The Fresnel optics of the EUSO-SPB pathfinder: modelling, characterization and data analysis

Abraham Diaz
Institute de Recherche en Astrophysique et Planetologie

Introduction

The Extreme Universe Space Observatory on a Super pressure balloon (EUSO-SPB) is the 2nd balloon pathfinder project for the JEM-EUSO mission, a proposed space observatory designed for the observation of Ultra High Energy Cosmic Rays (UHECRs) with $E > 5 \times 10^9\ eV$ from space (Fig 1) by using the air fluorescence detection method.

The main objectives of the EUSO-SPB mission are:

- Validate technologies for JEM-EUSO mission: Optics, detector, triggers, software
- Characterize UV background
- First time observation from above of UHECR's with E > $10^{19} eV$

The core objectives of the PhD are:

- Characterization and improvement of the optical model of the EUSO-SPB Fresnel lenses.
- Data analysis of the balloon flight in search for UHECR events.

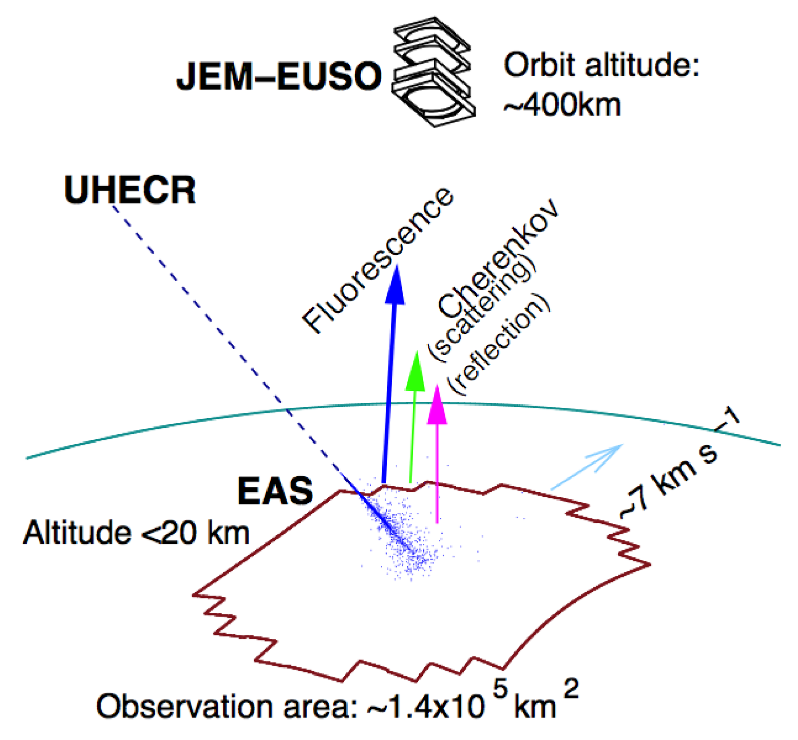

Fig. 1: JEM-EUSO Observation principle

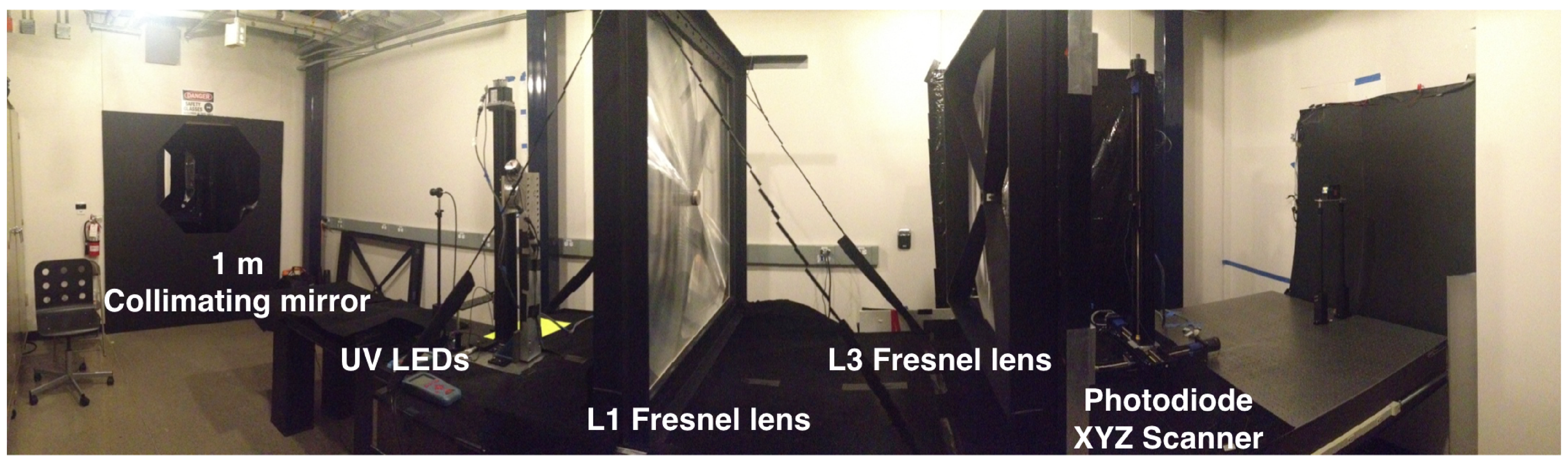

Fig. 2: Test setup of the EUSO-SPB Optics

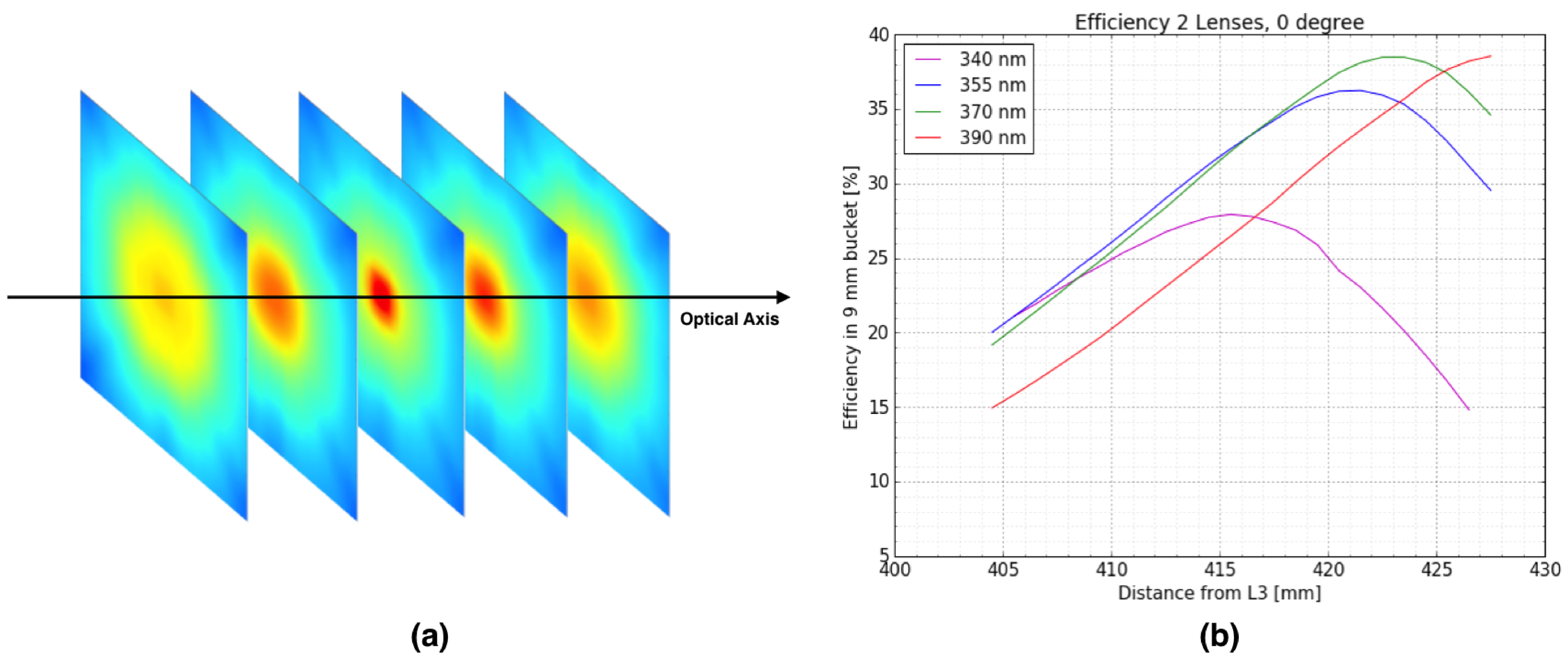

Fig. 3: Results of lens testing. a) Visualisation of 3D Scans. b) Efficiency in 9 mm bucket

Optical system characterization

The optical system is optimized to detect Ultraviolet air fluorescence wavelengths $300\ nm < \lambda < 405\ nm$

The baseline design of the optical system consisted in the use of 2 Fresnel Lenses and middle diffractive lens designed to reduce chromatic aberration.

The system was tested in 2 and 3 lens configuration to choose the best one for flight.

The system was characterized at the Colorado School of Mines with the test bench is shown in fig. 2.

A 3D linear scanner with a photodiode was used to measure the energy distribution of the Point Spread Function (PSF) at different planes normal to the optical axis (fig. 3a). The used wavelengths were 390,370,355 and 340 nm.

The efficiency (i.e. the throughput value in a 9 mm ⌀ bucket) was calculated for all wavelenghts at different intervals along the optical axis (fig. 3b). Overall results are shown in the following table:

	2 Lens system	3 Lens system
Efficiency	32-43 %	15-10%
PSF (RMS radius)	5 mm	2 mm
Chromatic aberration	20 mm	1 mm

2017 Balloon flight campaign

Characterization results showed that the 3 lens configuration provided a smaller PSF and reduced chromatic aberration at the price of lower efficiency.

The 2 lens configuration provided higher throughput and trigger efficiency and was chosen for flight.

The final tests and integration of all subsystems (Detector, Triggers, On-board software) were performed on the balloon campaign in Wanaka, New Zealand.

On April 24th 2017 the instrument was launched on NASA's super pressure balloon.

The french team took shifts at IRAP during the balloon flight to remotely monitor and operate the instrument.

On may 26th the Columbia Scientific Balloon Facility decided to terminate the mission due to a leak on the balloon and The instrument splashed down on the pacific ocean on may 27th, the flight track can be seen in figure 6.

Despite early termination of the mission more than 30 hrs of data was downloaded and it's currently under analysis.

Fig. 5: Instrument before flight

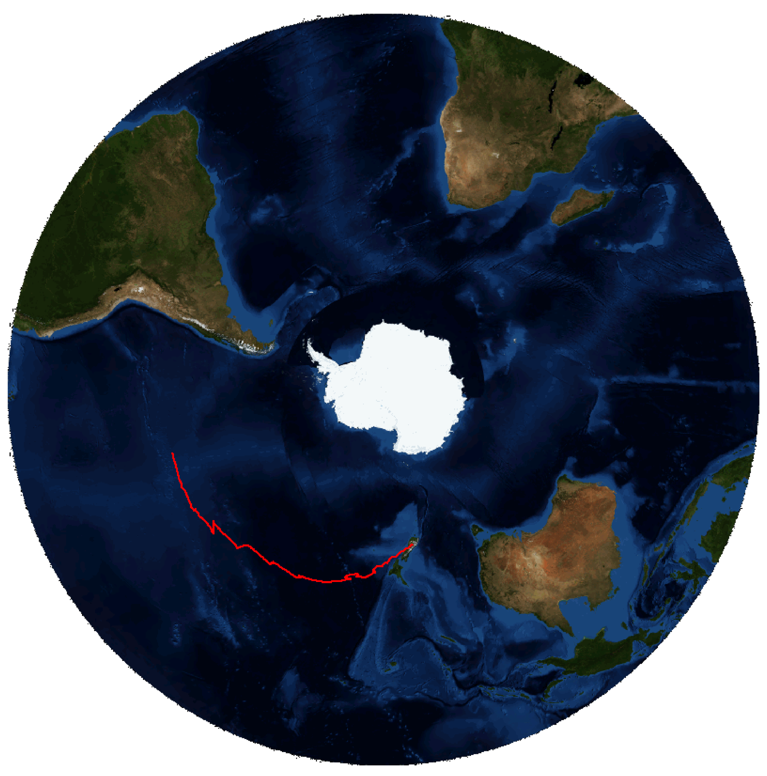

Fig. 6: Balloon flight path

Conclusion

After a successful characterization campaign of the optical system it was decided to fly the instrument with only 2 lenses, many questions remain regarding the optical performance of the system and one of the core problems of the thesis remain: fully understanding how Fresnel lenses work.

This problem will be tackled later in the thesis with the development of a new optical model based on wave optics, but at the moment the work priority will be on the flight data in order to try to find air showers and any other unexpected event that could of significance.

References

J. Adams et Al, "An evaluation of the exposure in nadir observation of the JEM-EUSO mission " Astroparticle Physics, vol. 44, pp. 76 – 90, 2013.

Acknowledgements

This PhD project is funded by the Centre Nationale d'Etudes Spatiales (CNES) and Mecano I&D.