Heliospheric Modulation Potential from SOHO/EPHIN Observations of Protons

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Abstract

We summarize observations of energetic H and He isotopes measured by EPHIN/SOHO instrument during 1996-97 solar minimum. Modulated Anomalous and Galactic Cosmic Ray fluxes reach maximum values during this period, showing a simultaneous absolute maximum around September 1997. Using the force-field approximation to fit proton spectrum, we obtain a modulation potential of ∼544 MV for 1996 quiet time periods.

1. Instrumentation

This work is based on data from the Electron Proton Helium INstrument (EPHIN) [6] aboard SOHO spacecraft. EPHIN is a stack of six silicon detectors surrounded by a plastic scintillator acting as veto detector for background noise reduction. It detects protons and helium nuclei from 4 to 53 MeV/n and electrons from 150 keV to 10 MeV. Geometric factor is 5,1 cm^2sr, and the sensor aperture points in the nominal direction of interplanetary magnetic field at 1 AU, 45° west of the spacecraft-Sun line.

2. Observations and data analysis

2.1. Modulation evolution during 1996-2000

Left panel on Fig. 1 shows proton fluxes measured by EPHIN from 1996 to 2000. The progression of solar activity during the rising phase of solar cycle 23th is more obvious in the lower energy channels P4 (4,3-7,8 MeV) and P8 (7,8-25 MeV), increasingly dominated by Solar Energetic Particle (SEP) Events contribution. Background flux level in channel P25+41 (25-53 MeV), provides a good representation of galactic cosmic ray (GCR) proton flux evolution parallel to this increase in solar activity. Modulation level of GCR remains near minimum value during 1996 and 1997, and then begins a progressive increase, showing a

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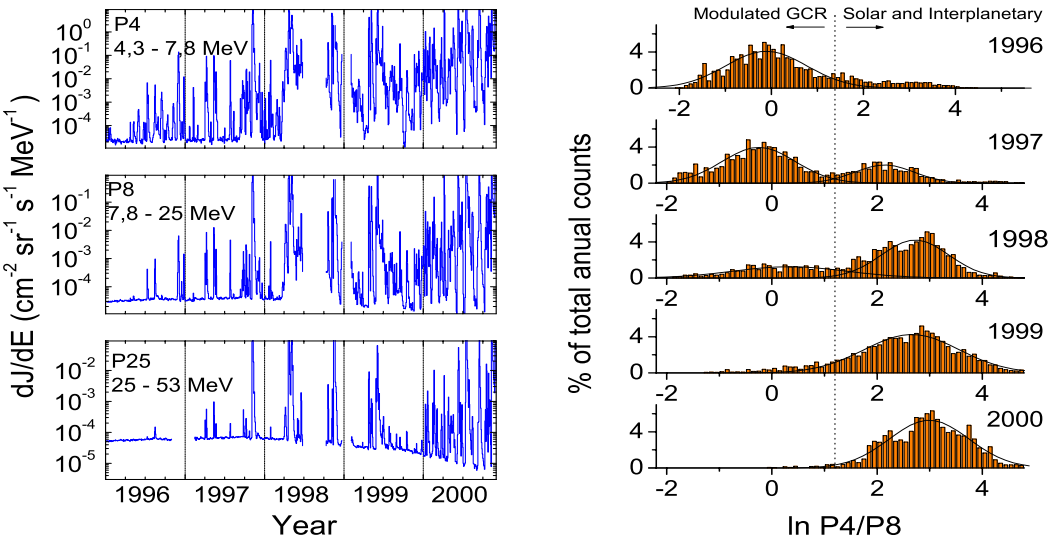

Fig. 1. Left: differential fluxes during 1996-2000 measured by EPHIN proton channels. Right: distributions of spectral parameter ln P4/P8 during 1996-2000.

plateau profile typical of qA>0 solar minima. Histograms on right panel of Fig. 1 show the temporal evolution of distributions of ln P4/P8 during 1996-2000. This parameter provides a rough characterization of spectral slope around 10 MeV, showing the progressive change from GCR-dominated to SEP-dominated fluxes due to growing solar activity and modulation during the rising phase of solar cycle 23.

In May 1996, smoothed monthly mean sunspot number reached a minimum value [8], this sunspot minimum marks the "official" beginning of 23rd solar cycle. In order to study the modulation evolution near solar minimum conditions, Fig. 2 shows two-day averaged particle fluxes from January 1996 to March 1998. Thick line represents a smoothed 13-day averaged flux where counts satisfying P4/P8>1,65 have been eliminated. This criterion excludes most of time periods with significant solar or interplanetary contribution. 25-53 MeV ^{1}H, 25-53 MeV/n ^{4}He, and high energy (>50 MeV/n) particle fluxes shows similar evolution, characterized by a transitory maximum between days 150-300 1996, followed by a definitive maximum around September 1997, more than one year after solar minimum. This maximum is reached simultaneously in all channels, there is not significant delay between GCR (dominant contribution for >25 MeV protons) and Anomalous Cosmic Rays (ACR) (dominant contribution for 7,8-25 MeV/n ^{4}He)

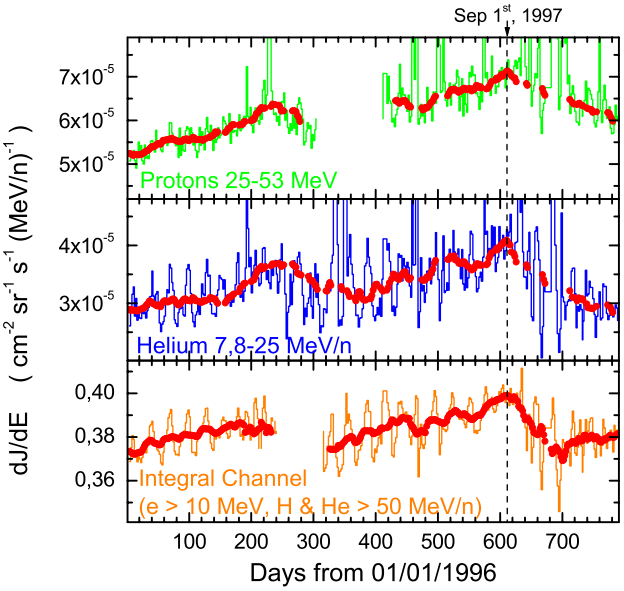

Fig. 2. Two-day averaged EPHIN particle fluxes from January 1996 to March 1998.

Table 1. Force-field modulation potential obtained using different LIS spectra to fit the modulated proton spectrum observed by EPHIN during 1996 quiet time periods

LIS Proton spectrum	ϕ(MV)
Webber et al. (1987) [7]	538 ± 7
Le Roux and Ptuskin(1995) [4]	518 ± 7
Gaisser et al. (1999) [1]	544 ± 7
Menn et al. (2000) [5]	574 ± 6
Gaisser et al. (2001) [2]	586 ± 6

2.2. Modulation potential during 1996 quiet time periods

Fig. 3(A) shows energy spectra of H and He isotopes determined by analysis of EPHIN pulse height data, using a sample of 217 days corresponding to 1996 quiet time periods. ^{1}H, ^{2}H, and ^{3}He spectra show a nearly-linear dependence in kinetic energy, typical of low-energy modulated GCR. ^{4}He spectrum is dominated by ACR contribution below ∼50 MeV/n, showing a flat profile, with maximum around ∼20 MeV/n. In spite of low energy interval covered by EPHIN, proton spectrum can be reasonably fitted using force-field modulation model [3]. Modulation potential obtained varies between 530-590 depending on Local Interstellar (LIS) spectrum used as input (Table 1). Fig. 3(B) shows a force-field fit of observed proton spectrum.

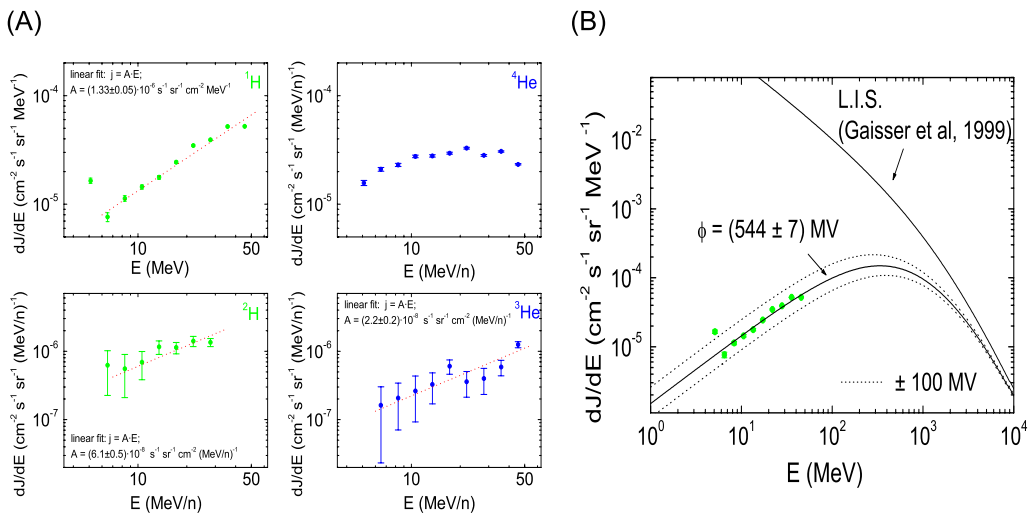

Fig. 3. (A) Energy spectra of H and He isotopes during 1996 quiet time periods. (B) Force field fit of proton spectrum

3. Conclusions

EPHIN observation of H and He isotopes shows that modulated ACR and GCR fluxes reach maximum values during 1996-97. Both populations exhibit similar temporal behaviour, with an absolute maximum flux around September 1997, followed by a progressive decrease correlated with increasing solar activity. Using the force-field approximation to fit 1996 quiet time proton spectrum, a modulation potential of ∼544 MV has been obtained.

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4. References

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