^{3}He-rich SEP events detected by EPHIN 1996-2000

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Abstract

Thirteen ^{3}He-rich impulsive events have been identified in EPHIN data between 1996 and 2000. Energy spectra, abundance ratios, and association with solar activity have been evaluated. Association with radio bursts III-type has been observed for all of them, but solar flare association has been found only for 8 of them. No acceleration above 30 MeV/nucleon has been appreciated. No deuterium has been detected for any event under study.

1. Introduction

From the SOHO launching, the EPHIN instrument has registered multiple SEP events with ^{3}He/^{4}He ratio above 0.01. However, the characteristics commonly associated to these events they hinder their study considerably: the intensities are usually low, the ion acceleration doesn't reach high energy, and the duration is usually short, so the events present poor statistics for the study of aspects like the isotopic composition or the energy spectrum. The situation gets complicated even more if one take into account that as the solar activity increases, it doesn't only grow the number of rich events in ^{3}He, but also the one of gradual events of longer duration and higher intensity, capable of to mask any event of small size. With object of to carry out a study of rich events in ^{3}He with enough statistical accuracy for the analysis, we have been carried out a search using particle flux and PHA data. Usually high ^{3}He fluxes are subject to a strong noise contribution, mainly during intense events that are accompanied of important increments in the electron flux. Confirmation of candidates requires the use unavoidably of PHA data. Recently Sierks et al., [1] have presented a summary of temporary intervals with high level of ^{3}He registered by EPHIN from the beginning of the mission until ends of 2000.

After the exam of the flows and the PHA data, it has been selected for their study a sample of 13 ^{3}He-rich SEP events. Selected events present ^{3}He-^{4}He ratios

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Table 1. Table of Data.

Event	Date	^{3}He/^{4}He	$\gamma_{^3He}$
1	Aug 10, 1997	0.29 ± 0.09	-
2	Nov 28, 1997	0.36 ± 0.07	3.2
3	Mar 21, 1999	0.42 ± 0.16	5
4	Mar 22, 1999	16 ± 16?	-
5	May 09, 1999	0.041 ± 0.007	-
6	May 12, 1999	1.87 ± 0.63	5.6
7	Jun 18, 1999	0.38 ± 0.04	3.5
8	Aug 07, 1999	6.5 ± 4.9	4.2
9	Aug 14, 1999	0.23 ± 0.06	-
10	Nov 01, 1999	0.87 ± 0.46	2.1
11	Dec 24, 1999	0.68 ± 0.09	2.9
12	May 23, 2000	0.31 ± 0.02	3.9
13	Aug 22, 2000	1.46 ± 0.28	4.9

above 0.04 in the energy interval 5-9 MeV/n. To achieve appropriate isotopic discrimination it becomes necessary to restrict the observation to particles with approximately parallel incidence to the sensor axis.

Table 1. lists selected events, abundance ratios in the 5-9 MeV/n energy range, energy spectral index in the 0.25-10 MeV energy range for electrons and below 30 MeV/n for ions. ^{3}He and ^{4}He spectral indexes have only been able to obtain in events with enough number of counts that guarantee a minimum quality in the spectrum.

2. Temporal profiles of particle fluxes

The electron temporal profiles exhibit diverse behaviours: while in events like the 1, 5 or 9, they present one only pick with a relatively slow exponential decay (of 12 hours to one day), others as 3, 6, and 8, the pick is of smaller intensity and its decay takes place of very quick form (less than 5 hours). Higher time resolution reveals structures with multiple spikes in events like the 7 or the 13 that present clear correlation with solar flares that are happened in chain. In some events as the 11 or 12, it is not possible to appreciate multiple spikes, but the existence of successive flares in very short lapse of time (event 11) or the presence of multiple spikes in the ion fluxes (event 12) they make think equally on multiple particle injections. Excepting the cases with no acceleration of protons (6 & 8), the proton and helium profiles present aspects in general qualitatively similar to each other.

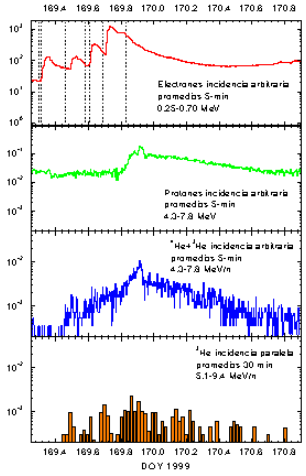

Fig. 1. Temporal profiles of particles during the June 18, 1999 ^{3}He-rich event.

3. Solar activity association

As it is usually in the impulsive events, almost all the studied events are presented accompanied by type III radio-bursts (excepting the event 2). For events with extremely short duration (3, 4, 6 & 8) it was not possible to associate them with solar flares. They have very high ^{3}He abundance, and low level of electron acceleration. Four events (5, 9, 12, and 13) they present a possible association to CMEs, although only in two of them (5 and 13) the speed overcomes the 500 km/s. In the event 13, the CME is presented accompanied by type II radio that suggests the existence of a coronal shock associated to the CME.

Some of the events seams not to be related to a flare (3, 4, 6, 8). Events 5 and 1 may have association with flares beyond the limb in 8537 and 8069 active regions respectively. Multiple spikes of event 7 seams to be associated to flare series in the active region 8582 that was very well magnetically connected with SOHO. The event 8 could be related with the active region 8656, again well-connected (W41). Event 9 seem to have their origin in the active region 8662 (W38). The poor connection of event 10 with the flares in N09E12, explains the drop intensity and slow decay. On the contrary, the high intensities give the events 12 and 13 they are possible thanks to a good magnetic connection (W43 for the 12, and W34 for the second pick gives the 13). Specially difficult it is to explain the propagation from the event 2 whose better candidate seems to be a flare in N19E54.

The event 11 presents a series of characteristic differentiated of the rest, highlighting by its long duration as well as the gradual shape of its temporal profiles. These characteristics can be explained by the association to multiple chained flares in short lapse of time originated in different active regions. Event

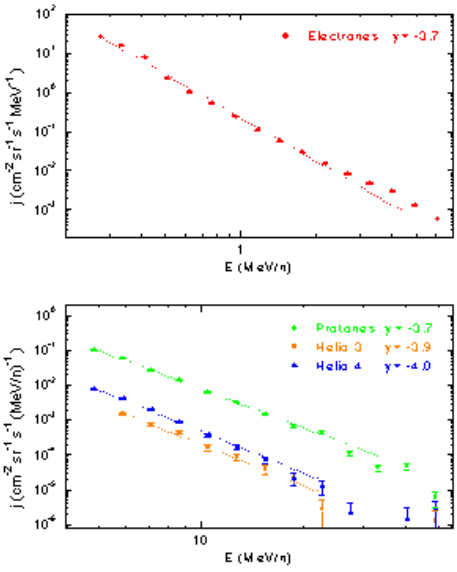

Fig. 2. Power law fit of the particle energy spectra during the May 23, 2000 event.

6 account immediately after a unusual low-density solar wind period.

The study of the interplanetary medium physical conditions have not allowed us to find any evident correlation among the properties of the solar wind and characteristics of the events. This gives us to think that the differences among events are consecuence of the acceleration conditions of the source region. Certain aspects like the temporal profile possibly also keep narrow relationship with the scattering of particles during the interplanetary transport, depending on the turbulence amount or short period oscillation in the solar wind not analysed in the present work.

4. Abundance ratios and Differential energy spectra

The ^{3}He/^{4}He ratio in the 5-9 MeV/n energy range vary from 0.04 to 16. Energy spectra of electrons, protons, ^{3}He and ^{4}He have been obtained. Power law fit to the spectra in the energy range 20-30 MeV/n for ions and 3-5 MeV for electrons provides satisfactory results for most of the events (Figure 2.) In general the ^{3}He spectrum is softer.

Acknowledgements

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References

1. Sierks, H. et al. 2001, Proc. 27th ICRC 3095-3098