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Modulations of galactic cosmic ray density and density gradient caused by sector boundary of solar wind magnetic field

Yoshitaka Okazaki[1]; Kazuoki Munakata[2]; Hiroshi Fukunishi[1]

[1] Dept. of Geophysics, Tohoku Univ.; [2] Physics Department, Shinshu Univ

Kota and Jokipii [1983] pointed out from their model calculation that latitudinal distributions of Galactic Cosmic Ray (GCR) density depend on the polarity of the solar magnetic field (A). It was shown that at the time when A is positive (A is negative) GCR density has its local maximum (minimum) at the sector boundary.

Co-rotating Interaction Region (CIR) is a compressed region formed at the leading edge of high-speed solar wind streams originating in coronal holes as they interact with the preceding slow wind. CIR is one of the structures causing a modulation of GCR density observed at the Earth with a time scale of several days. Because CIRs tend to have a sector boundary, modulation of GCR density observed at the Earth would be due to latitudinal density distributions of GCR and variations of solar wind speed and magnetic field

Richardson et al. [1996] and Richardson [2004] statistically investigated CIR-driven modulations using the data obtained by satellites such as Helios and IMP 8. By examining the GCR density depressions in CIRs with and without the sector boundaries, they concluded that sector boundaries do not organize the GCR density. On the other hand, a 22-year cycle in the amplitude of depressions of GCR density was confirmed. They suggested that this is caused by changes in large-scale solar magnetic filed.

In this study we have used the data of GCR density and density gradient in the interplanetary space obtained by the Muon detector network. We have examined a relationship between the density gradient and the solar wind magnetic field. It has been found that GCR density tends to have its local maximum (minimum) at the sector boundary when A is positive (A is negative). This result supports the latitudinal density distribution calculated by the model [Jokipii and Kota,1983].

Because the Muon detector network measures the higher energy (~60 GeV) GCR having a larger Larmor radius in the interplanetary magnetic field as compared with the satellite observations (more than several tens MeV), it is expected that GCR intensity observed by the network is more sensitive to an effect of large-scale solar wind magnetic field structure. The numerical model by Jokipii and Kota [1983] predicts the large-scale GCR distributions symmetry with respect to the sector boundary. Modulations of GCR density and density gradient derived from the observation with the Muon detector network, therefore, may show an effect caused by such large-scale latitudinal distribution.

In this study, we have investigated CIR-driven modulations of GCR density and density gradient. We have distinguished whether or not the CIR includes a sector boundary. Moreover, assuming a slab-shaped modulated region we have deduced the structure causing the observed variations of GCR density and density gradient. From the analysis using the data obtained for the period from 2001-2006 (A is negative), the structure which has its local maximum along the sector boundary tend to be deduced in case of CIR which includes a sector boundary. In case of CIR which does not include a sector boundary, the slab-shaped structure which has a depression of GCR density and inclines to the pole has been obtained in some events. This structure would correspond to the barrier structure accompanied with the local CIR structure as indicated by the Richardson et al. [1996].

In the presentation we will discuss the analysis result for the period from 1996-1997 (A is positive) in addition to the results mentioned above. We are planning to compare the Muon network data to the data obtained by Neutron detector. We will also report them.