



Search for neutrinos from transient sources with the ANTARES telescope and optical follow-up observations

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Overview

- Motivation
- ANTARES
- TATOO (Telescope-Antares Target of Oppotunity)
- Optical Follow-up
- Optical analysis

Introduction

Candidate transient sources AGN Flares, Micro-Quasars....

Long GRBs

- Core collapse of supermassive stars ($\Gamma \approx 100$)
- Expected prompt emission of neutrinos
- Prompt emission of gammas
- Afterglows (X, V, Radio...)
- Observed : 1 CCSN with HR jets /1000

Core collapse SNe

- Core collapse of massive stars ($\Gamma \approx \text{few}$)
- Expected prompt neutrino emission (TeV)
- hidden in gamma
- Afterglows (X, V, Radio...)



Credits: Hongfeng Yu

[Razzaque, Meszaros, Waxman (Mod. Phys. Lett. A 20, 1998)]







Introduction

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Core collapse SNe

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2.5

U+2.0

- hidden in gamma
- Afterglows (X, V, Radio...)





ANTARES The neutrino detector



Techniques for transient sources search in ANTARES

Triggered search

Neutrino Detection triggered by external detections (*SWIFT*, *INTEGRAL*, *FERMI*...) providing timing and position information Rolling Search

Search for HE neutrino events or multiplets (n>=2) within the same direction and temporal window.

Techniques for transient sources search in ANTARES

Triggered search

Neutrino Detection triggered by external detections (SWIFT, INTEGRAL, FERMI...) providing timing and position information

Advantages:

Nature and location of the sources are known Very low background

Disadvantages:

Dependence on external detections SWIFT (1.4 sr fov) \rightarrow Only ~1 / 9 GRB is detected (no external trigger for choked GRBs)

Look for neutrinos in dT and (Ra, Dec) (Off-line analysis)



Techniques for transient sources search in ANTARES

observation



Rolling Search

Search for HE neutrino events or multiplets (n>=2) within the same direction and temporal window.

Avantages:

- Covers full hemisphere
 - No external triggers

• No hypothesis on the nature of the source

Disadvantages:

The nature of the source is unknown \rightarrow Need follow up to confirm detection (nature, redshift...) \rightarrow need fast analysis and good angular resolution

TAT00

(Telescopes ANTARES Target of opportunity)



TAToO Triggers

Multiplets

- A burst of 2 v or more detected in
- Time window : 15 mn
- Direction window : 3°



• Expected Doublet alert rate ~ 7.10⁻³/yr

Data : No doublet detection in 3 years
Expected significance ;

N = 2
$$\rightarrow$$
 ~ 3 σ (N = 3 \rightarrow ~ 5 σ)

HE neutrino events

- Up-going only + Best reconstructed
- Cuts on simple energy estimators number of touched floors and hits amplitude (pe)

Tuned to trigger 1 to 2 false alerts /month mean energy :~5 TeV



TAT00

Expected performance on angular resolution



events are in the telescopes field-of-view

The ANTARES Telescope Neutrino Alert System Ageron et al. Submitted to Astroparticle Physics arXiv:1103.4477 **Expected off-line performances**



Follow up strategy

SN lightcurve:

slowly rising

520

GRB afterglow:

I - 3.52.5

-1.0

U+2.0



Optical data Oct 2009 to May 2011



Analysis strategy Image subtraction

Looking for varying signals!



Analysis strategy Image subtraction















- Bad image / reference
- deblending problems ...

Analysis strategy Background rejection (1)



The candidate must be detected at least 2 nights/ 2 observations



Analysis strategy Background rejection (2)

Additionnal cut

The light curve must be rising \rightarrow Fast light curve building implemented



Analysis strategy Background rejection (2)

Additionnal cut

The light curve must be rising \rightarrow Fast light curve building implemented



Analysis strategy Background rejection (3)

Comparison with catalogs



Overall efficiency «fake» supernovae

In a typical ROTSE alert (Limiting mag ~ 17) :

100 SNe type Ib/c injected in the images (R-band) Random Peak magnitude [12,18]



16

17

Peak Magnitude

18

15

13

14

12



Data analysis

GRB



- Analysis of 5 prompt observations of 30 images

GRB optical analysis is now finished !

 \rightarrow No GRB candidate brighter than ~15 mag was found within 75 s from the v trigger

Constraints on :

- jet parameters
- neutrino-afterglow time delay
- Luminosity

are being derived

Paper in preparation...



Conclusion

- TATOO is an optical follow-up program running efficiently since Feb. 2009
- Refined positions ($\Delta\theta \rightarrow 0.3^{\circ}$) are successfully sent to the telescopes (still needs to be automatized)
- SN optical analysis is in progress
- First results on optical analysis are being derived for GRBs
- A new low energy alert trigger compatible with a particular direction (local matter..) is being studied to increase sensitivity to cc-SNe
- Extension to bigger telescopes (Zadko) for deeper observations is being implemented

Conclusion Thesis achievements

- Setting the triggers for the neutrino selection
- Evaluating the sensitivity for CCSNe detection (preliminary)
- Implementation / adaptation of the optical analysis software
- Elaborating the analysis strategy for GRBs/ SNe
- Optical data analysis



GRB analysis

5 alerts with prompt observations \rightarrow analysis of the 1st night data (30 images)



Analysis strategy (SN example)



TATOO Efficiency

Time delay

Duty cycle



Optical follow up efficiency



•ROTSE strategy : 13 observations

•TAROT strategy : 12 observations

 \rightarrow More than 70% efficiency for most of the observations with ROTSE

Data correction and reduction

On-line

- Correction from fringe
- Dark subtraction
- Flat-fielding

Copy all telescope contributions on TAToO machine Off-line

- Source extraction using SExtractor

- Source calibration using USNO A2.0 to get astrometric and approximate photometric solutions

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Bad weather or strong winds alterate the data quality by :

- reducing the visibility depth (limiting magnitude)
- spreading the stellar FWHM (seeing)
- \rightarrow Calibration may fail (typically 1-2 images/alert)

Example :

Influence of the wind speed **mages** on the mean seeing of the images





Expected signal in ANTARES SN at 10 Mpc, $Ej = 3.10^{51}$ erg, 10s jet

corrected from jet opening angle



Expected signal with TATOO triggers

Expected events/SN (10 Mpc, 3E51 erg, 10s jet duration)



Level 3

(HE)

Total Nevents/SN = $5 \cdot 10^{-3}$



