Expected Performances of the JEM-EUSO Mission

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JEM-EUSO (Extreme Universe Space Observatory on Japanese Experiment Module, Ebisuzaki et al. 2012) is the new type space-based observatory for extreme energy cosmic ray (EECRs; \( E > 10^{19} \text{eV} \)) observation. The JEM-EUSO telescope will be accommodated on the International Space Station.

Observing from an ~400 km altitude, substantial numbers of photons from the EECR-initiated extensive air showers (EASs) are detected in UV band (\( \lambda = 300-400 \text{ nm} \)) by the JEM-EUSO telescope of a 4.5 m\(^2\) aperture. Thanks to an ~60\(^\circ\)-wide FOV, the JEM-EUSO is capable of measuring the full portion of EAS development especially for large zenith angles \( \theta \). The detected signals are characterised by directly arriving fluorescence photons and by Cherenkov light scattered or reflected from the Earth’s albedo. Extremely low fluxes of EECRs (few km\(^{-2}\) per millenium!) essentially require the huge exposure that is primarily determined by the aperture (geometrical and instrumental as of trigger probability) and background (BG) and atmospheric conditions.

The geometrical aperture, when the telescope points to nadir, is product of solid angle acceptance \( \pi \text{ sr} \) and observation area of \( 1.4 \times 10^{15} \text{km}^2 \) as is comparable of a part of it. The BG conditions limit the observation time and effective aperture. The predominant BG source is night glow that has an intensity of ~500 photons m\(^{-2}\) ns\(^{-1}\) sr\(^{-1}\) order (Garipov et al. 2005). Unlike ground-based observatories, the only back-scattered moonlight contributes to BG and therefore the observation time may be enhanced by accepting the Moon presence. With a threshold 1500 photons m\(^{-2}\) ns\(^{-1}\) sr\(^{-1}\), the observational duty cycle yields to 21%.

The locally affect BG sources include light pollution by the man-made light. The effect of such artificial light was evaluated using satellite data measured by DMSP which is also demonstrated in the previous FOV image. It was concluded that only ~9% area exceeds the same threshold level (Adams, Jr et al. in preparation).

In the condition of nominal BG level with no Moon, the trigger aperture was evaluated by the Monte Carlo simulation based on ESAF (Eusso Simulation and Analysis Framework) code (Berat et al. 2010). The ESAF which was originally developed for EAS-driven EUSO mission has been implemented with the baseline JEM-EUSO configuration and trigger algorithms (Catalano et al 2009, Kajino et al 2011 and Fenu 2011 et al.).

The following maps show the trigger probability as a function of core location with different cuts in \( E_0 \) or/and in \( \theta \) (only quadrant of FOV projected on Earth surface is shown since the detector response is symmetric). Inner part of FOV allows higher efficiency due to better optical response and closer distance.

Applying tight cuts in \( \theta > 60^\circ \), ie 1/4 of solid angle acceptance, select EASs with more intense signals. Those EASs landing within 150 km from the FOV centre provide ~100% trigger probability even at ~4 \times 10^{19} \text{eV}.

Releasing such cuts, the probability increases with \( E_0 \) and reach ~100% around 10^{20} \text{eV}.

In the orbit the JEM-EUSO telescope inevitably observes the region with clouds. The cloud impact compared to ground-based observation is less thanks to the fact that EAS development may reach its maximum above the cloud altitude. Observed shower profiles in cloudy conditions may be attenuated by the presence of optically thin clouds (eg. cirrus). In case of optically thick clouds (eg. strat), the photons emitted below cloud altitude are blocked, while intense reflection of Cherenkov light helps better identify core location.

To investigate the cloud impact more quantitatively, the cloud occurrences within the JEM-EUSO orbit were investigated using TOVS database in the matrix of cloud-top altitude \( H_C \) vs optical depth \( \tau_C \).

The reconstruction capabilities have been also estimated using the ESAF code. The technique to reconstruct the different shower parameters is extensively discussed in Fenu et al. 2011. At the current status of development of the reconstruction algorithms, proton EASs with \( \theta > 60^\circ \) are reconstructed in clear atmosphere at a typical energy resolution \( \Delta E/E \sim 20\% \) (25%) at \( E_0 = 10^{20} \text{eV} \). This result indicates that the reconstruction of events with \( E \leq 5 \times 10^{20} \text{eV} \) is feasible confirming the possibility of overlapping with ground based experiments over a sufficient wide energy range. For the arrival direction analysis, our current results indicate that showers of \( E \leq 7 \times 10^{20} \text{eV} \) and \( \theta > 60^\circ \) can be reconstructed less than 2.5\% (68\% CL). Eventually our still preliminary results indicate that the Xmax resolution (\( \Delta X_{\text{max}} \)) is better than 70 g cm\(^{-2}\) for \( E \sim 10^{20} \text{eV} \).

REFERENCES

- JH Adams, Jr et al. in preparation.
- DMSP (Defence Meteorological Satellite Program), http://www.ngdc.noaa.gov/dmsp/.
- TOVS (TIROS/N Operational Vertical Sounder) http://www.rscisat.noaa.gov/action/tovs.htm/