Stacking Search for Ultra-Luminous Infrared Galaxies with the KM3NeT/ARCA Detector

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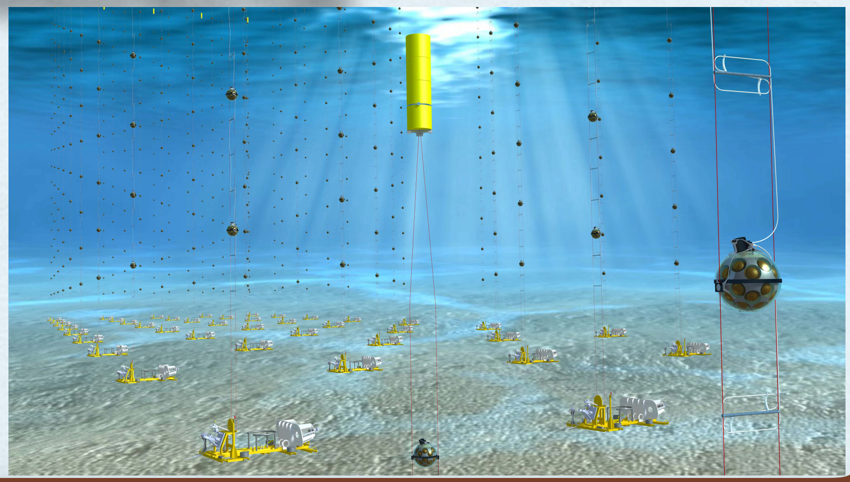
INTRODUCTION: THE KM3NET INFRASTRUCTURE

The KM3NeT infrastructure [1,2] comprises two cherenkov light detectors under construction in the Mediterranean sea: ORCA, optimized to measure low-energy neutrinos and ARCA, devoted to detect high-energy astrophysical neutrinos. Each detector is a 3D grid of digital optical modules and the ARCA detector is expected to have 230 lines. In this contribution, we employ 424 days of data comprising several configurations (ARCA 6,8,19,21) in order to perform a stacking analysis on Ultra-luminous infrared galaxies (ULIRGs).

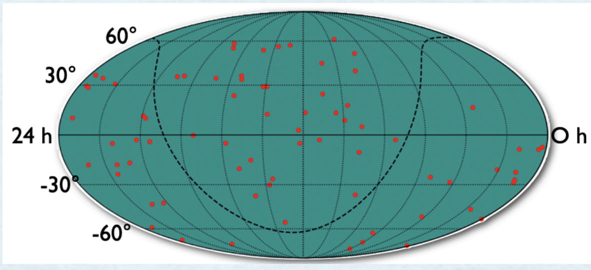


Right: an illustration of the KM3NeT final configuration

THEORETICAL FRAMEWORK

ULIRGs are sources with infrared luminosity greater than $10^{12} L_\odot$, with $L_\odot$ being the solar luminosity. They are characterized by an enhanced star forming activity. This activity produces high-energy cosmic rays (CRs) up to PeVs energies and it increases the amount of gas in the system, leading to an high probability of proton-proton (pp) collisions [3]. So, ULIRGs should be proton calorimeters, leading to production of γ-rays and neutrinos [3].

Here, following [4], we perform a stacking search over a catalogue of 75 ULIRGs throughout the whole sky.

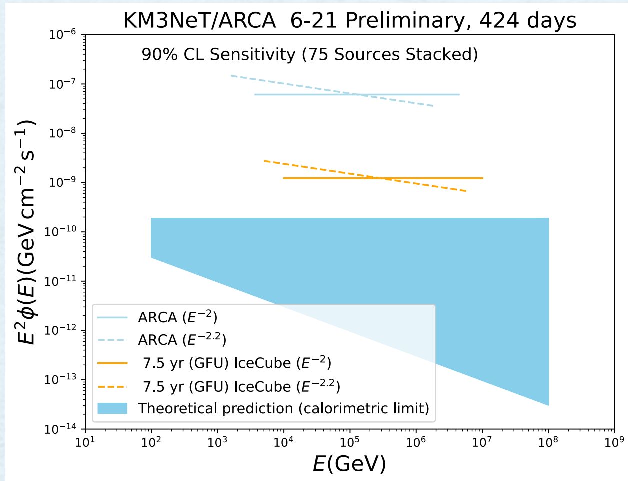


Above: Skymap of the ULIRG catalogue in equatorial coordinates

CATALOGUE RESULTS

This analysis allows us to constrain the role of ULIRGs as potential neutrino emitters.

On the right, we show the final sensitivity for the entire catalogue compared with the IceCube sensitivity for the same catalogue [4] and compared with the theoretical expectations assuming a total calorimetric assumption for each source [3].



At the moment, no neutrino telescope is able to probe the calorimetric limit of these sources, but the sensitivity will improve with time.

ANALYSIS DETAILS

- Dataset: ARCA6 (92 Days), ARCA8 (210 days), ARCA19 (69 days), ARCA21 (69 days) [datasets do not overlap]
- Event Selection: upgoing tracks

For each dataset:

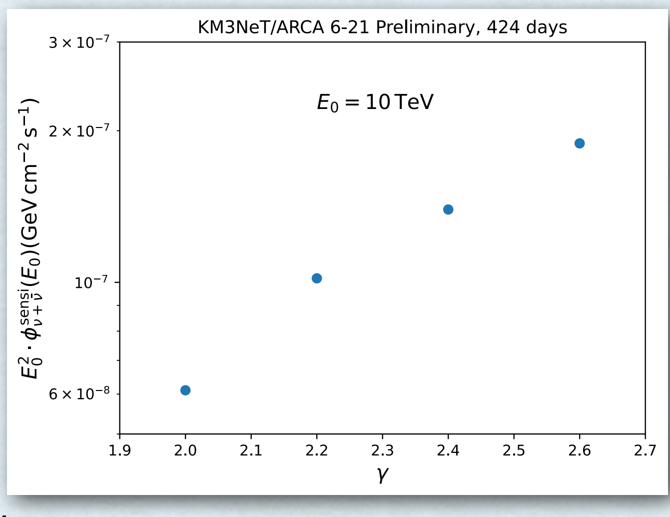
- Signal expectation (S) from Monte Carlo (MC)
- Background estimation (B), data driven from Data Sampling
- Performing Pseudo experiments for sensitivity calculation

The total likelihood is given by

$$\log L = \sum_{i,j} N_{i,j} \log(B_{i,j} + \mu S_{i,j}) - (B_{i,j} + \mu S_{i,j})$$

The sum is performed over the bins and the sources

- Each source is weighted according to L_{IR}/D^2, with D being the luminosity distance
- Each source is characterized by the same spectral index (γ)



Above: Final sensitivity (whole catalogue stacked) as a function of the spectral index

(See [4] for further details)

EXTRAPOLATION TO THE WHOLE SKY

The sensitivity can be translated into a 90% C.L. upper-limit to the whole ULIRG population, exploiting the properties of the catalogue [4].

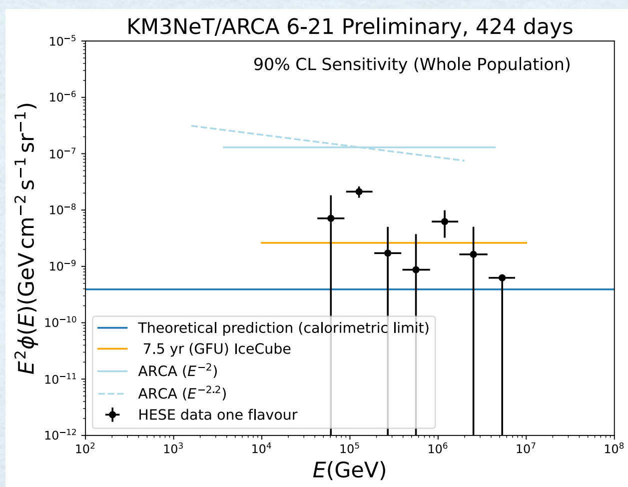
The catalogue is representative of the ULIRG population up to $z \lesssim 0.13$, with a correction factor ($\epsilon \simeq 1.1$), taking into account the (*in*)completeness of the catalogue [4].

$$\phi^{z \le 0.13}_{\mathrm{sensi}} = \epsilon \frac{\phi^{\mathrm{catalogue}}_{\mathrm{sensi}}}{4\pi}$$

Knowing the distribution of ULIRGs over redshift, the sensitivity can be extrapolated to the whole sky [4,5].

$$\phi^{z \le 4}_{\mathrm{sensi}} = \frac{\xi_{z=4}}{\xi_{z=0.13}} \phi^{z \le 0.13}_{\mathrm{sensi}}$$

On the right, we show the sensitivity extrapolated to the whole sky compared with the corresponding limits from the IceCube analysis [4] and the theoretical predictions [2]. The results are also compared with the 7.5 years of IceCube HESE data [6].



References

[1] *J.Phys.G* 43 (2016) 8, 084001, [2] 2402.08363 [astro-ph.HE], [3] 2402.18638 [astro-ph.HE], [4] *Astrophys.J.* 926 (2022) 1, 59, [5] 2004.03435 [astro-ph.HE], [6]*Phys.Rev.D* 104 (2021) 022002