The Long Period of 3He-rich Solar Energetic Particles Measured by Solar Orbiter 2020 November 17–23

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Abstract

We report observations of a relatively long period of 3He-rich solar energetic particles (SEPs) measured by Solar Orbiter. The period consists of several well-resolved ion injections. The high-resolution STEREO-A imaging observations reveal that the injections coincide with extreme ultraviolet jets and brightenings near the east limb, not far from the nominal magnetic connection of Solar Orbiter. The jets originated in two adjacent, large, and complex active regions, as observed by the Solar Dynamics Observatory when the regions rotated into the Earth's view. It appears that the sustained ion injections were related to the complex configuration of the sunspot group and the long period of 3He-rich SEPs to the longitudinal extent covered by the group during the analyzed time period.

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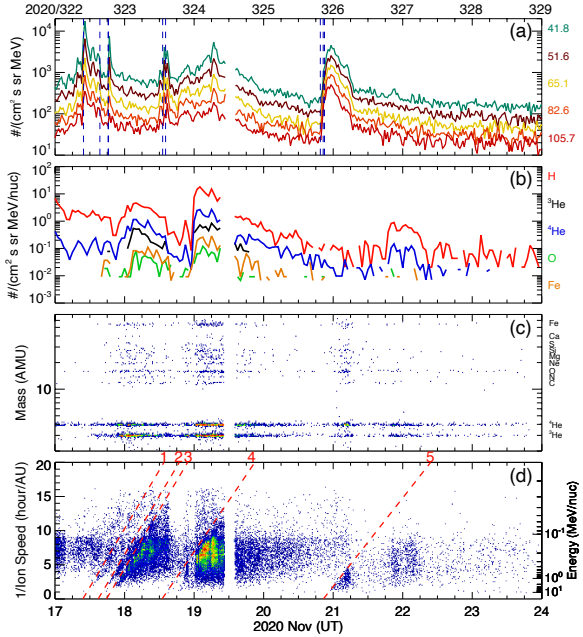
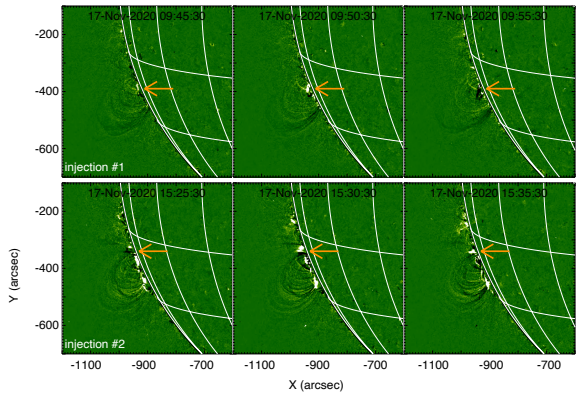
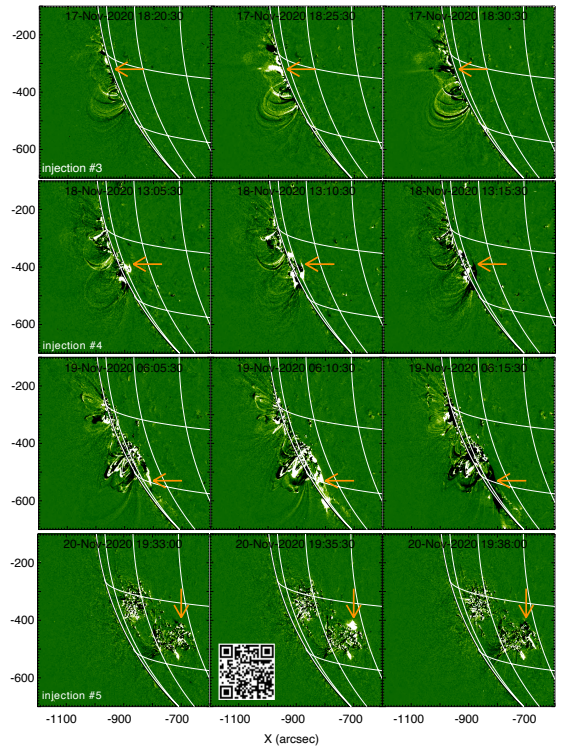
Motivation: ^{3}He-rich SEPs are thought to be produced in jets by a mechanism associated with magnetic reconnection. Multi-day periods of ^{3}He-rich SEPs have been often measured, but causes remain unclear. Previous studies discussed recurrent injections, magnetic connection, or trapping in the interplanetary structures.

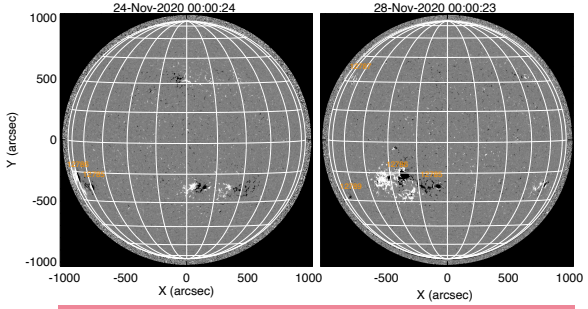


Solar Orbiter (SO) EPT electron (a) and SIS ion (b-d) measurements. Vertical dashed lines mark type III radio bursts, and sloped lines mark the ion injections.

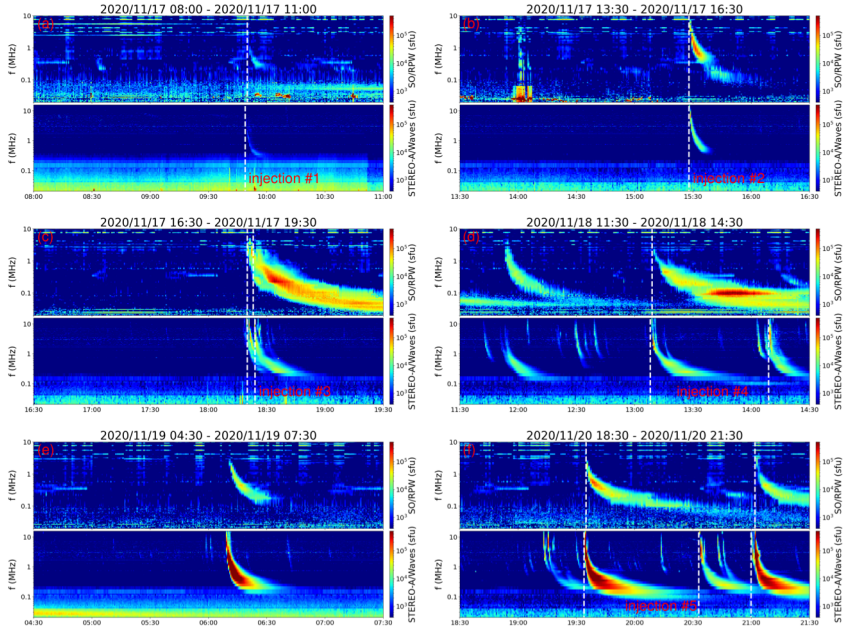




STEREO-A 195 Å running difference images around type III bursts; the arrow marks the solar source with recurrent brightening or jets. Brightenings in injection #5 were observed as jets from Earth (SDO).



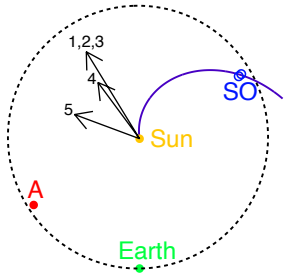
SDO HMI magnetograms. Candidate solar source ARs 12786 and 12785. AR 12786: $\beta\gamma$ magnetic class & sunspot area 1000 MH; AR 1275: β class & the area 140 MH.



SO & STEREO-A spectrograms. The vertical dashed lines mark type III bursts associated with the ion injections; unmarked type III bursts in spectrograms (d) and (e) correspond to the electron events, jets, and possibly to unresolved ion injections.

	Ion injection time (UT)	Type III start (UT)	STEREO-A EUVI event Type[a]	STEREO-A EUVI event Location	Separation angle[b] (°)	Elec. injection time (UT)	^{3}He/^{4}He[c]	Fe/O[c]
1	322.42 Nov-17 10:05	09:49 [41]	B	E90S22	20	09:20	0.61±0.08	2.00±0.37
2	322.62 Nov-17 14:53	15:28 [20]	B	E90S18	20	...	0.22±0.03	0.63±0.06
3	322.74 Nov-17 17:46	18:20 [12]	J	E90S18	20	18:20	0.90±0.03	0.91±0.01
		18:24 [16]	…	E90S18	20	…	…	…
4	323.54 Nov-18 12:58	13:08 [00]	B	E85S23	25	13:10	0.56±0.01	1.35±0.01
		14:09 [01]	B	E85S23	25	14:07	…	…
5	325.87 Nov-20 20:53	19:34 [26]	B	E48S19	62	19:30	0.32±0.03	0.76±0.03
		20:33 [25]	J	E52S17	58	…	…	…
		21:00 [52]	B	E48S19	62	…	…	…

Notes. [a] B: brightening; J: jet [b] Between the Solar Orbiter magnetic footpoint longitude on the Sun and the longitude of the EUVI event [c] 0.2–2.0 MeV/nucleon



Conclusions:

- The long period of ^{3}He-rich SEPs is related to the recurrent brightenings and jets in the two adjacent large and complex ARs
- Such configuration of ARs may be favorable for frequently occurring magnetic reconnection-related ion injections
- Two ARs produced a longitudinally extended source (~40°) in which spacecraft may be connected for a long period

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