Searches for point-like sources of cosmic neutrinos with 13 years of ANTARES data

G. Illuminati, on behalf of the ANTARES Collaboration

INFN - Sezione di Bologna, Viale Berti-Pichat 6/2, 40127 Bologna, Italy
Dipartimento di Fisica e Astronomia dell'Università, Viale Berti Pichat 6/2, 40127 Bologna, Italy

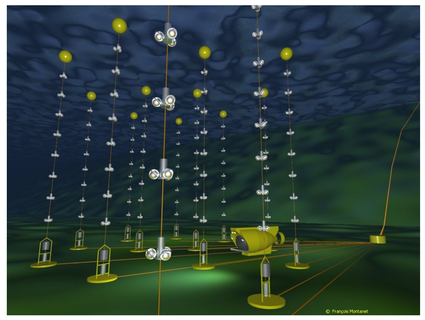
ANTARES telescope and data set

ANTARES telescope:

- Three-dimensional array of **885 photomultiplier tubes**
- 2500 m below the surface of the **Mediterranean Sea**
- 40 km off-shore from Toulon, France

Data set:

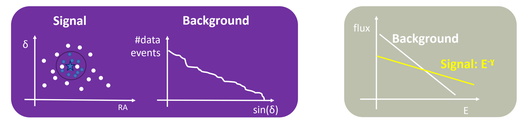
- From January 29, 2007 until February 29, 2020 - **3845 days livetime**
- **10162 track** and **225 shower** events
- Event selection optimised for 5σ discovery of $E^{-2.0}$ point-sources
- Tracks: **$\sim$0.4° median angular resolution**
- Showers: **$\sim$3° median angular resolution**



Search method: unbinned likelihood

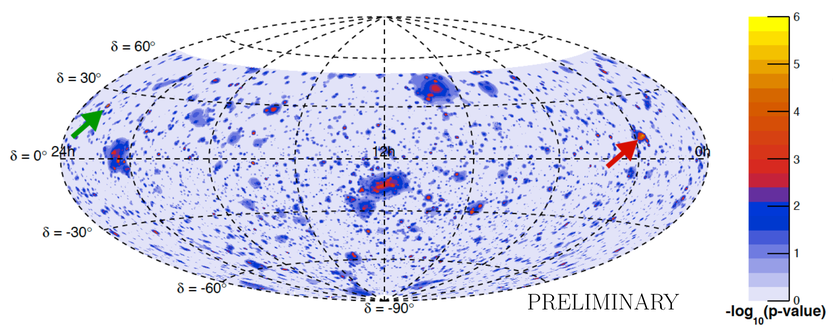
$$\log L(\underbrace{\mu_{sig}, \delta_s, \alpha_s}_{\text{free parameters: number of signal events, source coordinates}}) = \sum_{j\in\{tr,sh\}} \sum_{i\in j} \log\left[\frac{\mu^j_{sig}}{N^j} S^j_i(\delta_s, \alpha_s)) + \frac{N^j - \mu^j_{sig}}{N^j} B^j_i\right]$$

Signal PDFs: $S_i = S^{space} \cdot S^{energy}$ — Background PDFs: $B_i = B^{space} \cdot B^{energy}$



- Signal and background PDFs given by the product of a **directional and an energy term**
- Free parameters: **source equatorial coordinates** and/or **number of signal events**
- Test statistic: $Q = \log L^{\max} - \log L^{\text{bkg}}$

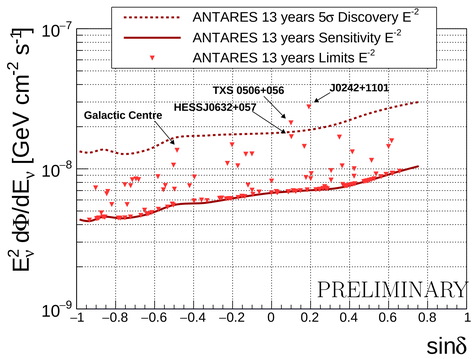
Full-sky search



Sky map of pre-trial p-values found at each investigated direction.

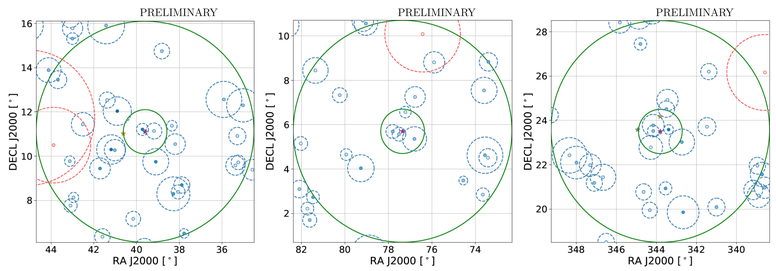
- **Most significant cluster** (red arrow) found at (RA = 39.6°, δ = 11.1°), 4.3σ pre-trial (48% post-trial) significance
- **Second most significant cluster** (green arrow) found at (RA = 343.8°, δ = 23.5°)

Candidate-list search



- **121 sources investigated**
- No significant evidence of cosmic neutrino source found
- **Highest significant source: radio-bright blazar J0242+1101**, 3.8σ pre-trial (2.4σ post-trial) significance
- J0242+1101 is located at 1° angular distance from the full-sky hotspot
- **Most significant sources after J0242+1101: TXS 0506+056** (2.8σ), **HESSJ0632+057** (2.1σ), the **Galactic Centre** (2.0σ)
- 90% C.L. limits on the one-flavour neutrino flux normalization set

Interesting locations



Green circles: 1° and 5° distance from the centre. Blue dots: tracks. Red dots: showers. Darker shades of red and blue indicate higher value of the energy estimator.

- Left: **full-sky hotspot**, close to J0242+1101 (orange star)
- Centre: **TXS 0506+056**
- Right: **Second full-sky hotspot**, close to blazar MG3 J225517+2409 (orange star) and IceCube high-energy muon track (grey star)

Search at the tidal disruption events AT2019dsg and AT2019fdr

- Limited data set: **from TDE discovery** (April 2019) **until last available fully-calibrated ANTARES data** (February 2020)
- Only one event detected within 5° from both TDEs
- **Upper limits on the one-flavour neutrino flux and fluence normalisation** for three spectral indices γ: 2.0, 2.5, 3.0

Source		Results						
Name	γ	$\hat{\mu}_{\text{sig}}$	p-value	$\Phi^{90\%\text{C.L.}}_0$		$\mathcal{F}^{90\%\text{C.L.}}$		$\log(\frac{E_{\min}}{\text{GeV}})$ - $\log(\frac{E_{\max}}{\text{GeV}})$
				sensitivity	limit	sensitivity	limit	
AT2019dsg	2.0	< 0.1	12.4%	7.3×10^{-8}	1.0×10^{-7}	14	19	3.6 - 6.6
	2.5	0.2	10.2%	1.5×10^{-5}	2.2×10^{-5}	29	43	2.8 - 5.5
	3.0	0.7	8.9%	1.2×10^{-3}	2.0×10^{-3}	230	380	2.1 - 4.7
AT2019fdr	2.0	0.5	6.7%	8.5×10^{-8}	1.3×10^{-7}	15	23	3.6 - 6.6
	2.5	0.5	7.9%	2.1×10^{-5}	3.0×10^{-5}	39	55	2.8 - 5.5
	3.0	0.6	9.1%	2.0×10^{-3}	3.0×10^{-3}	360	540	2.1 - 4.7