Observation and Interpretation of Energetic Neutral Hydrogen Atoms from the 5 December 2006 Solar Event

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STEREO SWG

Pasadena, CA

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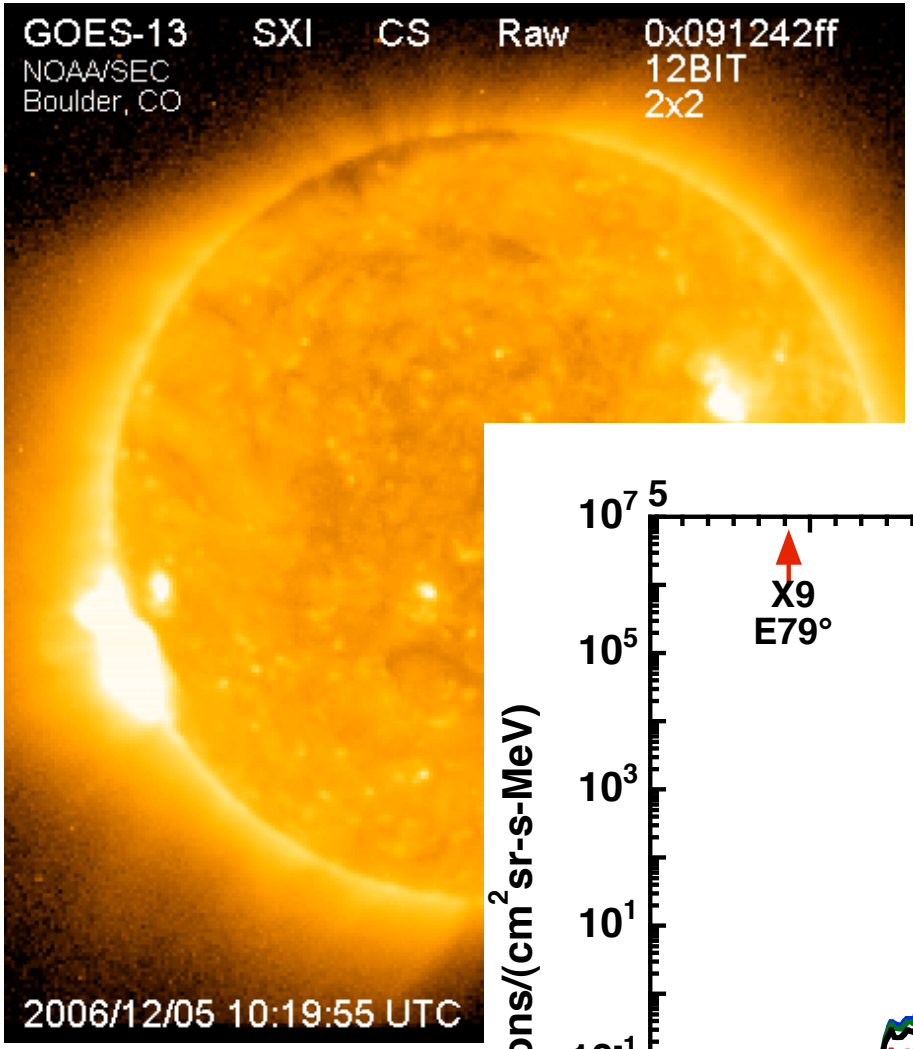
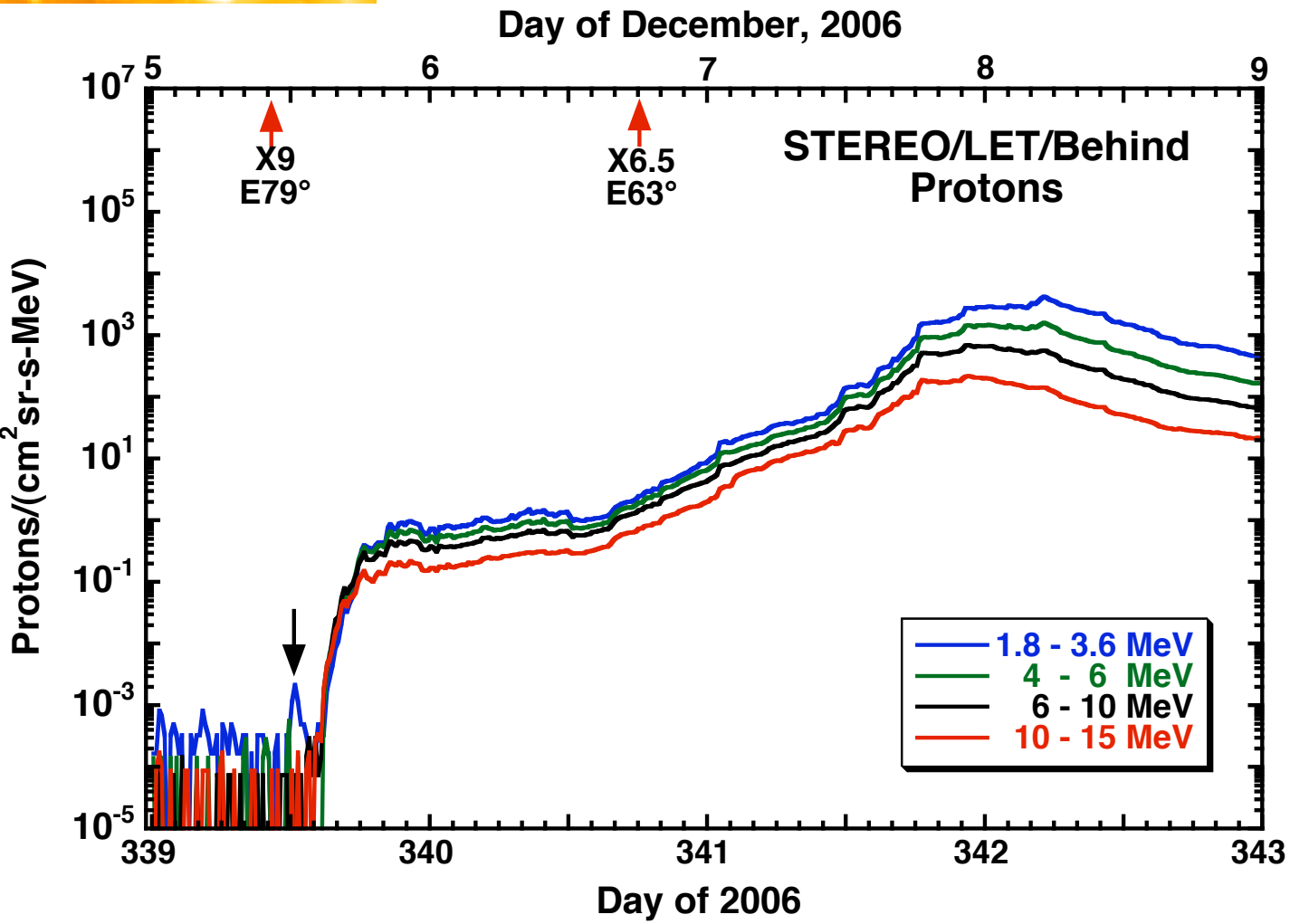
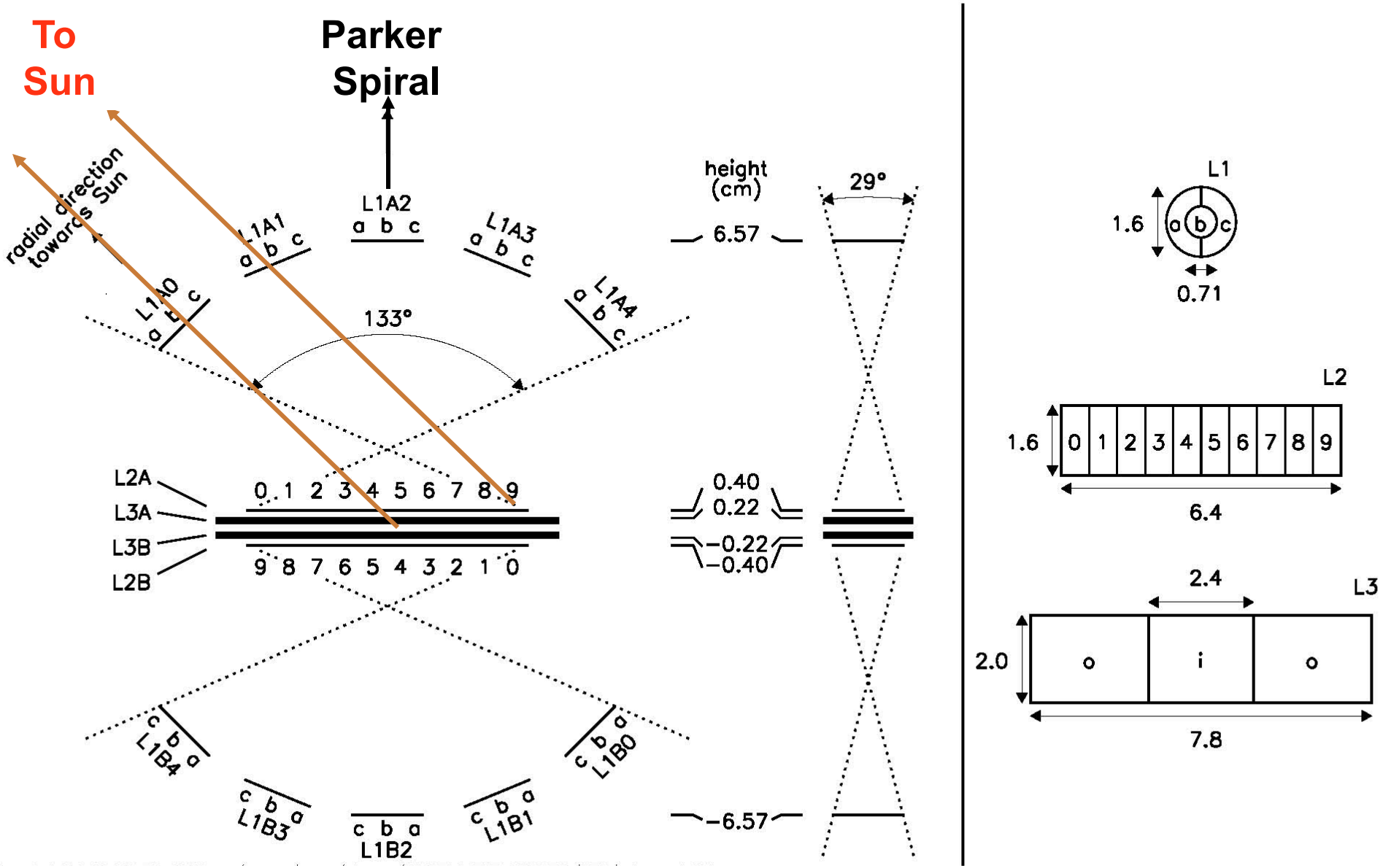


On December 5, 2006, the solar community was caught off guard by an X9 flare at E79. It was soon followed by 3 more X-class flares

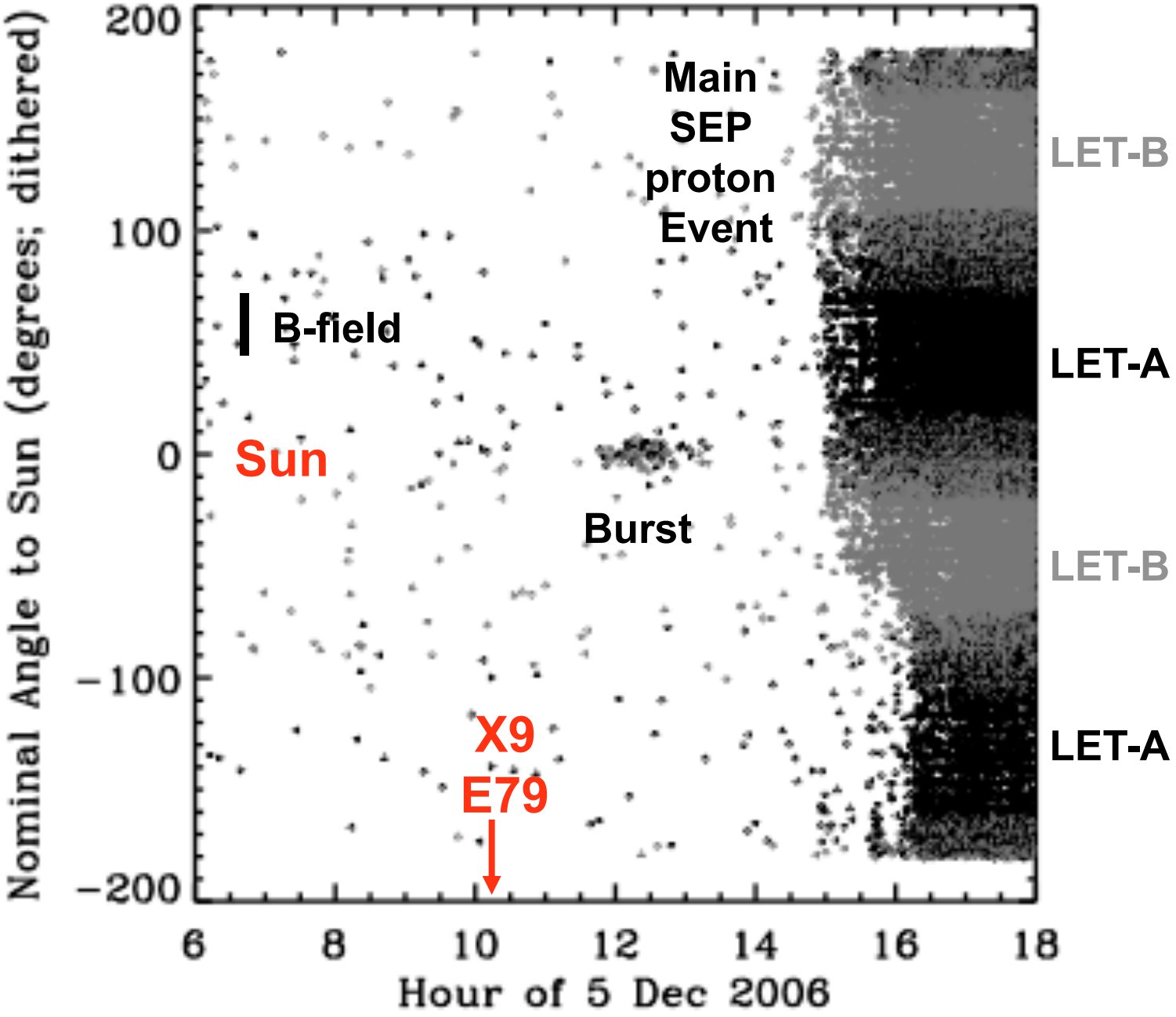


No CME data but was RHESSI γ-ray event

Low-Energy Telescopes on STEREO A & B

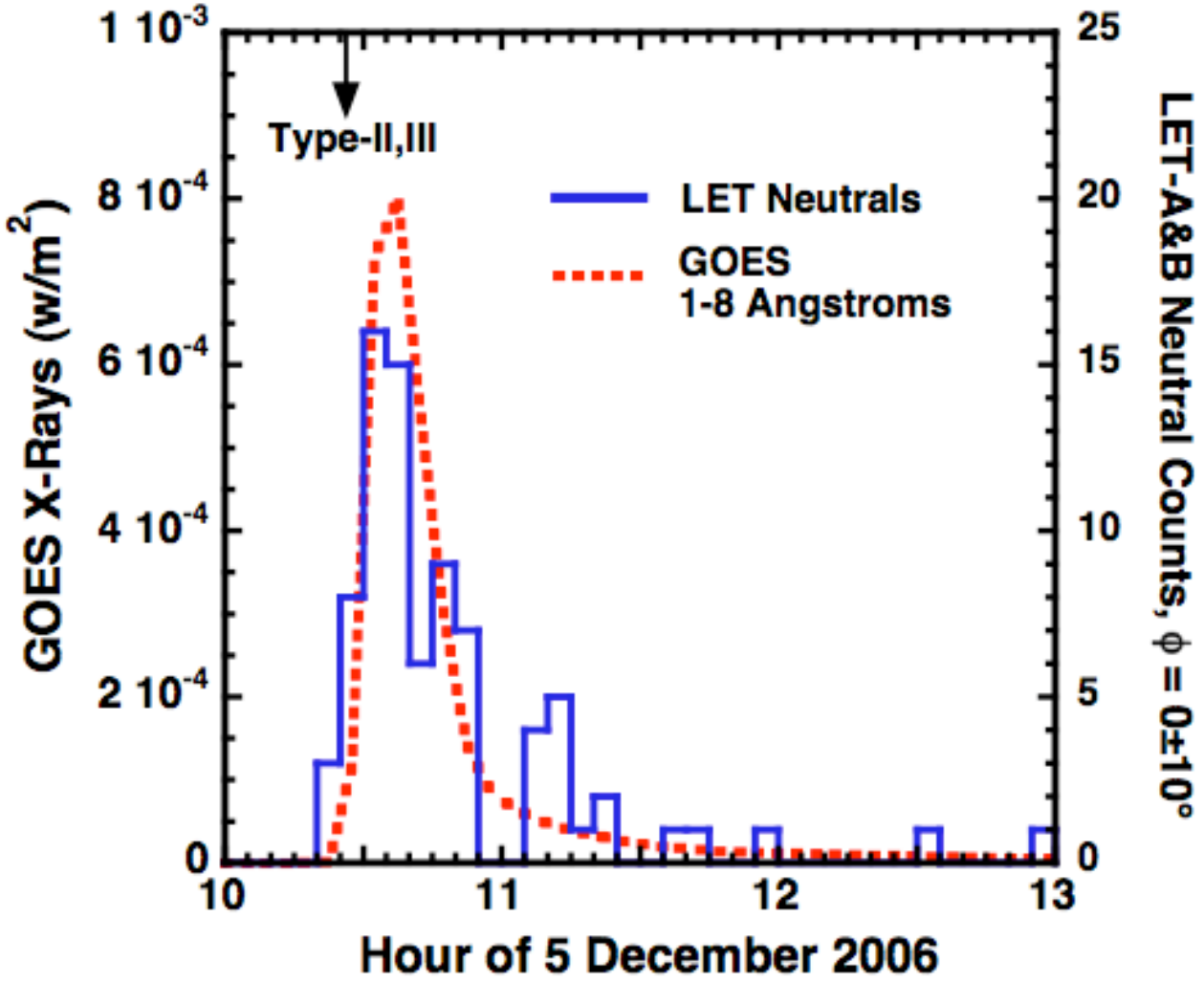


The precursor burst must be neutral !



Compute the neutral emission profile by tracing particles back to the Sun using the velocity obtained from the measured energy: $v = (2E/m)^{1/2}$

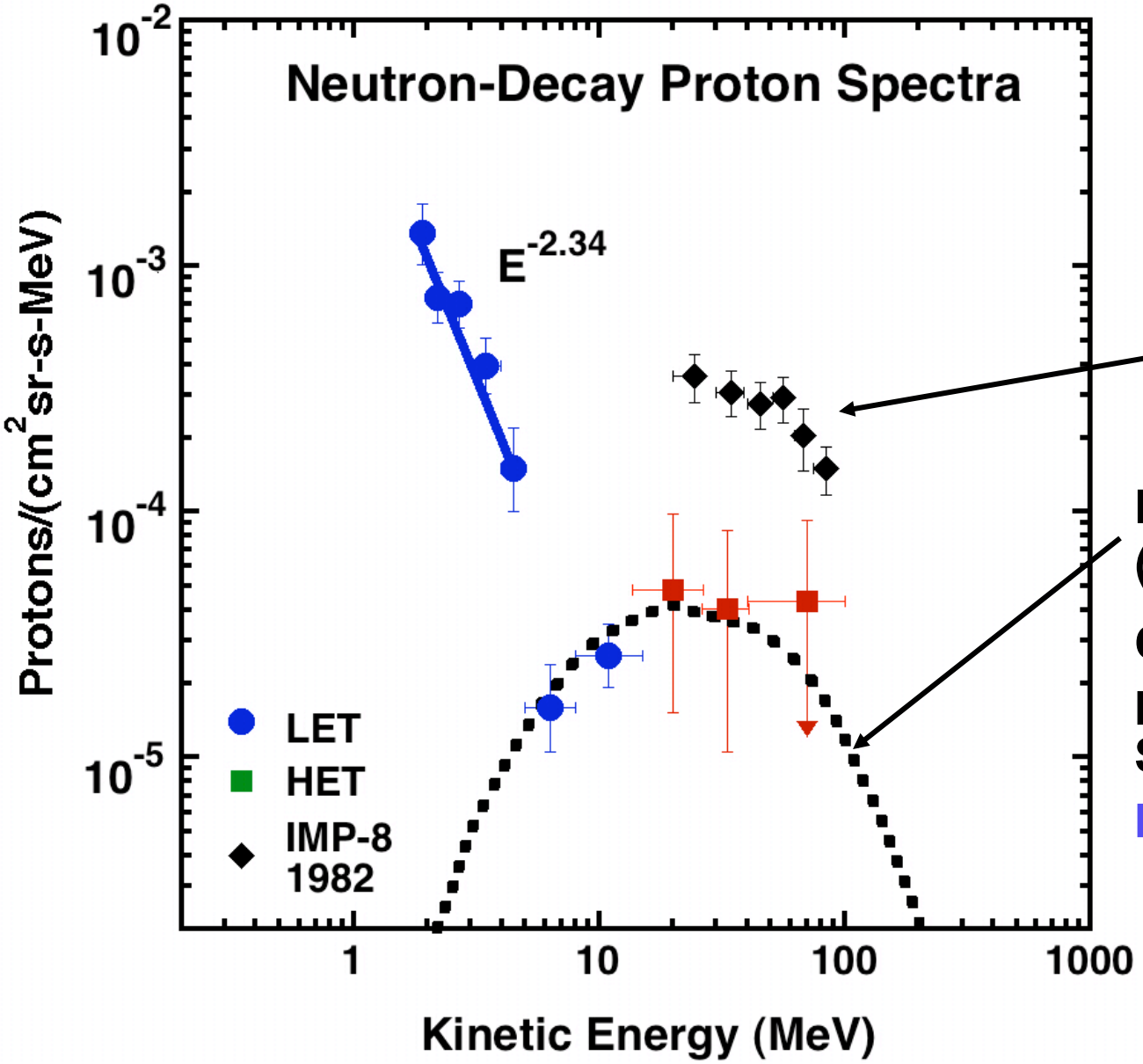
$$T_{Sun} = T_{obs} - (R_{St}/v) + 492 \text{ sec.}; \quad R_{St} = 0.983 \text{ AU}$$



Typical < 1 min uncertainty

Burst could be associated with either the flare or the CME !

Can they be neutron-decay protons?



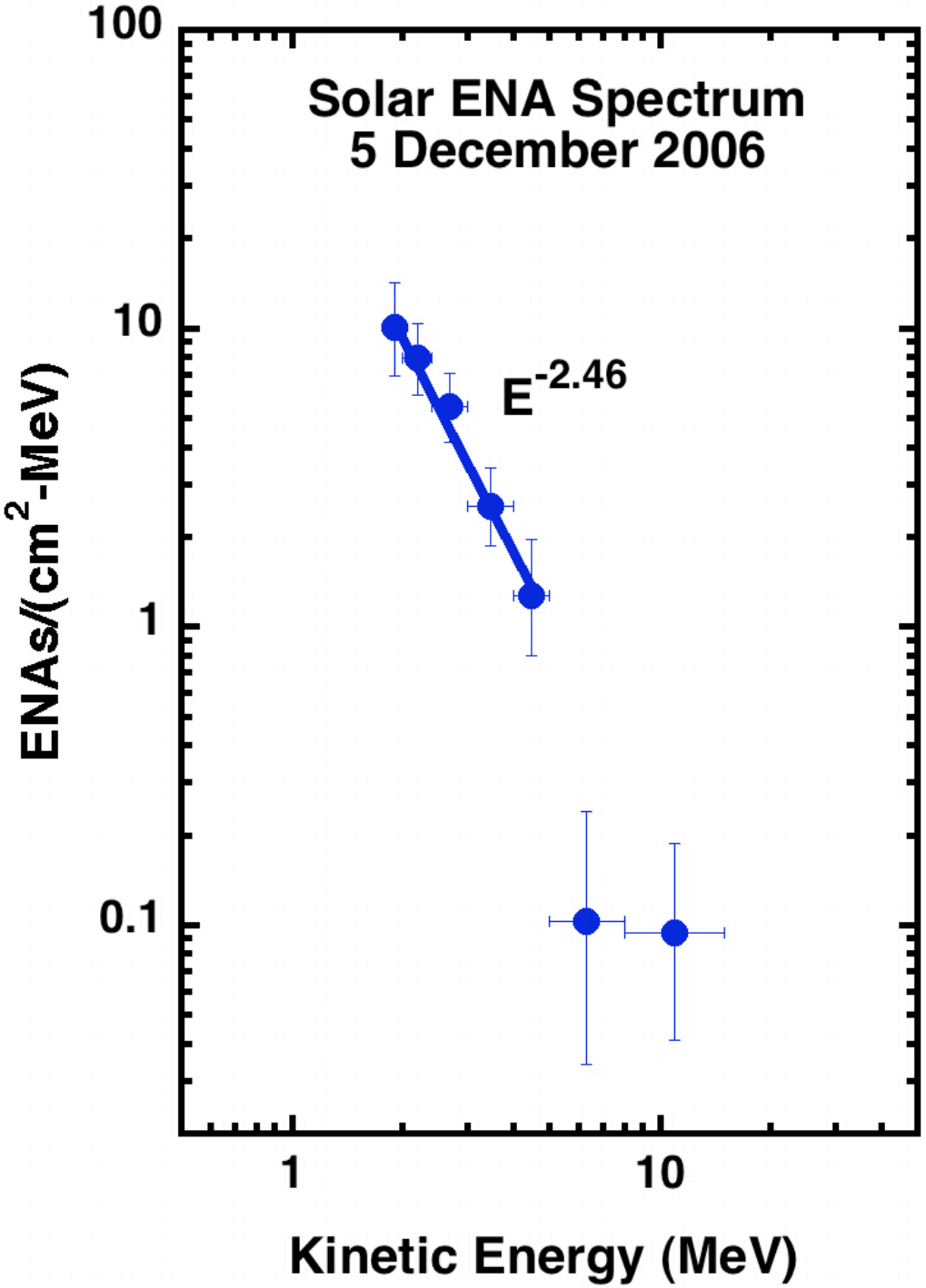
The <5 MeV neutrals can't be neutrons!

Could be neutrons >10 MeV

Evenson et al. 1983
IMP-8

Hua & Lingenfelter (1987)

Curve => 3 x 10^{32} protons >30 MeV at Sun => ~3.5 x 10^{35} protons of 1.8 - 5 MeV ($E^{-3.5}$ spectrum)

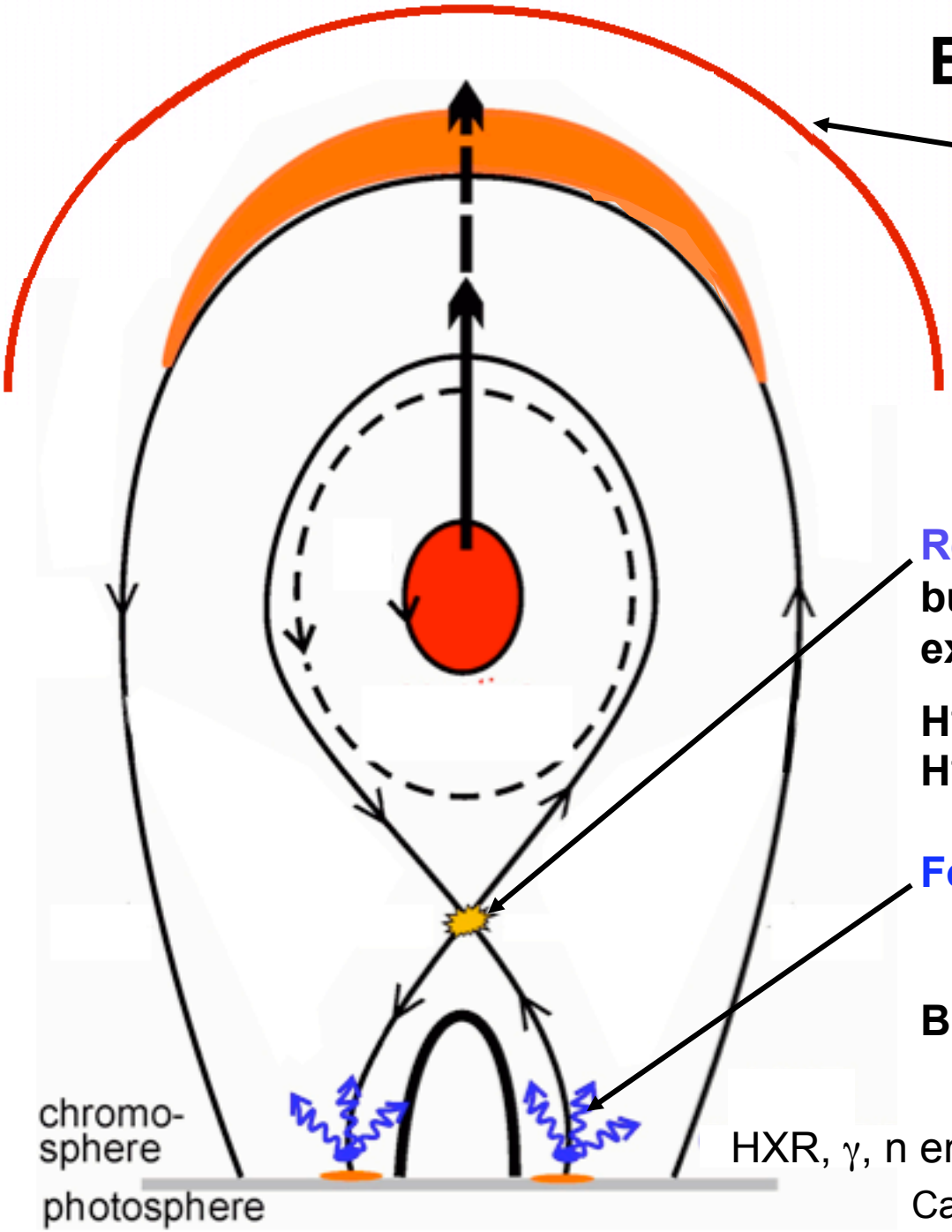


They must be energetic neutral hydrogen atoms! (ENAs)

Observed fluence => 2 x 10^{28} ENAs left the Sun

How are they made?

ENA Production Sites



CME-driven shock in high corona (or escaping flare particles)

$n \sim 10^4 - 10^6$ cm^{-3}

Reconnection region: $n \sim 10^9$ cm^{-3}; but no neutral H or He for charge exchange

$H^+ + e \rightarrow H + \gamma$ (radiative recomb.)
$H^+ + O^{+6} \rightarrow H + O^{+7}$, also Si, Fe

Footpoints: $n \sim 10^{10} - 10^{16}$ cm^{-3}
neutral H & He!

But, can ENAs escape from <1.1 R_S?

HXR, γ, n emission

Cartoon based on a RHESSI science nugget

How many ENAs are made as a proton slows from energy E to 1.8 MeV?

$$N_{ENA} = N_T \int_E^{1.8} \sigma_C(E)\ [dE/dx(E)]^{-1} dE$$

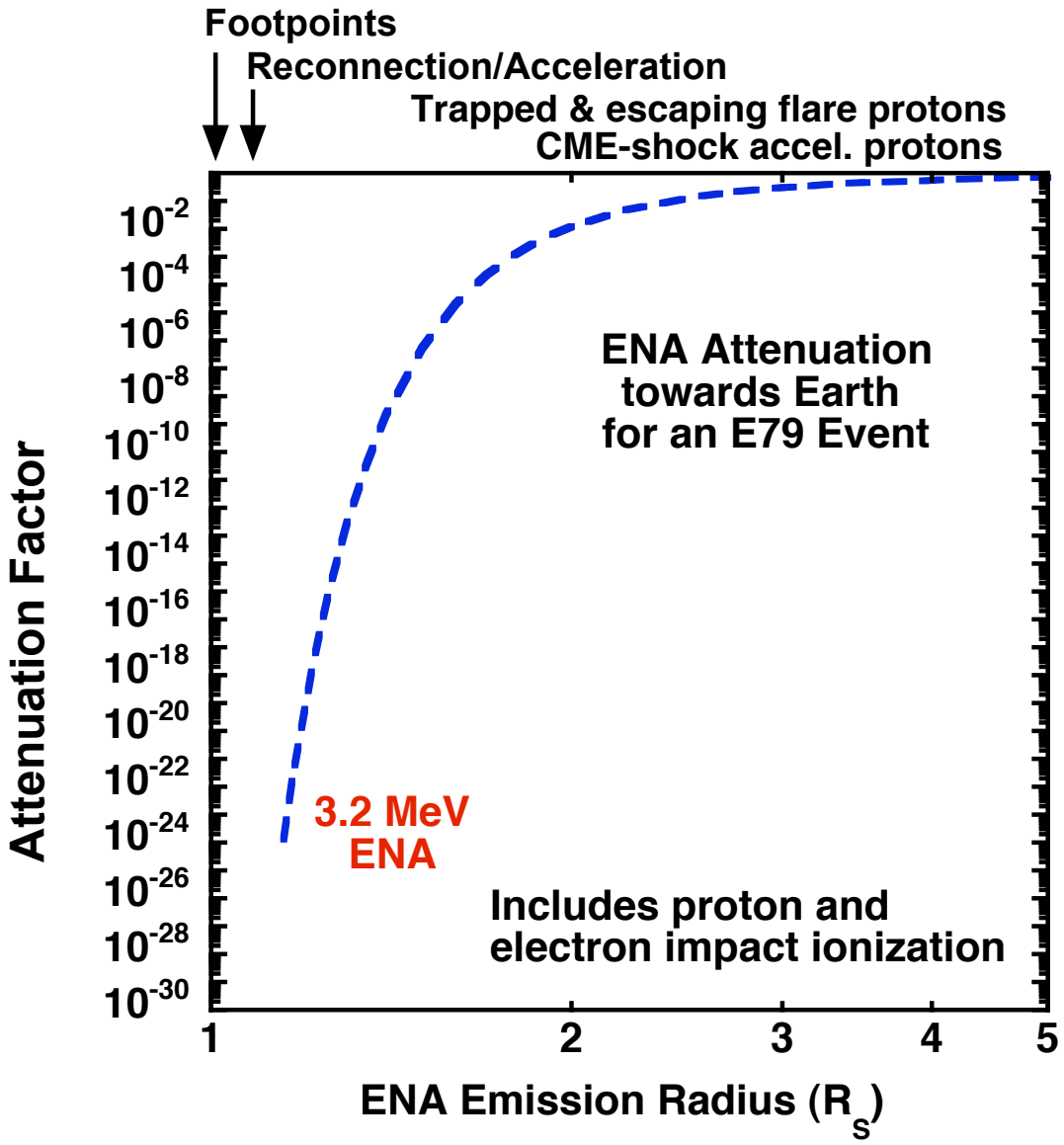
Allison (1958)

where: σ_{10} is the ENA production cross section

N_T is the number of target atoms/cm^2

- **A proton slowing from 5 MeV to 1.8 MeV produces ~0.01 ENAs**
- **~10^{33} ENAs are produced if all 3.5 x 10^{35} protons with 1.8 - 5 MeV slow and stop in the solar atmosphere**
- **~3.5 x 10^{28} ENAs needed to explain our observation**

=> Most ENAs do not escape the Sun



The ENAs we see must have been made in the high corona (>~1.7 Rs)

Could be either flare or CME-accelerated particles

Based on coronal densities from Sittler and Guhathakurta (1999)

Summary and Conclusions

- We have discovered energetic neutral hydrogen (1.8 - 5 MeV) from the 12/5/06 X9 event. To our knowledge, a first.
- Emission profile consistent with flare or CME-driven shock origin
- ENAs are made by radiative recombination, but we suggest partially-stripped heavy ions are a more important source
- Estimated total ENA production is $>10^4$ times that needed
- ENAs must originate >1.7 Rs from flare or CME accelerated protons
- STEREO observations may decide between sources
- ENAs can probe poorly-known flare acceleration of low-E ions
- ENAs can probe accelerated ions in the high corona

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