

Multi-spacecraft Observations of Gradual Solar Energetic Particle Events with Enhanced ^3He Abundance

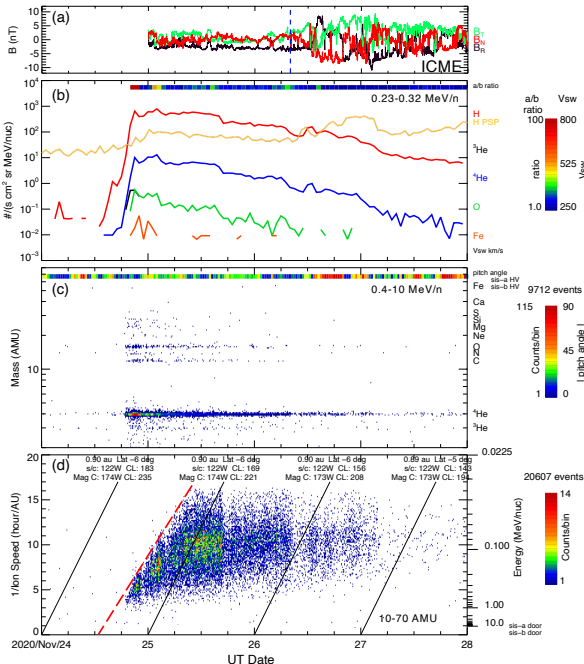
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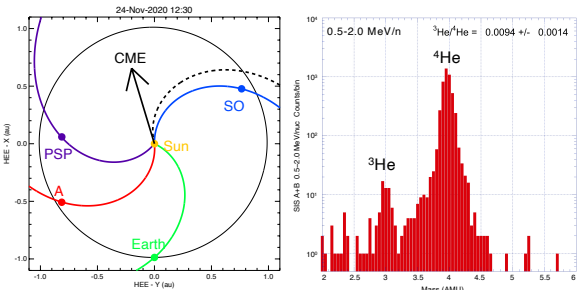
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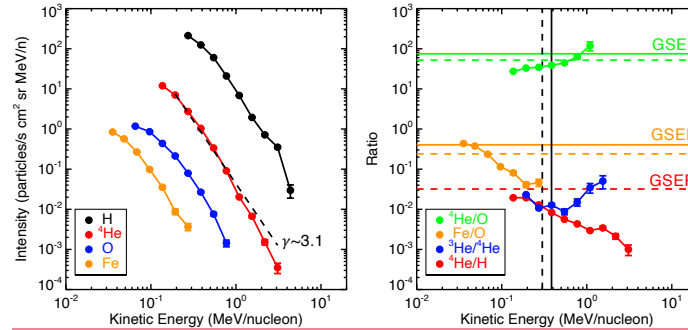
Motivation. The ^3He enhancement is commonly detected in gradual CME-driven shock SEP events. The origin of the enhancement remains largely unexplored. Two mechanisms have been suggested - remnant flare material or concomitant activity in the corona, e.g., parent active region (AR).



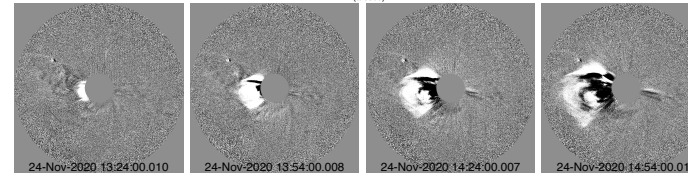
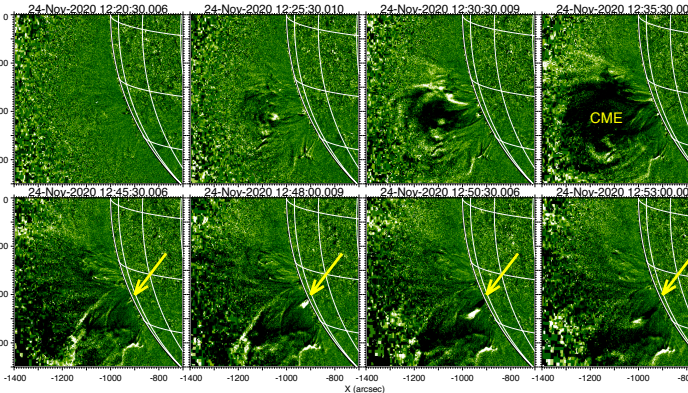
We examine the 2020 Nov 24, 1st gradual SEP (GSEP) event on Solar Orbiter (SO). The event shows enhanced ^3He abundance. It was detected marginally on Parker Solar Probe (PSP) & only at < 200 keV/n (shown as H count rates in 1/s in panel b).



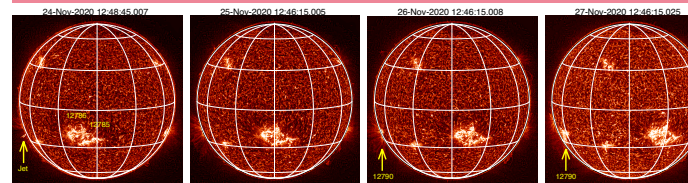
The event was not measured by STEREO-A or near Earth. The event $^3\text{He}/^4\text{He}$ on SO is $\sim 24\times$ higher than the coronal value.



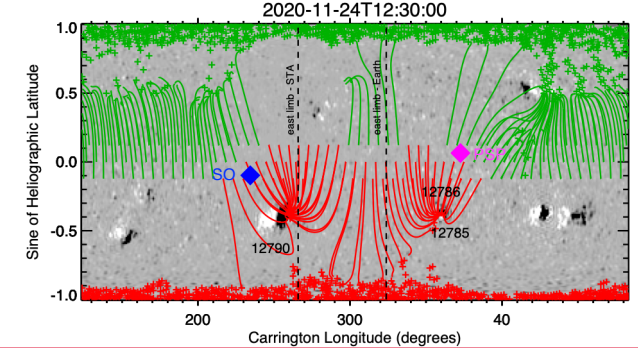
The event shows unusually soft spectra compared to typical low-energy GSEP event spectra with index $\gamma \sim 1.5$. The energy dependence of $^4\text{He}/\text{H}$, $^4\text{He}/\text{O}$, Fe/O is consistent with diffusive shock acceleration.



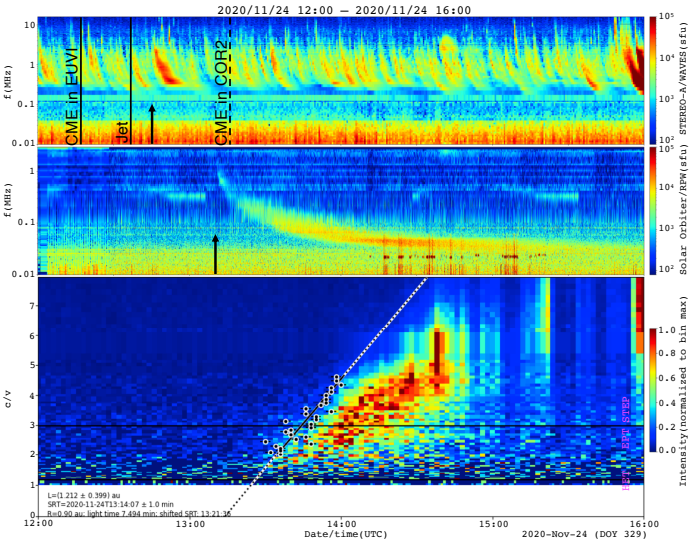
STEREO-A observations of (Top) Early evolution of the event-associated CME in EUVI 195 Å, (Middle) Following jet, (Bottom) Evolution of the CME (partial halo) in the COR2 coronagraph (reported speed 890 km/s).



Daily sequence of STEREO-A EUVI 304 Å images showing the CME source AR 12790 and probable source of the type III storms (ARs 12786, 12785).



PFSS model coronal open field lines that intersect ecliptic. SO could be connected to the CME parent AR. The SO & PSP magnetic foot-points are determined for 350 km/s.



(Top) Type III storms (the strong one marked by an arrow) seen by STEREO-A. The jet accidentally coincided with one storm type III. (Middle) The SO-observed event-related type III started at $\sim 8 R_{\odot}$. (Bottom) The type III-associated solar electron event measured on SO.

Conclusions. Possible origins of enhanced ^3He abundance:

- Probable – (1) parent AR showing open field lines where SO was connected augmented by unusually soft spectra of GSEP event (2) remnant ^3He from preceding ^3He injections on Nov 17-20 (see SH25B-2084)
- Less probable – the jet without measured type III that followed the CME
- Improbable – magnetically closed type III storm sites