29th International Cosmic Ray Conference Pune (2005) **2**, 453–456

CALET Observations of Galactic Electrons in the Heliosphere

Y. Komori[a], S. Torii[b], T. Tamura[c], K. Yoshida[c], J. Nishimura[d], T. Terasawa[e], H. Fuke[d], K. Hibino[c], M. Ichimura[f], K. Kasahara[g], K. Kashiwagi[c], Y. Katayose[h], H. Kitamura[i], T. Kobayashi[j], S. Kuramata[f], F. Makino[k], K. Mizutani[l], H. Murakami[m], S. Okuno[c], Y. Saito[d], M. Shibata[h], M. Takayanagi[d], N. Tateyama[c], H. Tomida[d], Y. Uchihori[i], S. Ueno[d], T. Yamagami[d] and T. Yuda[c]

(a) Kanagawa University of Human Services, Kanagawa 238-8522, Japan
(b) Advanced Research Institute for Science and Engineering, Waseda University
(c) Faculty of Engineering, Kanagawa University
(d) Institute of Space and Astronautical Science, JAXA
(e) Department of Earth and Planetary Physics, University of Tokyo
(f) Department of Physics, Hirosaki University
(g) Department of Electronic & Information Systems, Shibaura Institute of Technology
(h) Department of Physics, Yokohama National University
(i) National Institute of Radiological Sciences
(j) Department of Physics, Aoyama Gakuin University
(k) Space Environment Utilization Center, JAXA
(l) Department of Physics, Saitama University
(m) Department of Physics, Rikkyo University
Presenter: Y. Komori (komori-y@kuhs.ac.jp), jap-komori-Y-abs1-sh36-poster

The CALorimetric Electron Telescope(CALET) mission is proposed to measure galactic electrons and gamma rays on ISS/JEM for three years[1]. In this paper we report the purpose of this project in solar physics and the expected results from precise measurement of electron energy spectrum in the 1-100GeV energy range. The CALET measurement of long-term variations of the energy spectrum will produce a wealth of data to investigate electron propagation in the heliosphere. CALET does not distinguish positive charge from negative one. However, we can evaluate the charge sign dependence of solar modulation using correlation with the neutron monitors, since most particles are negative electrons in this energy range. Further we estimate transport parameters, mainly the energy dependence of diffusion coefficient in the heliosphere. CALET will also have a capability of measuring the short-term variation of around ten Forbush decreases(Fds) for three years. Precise measurements of the energy spectral variation of Fds will give a conclusion of the energy dependence of Fds.

1. Introduction

CALET has purposes to explore the electron origin nearby solar system and to search for dark matter signatures through electron and gamma-ray measurements in the energy range above 100GeV[2]. In the lower energy range below 100GeV, CALET will measure intensity variation of electrons caused by solar activity, both the long-term and the short-term variations. A number of balloon-borne and spacecraft measurements of cosmic ray electrons have been performed for 40 years, in which the long-term measurements have been limited below several GeV. Those results have shown that galactic cosmic rays are largely influenced by solar modulation. On the other hand the influences above several GeV have not yet been measured. The CALET instrument has capability of the precise measurement of electron spectral variations over a wide range of 1-100GeV energies. In this paper, we discuss expectations of some propagation models and Forbush decrease events from the CALET observations.

2. Long-term observations – modulation models –

Galactic cosmic rays are modulated by solar activity during the course of propagating in the heliosphere. Those modulations are estimated by several propagation models which are based on Parker's transport equation as reviewed by Potgieter [3]. The simple diffusion-convection model with a spherical symmetric geometry, the Force-Field(FF) approximation[4], has been widely used to interpret modulated results for cosmic ray measurements. Galactic electrons below 10GeV have been measured for long durations by the balloon-born instruments of LEE(1968–)+AESOP(1990–) and by the spacecraft experiments of ISEE3/ICE(1978–1994)[5] and Ulysses(1990–)[6][7]. Those results have shown the charge sign dependence of cosmic ray modulation throughout the change of solar magnetic field polarity. The drift dominated modulation model has been presented to explain the charge sign dependence. The long-term observation will be planed for the purpose of verifying these propagation models using the electron intensities in the wide energy range of 1-100GeV.

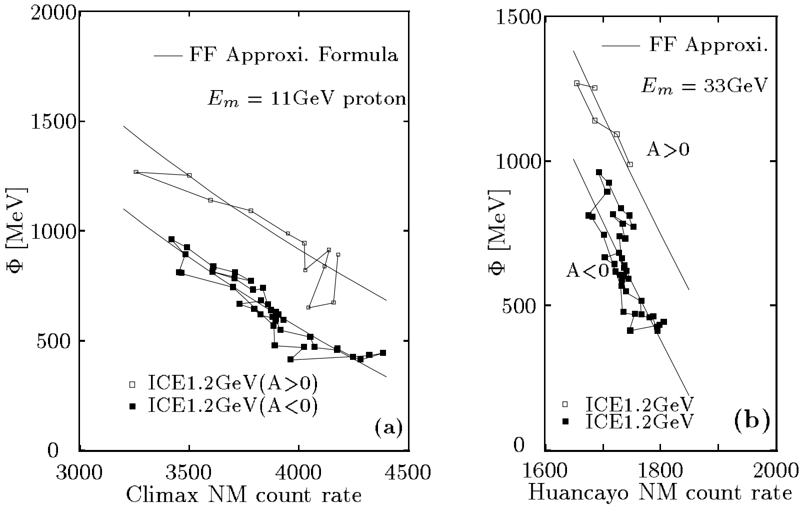

Figure 1. (a) The correlations between the modulation parameter Φ[MeV] and the Climax neutron monitor count rate N [8] . ICE 1.2GeV electron data[5] are estimated from the local interstellar spectrum shown in Fig. 2. The thin curves show 11GV proton curves of FF approximation formula with $N_{max} = 5000, 5800$. (b) Similarly shown in the case of Huancayo neutron monitor. The curves show 33GV proton curves with $N_{max} = 1900, 2000$.

The FF approximation has actually been used to interpret modulated results by the parameter Φ[MeV] for cosmic ray measurements. It depends on the structure of the magnetic field in the heliosphere through the diffusion coefficient of cosmic rays, the solar wind speed and the heliospheric boundary. As the two magnetic field models, Parker's model or Fisk's model are recently controversial, the structure has not been well known and therefore the application of FF approximation is not determined. The parameter Φ has the definite relationship with the neutron monitor count rate N at the response energy E_m as shown in Fig. 1. The CALET long-term observation will give a lot of (N, Φ) data and give verification of this $\Phi - N$ relationship at various energies. As shown in Fig 1, the ICE 1.2GeV data are separated into two groups of different solar polarities and each group generally agrees with the FF approximation curve at both the Climax(E_m = 11GeV) and Huancayo(E_m = 33GeV) neutron monitors. We will confirm this separation and investigate the correlations with various neutron monitor data.

The diffusion coefficient of galactic cosmic rays in the heliosphere is currently not well known. We will investigate how its energy dependence appears in the observed electron spectrum. The modulated electron spectra are shown in Fig. 2 in the case that the diffusion coefficient has the energy index $\alpha = 0.3,\ 1.0$. The smaller the value of α, the more modulated the electron spectrum with increasing energy. The observed data below 10GeV seem to agree with the curve of the index $\alpha = 1$. CALET will obtain the energy index of the diffusion coefficient from the spectral changes of 1-100GeV energy range.

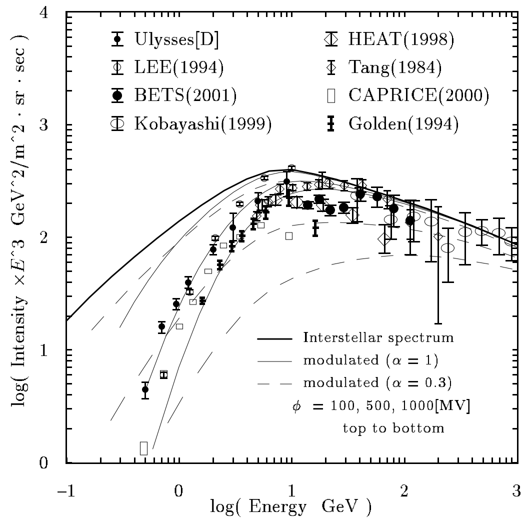

Figure 2. Expected electron modulated spectra with the energy dependence of diffusion coefficient of 0.3, 1. ϕ[MV] represents the parameter including the boundary of solar magnetosphere and the solar wind speed and is related with the energy part of the diffusion coefficient $D_2(E)$ of $\Phi \sim (p/D_2)\phi$.

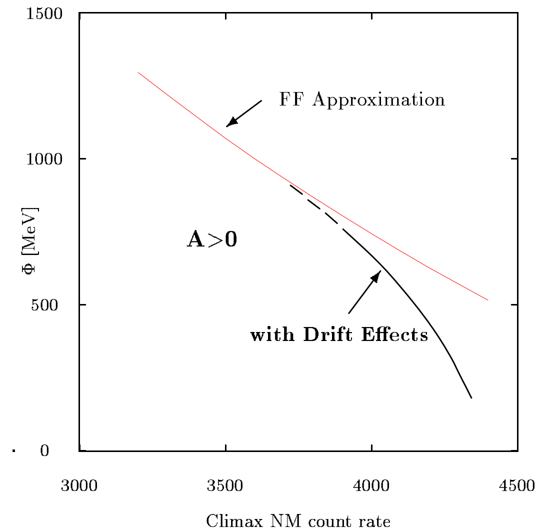

Figure 3. The $\Phi - N$ relationship : The thin red curve represents the FF approximation expression at the response energy 11GeV of the neutron monitor[8], while the thick curve is an expected $\Phi - N$ curve of electrons from the drift model in the solar quiet period of A>0, which is just estimated qualitatively.

The model considering drift effects in the heliospheric modulation of cosmic rays[9] is widely accepted because it can reproduce the flat (A>0) and the peak (A<0) shape in neutron monitor profile during solar minimum. As the solar magnetic field reverses the polarity every 11 years, the drift varies with this period. It has also been used for explaining the charge sign dependence of modulation. If the drift dominates, in the A>0 period after 2010, electron flux has a peak profile, while the neutron monitor count rate N has a flat profile. This means that electron flux, namely Φ, changes largely and N little changes, so that the slope of $\Phi - N$ curve is expected to be steeper with increasing N as shown in Fig. 3. We will confirm this steepness at various energies and indicate the drift effects quantitatively.

The recent results by BESS[10] and AESOP-LEE[5] experiments have suggested the charge sign dependence of modulation in solar maximum. On the other hand the recent Ulysses result[11] indicates that drifts are only of minor importance at solar maximum. Does the charge difference appear not only in solar minimum but in solar maximum? We are interested in both the magnitude of the difference and the period of the appearance. In addition, does only drift effect cause such charge sign dependence of modulation? In which level of the interstellar spectral calculation is FF approximation valid? The CALET observation will give some information about those questions.

3. Short-term observations – Forbush decreases –

Forbush decrease(Fd) events are so various and complex that the causes and mechanisms have not yet been solved. We will investigate the energy dependence and the charge sign dependence of Fds using spectral changes in the 1-100GeV energy range and correlations with the neutron monitor count rate. Fds are expected ∼5 events(>%4)/year at the solar minimum period and 7–10events at the maximum[12], so that more than ten Fds are expected for a three year exposure. Fds generally have the two-step decrease through the passages of the forward shock and the coronal mass ejection(CME)[13]. However some Fds are accompanied by no decrease by the shock or no decrease by CME. We will measure various types of Fd profiles for various energies. So far the charge sign dependence of Fds is controversial. Profiles of Fds in the recovery period may play an important role because the solar magnetic field largely influences that period. The Fd analysis of the IMP spacecraft and the neutron monitor over the period 1972–1984 have shown that the Fd recovery profile hardly depends on the solar polarity[14]. On the other hand other neutron monitor results in the period 1959–1980 say that the recovery in $A>0$ is more rapid than that in $A<0$ as expected from the drift effect[15]. We measure Fd profiles in the recovery period, compare with the neutron monitor profiles and copes with this controversy. In addition, the precise measurements of Fds are useful to estimate the background intensity for measurements of primary cosmic rays. If the measurement period of cosmic rays falls on Fd events, it becomes necessary to estimate the background intensity of the Fds. In particular, we consider that the measurement of Fds by electrons is valuable for the negative charge measurements below 10GeV.

4. Conclusions

The measurements of cosmic ray electrons on the space station not only have the great advantage of extremely low intensity above 1TeV but provide a lot of data of spectral variation below 100GeV for investigation of the solar modulation of cosmic rays. The CALET instrument has capability of the precise measurement of electron spectrum over a wide range of energies, so that it will give us the sufficient data for estimates of the energy dependence of cosmic ray propagation in the heliosphere and of the Fd events. Further the electron measurements will give certain information about the charge sign dependence of those variations.

References

[1] S. Torii et al., 29th ICRC, Pune, 2005
[2] K. Yoshida et al., 29th ICRC, Pune, 2005
[3] M.S. Potgieter, Space Sci.Rev., 83, 147, 1998
[4] L.J. Gleeson and W.I. Axford, ApJ, 154, 1011, 1968
[5] J.M. Clem et al., ApJ, 464, 507, 1996; JGR, 109, A07107, 2004
[6] C. Rastoin et al., A&A, 307, 981, 1996
[7] B. Heber et al., Geophys.Res.Lett., 26, 2133, 1999
[8] Y. Komori, 28th ICRC, 7, 3847, 2003
[9] J. Kota and J.R. Jokipii, ApJ, 265, 573, 1983
[10] Y. Asaoka et al., Phys.Rev.Lett., 88, 5, 2002
[11] B. Heber et al., 35th COAPAR Scientific Assembly, 2005
[12] http://helios.izmiran.rssi.ru/cosray/events.htm
[13] H.V. Cane, Space Sci.Rev., 93, 55, 2000
[14] J.A. Lockwood et al., JGR, 91, 2851, 1986
[15] M.S. Mulder et al., ApJ 303, L75, 1986