Gamma-Ray Bursts with the ANTARES neutrino telescope

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GRBs with ANTARES

Neutrino production in cosmic sources

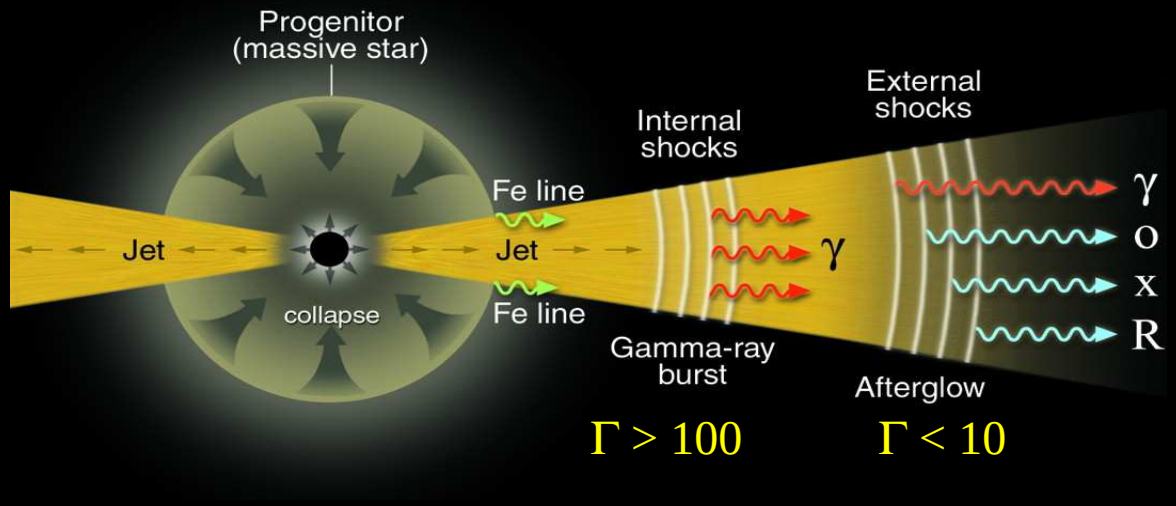
$$N + X \rightarrow \pi^{\pm}(K^{\pm}...) + Y \rightarrow \mu^{\pm} + \nu_{\mu}(\bar{\nu}_{\mu}) + Y$$

$$\downarrow$$

$$e^{\pm} + \bar{\nu}_{e}(\nu_{e}) + \bar{\nu}_{\mu}(\nu_{\mu})$$

Neutrinos are expected to be produced in the interaction of high energy nucleons with matter or radiation:

Fireball model



Photonuclear interactions of the observed gamma-rays with the protons accelerated by the internal shocks can produce high energy neutrinos.

GRB with ANTARES

Advantage in the search for GRBs

Small angular window
Small time window
} ➔ Background free search

Two search methods

Triggered search method

Satellite → GRB alert → ANTARES

Rolling search method

ANTARES → GRB alert → Optical follow-up

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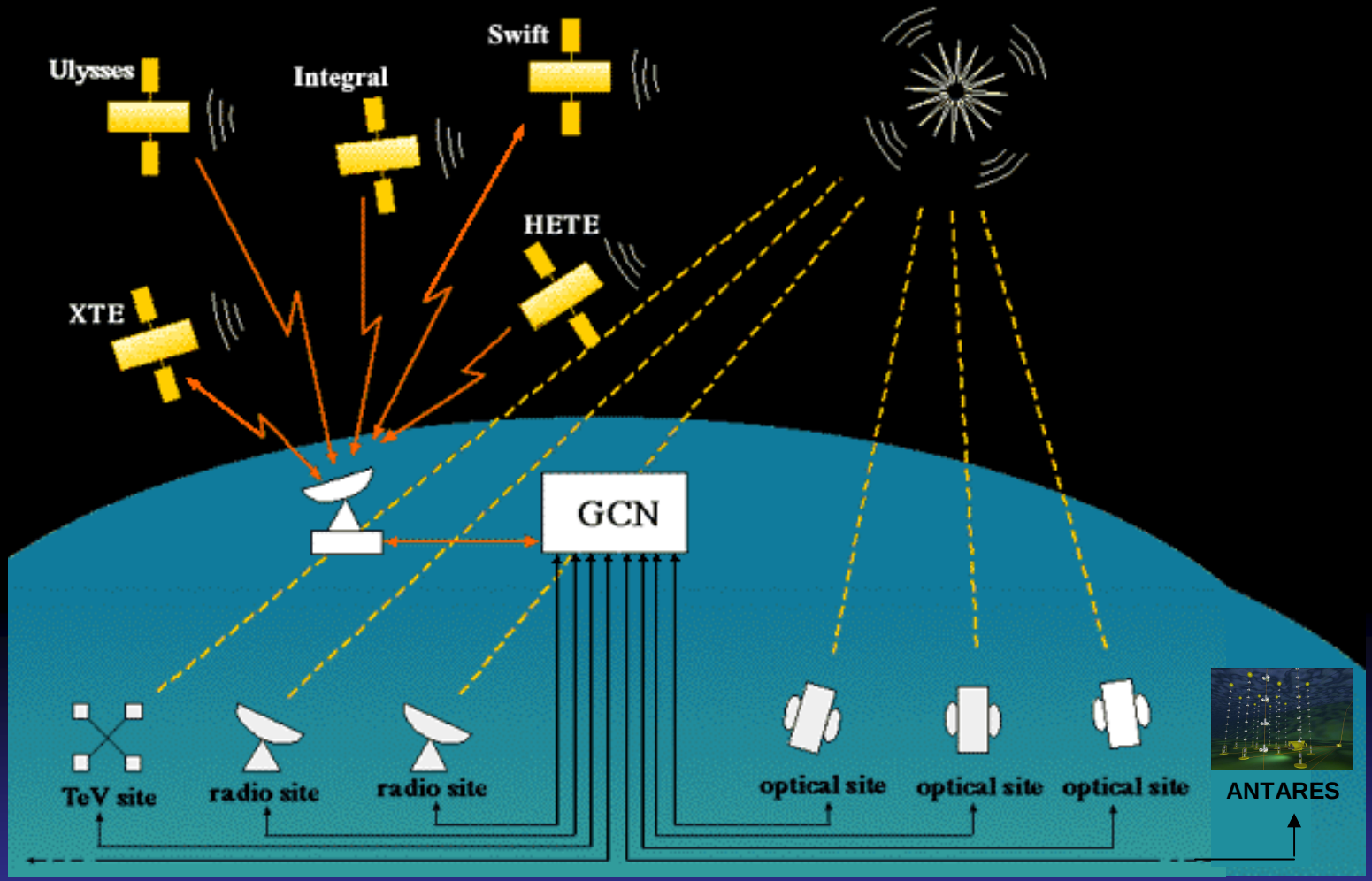
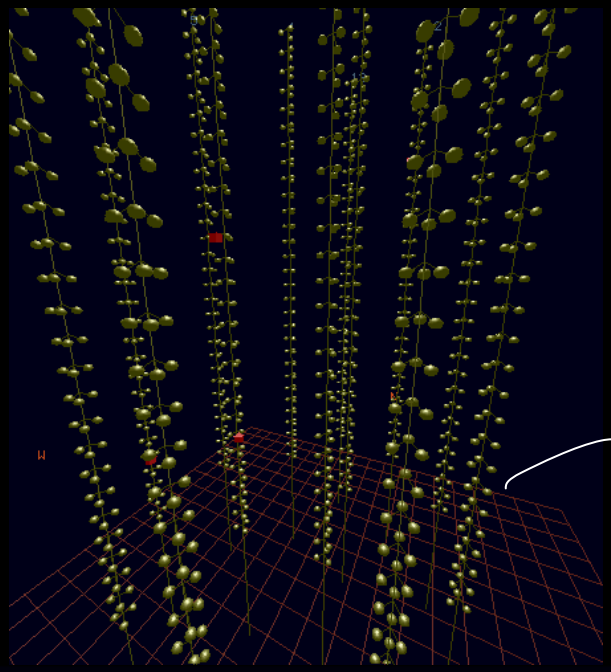


Based on the GRB Coordinates Network alerts

ANTARES standard data taking



12-line ANTARES detector

all-data-to-shore

50 kHz x 885 OMs

40 km

Junction Box

Control Room IMP
at La Seyne-sur-Mer

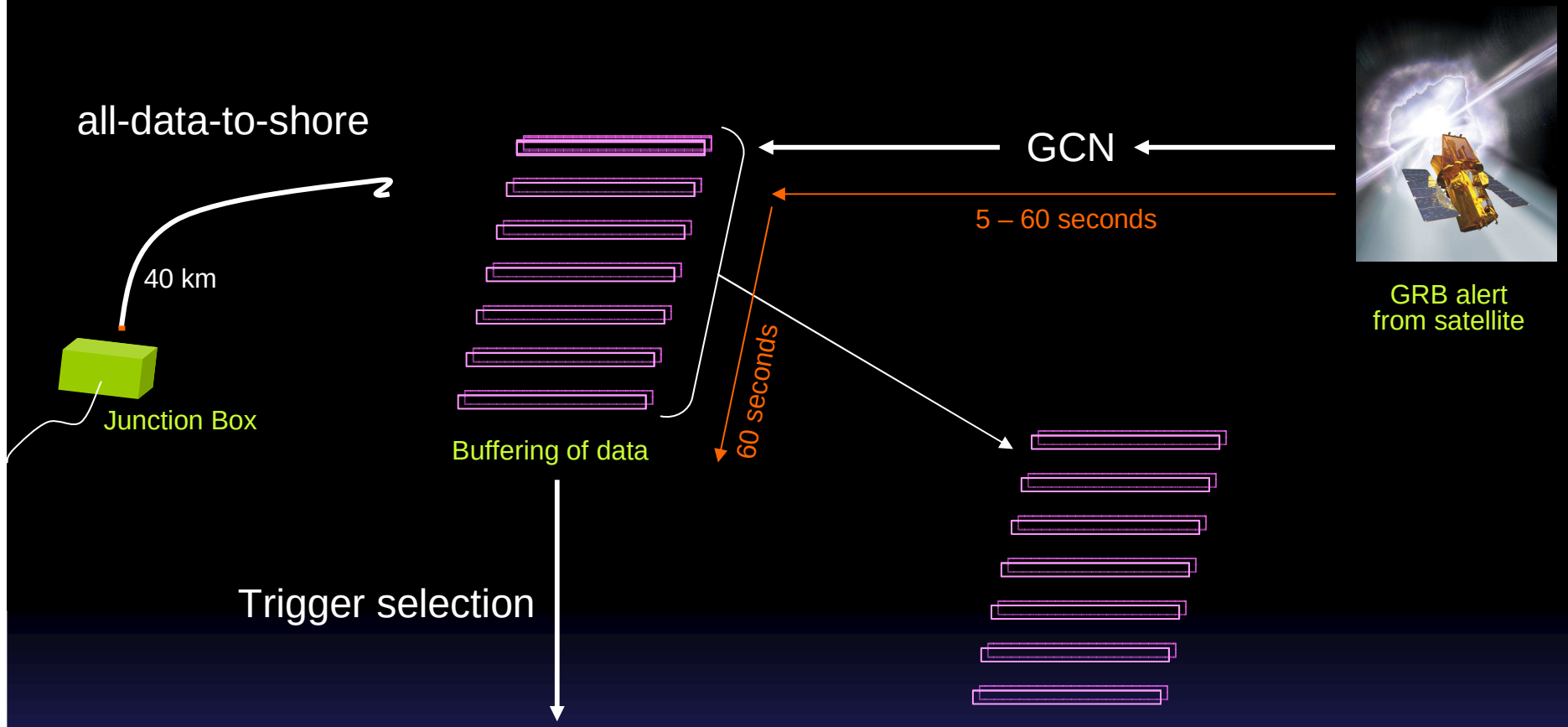
Trigger selection

~ 10 Hz

Storage of events

(all hits within 2.2 μs)

ANTARES special data taking



Standard data storage:

Filtering events

(all hits within 2.2 μs)

GRB data storage:

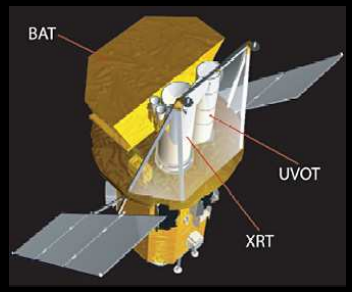
All data without filtering

during 2 minutes

Time delays

GRB alerts from three satellites

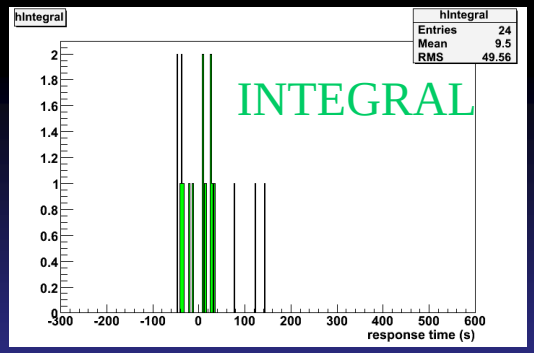
INTEGRAL

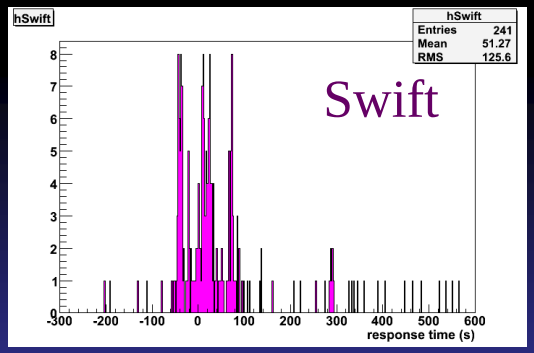


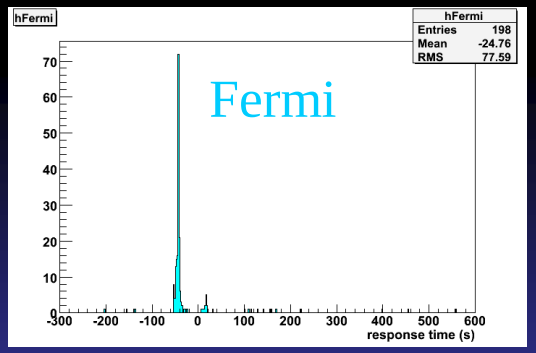
Swift

Fermi

Response time = time delay – buffering time







From February 2007 to May 2009

Status on the GRB alerts

ANTARES GRBs data taking

ANTARES data for 492 alerts:

29 during 2-line detector period
120 during 5-line detector period
57 during 10-line detector period
286 during 12-line detector period

Since 5-line detector:

24 alerts from INTEGRAL
241 alerts from Swift
198 alerts from Fermi

Advantages:

The nature and the location of the source is known

Very low background rate

Low energy threshold

Disadvantages:

Depend on external sources

SWIFT (1.4 sr fov) → only ~1 / 9 GRB is detected

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Rolling search method

The ANTARES detector

Advantages: Large cover of the sky (full hemisphere vs small fraction)

~100% efficient

No assumption of the nature of the source

Disadvantage: The nature of the source is unknown

For identification of neutrino transient sources

- Comparison with published catalogs

- Optical follow-up observations to identify transient sources

Idea initiated by the ICECUBE Collaboration
(astro-ph/0701618, M. Kowalski & A. Mohr)

Search strategy

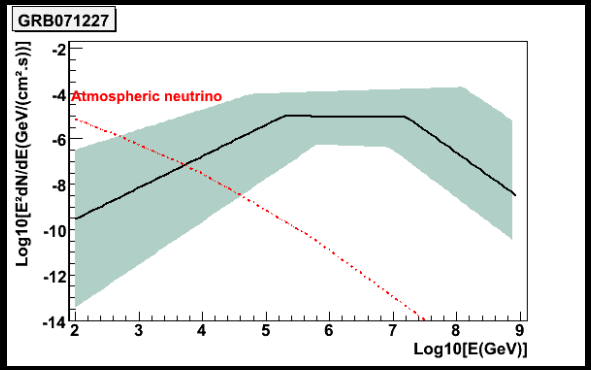
Background events are dominated by atmospheric neutrinos (ν_{atm})

<u>But:</u> The neutrino spectrum from GRB is expected harder than that of ν_{atm}

Selection criteria :

- Single High Energy Neutrino

  Above ~20 à 50 TeV, the background rate begins to be negligible



- Multiplet of neutrino events

  From the same direction and within a short time window

$$R_2^{atm} \approx 2\left(\frac{\Delta\Omega}{2\pi}\Delta t\right)\left(R_1^{atm}\right)^2$$

<u>Application to ANTARES:</u>

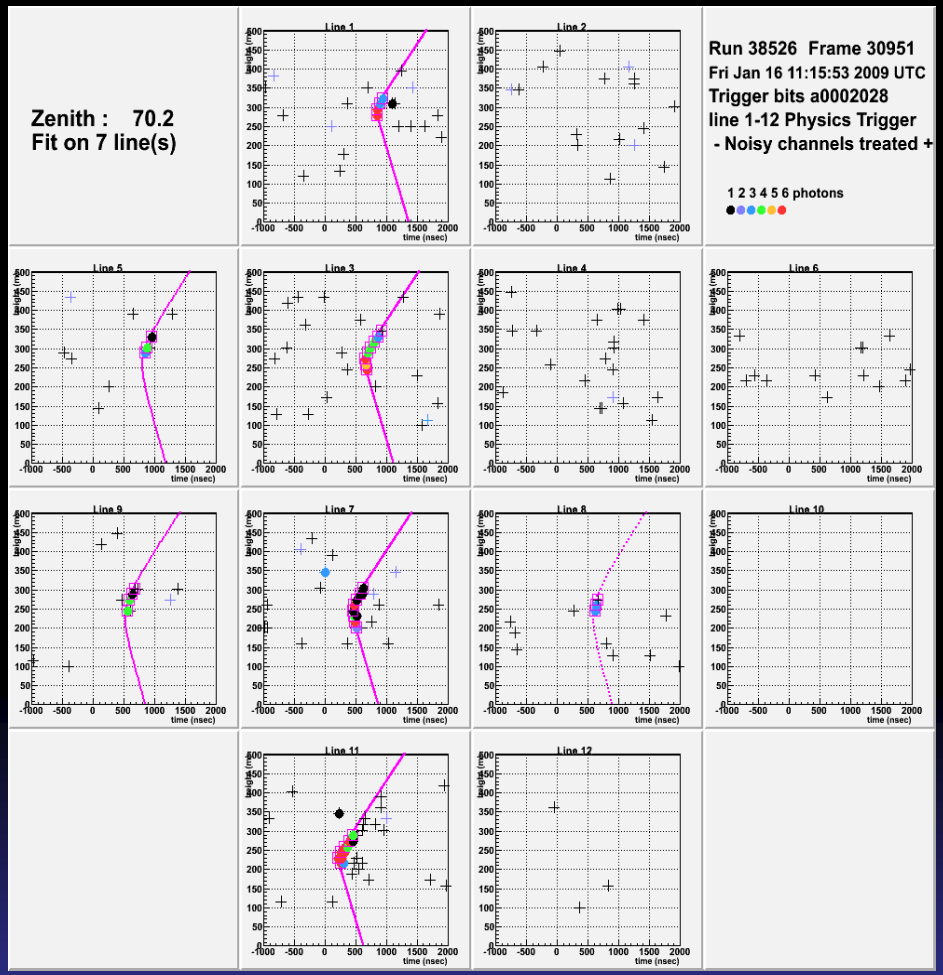
$R_1^{atm} \approx 1500\,yr^{-1}$

$\Delta\Omega = 2° \times 2°$

$\Delta t = 10$ min

$$R_2^{atm} \approx 0.01\,yr^{-1}$$

On-line reconstruction

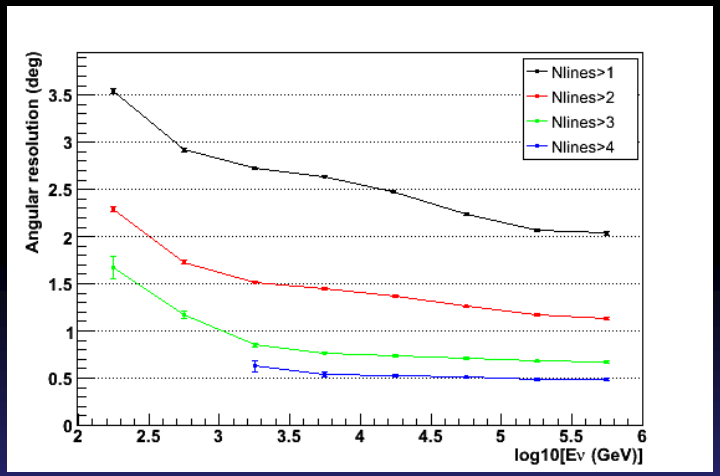


A neutrino candidate

Need of a very fast reconstruction tool,

Performance: 5-10 ms / event

with a good angular resolution

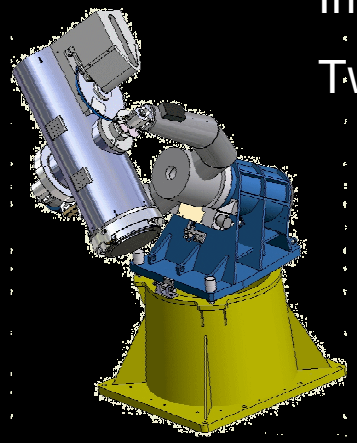


with 10-line detector data

Collaboration with TAROT

TAROT (**T**élescope à **A**ction **R**apide pour les **O**bjets **T**ransitoires)

(Fast action telescope for transient objects)



Implementation in 1998

Two robotic 25 cm diameter telescopes

- TAROT Calern, France
- TAROT La Silla, Chile

Field of view of 1.86° x 1.86°

Magnitude V<17 (10s)

V<19 (100s)

TAROT La Silla

TAROT operation

TAROT has two basic modes of operation :

Alert Mode : TAROT observes optical counterparts of GRBs when a satellite alert is received (Agile, Integral, Swift, …). The observation of the source starts between 5 and 10 seconds after the alert.

Survey Mode : Due to its large fov, TAROT can perform a scan survey of a part of the sky pointed by a satellite, in order to list variable sources.

TAROT observations

- The telescope pointing is performed within 5 seconds
- More than 60 observations since 1998
- 15 detections
- 1/3 of event with a slow rising part (not expected)

TAROT is specialized to the prompt phase observations in optical wavelengths

TAToO

(Tarot Antares Target of Opportunity)

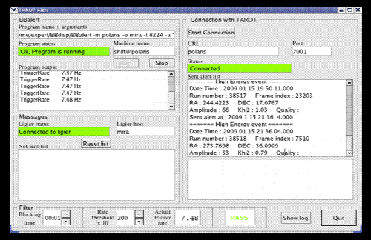
Implementation of an optical follow-up for ANTARES

GRB search strategy

Optimized selection cuts to send
1 or 2 alerts per month

↓

Alert transmission



↓

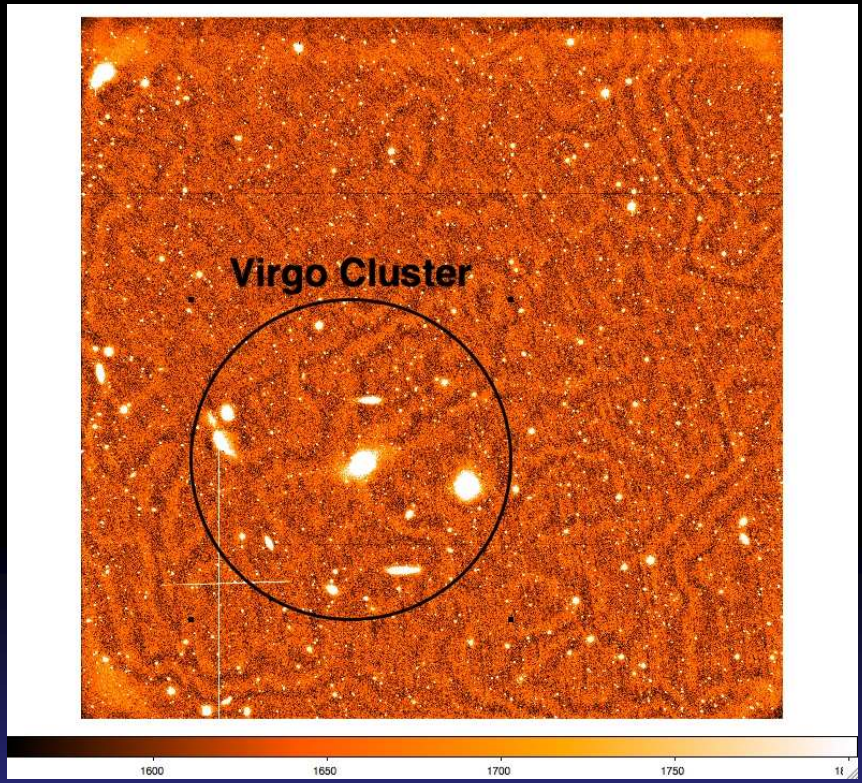
TAROT acquisition strategy

Real time acquisition of 6 images of 3 minutes:

- at T0
- at T0 + 1 day, T0 + 3 days, T0 + 9 days, T0 + 27 days

Test of the full acquisition chain

A fake alert has then been sent to TAROT in the direction of the Virgo Cluster (Ra:12:24:24.00 and Dec:+13:14:00.0).



The optical observation has been successfully performed:
6 exposures of 3 min each have been acquired (clear filter).

Optical image analysis

To be done: Optical image analysis

Image cleaning: to suppress the instrumental background

Astrometric calibration: to obtain the right absolute position

Objects identification:

- Comparison with catalogues
- Transient objects research:
  - Blink between consecutive images
  - Use of images subtraction tools

Summary and perspectives

Triggered search method

Special data without filtering for ~492 GRB alerts

Analysis is on progress

Rolling search method

Sensitivity for transient sources is significantly enhanced,
(complementing neutrino telescopes with an optical follow-up)

The system is now operational with TAROT.

Interesting to extend technique to other wavelengths (X-ray, radio).