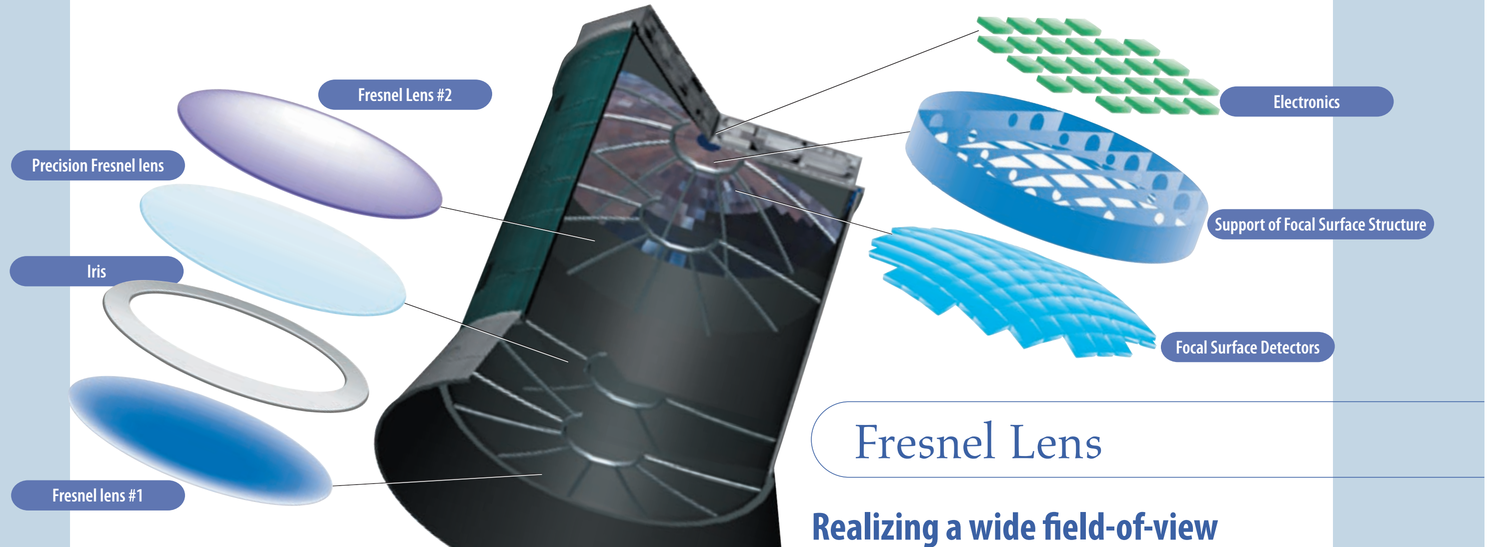
High Technologies are Supporting JEM-EUSO

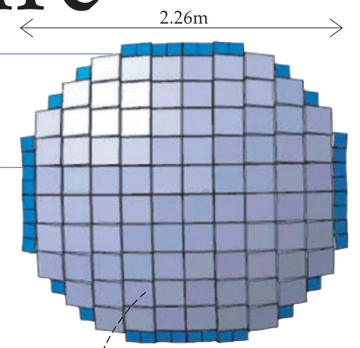


Structure

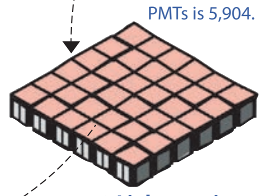
Focal Surface Detectors

6,000 photomultipliers

The focal surface is curved with a diameter of 2.26m. About 6,000 1-inch square multianode photomultiplier tubes (PMTs) detect the light from the different locations in the earth's atmosphere. Earlier PMTs had a limited photo-sensitive area of only 45%. JEM-EUSO and Hamamatsu Photonics jointly developed PMTs to have a higher effective area of 85%.



▲**Focal Surface**
It consists of 164 modules, and the total number of PMTs is 5,904.



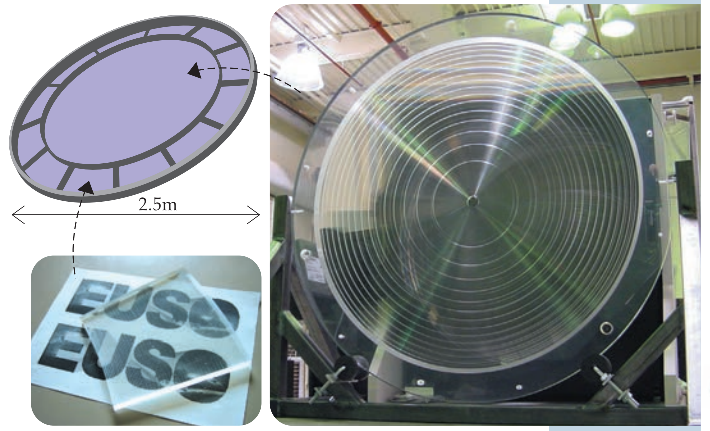
▲**Light-sensing module**
Covering a focal surface of 2.26m diameter with 5,904 PMTs, each PMT having 6 × 6 =36 photo-sensitive units.

▲**Photomultipliers**
The PMT surface has 85% active area, having 6 × 6 pixels with a total area of 26.2 mm square.

Fresnel Lens

Realizing a wide field-of-view and light-weight

The JEM-EUSO telescope uses Fresnel lenses. A Fresnel lens is a semi-flat lens having circular grooves that eliminate the large mass of a standard convective or concave lens. A thin and light Fresnel lens is necessary for use in space, performing the optical functions in the same way as a thick and heavy lens. JEM-EUSO uses two curved double-sided Fresnel lenses of UV-transmitting plastic and one micro-grating Fresnel lens. This design allows the best efficiency for the widest field-of-view. The size of the triple-lens is 2.5-m diameter, composed of the central 1.5-m part and the circular outer annular lenses.

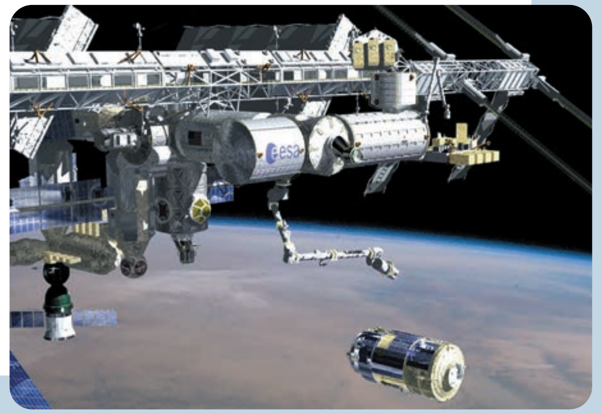


▲Central lens and annular lenses configuration enable a lens size larger than can be manufactured on a single machine.

Launch

JAXA's Space Station Transfer Vehicle (HTV) carries JEM-EUSO

HTV will be launched by a H-IIB rocket (JAXA) and autonomously carry JEM-EUSO to ISS. Robotic arms of ISS will deploy JEM-EUSO at JEM module of "Kibo."



▲Space Station Transfer Vehicle (HTV) approaching ISS ©JAXA

Comparison of JEM-EUSO with the largest ground observatories

	AGASA	HiRes	Auger	Telescope Array	JEM-EUSO
Organization	University of Tokyo	University of Utah	International Consortium	University of Tokyo and University of Utah	International Consortium
Location	Yamanashi, Japan	Utah, USA	Argentina	Utah, USA	International Space Station
Type of Detectors	Ground Array	Fluorescence Ground Telescope	Ground Array + Fluorescence Ground Telescope	Ground Array + Fluorescence Ground Telescope	Fluorescence Space Telescope
Period of operations	1990–2004	1997–2006	2005–	2007–	launch expected in 2013
Effective aperture (km^2-sr)	150	500	~7,000	760	125,000
Yield of EHE events (No./year)	1, experiments terminated	observed less than 1, experiments terminated	50 (expected), 3 (observed)	10 (expected)	350 – 1,700 (expected)

Mission Operation of JEM-EUSO

Altitude	about 400km	Number of pixels of the focal surface	about 0.2 million
Observation latitude and longitude	N51°– S51° × all longitudes	Resolution of the ground	about 0.8km
Filed of view	60°	Duty cycle	12–25%
Aperture (ground area size)	0.2 million km^2	Mission duration	3 (+2) years
Diameter of telescope	2.5m	Total mass	~1.9 ton
Optical system	Two double-sided Fresnel lens and a high-precision Fresnel lens	Power usage	< 1kW

International Partners

Japan	RIKEN Konan Univ. Fukui Tech. Univ. Aoyama Gakuin Univ. Saitama Univ. NIRS Univ. Tokyo Tohoku Univ. ICRR, Univ. Tokyo KEK Chiba Univ. NAOJ ISAS/JAXA Kanazawa Univ. Nagoya Univ. STE Lab., Nagoya Univ. Yukawa Inst., Kyoto Univ. Kyoto Univ. Kobe Univ. Kinki Univ. Hiroshima Univ. Hokkaido Univ Tokyo Inst. Tech.
USA	NASA/MSFC UAH LBL, UCB UCLA Vanderbilt Univ. Univ. Arizona.
France	APC-Paris 7 LAL, IN2P3-CNRS
Germany	MPI Munich Univ. Tuebingen MPI Bonn Univ. Erlangen LMU&MPQ
Italy	Univ. Florence Univ. Naples Univ. Palermo Univ. Rome "Tor Vergata" Univ. Turin INOA/CNR IASF-PA/INAF IFSI-TO/INAF INFN
Mexico	ICN-UNAM BUAP UMSNH
Republic of Korea	Ehwa W. Univ. Yonsei Univ.
Russia	SINP MSU Dubna JINR
Switzerland	Neuchatel, CSEM IACETH
Spain	Univ. Alcalá
Poland	IPJ Podlasie Univ. Kielce Univ. Jagiellonian Univ.
Slovakia	Inst. Experimental Physics, KOSICE

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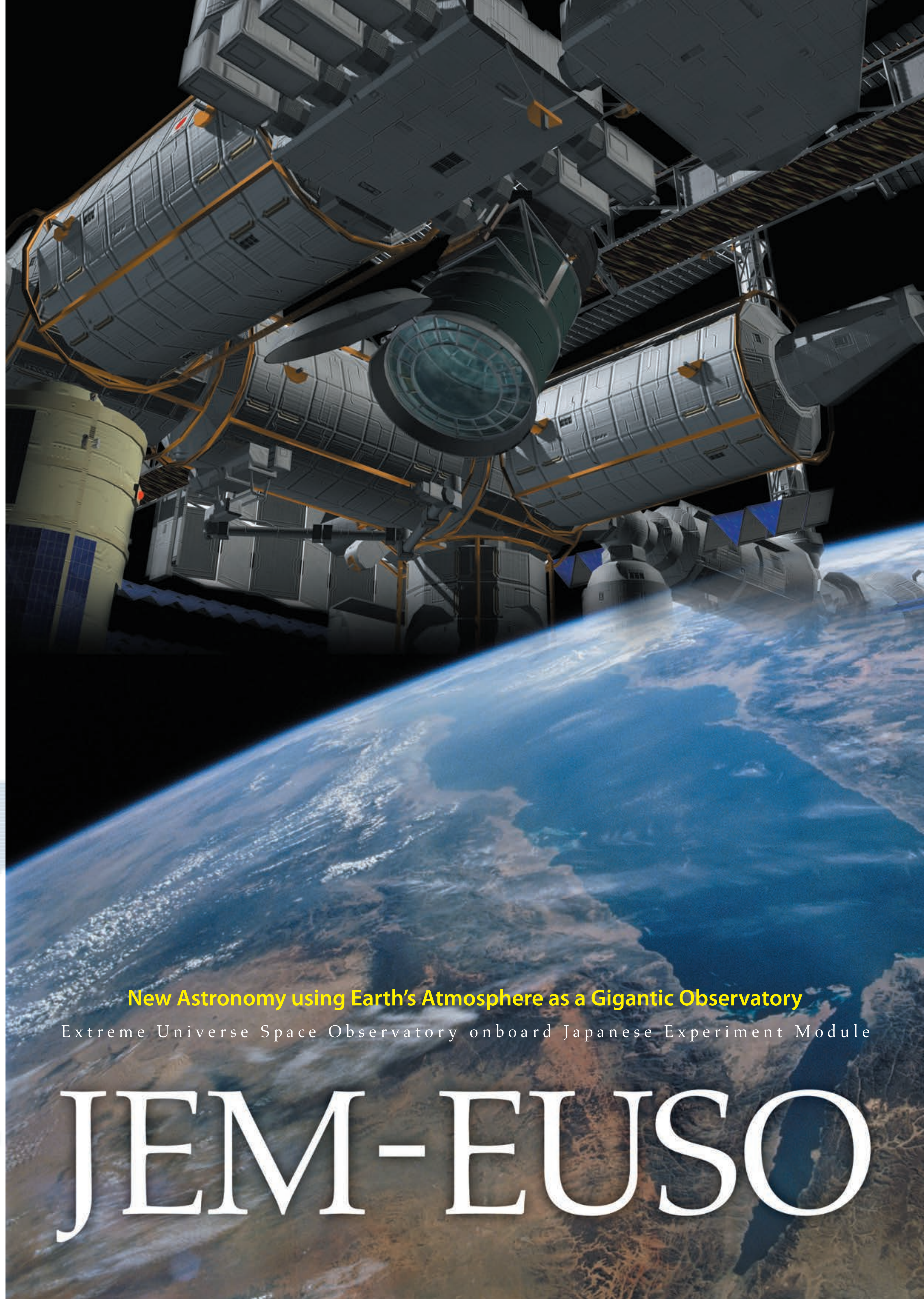


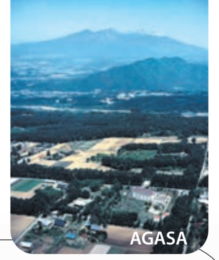
New Astronomy using Earth's Atmosphere as a Gigantic Observatory

Extreme Universe Space Observatory onboard Japanese Experiment Module

JEM-EUSO

JEM-EUSO on International Space Station explores the origin of the highest energy particles in Universe.

Genesis



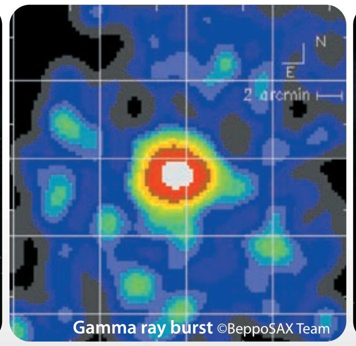
Highest energy above 10^{20}eV observed in the world

Thousands of charged particles bombard the Earth at every 1 m^2 each second. They are called cosmic rays. Their flux decreases with increasing particle energy. Arriving cosmic rays with energies above 4×10^{19} eV are expected to be extremely suppressed by losses due to collisions with microwaves throughout the universe.

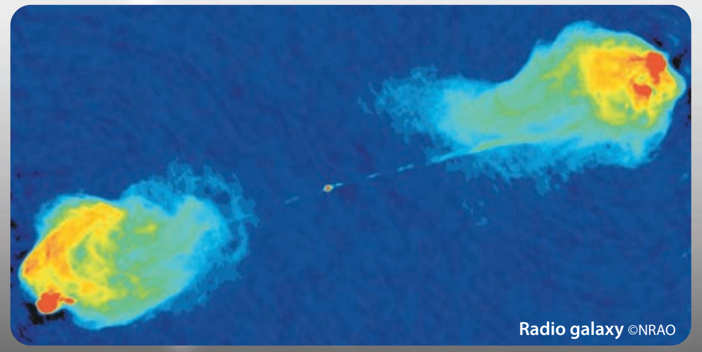
After the discovery of an event of 10^{20} eV* in 1962 by Linsley, a dozen new events were observed in 1990s by the Akeno-Giant-Air-Shower-Array (AGASA) from the University of Tokyo and Fly's Eye/Hi-Res experiment from the University of Utah. The origin of these highest energy particles is unknown and fascinating, and attracts considerable scientific interests.

*10^{20}eV : 16 Joules of energy that can heat 1 cc of water by About 4°C


Supernova explosion ©NASA et al.


Gamma ray burst ©BeppoSAX Team


Pulsar ©NASA et al.


Radio galaxy ©NRAO

▲Source candidates of extremely high energy particles include unknown stellar bodies

Puzzle

Is relativity limited? Are there unknown objects and mechanisms?

The expected suppression of the highest energy particles was theoretically predicted by Greisen, Zatsepin and Kuz'min (GZK cutoff) on the basis of the fact that the universe is filled with the cosmic microwave background (CMB) - the most prominent remnant of the Big-Bang. Highest energy cosmic rays collide with the CMB and lose energy within a distance of 150 million light-years (50 Mega parsec) of their passages, until their energies are reduced to 4×10^{19} eV (so long as Einstein's Special Relativity is valid at any energy and everywhere in the entire universe).

The fact that particles with energies significantly above the GZK-cutoff energies have been observed challenges our understanding of physics and astrophysics. There may be significant sources of the highest energy particles near our galaxy within 50Mpc. Sources could include the well-known brightest radio-galaxies (Centaur-A and Virgo M-87), or could be unknown objects. If none of the events point toward any known objects, then a bizarre doubt in special relativity or other fundamental physics principles may be invoked. The observations to date may or may not be right, and the puzzle at the energy frontier of universe is awaiting more decisive explorations.

Space

Observing earth from International Space Station

JEM-EUSO was planned to decisively resolve the GZK-suppression and to identify the astronomical origin of these particles. JEM-EUSO can detect 1,000 particles above 7×10^{19} eV in a three year mission. The energy and their direction will be accurately measured to clarify the origin of the highest-energy particles.

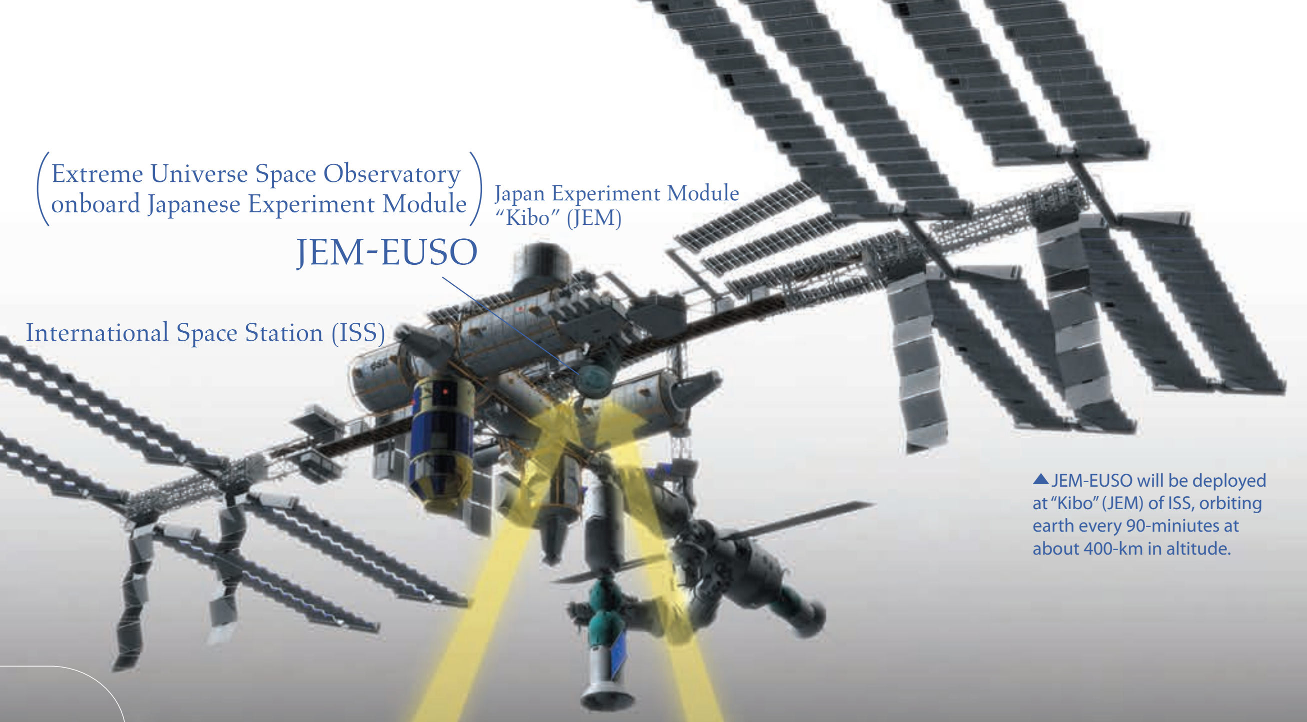
The Japan Experiment Module (JEM) on the International Space Station (ISS) will host JEM-EUSO. This astronomical telescope is not directed toward the universe, but rather looks down toward the earth's surface. Whereas an ordinary astronomical observatory looks up at the universe from earth, JEM-EUSO observes the universe by looking toward the earth because the earth's atmosphere is the largest detector yet employed in our quest to understand the origins of these elusive particles coming from the universe. JEM-EUSO is a new type of astronomical observatory, namely, an "earth-observing" astronomical telescope.

Watch

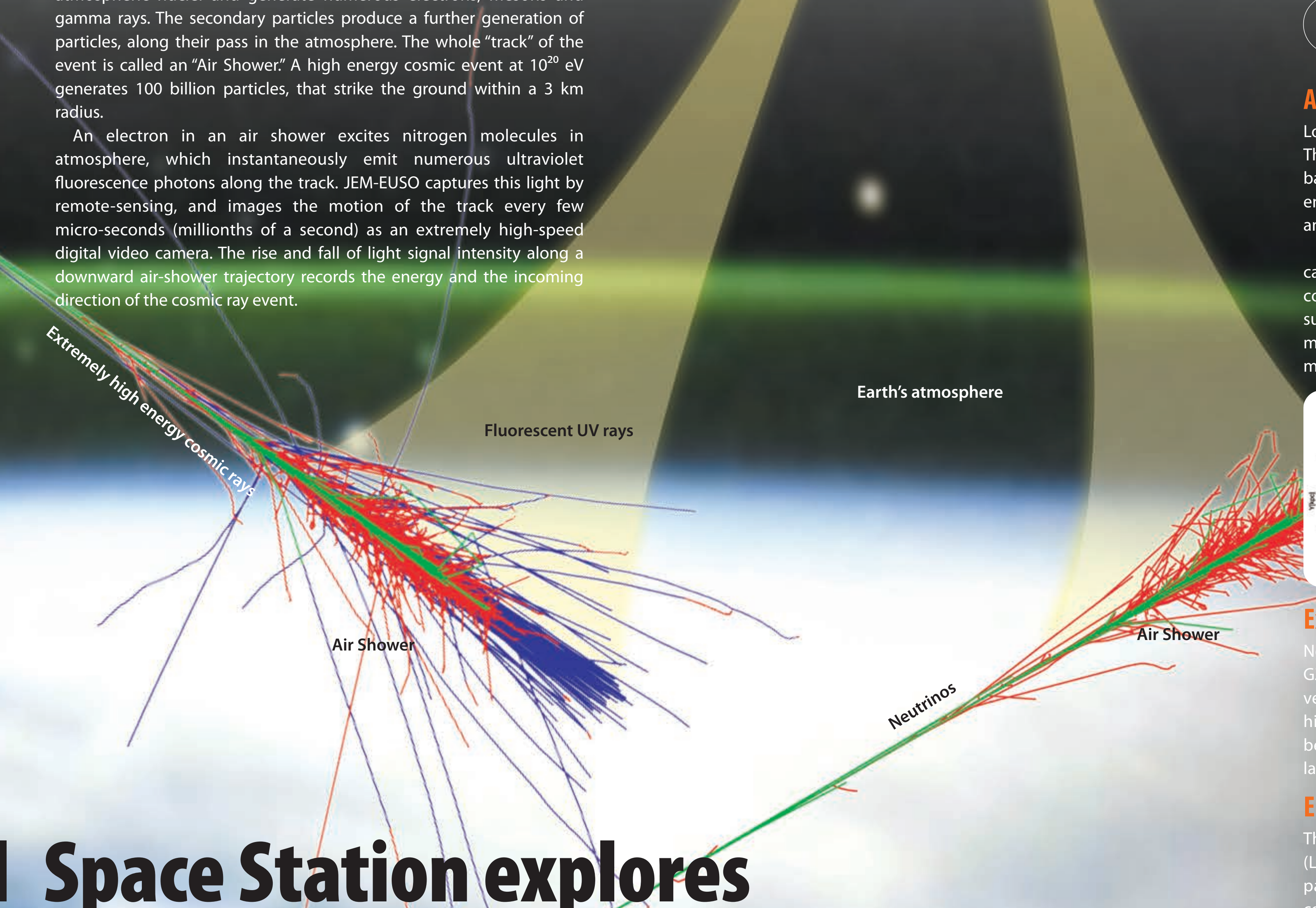
Capture ultraviolet rays from an air shower

Cosmic rays impinging on earth's atmosphere collide with the atmospheric nuclei and generate numerous electrons, mesons and gamma rays. The secondary particles produce a further generation of particles, along their pass in the atmosphere. The whole "track" of the event is called an "Air Shower." A high energy cosmic event at 10^{20} eV generates 100 billion particles, that strike the ground within a 3 km radius.

An electron in an air shower excites nitrogen molecules in atmosphere, which instantaneously emit numerous ultraviolet fluorescence photons along the track. JEM-EUSO captures this light by remote-sensing, and images the motion of the track every few micro-seconds (millionths of a second) as an extremely high-speed digital video camera. The rise and fall of light signal intensity along a downward air-shower trajectory records the energy and the incoming direction of the cosmic ray event.



▲JEM-EUSO will be deployed at "Kibo" (JEM) of ISS, orbiting earth every 90-miniutes at about 400-km in altitude.

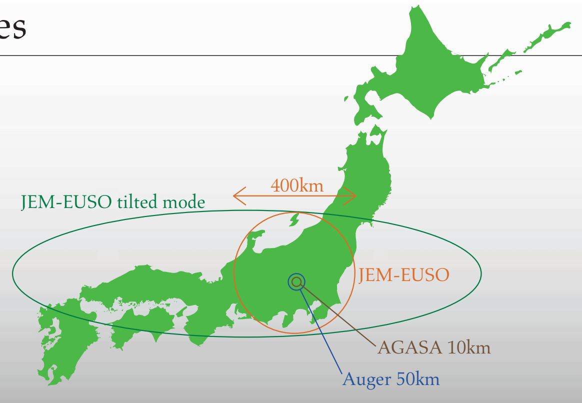


Leap

Aperture exceeds AGASA's by over 1,000 times

A very large area for observation is necessary to observe the rare highest-energy events. The University of Tokyo's Institute for Cosmic Ray Research has just constructed the "Telescope Array" experiment, with an area of 760 km^2, in Utah, USA, as the successor to AGASA. The largest array currently in existence, with an area of 3,500 km^2, started in 2005 in Argentina, is the Pierre Auger Observatory (PAO). (Pierre Auger is the name of a French scientist who first discovered air showers 70 years ago). Ground-based observatories are limited to observe the northern, or the southern sky, but not both.

The ground detectors of these large observatories have nearly reached the maximum extent possible on earth. A remote-sensing space observatory, JEM-EUSO, makes a giant leap in the observational area size, to 100,000 – 500,000 km^2 (more than a thousand times AGASA) by having a vantage point 400 km in the sky and having a wide field-of-view of 60°. The ISS flies over both northern and southern hemispheres. A uniform all-sky observation by a single device allows us to search for correlations with all known objects.



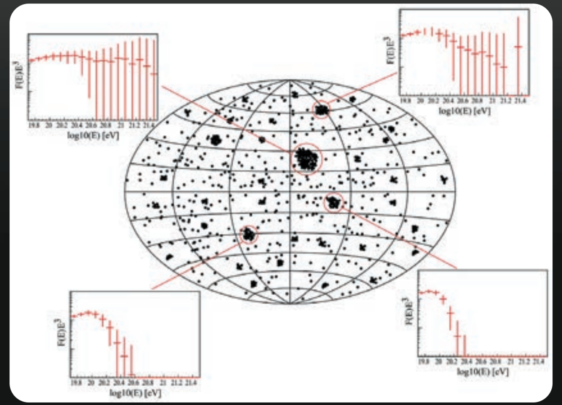
Challenge

Outcome from JEM-EUSO space telescope

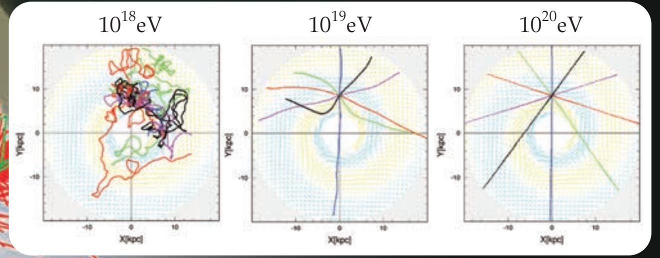
Astronomy by Charged Particles in Universe

Low energy charged particles are bent by magnetic fields in intergalactic and galactic space. The directional information of their origin is lost. However, the highest energy particles are barely bent, and so retain their information of the direction to the origin. In this way, highest energy particles qualify as cosmic messengers for astronomy, alongside visible light, X-rays, and Infrared light.

Various origins that could generate high energy particles have been postulated: candidates include supernovae, gamma-ray bursts, active galactic nuclei, pulsars, and recent collisions of radio galaxies and their super-massive central black holes. Most of these suggestions are, however, incapable of accelerating particles beyond 10^{20} eV by any known mechanism. It has been a consensus that there must be some unknown acceleration mechanism, or even a non-acceleration mechanism powering extreme energies.



▲Expected direction of origins for the highest-energy particles (1,000 events with JEM-EUSO). Multiple events cluster at a point where the strong origin is located.



◀Low-energy charged particles are bent and wound by magnetic fields, but those above 10^{20} eV travel along almost straight trajectories with little influence from magnetic fields, thereby keeping the original directional information.

Exploration of neutrinos at the highest energy

Neutrinos barely interact with matter and are not subject to the GZK-cutoff. No events have been detected so far because of the very low yield with the limited detector mass. Extremely high-energy neutrinos may be observable with JEM-EUSO, because the whole atmosphere of earth gives a sufficiently large target mass for detection of a few events per year.

Energy Frontier – exceeding LHC Physics

The largest man-made accelerator, the "Large Hadron Collider" (LHC), began operation in 2008. It generates high-energy particles to explore fundamental physics. Highest-energy cosmic rays discovered so far have laboratory energies more than three orders of magnitude higher. The energy frontier of fundamental physics can be extended by the highest-energy cosmic particles to be observed by JEM-EUSO.

Monitoring the atmospheric illumination from whole earth

JEM-EUSO can detect transient atmospheric-illuminating events in the night-sky: Examples are lightnings, meteors, and air-glows. Lightning occurs between clouds and earth, and between clouds. Some of the most exciting illumination events are large-scale upper-atmospheric discharge, called blue-jets, sprites, and elves. These events stream out of clouds to outer space. How often and where they occur on the earth's globe will be monitored, to help explore the cause of these tantalizing phenomena. Meteors are small solids from space diving into the earth's atmosphere. Observations of their size and fluorescent spectra are expected to help us learn about their mother asteroids, and other solar-system sources.

▲An interesting discharge: Carrot Sprite phenomenon.
Photo provided by Koji Ito (Suginami-ku, Tokyo).

▲Earth's atmosphere photographed from Space Shuttle ©NASA