ANTARES SEARCH FOR ALL-FLAVOR HIGH-ENERGY NEUTRINOS IN CORRELATION WITH VERY HIGH-ENERGY GAMMA-RAYS

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ABSTRACT

The first gamma-ray burst (GRB) detections at very-high energies (sub-TeV gamma-rays) have been announced recently: GRB190114C, observed by MAGIC, GRB180720B and GRB190829A, both detected by the H.E.S.S. telescopes. A dedicated search for all-flavor high-energy neutrinos in correlation with the gamma-ray emission has been performed using ANTARES data. The search covers both the prompt and afterglow phases. This contribution presents the results of this study and discusses the associated astrophysical constraints on the neutrino spectral fluence and the total energy radiated in high-energy neutrinos (TeV-PeV range).

GRB EVENTS

Detection of sub-TeV emission from three GRBs:

• **GRB180720B and GRB190829A**: observed by H.E.S.S. ~5-10 h after the trigger (late afterglow)![1, 2].
• **GRB190114C** : detected by MAGIC ~50 s after the trigger, see [3, 4].

Motivation: Search for neutrinos emitted by an hadronic component of the GRB. Although data is compatible with Synchrotron Self Compton radiation, a sub-dominant hadronic component is not ruled out.

NEUTRINO SEARCH

Search for high-energy neutrinos in time and space coincidence with sub-TeV gamma-ray detections:

- Search time window covers full EM observation: prompt and afterglow emission.
- Search for *tracks* induced by ν_μ interactions, and *showers* generated by all flavor neutral current neutrino interactions and ν_e CC interactions.
- Space search region: Optimised using the ANTARES angular resolution (~1-2 deg around the source for tracks and 10-20 deg for showers).
- 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 [6].

RESULTS AND UPPER LIMITS FROM ANTARES DATA

NO NEUTRINO FOUND IN TIME AND SPACE COINCIDENCE WITH ANY OF THE THREE GRBs in ANTARES data

Table 1: Neutrino spectral fluence upper limits ($\phi_0^{90\%}$) obtained for the three VHE GRB searches, separately for upgoing and downgoing events. The serach window δt is also given. The hyphen indicates that this GRB was not seen as upgoing during the gamma-ray emission.

Event	δt upgoing	$\phi_0^{90\%}$ upgoing	δt downgoing	$\phi_0^{90\%}$ downgoing
GRB180720A	7.6 h	1.5±0.5 GeV cm^{-2}	4.4 h	11±4 GeV cm^{-2}
GRB190114C	-	-	0.44 s	1.6±0.7 GeV cm^{-2}
GRB190829B	2.75 h	1.4±0.5 GeV cm^{-2}	5.25 h	4±2 GeV cm^{-2}

Table 2: Upper limits in the total energy emitted in neutrinos ($E^{90\%}_{\nu,\mathrm{iso}}$) for the three VHE GRB searches, separately for upgoing and downgoing events. The 5-95% energy range of the analysis ($\mathrm{E}^{\mathrm{up}}_{5-95\%}$ and $\mathrm{E}^{\mathrm{down}}_{5-95\%}$) is also given. The hyphen indicates that this GRB was not seen as upgoing during the gamma-ray emission. Last column shows the isotropic photon energy measured, $E_{\gamma,\mathrm{iso}}$.

Event	redshift	$\mathrm{E}^{\mathrm{up}}_{5-95\%}$	$E^{90\%}_{\nu,\mathrm{iso}}$ upgoing	$\mathrm{E}^{\mathrm{down}}_{5-95\%}$	$E^{90\%}_{\nu,\mathrm{iso}}$ downgoing	$E_{\gamma,\mathrm{iso}}$
GRB180720A	0.653	2.5 TeV - 4.0 PeV	1.8×10^{55} erg	20 TeV - 30 PeV	1.4×10^{56} erg	6×10^{53} erg
GRB190114C	0.42	-	-	10 TeV - 20 PeV	8.3×10^{54} erg	3×10^{53} erg
GRB190829B	0.0785	2.5 TeV - 4.0 PeV	2.3×10^{53} erg	15 TeV - 25 PeV	6.6×10^{53} erg	2.967×10^{50} erg

RESULTS ON GRB 190114C

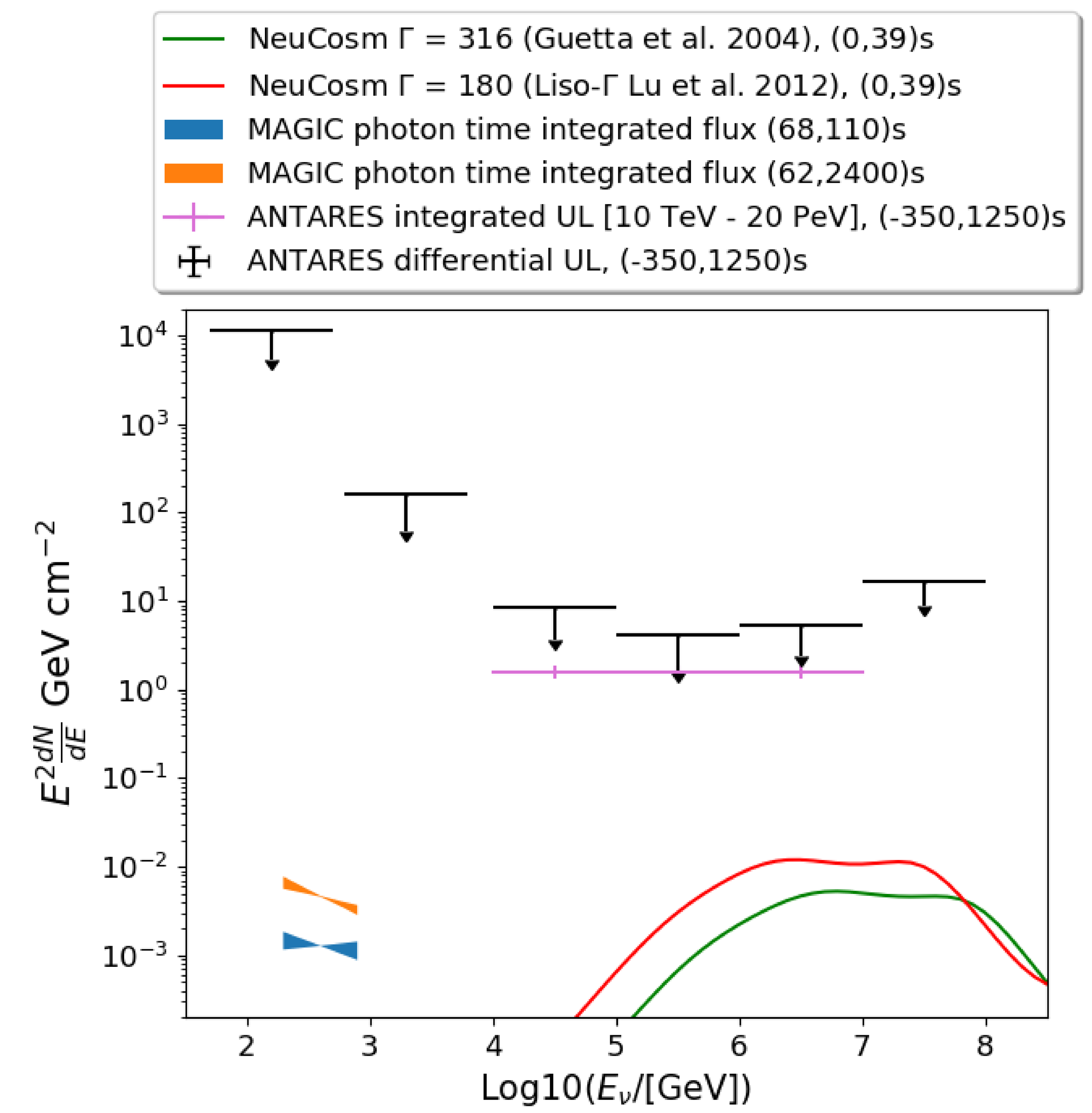

Figure 1: ANTARES 90% differential (black arrows) and integrated (violet line) UL as a function of the neutrino energy, evaluated over 0.44 h assuming an E^{-2} neutrino spectrum. The predicted time integrated neutrino flux over 39 s by the NeuCosmA model [5] is computed using the GRB parameters as measured by Fermi-GBM, and for two different Lorentz factors (green and red lines). MAGIC fluence normalisation for the first time bin (62-110s, blue band), and for the overall time window (62-2400s, orange band).

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.

The MAGIC data [3] is used to compute the fluence is by integrating the fitted spectral flux normalisation over the corresponding time window (Δt) as follows:

$$E_\gamma^2 \frac{dN}{dE_\nu} = \phi_0^\gamma \times (\frac{E_\gamma}{E_{\mathrm{pivot}}})^{-\alpha} \times \Delta t \times \times E_\gamma^2$$

The ANTARES limits are compared to MAGIC observations and to the predictions by the internal shock model (NeuCosmA) for the prompt neutrino emission.

CONCLUSIONS

• First sub-TeV detections of GRB events are a highlight for the astroparticle physics community. Interesting theoretical interpretations may come out of these data.

• The search in ANTARES data yields no high-energy neutrino in time and space coincidence, detected at 3σ level, with any of the three GRB events analysed.

REFERENCES

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