On the Possible Detection of the Outer Heliospheric Boundary Signatures in Accelerated Ions Seen by Voyager 1 Beginning From July 2002

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Abstract

Highly variable and enhanced ≈0.5-17 MeV proton fluxes during the second half of 2002 measured aboard Voyager 1 by LECP and CRS instruments are discussed. It is tentatively interpreted as a possible manifestation of a combined phenomenon including the global merged interaction region and an upstream precursor of the heliospheric termination shock. The simultaneous increase of >70 MeV proton intensity could be associated with the easier penetration of galactic cosmic rays into the heliosphere due to the solar activity decrease and/or because of enhanced amount of anomalous H accelerated at the termination shock.

1. Introduction

Expected signatures and early warning of the approach to the solar wind termination shock (TS) has been a target of continuous search for years. Several kHz radio emissions were interpreted as manifestation of echoes of solar flares at the outer heliospheric boundaries [4], when their possible motions due to field variations are quite plausible [2]. The anticipated gradient of the cosmic rays at the TS had been considered in [3]. The TS encounter was expected as early as 2002 [6] or in the last quarter of 2001 [7]. Decker and Krimigis [1] reported on observations of the GMIR arrival at the position of the Voyager 1 (V1) in July 2002.

2. Data Presentation and Analysis

The data of the LECP instrument (principal investigator S. Krimigis, as available to us at http://hurlbut.jhuapl.edu/VOYAGER) aboard V1 and V2 in 1997-2003 have been examined. In Fig. 1 the significant abrupt increase of 0.57-1.78 MeV proton intensity is clearly seen in July 2002 on V1 (≈85 AU, 33.9 N, longitude 171.8 deg); whereas V2 (≈69 AU, 24.2 S, 215 deg) displays

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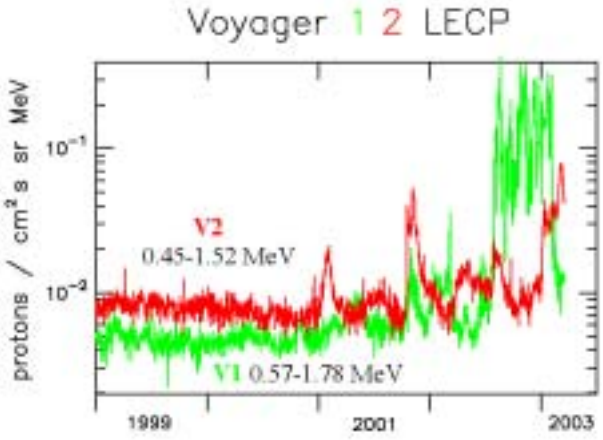

Fig. 1. Time profiles of LECP fluxes.

nearly background fluxes. A similar pattern of intensity enhancements for >0.5 MeV/nucl ions was detected by the CRS instrument (principal investigator E. Stone, data from http://voycrs.gsfc.nasa.gov/heliopause) at V1 in July 2002 - March 2003.

The low-energy proton increases at V1 seem to be very similar to those in the vicinity of the a magnetospheric bow shock. It may be assumed that particles undergo local accumulation or acceleration. In contrast to the bow shock where spectral indices are higher during particle increases in this case several particle increases exhibit hardening of energy spectra in comparison with background population. The flux ratio of the lowest channels on V1 is minimal at the beginning of increase from the middle up to end of July 2002. This effect may be explained as a faster arrival of higher energy particles from the site of acceleration. However, a hard spectrum was observed also from 28 August to 10 September 2002. Now we cannot find the reason of these spectral changes. Similar things did not happen during the last prominent GMIR observed by either Voyager in 1991 in the distant heliosphere when the ratio of the two lowest energy channels increased from the background value of about 20 to ≈60-70 and remained nearly constant throughout the particle event. The results obtained indicate a probability that V1 crossed by the particle impulses generated at the TS several times. At the same time the V2 profiles display something else (of course, if V1 sees the boundary and if the TS is a spherical and stationary structure, V2 should see TS later by ≈4 years).

Figure 2 shows that >70 MeV proton count rates at V2 (CRS instrument) went up and down from April 2002 up to Feb 2003 whereas at V1 a permanent increase is observed. Other trends are observed in Apatity neutron monitor data. The different time behaviors can be due to several processes like acceleration of anomalous H near the TS; an easier access of galactic protons to V1 as the main

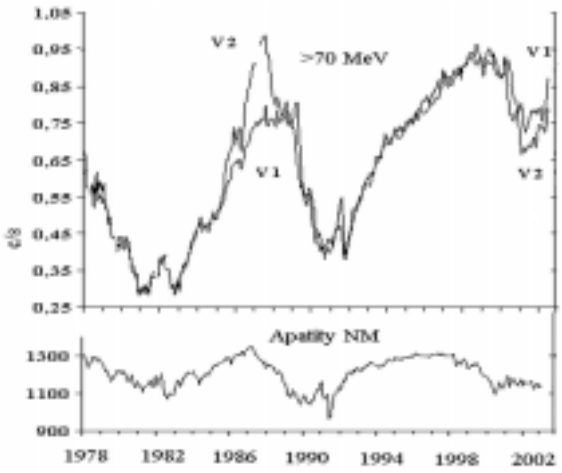

Fig. 2. High energy proton fluxes (CRS) and neutron monitor data.

part of modulation region remains behind V1; or the decrease of the solar activity leading to the GCR intensity increase.

3. Discussion and Possible Interpretation

The subsequent development of the events after July 2002 till March 2003 reveals unusual characteristics: 1) increase of fluxes at all energies (low- and high-energy protons representing solar-heliospheric and galactic components, respectively); 2) the time variability of 0.57-1.78 MeV proton flux (see Fig. 1) is enormously high; 3) the energy spectral ratios are not typical and differ from GMIRs in 1991; 4) the strong difference in V1 and V2 responses indicates a more and specific character of the phenomenon rather than a global one, with no response in the southern latitudes at the V2 position, 18 AU closer to the Sun; 5) GCR (protons >70 MeV) permanently increase at V1 during the second half of 2002, which make this event different from other GMIRs. Taken all this together suggests that the events of the second half of 2002 can be ascribed not only to a GMIR, but also to something else. One could expect a rather non-stationary termination bow shock position and internal structure because of the solar activity manifestations [6]. The position of the heliopause is determined by the pressure balance between the supermagnetosonic solar wind and the local interstellar medium. The solar wind dynamic pressure is several tens of percent lower during solar maxima [5]. Accordingly, the size of the heliosphere should be lower during this time. Additionally, the dispersion of the solar wind parameters is higher at that time. Both factors increase the probability to meet occasionally closer distances of the heliospheric boundaries to the Sun at solar maxima in comparison with minima. The third important factor, which increases the op-

portunity to meet precursors in accelerated particles during the SC maxima, is related also to the higher level of the turbulence and correspondingly stronger acceleration processes inside the heliosphere and at its boundaries. The TS position temporarily shifts closer to the Sun from its nominal position when the perturbed solar wind arrives. Hence, the probability to register the TS or its indirect signatures increases during these maximal activity periods in the distant heliosphere. The quasi-stationary magnetic field pattern in the outer heliosphere rotates with the spin period of the Sun. When V1 approaches the heliospheric boundaries, the GCR modulation appreciably decreases with time at the s/c. The position of these boundaries will be less variable and more distant (of the order 1 AU/year) during the forthcoming minimum between the 23rd and 24th SC.

4. Conclusions

An unusual amplitude and spectra behavior of the LECP low-energy protons with energies from 0.57 to >70 MeV seen by CRS have been observed aboard Voyager 1 from July 2002. The tentative interpretation suggested that the observed phenomena could be partially associated with the temporary presence of the heliospheric termination shock not far from the Voyager 1 position at that time in combination with the arrival of the GMIR event generated by the solar activity in the fall of 2001.

5. Acknowledgements

Voyager energetic particle and neutron monitor Apatity data have been available from internet sites. The work in MSU is supported by RFBR grants 01-02-16579, 00-15-96623, 03-02-17121. K.K. thanks Hungarian grant OTKA T034566 for support.

6. References

1. Decker R. and Krimigis S.T. 2002, AGU 2002 Fall Meeting, SH11A-0386
2. Grzedzielski S. and Lazarus A. 1993, J. Geophys. Res., 98, 5551
3. Jokipii J.R., Kóta J., and Merényi E. 1993, J. Astrophys., 265, 573
4. Kurth W. et al. 1984, Nature, 312, 27
5. Veselovsky I.S. et al. 1999, Astronomy Reports, 76, N7, 558
6. Wang C. and Belcher J.W. 1999, Solar Wind Nine, AIP CP 471, 775
7. Webber W.R. et al. 2001, J. Geophys. Res. 106, 253