UHECR from Space: status and perspectives plus one proposal for the measurement of background

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The $\mathcal{EUSO}$ lesson

- $\mathcal{EUSO}$ works in an energy range which makes it an experiment complementary to ground-based experiments, PAO and TA in particular.
- $\mathcal{EUSO}$ is technically feasible with up-to-date technology.
- Any $\mathcal{EUSO}$-like space-mission is a real challenge due to the many (scientific and technical) requirements and constraints.
  A huge and coordinated effort is necessary to carry on such an enterprise.
  Unconventional solutions might be required.
- The Observational Approach implemented by $\mathcal{EUSO}$ makes it the precursor and pioneer of a new generation of experiments in the UHECR field.
  We have started to learn how to do such a kind of Experiment/Mission.

What after the PAO, TA and $\mathcal{EUSO}$?

- ESA invited the community to participate in a Call for Themes for Cosmic Vision 2015-2025, to assist in developing the future plans of the Cosmic Vision programme of the ESA D/SCI.
  $\Longrightarrow$ Letter of Intent on *Particle Astronomy*.
- An LoI was submitted signed by one hundred physicists
  hopefully only a subset of the interested scientists
  from the Cosmic Rays Physics Community and beyond.
- Opening Particle Astronomy (with UHECR) to probe and understand the evolving Universe.
  To open the field of *Particle Astronomy*,
  already initiated by AGASA, HiRes, the PAO, TA and $\mathcal{EUSO}$,
  aiming to go one step forward with an ambitious space-based experiment (or experiments...),
  aiming to an instantaneous geometrical aperture two orders of magnitude larger than the PAO,
  and/or and energy threshold near 10^{18} eV.

It is an extraordinary challenge !

How to reach the goal ?

- To conceive and study this experiment(s), an ambitious R&D program must be started (soon !). Some of the topics to be studied/developed (accounting for the space environment and resource limitations):
  - large aperture, large FoV and high transmission optics, suitable for operation in space: (refractive versus reflective ?);
  - dedicated, very efficient, fast, pixelized near-UV sensors, suitable for operation in space;
  - deployability of a large apparatus in space;
  - dedicated trigger and (on-board) data analysis electronics;
  - instrument on-flight calibration techniques;
  - ancillary instrumentation for atmosphere monitoring;
  - use of ISS as a space factory to build and deploy the apparatus;
  - ... many others

How to succeed ?

Such an ambitious program must be coordinated inside all the Cosmic Rays physics community.
Time frame: $\gtrsim 2015$. No conflict with: TA, Auger-North and $\mathcal{EUSO}$.

- the support of the whole Cosmic Rays Physics community and an agreement on the goals of this project is mandatory;
- convince the whole scientific community that it is one step forward in the understanding of the universe;
- build a solid, competent and credible R&D project with laboratories and industrial companies.
- Time is short !!! The required effort is huge and challenging.

Looking at the future

- After the Pierre Auger project (both south and north Observatories!!!) and TA will have clarified the UHECR properties around the GZK-cutoff region a different approach is probably needed to explore the higher energies.
- The full understanding of the space-based approach, proposed more than 20 years ago, is now reaching its maturity, and it is now ready to pass into the implementation Phase.
- UHECR observation from space is a challenging task, requiring a huge and well-coordinated effort by the whole Cosmic Rays physics community.

How to prepare the Mission

Preparation of the Mission

In order to prepare the Mission one needs:

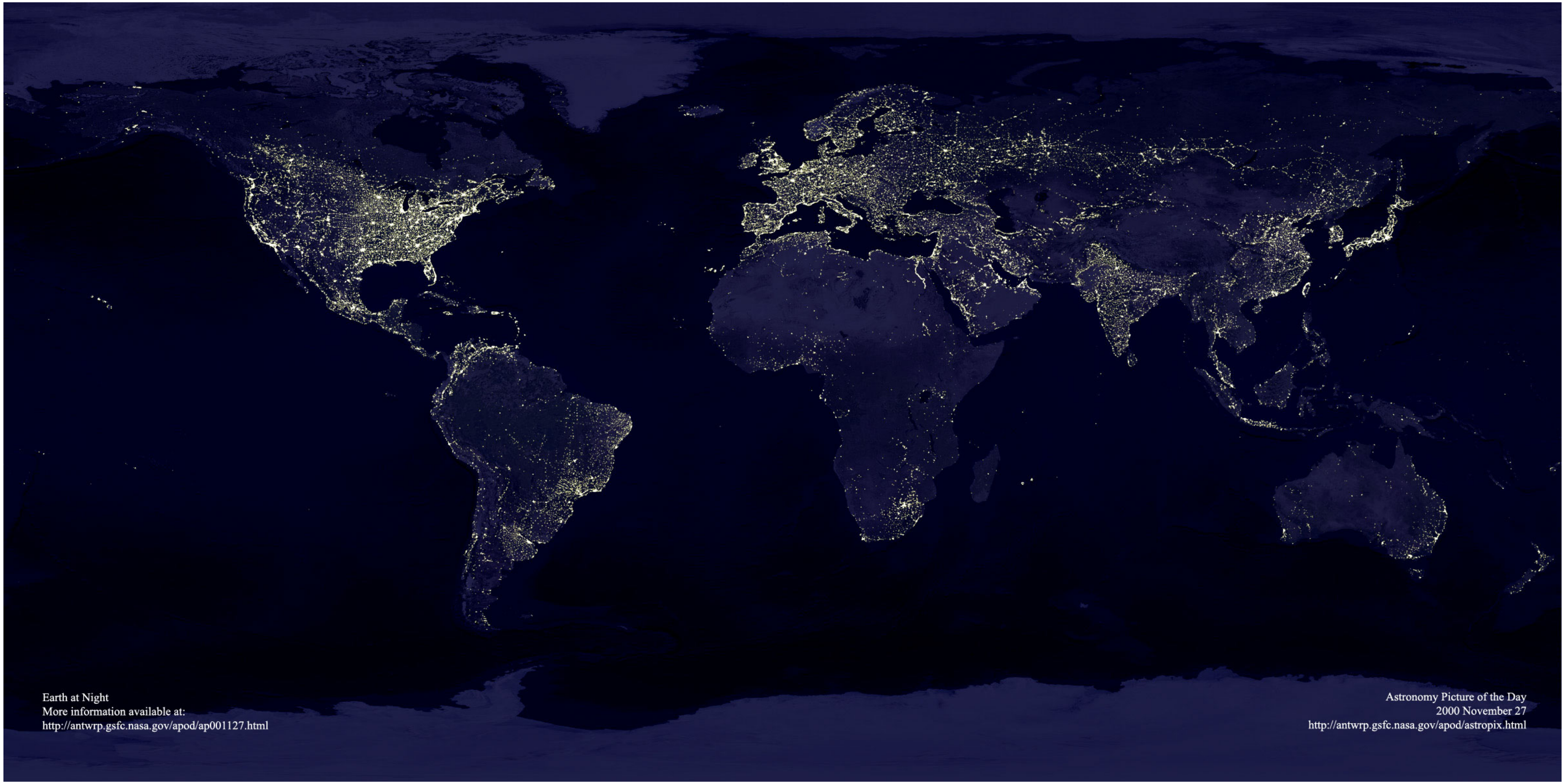
- a serious R&D program;
- a number of technological tests and intermediate steps.

Intermediate steps ?

Intermediate steps might include:

- a long term balloon flight in Antarctica to measure some low-energy CR;
- technological tests via stratospheric airplane flights;
- a small mission to measure the background from space and do partial tests on some technological items;
- ...

The background: night-glow, ⊕ ...



The background to UHECR observation from Space

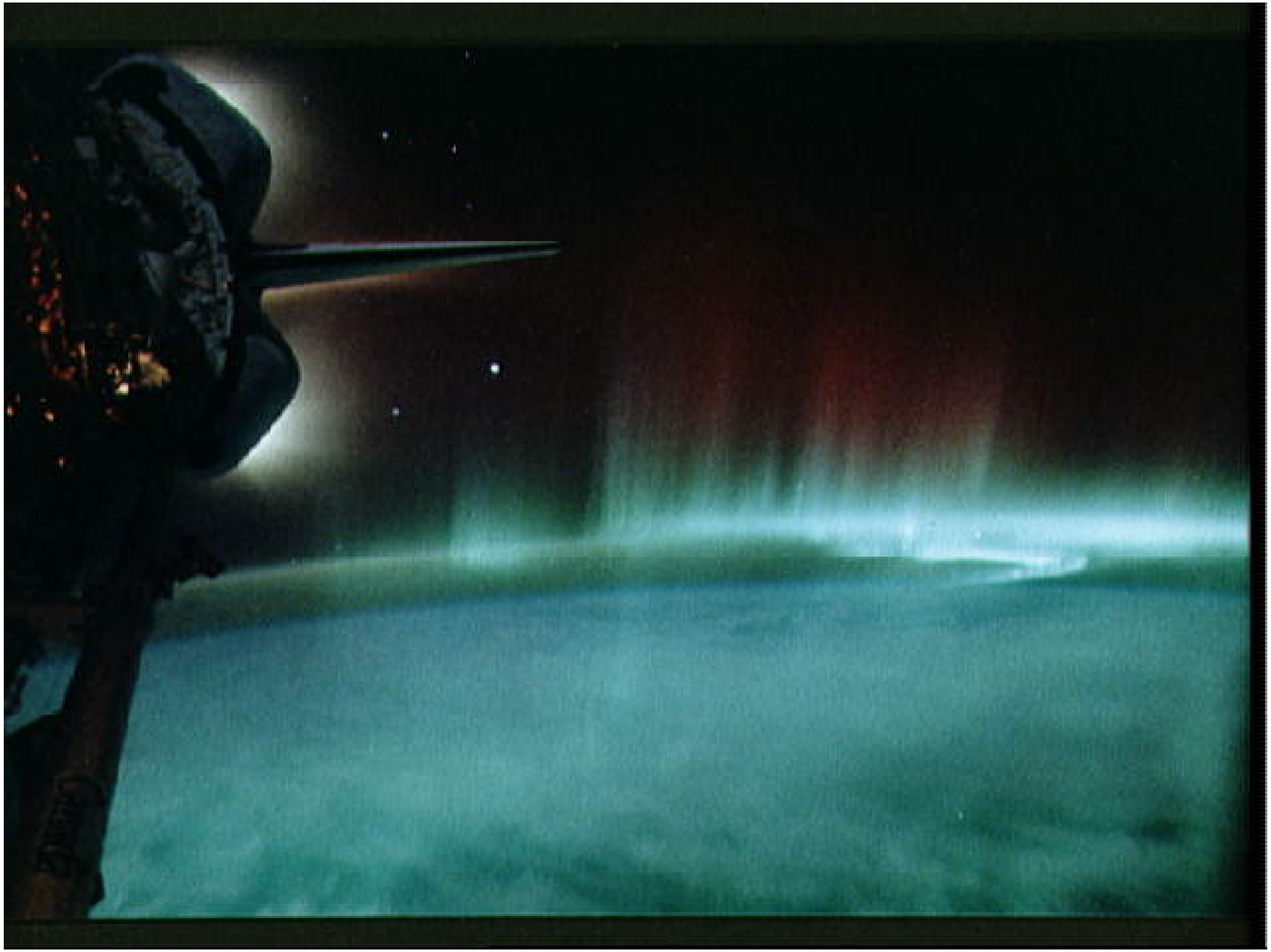
- UHECR observation from Space will be operated at night looking at nadir from an altitude of $\approx (300 \div 500)$ km, and it is sensitive to wavelengths $300 \text{ nm} \lesssim \lambda \lesssim 400 \text{ nm}$.
- The orbital motion implies that the entire sources of background around the Earth must be considered.
- The luminosity of the sources has to be studied and their variability in space and time coordinates as well.
- The nadir viewing implies that specific conditions of the earth atmosphere within the field of view must be considered.
- While the upward diffusion of light by the atmosphere is dominated in clear sky conditions by molecular scattering in this wavelength band, the earth atmosphere albedo will be modified in presence of clouds and/or aerosols.

The background to UHECR observation from Space

The many sources of background can be roughly divided in three broad categories:

- natural night sky diffuse and slowly varying sources;
- man made sources like city lights;
- transient luminous phenomena in lower and upper atmosphere.

Other sources include: satellites and debris in the sun light, meteors, airplanes, low-energy Cosmic Rays as well as any *satellite glow*.



The background to UHECR observation from Space

A mix of measurements and guess-estimates allows the following random background to be quoted, within large uncertainties:

$$B \approx (3 \div 9) \cdot 10^{11} \text{ photons} \cdot \text{m}^{-2} \cdot \text{s}^{-1} \cdot \text{sr}^{-1}.$$

The presence of clouds increase the level by a factor: ≈ 1.5.

A possible mission for background measurement to UHECR from Space

A small satellite would be sufficient to figure out the background in the wavelength range: $300\ \mathrm{nm} \lesssim \lambda \lesssim 400\ \mathrm{nm}$.

- In orbit at $H \approx 400\ \mathrm{km}$ (suitably chosen), inclination $i \simeq 50^\circ$.
- Optics aperture: $D \simeq 0.5\ \mathrm{m}$, with optical throughput $\varepsilon \gtrsim 0.5$.
- Optics Field Of View: $\gamma \simeq 3^\circ$ (half-angle).
- Focal Length: $f \simeq 1.0\ \mathrm{m}$.
- Diameter focal surface: $D_{FS} \simeq 0.1\ \mathrm{m}$.
- Focal Surface made of: ≈ 16 R7600/R8900 Hamamatsu MAPMT (1024 channels).
- Estimated background rate on the Photo-Detector:
  $B_O \approx 60\ \mathrm{MHz}$ (overall). $B_O \approx 60\ \mathrm{kHz}$ (per pixel).

Design and Operation

- Calibration by observation of known sources at the Earth, after measuring the Atmospheric transmission.
- The Focal Surface can be covered with different types of sensors.

Conclusion ?

- Other uses of such a instrument might be possible...???
  Atmospheric phenomena in the upper atmosphere might be observed (Sprites, Blue Jets and Elves).
- It is a large effort, even if it is for a small Mission ! Collaboration ?
- Costs ?
- Partners ?