JEM-EUSO-RD

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Participant International Countries:

JAPAN, USA, FRANCE, GERMANY, MEXICO, RUSSIA, SOUTH KOREA SWITZERLAND, SPAIN, POLAND, SLOVAKIA, BULGARIA

1 Introduction

The origin and nature of Ultra-High Energy Cosmic Rays (UHECRs) remain unsolved in contemporary astroparticle physics. A cutoff in the cosmic ray energy spectrum clearly appears at $\sim 10^{20}$ eV in the data of HiReS [1], Telescope Array [2] and Auger [3] on ground experiments. It is well known that the detection of events with energy $\geq 10^{20}$ eV is challenged by the GZK effect [4, 5], which limits the highest detectable energy at $\sim 10^{20}$ eV due to photopion production in the interaction of UHECR on the microwave fossil radiation of the Big Bang, as suggested also by the HiReS and Telescope Array data, or by nuclei photodisintegration as indicated by the Auger results. However, the possibility that the cutoff at $\sim 10^{20}$ eV can be intrinsic to the acceleration power of the astrophysics cosmic ray sources remains alive. Moreover, indications of sources or excesses in the arrival direction distribution of UHECRs have been claimed by the Auger experiment, though not fully confirmed. To give an answer to these questions is rather challenging because of the extremely low flux of a few per km^2 per century at extreme energies such as $E > 5 \times 10^{19}$ eV.

The JEM-EUSO experiment, Extreme Universe Space Observatory at the Japanese Experiment Module of the International Space Station, is the first space mission devoted to the scientific research of cosmic rays at the highest energies. Its super-wide-field telescope looks down from the International Space Station onto the night sky to detect UV photons emitted from air showers generated by UHECRs in the atmosphere.

13 Countries, 77 Institutes and about 280 researchers are collaborating in JEM-EUSO, with the support of the most important International and National Space Agencies and research funding institutions. JEM-EUSO is currently in the evaluation phase (Phase A) by the Japanese Space Agency (JAXA).

2 The JEM-EUSO Mission

JEM-EUSO on the International Space Station is a new type of observatory, based on a UV telescope, which uses the whole Earth as detector. It will observe, from an altitude of ~ 400 km, the fluorescence tracks produced at $(330 \div 400)$ nm by Extensive Air Showers (EAS) originated by UHE primaries which traverse the Earth's atmosphere at ultra-relativistic speed. JEM-EUSO will be launched by an H2B rocket and will be conveyed to the ISS by the H-II Transfer Vehicle (HTV). It will be then attached to one of the ports for non-standard payloads of the Exposure Facility (EF) of the Japanese Experiment Module (JEM). Data will be transmitted via TDRS (Tracking and Data Relay Satellite) to the Mission Operation Center hosted by JAXA in the Tsukuba Space Centre (Fig.1).

The launch is foreseen for 2017 and the mission will last at least 5 years. JEM-EUSO will be operated for three years in Nadir configuration to maximize statistics at the lowest energies in order to cross calibrate with the current generation of ground-based detectors. The instrument will be then tilted (about 30°) with respect to Nadir in order to exploit a larger amount of atmosphere and to maximize the statistics of events at the highest energies. JEM-EUSO will significantly increase the exposure to UHECRs compared to the largest ground-based air shower arrays presently in operation.

Two pathfinder test experiments are currently prepared; one to observe the fluorescence background from the edge of the Atmosphere (EUSO-Balloon) and the other at ground for an inter-calibration with the fluorescence detector (EUSO-TA) of the Telescope Array experiment. The main parameters of the mission at ISS are described in Table 1.

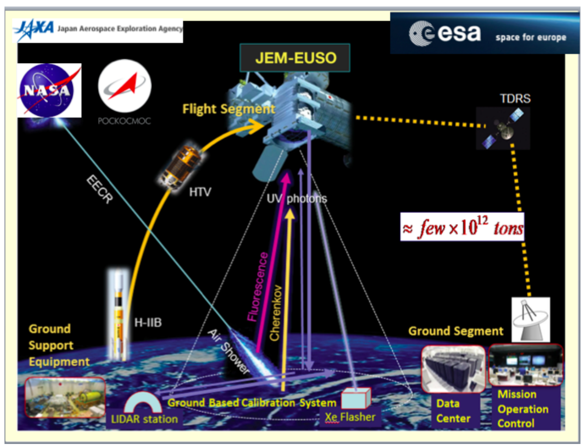

Figure 1: The JEM-EUSO Mission concept

Table 1: JEM-EUSO Main Parameters

Expected launch date	JFY 2017
Mission Lifetime	3+2 year
Launch Rocket	H2B
Transport Vehicle	HTV
Accommodation on JEM	EF n.2 (or 9)
Instrument Mass	1938 kg
Height of the Orbit	400 km
Inclination of the Orbit	51.6

3 The Science Case

JEM-EUSO will address basic problems of fundamental physics and high-energy astrophysics studying the nature and origin of the Ultra High Energy Cosmic Rays ($E > 3 \times 10^{19}$ eV).

JEM-EUSO will pioneer the investigation from Space of UHECR-induced Extensive Air Showers making precise measurements with unprecedented statistical accuracy of the primary energy, arrival direction and composition of UHECRs, using a target volume far greater than it is possible from the ground. Such data will shed light on the origin of the UHECRs, on the sources that are producing them, on the propagation environment from the source to the Earth and, possibly, on the particle physics mechanisms at energies well beyond the ones achievable in man-made accelerators. Moreover, exploratory objectives such as constraining the galactic and extragalactic magnetic fields, the detection of extreme energy neutrinos and gamma rays, the verification of special relativity at extremely large Lorentz factors, the examination of possible quantum gravity effects at extreme energies, and the systematic surveillance of atmospheric phenomena, complete the scenario of the JEM-EUSO science goals.
Below, the scientific objectives of the JEM-EUSO mission are summarized.

Astrophysics and Cosmology

Main Science Objectives:
- Identification of UHE sources
- Measurement of the energy spectra of individual sources
- Measurement of the trans-GZK spectrum

Exploratory objectives:
- Discovery of UHE neutrinos
- Discovery of UHE Gamma-rays
- Study of the galactic and local extragalactic magnetic field

Atmospheric Science
- Nightglow
- Transient Luminous Events (TLE)
- Meteors and Meteoroids

A new window on the unknown
- Particle Physics: String Theory
- Relativity and quantum gravity effect

4 Observational Principle

In the JEM-EUSO mission, the UHECR observation is based on the measurement of the fluorescence and Cherenkov photons produced in the extensive air shower (EAS) phenomenon. An UHECR, interacting with atmospheric nuclei, produces secondary particles that in turn collide with the air atoms giving rise to a propagating cascade of particles. The number of the secondary particles in an EAS is related to the energy of the primary UHECR. The most dominant particles in EAS are electrons moving through the atmosphere, which excite metastable energy levels in atmospheric atoms and molecules, in particular nitrogen, that return to ground state emitting characteristic fluorescence light in the ultraviolet (UV) band with wavelengths between 330 and 400 nm. The emitted light is isotropic and its intensity is proportional to the energy deposited

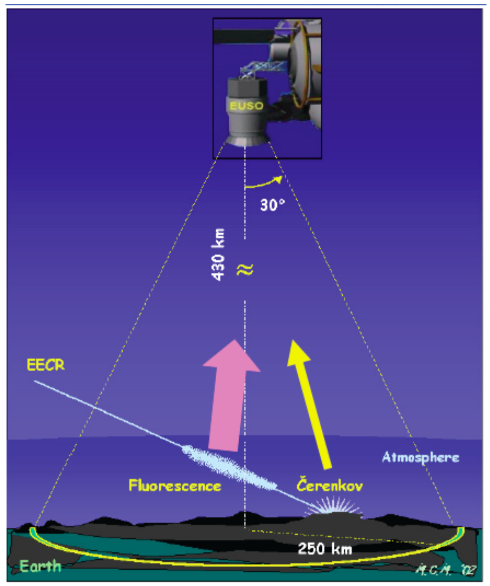

Figure 2: Artistic view of the JEM-EUSO Observational Principle

in the atmosphere. An UHECR-induced EAS then forms a significant streak of fluorescence light along its passage in the atmosphere, depending on the energy and zenith angle of the primary UHECR. Numerous secondary particles have velocities higher than that of the light and therefore they emit Cherenkov photons. These Cherenkov photons are highly beamed within a cone of $< 1.3^\circ$ radius along the trajectory and may be scattered by the molecular and aerosol content in the atmosphere. Part of these photons will be isotropically diffused when reaching land, sea or clouds. Looking downward the dark Earth atmosphere, the JEM-EUSO telescope will detect such fluorescence light as sketched in Figure 2. EAS appears as a small disc-shaped luminous object which, when viewed continuously, moves on a straight path at the speed of light. The recorded amount of light is nearly proportional to the shower size at the various depths in the atmosphere. By imaging the motion of the streak every few microseconds, it is possible to determine the arrival direction of the primary UHECR. The integral of light recorded is an important information to determine the energy of the primary UHECR. The cascade shape (especially the position of the shower maximum in the traversed slant depth) gives an indication about the nature of the primary.

5 The Instrument

The JEM-EUSO instrument (Fig.3) basically consists of an UHECR telescope assisted by an atmosphere monitoring device and controlled by a calibration system.

The JEM-EUSO telescope is a fast, high-pixelized, large-aperture and large field-of-view digital camera, working in the near-UV wavelength range ($330 \div 400$ nm) with single photon counting capability. The main components of the telescope are the collecting optics, the focal surface detector, the electronics and the structure. The optics system is composed of two Fresnel lenses and one diffractive precision Fresnel lens. The focal surface detector is composed by a grid of $\sim$ 5000 multi-anode photomultipliers (MAPMT), 64 pixels in each, that convert the energy of the incoming photons into electric pulses. They are arranged in 137 PDM (Photo Detector Module), with 2304 pixels in each. The electronics counts-up the number of the electric pulses in

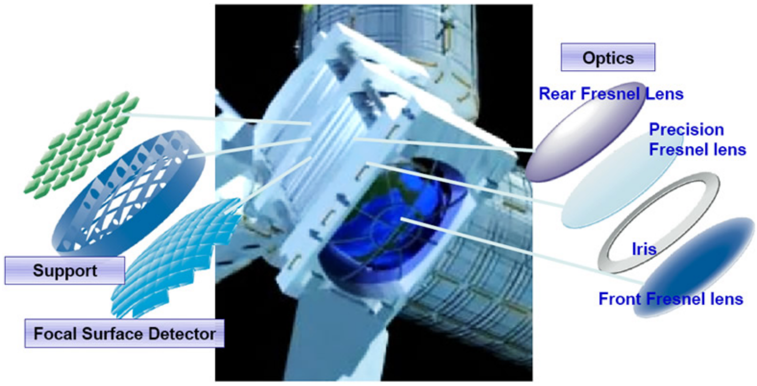

Figure 3: The JEM-EUSO Instrument

time periods of 2.5 μs. The JEM-EUSO atmosphere monitoring will use an infrared (IR) camera and a Lidar (Light Detection and Ranging) with ultraviolet laser to observe the conditions of the atmosphere in the field of view of the telescope.

JEM-EUSO will be calibrated through instrumentations both onboard and on ground. The onboard calibration system is composed of a set of three LEDs with different wavelengths (from 300 to 500 nm) that will be installed in the telescope cylinder as diffusive light sources. On ground, the monitoring and calibration will be performed by a Global Light System (GLS) of lasers and xenon light sources located in 12 sites around the world, supplemented with an aircraft system.

6 The Pathfinders: EUSO-TA and EUSO-Balloon

The JEM-EUSO collaboration is currently involved in the development of two pathfinders for the JEM-EUSO mission: a ground-based telescope (EUSO-TA) and a space-based one (EUSO-Balloon). EUSO-TA is a ground-based telescope formed by one Photo Detector Module and two fresnel lenses, protoypes of those foreseen in JEM-EUSO. It will be located at Telescope Array site (Utah) in early 2013. The principle of such instrument is to monitor the UV light ($290 \div 430$ nm) in the atmosphere in its field of view (FoV) of 4 degrees, continuously, during the night, at a rate of 4×10^5 frames/s. The telescope is sensitive also to air showers with energies $E > 10^{18}$ eV falling in the FoV.

EUSO-Balloon is developed as a demonstrator for the technologies and methods featured in the space instrument. EUSO-Balloon is an imaging UV telescope as JEM-EUSO. The balloon-borne instrument points towards the Nadir from a float altitude of about 40 km. With its Fresnel Optics and Photo-Detector Module similar to TA-EUSO, the instrument monitors a $12° \times 12°$ wide field of view at the same rate as TA-EUSO. The instrument is presently built by various institutes of the entire JEM-EUSO collaboration. Balloon flights will be managed and performed by the balloon division of the French Space Agency CNES; a first flight is scheduled in 2014.

7 The participation and contribution of the italian groups

JEM-EUSO in Italy is presently funded by the Istituto Nazionale di Fisica Nucleare (INFN) within the National Scientific Committee for Astroparticle and Neutrino Physics; funds have been provided for several years also by the Italian Space Agency (ASI). The full commitment of ASI is depending on the final approval of the mission. The tasks and responsibilities, briefly summarized, are the following:

Focal Surface Subsystem:

- PDM Structure
- Focal Surface Structure
- Focal Surface integration

Data Handling Subsystem:

- Mission Data Processor
- Telemetry Command Unit
- Data Acquisition Interface Board
- Clock Board

Atmospheric Monitoring Subsystem

Simulation Tools

The Italian Collaboration is presently fully involved also in the realization of the two pathfinders, EUSO-Balloon and EUSO-TA. CPU, Telemetry, Clock and transmission system have been integrated and tested. For EUSO-TA, moreover, the mechanical supporting structure of the instrument, with a dedicated inclination system, has been constructed.

8 Activity of the LNF group during year 2012 and for 2013

The LNF JEM-EUSO group is responsible (in collaboration with the SPCM LNF Service) of the design of the Focal Surface (FS) mechanical structure and of the 137 PDMs which cover the entire FS and where the 4932 multi anode Photomultipliers Hamamatsu M64 are accommodated (Fig.4).

So far, the engineering studies have been carried out, including 3D CAD design of the structure, finite element model calculations, vibration mode studies related to the launch vehicle parameters. In 2012, first assembled prototypes of PDMs for testing and for both EUSO-TA and EUSO-Balloon have been produced. Members of the group are involved in the JEM-EUSO Editor's Team, which takes care of the editing of successive updated versions of the Technical Reports, and in the JEM-EUSO Speaker's Bureau which manages and organizes the activities related to publications and conferences. The group participates and contributes also to the definition and assessment of the scientific objectives of the mission. In 2013, the activity will be mainly dedicated to the continuation of the engineering project of the FS structure, to the production of more PDMs, in an updated configuration as far as the front end, the DAQ and the power supply electronic boards design is consolidated, in view of reaching the successive Technical Readiness Levels required by a Space mission. The activities related to publications, presentation at Conferences and contact and meetings with national aerospace Companies constitute a relevant part of the tasks foreseen in 2013.

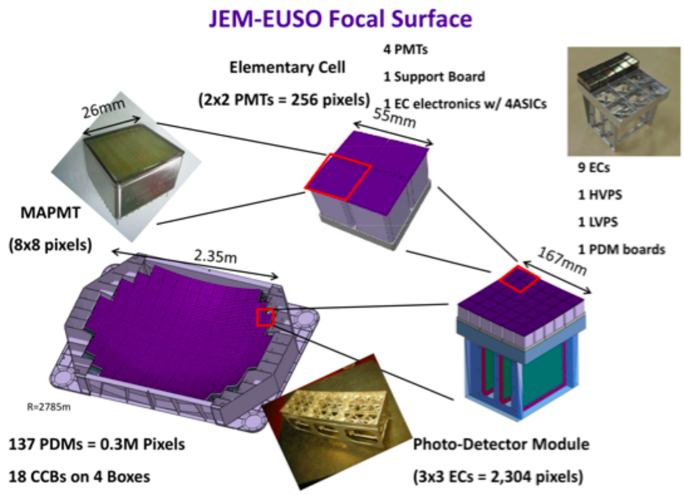

Figure 4: The JEM-EUSO Focal Surface Structure components

9 Recent publications

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