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^{3}HE IN SOLAR NON-RELATIVISTIC ELECTRON EVENTS

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ABSTRACT

We report on a systematic study of the presence of ^{3}He in 187 solar electron events observed on the ISEE-3 spacecraft during a 9-month period beginning in Aug 1978. ^{3}He is present in over half of the events and in 2/3 of events with 19 keV electrons, suggesting that ^{3}He would be found in all electron events given somewhat greater collection efficiency.

1. Introduction In a recent paper Reames, von Rosenvinge and Lin (RvL, 1985) suggested a common origin for solar ^{3}He-rich events and non-relativistic electron events. This association was based upon the close temporal relationship between the two species which share nearly scatter-free propagation from the sun and upon the observation of electrons in all of the ^{3}He-rich event periods.

In this paper we examine the inverse relationship by asking the extent to which all solar electron events are accompanied by ^{3}He. To this end, we have begun with a list of solar electron events observed by the Univ. of California experiment on the ISEE-3 spacecraft and, for each event, we have examined data from the very-low-energy telescope of the GSFC experiment on the same spacecraft for the presence of ^{3}He.

2. Observations and Results The solar electron event list used in this study gives the onset time of each event and the intensity of electrons at 2 and 19 keV. Of the 187 events during the study period, 103 (55%) had measurable fluxes of 19 keV electrons, the remainder being observed only at lower energies. Where possible, the source of the event has been identified by the metric Type III radio emission and/or the H-alpha flare characteristics using Solar-Geophysical Data.

The measurements in RvL (1985) showed the 1.34-1.63 MeV ^{3}He onset to occur 2-4 hrs after the electron onset and the ^{3}He maximum to occur 1-2 hrs later. We therefore scanned the hourly-averaged ^{3}He data during the 8-hr interval from 2 to 10 hrs after the electron onset and recorded the ^{3}He intensity. This technique allowed us to press for the maximum sensitivity to ^{3}He without introducing an unacceptable number of spurious events

from ^{3}He background or from recounting multiple events. The ^{3}He background estimated at about one particle every 3-4 days would be expected to contribute 2 to 3 spurious events out of the 85 observed.

In 34 (18%) of the 187 events it was not possible either to observe or to set meaningful limits on the ^{3}He, usually because of a large particle event in progress but also occasionally because of data gaps. Of the subset of 103 events with 19-keV electrons, 17 were similarly excluded. The remaining events, 153 total and 86 with 19-keV electrons, are categorized by their ^{3}He content in Table 1. In Table 1 we see that over half (56%) of the electron events have ^{3}He and that fraction jumps to 2/3 (66%) for events with 19-keV electrons.

Table 1 ^{3}He in Electron Events

	^{3}He	no ^{3}He	total
All electron events	85(56%)	68(44%)	153
19-keV elect events	57(66%)	29(34%)	86

We explore the ^{3}He association as a function of electron intensity and spectral index in Tables 2 and 3. Here the highest electron intensities and flattest spectra show a high probability of ^{3}He association. Otherwise, the correlation with intensity is weak, especially for 2-keV electrons. For those events with ^{3}He, the ^{3}He intensity is plotted versus the electron intensities in Figure 1. There appears to be no correlation with 2-keV electrons in Fig. 1a , however, a broad correlation seems to exist with the 19-keV electrons in Fig. 1b but the limited dynamic range of the instruments makes its observation difficult.

Table 2 ^{3}He Observation vs. Electron Intensity

(a) 2-keV Electrons Intensity (x1000)	^{3}He	no ^{3}He	(b) 19-keV Electrons Intensity	^{3}He	no ^{3}He
>100	7(78%)	1	>10	9(78%)	1
10-100	28(55%)	23	1-10	26(65%)	14
1-10	36(54%)	31	0.1-1	22(61%)	14
<1	14(52%)	13	Total	57(66%)	29
Total	85(56%)	68	None(<0.3)	28(42%)	39

Table 3 ^{3}He Observation vs. Electron Spectral Index

Index	^{3}He	no ^{3}He
<2.0	1	0
2.0-2.9	9(69%)	4
3.0-3.9	22(59%)	15
4.0-4.9	15(68%)	7
>5.0	2(50%)	2

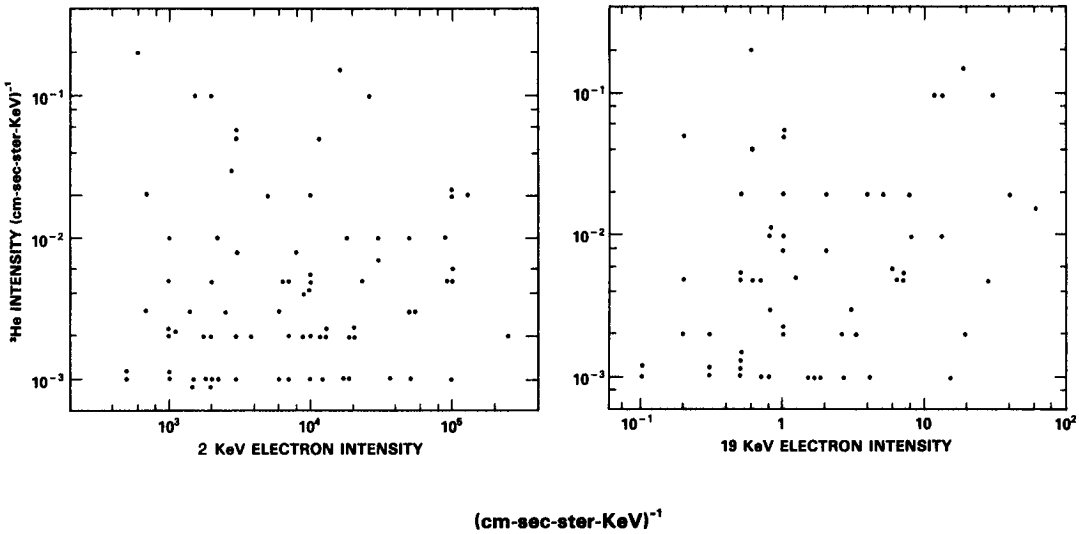

Fig. 1 ^{3}He vs. electron intensities for two electron energies.

With Figure 2 we address the question of the relative importance of electron intensity versus spectral index in determining the ^{3}He intensity. Symbols on the plot denote the most intense 13 ^{3}He events, other ^{3}He events, and events with no ^{3}He. The tendency of the more ^{3}He-rich events to lie toward the top of the plot (greater 19-keV intensity) is stronger than their tendency toward flatter spectra. Of the 23 events with 19-keV electron intensity above 3 (cm^2-ster-sec-MeV/AMU)$^{-1}$ (30% of plotted data), 19 (83%) exhibit ^{3}He and 8 (62%) of the 13 largest ^{3}He events are found in this region.

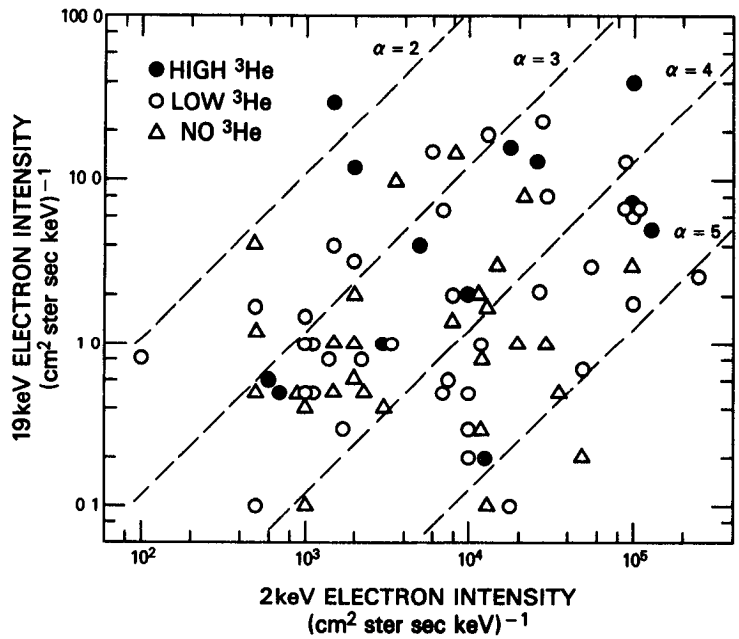

Fig 2. Electron intensity cross-plot with ^{3}He content shown for each event. Electron power spectral indices are diagonal lines.

3. Relation to Solar Events The results of the preceding section lead to the conclusion that ^{3}He-rich events are not unusual, but are, in fact, a further manifestation of the same mechanism that accelerates electrons in the impulsive phase of solar events. Our ability to associate these particles in space with the corresponding radio, optical and X-ray features at the sun depends upon the size and character of the events.

We have used our preliminary radio and optical event associations in table 4 to show how the likelihood of identification of such events depends upon the presence of ^{3}He or 19-keV electrons in the event. We have included all radio events in the Type III column even though a small percentage of them are Type I.

Table 4 Number of Radio and Flare Associations for Events with Various Properties

	Type III	Flare	Total
^{3}He	61(72%)	40(47%)	85
No ^{3}He	41(61%)	18(26%)	68
Total	102(66%)	58(40%)	153
19-keV Electrons	84(82%)	60(58%)	103
No 19-keV Electrons	41(49%)	16(19%)	84
Total	125(67%)	76(41%)	187

Since metric Type III radio emission is a signature of electron ejection from the solar corona, it is not surprising to find a good correlation (67%) for all electron events. This correlation is improved substantially for events with 19-keV electrons (82%) and slightly for the ^{3}He events.

The correlation with H-alpha flares is not as good as with Type III events but again improves with both subsets of particle events. Particles accelerated on open magnetic field lines in the high corona may not have adequate access below the corona to produce significant H-alpha or X-ray events.

Of the 61 radio associations of the ^{3}He events, 6 are Type I events and 55 Type III; 8 of the latter are Type III, V. Most of the events are groups (G or GG) and about half have radio intensity 2 or 3. None of the 61 events show Type II or IV emission or other shock-related features.

The 40 flares associated with the ^{3}He events show the solar longitude distribution of typical impulsive well connected events with only 8 of the 40 in the eastern hemisphere. Two of the flares are importance 2, 6 are importance 1 and the remaining 32 are subflares.

REFERENCES

Reames, D.V., T.T. von Rosenvinge and R.P. Lin, 1985, Astrophys. J. 292, 716.