PROCEEDINGS OF SCIENCE

Latest results of Antares Observatory and recent news of KM3NeT-ARCA Observatory

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The ANTARES detector, located 40 km off the French coast, is the largest deep-sea neutrino telescope in the Northern Hemisphere with an instrumented volume of more than 0.01 cubic kilometers. It has been taking data continuously since 2007. The KM3NeT-ARCA telescope is currently under construction in the Mediterranean sea and has been designed to be the next generation deep-sea telescope with an instrumented volume of the order of the cubic kilometer. Both telescopes consist of an array of optical modules detecting the Cherenkov light induced by charged leptons produced by neutrino interactions in and around the detector. The first detection lines of KM3NeT have been deployed successfully and the first muons observed. Their primary goal is to search for high energy astrophysical neutrinos as diffuse flux or coming from astrophysical sources such as Active Galactic Nuclei or Galactic sources. The search program also includes multi-messenger analyses based on time and/or space coincidences with other cosmic probes.

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1. Introduction

Underwater neutrino telescopes such as ANTARES and KM3NeT-ARCA are mainly meant for the detection of high energy neutrinos. ANTARES data have been used to perform searches both for point-like neutrino emitters and for a diffuse flux component, such as the one discovered by the IceCube neutrino telescope, located at the South Pole [1]. Due to the optical properties of the sea water, the angular accuracy as reported by the ANTARES collaboration [2], together with the large detection volume of the KM3NeT-ARCA telescope and with an excellent visibility of the Galactic Plane, will allow to detect the neutrino flux reported by IceCube in less than one year of operation and to make definite statements about a neutrino flux from several Galactic candidates. Studies on atmospheric neutrinos and dark matter have also been performed by the ANTARES collaboration but will not be discussed in this contribution. Details can be found in [3] and [4].

2. The ANTARES and KM3NeT-ARCA telescopes

The ANTARES neutrino telescope is located 40 km off-shore Toulon (France), on the sea bed at a depth of 2475 m. Its location allows for an optimal observation of the Galactic plane and the Galactic centre, in the southern sky, where candidate emitters of astrophysical neutrinos could be hosted. The telescope consists of a three dimensional array of 885 optical detectors (Photomultiplier Tubes - PMT). The Cherenkov light emitted along the path of the charged particles produced in the neutrino interactions is collected and the position, time and charge of the signals in the PMTs are used to reconstruct the direction and energy of the incident neutrino. The events can be classified according to two topologies: the track-like events due to charged current (CC) interactions of muon neutrinos and the shower-like events due to neutral current (NC) interactions, and electron neutrinos and tau neutrinos CC interactions. The track-like events have a median angular resolution better than 1°. The shower-like events allow for an energy resolution of about $5-10\%$.
The KM3NeT-ARCA neutrino telescope is currently under construction off-shore Sicily (Italy) at a depth of about 3500 m. The instrumented volume of more than $1\,\mathrm{km}^3$ together with an improved design of the optical modules will allow[1] an angular resolution of less than 0.2° for tracks and less than 2° for showers and an energy resolution better than 30% for tracks and 5% for showers.

3. Diffuse fluxes searches

Searches for a diffuse flux of neutrinos above the atmospheric neutrino background have been performed using 9 years of ANTARES data, from 2007 up to 2015 [5]. An excess of events above the energy cut has been looking for taking into account both track- and shower-like events. A total of 33 events have been observed, while 24 were expected from pure background and about 8 from the astrophysical flux. The best-fit cosmic flux is shown as a white marker in the plot of figure 1. Even though the hypothesis of a null cosmic flux is not excluded with a large significance (1.6σ), the ANTARES result supports the hypothesis of the IceCube flux being of cosmic origin. A quick confirmation of the IceCube signal should be provided by KM3NeT-ARCA.

[1] in the energy range $[10\,\mathrm{TeV}, 100\,\mathrm{PeV}]$

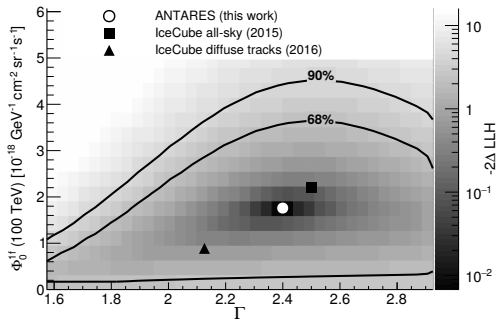

Figure 1: 2D log-likelihood scan of the diffuse cosmic flux normalization and spectral index obtained in the latest ANTARES search for a diffuse flux [5]

4. Point source searches

The pointing accuracy of neutrino telescopes in water allows to reject most of the atmospheric background when looking for point like sources. A recent analysis has been performed with the 7629 track-like events and with the 180 shower-like events detected between 2007 and 2015. No significant excess has been observed, neither in the all-sky search, nor in the study of a list of more than 100 candidate sources (including 13 IceCube HESE). As it can be seen in the left plot of figure 2 and despite its small size, ANTARES has set the best world limits in a wide region of the Southern sky.

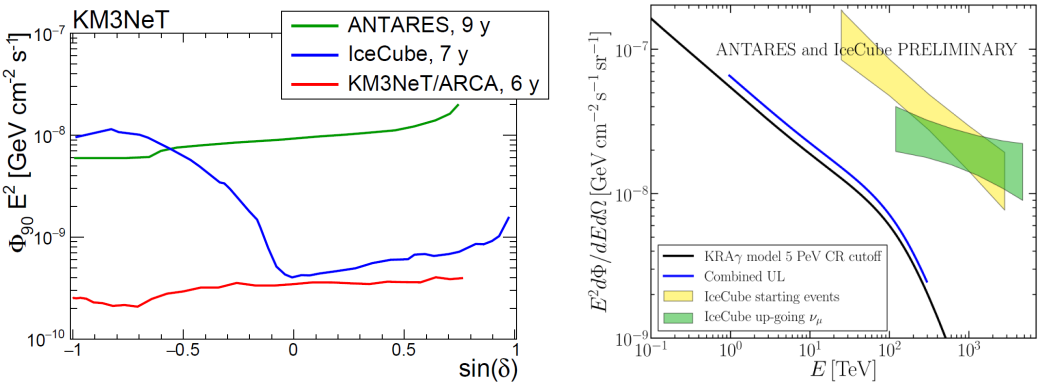

Figure 2: In the left plot, ANTARES [6] and IceCube [7] fluxes as a function of the declination. The sensitivity for a point-like source with a E^2 flux for 6 years of data-taking of KM3NeT-ARCA using only track-like events is also shown. In the right plot, combined upper limit at 90% confidence level (blue lines) on the three-flavour neutrino flux of the KRA-γ model with the 5 PeV energy cut-off (black lines). The boxes represent the isotropic astrophysical neutrino fluxes measured by IceCube using starting events (yellow) and upgoing tracks (green).

The ANTARES and KM3NeT-ARCA telescopes are particularly well suited to study the Galactic plane sources and the discrepancy between the measured neutrino spectral energy distributions of the two hemispheres observed by IceCube [8]. In a recent ANTARES work, a search for a diffuse Galactic dominated neutrino flux using 10 years of ANTARES tracks and cascades combined with 9 years of IceCube muon tracks has been performed, see right plot of figure 2. The

main result is that the flux upper limit constrains the percentage of cosmic neutrino events of the HESE sample that can originate from diffuse Galactic cosmic ray interactions to a maximum of 9.6%. Moreover, the result of this analysis rules out the hypothesis of the diffuse Galactic neutrino emission being a possible cause of the IceCube spectral anomaly.

5. Multi-messenger searches

A multi-messenger program has been initiated between ANTARES and several other observatories. The main objective is to detect sources via their different transient emissions. This program concerns electromagnetic observatories, as well as cosmic ray, gravitational wave and neutrino detectors. One of the most recent results of such studies concerns the neutrino counterparts of gravitational wave (GW) events detected by the LIGO and Virgo interferometers. ANTARES has been participating together with IceCube to a follow-up of the gravitational wave signal GW150914, providing the first constraint on high-energy neutrino emission from a binary black hole coalescence [9]. In the same way, the neutrino observatories have been looking for a neutrino counterpart to GW170817, the first event involving the coalescence of two neutron stars [10]. No neutrinos were detected within $\pm 500\,\mathrm{s}$ around the merger time from the direction of the GW event. The non-detection is consistent with scenarios where a jet of highly energetic particles were produced off the line of sight of the source.

References

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