Study on the solar modulation of GeV-energy electrons observed with the CALET

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Abstract:

In August 2015, the CALorimetric Electron Telescope (CALET), designed for long term observations of high energy cosmic rays, docked with the International Space Station (ISS) and began to collect data from the middle of October 2015. The CALET measures the cosmic ray electron spectrum over the energy range of 1 GeV to 20 TeV. One of important purposes of the CALET observations is the variation of cosmic ray flux which is correlated with 11 years-cycle-variation of sun-spot numbers. The CALET observes GeV-energy events with Low-Energy Trigger (LE-trigger); energy thresholds are set to detect shower events with energies over 1.0 GeV. Measurement of GeV-energy electrons with LE-trigger is active only at high latitude where maximum cutoff rigidity is 5.0GV. As ISS moves 1 cycle of its orbit, LE mode works 2 times at north and south for 90 seconds in each.

In this paper, we will analyze the observed short and long term variations of the electron flux. For long term variation, we will present modulation parameter (ϕ) by using Force Field approximation which is shown below.

$$\frac{J(E)}{E^2 - m^2} = \frac{J_{LIS}(E+\phi)}{(E+\phi)^2 - m^2}$$

In this equation, $J(E)$ is the observed flux, and $J_{LIS}(E+\phi)$ is the Local Interstellar Spectrum (LIS). For this calculation, we use the LIS model which was calculated by Potgieter et al.[2] by using the results of PAMELA observation from 2006 to 2009. At the time that CALET's observation began, ϕ was 819 ± 30 [MV], and then it was decreasing as time passed until 531 ± 36 [MV] on July 2018. For short term variation, we will analyze Forbush decrease caused by solar activity. As presented in Table 1, eight Forbush decreases have been observed by the CALET until now. As an example, the CALET observed a Forbush decrease following an X-class solar flare occurred on Sep. 2017 as presented in Fig. 1. In this Forbush decrease, the average electron counting rate was 0.171 ± 0.006 [Hz], while the average electron counting rate outside the period was 0.201 ± 0.003. Therefore, the average counting rate decreased about 15% in this Forbush decrease. In addition, we fit the following function $I_0(t)$ of time *t* to the counting rate observed during the Forbush decrease.

$$I = I_0 - A \cdot \exp(-t/\tau) \text{ [1]}$$

, where I_0 and A are free parameters, together with τ representing the recovery time. In case of the X-class solar flare, therse values are obtained as; $I_0 = 0.195 \pm 0.003$ [Hz], A=0.040±0.008 [Hz], τ =8.86±4.22 [day], with $\chi^2/NDF = 1.36$.

Moreover, we will describe an automatical GeV-electron analysis system which is developed by us and useful to observe the short term variation of the electron flux in real time.

Table 1 Date of Forbush Decreases and Flares which occurred at the same time

Date of Forbush Decrease	Date of Flare	Size of Flare
2017/09/08	2017/09/06	X
2017/08/17	2017/08/14	C
2017/07/17	2017/07/14	M
2016/10/12	2016/10/12	C
2016/07/20	2016/07/18	C
2015/12/31	2015/12/29	M
2015/12/20	2015/12/19	C
2015/11/07	2015/11/05	M

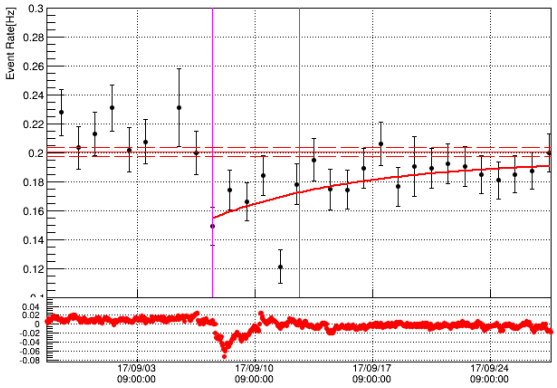

Fig.1 CALET observation of Forbush decrease on Sep. 2017(3.6～10GeV). Black plots show GeV-energy electron counting rate and red plots show neutron monitor counting rate at OULU station. The left pink line shows the time when the Forbush decrease occurred, and the right pink line shows 5 days after the decrease.

Reference:

[1] Ilya G. Usoskin, et al. , Proc of the 30th International Cosmic Ray Conference, 2008, vol1, p.327-330

[2] M.S.Potgieter, et al., Modulation of Galactic Electrons in the Heliosphere During the Unusual Solar Minimum of 2006-2009:A Modeling Approach. The Astrophysical Journal. 2015, vol.810, p.141-150.