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ANALISYS OF INTERPLANETARY STRUCTURES ASSOCIATED WITH COSMIC RAYS PRECURSORY ANISOTROPIES AND INTENSE GEOMAGNETIC STORMS

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ABSTRACT

Throughout the 11 year solar cycle a number of energetic phenomena such as "flares" and coronal mass ejections (CME) give rise at Earth to the so-called magnetic storms. These storms are characterized by a decrease in the H component of terrestrial magnetic field, lasting some dozens of hours. They are associated to interplanetary structures whose Interplanetary Magnetic Field component in the Z direction (Bz) is southward, i.e., antiparalell to the Earth's Magnetic Field direction. Thus, the interplanetary magnetic field interconnects with the geomagnetic field causing energy to be transported inwards. Some of these structures are associated with precursory anisotropy observed in ground cosmic ray data (muons). This work uses a set of intense geomagnetic storm events (Dst<-100nT), already studied by Munakata et al (2000) in terms of cosmic ray signatures, and identify their interplanetary structures using observations made by ACE, Wind and IMP-8 satellites. We use the following interplanetary data: plasma (solar wind speed, density and temperature of protons), interplanetary magnetic field (B, Bx, By, Bz), observed by IMP-8, WIND and ACE satellites, and Dst index from Kyoto to characterize the storms.

GEOMAGNETIC STORMS

It is believed that the physical mechanism responsible for the energy transfer from the solar wind to the Earth's Magnetosphere is magnetic reconnection between the Interplanetary Magnetic Field (IMF) and the Earth's Magnetic Field (Tsurutani and Gonzalez, 1997). Thus, it is necessary that the IMF has substantial component in the –Z direction (considering GSM coordinate system), also called Bs, southward Bz. The interplanetary criteria for an intense geomagnetic storm, Dst < -100 nT, is a dawn-dusk interplanetary electric field greater than 5 mV/m for a period greater than 3 hours (Tsurutani and Gonzalez, 1987).

FORECASTING INTERPLANETARY DISTURBANCES USING COSMIC RAYS

An interplanetary disturbance, propagating from the Sun to the Earth, affects the galactic cosmic ray population in many ways. One of the most known is the "Forbush decrease". Some interplanetary disturbances like the interplanetary counterparts of coronal mass ejections (CME) can cause depressions in high energy cosmic rays along the IMF main direction, being detected up to 10 hours before the arrival of the CME to the earth (Munakata et al., 2000), according to the diagrama shown in Figure 1.

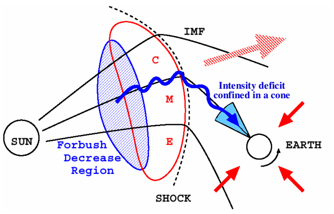

Fig. 1 – Loss-cone precursors. Nagashima et al. [1992], Ruffolo [1999].

Cosmic ray particles traveling close to light speed from this "depressed" region are observed as a "loss-cone precursor" at Earth typically 4 to 8 hours before the arrival of the interplanetary disturbance (Munakata et al., 2000). Since these structures are the main cause of intense geomagnetic storms, cosmic ray loss-cone precursors are used to forecast space weather variability.

EVENT OF NOVEMBER 18-20th, 2003

In November 18th 2003, 18:48 UT a flare was observed close to the central meridian of the Sun. In November 20th 2003, the most intense geomagnetic storm of the Solar Cicle 23 was observed, as indicated by the decrease in the Dst index, reaching –472 nT (Figure 2).

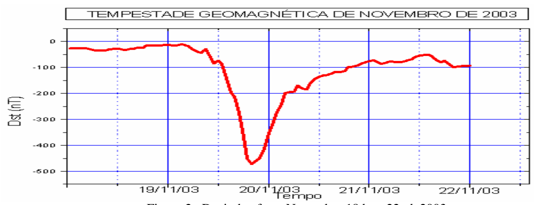

Figure 2 –Dst index from November 18th to 22nd, 2003

A sudden increase in the intensity of the Interplanetary Magnetic Field B, density, speed and temperature, on November 20th (at ~08:00 UT), indicating the arrival of a shock wave, as observed by the ACE satellite is shown in Figure 4. Following this shock, a southward excursion of the Bz component some hours later was observed. This event had the characteristics of an interplanetary magnetic cloud, given its smooth rotation in the direction of the magnetic field.

The observations with the Ground Multi-Directional Cosmic Ray-Muon Detector, Figure 3, installed in the at Southern Space Observatory – SSO, in São Martinho da Serra, South of Brazil, from 18 to 22 of November 2003, is presented in Figure 5. It shows the percent variation, in relation to the annual average value, for the vertical direction, V (top panel), and the other directions below it. One can observe a decrease on November 20th, 2003 at 22:00 UT. This decrease was caused by the interplanetary magnetic cloud and its associated shock wave of Figure 4.

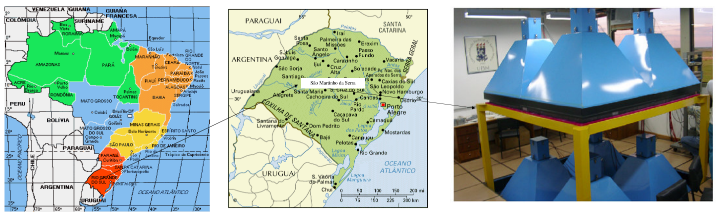
Figure 3 - The Ground Multi-Directional Cosmic Ray-Muon Detector installed at the Southern Space Observatory – SSO, in São Martinho da Serra, South of Brazil.

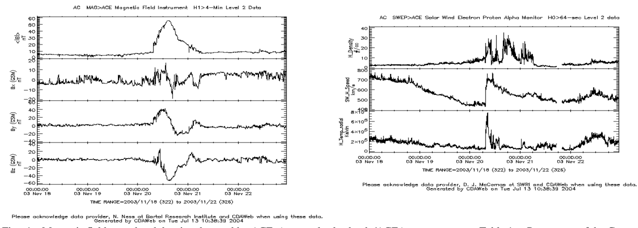

Fig. 4 – Magnetic field, speed and density observed by ACE. (www.srl.caltech.edu/ACE).

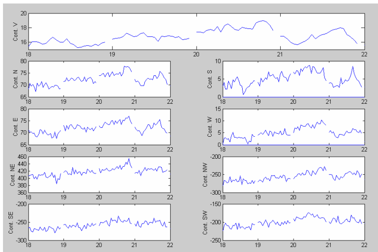
Fig. 5 – Muon data from 18th to 20th of November, 2003 obtained with the Multi-Directional Cosmic Ray Detector, SSO, Brazil, showing the decrease on November 20th, 2003.

Table 1 – Parameters of the Geomagnetic Events

Date	Loss-cone/hours in advance* (Munakata et al., 2000)	Interplanetary observation	Type of interplanetary structure	Peak marnetic field in the sheath (nT)	Peak magnetic field inside the ejecta (nT)
Mar. 8th (1993)	NP	IMP-8	2 Shock/sheath	20 (35?)**	-
May 15th (1997)	EV / 9 hours	WIND	Shock/Cloud	25	25
Nov. 6th (1997)	NP	WIND	Shock/Cloud(?)	20	20
Sep. 24th (1998)	LC / 3.5 hours	ACE	Shock/Cloud(?)	40	20

* NP = no precursor; EV = enhanced variation; LC = loss-cone (Munakata et al, 2000).
** Short duration peak.

CONCLUSIONS

Analyzing Munakata et al. (2000) events, where they identified loss-cone precursors for several disturbed periods, we could find good quality interplanetary data for 4 of them: March 8th, 1993 (IMP-8); May 15th, 1997 (WIND); November 6th, 1997 (WIND); and September 24th, 1998 (ACE), shown in Table 1.

The event of March 8th, 1993 was a double shock, with no clear eject signature. Magnetic field after the second shock was around 20 nT for some hours, with a fast excursion to 35 nT. The event of May 15th, 1997 was a clear magnetic cloud after a shock front. Magnetic field inside both the cloud and the sheath region was around 25 nT for several hours. The event of November 6th, 1997 event was a cloud-like structure after a shock front. Magnetic field was less than 20 nT during the event. The event of September 24th, 1998 was a cloud-like structure, after a shock front. In the sheath, magnetic field reached 40 nT, and inside the cloud-like structure it was around 20 nT for some hours. According to Table 1, in 2 of these events no precursors was observed (NP), one loss-cone structure was observed (LC) and one enhanced variation (EV).

We have presented a brief analysis of the interplanetary origins of the intense geomagnetic storm on November 20th, 2003 together with a preliminary analysis of the cosmic rays (muons) observations made at the Southern Space Observatory – SSO, Brazil. We analyzed the interplanetary structures associated with 4 events studied by Munakata et al. (2000).

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