Active Galactic Nuclei population studies with the Cherenkov Telescope Array

cherenkov telescope array

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ABSTRACT

The envisaged advances in performance will see Cherenkov Telescope Array (CTA) heralding in a new era for high-energy astrophysics, with the emphasis shifting from source discovery, to population studies and precision measurements. Here we quantify CTA's ability to conduct source population studies of gamma-ray bright Active Galactic Nuclei (AGN), in particular comparing CTA's initial 'alpha' and final 'omega' configurations. In particular we show that even during the construction phase, CTA will already be able to double the amount of extragalactic source detected. However, to realise CTA's full potential for several key science programmes, the full omega array configuration is needed.

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Introduction

CTA is designed to achieve an order of magnitude improvement in sensitivity with respect to the current generation of IACTs, with unprecedented angular and energy resolution over nearly 4 decades in energy, from 20 GeV to beyond 100 TeV. The envisaged step-change in performance afforded by CTA will in part be due to CTA's sheer size, and the fact that it will be comprised of three telescope size classes, the Small-Sized-Telescopes (SST), Medium-Sized-Telescopes (MST) and Large-Sized-Telescopes (LST), with each size class optimised to observe a different gamma-ray energy range. During the initial phase of constructing CTA, first arrays of telescopes will enable early scientific observations, with 4 LSTs and 9 MSTs in the Northern array, and 14 MSTs and 37 SSTs on the Southern site, whilst a later construction phase will follow to complete the array. In the following study, this is referred as "alpha configuration", while the full-scope CTA arrays will be referred as "omega configuration".

4LAC & extrapolation the spectra

The 4LAC catalogue lists all gamma-ray bright AGN detected by the LAT during the first 8 years of the *Fermi* gamma-ray satellite mission. Importantly, all AGN detected by IACTs are present in the 4LAC. As such, we use all AGN in the 4LAC, with known redshift as our target sample. In total 1551 AGN are considered.

From the 4LAC, we extended the observed LAT spectra into the CTA energy range considering two important factors: (i) the Extragalactic Background Light (EBL) and (ii) the extrapolation scheme. For the EBL we used the Dominguez 2011 model. For the extrapolation scheme, we used a bracketing approach assuming an optimistic power-law (PL) spectral form and a pessimistic log-parabola (LP) spectral form.

CTA-North Omega	30 GeV	50 GeV	100 GeV	300 GeV	500 GeV	1 TeV
5 hour - PL	51	84	114	98	83	65
20 hour - PL	93	171	209	164	135	103
5 hour - LP	30	50	73	62	54	41
20 hour - LP	51	101	131	107	87	64
CTA-North Alpha	30 GeV	50 GeV	100 GeV	300 GeV	500 GeV	1 TeV
5 hour - PL	30	53	76	73	63	49
20 hour - PL	60	117	154	131	105	84
5 hour - LP	19	35	45	45	40	27
20 hour - LP	33	64	96	86	68	56

CTA-South Omega	100 GeV	300 GeV	500 GeV	1 TeV
5 hour - PL	117	112	90	71
20 hour - PL	209	173	147	116
5 hour - LP	68	66	52	45
20 hour - LP	122	108	92	73
CTA-South Alpha	100 GeV	300 GeV	500 GeV	1 TeV
5 hour - PL	50	72	72	53
20 hour - PL	100	124	125	96
5 hour - LP	30	45	46	39
20 hour - LP	57	78	74	56

Fig. 1: Number of AGN detected for the CTA-North alpha & omega arrays (top), and CTA-South alpha & omega arrays (bottom), for all parameters considered in this study.

Results

For this study, we use gammapy v0.17 to simulate CTA's response to the input extrapolated spectra. We consider 5 and 20 hour exposures, and simulated 3 zenith angles of observations: 20º, 40º and 60º. In addition we consider 6 different energy thresholds for the analysis: 30 GeV, 50 GeV, 100 GeV, 300 GeV, 500 GeV and 1 TeV. The number of AGN detected for the different analysis and instrument response configurations considered in our study are shown in Figure 1. We find that in some cases the omega configuration detects over double the AGN compared to the alpha configuration.

Figure 2 shows several examples of the redshift reach expected for the AGN detected by CTA. In both cases, the omega array detects significantly more AGN at large redshifts compared to the alpha configuration.

Figure 3 shows the photon index-photon flux parameter space that CTA will be able to probe. With the omega configuration CTA will be able to detect fainter and/or softer AGN than is possible with the smaller initial alpha configuration.

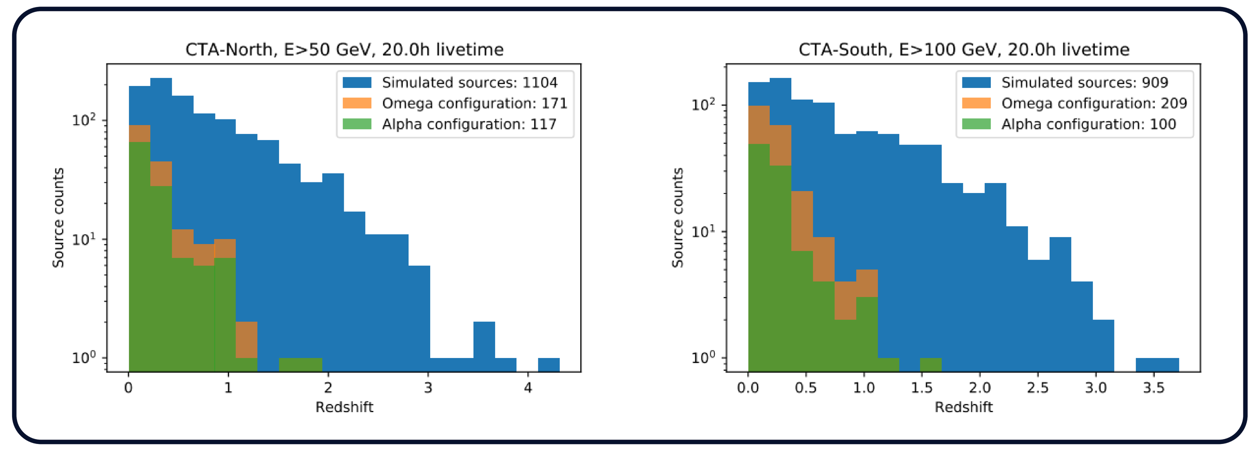

Fig. 2: Redshift distributions of AGN detected by CTA-North (left) and CTA-South (right) with 20 h exposures considering a PL extrapolation scheme.

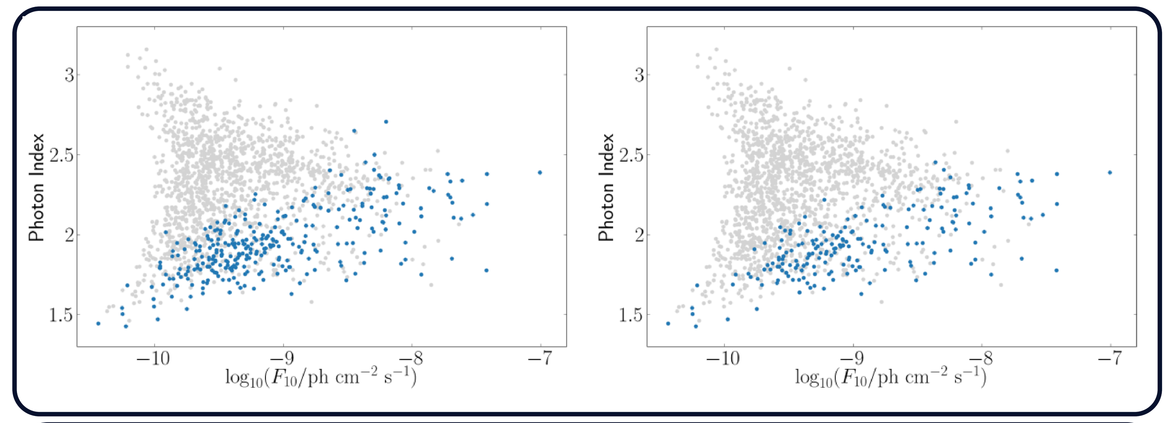

Fig. 3: Flux vs index parameter space for the AGN considered in this study. The grey symbols indicateall AGN simulated, whilst the blue symbols represent the AGN detected by CTA (by either CTA-North or CTA-South). From left to right, the panels depict the results for the omega and alpha configurations, respectively.

Discussion

We find that in all analysis configurations considered in this study, the omega configuration performs better than the initial alpha configuration, which shows that we will be able to expand science reach of CTA as more telescopes are installed.

Gamma-ray cosmology studies which require the detection of numerous AGN across a large redshift range, such as investigating Lorentz invariance violation, would greatly profit from the inclusion of LSTs in the CTA-South array.

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