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The event of 21 June 1980 and the origin of solar cosmic rays

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RESUMEN

A partir de las observaciones de una perturbación en el medio interplanetario, se discuten dos posibles fuentes de rayos cósmicos solares: los más energéticos son generados en el propio proceso de origen del destello en Hα asociado a la perturbación, los de menor energía son generados en el frente de onda de la perturbación. Se hace un estimado de la distancia en que se produce la activación del mecanismo de generación en el frente de onda.

PALABRAS CLAVE: Actividad solar, aceleración de partículas.

ABSTRACT

We present well-observed interplanetary disturbances in the near Earth environment and discuss their behavior. From these observations a hypothetical two source origin of Solar Cosmic Rays is discussed. The hypothesis proposes that high-energy particles are generated by flare process and that low energy particles are generated at the interplanetary disturbance shock. An estimate of the distance for shock activation is presented.

KEY WORDS: Solar activity, particle acceleration.

INTRODUCTION

The origin of Solar Cosmic Rays (SCR) is not a solved problem. Gosling (1993) puts the subject in terms of a flare vs. coronal mass ejection (CME) controversy.

Geomagnetic disturbances have been assumed to be driven by a flare which generates SCR, and a shock which produces a geomagnetic storm when impacting the magnetosphere (Cane 1997). The existence of the shock was inferred from type II radio bursts frequently accompanying the flare, while the type IV radio burst was considered to be the piston driving the shock.

However, after the Solar Maximum Mission, a relation between the flare and the CME was blurred out (Gosling 1997). Flares as the main particle accelerating process for energetic particles to space lost credibility, and CME gained in importance as a probable source of energetic particles in space.

In this paper we discuss the interplanetary disturbance of June 21, 1980 in the near Earth environment. A hypothetical two source origin of SCR is discussed. We propose that high-energy particles are generated by the flare and that low-energy particles are generated at the interplanetary disturbance shock. An estimate of the distance for shock activation is presented.

RESULTS AND DISCUSSION

The data was obtained from OMNIWeb database accessed from http: //nssdc/gsfc/nasa.gov/. It includes proton fluxes in energies >1, >2, >4, >10, >30 and >60 MeV, plasma temperature, ion density and flow speed. The perturbations measured in the near Earth environment are associated to a flare of importance 2N on June 21, 1980 at 00h 03m UT in Hale Plague Region No. 16918 (SGD 459, II, 1982).

The abrupt increase in the proton flux with energies >30 MeV is seen on Figure 1. An increase of the flux is barely noted in the >4 MeV band (Figure 2). This reinforcement of the proton flux occurs almost at the same time of the flare, and does not show a noticeable displacement of the maximum with the energy of the particles. The maxima approximately coincide in the >4Mev to >60MeV bands.

On the other hand, in Figure 2, we see another maximum on June 24 coinciding with the arrival to the near Earth environment of an interplanetary disturbance and a shock front (Figure 3). There is no time displacement of the maximum with the energy band of the particle observation.

Consider the spectra of the maximum on June 21, the maximum on June 24, and a point on June 23 before the June 24 maximum (showed by an arrow in Figure 2). These spectra are shown in Figure 5. The difference between the

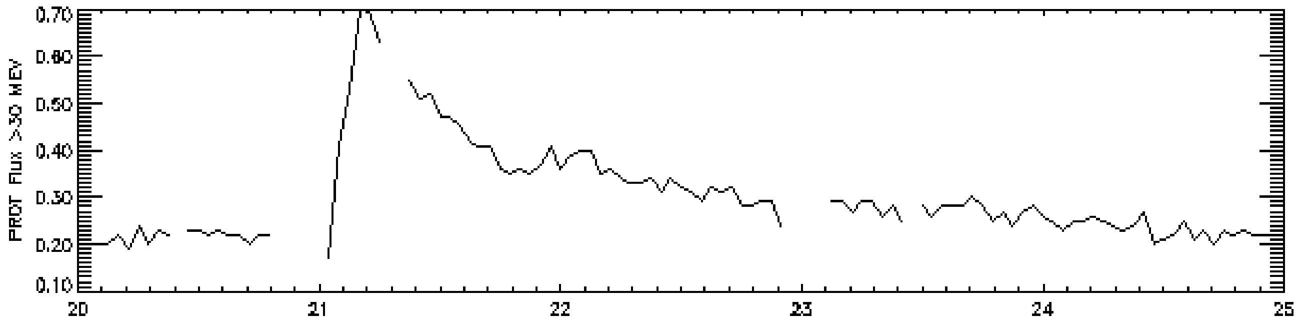

Fig.1 Proton flux for energies greater than 30 MeV. The x-axis is referred to time in days in June, the y-axis is referred to proton fluxes in cm^{-2} s^{-1} $steradian^{-1}$.

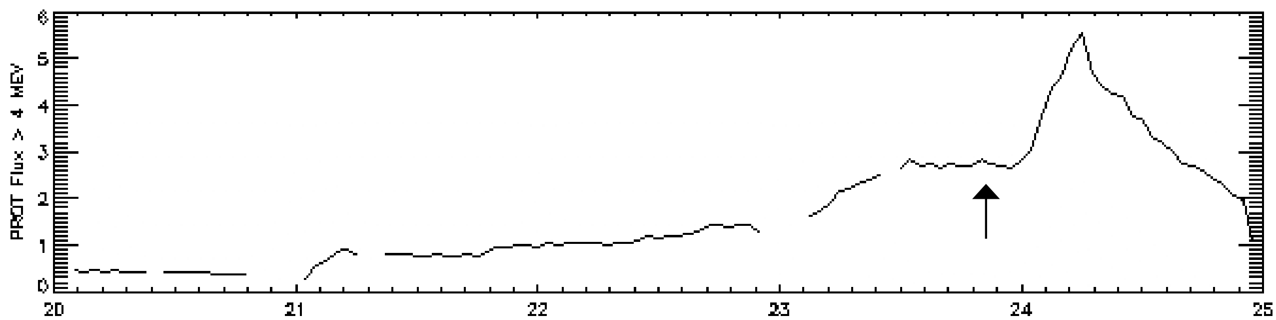

Fig.2 Proton flux for energies greater than 4 MeV. The x-axis is referred to time in days in June, the y-axis is referred to proton fluxes in cm^{-2} s^{-1} $steradian^{-1}$. The arrow points to a non-related to maximum moment used to calculate the spectra.

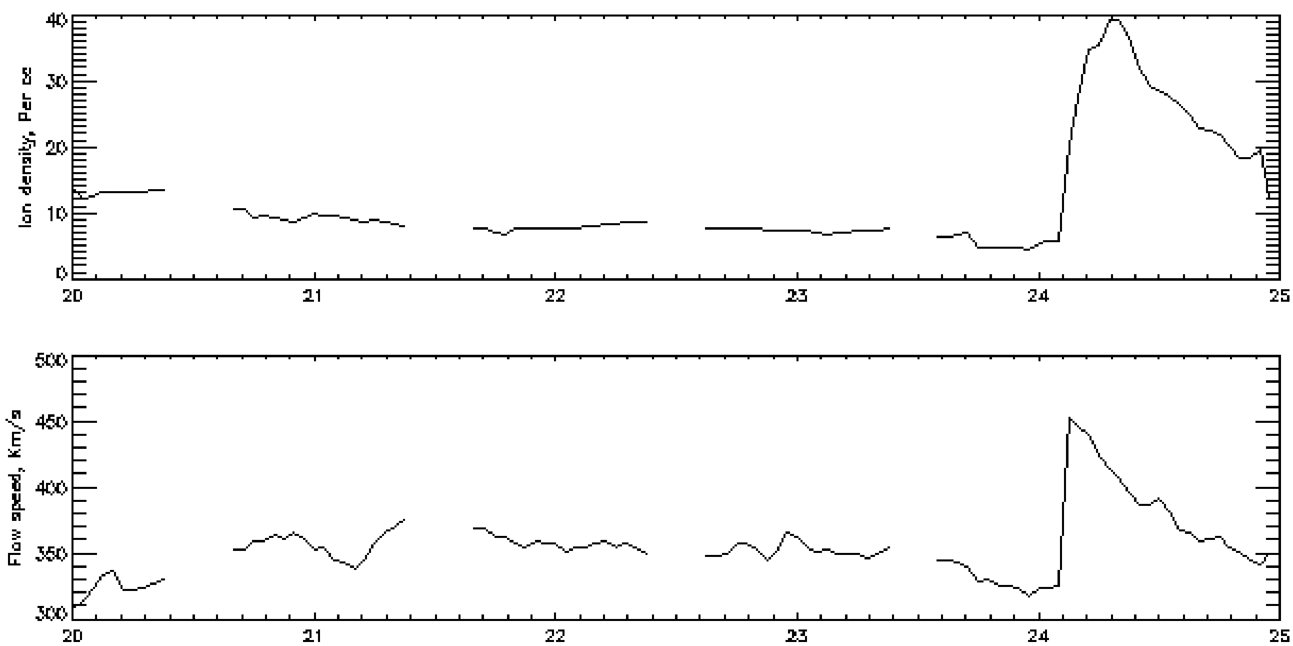

Fig. 3 Ion density and flux speed of the interplanetary medium in the near Earth environment. The x-axis is referred to time in days in June. Notice the increase of both ion density and flux speed on day 24 pointing to the presence of a shock front.

spectra of the maxima on June 21 and June 24 is obvious. The flare-associated spectrum is almost flat, and the associated shock is a decreasing one.

The flare-associated maximum has a sudden commencement and appears to be generated by a mechanism that accelerates particles in the high-energy band only. This result points to an accelerating mechanism operating in an energy band near 10 MeV. No significant amounts of accelerated protons are found in the low energy bands, which should have provided a displacement of the time of the maximum at lower energies.

In the low-energy band, on the other hand, the proton flux profiles are increasing slowly until the shock-associated peak is registered on June 24. A plateau lasting from about 10 hours (on >4 MeV) to 3 hours (on >1MeV) is also noticed. The pre-shock spectrum is related to this feature. Note that the ratio of the plateau fluxes to the corresponding shock-associated maximum increases with the energy of the protons (Figure 4). If diffusive shock acceleration is the mechanism generating a particle trapping region (Lee 1983), this increase of the protons may be interpreted as a measure of the shock capability to trap protons in different energy ranges (Reames 1997). Thus the population of low-energy particles arriving with the shock is much more significant for the less energetic particles.

The more pronounced increase of proton flux in the pre-shock solar interplanetary medium for high-energy protons might be interpreted as generated by escaped particles.

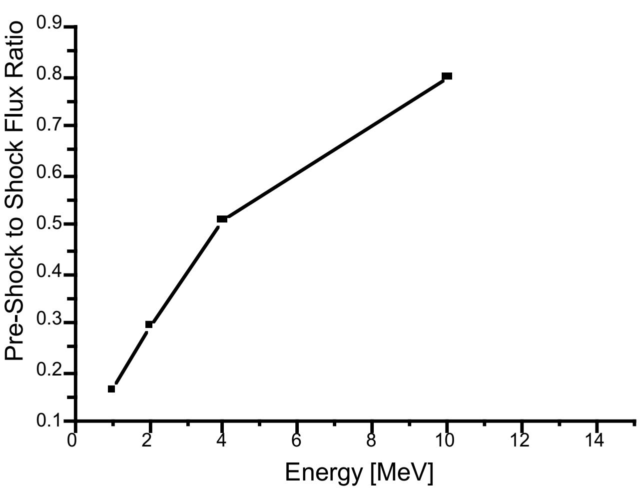

Fig. 4 Behavior of the ratio of the "plateau" fluxes to the corresponding shock-associated maximum. Notice the increases with the energy of the protons.

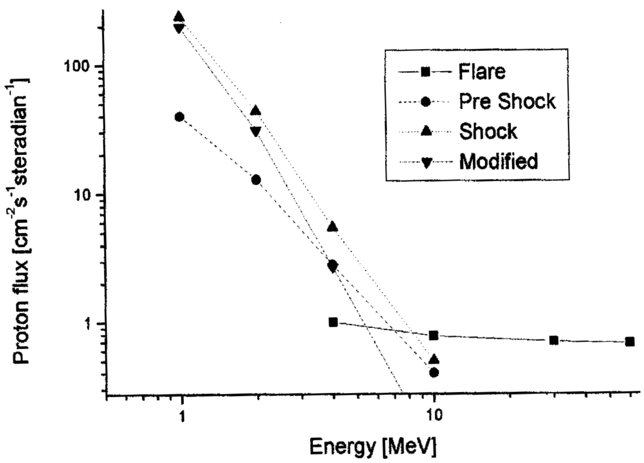

Fig. 5. The proton flux spectra for the moments associated to the maximum on June 21 (indicated as flare in the figure), the maximum on June 24 (indicated as shock in the figure), and the point on June 23 before the June 24 maximum (indicated as pre shock in the figure) are shown. A modified spectrum of the shock-associated maximum calculated as the value of the flux of the maximum on June 24 minus the flux level on June 23 before the June 24 maximum is show too (as modified in figure).

In the high-energy band, the profile of the proton flux after the flare-associated maximum decreases until 21h UT on June 21, when a reinforcement of the proton flux is noticeable on the >30 and >60 MeV bands. In the >10 MeV band the flux is almost steady until the arrival of the shock, and it decreases afterwards. If these reinforcements are due to the arrival of protons produced by the shock we may estimate the distance at which the shock begins to act efficiently as proton accelerator. Assuming that the CME moves at approximately 450 km/s, and that the time lag between the flare peak and the slope change in the proton flux decay is of approximate 24 hours, the distance at which the shock ignites is 39 x 10^6 km, or about 56 solar radii.

CONCLUSIONS

In previous works we have suggested a two-source proton acceleration process (Rodríguez *et al*. 1998). The event of June 21 supports a qualitative interpretation based on a two-source model for SCR. In the present model, the high-energy SCR (>10 MeV) are generated mainly in the flare process, while the low-energy protons are generated in the interplanetary disturbance shock. An estimate of the distance where the "shock mechanism" ignites is provided.

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