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Cosmic ray intensity variation during a CME

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Abstract

The June 6, 2000 coronal mass ejection was an exceptional full halo, which made it possible to measure cosmic ray (CR) decrease with a simple experimental set-up. Variation in the local secondary cosmic ray density has been investigated by means of gamma rays. The experiment site was located in Istanbul (41.1N, 29.0E). CR electrons and slow gamma rays have been eliminated. The CR density has dropped drastically starting on June 8, 2000. The counts have been compared with the pre-shock levels and some other cases of CMEs. During strong solar modulation, the local counts of secondary CR intensity values dropped down as much as 24%.

Keywords: Cosmic rays; CME; Solar modulation; Gamma rays; Solar flares

1. Introduction

Cosmic ray (CR) intensity is modulated by the sun. Solar modulation is mainly observed as (1) a daily variation, (2) a 27-day variation, (3) an anti-correlation with 11-year solar activity, (4) Forbush decreases (FD) of a few days duration and (5) flare generated CR increases that last only a few minutes. During the last five solar cycles neutron monitors, scintillation counters and ionization chambers have recorded CR intensity changes.

Forbush-type CR intensity decreases follow some important coronal mass ejections (CMEs). Forbush decreases and their connection to effects on Earth are investigated during both solar maximum and minimum. Maximum years of solar activity are ideal times to investigate FD. Development of an FD is described in e.g., Fenton et al. (1984), Cane et al. (1994, 1996), Makela et al. (1998), Cane (2000). When the sun releases a considerable amount of material and magnetic disturbance, CRs interact with this plasma. CME material arrives at Earth within a few days. This fast moving plasma sweeps out some CRs and decreases the number. Thus, a CR intensity decrease, called an FD is recorded. It generally takes less than a day to reach the minimum. Recovery back to the previous CR intensity values continues for several days after the CME.

Sometimes recurrent FD are observed; these originate from corotating high speed solar wind streams. Generally, FD are non-recurrent; such FD are associated with CMEs. Cane et al. (1994) indicate that while a CME is passing, CR counts drop sharply and recover again with a sharp increase. Generally, FD have two components, or, they are observed with "two steps". The first step or decrease is due to the shock. The fast CME material creates a shock wave in the medium ahead of the CME. This turbulent shock region includes closed magnetic field lines. Therefore, a decrease of CR occurs inside this region.

The second step is due to the CME. Cane (2000) explains the continuation of the CME in the interplanetary medium; the interplanetary counterpart of the CME is "ejecta". Cane indicates that according to the position of the observer, there are three possibilities: CR decrease may be observed with both shock and ejecta, only with the shock or only with ejecta. Cane (2000) indicates that most observations are of the two-step type. Only very energetic CMEs may produce shock-only-type FD for the observer. Makela et al. (1998) give examples for the cases that prolonged connection to magnetic turbulence of the shock result in a gradual decrease and a slow recovery, while the direct effect of the ejecta is a sharp decrease and a sharp recovery. They describe three CR decreases observed by the SOHO spacecraft during 1997. It is generally thought that cumulative effects result in a net decrease of CR while a series of solar activity events cause step decreases in the CR intensity.

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If a flare is also involved with a CME, before the FD, neutron monitors usually detect a sharp increase due to solar protons generated by the flare. There is no clear relationship between flares and CMEs. Although they seem to originate from the same place and start at the same time, there are several ejections with no relation to flares (e.g., Hundhausen, 1996). In a study comparing CMEs and the characteristics of the resulting interplanetary plasma, Lindsay et al. (1999) mention that the speeds of CMEs in the corona may depend on whether they are flare or prominence associated as they compare CMEs and the characteristics of the resulting interplanetary disturbance. A simple explanation is possible for this relation: Major events include important flares. This leads to a tendency to relate them (Cane, 2000). A similar statistical relation exists between FD and magnetic storms. Not all solar flares and CMEs are followed by magnetic storms. In one of the earlier studies, Shukla et al. (1979) indicate that large solar wind streams associated with solar flares produced large decreases of CR intensity and variations of geomagnetic field; streams that are not associated with any flare produce only geomagnetic field variations and that they do not change the CR intensity. Therefore, it may be expected that only some important CMEs cause enough disturbance that leads to a geomagnetic storm. Models for magnetic clouds indicate thickness of magnetosheaths of CMEs (Russell and Mulligan, 2000). It would be interesting to interpret the Forbush decreases by means of the magnetosheaths of the CMEs.

2. Aim of the experiment

Our experiment has been performed using a basic coincidence circuit set aiming to locally detect flare and CME effects on secondary CR. The aim of the experiment is to investigate

1. The possibility to observe the flare triggered CR intensity increases
2. To observe the CME originated CR intensity decreases (FD), to measure their amount and to see if the decreases due to the shock and ejecta are separable.

3. The experimental set-up

The Institute of Nuclear Physics of the Istanbul Technical University (41.1N and 29.0E) did the CR intensity measurements. The experimental set-up employed two identical Teledyne Isotopes scintillation counters, each containing a Tl activated NaI crystal, 7.6 cm in diameter × 7.6 cm in height. These are integrally mounted to photomultiplier tubes and hermetically sealed with Al shielding, thus eliminating CR electrons and the gamma rays which are too slow. Actually, the experiment was adjusted for the measurement of slow gamma ray photons, since these are more sensitive to CR intensity changes. The energy range of our experiment is about 0.5–1.5 MeV. The power supply applied 1000 V to the photomultiplier tubes. The coincidence circuit and the timer are driven by a PC. Same experimental set-up has been used in a previous study where variation of CR intensity during a solar eclipse has been measured (Kandemir et al., 2000). The electron–photon fluxes recorded by similar scintillation counters as well as NM which observe proton–neutron fluxes observed secondary CR which are the products of primary CR protons, alpha particles and heavier nuclei with much higher energies. Only NM can detect some lower energy neutrons and they may detect the solar protons produced during flare events. Thus, photons recorded by our detector are the soft component of secondary CR which are generated in the electron–photon cascade in the atmosphere.

4. The experiment

The sun was extraordinarily active during June and July 2000. Totally, there were seven X class X-ray flares reported during this period. NOAA's Space Environment Center reported two X-type flares on June 6 and one on June 7 (The other X-type flares were on June 18, July, 11, 12 and 14). It has been reported by NASA Space Weather Bureau that an interplanetary shock wave from June 6 CME passed NASA's ACE satellite at 08:41 UT on June 8 and arrived at Earth about an hour later. It has also been reported that ACE recorded a sudden increase of solar wind velocity from 522 to 734 km/s in 1 min, i.e., from 08:41 UT to 08:42 UT as well as recording a doubling of proton density in the same time interval.

CR intensity decreases that seem to be due to the shock and ejecta on June 8 are recorded in our Istanbul Technical University experiment. The first decrease in Fig. 1 seems to indicate the shock on June 8. Its start, which should be the arrival of the shock, is with 1.55 counts/second (c/s) at 9:52 UT (also at 9000 s in Fig. 1). The minimum value at the ejecta is 1.50 c/s at 10:00 UT (13,000 s). Recovery near the pre-shock values is with 1.51 c/s at 12:05 UT (17,000 s). The values 1.55 and 1.51 c/s indicate a decrease of 2.45%. The second sharper decrease of counts start with 1.49 c/s at 13:12 UT (21,000 s) and probably indicate the arrival of the ejecta. Its minimum value recorded in our experiment is 1.125 c/s at 16:32 UT (33,000 s). This means that the counts drop by 24.4%. Measurements recover up to 1.36 c/s at 18:45 UT (41,000 s). There was an interruption in the experiment until 10:10 UT the next day when the counts were at the level of 1.58 c/s.

Our experiment seems to detect FD; but it is not capable of detecting the solar protons. Fig. 2 gives CR counts for June 8, 2000 and for the following 40 days. The counts are recorded every 4000 s. Daily averages are defined as their mean value. The measurements start with 1.55 c/s on June 8 and drop down to 1.4 c/s after the FD and remain around the level of 1.4 c/s until the end of June. This trend seems to continue

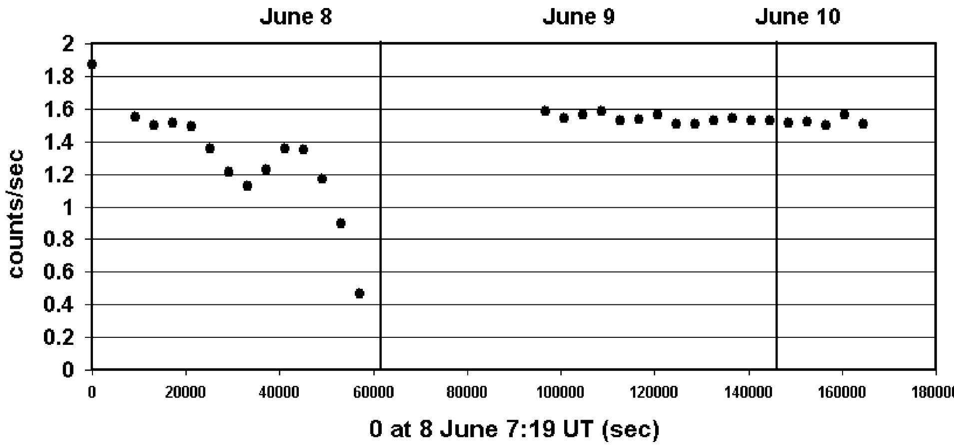

Fig. 1. CR counts of June 8–10, 2000. X-axis values start on 8 June, 2000 at 7:20 UT and ends on 10 June, 2000 at 5:00 UT.

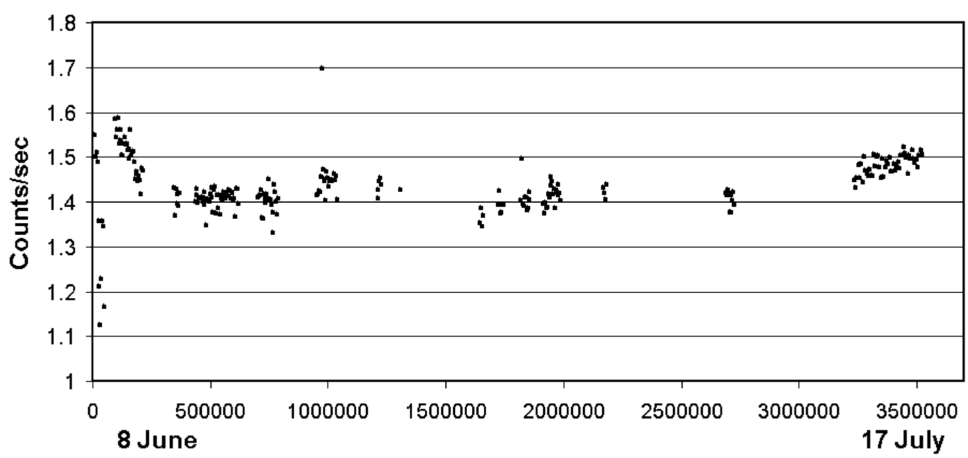

Fig. 2. Daily average values of CR counts for 40 days starting on June 8, 2000. Counts start at 7:19 UT on June 8 and end on July 17, 2000.

during July as can be seen from Fig. 2. A cumulative effect of solar activity seems to lower the CR intensity during the very active period of June–mid July 2000. The X-5 class flare on July 14 is known to cause a full halo CME and a severe magnetic storm on July 15–16. In our experiment, it was not possible for this CME to recognize the shock and ejecta as done for the previous CME.

5. Results of the experiment

1. The experiment was not sensitive for any flare events. This is in agreement with expectation. Only NM can detect solar low energy protons.
2. It was possible to observe the Forbush decrease starting on June 8 which was caused by full halo CMEs associated with the flares of June 6 and 7. The experiment indicates that during some strong solar modulation, local counts of secondary CR intensity values may drop down as much as 30% compared to the pre-shock values.
3. The trend of values during the active period June–July 2000 indicate a net decrease of CR. A recovery is observed towards the end of July.

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References

Cane, H.V., 2000. Space Sci. Rev. 93 (1/2), 55–57.
Cane, H.V., Richardson, I.G., von Rosenvinge, T.T., Wibberenz, G., 1994. J. Geophys. Res. 99, 21,429–21,441.

Cane, H.V., Richardson, I.G., von Rosenvinge, T.T., 1996. J. Geophys. Res. 101, 21,561–21,572.

Fenton, A.G., Fenton, K.B., Humble, J.E., 1984. Astron. Soc. Aust. Proc. 5, 590–593.

Hundhausen, A.J., 1996 In: Kivelson, M.G., Russell, C.T. (Eds.), Introduction to Space Physics. Cambridge University Press, Cambridge, pp. 91–128.

Kandemir, G., Guclu, M.C., Geckinli, M., Firat, C., Boydag, S., Ozguc, A., Yasar, T., 2000. In: Livingston, W., Ozguc, A. (Eds.), The Last Total Eclipse of the Millennium in Turkey. ASP Conference Series, Vol. 205, pp. 202–207.

Lindsay, G.M., Luhman, J.G., Russell, C.T., Gosling, J.T., 1999. J. Geophys. Res. 104, 12,515–12,523.

Makela, P., Torsti, J., Teittinen, M., Valtonen, E., Riihonen, E., Ipavich, F., 1998. Observations of galactic cosmic ray modulation during Earth-directed coronal mass ejections. Geophys. Res. Lett. 25, 2951–2954.

Russell, C.T., Mulligan, T., 2000. In: Intercomparative Magnetosheath Studies, Antalya, Turkey, September 4–8. (Abstract Book, 35).

Shukla, J.P., Shukla, A.K., Singh, R.L., Agrawal, S.P., 1979. Indian J. Radio Space Phys. 8, 230–232.