The Extreme Universe Space Observatory (EUSO) Mission in the context of ESA

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Abstract

The European Space Agency, ESA, is currently studying four high-energy astronomy missions that use the external facilities offered by the International Space Station (ISS). These are Lobster-ISS, an all-sky imaging X-ray monitor, Rosita - a medium-energy X-ray survey telescope array, XEUS - the X-ray Evolving Universe Spectroscopy Mission, a potential successor to ESA's XMM-Newton X-ray observatory. and the Extreme Universe Space Observatory (EUSO) which will study the highest energy cosmic rays using the Earth's atmosphere as a giant detector These missions are designed to be attached to the external platforms on the Columbus module, except for XEUS which will visit the ISS to enlarge the original 4.5 meter mirrors to their full 10 meter diameter.

1. Introduction

Europe is one of the major partners building the International Space Station (ISS) and European industry, together with ESA, is responsible for many station components including the Columbus Orbital Facility, the Automated Transport Vehicle, two connecting modules and the European Robotic Arm. Together with this impressive list of contributions there is a strong desire within the ESA Member States to benefit from this investment by using the unique capabilities of the ISS to perform world-class science. The Human Spaceflight and Science Directorates are studying four such high-energy missions: Lobster-ISS, an all-sky imaging X-ray monitor, Rosita, a medium energy X-ray imaging survey, the Extreme Universe Space Observatory (EUSO) which will study the highest energy cosmic rays using the Earth's atmosphere as a giant detector and XEUS, the X-ray Evolving Universe Spectroscopy Mission.

A mission is studied before final approval to allow its overall design to be elaborated, the scientific and technical feasibility demonstrated and most importantly, the costs evaluated and commitments obtained for all the necessary elements. These activities are normally part of a so-called "Phase A Study" fol-

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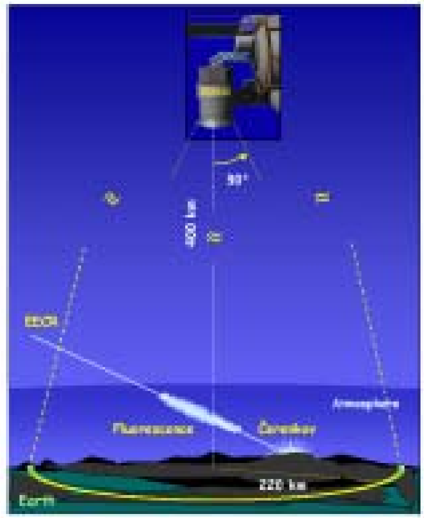

Fig. 1. EUSO will observe downwards from the ISS at a height of 400 km with a 60° field of view and detect the fluorescent and reflected Cerenkov radiation produced when an EECR interacts with the Earth's atmosphere.

lowing a successful outcome of which, a project can move forward into detailed design and build phases as an approved mission.

2. Observing the Highest Energy Phenomena in the Universe

The Earth is being continuously bombarded by high-energy cosmic rays. While cosmic rays with energies up to 10^{15} eV almost certainly originate from comparatively well understood objects in our own Galaxy, such as the expanding shocks of exploded stars, understanding the origin of the highest energy cosmic rays with energies $>5\,10^{19}$ eV is one of the great challenges in astrophysics. Although these extreme energy cosmic rays (EECR), believed to be probably mostly protons, are very rare (only around 1 per square kilometre per century!) they are the most energetic particles known in the Universe. Only about 30 such events have been detected using different ground based air shower detectors in the past 30 years. There has been no convincing identification of any of these events with a likely astronomical source.

At such extreme energies, cosmic ray protons interact with the cosmic microwave background and the distance that an EECR can travel is limited to our galactic neighbourhood. Intriguingly, all the astronomical objects that could conceivably produce EECR such as massive black holes, colliding galaxies, or gamma-ray bursts, are much further away than this. This has led to the idea that the decay of topological defects, or other massive relics of the big bang may

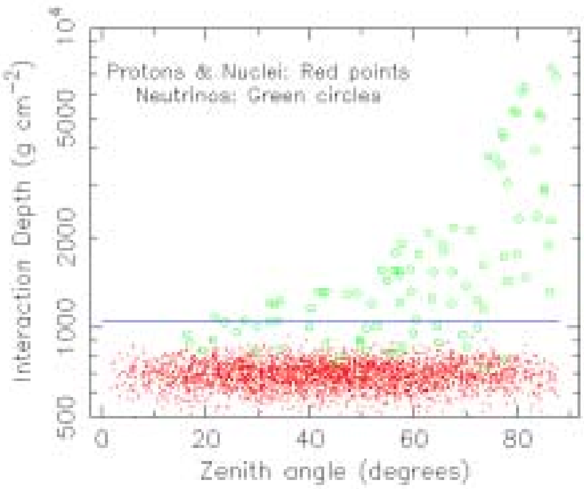

Fig. 2. Extreme energy cosmic ray interaction depth simulations showing how particle (open circles) and neutrino (dots) induced events can be distinguished. Events with high interaction depths and zenith angles will almost certainly be neutrinos.

instead produce EECR - implying the existence of “new physics”. This paradox is at the heart of EUSO which will study EECR by using the Earth’s atmosphere as a giant cosmic ray detector. EUSO will observe the flash of fluorescence light and the reflected Cerenkov light produced when an EECR interacts with the Earth’s atmosphere (Fig. 1). Imaging of the light track and its intensity variations will allow the sky position of the event and the overall energy to be reconstructed. EUSO will take advantage of the continuous nadir pointing provided by the lowest external location on Columbus. By looking down with a 60° field of view, EUSO will detect around 1000 events per year with energies $>4 \times 10^{19}$ erg s^{-1} allowing a sensitive search for the objects producing EECR to be made.

Protons are not the only type of extreme energy particle that will be observed by EUSO. Models for EECR indicate that large numbers of neutrinos should also be produced. Since neutrinos propagate, on average, much deeper into the atmosphere than protons before interacting, EUSO will be able to distinguish between the two types of particles by selecting on interaction depth and so open up the new field of high-energy neutrino astronomy (Fig. 2).

3. The EUSO Phase A Study

The EUSO proposal was submitted to ESA in response to the same call for Flexi-Mission proposals (F2 and F3) as Lobster-ISS. The Principle Investigator is Prof. L. Scarsi from IASF-CNR, Palermo, Italy, who leads a large consortium of astronomers, cosmic-ray and particle physicists. EUSO will consist of a UV telescope with a large collecting area and field of view utilising light weight Fresnel lens optics, a highly segmented focal surface detector array and sophisticated

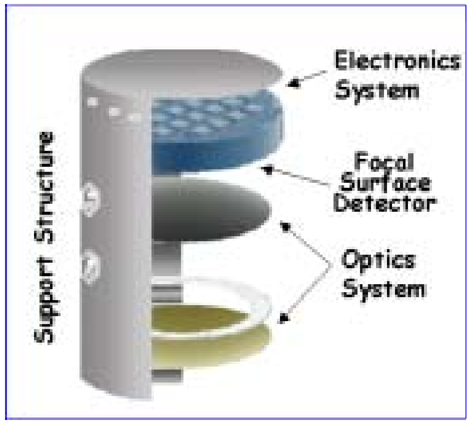

Fig. 3. The proposed EUSO layout showing the principal components including the double Fresnel lens optics and the highly modular focal surface.

Fig. 4. EUSO is the cylindrical structure attached to the left side of ESA's Columbus External Payload Facility. The docking port for the Space Shuttle and the Japanese module can be seen to the right of the Columbus module.

on-board image processing. The image processing will provide a sensitive discrimination between EECR and other forms of UV radiation such as lightening, meteoroids, aurorae, and man made illumination. EUSO will need a carrier such as the Integrated Cargo Carrier due to its 2.5 meter diameter and 4 meter length cylindrical dimensions (Fig. 3). Following an initial feasibility study, the best way of accommodating such a complex payload on the ISS is one of the key topics of the ESA Phase A study which was started in March 2002 by Alenia Spazio of Torino, Italy. Assuming approval by the ESA advisory structure in beginning of 2004, and funding availability to the PI consortium, EUSO could be launched as early as October 2008. A view of what EUSO may look like attached to the Columbus module is shown in Fig. 4.