



1

Study on the Solar Modulation of GeV-energy Electrons Observed with the CALET

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Appreciation NIPR for Polar Patrol Balloon(PPB) !!

PPB-BETS is the former experiment of CALET.

This experiment was conducted in 2004 with the support of NIPR, especially Yamagishi-sensei and Kadokura-sensei.

We appreciate NIPR for PPB-BETS as the CALET members!! Without PPB-BETS, there was no CALET!







CALorimetric Electron Telescope (CALET) on the ISS



Detector for Observation of e^{-}(+e^{+})



CHD (Charge Detector)

- Charge measurement
- **IMC** (Imaging Calorimeter)
 - Arrival direction

TASC(Total Absorption Calorimeter)

• Energy measurement (27X₀)

High energy cosmic ray initiate shower development in the calorimeter.



GeV-energy Electron Shower Example: Electromagnetic Cascade



GeV-energy Proton Shower Example: Hadronic interaction and Electromagnetic Cascade

Detector for Observation of $e^{-}(+e^{+})$





CHD (Charge Detector)

- Charge measurement
- **IMC** (Imaging Calorimeter)
 - Arrival direction

TASC(Total Absorption Calorimeter)

Energy measurement $(27X_0)$

<u>Measurements for GeV-energy $e^{-}(+e^{+})$ </u>

- 1. Energy threshold: Trigger GeV-energy **Events by IMC+TASC**
- 2. Tracking: Determine direction by IMC
- 3. Charge determination: Detect charge by CHD
 - CHD energy deposit to remove $Z \ge 2$
- 4. e/p separation: Determine by shower development of IMC+TASC · Proton contamination = 5% over 2GeV
- 5. Energy Reconstruction: Use Energy deposit of IMC+TASC
 - Energy resolution = 8% @ 3GeV

Yearly: Observation of 11(22) years-cycle

CALET observed GeV-energy $e^{-}(+e^{+})$ (here after electron) during the period of solar minimum.

Approaching the solar minimum, **GeV-energy electron flux is increasing steadily**. ⇒Also, solar activity is going to be weakened ("Grand" Solar Minimum). It could be expected that electron flux will rise in the near future.



Fig.2 Solar Modulation 11(22) years-cycle

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Monthly: Long term variation of electron count rate

Electron which has lower energy is susceptible to solar activity.

Moreover, from July to Sep. in 2017, it might be considered that not only CME (including both of foreside and backside CME) caused reduction of 1~5 GeV electron count rate, but also CIR would affect the count rate.



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Daily: Observation of Forbush Decrease with CALET

- According to the Space Weather Services, Forbush decreases(FD) were observed 8 times during CALET's observation period.
- To get much more events for daily analysis, a higher Rigidity Cutoff (<3.0GV) is selected for observation in energy range of 3.6-10GeV.
- As seen in Fig.5, a FD event is detected in coincident with X-class solar flare. By fitting with the following equation, we obtained a recovery time of τ =8.9±4.2 [day]. I = I₀ - A · exp(-t/τ)
- Second decrease was observed during the recovery timing of FD although the statistical significance is not so high.
 Since this kind decrease has not been reported in other observations, it is necessary to study the origin.

Tab.1 Date of Forbush Decreases and Flares		
which occurred at the same time		
ate of Forbush Decrease	Date of Flare	Size of Flare
2017/09/08	2017/09/06	Х
2017/08/17	2017/08/14	С
2017/07/17	2017/07/14	Μ
2016/10/12	2016/10/12	С
2016/07/20	2016/07/18	С
2015/12/31	2015/12/29	Μ
2015/12/20	2015/12/19	С
2015/11/07	2015/11/05	Μ



Development of automatic GeVenergy electron analysis system for quick report of Space Weather

To provide a prompt information of the daily count rates, an automatic analysis system has been developed. The following data are created and are shown on local data monitor.

- Daily electron Count Rate
 - Energy: 3.6~10GeV
 - Rigidity Cutoff: <3.0GV
 - NM count rate is shown bottom.
 - It can be used for observation of Forbush decrease.
- Daily/Monthly electron Flux
 - Energy: 3 energy range(1-2, 2-5, 5-10GeV)
 - Rigidity Cutoff: <0.8GV
 - These figures could show not only short-term but also long-term variation.
- This system will be served for quick Space Weather report.



Summary

CALET GeV-electron observations are reported in following three time-scale.

- Yearly: Solar Modulation
 - Correlation between the GeV-energy electron flux with CALET and NM count rate is observed.
 - The GeV-energy electron flux is increasing steadily toward "Grand" Solar Minimum in following years.
- Monthly: CIR+CME?? And/or Backside CME??
 - In July-Sep. 2017, monthly decrease of GeV-energy electron flux occurred.
 - As hypothesis, CIR + CME(including backside CME) could cause this decrease.
- > Daily: Forbush Decrease
 - Forbush decrease, caused by X-class Flare, was observed.
 - Although the statistical significance is not so high, unexpected second decrease was observed.
- Quick automatic analysis system was developed for these observations for future Space Weather Broadcast.