PROTONS ASSOCIATED WITH CENTRES OF SOLAR ACTIVITY AND THEIR PROPAGATION IN INTERPLANETARY MAGNETIC-FIELD REGIONS CO-ROTATING WITH THE SUN*

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ABSTRACT

The Pioneer-6 and Pioneer-7 space probes carried charged-particle telescopes which measure, for the first time, both the direction of arrival and differential energy spectra of protons and alpha particles. The intensity changes, directional distributions and energy spectra of proton fluxes associated with solar activity are investigated. The data were obtained in the beginning of the new solar cycle (no. 20), when it is possible to unambiguously associate proton-flux increases with specific solar active regions. The origin, possibly long-term storage, and propagation of these proton fluxes are investigated. It was observed that enhanced 0·6–13 MeV proton fluxes associated with specific active regions were present over heliographic longitude ranges as great as $\sim 180°$. These enhanced fluxes exhibit definite onsets and cut-offs which appear to be associated with the magnetic-sector boundaries observed by Ness on Pioneer-6. Discrete flare-produced intensity increases extending in energy to more than 50 MeV are observed, superposed on the enhanced flux. These increases displayed short transit times and short rise times. Both the enhanced and flare-produced fluxes propagate along the spiral interplanetary magnetic field from the Western hemisphere of the Sun. From these observations we are led to a model in which the magnetic fields from the active region are spread out over a longitude range of 100–180° in the solar corona. The existence of strong unidirectional anisotropies in the initial phases of flare-proton events implies that little scattering occurs between the Sun and spacecraft. However, the gradual approach to an isotropic flux at late times indicates that the decay phase is controlled by the interplanetary magnetic field.

DISCUSSION

Acton: Have you been able to decide where these low-energy protons are accelerated? Is it in the chromosphere, corona, or in interplanetary space?

Pick: The association of solar active regions with enhanced proton fluxes at low energies is a strong evidence for the solar origin (chromosphere or corona) of these protons. By another way, their energy spectrum is similar to solar flare-proton spectra.

Noyes: It was my understanding that there was no obvious solar activity associated with the proton-emitting region in December 1963. Was, in fact, some related activity detected?

Pick: This problem is not resolved. It is very difficult to know near the solar minimum cycle if there is a correlation between active regions and proton-flux enhancements. In December 1963, the situation was confused but we cannot say that there was no related solar activity.

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Kiepenheuer (ed.), Structure and Development of Solar Active Regions, 403.