JEM-EUSO
The Extreme Universe Space Observatory (EUSO) onboard the Japan Experiment Module (JEM) of the International Space Station

The JEM-EUSO Collaboration, led by RIKEN-Japan, brings together about 250 scientists, 76 Institutes from 13 Countries:

Japan, Europe, US, Korea, Mexico
An Innovative Space Mission doing astronomy by looking downward from the Space Station at the Earth Atmosphere.

*EUSO* is devoted to the exploration from space of the highest energy processes present and accessible in the Universe. They are directly related to the extreme boundaries of the physical world.
EUSO Science Goals

EUSO is intended to address basic problems of Fundamental Physics and high energy astrophysics.

- Investigation of the highest energy processes present and accessible in the Universe through the detection and investigation of the Extreme Energy Component of the Cosmic Radiation (EECRs / UHECRs with $E > 5 \times 10^{19}$ eV).
- Arrival directions and small-scale clustering will provide information on the origin of the EECRs and inter-galactic magnetic fields.
- Open the Channel of High Energy Neutrino Astronomy to probe the boundaries of the Extreme Universe and to investigate the nature and distribution of the EECR sources.

Parallel fields of scientific interest are represented by the systematic surveillance of Atmospheric Phenomena: Atmosphere as a Physical System, and Meteors.
DETECTION TECHNIQUE

Euso will observe the fluorescence signal looking to Nadir at the dark Earth atmosphere from its location on the ISS under a 60° full field of view. Fluorescence light will be imaged by a large Fresnel lens onto a finely segmented focal surface. A Cerenkov signal will be detected in a delayed coincidence with the fluorescence signal. The segmentation and the time resolution adopted will enable the reconstruction of the arrival direction and EAS energy, with an accuracy of order $\Delta E/E \sim 30\%$, and arrival direction ranging from a fraction of a degree to a few degrees depending on energy and zenith angle of the primary particle.
THE NATURAL DETECTOR
EARTH ATMOSPHERE

Atmosphere is required for the primary particle to interact and develop shower with a production of:

- Cherenkov light
- Fluorescence light

Details of the UV light production yield details of the primary particle:

- The amount of UV light produced is \( \propto \) to the particle’s energy
- The shape of the shower profile and the atmospheric depth of the shower maximum contain information about particle mass composition
HTV Transfer Vehicle

4m diameter, 10 m long
Outline of JEM Exposure Facility

Pressurized Module

Robotic Arm

Candidate position for JEM-EUSO
A monocular compact instrument

- Fresnel lens
- Focal surface
- Support structure
- System electronics

Diagram illustrating the components of the instrument.
Observation mode of JEM-EUSO

Vertical Mode

Tilted Mode

Larger exposure can be obtained
Field of View
SYSTEM ELECTRONICS

Multi-level trigger implementation

- **Trigger Mode 1 or normal mode**
  (EECRs up to 300µs, GTU=833ns)

- **Trigger Mode 2 or slow mode**
  (ex. Meteors up to 2 sec, GTU=833ns-- 1ms)

- **Trigger Mode 3 or fast mode**
  (ex. Calibration, GTU=200ns)

- ...
EUSO DETECTION TECHNIQUE

background measurement

BABY balloon flight: UV data profile (300 - 400 nm).
Science Objectives

- **Fundamental Objective**
  
  Extreme energy astronomy by particle channel
  
  Determine their origin and the acceleration mechanism

- **Exploratory Objectives**
  
  - Detection of extreme energy gamma rays
  - Detection of extreme energy neutrinos
  - Study of the galactic magnetic field
  - Verification of the relativity and the quantum gravity effect in extreme energy
  - Global observations of nightglows, plasma discharges and lightning
Cosmic Rays
Flux

From N. Sakaki
2nd AGASA
Mini Workshop, 2000
To obtain a statistical significant sample of EECR events at $E > 10^{20}$ eV, with flux value at the level of:

$$1 \text{ particle/} \text{year/}100 \text{ km}^2$$

or with very low interaction cross section (neutrinos), a giant detector is required. The Earth atmosphere, viewed from space with an acceptance area of the order of $5 \times 10^5 \text{ km}^2 \text{ sr}$, and a target mass of the order of $2 \times 10^{12} \text{ tons}$ constitutes an ideal target to UHE CR and cosmic neutrinos.
GZK Cutoff

\[
p + \gamma \rightarrow p + \pi^0 \\
p + \gamma \rightarrow n + \pi^+ \\
E_{\text{thr}} = 6.8 \times 10^{19} \text{ eV} \\
L = 1/\sigma \rho = 6 \text{ Mpc} \\
\rho \sim 4 \times 10^{\gamma} \text{ cm}^{-3} \\
\sigma = 135 \text{ mbarn}
\]
Success Criteria of the Mission

- **Full Success**: 
  Number of Events above $7 \times 10^{19}$ eV $> 1,000$

- **Minimum Success**: 
  Number of Events $> 500$
  Critical number to clarify the origin of EECRS

- **Extra Success**: 
  Achieve one or all of the exploratory objectives
Particle Astronomy by JEM-EUSO

- 1,000 events: $E > 7 \times 10^{19}$ eV
- Several dozen clusters expected
- All sky coverage

Distant source
EUSO in a year operation will cover all sky directions.

Total sky coverage plays an important role for anisotropy study.
Hillas plot
# Comparison with current observatories

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Aperture (km² sr)</th>
<th>Status</th>
<th>Start</th>
<th>Lifetime (years)</th>
<th>Duty cycle (incl. clouds)</th>
<th>Exposure (km² sr y)</th>
<th>Relative to Auger</th>
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</thead>
<tbody>
<tr>
<td>Auger</td>
<td>7,000</td>
<td>Operations</td>
<td>2006</td>
<td>4 (16)</td>
<td>1.0</td>
<td>27,370 (110,000)</td>
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<tr>
<td>TA</td>
<td>1,200</td>
<td>Operations</td>
<td>2008</td>
<td>2 (14)</td>
<td>1.0</td>
<td>2400 (16,000)</td>
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<td>TUS</td>
<td>30,000</td>
<td>developed</td>
<td>2012</td>
<td>5</td>
<td>0.14</td>
<td>18,750</td>
<td>0.2</td>
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<tr>
<td>JEM-EUSO (E~100 EeV) Nadir-Mode</td>
<td>470,000 (10xAuger including DC)</td>
<td>proposed</td>
<td>2017</td>
<td>5</td>
<td>0.14</td>
<td>330000 (5 years Nadir)</td>
<td>3</td>
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<tr>
<td>JEM-EUSO (highest Energies) Tilted-Mode</td>
<td>1,300,000 (26xAuger including DC)</td>
<td>proposed</td>
<td>2017</td>
<td>5</td>
<td>0.14</td>
<td>910000 (5 years tilted)</td>
<td>8</td>
</tr>
</tbody>
</table>
Protons & Nuclei, red points
Neutrinos, green circles
Upper limits on neutrino flux
Atmospheric Luminous Phenomena

- OH airlow from ground
- Lightning picture observed from ISS
- Leonid meteor swarm in 2001
- Various airglows
SUMMARY AND CONCLUSIONS

**JEM EUSO** is an innovative Space Mission doing astronomy by looking downward from the Space Station at the Earth Atmosphere

**JEM EUSO will provide unique results in:**

- 1 – Astrophysics
- 2 – Astroparticle Physics
- 3 – Cosmology
- 4 – Neutrino Astrophysics
- 5 – Fundamental Physics
- 6 – Atmospheric sounding