Limits on point-like sources with different spectral indexes around the Galactic Centre using the ANTARES neutrino telescope

J. Barrios-Martí, on behalf of the ANTARES Collaboration

Institut de Física Corpuscular - Universitat de València / CSIC

Introduction

- Excess of high energy neutrinos reported by IceCube which cannot be of atmospheric origin.
- Accumulation of events close to the Galactic Centre (not enough significance to identify a point-source).
- Analysis around the GC previously performed in ANTARES, current analysis extended for energy spectra, γ, between 2.0 and 2.5.

Number of expected events

- Number used in order to estimate the sensitivity and upper limits.
- Power-law spectra of $d\Phi/dE_\nu = \Phi_0(E_\nu/GeV)^{-\gamma}$ are assumed.
- Number of source events can be expressed as,

$$N(\delta,\gamma) = \int dt \int dE_\nu A_{eff}(E_\nu,\delta)\Phi_0 \left(\frac{E_\nu}{GeV}\right)^{-\gamma}, \quad (1)$$

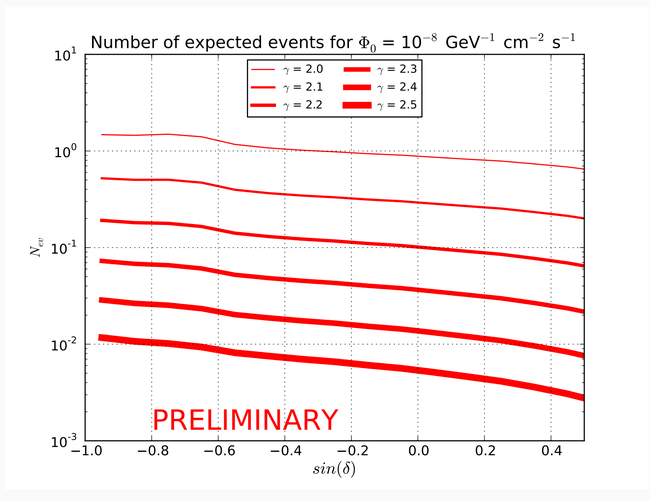

Figure 1: Number of expected signal events as a function of the declination, δ, for energy source spectra between 2.0 and 2.5 in steps of 0.1. A normalization flux of $\Phi_0 = 10^{-8}$ GeV^{-1}cm^{-1}s^{-1} has been assumed in all cases.

Search method

The likelihood used for the analysis can be described as,

$$\log L(n_s) = \sum_i \log\left[\frac{n_s}{N}S_i + \left(1-\frac{n_s}{N}\right)B_i\right], \quad (2)$$

- n_s: fitted number of signal source events
- N: Total number of events in the sample
- B_i, S_i: Background and signal PDFs for the ith event, respectively.

Signal PSF

$$S_i = \frac{1}{2\pi\beta_i^2}\exp\left(-\frac{\psi_i(\vec{x}_s)^2}{2\beta_i^2}\right)P_s(\mathcal{N}_i^{hits},\beta_i|\gamma)$$

- $\vec{x}_s = (\alpha,\delta)$: position of the source in equatorial coordinates
- $\psi_i(\vec{x}_s)^2$: angular distance to the assumed source direction.
- $P_s(\mathcal{N}_i^{hits},\beta_i|\gamma)$: Probability for the ith event to be reconstructed as signal given a number of hits of $\mathcal{N}_i^{hits}$ and an angular error estimate of β_i for a spectral index of γ.

Background PSF

$$B_i = \frac{B(\delta_i)}{2\pi}P_b(\mathcal{N}_i^{hits},\beta_i),$$

- $B(\delta_i)$: Probability for an event to be background given its declination, δ_i.
- $P_b(\mathcal{N}_i^{hits},\beta_i)$ is the probability for an event to be reconstructed as background with an angular error estimate of β_i and a number of hits $\mathcal{N}_i^{hits}$.

- Test statistic, TS, defined as TS = $\log L(n_s) - \log L(n_s = 0)$. Larger values of the TS designate a smaller probability of the cluster to be generated from only atmospheric events.
- Search around a region of 20° around the proposed location $(\alpha,\ \delta) = (-79°\ -23°)$ is performed (large estimated angular error in IC events).

Results

- No significant cluster has been found in the defined area around the Galactic Centre.
- 90% C.L. upper limits on the flux normalisation, Φ_0, for the different assumed source spectra and as function of the declination can be seen in figure .
- Figure shows the limits for a declination of δ = -29°.
  - Expected flux normalisation depending on the number of HESE events.
- A point-like source with values of the spectral index closer to 2.5 are more disfavoured than for values closer to 2.0.

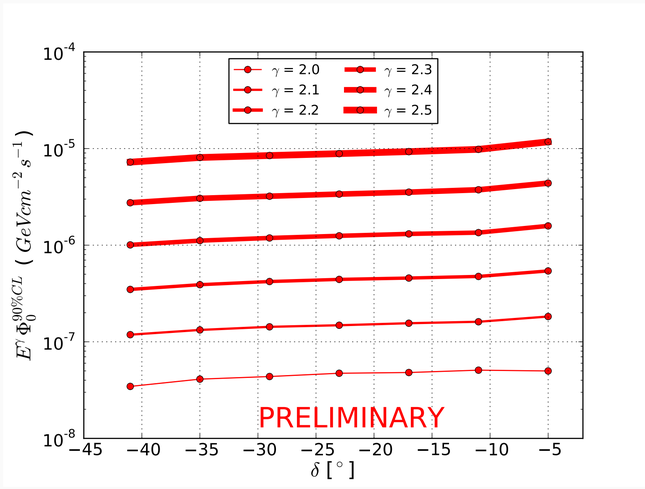

Figure 2: 90% C.L. upper limits for source spectra between 2.0 and 2.5 as a function of the declination of the source.

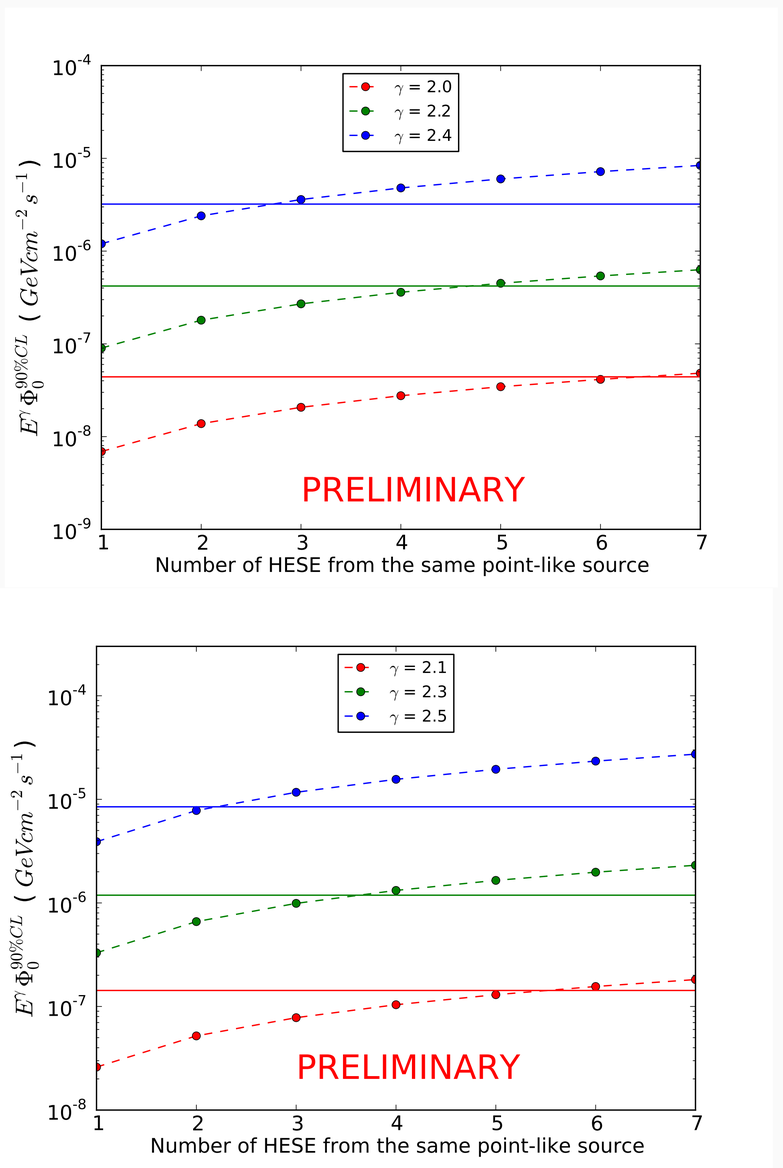

Figure 3: Solid lines: 90% C.L. upper limits for source spectra between 2.0 and 2.5 and a source declination of $\delta = -29°$. The figure on the left contains the values for γ = 2.0, 2.2, and 2.4, whereas the figure on the right contains the ones for γ = 2.1, 2.3 and 2.5. Dashed lines: expected flux normalisation of the proposed source as a function of the number of HESE events coming from this source. Values above the solid lines are disfavoured with a confidence level larger than 90%.

Conclusions

A point-source search around the Galactic Centre for spectral indices between 2.0 and 2.5 with the ANTARES neutrino telescope has been performed. No significant cluster has been found, and 90% C.L. upper limits have been set. According to these limits, point-like sources with softer spectra are more disfavoured to explain the accumulation of events observed by IceCube.

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