Sensitivity of the Cherenkov Telescope Array to emission from the gamma-ray counterparts of neutrino events

cta cherenkov telescope array

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ABSTRACT

We investigate the possibility of detection of the VHE gamma-ray counterparts to the neutrino astrophysical sources within the Neutrino Target of Opportunity (NToO) program of CTA [1] using the populations simulated by the FIRESONG software to resemble the diffuse astrophysical neutrino flux measured by IceCube. We derive the detection probability for different zenith angles and geomagnetic field configurations. The difference in detectability of sources between CTA-North and CTA-South for the average geomagnetic field is not substantial. We investigate the effect of a higher night-sky background and the preliminary CTA Alpha layout on the detection probability.

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The sources of astrophysical high-energy neutrinos have not been unequivocally identified. Observations of TXS 0506+056 provide evidence that blazars or a sub-population of blazars are responsible for the neutrino flux [2]. Nevertheless, evidence has only been claimed for one blazar/neutrino correlation, therefore, one has to be careful while extending its properties to describe the whole population of neutrino sources. The population of potential neutrino sources responsible for this flux can be parametrized in terms of local density (local density rate) vs. neutrino luminosity (flare energy) for steady (flaring) sources.

FIRESONG

FIRESONG [3] is an open-source software that simulates neutrino source populations for a given local density and neutrino luminosity, by making additional assumptions on the source density evolution and their luminosity functions.

We explore a source population which does not evolve with redshift (which is a simplified way to describe blazars) and one that follows the star formation rate (SFR) evolution [4]. In both populations, sources are described as standard candles, i.e., all sources share the same neutrino luminosity. We also assume that the specific simulated class is responsible for 100% of the astrophysical neutrino flux.

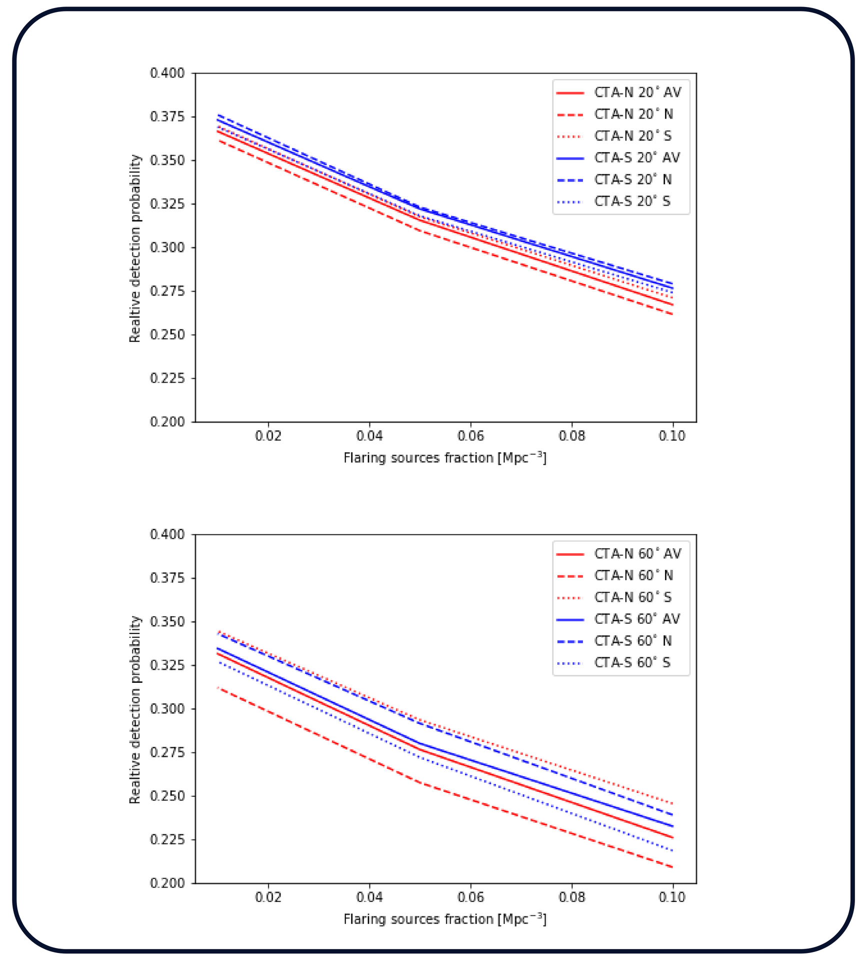

Fig. 1: Detection probability as a function of flaring sources fraction *F* for 30 min observation time

CTA SIMULATIONS

To calculate the gamma-ray flux emitted together with neutrinos we assume that they are produced in proton interactions with the surrounding photon field as usually postulated for AGN and do not consider any additional absorption or cascading of gamma rays inside the source. In the case of neutrino-flaring blazars we adapt the phenomenological model of [5]. To simulate 30 min CTA follow-up observations of the neutrino alerts we use the ctools package with gammalib [6]. We employed the prod3b-v2 CTA instrument response functions (IRFs). For all sources we take into account the extragalactic background light (EBL) absorption [7].

RESULTS

For the neutrino-flaring blazars the detection probability is almost identical for CTA-N and CTA-S (difference <1%) with average azimuth direction. There's also almost no difference for 20° and 40° zenith IRFs (again <1%), but with higher zenith angles (60°) we measure a decreases of ~4%. For the steady sources with low to mid zenith angle observations (20°-40°) CTA-N will be able to detect all sources down to the density of 10^{-9} Mpc^{-3}.

A drastic performance loss, up to 65%, is measured at high zeniths (60°). The CTA-S array shows a similar response as for CTA-N (within 10% for average azimuth). The highest redshift reach is given by the density 10^{-12} Mpc^{-3} and is up to z~2.8. For observations at 20° and 40° in zenith, the redshift reach is similar, however there is a big drop for 60°.

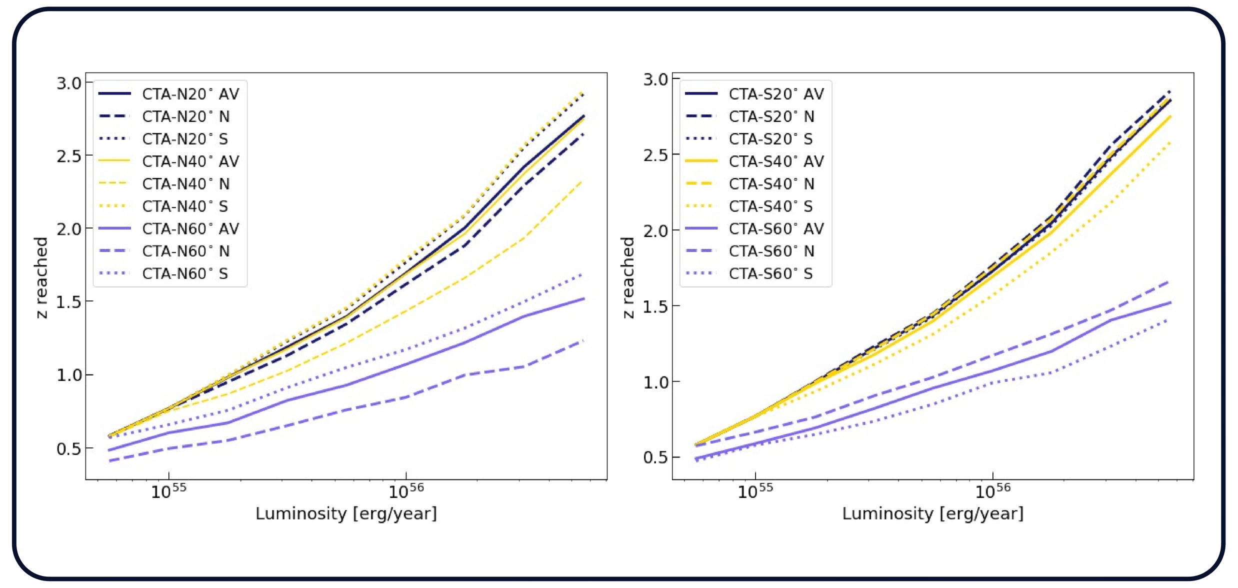

Fig. 2: Redshift reach from the CTA-N and CTA-S simulations for the steady sources with density 10^{-12} Mpc^{-3} following SFR evolution

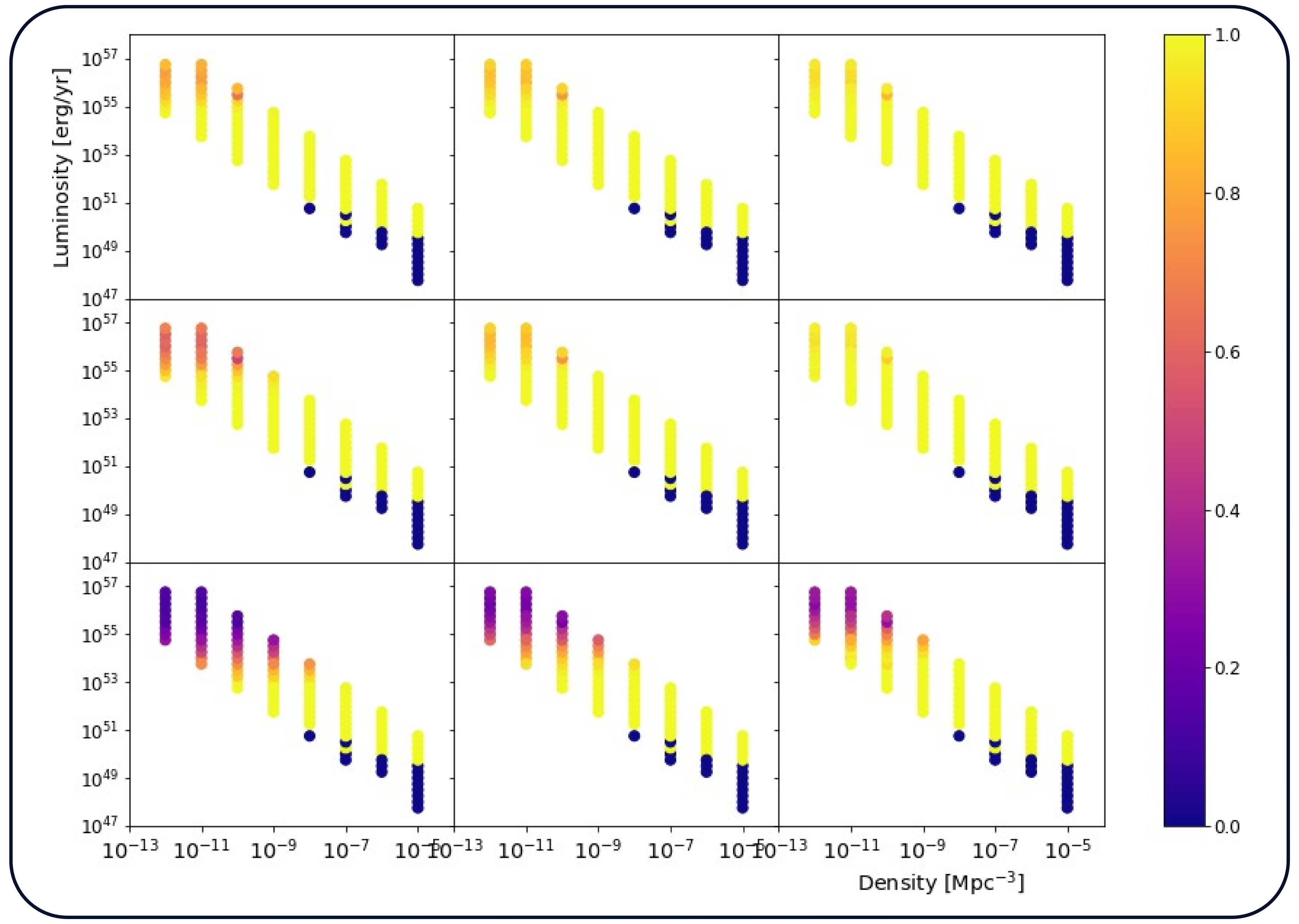

Fig. 3: Detection probability as a function of source luminosity and local density for sources following the SFR redshift evolution for 30 min observations with CTA-N

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