MAGIC Upper Limits for two Milagro-detected Bright Fermi Sources in the Region of SNR G65.1+0.6

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Motivation

The region around SNR G65.1+0.6 is densely populated (fig. 1), and the identification and association of detected structures remains an open debate. This region hosts the two bright GeV gamma-ray sources [2] 1FGL J1954.3+2836 (**3**) and 1FGL J1958.6+2845 (**4**). They are identified as GeV pulsars and both have a possible counterpart detected at about 35 TeV with ~20% of the Crab Nebula flux by the Milagro observatory [1]. We report upper limits on this region with the stand-alone MAGIC-I telescope, bridging the spectra at lower and higher energies.

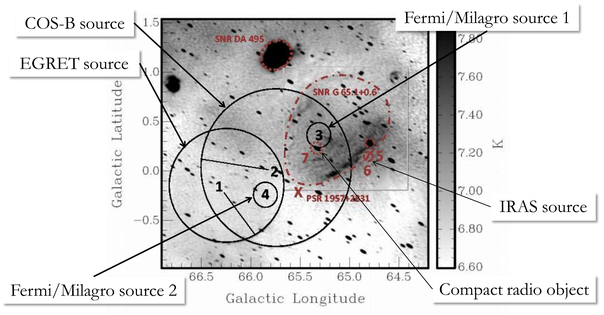

Fig. 1 – Radio image of G65 [6], with other existing objects.

Observations

The MAGIC telescopes use the Cherenkov imaging technique and are located on the Canary Island of La Palma (28.8N, 17.8W, 2220m a.s.l.). In these observations, the data used comes only from the stand-alone MAGIC-I telescope [4].

The instrument collected:

- 25.5 hours on 1FGL J1954.3+2836 (J1954),
- 13.8 hours on 1FGL J1958.6+2845 (J1958), because it appeared in the field of view of the previous one (see fig. 2)

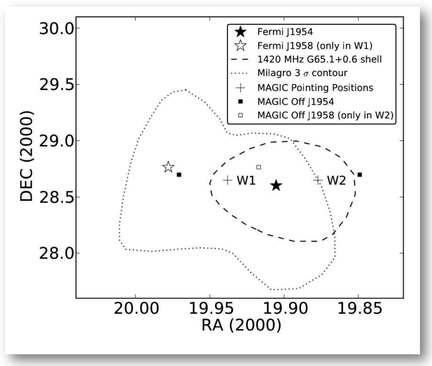

Fig. 2 – Observation setup with the MAGIC telescope.

Analysis

The main target of the observation, **J1954**, is analyzed using standard wobble analysis procedures within the MARS analysis framework [7].
In the case of **J1958**, the analysis was done in ON/OFF manner, using the near wobble sample as ON-source data and the far wobble sample as OFF-source data (hollow squares in fig. 2).

To test the presence of gamma-ray signal, the distributions of squared angular distances (θ^2) between photon directions and the source positions were used (i.e. fig. 3). However, we report the absence of a significant signal for both sources.

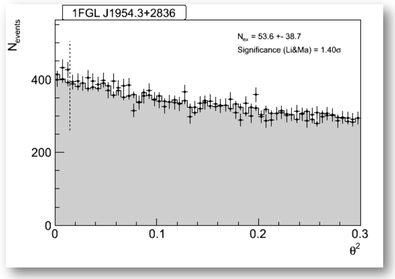

Fig. 3 – Distribution of θ^2 for 1FGL J1954.3+2836.

Flux upper limits

We convert our data into three differential flux upper limits for each source, dividing each sample into three bins of estimated energy. For each bin, an event number upper limit is calculated from the before-mentioned θ^2-plots, at 95% confidence level (c.l.) [8]. This analysis assumes a source extension $\leq 0.08^o$ (i.e., the PSF of MAGIC in this case).
Assuming the **point-like** case, our data restricts the photon index in the energy range of 1 to 35TeV to be:

- harder than 2.2 for J1954, and
- harder than 2.1 for J1958.

Since the Milagro source may be extended, a second analysis was done, assuming an extension of 0.3º instead.
In this **extended** case, the photon indices are limited to:

- ≤ 2.6 for J1954, and
- ≤ 2.2 for J1958.

Figures 4 and 5 display the 95% c.l. flux upper limits in the context of the published satellite data from Fermi (and EGRET, for J1958), and the Milagro flux estimation.

Bringing together the existing flux data and our upper limits, we conclude that the most likely scenario to explain the gamma-ray production measured by Milagro is probably the existence of two **PWN**, associated with the Fermi pulsars.

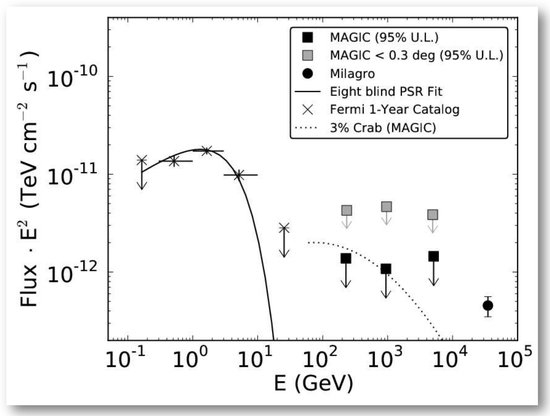

Fig. 4 - Compilation of flux measurements and upper limits for **1FGL J1954.3+2836** from Fermi [2], [9], MAGIC and Milagro [1].

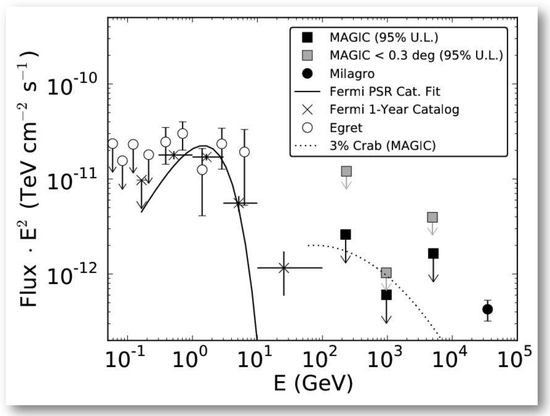

Fig. 5 - Compilation of flux measurements and upper limits for **1FGL J1958.6+2845** from EGRET [5] Fermi [2], [3], MAGIC and Milagro [1].

Concluding remarks

We have reported differential flux upper limits on the region G65.1+0.6, assuming the emission to be point-like (< 0.1 degrees) or within a radius of 0.3 degrees.

In the point-like scenario, the flux limits around 1 TeV are at the level of 3% and 2% of the Crab Nebula flux, for 1FGL J1959.3 +2836 and 1FGL J1958.6+2845 respectively. This implies that the Milagro emission is either:

- extended over a much larger area than our point spread function, or
- it must be peaked at energies beyond 1 TeV, resulting in a photon index harder than 2.2 in the TeV band.

Our data therefore supports the existence of two distinct mechanisms or components behind the production of gamma rays reported by Fermi and Milagro.
The MAGIC upper limits constrains the Milagro emission either to be very extended, or peaking at energies well above 1TeV, or both.

A plausible scenario that explains the gamma-ray emission from both sources consist in two GeV pulsars that power two old pulsar wind nebulae. The multi-TeV emission detected by Milagro would be produced by the latter.

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