Anomalous ^{4}He observation with EPHIN on board SOHO during 1996 and 1997

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Abstract

The analysis of the ^{4}He spectrum during solar quiet time periods has demonstrated that the main source is of anomalous origin. It has been determined that this anomalous component reached similar levels to the observed ones during the 1976 solar minimum, revealing the importance of the solar polarity in the particle transport inside the heliosphere. Acceleration conditions of anomalous cosmic rays in the solar wind termination shock have been obtained.

1. Introduction

In 1972, near the final minimum of the 20 solar cycle, García-Muñoz, Mason and Simpson [3] observed an anomalous behaviour in the helium spectrum obtained by IMP5 satellite. This spectrum presented higher helium abundance than protons below 30 MeV/n. Such a behaviour could not be explained by the same models of modulation used to explain the observed protons spectrum. For this reason, it was assumed then the some kind of additional contribution existence that was called anomalous component of cosmic radiation or anomalous cosmic rays (ACR). Only some years later a similar behaviour was found in the spectrum of other ions like the N, O and Ne. All of them having high first ionization potential.

From the discovery of the ACR numerous hypothesis have been developed on their origin. The most accepted theory at the present time [Fisk], it supposes that the ACR ions have their origin in the interstellar medium atoms that penetrate easily in the heliosphere until near the Sun where they are ionized by solar photons or solar wind particles. This ions are conducted again with the solar wind until the heliosphere limits, being able to accelerate at the solar wind termination shock. [8]. Then re-enter in the heliosphere being detected near Earth. Experimental observations have demonstrated the existence in the heliosphere of pickup ions from interstellar and heliospheric origin that are seed population to

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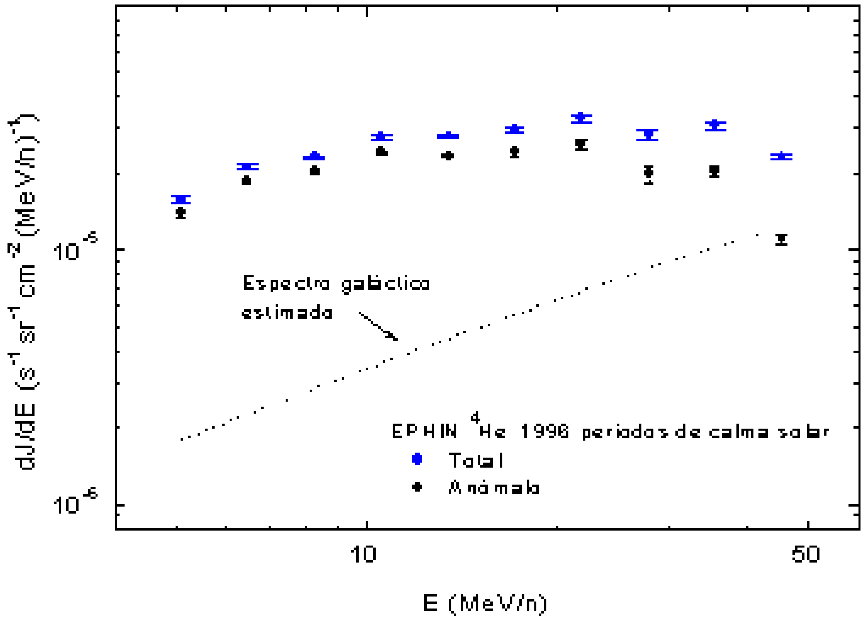

Fig. 1. ^{4}He spectrum from EPHIN. Galactic contribution calculation and anomalous obtained by substraction.

the ACR. Isotopic composition of ACR show that they are not generated by fragmentation process as galactic cosmic rays because of the absence of fragmentation products as ^{3}He, ^{15}N or ^{18}O [6] with an isotopic composition more similar to the solar system that those of the galactic cosmic rays. Most of the ACR are single ionized ions [1]. ACR are less sensitive to the heliospheric modulation because of their higher rigidity, but they are more sensitive to changes in modulation than galactic cosmic rays [4]. Actually, it is known that He, N, O, Ne, S, Mg, Si and Ar have been found in the ACR composition, but no observation of Ca, Ti, Cr, Fe and C has been found [9].

2. Galactic contribution of the ^{4}He

The ^{4}He energy spectrum shows its anomalous origin as main component. But it is necessary to estimate the galactic cosmic ray contribution. To carry out this estimation, it has been made use of obtained modulation potential with force-field model from the proton spectrum. We have used as interstellar spectrum of ^{4}He the Le Roux et al. [5] parametrization:

$$j(E) = \frac{0.38E^{0.52}}{(E + E_0/A)^{2.6}}\mathrm{m}^{-2}\mathrm{sr}^{-1}\mathrm{s}^{-1}(\mathrm{MeV/n})^{-1} \qquad (1)$$

where E is the kinetic energy in GeV/n and E_0 is the proton rest energy in GeV. In Fig., 1 is shown the galactic spectrum obtained by this method.

3. Anomalous ^{4}He energy spectrum

The ACR generation in the SWTS has been the topic of several works. It is generally assumed to be a diffusive acceleration process in a spherics shock where the ions are injected with an initial energy distribution corresponding to those of the ambient solar wind. At low energy, the diffusion mean free path into the shock: $\lambda_{diff} = \frac{k_{rr}}{v_{sw}}$ is much longer than the shock thickness and much shorter than its curvature radius r_s. The spectrum must follow a power law in the energy. At higher energies the shock curvature become important in comparison with the diffusion mean free path. The energy spectrum increase its spectral index changing from a power law to an exponential behaviour. Moraal and Steenberg [7] give the following parametrization:

$$j_{swts} = j_0 \left(\frac{E}{E_c}\right)^{-\frac{s+2}{2s-2}} \exp\left\{-(-0.083\gamma + 0.272)\left(\frac{E}{E_c}\right)^{0.689\gamma+1.34}\right\} \qquad (2)$$

with γ the exponent of the radial diffusion mean free path as function of the rigidity and s is the compression ratio of the SWTS. Fig. 2 shows the anomalous 4He energy spectra dependence on the Moraal and Steenberg model. Dashed line is the spectrum obtained by Cummings and Stone in 1996 [1].

Acknowledgements

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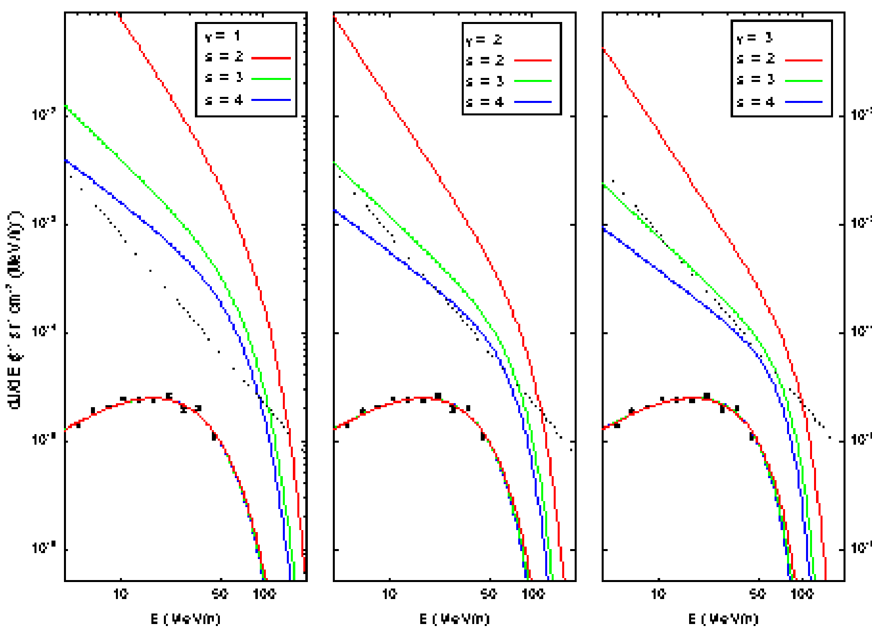

Fig. 2. $^{4}He^{+}$ anomalous fit using force-field model with several physical parameters γ and s. Dashed line is the SWTS spectrum obtained by Cummings and Stone in 1996[]