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THE EFFECTS OF CORONAL MASS EJECTIONS ON GALACTIC COSMIC RAYS IN THE HIGH LATITUDE HELIOSPHERE: OBSERVATIONS FROM ULYSSES' FIRST ORBIT

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ABSTRACT

During its first solar orbit the Ulysses spacecraft detected several coronal mass ejections (CMEs) at high heliographic latitudes. We present first observations on the effects of these high-latitude CMEs on galactic cosmic rays (GCRs) using measurements from the Kiel Electron Telescope (KET) which is part of the Cosmic Ray and Solar Particle Investigation (COSPIN) experiment, the Los Alamos SWOOPS (Solar Wind Observations Over the Poles of the Sun) experiment and the magnetic field experiments. We find the passage of these CMEs over the spacecraft to be associated with short-term decreases of GCR intensities. The relatively weak shocks in these events, driven by the CMEs' over-expansion, had no strong influence on the GCRs. The intensity minimums of GCRs occurred on closed magnetic field lines inside the CMEs themselves, as indicated by bidirectional fluxes of suprathermal electrons. Short episodes of intensity increases of GCRs inside CMEs, at times when the bidirectional fluxes of suprathermal electrons disappeared, can be interpreted as evidence that GCRs can easily access the interior of those CMEs in which open magnetic field lines are embedded.

INTRODUCTION

The Ulysses spacecraft provides first observations of the uncharted third dimension of our solar system. Ulysses was launched in October 1990. A gravity assist maneuver around Jupiter was used to deflect the s/c over the solar poles. Ulysses reached its most southern heliographic latitude of 80.2°S, at a radial distance of 2.3 AU from the Sun, in mid-September 1994. After a rapid swing across the ecliptic in March 1995, the s/c reached end of July 1995 the latitude of 80.2° in the northern hemisphere. Ulysses completed its first solar orbit end of September 1995.

One of the key Ulysses investigations concerns the physical properties of galactic cosmic rays (GCRs) in the high latitude heliosphere. The recent Ulysses observations have shown that co-rotating interaction regions (CIRs) cause recurrent decreases of cosmic rays (CRs) up to high heliographic latitudes (see, e.g., Kunow et al., this conference). The aim of this paper is to present the first observations of transient intensity decreases of GCRs at high latitudes.

INSTRUMENTATION

The measurements presented here were made with the Kiel Electron Telescope (KET) on the Ulysses spacecraft. The KET is one of five telescopes which make up the COSPIN (Cosmic Ray and Solar Particle Investigation) instrument (see Simpson et al., 1992). The KET measures protons and α-particles in the energy range from 6 MeV/n to above 2 GeV/n and electrons in the energy range from 3 MeV to some GeV. Here we have used the KET's 250-2200 MeV proton channel.

The Ulysses solar wind measurements shown here were made with the Los Alamos ion sensor (Bame et al., 1992) while magnetic field measurements were obtained by the Ulysses magnetometer (Balogh et al., 1992).

OBSERVATIONS

Figure 1 shows 6 hour averaged values of proton flux in the energy range 250-2200 MeV, solar wind speed, density, temperature and magnetic field magnitude for a transient GCR intensity decrease detected by Ulysses in June 1993 at 32°S, at 4.6 AU. Ulysses was usually immersed in high speed solar wind with uniform magnetic polarity after the latitude had increased beyond ~30°S (Phillips et al., 1994; Smith et al., 1993).

The decrease in proton flux, at the order of ~12% below background level, started at Ulysses at ~12 UT on June 9 (day 160) 1993. The comparison of KET data with plasma and magnetic field measurements reveals that it was related to the passage of a CME over Ulysses. Dashed lines mark the forward/reverse shocks driven by the CME, solid lines mark the CME's boundaries identified from bi-directional electrons (BDEs) (Gosling et al., 1994). This is the first observation of a CR decrease associated with the newly identified class of forward-reverse shocks in the solar wind driven by over-expansion of CMEs due to their high internal plasma and magnetic field pressure. Expansion shocks are usually weak compared to those shocks driven by CMEs that propagate with considerably higher speed than the ambient solar wind ahead.

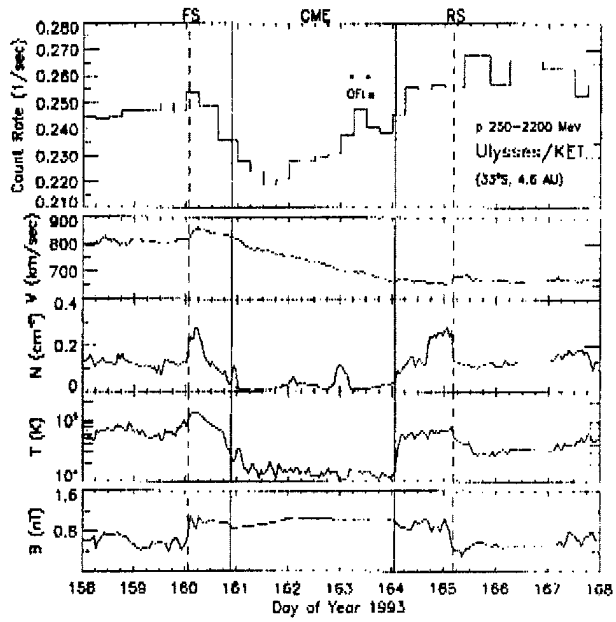

Fig. 1: 6 hour averages of the proton flux for the energy range 250-2200 MeV measured with the KET during a CR decrease observed in June 1993 at 4.6 AU, at 32°S. The next panels show 1 hour averages of solar wind speed, density, temperature and magnetic field magnitude. The forward-reverse shock pair of the over-expanding CME is indicated by dashed lines, the time-interval of the CME is marked with solid lines. A time interval of presumably open magnetic field lines (OFLs) is indicated.

The intensity decrease of the protons started after the forward shock and before the passage of the CME. However, an exact association of the onset of the CR decrease to either shock or CME passage is difficult because of the 6 hour averaging time of the particle data which provides reliable values for the proton count rates. The intensity minimum occurred within the CME at ~12 UT on June 10 (day 161). From the end of June 10, until the trailing edge of the CME is reached early on June 13 (day 164), the CR intensity recovers slowly to background level. No intensity decrease is observed at the CME's reverse shock. The weak expansion shocks obviously had no strong influence on CR intensities. We believe that the passage of the CME was the main cause of this CR decrease.

A remarkable feature of this CME, which was a magnetic flux rope (Gosling et al., 1994), was the disappearance of the bi-directional electron streaming within a fraction of the CME's trailing portion. From ~4 UT through ~14 UT on June 12 (day 163) unidirectional streaming of suprathermal electrons was observed (Gosling et al., 1995a).

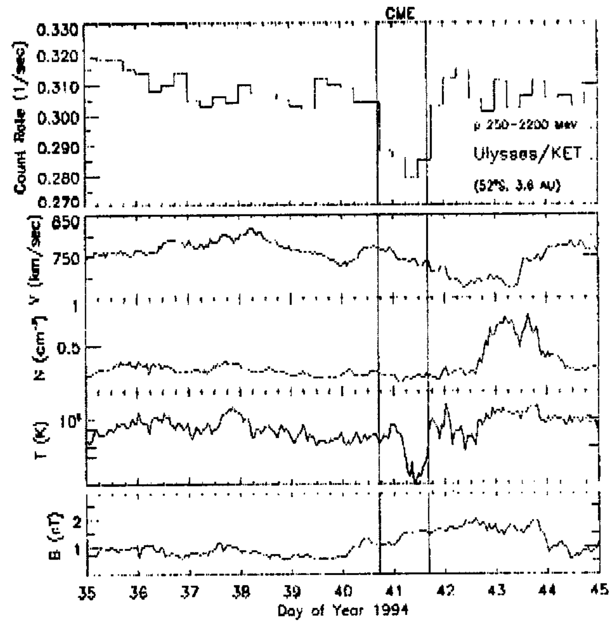

Fig. 2: Ulysses particle and solar wind data for a CR decrease observed on February 9/10, 1994. See Figure 1 for an explanation of the data.

Gosling et al. (1995a) have interpreted this observation as evidence for open magnetic field lines embedded within this CME. Note that it is commonly believed that counterstreaming electrons are observed on magnetic field lines that remain rooted at the Sun at both ends (Gosling, 1990). Following this interpretation one may expect an intensity increase of CRs on open field lines to which energetic particles should easily gain access (Bothmer et al., 1996). Figure 1 supports this assumption. During the time interval when presumably open field lines (OFLs) were embedded within the CME, the CR intensity increased to about pre-event level. Note that particles at cosmic ray intensities have large gyroradii so that shorter time-intervals of open field lines within CMEs may become unidentifiable.

Figure 2 presents data for a transient CR decrease observed by Ulysses on February 9/10 (days 40/41), 1994. Ulysses was at 52°S, at 3.6 AU. There were no signatures of a forward/reverse shock pair in the plasma and magnetic field data. The decrease of CRs, which was at the order of ~10%, is strikingly well correlated in time with the boundaries of the CME as identified from the BDEs (see also Bothmer et al., 1995). This observation supports our conclusion that the CR decrease shown in Figure 1 was obviously caused by the CME itself, rather than by the CME's expansion shocks.

Another CR decrease, shown in Figure 3, was detected by Ulysses on February 27/28 (days 58/59), 1994. Ulysses was at 54°S, at 3.5 AU. The CR decrease, which was at the order of ~7%, again shows a striking correlation with the time of the passage of a CME over Ulysses (Gosling et al., 1995b). Again there is no obvious influence of the expansion shocks on CR intensity. The short CR intensity increase in the CME's leading portion at ~18 UT on February 27 (day 58) may be indicative for the presence of open field lines within this portion of the CME, but a detailed comparison with the suprathermal electron data is necessary to substantiate this assumption.

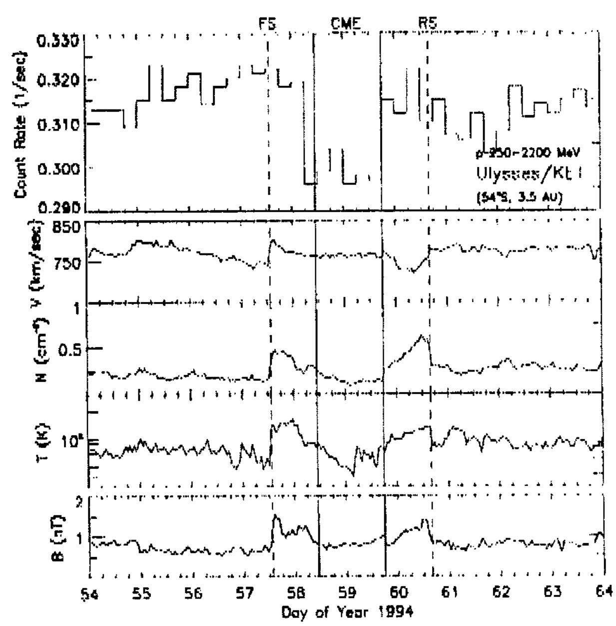

Fig. 3: A CR decrease detected by Ulysses on February 27/28, 1994. See Figure 1 for explanations.

SUMMARY

We have investigated Ulysses/KET data obtained at high heliographic latitudes during Ulysses' first solar orbit for transient galactic cosmic ray (GCR) decreases making additional use of solar wind and magnetic field data. Our investigations of the characteristics of CR decreases observed under solar minimum conditions in the high latitude heliopshere can be summarized as follows:

- Transient CR decreases at high heliographic latitudes were associated with passage of CMEs over Ulysses.
- The weak expansion shocks driven by over-expanding CMEs had no strong influence on CR intensities.
- The decreases in CR intensity were related to the CMEs' specific plasma and magnetic field characteristics.
- CR intensity variations within CMEs support the assumption that the topology of some CMEs involves open and closed magnetic field lines.

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REFERENCES

Balogh, A., et al., Astron. Astrophys. Suppl. Ser., 92, pp 221-236 (1992).
Bame, S.J., et al., Astron. Astrophys. Suppl. Ser., 92, pp 237-265 (1992).
Bothmer, V., et al., Geophys. Res. Lett., 22, pp 3369-3372 (1995).
Bothmer, V., et al., Astron. Astrophys., 316, No.2, pp 493-497 (1996).
Gosling, J.T., in Physics of Magnetic Flux Ropes, Geophys. Monogr. 58, ed. by C.T. Russell, E.R. Priest, and L.C. Lee, AGU, Washington D.C., pp 343-364 (1990).
Gosling, J.T., et al., Geophys. Res. Lett., 21, pp 237-240 (1994).
Gosling, J.T., et al., Geophys. Res. Lett., 22, pp 869-872 (1995a).
Gosling, J.T., et al., Geophys. Res. Lett., 22, pp 1753-1756 (1995b).
Kunow, H., et al., this conference, SH 3.2.1.
Phillips, J.L., et al., Geophys. Res. Lett., 21, pp 1105-1108 (1994).
Simpson, J.A., et al., Astron. and Astrophys. Suppl. Series, 92, pp 365-399 (1992).
Smith, E.J., et al., Geophys. Res. Lett., 20, pp 2327-2330 (1993).

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