EUSO
Extreme Universe Space Observatory Update

Angela V. Olinto
The University of Chicago
Energy range of Radiation

total 28+ orders of magnitude
from $10^{-8}$ eV to 0.3 ZeV (CR: from $10^8$ to $10^{20}$ eV)
Fluxes of Cosmic Rays

by 2022

- Voyager I & II
- ACE/CRIS
- PAMELA
- AMS
- CALET
- ISS-CREAM
- ISS
- Balloon
- Satellites
- Extragalactic Cosmic Rays
- Galactic Cosmic Rays

Solar Influence

Super-TIGER

JEM-EUSO

Energy (eV)
Ultra High Energy Cosmic Rays

1962 John Linsley
$10^{20}$ eV event
Hillas Plot: $E_{\text{max}}$ required

Kotera & AO'11
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
Anisotropy Hints $> 60$ EeV
Statistically limited

E $> 5.7 \times 10^{19}$ eV  20° smoothing

Telescope Array

Auger Observatory

$\approx 5 \sigma$ pretrial

$\approx 3 \sigma$ pretrial
Extreme Universe Space Observatory (EUSO) in the Japanese Experiment Module (JEM) of the International Space Station (ISS)

Japan, USA, Korea, Mexico, Russia, Algeria
Europe: Bulgaria, France, Germany, Italy, Poland, Slovakia, Spain, Switzerland, Sweden
16 Countries, 300 researchers
Leading institution: RIKEN
PI: Piergiorgio Picozza
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<th>Near-Term</th>
<th>Formative</th>
<th>Visionary</th>
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<tr>
<td>Gravitational Waves</td>
<td>Gravitational Wave Surveyor</td>
<td>Gravitational Wave Mapper</td>
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<td>Cosmic rays</td>
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<td>Radio</td>
<td>Cosmic Dawn Mapper</td>
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<td>Microwaves</td>
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<td>Infrared</td>
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<td>Optical</td>
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<td>Ultraviolet</td>
<td>LUVOIR Surveyor</td>
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<tr>
<td>X-rays</td>
<td>ExoEarth Mapper</td>
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Science Instrument
Focal Surface Detector

4932 MAPMTs (8x8 pixels)

26mm

55mm

Elementary Cell
(2x2 PMTs = 256 pixels)

2.35m

167mm

Focal Surface detector
137 PDMs
= 0.3M Pixels

Photo-Detector Module
(3x3 ECs = 2,304 pixels)

1 High Voltage / PDM
Full Sky Coverage
with nearly uniform exposure

Inclination: 51.6°
Height: ~400km

The ISS ORBIT
Fluorescence from SPACE

Fast Signal: 50 - 150 \( \mu s \)

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

Photon types

- Blue: Fluo : 7131
- Red: Dir. Cher. : 568
- Green: Bck. Cher. : 918

10^{20} \text{ eV}, 60^{\circ}

1 \text{ GTU} = 2.5 \mu s

Background: 500 /m^2 sr ns
### JEM EUSO GLS Some Candidate Locations

<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>
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<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>
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<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>
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<tr>
<td>Mauna Kea (HI, USA)</td>
<td>20° N</td>
<td>&gt;3.0 km</td>
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</tr>
<tr>
<td>HAWC Site (Mexico)</td>
<td>19° N</td>
<td>3.4 km</td>
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</table>
The EUSO program

1. TA-EUSO: Ground detector at Telescope Array site: 2013

2. EUSO-BALLOON: 1st flight from Timmins, Canada, August 2014

3. EUSO-SPB from Wanaka, NZ (2016-17)


4. KLYPVE → K-EUSO (2020)

5. JEM-EUSO (U.S.; >2020+)
EUSO – Balloon

1st flight from Timmins, Canada (CNES)
August 24-25, 2014
EUSO Balloon:
1st flight and first light on 24-25.8.2014
"Lake Euso" - the site of euler balloon's splashdown;

the instrument booth floating above the waterline

20:53 LT launch
22:50 LT switched on 32 km
23:43 LT reached 38300 m
4:20 LT terminated
4:36 LT splashed down
US helicopter with lasers & Xe flashers tracked the balloon > 5hrs of data
Observed flashes, Laser shots

Low energy CRs with Geiger counter + IR camera cloud cover
EUSO-SPB

Ultra Long Duration flight
Super Pressure Balloon
First observations of UHECRs from space
Test SiPM focal surface

~ 10 - 30 days
How many UHECRs > 60 EeV?

Auger + TA ~30 events/yr

JEM-EUSO
~200 events > 60 EeV/yr

Earth - surface ~ 5 \(10^8\) km\(^2\)

~3.4 \(10^6\) events/yr
How many UHECRs > 60 EeV?

Auger + TA ~30 events/yr

JEM-EUSO

~200 events > 60 EeV/yr

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

~3.4 $10^6$ events/yr
Extreme Energy Frontier
Mysteries to be
Resolved from Space!

Thanks!
Anisotropy Hints > 60 EeV

Oversampling with 20°-radius circle

- Reconstruction with loose cuts optimized for statistics (72 events above 57 EeV in 5 yr).
- After accounting for arbitrary position and opening angles 15°, 20°, 25°, 30°, 35° the significance 3.4σ (post-trial).
Simulated air shower image on the focal surface detector.

Detected photoelectrons are recorded every Gate Time Unit (GTU) of 2.5μs continuously.