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Energy Calibration of Cherenkov Telescopes using GLAST Data

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Abstract: We discuss the possibility of using the observations by GLAST of steady gamma sources, as the Crab Nebula and some selected AGNs, to calibrate the Imaging Air Cherenkov Telescopes (IACT) and improve their energy resolution. We show that at around 100 GeV, exploiting the features in the spectrum of the Crab Nebula, the absolute energy calibration uncertainty of Cherenkov telescopes can be reduced to $< 10\%$. Other reconstruction uncertainties can be taken care of, as soon as new sources become observable by GLAST and by Cherenkov telescopes. This is the case of AGNs, with their exponential cutoff mainly due to the interaction with the Metagalactic Radiation Field (MRF). This method provides estimates of uncertainties comparable with the current ones.

Introduction

Full multiwavelength coverage of galactic and extragalactic sources over as wide an energy range as possible is needed to understand aspects of fundamental physics and astrophysics as well. Up to now, there still exists an observational window, between ~ 10 and $\sim 100\,\mathrm{GeV}$, largely unknown due to experimental detection difficulties; indeed, this energy range stands between the highest energies significantly detected by satellites and the lowest energy threshold of ground based instruments.

Among ground-based detectors, IACTs are expected to reach the lowest energies: MAGIC, currently detaining the lowest energy threshold among IACTs, has a γ-ray trigger threshold of $\sim 60\,\mathrm{GeV}$ (at zenith) and a spectral threshold of $\sim 100\,\mathrm{GeV}$ [1]. Comparing IACTs with satellite detectors, and GLAST in particular, on the one hand, IACTS feature huge collection areas, an excellent angular resolution and a good energy confinement. On the other hand, they suffer from a low duty-cycle, a small field of view $(< 5°)$ and systematic calibration uncertainties in both energy and sensitivity. In

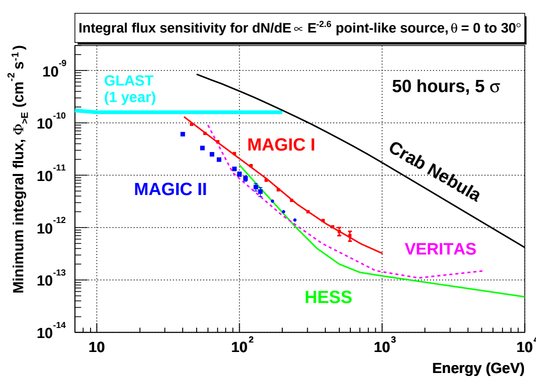

Figure 1: Predicted sensitivities for some operating and proposed detectors. Note the wide overlap region between GLAST and present Cherenkov telescopes. The blue dots are the expected sensitivity for MAGIC II, a second telescope, *clone* of the current MAGIC, that is being built at $\sim 85\,\mathrm{m}$ of distance from MAGIC. Start of operation for MAGIC II is envisaged for the beginning of 2008, just around the scheduled launch of GLAST.

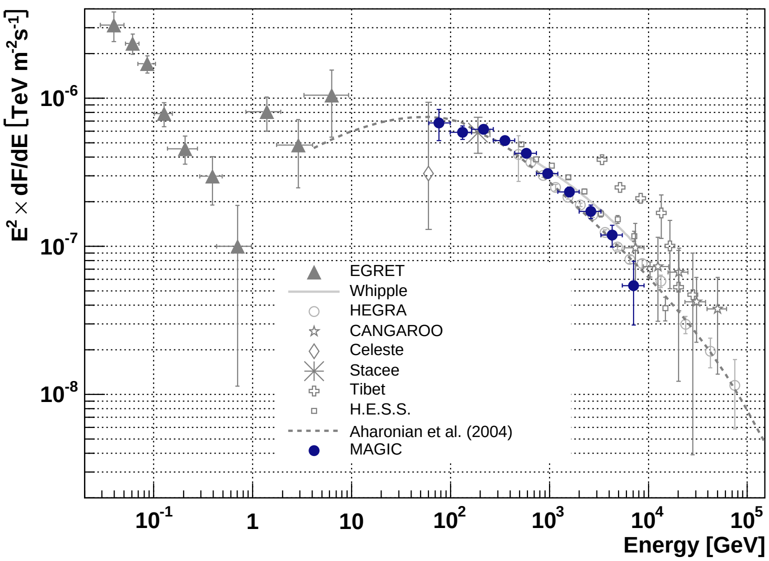

Figure 2: Spectral energy distribution (SED) of the γ-ray emission of Crab Nebula as seen by MAGIC.

fact, whereas IACTs could reach an intrinsic energy resolution as low as $\sim 5\%$, the absolute energy scale remains quite elusive, as the energy reconstruction in the $30 \div 300$ GeV range is dominated by uncertainties on Monte Carlo simulations and on the atmospheric model [2].

GLAST, contrarily to IACT, is calibrated in a well-controlled laboratory environment using test beams and an energy resolution of $\sim 10\%$ or better is expected. After GLAST launch, while LIDARs can provide IACTs with regular measurements of atmospheric transmission, GLAST observations of higher energies sources can be used to reduce systematic errors in the absolute energy scale determination of IACT events.

Calibrating IACTs with GLAST using the Crab

To calibrate IACTs, a good source has to satisfy three requirements:

- to be stable, at least on the time scale of typical observations (depends on the actual flux, but on the order of months);
- to have a flux detectable by both classes of experiment;
- to present a clear spectral feature, a deviation from a pure power-law such as a change in the spectral index or an exponential cutoff.

A source complying with all three items is the Crab Nebula: already observed with enough statistics by IACTs and stable since many years. The spectrum of the Crab Nebula in the overlap region is poorly known, but the variation in spectral index, from EGRET to IACT energies, can be used to define a unique energy scale.

In fact, the spectrum can be parameterised with two different spectral indexes: one fitting data at low energies and one at higher energies (conservatively: 2.0 and 2.7 respectively). A larger difference between the indexes will make the spectral feature more prominent and allow a more precise determination of E_{brk}, the energy at which the two power laws meet, expected to lie at around 100 GeV.

The position of this spectral break, well determined by GLAST, can be used to calibrate IACTs.

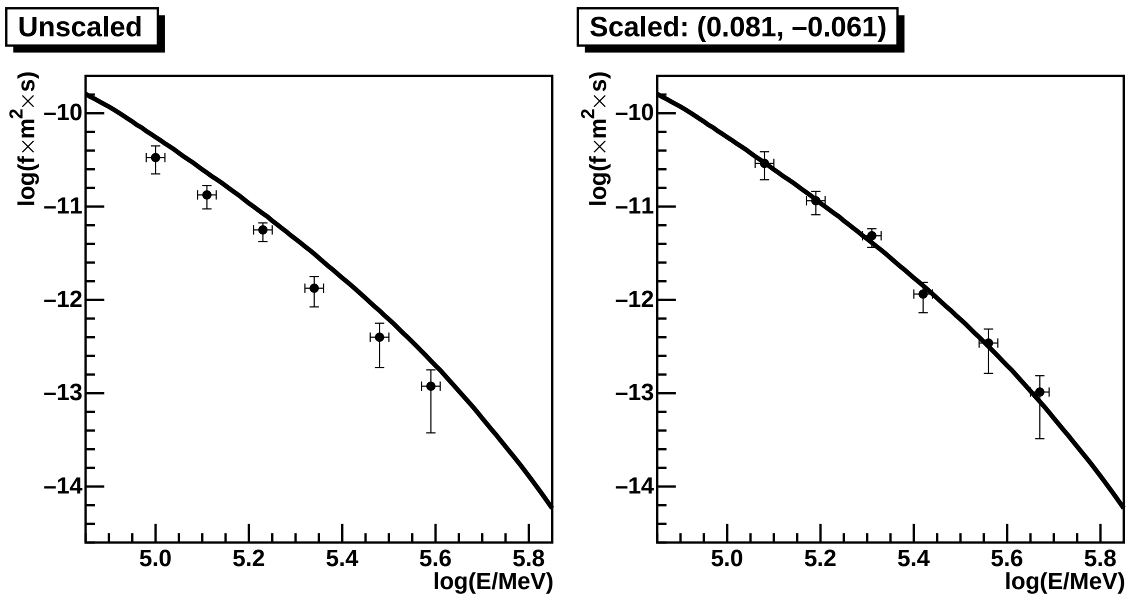

Figure 3: Spectrum of PG 1553+113 as estimated by using the GLAST performance data for one year (line), MAGIC data from [3] (left) and scaled (right). Constraints on scale factors are set by the reconstructed spectrum of PG 1553+113, 1ES 1218+30.4 and the Crab Nebula.

As far as IACTs are concerned, the lower energy spectrum of the Crab Nebula is provided by MAGIC at energies above $60\ \mathrm{GeV}$ and confirms the bending of the spectrum as can be seen in fig. 2 [1].

During the first year, GLAST will observe the sky in survey (scanning) mode, therefore a uniform exposure at a 90% level can be conservatively assumed (see, *e.g.* The GLAST Science Document). As its field of view is around 2.4 sr, *i.e.*, $\sim \frac{1}{5}$ of the full sky, GLAST will observe every source, and in particular the Crab Nebula, for $\frac{1}{5}$ of a year. Most of the time the source will be off-axis by 40° on average, and the effective area is correspondingly reduced by a factor of 0.8 (for GLAST performance: *http://www-glast.slac.stanford.edu/software/IS/glast_lat_performance.htm*).

Since the Crab Nebula is also observable by GLAST, the spectral feature represented by $E_{\rm brk}$ can be used to determine the absolute scale of IACTs within 10% [4], provided $E_{\rm brk} \lesssim 100\ \mathrm{GeV}$ as suggested by MAGIC observations.

Calibrating IACTs with GLAST using AGN spectra

Beside the Crab, many other sources, typically AGNs, do show a featured spectrum. Their power-law spectrum is in fact folded with an exponential cutoff due to the absorption by the MRF. The position of this cutoff, if reconstructed both by GLAST and IACTs, can be used to reduce the absolute scale uncertainty as in the case of the Crab. Moreover, they can also help in reducing other possible systematic misbehaviours: there can be in fact some scaling error in reconstructing the fluxes or the energies. For this purpose, we used the data collected on PG 1553+113 [3] and 1ES 1218+304 [5]. Estimating the GLAST observation from its performance and comparing it with the data obtained by IACTs, one can infer the two scale factors that should affect flux and energy. As can be seen from Fig. 3, just two AGNs and the Crab Nebula are enough to constrain these factors with uncertainties comparable with the current estimates. The numbers quoted in the caption of the right plot in Fig. 3 correspond to the logarithm of the scaling factors to be applied to MAGIC estimates for energy and flux, or a rescaling of $\sim 1.20 = 10^{0.081}$ for the energy scale and $\sim 0.87 = 10^{-0.061}$ for the fluxes.

Conclusions

We showed how to reduce the uncertainties in the spectrum reconstructed by the IACTs. This approach was proven to be comparable with the current estimates of the systematic errors affecting the measurements. As the GLAST catalogue will embrace more and more sources, these errors will get smaller allowing us to close the observational gap in electromagnetic spectrum and observe the sky at all energies with unprecedented precision.

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