Isotopic Composition and Spectral characteristics of impulsive solar energetic particle events

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1 Introduction

The SOHO spacecraft was launched on December 1995 and injected into a halo orbit around the inner Lagrangian point, L1, reaching its final destination, on February 1996. It is observing the Sun continuously from its privileged position outside of the Earth magnetosphere. Electron Proton Helium INstrument (EPHIN) forms part of the COSTEP (Müller-Mellin et al. [1]) experiment that studies the suprathermal

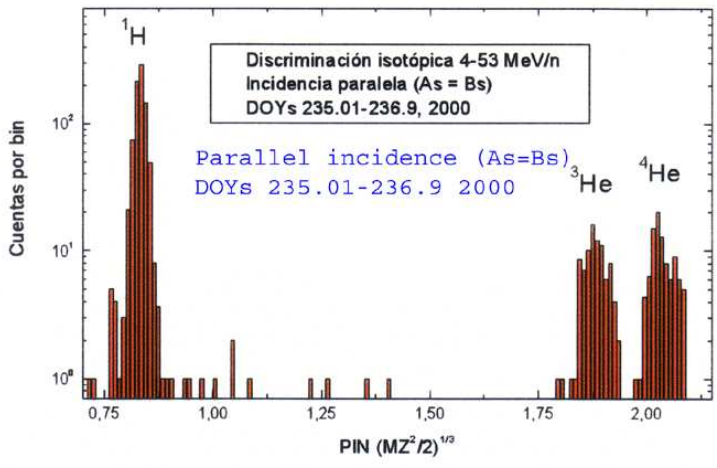

Figure 1: Isotopic discrimination obtained from August 22nd 2000 ^{3}He-rich event. Parallel incidence ring was on.

and energetic particle populations of solar, interplanetary, and galactic origin. SOHO

is a 3-axis stabilized spacecraft where the EPHIN sensor points to the nominal interplanetary magnetic field direction at 0.99 AU and 45° west of the spacecraft-Sun line.

EPHIN sensor is a stack of six cylindrical solid state detectors surrounded by a plastic scintillator acting as veto detector for background noise reduction. The two first thinner detectors are divided in six sectors to allow a rough trajectory determination and particle range corrections, which improve isotopic discrimination for light nuclei. The energy range for electrons is 0.150 to 10 MeV and for protons and Helium nuclei is 4.3 to 53 MeV/n. The EPHIN geometrical factor of 5.1 cm^2 sr can be reduced by a factor of 24 either automatically or by telecommand to allow high counting rates without significant dead time losses. A detailed description of the detector can be found in Müller-Mellin et al. [1].

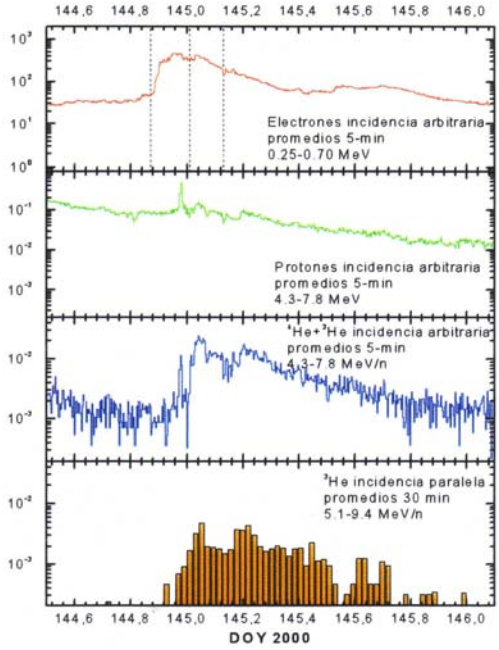

Figure 2: Differential flux registered by EPHIN during the May 23rd, 2000 event. Marks in the electron flux show the starting times of solar flares in X-rays.

2 Impulsive Solar Energetic Particle Events

Solar energetic particle events present temporal increases in the particle fluxes related with solar activity transient phenomena as flares or coronal mass ejections (CMEs).

Solar energetic particle events may be gradual or impulsive, with observational characteristics well discriminated [2].

Following the highly accepted paradigm, impulsive solar energetic particle events are characterized by short temporal scale and are due to solar flares, while for gradual solar energetic particle events is the shock wave coronal/interplanetary associated to a high velocity CME (source spatially spread and long time duration) the acceleration region of these events. Impulsive solar energetic particle events use to present ^{3}He isotope superabundance, with ^{3}He/^{4}He ratios that may exceed unity, many orders of magnitude higher than that typical of the corona and solar wind (^{3}He/^{4}He $\sim 10^{-3} - 10^{-4}$). Such enhancement might has its origin in resonance acceleration mechanisms that accelerate such isotopes preferentially[3].

3 Data analysis

Since SOHO launch in December 1995, EPHIN has registered solar energetic particle events with high ^{3}He abundances (^{3}He/^{4}He ratios higher than 0,01), while its study seems to be problematic due to the fact that these are short time duration events with moderates intensities and therefore these events are not good enough to acquire energetic spectra with high statistic quality. Figure 1 shows the isotopic discrimination corresponding to a rich ^{3}He event registered by EPHIN on August 22nd, (2000).

An analysis of 13 ^{3}He rich events observed by EPHIN is presented between August 1997 and August 2000. The differential energy spectra of electrons and ions have been analyzed, as well as the temporal profiles of they fluxes and the relative abundances of the H and He isotopes. The main results are summarized in Table 1. Figure 2 shows the temporal profiles of the particle fluxes during the May 23rd, 2000 event.

4 Interpretation and Conclusions

The ^{4}He/p ratio fluctuates between 0.004 and 0.3, where the lowest values correspond to events piled up over the fall phase of a previous gradual event. The ^{3}He/^{4}He ratio vary from 0.04 to 16, while it has been just selected those events with a clear ^{3}He enrichment. Moreover, any of these events show deuterium isotopes. The obtained spectra follow in good approximation power laws with spectral index between 2 and 5. Finally no significant acceleration has been found in the energy range over $\sim$ 30 MeV/n. The study of the correlations between solar events and solar activity phenomena has let to state that most of the solar events, unless event 2, appear associated to III-type radio bursts, while only four events appear related to CMEs. Nevertheless, the correlation with solar flares seems to be not very well established, because it has been found 5 impulsive events not related to any solar flares.

Event	^{4}He/p	^{3}He/^{4}He	γ(e)	γ(p)	γ(^{3}He)	γ(^{4}He)
August, 10 1997	0.27 ± 0.05	0.29 ± 0.09	3.1	2.9	-	2.8
Nov., 28 1997	0.16 ± 0.02	0.36 ± 0.07	3.2	2.4	3.2	2.4
March, 21 1999	0.13 ± 0.03	0.42 ± 0.16	2.4	2.9	5	3.1
March, 22 1999	0.04 ± 0.04	16 ± 16	1.9	3.7	-	-
May, 9 1999	0.0089 ± 0.0003	0.041 ± 0.007	3.6	2.8	-	3.2
May, 12 1999	0.0011 ± 0.003	1.9 ± 0.7	3.2	3.7	5.6	3.5
June, 18 1999	0.029 ± 0.002	0.38 ± 0.04	3.7	3.2	3.5	3.3
August, 7 1999	0.004 ± 0.003	7 ± 5	3.2	3.9	4.2	-
August, 14 1999	0.10 ± 0.01	0.23 ± 0.06	3.1	3.3	-	2.0
Nov., 1 1999	0.22 ± 0.09	0.9 ± 0.5	2.2	2.7	2.1	-
Dec., 24 1999	0.015 ± 0.002	0.68 ± 0.09	3.6	3.3	2.9	3.3
May, 23 2000	0.073 ± 0.003	0.31 ± 0.02	3.8	3.7	3.9	4.0
August, 22 2000	0.11 ± 0.02	1.5 ± 0.3	2.4	3.7	4.9	4.1

Table 1: Spectral features of analyzed events: Date, abundance ratios between 5-9 MeV/n and spectral index of the power law fit.

SOHO is a project of international cooperation between ESA and NASA. This work has been supported under BXX2000-0784 project and by the Junta de Comunidades de Castilla La Mancha under a postdoctoral grant to Raúl Gómez Herrero.

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