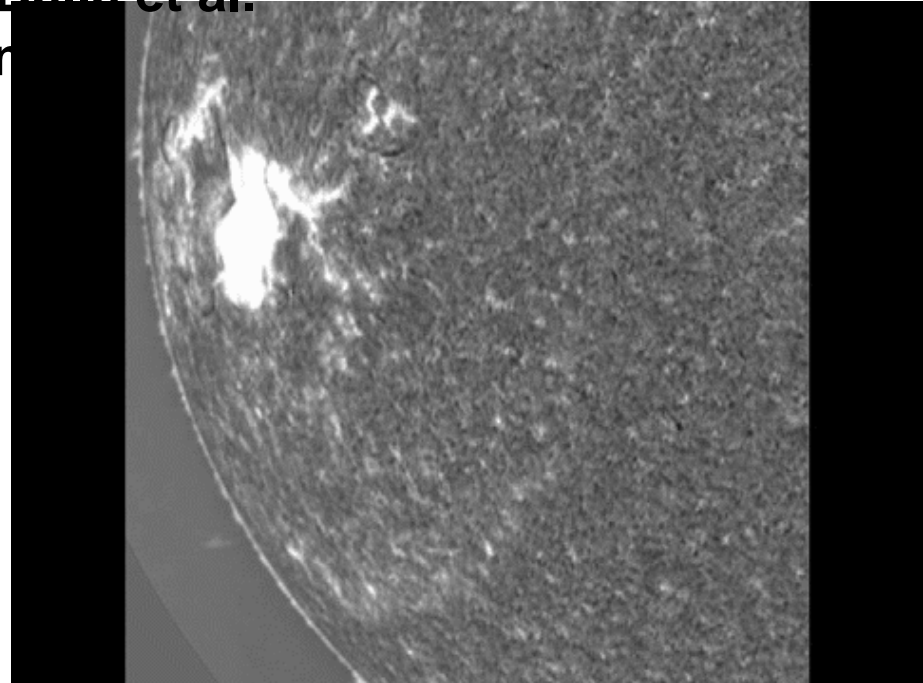


ULYSSES/STEREO-B OBSERVATIONS



How do SEPs reach high latitude?

- **Field line connection? (Smith et al. 2001) - Unlikely, since Ulysses in fast wind and AR in slow wind**
- **Accelerated by coronal shock? (Cliver et al. 1995)**
 - **Delay to ACE: 3.6 Hr (Dec 5)**
 - **Delay to Ulysses: 9.6 Hr**
 - **Coronal shock travel time: ~13 minutes**
- **Cross field diffusion? (Zhang 2003; Dalla et al. 2003) - possible, but no local evidence**



Credit: NSO/Optical Solar Patrol Network Telescope

December 2006 SEP events

- Unique observation of a high latitude event in the history of Ulysses mission during a period of relatively quiet and stable conditions in the heliosphere
 - Simple structure of the heliosphere and Ulysses in high-speed coronal hole flow exclude the possibility that low latitudes magnetic fields lines reached Ulysses
 - EP released when the propagating coronal waves reached high latitude magnetic field lines connected to Ulysses/EP underwent perpendicular diffusion
 - Rise phase of the event at STEREO & ACE in response to the X9.0 flare faster than at Ulysses \Rightarrow more diffusive transport to high latitudes and to 3 AU than to STEREO, ACE
 - ‘Reservoir effect’ observed late in the decay phase of the particle events
- ✓ **Malandraki et al., *Astrophys. J.*, 704, 469, 2009**