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Nocturnal atmospheric UV background measurements in the 300-400 nm wavelengths band with BABY 2001: A transmediterranean balloon borne experiment.

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Abstract. In the framework of the EUSO project (an experiment approved by ESA to be accommodate on board of the ISS) we present a new balloon borne experimental apparatus, named BABY 2001 that is devoted to systematic and exhaustive observations of the UV nocturnal atmospheric background. The BABY 2001 experiment is foreseen to flight on the 3rd- 4th week of July 2001 from the Milo-Trapani base on board of a transmediterranean balloon, looking downward from about 40 km of altitude the dark nocturnal atmosphere over the sea. The apparatus used for the BABY 2001 experiment was designed and built at the IFCAI-CNR in Palermo. The instrument is composed by 8 filtered and collimated fast photomultipliers, two of them detecting the UV light in the 300-400 nm wavelengths band and the others in the three narrow bands centered at the emission lines of the atmospheric Nitrogen molecules.

1 Introduction

The systematic observation of the UV nocturnal atmospheric background is the main objective of the balloon borne experiment BABY 2001 (BAckground BYpass). It belongs to a category of projects, EUSO (Extreme Universe Space Observatory) included, devoted to the observation of the Extreme Energy Cosmic Rays (EECRs) from space, detecting the faint UV fluorescence light emitted by the atmosphere as a final result of the cosmic rays interacting with the Earth's atmosphere (Euso team, 2001).

The mission EUSO, approved by the European Space Agency (ESA) to be accommodate on board of the International Space Station (ISS), explores the highest energy cosmic rays component in the region above 10^{19} eV. Its science covers basic problems in the fields of fundamental physics, cosmology and astrophysics.

The very interesting technique to detect and study the EECRs with $E > 10^{19}$ eV, using the Earth's atmosphere as a scintillating giant absorber was suggested several years ago by Linsley and others (Linsley, 1982).

To measure the very fast (hundreds of μs) and faint UV signals, a very high sensitivity detection system is required for the EUSO experiment. This implies an optical system with large collecting area, a focal plane detector with high segmentation and high resolving time and a suitable trigger and read-out electronic systems. To obtain the best performance in detecting EECRs events the signal to noise ratio has to be naturally optimized.

In this framework one of the fundamental information concerns the knowledge of the UV atmospheric background level. The UV background is one of the most important contribute to the sensitivity of the instrument. It gives the lowest energy detectable and, in turn, the goodness of the design in order to build an instrument that could exploit what expected.

Sources of UV nocturnal atmospheric background looking downward straight the Earth are: light pollution from cities, planes and ships, naturally occurring bioluminescence, lightning flashes, reflected moonlight and starlight, auroral flashes, low energy cosmic ray air showers and atmospheric chemical reactions.

Unfortunately, not many measurements have been made in the past to accurately estimate the amount of UV background looking down from space. One of the most recent measurements was made with the first version of the BABY instrument (La Rosa, G., et al., 1999) (Catalano, O., et al., 2001) that, thanks to an opportunity offered by the Italian Space Agency, was hosted on a technological balloon flight, named BOOMERANG, during the summer

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’98 flight-campaign at the Milo-Trapani base. The BABY has flown looking down from an altitude of about 26 Km of height, flew over the territory of the west Sicily and the Mediterranean sea for a duration time of 5 hours on the 30 July 1998 in a clear night and moonless condition. The UV background level measurements were made in the wavelength band of 300–400 nm and didn’t take into account the absorption of the ozone layer because of the not very high altitude reached by the balloon. The brightness value measured over the sea was 4.5 10^2 photons $m^{-2}sr^{-1}ns^{-1}$, comparable with previous rocket observations (Hennes, J.P., 1966) (Greer, R.G.H., 1986).

With BABY 2001 we expect to improve and refine the measurements carried out with the previous experiment. First of all, a more realistic and detailed UV background measurement can be made flying higher in the atmosphere (~ 40 km), thus to include the ozone layer, and by observing the UV level in narrow wavelength bands centered around 337, 357 and 391 nm, where lie the lines of emission of the atmospheric Nitrogen molecules.

The observation of the background in the three narrow bands is important for a better design of the EUSO optical system.

2 The balloon borne experimental apparatus

The atmospheric UV background measurement in the wavelength band between 300-400 nm is the main aim of the BABY 2001 experiment.

This measurement will be carried out by means of a couple of collimated fast photomultipliers (PMTs), one working in photon counting mode whereas the other in charge integration mode (Fig. 1). The use of these two different techniques is motivated by a twofold demand: Crosscheck of the measurements to get reliable results and, more important, demonstrate that photon counting with a fast detector is a technique that can be peculiarly used in such types of physics observations, such as in the EUSO experiment.

The entire experimental apparatus will be composed by four couple of PMTs filtered with different filters. One couple is filtered with a BG1 optical filter and cover the whole wavelength band of interest (300-400 nm). The others are coupled with a narrow bandwidth interferential filters (10 nm) centered on the lines of emission of the atmospheric Nitrogen molecules (337, 357 and 391 nm).

To reduce the amount of light level seen by the PMTs (that is, the photoelectrons rate) and in order to allow the PMT to work in a linear region and in safety conditions, each PMT is collimated in order to reduce the field of view of a known geometrical factor (for example in our case, 1/100 str).

The characteristics of the PMTs used in our experiment are: fast response (< 5 ns), high quantum efficiency (20-25 %) and high gain (> 10^6).

In each couple of PMTs the electronic chains will be designed in such a way to have both the charge integration and the single photon counting modalities.

Temperature sensors are positioned inside the instrument and the electronic boxes to allow a constant monitoring of the health of the instrument.

We foresee a reduced use of the telemetry, limited only to the transmission of the housekeeping data. The scientific data coming from the acquisition channels will be stored in a hard disk by means of a dedicated on board PC.

The mechanical assembly of the instrument (Figg. 2, 3) is very simple. It is composed by the following parts:

- Detector unit, which is the part of the instrument that must be oriented to look downward straight to the Earth.
- Electronic unit, composed by the front-end (in both modality, single photon counting and charge integration) and the control & acquisition system.
- On board computer, to control the experiment and to acquire and to store the scientific (and housekeeping) data.
- Battery supply unit

An estimate of the weights and the overall dimensions is below reported:

Detector unit	(4 x) 3 kg	(4 x) ϕ 10 cm x 30 cm
Electronic unit	25 kg	50 cm x 50 cm x 25 cm
Computer	35 kg	50 cm x 50 cm x 25 cm
Battery unit	10 kg	50 cm x 50 cm x 13 cm

3 Conclusion

The BABY 2001 experiment is foreseen to flight on the 3rd- 4th week of July 2001 from the Milo-Trapani base on board of a transmediterranean balloon, looking downward from about 40 km of altitude the dark nocturnal atmosphere over the sea.

This is another step of a complete program of systematic and exhaustive observations of the UV nocturnal atmospheric background. In fact, with the BABY 2001 instrument we are also planning to make several balloon flight campaigns. Balloon campaigns in South America (Brazil, Bolivia) and other Earth regions permit to measure the UV background at different latitude and different observational conditions like desert, forest, tableland, mountain, land and sea.

Summarizing, many important aspects could be investigated with further balloon missions:

- Differences in sky-noise with and without clouds.
- Differences in sky-noise at various Moon phases.
- Sky-noise at different latitudes and longitudes.
- Sky-noise at different environing condition: sea, land, cities etc.

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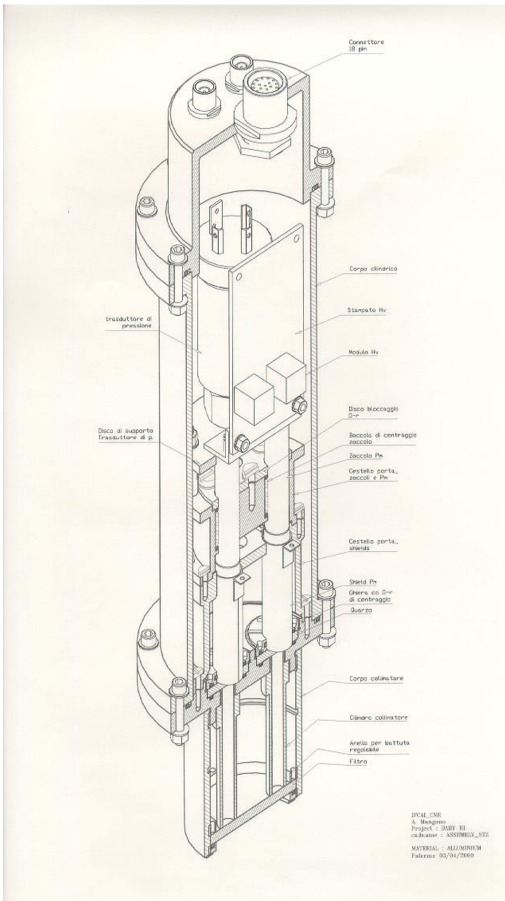

Fig. 1 Schematic of one module of the detector unit

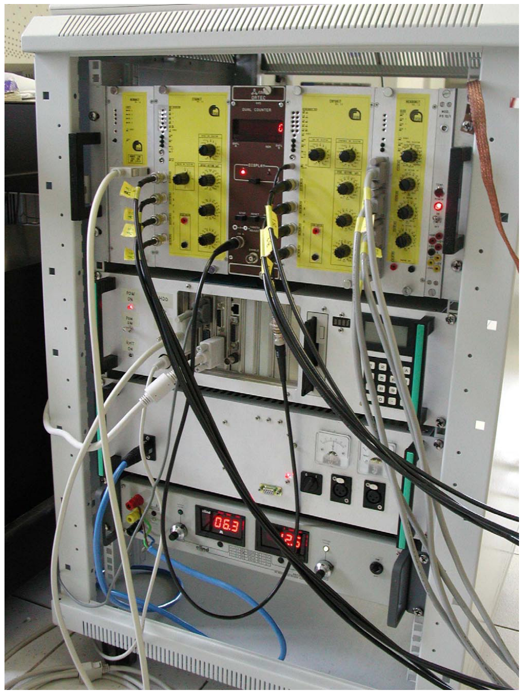

Fig. 2 The electronic and the battery supply units and the computer box

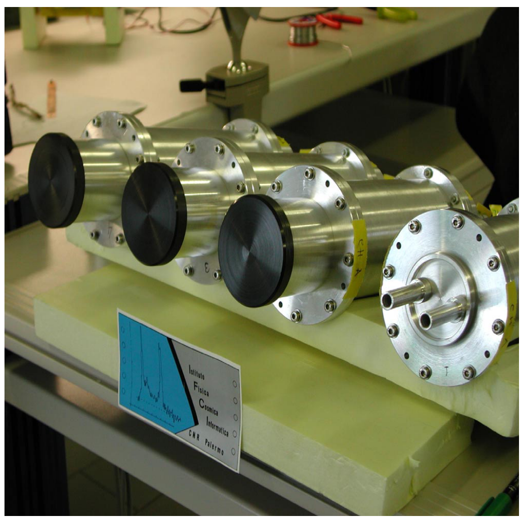

Fig. 3 The detector units