LATITUDE DEPENDENCE OF CO-ROTATING SHOCK ACCELERATION

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ABSTRACT

We briefly discuss energetic particle observations in the outer heliosphere ($\gtrsim$12 A.U.) by the LECP instruments on the Voyager 1 and Voyager 2 spacecraft that show a definite latitude dependence of the number and intensity of particle enhancements produced by co-rotating interplanetary regions during an interval when no solar energetic particle events were observed. The particle enhancements are fewer in number and less intense at higher (~20°) heliolatitudes. However, the similar spectral shapes of the accelerated particles at the two spacecraft indicate that the acceleration process is the same at the two latitudes, but less intense at the higher latitude.

1. Introduction. Particles accelerated in various regions of the heliosphere -- e.g., planetary bow shocks and magnetospheres, interplanetary traveling shocks, co-rotating interaction regions -- have been studied extensively near Earth (1 A.U.) [e.g., review by Gloeckler, 1984]. The progression of the two Voyager spacecraft deep into the outer heliosphere, beyond the orbit of Saturn, at nearly the same heliolongitude provides the opportunity to study interplanetary shock acceleration processes in the outer heliosphere as well as to search for heliolatitude dependences of the acceleration processes.

This brief note presents the results of some initial analyses of Voyager data during the period when the Voyager 1 (V1) spacecraft was at high heliolatitudes. The data used are from the Low Energy Charged Particle (LECP) instrument flown on both Voyager spacecraft [Krimigis et al., 1967]. Ion and proton data from selected sub-systems of the instrument are used.

2. Observations. Plotted in Figure 1 are the daily average fluxes of low energy ions and higher energy protons for the interval 1981 to mid-1984. The higher energy fluxes shown provide information on the occurrences of solar energetic particle events. The lower energy fluxes provide information on the occurrences of co-rotating interplanetary regions which can accelerate particles. The enhanced co-rotating particle fluxes are seen to occur sporadically at each spacecraft.

While there are a number of interesting intervals in the data (see Gold et al., 1985 for discussions of other aspects of these data), we concentrate specifically on the ~200 days of data between day 243, 1983, and day 75, 1984. During this interval of 1983-84 the two Voyager spacecraft were at approximately the same heliolongitude, with Voyager 1 increasing in heliolatitude from ~20.5 to ~22.5° and in distance from ~17.2 to ~19 A.U. while Voyager 2 remained approximately in

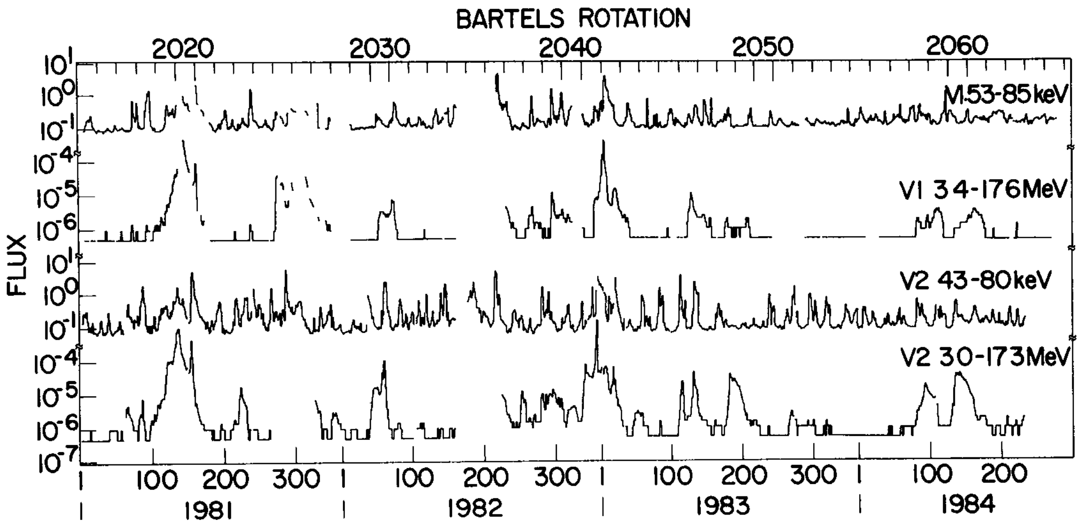

Fig. 1 Plot of daily average fluxes in ion and proton channels from LECP experiment on Voyager 1 and Voyager 2 spacecraft, 1981 to mid-1984.

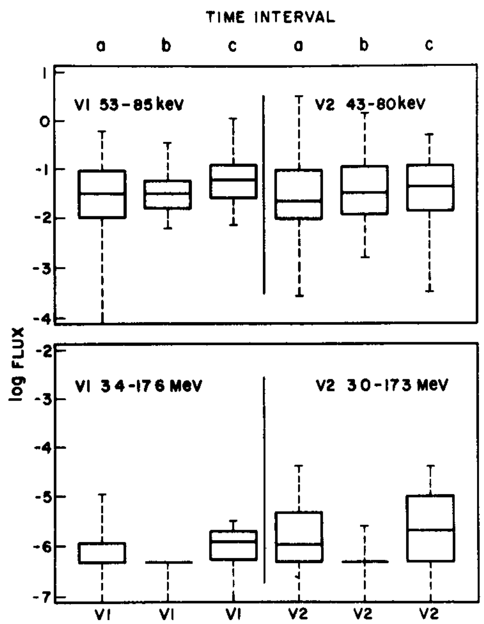

Fig. 2 Statistical distributions (represented as box plots) of fluxes in ion and proton channels on the two Voyager spacecraft for three time intervals. The interval (b) corresponds to day 243, 1983, to day 75, 1984. Intervals (a) and (c) correspond to a 200 day period preceding and a 150 day period following interval (b).

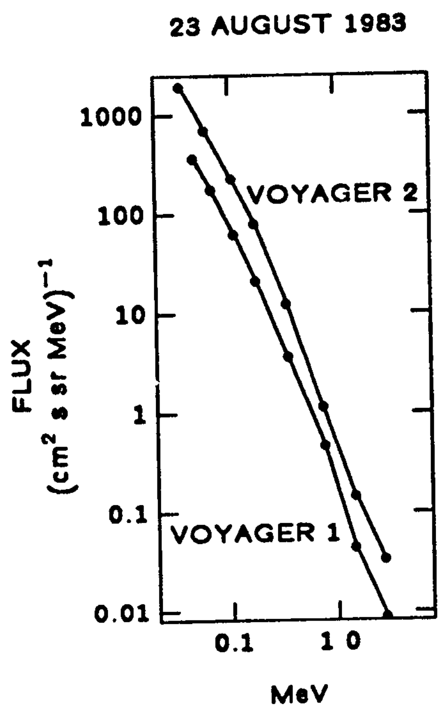

Fig. 3 Daily average ion spectra from Voyager 1 and Voyager 2 on day 235, 1983.

the ecliptic plane, moving from ~12.3 to 13.7 A.U. Within this time interval essentially no enhancements indicative of transient solar particle events were seen in the 3.4-17.6 MeV proton fluxes on Voyager 1. Voyager 2, in the ecliptic plane, observed some proton activity at about day 270, but in general the activity of the higher energy protons during this interval was considerably suppressed compared to that before and after.

In contrast to the higher energy protons, the low energy ion fluxes are enhanced sporadically throughout the interval of interest. The enhancements, produced by co-rotating interplanetary interaction (shock) regions, are less numerous and less intense at Voyager 1 (Figure 1).

The distinction between the ion and proton fluxes for time intervals before and after the interval of special interest (i.e., day 243, 1983 to day 75, 1984) is illustrated by the statistical box plots of Figure 2. The intervals denoted as (a), (b), and (c) correspond to 200 days preceding the special interval, the interval of interest, and 150 days following. Each box represents 50% of the distribution of particle fluxes during each time interval, with the median indicated by the line across the middle or lower edge of the box. The "error bars" indicate the distributions of fluxes for the upper 25% and lower 25% of the fluxes. A background, consisting of linear interpolations between the lowest flux rate in each respective Bartels rotation, has been subtracted from the data before compiling the statistics. The statistical distributions show clearly that the low energy ion fluxes have essentially the same distributions for each time interval at each spacecraft. The distributions of the higher energy protons are vastly different, quantitatively, in interval (b) than in the other two intervals. At Voyager 1, the fluxes in interval (b) were all basically near background, as is qualitatively evident from Figure 1.

Daily average ion spectra from both spacecraft on day 235, 1983, during a co-rotating event at each location, are shown in Figure 3. (A different co-rotating region, of course, is seen at each location.) The spectral shapes at the two locations are similar. The similarity in the spectra together with the statistical result showing decreased amplitudes at higher latitudes indicates that the co-rotating acceleration process is the same in and out of the ecliptic, but less effective at higher latitudes.

3. Discussion. During the ~200 days of quiescence in the outer heliosphere, when the interplanetary environment was essentially undisturbed by intermittent solar energetic particle events and the accompanying transient interplanetary disturbances, the particle enhancements associated with co-rotating interaction regions were more intense in the ecliptic plane than at latitudes ~20° above the plane. This conclusion was also reached by the Voyager cosmic ray instrument team studying >0.5 MeV protons [Christon and Stone, 1985]. The acceleration process, however, appears to be the same at both locations. For the ~200 days, the medium may have resembled the prediction of Burlaga [1983], who speculated that beyond ~10 A.U. the large scale dynamics of the interplanetary medium could be dominated by pressure waves; the originating coronal signatures would be lost. The solar wind would therefore be more homogeneous on a large scale [see also Smith et al., 1985, and Whang and Burlaga 1985]. Finally, Lanzerotti et al. [1985] suggested that the undisturbed (by transient events) outer heliosphere during this interval facilitated the detection of the enhanced levels of 3 kHz plasma waves that Kurth et al. [1984] attributed to plasma processes produced at the heliosphere boundary between the interaction of the solar wind with the interstellar medium.

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5. References

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