JEM-EUSO Mission

Extreme Universe Space Observatory (EUSO)
In the Japanese Experiment Module (JEM) of the International Space Station (ISS)

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Current Observatories of Ultrahigh Energy Cosmic Rays

Telescope Array
Utah, USA
(5 country collaboration)
700 km² array
3 fluorescence telescopes

Pierre Auger Observatory
Mendoza, Argentina
(19 country collaboration)
3,000 km² array
4 fluorescence telescopes
The era of particle astronomy begins

Prior to space exploration, astronomy relied on atmospheric transparency windows:

credit: NASA
The era of particle astronomy begins

Charged particle astronomy transparency window
Lower bound: deflection by magnetic fields
Upper bound: GZK cutoff

Magnetic fields
- galactic: microgauss [Vallée, New Astron Rev., 48, 763]
- intergalactic (in clusters): nanogauss

Deflections can interfere at energies below 10 EeV, even for relatively nearby extragalactic sources.

Need to go beyond HiRes, PAO, and TA.
The era of particle astronomy begins

Charged particle astronomy transparency window
Lower bound: deflection by magnetic fields
Upper bound: GZK cutoff (?)
The era of particle astronomy begins

Charged particle astronomy transparency window

Lower bound: deflection by magnetic fields
Upper bound: GZK cutoff

Transparency window:
  tens of EeV, for nearby sources

Need many events at tens of EeV energies!
Cosmic Ray Flux $\times E^2$

- ATIC
- Proton
- RUNJOB
- Tibet AS-γ (SIBYLL 2.1)
- KASCADE (QGSJET 01)
- KASCADE (SYBILL 2.1)
- KASCADE-Grande 2009
- HiRes I
- HiRes II
- Auger 2010

Kotera, AO 2011
Particle physics:
In a decade, we can probe particle interactions at >300 TeV CM from Space!!!
Composition mystery

Pierre Auger

HiRes and TA
How many EECRs $> 60$ EeV?

Before we see the sources?

1,000 is a good o.o.m. estimate

Dipole from direction of Cen A in Auger $> 60$ EeV:

(a posteriori) right ascension harmonic analyses

$$\alpha_d \hat{d} = \frac{3}{N} \int J(\hat{u}) \hat{u} \, d\Omega$$

$\alpha_d = 0.25$

Anchordoqui, Goldberg & Weiler ‘11

$5\sigma$ discovery requires 1,000 events (with whole sky coverage)
Population Separation needs 
1,000 events above 60 EeV

Kalli, Lemoine, Kotera ‘10

\[ X_C = \sum_{i=1}^{N_{tot}} \frac{(N_i^T - \langle N_{i,LSS} \rangle)(\langle N_{i,iso} \rangle - \langle N_{i,LSS} \rangle)}{\langle N_{i,LSS} \rangle} \]
or >250 events $E>80$ EeV mixed

Protons cut exponentially $>15$ EeV
Heavier nuclei dominate $>80$ EeV

Rouille D’Orfeil et al ‘13
How many EECRs > 60 EeV?

Auger w/ 3,000 km$^2$
- ~20 events > 60 EeV/yr

Telescope Array w/ 700 km$^2$
- ~5 events > 60 EeV/yr

Auger + TA ~ 25 events/yr > 60 EeV
40 years to reach 1,000
How many EECRs > 60 EeV?

Auger w/ 3,000 km$^2$
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Auger + TA ~ 25 events/yr

40 years to reach 1,000

Earth - surface ~ 5 $10^8$km$^2$

~3.4 $10^6$ events/yr
JEM-EUSO Mission

Japan, USA, Korea, Mexico, Russia, Europe: Bulgaria, France, Germany, Italy, Poland, Slovakia, Spain, Switzerland

13 Countries, 73 Institutions, 250 researchers
AMS Launch May 16, 2011

ISS-CREAM Sp-X Launch 2014

JEM-EUSO Launch Tentatively planned for 2017

CALET on JEM HTV Launch 2014

View from NASA: “Cosmic Ray Observatory on the ISS”
JEM-EUSO goals

- pioneer the study of EECR from Space
- increase exposure to EECR by 1 order of magnitude
- discover the nearby sources of UHECRs

EECR: Extreme Energy CRs $> 60$ EeV
UHECR: Ultrahigh Energy CRs $> 1$ EeV $= 10^{18}$ eV
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch date</td>
<td>2017</td>
</tr>
<tr>
<td>Mission Lifetime</td>
<td>3+2 years</td>
</tr>
<tr>
<td>Rocket</td>
<td>H2B (or <strong>Falcon9</strong>)</td>
</tr>
<tr>
<td>Transport Vehicle</td>
<td>HTV (or Dragon)</td>
</tr>
<tr>
<td>Accommodation on JEM</td>
<td>EF#9</td>
</tr>
<tr>
<td>Mass</td>
<td>1938 kg</td>
</tr>
<tr>
<td>Power</td>
<td>926 W (op.) 352 W (non op.)</td>
</tr>
<tr>
<td>Data rate</td>
<td>285 kbps (+ on board storage)</td>
</tr>
<tr>
<td>Orbit</td>
<td>400 km</td>
</tr>
<tr>
<td>Inclination of the Orbit</td>
<td>51.6°</td>
</tr>
<tr>
<td>Operation Temperature</td>
<td>-10° to +50°</td>
</tr>
</tbody>
</table>
Full Sky Coverage
with nearly uniform exposure

The ISS ORBIT

Inclination: 51.6°
Height: ~400km
Duty Cycle

Universitetsky Tatiana: satellite (Moscow State Univ) – operated January 2005 - March 2007, altitude 950 km, FOV 15° atmospheric surface of 250 km in diameter UV (310-400 nm) light

Duty Cycle between 18.4 and 22.2%

Figure 1. Duty cycle evaluated from real ISS trajectory in years 2005 till 2007 and simulated moonlight BG light.
Payload

- DAQ Electronics
- Support Structure
- Focal Surface Detector
- Housekeeping
- Simulation: Worldwide
- Optics
- Rear Fresnel Lens
- Iris
- Precision Fresnel lens
- Front Fresnel lens
- Telescope Structure
- BUS System: JAXA
- On-board Calibration
- Ground Based Calibration
- Ground Support Equipment
- Atmospheric Monitoring
FAST SIGNAL
duration 50 - 150 μs

a) Fluorescence
b) Scattered Cherenkov
c) Direct (diffusively reflected Cherenkov)

1 GTU gate time units = 2.5 μs

Background: 500 /m^2 sr ns

p, 10^{20} eV, 60 deg
JEM-EUSO Balloon

- Look down from the balloon with an UV telescope
  (3 lenses system + 1 PDM EM)
- Engineering test
- Background test
- Airshower from 40 km altitude

2009 Proposal submitted to CNES (France)
2011/6 Approved by CNES
2012/2 Approved to go to Phase B
→ 2014 spring, first launch from Canada or Sweden
Testing EUSO-Balloon (US NASA APRA)
Fly one aircraft equipped with two types of calibrated pulsed UV light sources.

Point Test: Fly airplane in field of view and fire flash lamp. Light travels directly from lamp to detector.

Track Test: Fly airplane outside field of view and shoot a UV pulsed laser across field of view. Light scatters out of the beam to the detector. (5 mJ Laser ~100 EeV Cosmic Ray)

Fly aircraft at altitudes between 2,000 and 10,000 feet.
JEM-EUSO in USA

Global Light System
<table>
<thead>
<tr>
<th>Location</th>
<th>Latitude</th>
<th>Elevation</th>
<th>Location</th>
<th>Latitude</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jungfraujoch (Switzerland)</td>
<td>47°N</td>
<td>3.9 km</td>
<td>Chacaltaya (Bolivia)</td>
<td>16° S</td>
<td>5.3 km</td>
</tr>
<tr>
<td>Mt. Washington (NH, USA)</td>
<td>44° N</td>
<td>1.9 km</td>
<td>La Reunion (Madagascar)</td>
<td>21° S</td>
<td>1.0 km</td>
</tr>
<tr>
<td>Alma-Ata (Kazakhstan)</td>
<td>44° N</td>
<td>3.0 km</td>
<td>Cerro Tololo (Chile)</td>
<td>30° S</td>
<td>2.2 km</td>
</tr>
<tr>
<td>Climax (CO, USA)</td>
<td>39° N</td>
<td>3.5 km</td>
<td>Sutherland (South Africa)</td>
<td>32° S</td>
<td>1.8 m</td>
</tr>
<tr>
<td>Frisco Peak (UT, USA)</td>
<td>39° N</td>
<td>2.9 km</td>
<td>Pierre Auger (Argentina)</td>
<td>35° S</td>
<td>1.4 km</td>
</tr>
<tr>
<td>Mt Norikura (Japan)</td>
<td>30° N</td>
<td>4.3 km</td>
<td>South Island (New Zealand)</td>
<td>43° S</td>
<td>1.0 km</td>
</tr>
<tr>
<td>Mauna Kea (HI, USA)</td>
<td>20° N</td>
<td>&gt;3.0 km</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAWC Site (Mexico)</td>
<td>19° N</td>
<td>3.4 km</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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