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The effect of CME on forbush decreases

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Abstract

The Forbush decrease is usually observable by particle detectors on Earth within a few days after the CME, and the decrease takes place over the course of a few hours. Over the following several days, the solar cosmic ray intensity returns to normal. Forbush decreases have also been observed by humans on Mir and the International Space Station (ISS), and by instruments onboard Pioneer 10 and 11 and Voyager 1 and 2, even past the orbit of Neptune. The magnitude of a Forbush decrease depends on three factors: his size of the CME, the strength of the magnetic fields in the CME, the proximity of the CME to the Earth. These energetic particle effects can often be used to identify CMEs in the interplanetary medium, where they are usually called `Ejecta'. When both the Ejecta and shock effects are present the resulting cosmic ray event is called a `classical, two-step' Forbush decrease.

Keywords: coronal mass ejection, forbush, decrease

Introduction

A typical coronal mass ejection may have any or all of three distinctive features: a cavity of low electron density, a dense core (the prominence, which appears on coronagraph images as a bright region embedded in this cavity), and a bright leading edge.

Most ejections originate from active regions on the Sun's surface, such as groupings of sunspots associated with frequent flares. These regions have closed magnetic field lines, in which the magnetic field strength is large enough to contain the plasma. These field lines must be broken or weakened for the ejection to escape from the Sun. However, CMEs may also be initiated in quiet surface regions, although in many cases the quiet region was recently active. During solar minimum, CMEs form primarily in the coronal streamer belt near the solar magnetic equator. During solar maximum, they originate from active regions whose latitudinal distribution is more homogeneous.

Coronal mass ejections reach velocities from 20 to 3,200 km/s (12 to 1,988 mi/s) with an average speed of 489 km/s (304 mi/s), based on SOHO/LASCO measurements between 1996 and 2003. These speeds correspond to transit times from the Sun out to the mean radius of Earth's orbit of about 13 hours to 86 days (extremes), with about 3.5 days as the average. The average mass ejected is 1.6×10^{12} kg (3.5×10^{12} lb). However, the estimated mass values for CMEs are only lower limits, because coronagraph measurements provide only two-dimensional data. The frequency of ejections depends on the phase of the solar cycle: from about one every fifth day near the solar minimum to 3.5 per day near the solar maximum (Carroll, *et al.* 2007) [1]. These values are also lower limits because ejections propagating away from Earth (backside CMEs) usually cannot be detected by coronagraphs.

Current knowledge of coronal mass ejection kinematics indicates that the ejection starts with an initial pre-acceleration phase characterized by a slow rising motion, followed by a period of rapid acceleration away from the Sun until a near-constant velocity is reached. Some *balloon* CMEs, usually the slowest ones, lack this three-stage evolution, instead accelerating slowly and continuously throughout their flight. Even for CMEs with a well-defined acceleration stage, the pre-acceleration stage is often absent, or perhaps unobservable.

The first detection of a CME as such was made on 14 December 1971, by R. Tousey (1973) of the Naval Research Laboratory using the seventh Orbiting Solar Observatory (OSO-7) [2]. The discovery image (256 × 256 pixels) was collected on a Secondary Electron Conduction (SEC) vidicon tube, transferred to the instrument computer after being digitized to 7 bits. Then it was compressed using a simple run-length encoding scheme and sent down to the ground at 200 bit/s. A full, uncompressed image would take 44 minutes to send down to the ground. The telemetry was sent to ground support equipment (GSE) which built up the image onto Polaroid print. David Roberts, an electronics technician working for NRL who had been responsible for the testing of the SEC-vidicon camera, was in charge of day-to-day operations. He thought that his camera had failed because certain areas of the image were much brighter than normal. But on the next image the bright area had moved away from the Sun and he immediately recognized this as being unusual and took it to his supervisor, Dr. Guenter Brueckner [3], and then to the solar physics branch head, Dr. Tousey. Earlier observations of *coronal transients*or even phenomena observed visually during solar eclipses are now understood as essentially the same thing.

Forbush decreases are transient depressions in the galactic cosmic ray intensity which are characterized by a sudden onset, reaching a minimum within about a day, followed by a more gradual recovery phase typically lasting several days. Though originally thought to be associated with geomagnetic storms [Forbush, 1937] [4], it is now known from spacecraft measurements that Forbush decreases are also observed distant from planets and so are present in the interplanetary medium [Webber *et al*., 1986, 2002] [5-6]. These decreases are most likely produced by perturbations in the interplanetary magnetic field and particle flow which propagate away from the Sun (Morrison, 1956; Parker, 1963) [7-8].

Observation

Observations of energetic particles over a wide range of rigidities can provide information on the presence and on the structure of interplanetary CMEs (ICMEs, CME ejecta). A large fraction of ejecta produce local depressions of the cosmic ray intensity. The depression typically extends over the ejecta region as determined from a range of the ejecta plasma signatures. The bi-directional particle flows are present in regions of some ejecta. In particular there were frequent observations of bi-directional heat fluxes of solar wind electrons (~100-200eV), BDE (Gosling *et al.* 1987) [9]. Bi-directional flows of solar wind electron heat fluxes indicate that magnetic field lines within ICMEs are connected to the Sun at both ends. However, the bi-directional electron flows are frequently observed to be intermittent (Shohdan *et al.* 2000) [10]. It has been suggested that this occurs when field lines inside the ICME connect with open field lines of the normal solar wind. Occasionally the heat flux is entirely absent, indicating a completely open structure. In either case this means that there are open field lines within the ICME along which cosmic rays may gain easy access.

Cane *et al.* (1997) [11] predominantly used cosmic ray observations made by the anti-coincidence guard of the Goddard experiment on IMP 8, which detects > 60 MeV particles. They examined whether the size of the cosmic ray depression is correlated with the percentage duration of the associated magnetic cloud which exhibits bi-directional electron heat flux flows. Authors have also examined individual ICMEs.

They conclude that while their results suggest some support for the expectation that GCRs are excluded from closed field regions within ICMEs and can gain easier access along field lines connected to the IMF, there is no clear relationship between the GCR intensity and the presence or absence of BDEs individual ICMEs.

Recently, Richardson *et al.* (1999) [12] compared observations of bi-directional ~1 MeV/nucl ions made by near-earth spacecraft during 1982 with intervals of bi-directional flows observed in GCRs at ~4GV. The GCR fluxes were inferred by combining data from a worldwide network of 42 neutron monitors regarded as a single multi-channel instrument. Richardson *et al.* (2001) [13] reported recent episodes of bi-directional flows of ~1MeV/nucl ions (IMP 8) and ~4GV GCRs. In particular, they identity two periods of bi-directional particle flows occurred in mid-July 2000 after the "Bastille Day" eruption (Ihara *et al.* 2001) [14]. Richardson *et al.* 2001 [13] confirm their earlier finding that bi-directional GCR flows observed by the NM network tend to be associated with (ICMEs and with bi-directional GCRs are only present in a small fraction (~10%) of the ICMEs which pass the earth.

The most powerful solar event observed over current cycle occurred on 14 July, 2000 accompanied by the class X5.7 X-ray flare and halo coronal mass ejection that initially was travelling at a velocity of >1700 km/s. However, the solar activity relating to the Bastille Day event began with flare on 12 July and associated coronal mass ejection. Over a five day period starting on 13 July, space crafts at ~ 1AU observed three shocks and four CMEs. In particular, GEOTAIL observations of an interplanetary shock caused by the solar eruption were reported by Terasawa *et al.* (2001) [15]. It was expected at the given solar wind structure observed at 1 AU that by 4 AU this system had evolved into a large merged interaction region bounded by forward and reverse shocks (McDonald *et al.* 2001) [16].

The 17.07.2000 event was superimposed on a disturbed interplanetary background when GLE began a strong Forbush decrease was in progress. Analysis of many relevant data suggests that the particle acceleration up to relativistic energies occurred during the early phase of the flare and the proton enhancement had a relatively soft energy spectrum.

Bieber *et al.* (1998) [17] use a nine neutron monitor network to derive the time profile of density and anisotropy of relativistic protons and fit these observations to numerical models. Also Wind electrons have been analyzed. To explain fully the observations, however, one should invoke a kind of magnetic barrier or magnetic bottle associated with an earlier CME that was located ~0.3 AU beyond earth's orbit at the time of the event.

Some 177 days after the Bastille Day at Voyager 2 (63AU, 24°S) there began a step decrease in the cosmic intensity (15% for 265 Mev/n GCR He) and a complex enhancement with multiple structure in magnitude of the interplanetary magnetic field. For low energy 2.3MeV protons there was a 10 fold increase intensity that tracks very closely the increase in the solar wind velocity which reached peak value of ~450 km/s (McDonald *et al.* 2001) [16].

Belov *et al.* (2001b) [18] reviewed pitch-angle features in cosmic rays in advance of severe magnetic storms as observed by the neutron monitor network. Before CME arrives at earth, a combination of cosmic ray reflection and acceleration at the shock and the 'loss cone' effect change neutron monitor count rates. Those cosmic ray precursors are expected to play a role for forecasting of severe geomagnetic storms. Belov *et al.* (2001b) [18] have performed a survey of 14 major geomagnetic storms which revealed peculiar angular distributions in 11 cases, including 7 precursors with clear loss cone characteristics, in which the pre-decrease is confined to a narrow region around the sunward interplanetary magnetic field.

Conclusion

The frequency of forbush decreases are maximum during solar activity maximum period we also observed large magnitude decreases during the said period. Total number of forbush decrease vary significantly from one solar cycle to other. For 80% of events forbush decrease are followed by blob with the time difference of less than 5 hours. Coronal Mass Ejections (CMEs) are plasma eruptions from the solar atmosphere involving previously closed field regions which are expelled into the interplanetary medium. Such regions, and the shocks which they may generate, have pronounced effects on cosmic ray densities both locally and at some distance away. These energetic particle effects can often be used to identify CMEs in the interplanetary medium, where they are usually called `ejecta'. When both the ejecta and shock effects are present the resulting cosmic ray event is called a `classical, two-step' Forbush decrease.

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