Sensitivity of the Cherenkov Telescope Array Observatory to the gamma-ray emission from neutrino sources detected by IceCube

CTAO CONSORTIUM

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ABSTRACT

Gamma-ray observations of astrophysical neutrino sources are fundamentally important for understanding the underlying neutrino production mechanisms. We investigate the Cherenkov Telescope Array Observatory (CTAO) prospects for detecting the very-high-energy (VHE) gamma-ray counterparts to neutrino-emitting extragalactic sources. The performance of CTAO under different configurations (including the so-called "Alpha" and "Omega" configurations) is computed based on neutrino and gamma-ray simulations of steady sources and of flaring blazars, assuming that the neutrino events are detected with the IceCube neutrino telescope. The detection probability for CTAO is calculated for both sites of the Observatory, taking into account visibility constraints. We find that, under optimal observing conditions, within 30 minutes of observation, CTAO could detect the VHE gamma-ray emission associated with at least 3 neutrino events per year. We investigate the detectability of the blazars given either 1 or 5 h observation windows.

FIRESONG

FIRESONG [1] 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. These populations can be parametrized in terms of local density (local density rate) vs neutrino luminosity (flare energy) for steady (flaring) sources.

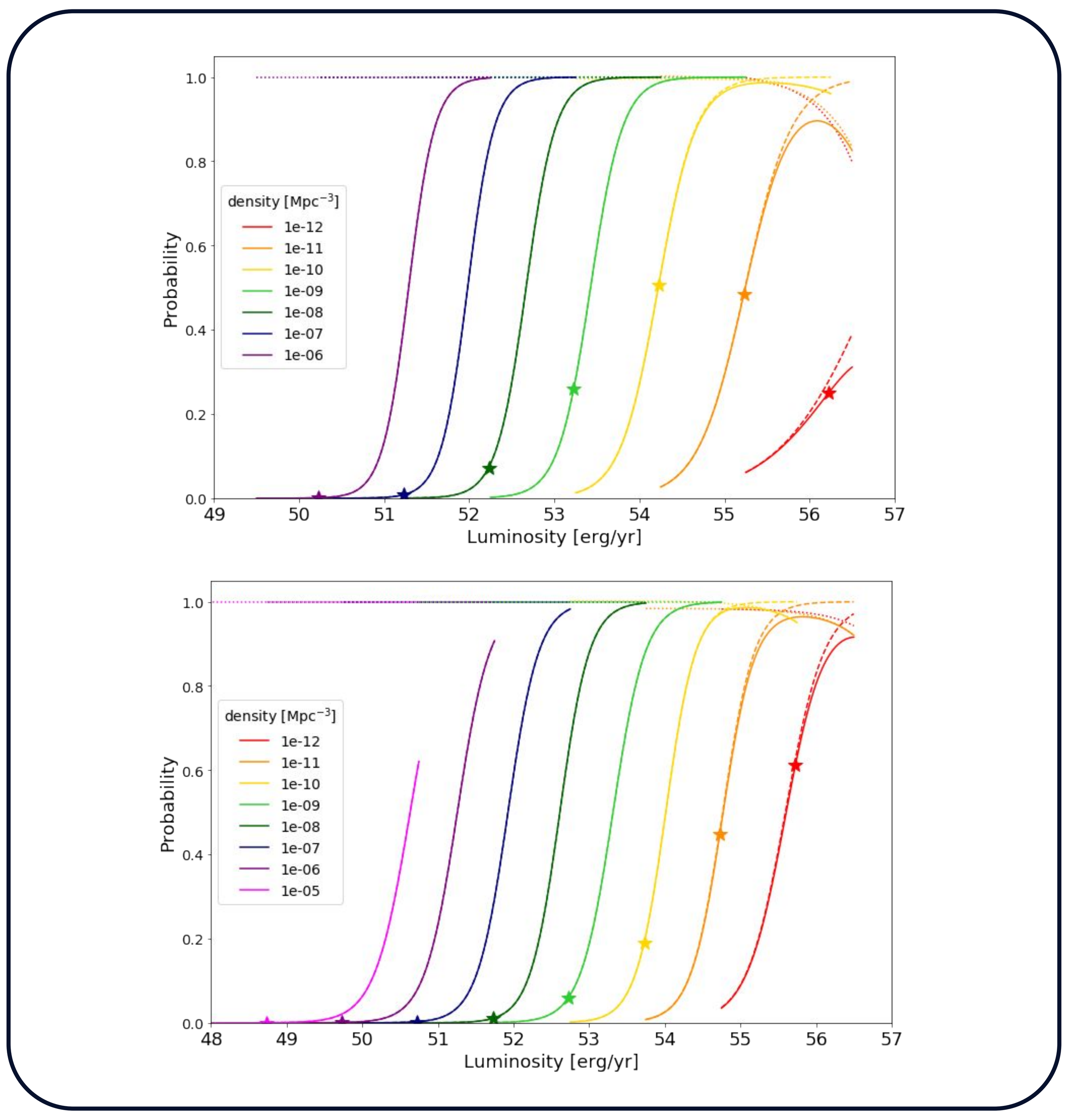

Fig. 1: Detection probability as a function of source luminosity for the steady sources following flat redshift evolution (top) and star formation rate evolution (bottom) for 30 min observations with CTA-N Omega, including visibility constraints

We explore steady source populations which do not evolve with redshift (which is a simplified way to describe blazars) and ones that follow the star formation rate evolution [2], and the populations of flaring blazars. In all cases, 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.

CTAO 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 adopt the phenomenological model of [3].
These assumptions give a baseline model, but the real neutrino sources and their populations are more complex.

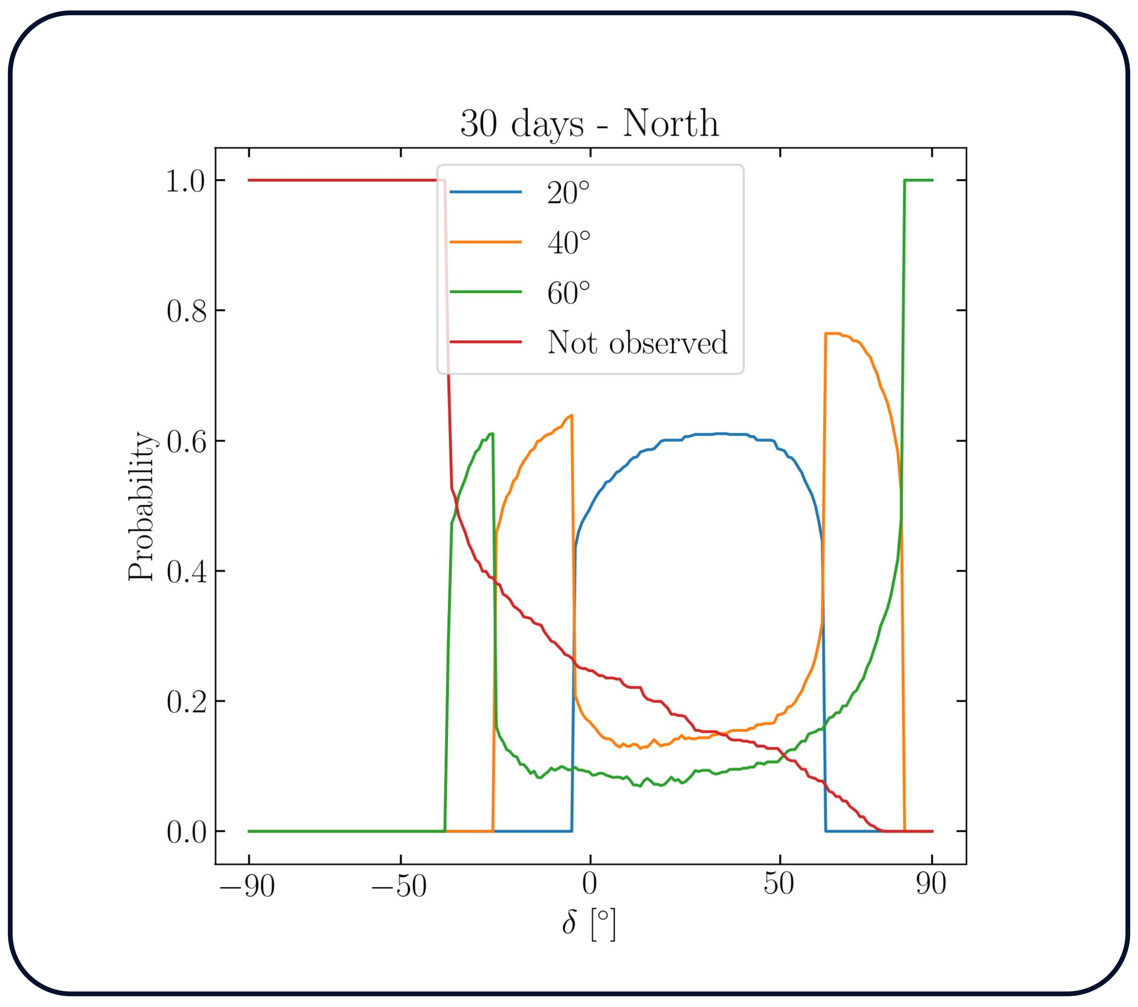

Fig. 2: Probability of observation of the alert at CTA-N in different zenith bins as a function of the alert declination

To simulate 30 min CTAO observations we use the ctools package with gammalib [4] and employ the prod3b-v2 CTAO instrument response functions (IRFs) for CTAO Omega and prod5-v0.1 IRFs for CTAO Alpha. For all sources we take into account the extragalactic background light absorption [5].
For flaring blazars we also simulate 1 h and 5 h CTAO observations.

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[5] A. Dominguez et al., Mon. Not. Roy. Astron. Soc., 410, 2556 (2011)

prod3b-v2 IRFs can be found here:
https://doi.org/10.5281/zenodo.5163272

prod5-v0.1 IRFs can be found here:
https://doi.org/10.5281/zenodo.5499839

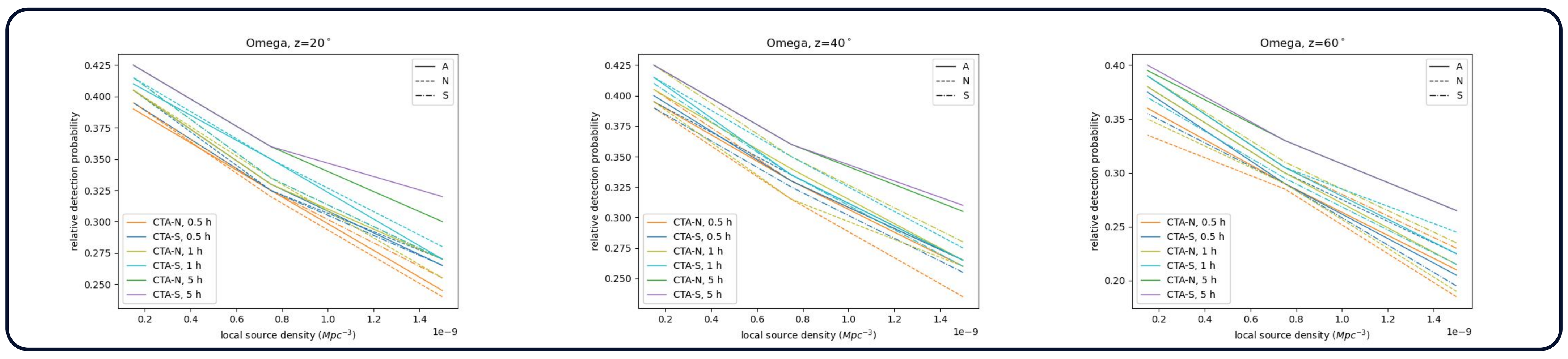

Fig. 3: Detection probability for flaring blazars observed with the CTAO Omega configuration for different durations of observation and geomagnetic field configurations

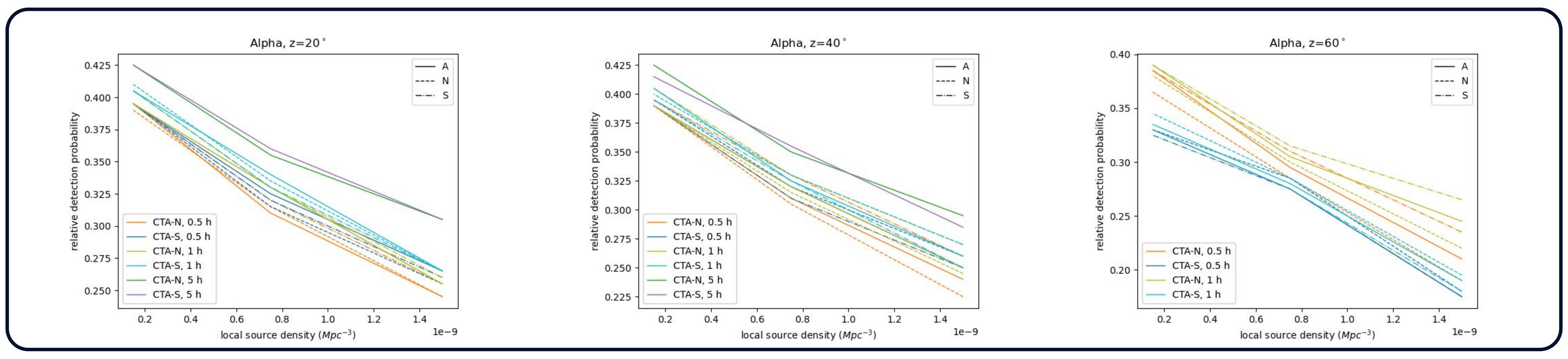

Fig. 4: Detection probability for flaring blazars observed with the CTAO Alpha configuration for different durations of observation and geomagnetic field configurations

This work was conducted in the context of the CTAO Consortium. We gratefully acknowledge financial support from the agencies and organizations listed here: www.cta-observatory.org/consortium_acknowledgments. This research has made use of the CTAO instrument response functions provided by the CTAO Consortium, see https://www.ctao.org/for-scientists/performance/ for more details. This research has made use of ctools, a community-developed analysis package for Imaging Air Cherenkov Telescope data. ctools is based on GammaLib, a community-developed toolbox for the scientific analysis of astronomical gamma-ray data.

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