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The JEM-EUSO space mission @ forefront of the highest energies never observed from Space

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Abstract. Cosmic Rays Physics is one of the fundamental key issues and an essential tool of Astroparticle Physics that aims, in a unique way to address many fundamental questions of the extreme and non-thermal Universe in the Astroparticle Physics domain at the highest energies never detected so far. Moreover, Ultra High Energy Cosmic Rays (UHECR) has witnessed a major breakthrough with the Pierre Auger Observatory (PAO) success. The results on UHECR by the PAO have pointed out the huge physics potential of this field that can be achieved by an upgrade of the performance of current ground-based instruments and new space-based missions, as the JEM-EUSO space observatory, to fully address the Cosmic Ray Physics potential and to achieve one of our main goals, reach the so called "Particle Astronomy Era".

Key words. Astroparticle Physics: Ultra-High Energy Cosmic Rays – Space Physics: Space Instrumentation – Space Physics: Space Qualified Infrared Camera

1. Introduction

To fully explore the Extreme Universe, next-generation observatories need to observe the full sky and increase significantly the UHECR exposure. To reach the largest exposures, space observatories are likely to be essential. The JEM-EUSO space mission (Fig. 1), led by Japan, is the Extreme-Universe Space Observatory (EUSO) which will be located at the Japanese Experiment Module (JEM) on the International Space Station (ISS), thus allowing a full-sky monitoring capability. The main scientific objective of JEM-EUSO (JEM-EUSO website , 2007; JEM-EUSO Collaboration , 2008, 2009) is to open the charged-particle Astronomy channel in the Extremely High Energy Cosmic Rays (EHECR) domain with $E_0 > 10^{19}$ eV, by sampling a huge EHECR statistics with ~1000 CR events above E_0, in 3-5 years of operation. The JEM-EUSO refractive telescope has a super-wide Field-of-View (FoV) (±30°) with two double sided curved Fresnel lenses, to observe the time and space resolved atmospheric fluorescence tracks, in the near UV region, of the Extensive Air Showers (EAS), with 2.5 μs time resolution and about 0.75 km spatial resolution, corresponding to 0.1°. The focal surface of the JEM-EUSO telescope allocates 6,000 multi-anode PMTs with nearly two hundred thousands pixels.

The JEM-EUSO space observatory can reconstruct the incoming direction of the extreme energy cosmic rays particles with an accuracy

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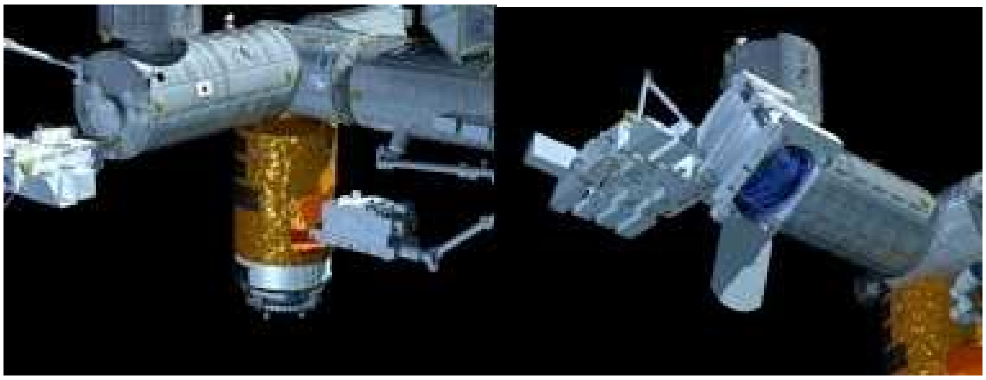

Fig. 1. The JEM-EUSO Space Mission onboard the Japanese module of the International Space Station (JEM-EUSO Internal Report, Purple Book, 2010).

better than several degrees. Its observational aperture of the ground area is a circle with 250 km radius and its atmospheric volume above it with a 60-degree FoV is around 1 Tera-Ton of atmosphere, while the target volume for upward neutrino events exceeds 10 Tera-Tons. The instantaneous aperture of JEM-EUSO is larger than the Pierre Auger Observatory by a factor of 56 – 280. The key technological issues of JEM-EUSO are mainly the implementation of new lens material and an improved optical design, detectors with higher quantum efficiency and an improved algorithm for event trigger. The increase in effective area is realized by inclining the telescope from *"nadir mode"* to what is named as *"tilted mode"*, where the threshold energy increases since the mean distance to EAS and atmospheric absorption both increase and therefore the first half of the mission lifetime is devoted to observe the lower Cosmic Ray energy domain in nadir mode and the second half of the mission to observe the high energy Cosmic Ray region by tilted mode.

One of the major challenge of the JEM-EUSO Space Observatory is its large aperture. It is expected that JEM-EUSO will reach at the end of the decade an exposure of 1 Mega Linsley (Fig. 2). Since the structure of the GZK feature is highly dependent on distance, the combination of anisotropy and spectral information can help to pinpoint the type of astrophysical objects responsible for the origin of UHECR and even to identify individual sources. Fig. 2 shows the exposure expected by JEM-EUSO in both Nadir and tilted mode, reaching 1 Mega Linsley by 2020.

2. The Atmospheric Monitoring System of JEM-EUSO

At the energies observed by JEM-EUSO, above 10^{19} eV, the existence of clouds will blur the observation of UHECRs. Therefore, the monitoring of the cloud coverage by JEM-EUSO Atmospheric Monitor System (AMS), is crucial to estimate the effective exposure with high accuracy and to increase the confidence level in the UHECRs and EHECRs events just above the threshold energy of the telescope (Sáez-Cano et al. , 2011). Therefore, the JEM-EUSO mission has implemented the AMS as far as the impact onto mass and power budget is negligible. It consists of: 1) Infrared (IR) camera; 2) LIDAR; 3) slow data of the JEM-EUSO telescope (Fig. **??**).

The Atmospheric Monitoring System (AMS) IR Camera is an infrared imaging system used to detect the presence of clouds and to obtain the cloud coverage and cloud top altitude during the observation period of the JEM-EUSO main instrument. Cloud top height retrieval can be performed using either stereo vision algorithms (therefore, two different views of the same scene are needed) or accurate adiometric information, since the

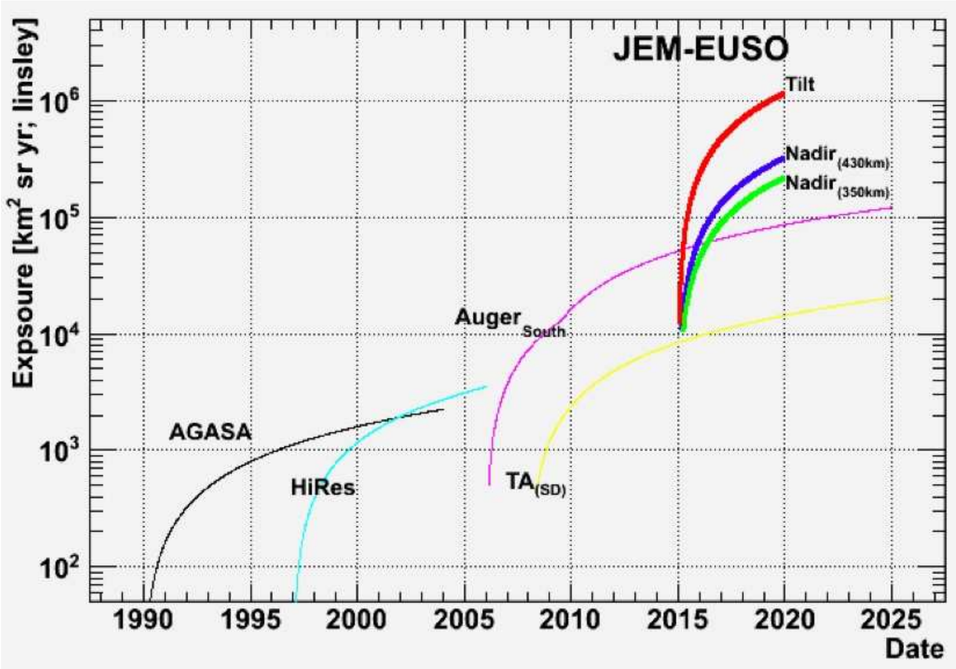

Fig. 2. Expected cumulative exposure of JEM-EUSO (Thick blue curve). For comparison, the evolution of exposure by other previous and presently running UHECR observatories is shown (JEM-EUSO Internal Report, Purple Book, 2010.

Table 1. Requirements of the JEM-EUSO IR camera, where its full design, prototyping, space qualified construction, assembly, verification and integration in under responsability of the Spanish Consortium involved in JEM-EUSO.

Parameter Meadurement	Target value	Comments
Measurement range	200-320 K	Annual variation of cloud temperature + 20 K margin
Wavelength	10-12 μm	Two atmospheric windows avalaible: 10.3-11.3 μm 11.5-12.5μm
FoV	60^o	Same as main instrument
Spatial resolution	0.25^o@FoV cent. 0.22^o@FoV edge	Threshold values.
Absolute temp. accuracy	3 K	500 m in cloud top altitude
Mass	≤ 7 kg	Inc 30 % margin.
Dimensions	200×280 $\times 320$mm.	$300 \times 300 \times 500$mm
Power	≤ 11 W	Inc 30% margin.

measured radiance is basically related to the target temperature and therefore, according to standard atmospheric models, to its altitude (Wada et al. , 2009).

3. The infrared camera of the JEM-EUSO space mission

The AMS IR Camera of JEM-EUSO (Morales de los Ríos et al., 2011) is an infrared imaging

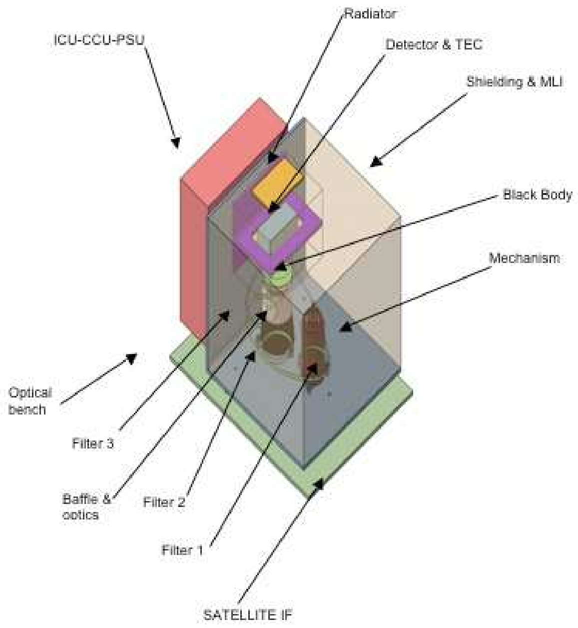

Fig. 3. Preliminar design of the JEM-EUSO Infrared Camera (JEM-EUSO Internal Report, Purple Book, 2010).

system aimed to detect the presence of clouds and to obtain the cloud coverage and cloud top altitude during the observation period of the JEM-EUSO main instrument. Its full design, prototyping, space qualified construction, assembly, verification and integration is under responsability of the Spanish Consortium involved in JEM-EUSO. Moreover, since measurements shall be performed at night, it shall be based on cloud IR emission. The observed radiation is basically related to the target temperature and emissivity and, in this particular case, it can be used to get an estimate of how high clouds are, since their temperatures decrease linearly with height at 6 K/km in the Troposphere.

The IR camera on board of JEM-EUSO will consist of a refractive optics made of germanium and zinc selenide and an uncooled microbolometer array detector. Interferometer filters will limit the wavelength band to 10-12 μm. In the current configuration, two $\delta\lambda$ = 1 μm wide filters will be used centered at the wavelengths $\sim$ 10.8μm and $\sim$ 12μm to increase the precision of the radiative temperature measurements. The FoV of the IR camera is 60°, totally matching the FoV of the main JEM-EUSO telescope. The angular resolution, which corresponds to one pixel, is about 0.1°. A temperature-controlled shutter in the camera and mirrors are used to calibrate background noise and gains of the detector to achieve an absolute temperature accuracy of $\sim$ 3 K. Though the IR camera takes images continuously at a video frame rate (equal to 1/30 s), the transfer of the images takes place every 30 s, in which the ISS moves half of the FoV of the JEM-EUSO telescope. Table 1 summarizes the current scientific and mission requirements for the JEM-EUSO AMS IR camera. Although there are no formal requirements for data retrieval, it has been assumed that the IR camera retrieval of the cloud top altitude could be performed on-ground by using stereo vision techniques or radiometric algorithms based on the radiance measured in one or several spectral channels (i.e. split-window techniques). Therefore, the IR camera preliminary design (Fig. 3) should be complaint with both types of data processing.

4. Conclusions

The Extreme Universe Space Observatory on the Japanese Experiment Module (JEM-EUSO) of the International Space Station (ISS) is the first space-based mission worldwide in the field of Ultra High-Energy Cosmic Rays (UHECR) and will provide a real breakthrough toward the understanding of the Extreme Universe at the highest energies never detected from Space so far. JEM-EUSO is the first step from Space: a pioneer and a pathfinder in our Cosmic Ray field. The JEM-EUSO collaboration is presently a joint effort of 13 countries and 270 researchers, where Europe has a consolidated position with 8 countries involved in this space mission led by Japan.

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