Efficiency for RSP Acceleration in the 14.07.2000 and 15.04.2001 Events

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Abstract

The interpretation of relativistic solar proton (RSP) spectra obtained during GLEs of present solar cycle has been carried out on basis to two different particle populations, a prompt (PC) and a delayed component (DC). We derive the acceleration parameters of the DC for the 14.07.2000 and 15.04.2001 events from a stochastic process.

1. Introduction

The worldwide neutron monitor (NM) network is generally used as a unit multidirectional instrument to study RSP, that under adequate modeling techniques, the parameters of the primary RSP in the interplanetary space may be derived, as in the case of the 14.07.2000 and the 15.04.2001 derived [1–3]: dynamical changes of the spectrum, pitch-angle distributions (PAD) and anisotropy in succesive moments of time that together with their time profile reveals the existence of two distinct RSP populations, a prompt component (PC) characterized by an impulse-like intensity increase, rigid spectrum and high anisotropy, followed by a delayed component (DC) presenting a gradual increase, soft spectrum and low anisotropy. As shown in [3] spectra at the early stage of the events are very hard, just at the time when the PAD in both events are the most narrow. As the PAD widen with time the spectra becomes softer. The observational spectra as derived in [3] are shown in Fig. 1 for the Bastille-day event: at the initial time, the spectrum shows a very peculiar exponential energy dependence, but by 11:05 UT the spectral shape changes radically and rest without drastic changes up to 12:30 UT when high energy portion has a fast intensity drop. A similar, behavior occurs in the 15.04.2001 event [3]. For the interpretation of this phenomenon a two-source scenario has been developed in a series of works (e.g. [4–7]) that reproduces the PC observational spectra of the 23.2.1956, 7.12.1982, 16.2.1984 events [6] and the DC spectra of the 29.09.89 and 22.10.89 events [7]. Here we

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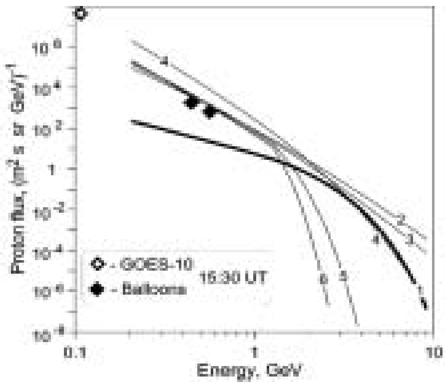

Fig. 1. NM data of the 14.07.2000 at 6 times, the thick line corresponds to the PC,[3]

attempt to substantiate the production of RSP of the DC for the two events of the present solar cycle on basis to stochastic acceleration by the fast MHD mode.

2. Scenario with turbulent acceleration in sources of the DC

The model developed in (eg. [4–7]) assumes that the DC is produced during the impulsive phase in the flare body, within an expanding closed magnetic structure in the low corona where the bulk of particles are stochastically accelerated. This population is injected into the interplanetary space as a consequence of an opening of the closed structure due to plasma instabilities, or because they are carried off by an arising CME. The so called PC is produced afterward in an anisotropic source located in a region of open field lines, allowing particles to drift azimuthally and reach the earth before the bulk of the DC. The acceleration of the PC is attributed to impulsive electric fields generated in a reconnection process in magnetic structures of opposite polarity, e.g, the trailing part of coronal transients, or in the neutral current sheet formed when a flare expanding structure get in touch with lines of opposite polarity from neighboring loops, arcades or new emerging magnetic fluxes. A synthesis of recent observations and theoretical concepts of particle acceleration in flares [8] shows that present high-precision timing measurements combined with high-resolution imaging of flares provide the required physical parameters to conduct quantitative data analysis on acceleration kinematics of SRP. This new information imposes several constraints on the time-dependent location and geometry of acceleration regions, limiting the role of speculative models. According to [8] most of flare events are associated with magnetic reconnection between open-closed and closed-closed field lines. The geometry of acceleration regions inferred from magnetic topology constraints is illustrated on Fig 7 in [8], where two distinct acceleration regions in the flare body can be appreciated, one of which in some cases is associated with open magnetic

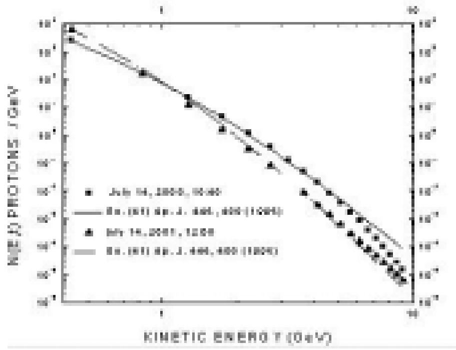

Fig. 2. Fitting of the DC of the 14.07.2000 event with stochastic acceleration

field lines, as in the case of the14.07.2000 flare,(schematized in Fig. 46 of [8]). Therefore, the scenario worked out in [4–7] cannot be ruled out in the light of modern observations, but on the contrary it seems to be reinforced. The observational evidences of the opening of field lines in the evolution process of magnetic reconnection in closed-open structures supports the origin of the PC as proposed in the two source model. Related with the DC let us remind that acceleration by wave-particle scattering invokes several kind of turbulent waves. Due to mass motions, magnetic reconnection and instabilities of macroscopic magnetized systems in flares, the presence of fast MHD turbulence seems highly probable. The relative efficiency for turbulent acceleration among different wave modes has been studied in [11–14]. Results are sumarized in Tables 1–2 in [4]. The study of acceleration efficiencies shows that acceleration by short wave turbulence (Bernstein modes) may be higher than other longitudinal waves (as Langmuir turbulence), representing a promising acceleration process in the non-relativistic particle domain [12] but not for RSP. The low magnetosonic mode of MHD turbulence may be an interesting option to accelerate particles from the thermal background at chromospheric levels [11], but in the colonal plasma requires of a continuous source of turbulence at a rate $\geq 10^3 erg/cm^3$. Acceleretaion by the Alfven MHD mode, requires initial velocities higher than the local hydromagnetic velocity. The fast MHD mode, can accelerate protons up to energies higher than $1GeV$ in a time $t < 1s$ [13, 14]. However, the number of accalerated protons is many orders of magnitude smaller than the observational one. To reproduce the observed amount of accelerated particles, it must be assumed an injection to the process with a supra-alifvenic energy E_o.

3. Results and conclusions

To fit the observational data we use the time-dependent spectrum given by Eq. (41) in [10]. Results are displayed in Figs. 2–3, where the acceleration

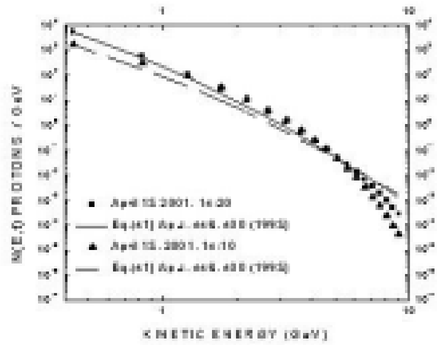

Fig. 3. Fitting of the DC of the 15.04.2001 event with stochastic acceleration.

parameters for the 14.07.2000 event are: $\alpha = 0.1/s$, $\tau = 0.5$ s, $t = 0.1$ s, $E_o =$ 1 MeV at 10:40 UT (squares), and $\alpha = 0.062/s$, $\tau = 0.5$ s, $t = 1.0$ s, $E_o =$ 1 MeV at 12:00 UT (triangles). For the 15.04.2001 event the obtained acceleration parameters: $\alpha = 0.095/s$, $\tau = 0.7$ s, $t = 0.3$ s, $E_o = 1$ MeV at 14:10 UT (squares), and $\alpha = 0.085/s$, $\tau = 0.1$ s, $t = 0.1$ s, $E_o = 1$ MeV at 14:20 UT (triangles): Energy spectra of the PC in RPS events can be reproduced by an spectrum from Neutral Current Sheet acceleration [4–6]. Here, we reproduce the spectra of the DC and found that the parameters for the accelelation efiiciency are within the expected values in the coronal flare. Hence, we claim that the DC population is produced in an stochastic procces.

4. Reference

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