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The August 19, 2003 ^{3}He-rich event. Observations with EPHIN

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Analysis of the ^{3}He-rich event observed with SOHO/EPHIN on August 19, 2003 is presented. This high intensity ^{3}He event was associated with the active region 10431 located at S12W63 heliographic coordinates. The ^{3}He/^{4}He abundance ratio remained above 0.5 over nearly 48 hours during this event. Isotopic abundances of H and He during the event as well as the energy spectra in the 5-50 MeV/n energy range have been analyzed.

1. Introduction

Impulsive events are characterised by dramatic enhancements in ^{3}He/^{4}He ratios, which can reach values ~1 at energies ~1 MeV. These large ratios represent an enhancement of 10^{3}-10^{4} over coronal and solar wind values. ^{3}He-rich events are also characterised by enrichments in elements heavier than Fe [1]. The abundance enhancements can be explained by resonant wave-particle interactions at flare site [2], [3]. Impulsive events are associated with short duration (tens of minutes) soft X-ray bursts and type III and V radio bursts due to electrons moving through the corona [4]. Pure impulsive events are usually not accompanied by type II and IV radio bursts associated with coronal shocks [5]. In this work, a two-day-long ^{3}He-rich event observed by Electron proton Helium Instrument (EPHIN) on August 19, 2003 is studied..

2. Instrumentation

EPHIN forms part of the COSTEP [6] experiment that studies suprathermal and energetic particle populations of solar, interplanetary, and galactic origin. The instrument is located aboard the SOHO spacecraft, in a halo orbit centered at the inner Lagrange point, outside Earth's magnetosphere. EPHIN is a multi-element array of solid state detectors designed to detect Hydrogen and Helium isotopes in the energy range 4.3-53 MeV/n, and electrons in the energy range 0.25-10 MeV. The geometric factor is 5.1 cm^{2} sr, however, to obtain an adequate discrimination between ^{4}He and ^{3}He it is necessary to restrict to particles trajectories approximately parallel to the sensor axis. This restriction reduces the geometric factor to 1.02 cm^{2} sr, thus isotopic resolution is improved at the expense of statistical accuracy.

3. Observations and data analysis

At 7:55 UT on August 19, 2003, a M2.0 X-ray solar flare was observed by GOES satellites (Solar Geophysical Data). This flare with an importance 2B in Hα was located in the active region NOAA 10431 with heliographic coordinates S13W63, offering excellent magnetic connection with SOHO through the ideal interplanetary magnetic field lines for a solar wind speed of 400-500 km/s. At 8:16 UT, seven minutes after the end of the flare, EPHIN detected an increase of ~0.5 MeV electron flux. The onset for ~5 MeV protons, ^{4}He and ^{3}He was observed about two hours later, at ~10:12 UT. The maximum fluxes were reached at ~9:50 UT for 0.5 MeV electrons and at ~13:30 UT for 5 MeV/n ions. Subsequent C2.8 and C2.0 X-ray flares took place at 8:46 and 9:06, respectively. Another strong flare, classified as 2F in Hα and M2.7 in Xrays, was observed between 9:45 UT and 10:06 at S10W57 in the same active region NOAA 10431. This flare was followed by a ~500 km/s CME observed by SOHO/LASCO at 10:30 UT. At ~16:45 UT, six hours after the observation of this CME, a gradual increase of energetic ^{1}H, ^{3}He and ^{4}He from ~16:45 UT until ~23:50 UT, was observed. This increase was followed by a slow decay phase lasting more than 24 h. The temporal evolution of particle fluxes measured by the lower-energy channels of the EPHIN instrument during the entire event is shown in Figure 1(A)

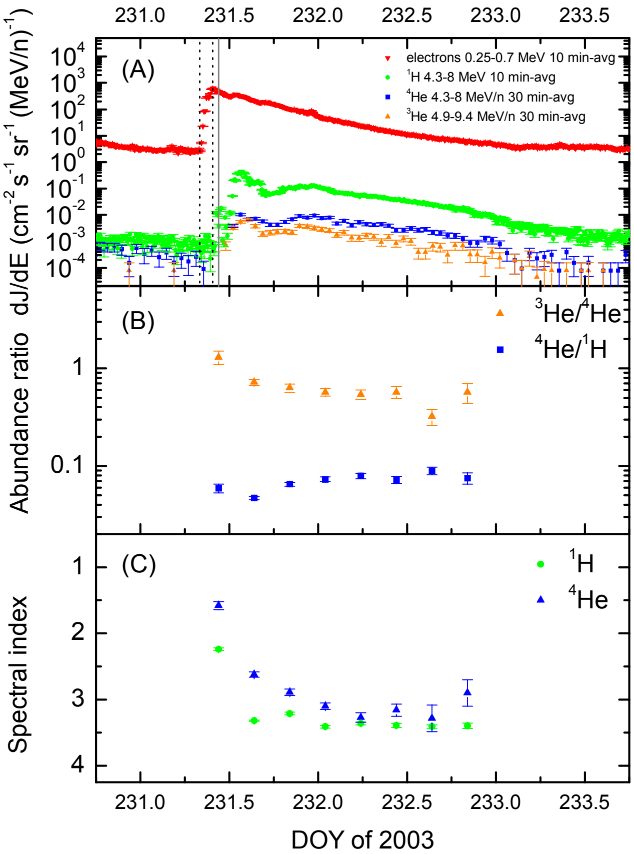

Figure 1. (A) Electron, proton, ^{3}He and ^{4}He differential fluxes measured by EPHIN during the August 19, 2003 event. Vertical dashed lines mark the occurrence of M2.0 and M2.7 X-ray flares at the Sun. Vertical solid line marks a ~500 km/s CME observed by SOHO/LASCO at 10:30 UT **(B)** Temporal evolution of ^{4}He/^{1}H and ^{3}He/^{4}He abundance ratios. **(C)** Temporal evolution of spectral indices obtained from power-law fits of ^{1}H and ^{4}He spectra.

Isotopic abundances

Pulse height analysed (PHA) data have been discriminated using a ΔE-E procedure in order to obtain isotopic abundances of hydrogen and helium nuclei. Figure 2 shows the isotopic separation of ^{3}He and ^{4}He obtained restricting to parallel incidence counts. ^{4}He/^{1}H and ^{3}He/^{4}He ratios calculated using these data are presented in Table 1. The abundance ratios obtained are similar to those typical of impulsive ^{3}He-rich events (^{4}He/^{1}H~0.1 and ^{3}He/^{4}He>0.1). The temporal evolution of these ratios in the energy range 5-25 MeV/n is shown in Figure 1 (B). The event is characterized by a maximum ^{3}He and ^{1}H abundance (relative to ^{4}He) during the first 7-8 hours, followed by a nearly invariable composition from 231.75 (18:00 UT) until the end of the event.

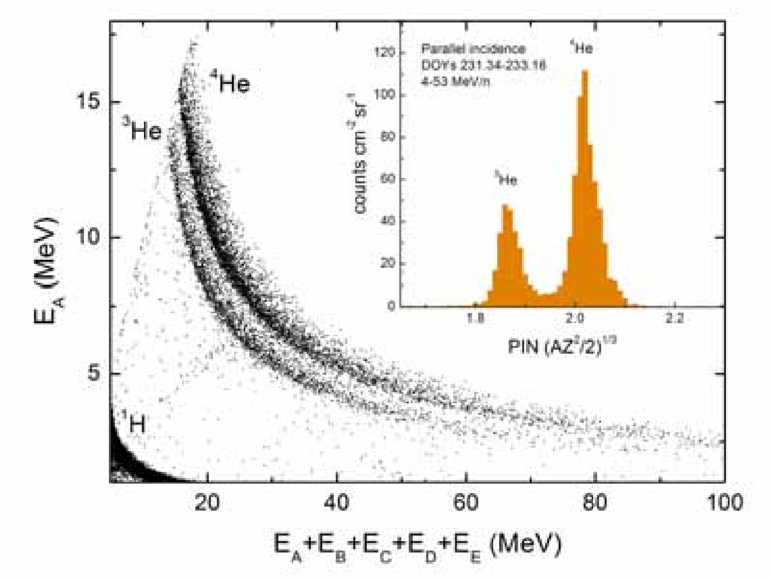

Figure 2. ΔE vs E plot for August 19, 2003 ^{3}He-rich event. In order to improve the isotopic discrimination, only parallel incidence counts has been selected. The insert shows the isotopic discrimination achieved for ^{3}He and ^{4}He.

Table 1. Event-averaged isotopic abundance ratios (5-25 MeV/n , parallel incidence)

^{4}He/^{1}H	0.063±0.001
^{3}He/^{4}He	0.64±0.03

Energy spectra

Using PHA data the differential energy spectra for ^{1}H, ^{3}He and ^{4}He have been obtained. Figure 3 shows the event-averaged spectra. Spectral indices obtained from power law fits of these spectra are shown in Table 2. With the aim of studying the temporal evolution of the spectral shape, individual spectra have been obtained every 4.8 h averaging period in the whole interval DOY 231.34-231.94. A power-law fit $dJ/dE = AE^{-\gamma}$ for every individual spectrum has been performed. Figure 1(C) shows the temporal evolution of the fitted parameter γ for ^{1}H and ^{4}He. The low values in the beginning of the event (γ (^{4}He) ~ 1.5 and γ (^{1}H) ~ 2.2) are due to velocity dispersion. The decay phase of the event is characterized by nearly invariant spectral shapes of ^{1}H and ^{4}He, with a similar value γ~3.2 for both isotopes.

4. Discussion and conclusions

The August 19, 2003 event starts with rapid increase in electron, proton, ^{3}He and ^{4}He fluxes well correlated with the occurrence of a M2.0 X-ray flare in the western hemisphere of the Sun, optimally connected with the location of SOHO. Electron fluxes are characterized by a fast increase to the absolute maximum flux, followed by a monotonous decay. ^{1}H, ^{3}He and ^{4}He temporal profiles show a secondary gradual increase, followed by a decay phase characterized by nearly constant spectral shape and composition. The relatively long duration of this impulsive event and these invariant features during the decay phase may be related to interplanetary reacceleration of previously accelerated ions [7], [8], [9] probably in a shock associated with the CME observed by LASCO at 10:30 UT.

Table 2. Event-averaged spectral indices for ^{1}H, ^{3}He and ^{4}He

^{1}H	3.24±0.02
^{3}He	2.95±0.06
^{4}He	2.84±0.05

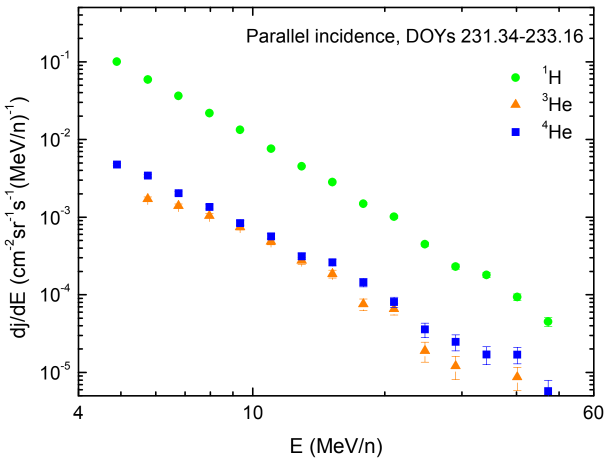

Figure 3. Event-averaged differential energy spectra of ^{1}H, ^{3}He and ^{4}He.

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