



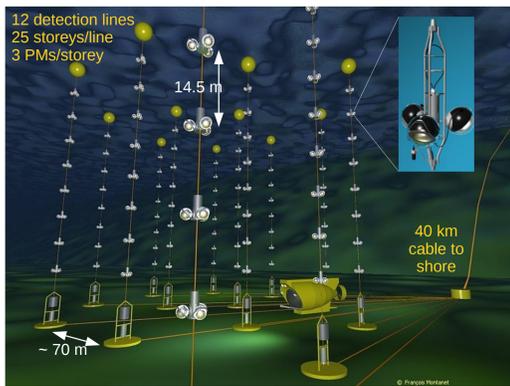
Follow-up of high energy neutrinos detected by the ANTARES telescope



A. Mathieu, on behalf of the ANTARES Collaboration

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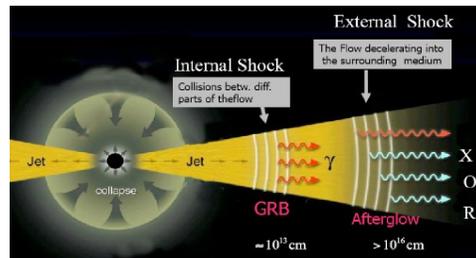
The ANTARES neutrino telescope



Performances :

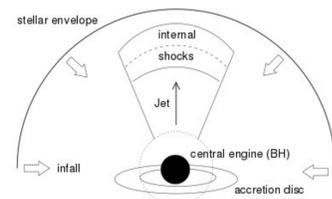
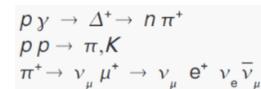
- 12-lines data taking since 2008
- Angular resolution: 0.3 – 0.4°
- Effective area: ~ 1m² (30 TeV)
- Visibility: 3/4 of the sky, majority of the galactic plane
- Real-time data processing

Transient sources

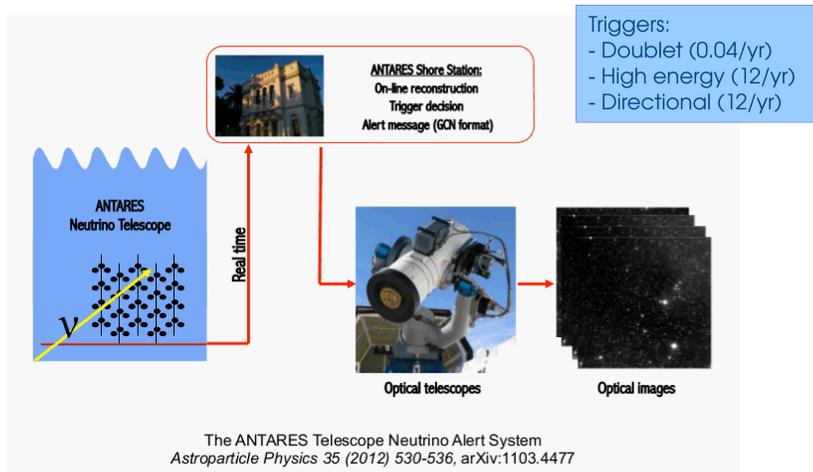


Core-collapse supernova (CCSN) neutrinos:
connection GRB-SN (choked jet, mildly relativistic)
⇒ 100 GeV-10 TeV neutrinos

Gamma-ray burst (GRB) neutrinos:
relativistic jets (Fireball model)
⇒ 10 TeV-10 PeV neutrinos



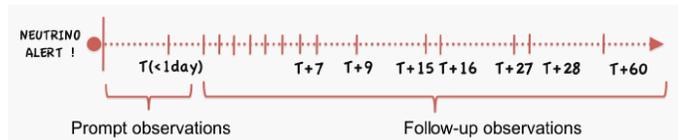
TAToO



Strategy

Optical:

- Early follow-up: images taken as soon as possible and within 24 hours after the neutrino alert (best response: 17 s)
- Long term follow-up: images taken up to 2 months after the neutrino alert

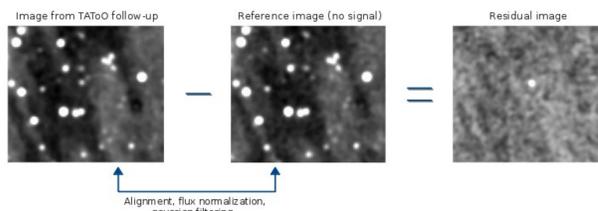


X-ray:

- Real-time: automatic response to ToO (up to 4 tiles of 2 ks) with an online analysis
- Follow-up: further observations only if an interesting candidate is found

Image analysis

Optical: development of a new pipeline based on a subtraction method



2 criteria to select a candidate:

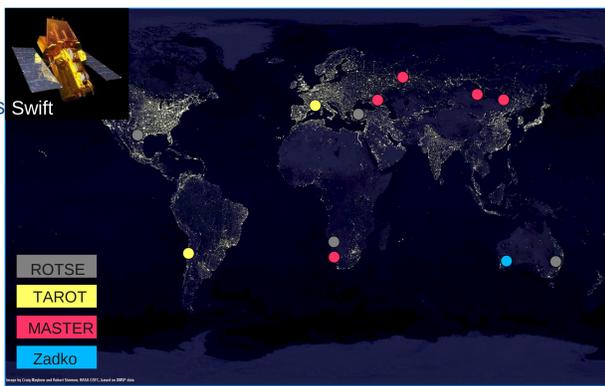
- Source brighter in the image than in the reference (at least 0.5 magnitude)
- Source visible in the image and not in the reference

X-ray: data automatically analysed at the UK Swift Science Data Centre

Interesting candidate to be the counterpart to the neutrino trigger:

- Bright source: 3σ above the Rosat All Sky Survey upper limit
- Fading source: the last bin of the candidate light curve at least 1σ below the first bin

- **TAROT:** two 25 cm telescopes
FOV 1.86° x 1.86°
- **MASTER:** five 2x40 cm telescopes
FOV 2 x (2° x 2°)
- **Zadko:** one-metre telescope
FOV 23 x 23 arcmin
- **ROTSE:** Four 45 cm telescopes
Disconnected in 2014
FOV 1.85° x 1.85°
- **Swift:** X-ray follow-up
FOV 23.6 x 23.6 arcmin



Results

Early follow-up:

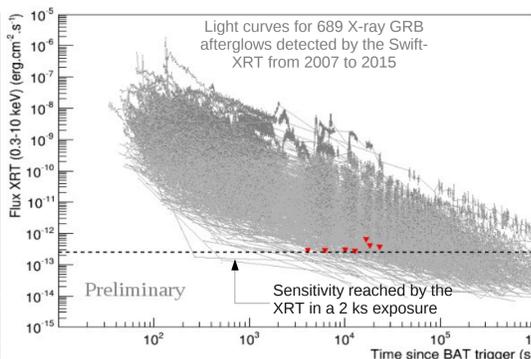
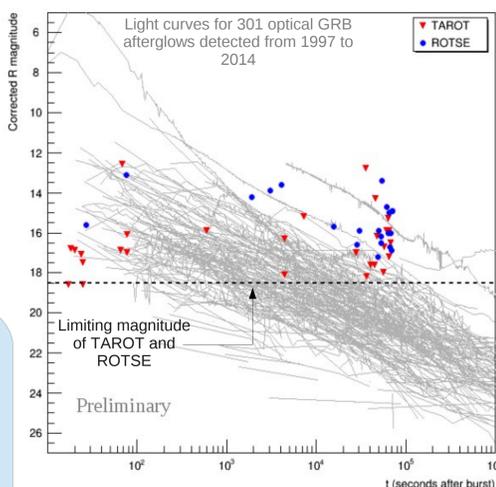
42 alerts with early optical images and 7 alerts with X-ray data

⇒ No optical or X-ray counterpart in association with a neutrino trigger

⇒ Upper limits on transient source magnitudes/fluxes

Interpretation in the case of GRBs:

- Comparison with optical GRB afterglow: GRB origin rejected at a better than 80% confidence level for images taken within 1 minute after the trigger



- Comparison with X-ray GRB afterglow: probability to reject a GRB origin as high as 71% with data collected 1.1 hour after the neutrino trigger

Long term follow-up:

71 neutrino alerts with optical images analysed

⇒ No optical counterpart found in coincidence with a neutrino trigger

⇒ Result consistent with the small expectation value of 0.2 accidentally discovered SNe for 71 alerts

Implication for the CCSN neutrino production model of Ando & Beacom (1) (mildly relativistic choked jets):

- Constraints on the jet energy, the Lorentz boost factor and the rate of CCSNe with such jets (ongoing)

[1]: Ando S. & Beacom J.F. 2005, Phys. Rev. Lett., 95, 061103