The CALET Project for Investigating High Energy Universe

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Kashiwa February 24th 2006
Cosmic Ray Energy Spectrum at the Highest Energy for Electrons and Protons

Nearby (or Unknown) Sources
- Distance: < 1 kpc
- Age: < 10^5 year

Hadron
- GZK Cut-off

Electron
- IC, Synchrotron Cut-off

> 1 TeV

Knee
- (1 particle per m^2-year)

Anise
- (1 particle per km^2-year)

10^30 Scale
CALET: CALorimetric Electron Telescope

CALET Mission Concept

● Instrument:
  High Energy Electron and Gamma-Ray Telescope Consisted of
  - Imaging Calorimeter (IMC)
  - Total Absorption Calorimeter (TASC)

● Launch:
  HTV: H-IIA Transfer Vehicle

● Attach Point on the ISS:
  Exposed Facility of Japanese Experiment Module (JEM-EF)

● Nominal Orbit:
  407 km, 51.6° inclination

● Life Time:
  3 years (minimum)

● Mission Status
  Mission Concept Study
  Launch around 2012 in Plan

CALET Payload:

- 1 GeV ~ 10 TeV for electrons
- 20 MeV ~ TeV for gamma-rays
- several 10 GeV ~ 1000 TeV for p~Fe
- Weight: 2500 kg
- Geometrical Factor: 1 m²sr
- Power Consumption: 600 W
- Data Rate: 600 kbps
Origin and Propagation of Electrons

- Detection of Nearby Sources
- Electron Propagation in Our Galaxy
- Acceleration by Supernova Shock Wave
- Solar Modulation

Expected Observation by CALET

- Galactic component excluding $T \leq 10^5$ yr and $r \leq 1$ kpc
- Monogem
- Cygnus Loop
- Vela

Energy Budget in the High Energy Universe, ICRR, Kashiwa
Model Dependence of Nearby Source Effect

Ec=∞, ΔT=0 yr, Do=2 x 10^{29} \text{ cm}^2/\text{s}

Ec=20 \text{ TeV}, ΔT=1-10^4 \text{ yr}

Do=5 \times 10^{29} \text{ cm}^2/\text{s}
Gamma-Ray Observation in 20 MeV~10 TeV

CALET on the ISS orbit without attitude control of the instrument:
Wide FOV (~45°) and Large Effective Area (~0.5 m²) in 20 MeV-10 GeV

- Sky coverage of 70% for one day
- All sky coverage in 20 days
- Typical exposure factor of ~50 days for point source

Good Energy Resolution (< a few %) over 100 GeV

- Measurement of change of power-law spectral index
- Possible detection of gamma-ray lines from Neutralino annihilation

Point Source Sensitivity in One-Year Observation
Nature of Cosmic Gamma-Ray Sources (1)

- **Diffuse Components**

  **Electron or Proton Origin in the Galetic Plane?**
  **Origins in the Extra-Galactic Space?**

**Galactic Diffuse Component**

**Extra-Galactic Diffuse Component**

Detrection Limit by CALET
Nature of Cosmic Gamma-Ray Sources (2)

- AGN sources and absorption by IR background

Expected AGN spectra after absorption by IR background

- Supernova Remnants and Pulsar

Predicted CALET measurement region of Crab unpulsed spectrum in the overlap region with ground-based Cherenkov telescopes.
Nature of Cosmic Gamma-Ray Sources(3)

- High Energy Gamma-Ray Bursts

An expected gamma-ray burst spectrum, assuming a power-law
Origin and Propagation of Proton and Nucleus (1)

- *Supernova Shock Acceleration*

*Change of power spectrum index depending on Z?*

**Measurements of proton and heavy ion flux in the energy region exceeding 1 TeV, in which magnet spectrometer is not capable.**

**For proton measurement:**

\[ S_{\text{eff}} \sim 0.5 \, \text{m}^2 \times \frac{1}{3} \text{ (for p)} \sim 0.17 \, \text{m}^2 \]

**Exposure factor for 1000 days:**

\[ 170 \, \text{m}^2 \text{ sr day} \sim 1.5 \times 10^{-7} \, \text{m}^2 \text{ s sr} \]

**Expected numbers of protons:**

<table>
<thead>
<tr>
<th>Energy (TeV)</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>( \sim 10^6 )</td>
</tr>
<tr>
<td>10</td>
<td>1.8 \times 10^4</td>
</tr>
<tr>
<td>100</td>
<td>3.2 \times 10^2</td>
</tr>
<tr>
<td>1000</td>
<td>6</td>
</tr>
</tbody>
</table>

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Energy Budget in the High Energy Universe, ICRR, Kashiwa
Origin and Propagation of Proton and Nucleus (2)

- Propagation in Our Galaxy : Structure of the Galaxy
  Leaky box model is still valid in the Knee region?

$B / C$ Ratio

$Sub Fe / Fe$
SUSY Dark Matter Search by Gamma-Ray Line

- 690 GeV neutralino annihilating to $\gamma \gamma$
- Clumpy halo as realized in N-body simulation by Moore et al. (ApJL 1999)
- Simulated Signal in CALET for 3 years

Energy Resolution
$\sim 1.2\%$

$\chi \chi \rightarrow \gamma, \nu$

$K, K DM \rightarrow e^\pm$

$\Phi_\gamma = \frac{N_\gamma \sigma v}{m_\chi^2} \frac{1}{4\pi} \int \int_{\text{line of sight}} \rho^2(\ell) d\ell d\Omega$

$m_\chi = 690\,\text{GeV}$

$N_\gamma \sigma v = 1.5 \times 10^{-28}\,\text{cm}^3\text{s}^{-1}$
Dark Matter Search by Positrons ( & Electrons )

Positron will be measured by
- PAMELA flying soon
- AMS to be launched in 2008 on ISS
- CALET on ISS (can not separate e+ and e-)

Simulation for 300 GeV KK DM

Conceptual Structure of CALET

Requirements:
- Large Acceptance: 1 m² sr
- Imaging Capability: < 1 mm
- Hadron Rejection Power: ~10⁶
- Energy Measurement:
  - 20 MeV~10 TeV for e, γ
  - 1 ~ 1000 TeV for hadrons (Optional)

SciFi/Lead Imaging Calorimeter (IMC):
- Area: ~1 m²
- SciFi Belt: 1 mm square x ~1 m length
  - 17 layers (x & y)
- Lead Thickness: 4 r.l, 0.13 m.f.p

Total Absorption Calorimeter (TASC):
- Area: ~0.5 m²
- BGO Log: 25 x 25 x 350 mm
  - 7 layers (x & y)
- Thickness: 32 r.l, 1.6 m.f.p

Schematic Side View of CALET
- Anti-Coincidence System for Low E. γ
- Silicon Detector for High Z and Particle ID

Detector Weight: 1760 kg
Total Absorber Thickness: 36 r.l, ~1.7 m.f.p
Detector Components

SciFi Belt (32 x 2 layers)  64-anode PMT

FEC (VA32, TA, 16bits ADC, FPGA)

Si PIN Photodiodes  FEC with PD

BGO or PbWO₄

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Examples of Shower Profile by Simulation

- Gamma-ray 20 MeV
  - pair creation
- Gamma-ray 100 MeV
  - pair creation
- Gamma-ray 1 GeV
  - shower
- Gamma-ray 10 GeV
  - shower
- Electron 10 GeV
- Electron 100 GeV
- Electron 10 TeV
- Proton 3 TeV
- Proton 3 TeV
Electron Detection by CALET

Proton Rejection Power $\sim 10^6$

![Graph showing electron detection and proton rejection power. The graph plots $E_e^3 dN/dE_e$ (m$^{-2}$s$^{-1}$sr$^{-1}$GeV$^2$) against energy (GeV). The proton rejection power is indicated as $\sim 10^6$. The graph compares background protons and electrons with rejection power $x 10^{-5}$.](image)
Electron and Gamma-ray Separation

Gamma-ray selection from electron \( \sim 10^2 \)
Examples of Observed Showers in Beam Test at CERN

- **Trigger**: IMC (512 SciFis+ 4r.l thick Lead)
- **Anti Trigger**: TASC (26 logs of BGO)
- **Beam**

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**Examples of Observed Showers**

- **e 100 GeV/c**
- **p 150 GeV/c**

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Imaging Calorimeter

MAPMT

HV Connector

Interface Connector

SciFi Belts

32 SciFi

64 SciFi

SciFi Belts 12 layers

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**Total Absorption Calorimeter**

- **BGO Crystal**
  - 25mm × 25mm × 300mm

- **Teflon Sheet**
  - 0.1mm thick × 3

- **Photodiode**
  - S3204-08
  - Area: 18mm × 18mm

- **Aluminized Sheet**
  - 12µm thick on both side

- **Beam**

- **Pre-amplifier**

- **Shaping Amplifier**
  - Shaping time ~2µs

**BGO Logs and PD**
CALET ~1/64 Scale Model for Balloon Experiment in 2006

- **Effective Area**: 128 mm × 128 mm (~164 cm²)
- **IMC**: 1024ch SciFi (1mm square) + 64-Anode PMT
- **TASC**: 24ch BGO Logs (2.5 cm × 2.5 cm × 30 cm) + Si PIN PD
Member List

Japan:

(1) RISE, Waseda University  (2) Kanagawa University  (3) JAXA  (4) Yokohama National University  
(5) Hirosaki University  (6) National Institute of Radiological Sciences  
(7) Shibaura Institute of Technology  (8) Rikkyo University  (9) Aoyama Gakuin University  (10) Kanagawa University of Human Services  
(11) Saitama University  (12) University of Tokyo

USA:
USRA: A. A. Moissev, J.F. Krizmanic

Louisiana State University: G. Case, M. L. Cherry, T. G. Guzik, J. B. Isbert, J. P. Wefel
Washington University in St Louis: W. R. Binns, M. H. Israel, H. S. Krawczynski
University of Denver: J. F. Ormes

Italy:
University of Siena and INFN: P.S. Marrocchesi, P. Maestro, M. G. Bagliesi, V. Millucci, M. Meucci, G. Bigongiari, R. Zei
University of Florence: O. Adriani, P. Papini, P. Spillantini, L. Bonechi, L. E. Vannucci
Scuola Normale Superiore & INFN Pisa: F. Morsani, F. Ligabue

China:
Purple Mountain Observatory, Chinese Academy of Science: J. Chang, W. Gan, T. Lu

JEM (KIBO) Survived

Thanks very much to both !!!
Launching Procedure of CALET

H-IIA Transfer Vehicle (HTV) (Japanese Carrier)

Launching of H-II Rocket

Separation from H-II

CALET launched by HTV

Approach to ISS

Pickup of CALET

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**Summary and Future Prospects**

- The JEM/EF facility of ISS is very suitable to cosmic ray observation at very high energies with a heavy payload.
- We have successfully been developing the CALET instrument for JEM/EF facility from the experience of balloon experiments.
- The CALET has capabilities to observe the electrons up to 10 TeV, gamma-rays in 20 MeV - a few TeV, proton and heavy ions in several 10 GeV - 1000 TeV, for investigation of high energy phenomena in Universe.
- We have already completed a pre-phase A study in last 6 years, and expect to start operations on the ISS/JEM around 2012.

*This work is supported by a part of “Ground-based Research Announcement for Space Utilization” promoted by Japan Space Forum*