NEUTRINO FOLLOW-UP OF GRAVITATIONAL-WAVE EVENTS WITH ANTARES DATA

Marta Colomer Molla, on behalf of the ANTARES Collaboration

(1)Université de Paris, Astroparticule et Cosmologie, Paris, (2)Instituto de Física Corpuscular (Universitat de València), Valencia

ABSTRACT

Since 2015, fifty gravitational-wave (GW) signals have been identified and published in two catalogs [1, 2], marking the growth of the GW astronomy. Even though compact binary mergers are promising candidates, no neutrino has been detected yet from these sources in coincidence with a GW signal.
The ANTARES neutrino telescope has been taking data for more than twelve years, and it has actively participated in the follow-up of the gravitational-wave triggers. Two analyses are detailed in this poster. Firstly, the results of an all-flavor neutrino follow-up of six binary black hole (BBH) events observed during O2 run are shown. Secondly, the first ANTARES results using O3 data are presented, with the follow-up of the two GW candidates identified during O3a for which the nature of one of the two compact merging objects (NS, BH or other) is not known: GW190814 and GW190426.

ANTARES NEUTRINO SEARCH

- Search for *tracks* induced by ν_μ interactions, and *showers* generated by all flavor neutral current neutrino interactions and ν_e CC interactions.
- Search for time and space coincidences: inside the 90% confidence level area of the GW event during $\pm$500 s around the GW trigger time.
- All-flavor and full sky neutrino search: separate search below (upgoing events) and above (downgoing events) the ANTARES horizon.

Optimisation: One event passing the cuts, that is found in time and space coincidence, leads to a 3σ detection + cuts maximizing the signal expectation. Event selection described in [3].

Table 1: Quality parameters of the reconstruction used for the event selection, for each event sample.

Sample	Quality parameters
Upgoing tracks	Likelihood of the track reconstruction (Λ) [4]
Downgoing tracks	Λ and track energy estimate ($N_{\mathrm{hits,tr}}$) [4]
Upgoing showers	Likelihood ratio (L_μ) [5] and Random Decision Forest classifier [6]
Downgoing showers	L_μ and shower energy estimate ($N_{\mathrm{hits,sh}}$) [5]

Contact: *mcolomer@apc.in2p3.fr, comomar@ific.uv.es*

REFERENCES

[1] B.P. Abbott et al. , LIGO Scientific and Virgo Collaborations. *Phys. Rev. X*, 9:031040, 2019.

[2] B.P. Abbott et al. , LIGO Scientific and Virgo Collaborations. *arXiv:2010.14527 [gr-qc]*, 2020.

[3] A. Albert et al. , ANTARES Collaboration. *Eur. Phys. J. C*, 80:487, 2020.

[4] S. Adrián-Martínez et al. , ANTARES Collaboration. *Astrophys. J.*, 760:53, 2012.

[5] A. Albert et al. , ANTARES Collaboration. *The Astron. J.*, 154:275, 2017.

[6] A. Albert et al. , ANTARES Collaboration. *Eur. Phys. J. C*, 77:419, 2017.

RESULTS OF O2 BBHS FOLLOW-UP

→ **NO NEUTRINO FOUND IN TIME AND SPACE COINCIDENCE WITH ANY OF THE GW SIGNALS**
→ **SET CONSTRAINTS ON THE NEUTRINO EMISSION FROM BBH MERGERS**

The fluence at the detector for an E^{-2} neutrino spectrum can be expressed as:

$$\phi_0 = E_\nu^2 \frac{dN}{dE_\nu} \quad [\mathrm{GeV} \cdot \mathrm{cm}^{-2}]$$

The 90% CL fluence upper limit (UL) is given by the Poisson limit of number of events, $N^{90\%} = 2.3$, through the relation:

$$\phi_0^{90\%} = \frac{N^{90\%}}{\mathrm{acceptance}} \Delta t \quad [\mathrm{GeV} \cdot \mathrm{cm}^{-2}]$$

The detector acceptance is defined by the number of expected signal events passing the cuts per unit flux.

Table 2: Average neutrino spectral fluence upper limit inside the 90% GW CL contour.

GW event	$\phi_0^{90\%}$ (GeV cm^{-2})	
	Upgoing	Downgoing
GW170608	1.6±0.5	2.2±0.9
GW170729	1.7±0.5	4.0±1.0
GW170809	1.1±0.3	1.2±0.5
GW170814	1.1±0.3	-
GW170818	-	9.0±4.0
GW170823	1.7±0.5	6.0±2.0

Upper limits on the total isotropic neutrino energy emitted as a function of the redshift:

$$E_{\nu,\mathrm{iso}} = \frac{4\pi D_L(z)^2}{1+z} \int_{E^{5\%}}^{E^{95\%}} E_\nu^{-2} \phi_0^{90\%} E_\nu dE_\nu$$

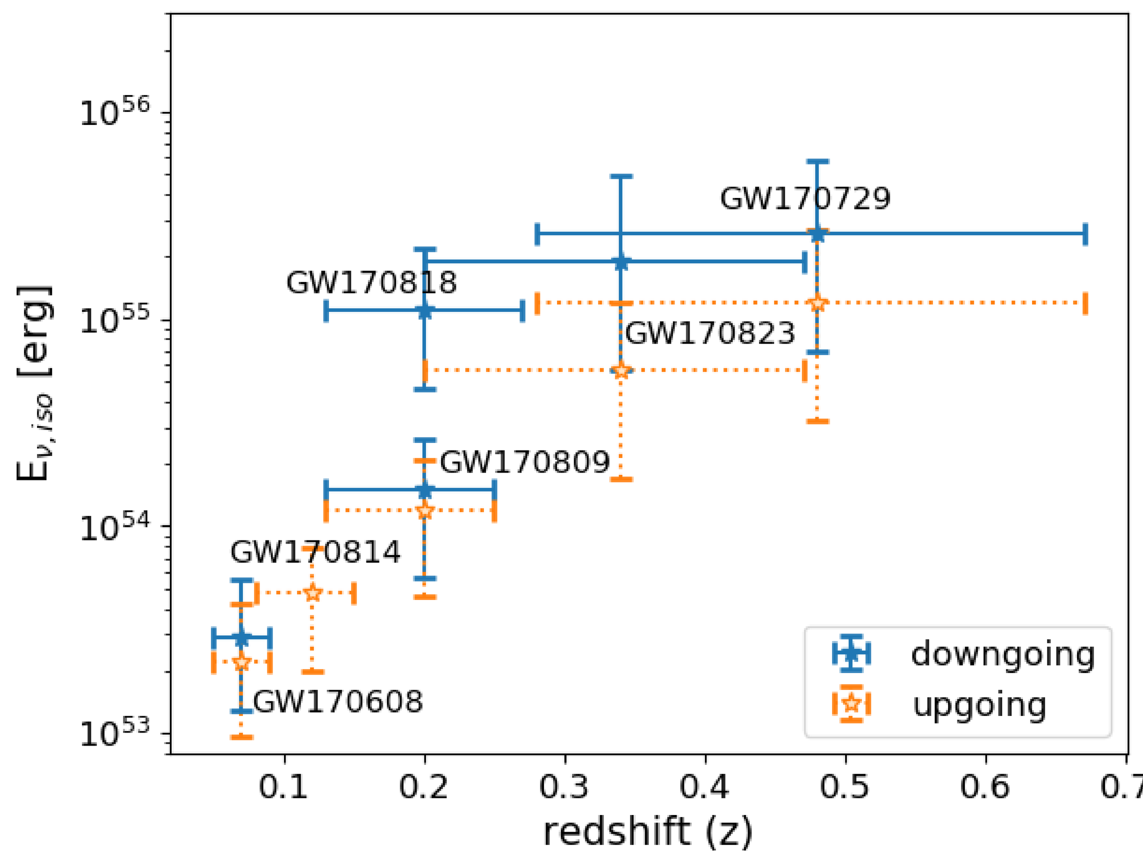

Figure 1: 90% CL upper limits on the total isotropic energy emitted in neutrinos within the 5-95% energy range of the search for the six GW events analysed as a function of the estimated redshift. Results are given for the ANTARES downgoing (blue) and upgoing (orange) searches.

FIRST RESULTS OF O3A DATA

Follow-up of two GW events identified during O3a in the mass gap (one component mass is [2.5; 5] $M_\odot$):
→ **No neutrino found in coincidence with any of the two events in ANTARES data**

GW190418
- Best localised event observed during O3 run.
- 100% upgoing in ANTARES at the time of the alert.
- 90% CL fluence upper limit: ~0.8 GeV cm^{-2} (IceCube result: 0.029–0.639 GeV·cm^{-2}, #GCN25321)

GW190426
- Candidate astrophysical GW source.
- ~50% of the 90% CL GW area inside the ANTARES field of view.
- Fluence UL changes with the source position.

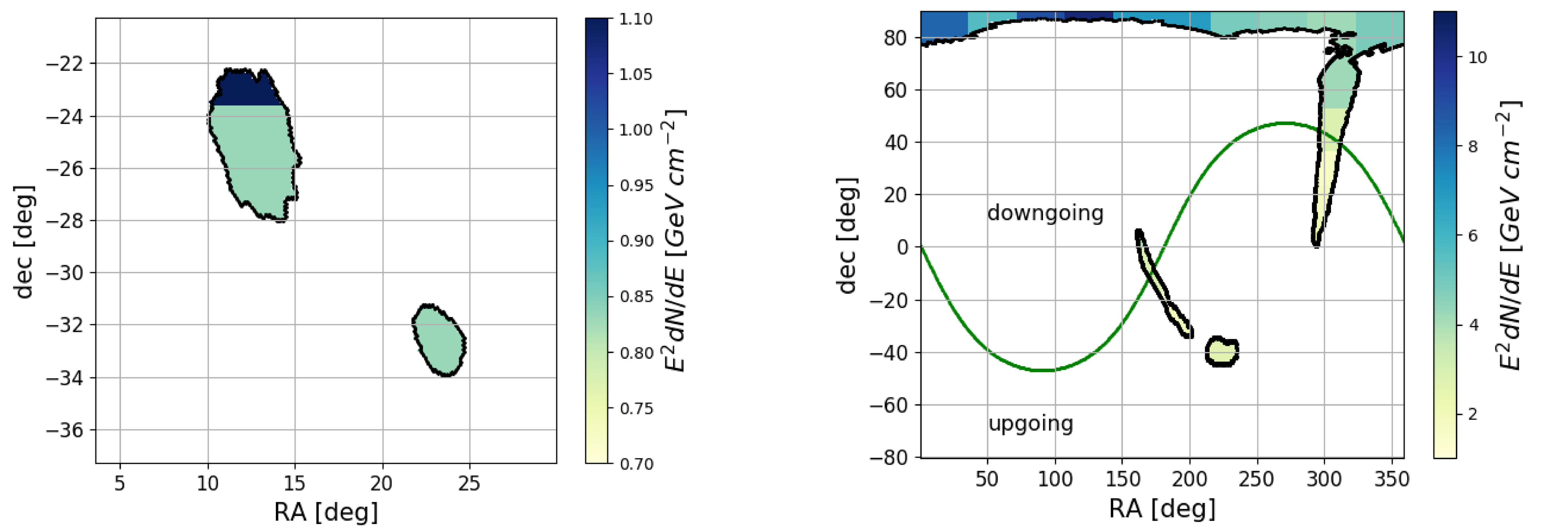

Figure 2: Neutrino fluence 90% CL upper limits as a function of the position in the sky. Left: GW190814. Right: GW190426.

CONCLUSIONS

-) Refined all-flavor analysis published by ANTARES [3] for all GW events in the catalog GWTC-1 [1].
-) Results of the first offline analysis of the two mass gap GW events identified during O3a, **more to come**!
-) Combined results when the source is inside the ANTARES horizon (upgoing) and downgoing for IceCube might bring an improvement (limits at the same level).