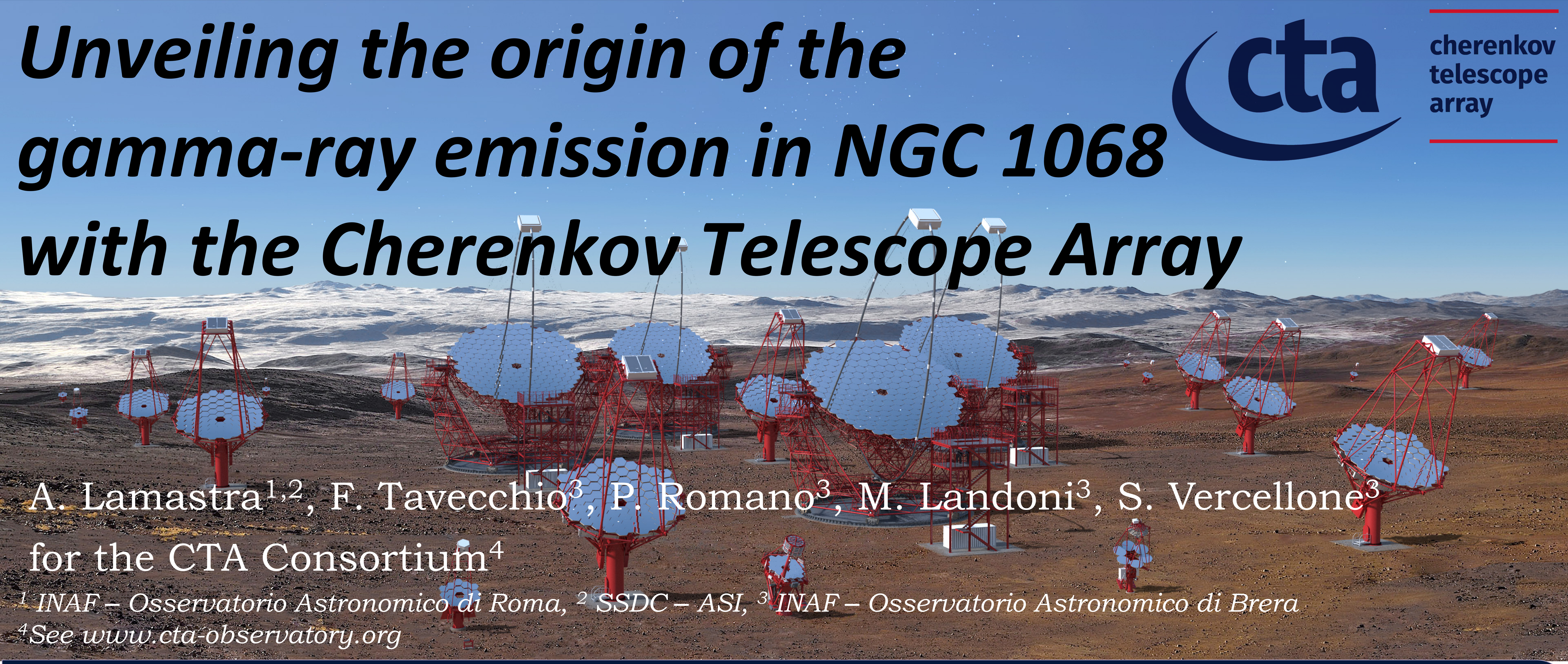

Unveiling the origin of the gamma-ray emission in NGC 1068 with the Cherenkov Telescope Array

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cherenkov telescope array

ABSTRACT

Several observations are revealing the widespread occurrence of mildly relativistic wide-angle AGN winds strongly interacting with the gas of their host galaxy. Such winds are potential cosmic-ray accelerators, as supported by gamma-ray observations of the nearby Seyfert galaxy NGC 1068 with the Fermi gamma-ray space telescope. The non-thermal emission produced by relativistic particles accelerated by the AGN driven wind observed in the circum-nuclear molecular disk of such galaxy is invoked to produce the gamma-ray spectrum. The AGN wind model predicts a hard spectrum that extends into the VHE band which differs significantly from those corresponding to other models discussed in the literature, like starburst or AGN jet. With dedicated simulations in the context of the Cherenkov Telescope Array (CTA), we demonstrate that, considering 50 hours of observations, CTA can be effectively used to constrain the different acceleration models.

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THEORETICAL MODELS

AGN wind model: the gamma-ray emission is produced by relativistic particles that are accelerated by the AGN-driven molecular outflow observed in the galaxy disk (Krips et al. 2011, Garcia-Burillo et al. 2014). The gamma-ray spectrum has a hadronic component produced by pion decays following inelastic proton-proton collisions, and a leptonic component produced by inverse Compton scattering and bremsstrahlung emission from the accelerated electrons (Fig. 1, Lamastra et al. 2016, 2018).

AGN jet model: the gamma-ray emission is produced through inverse Compton scattering of infrared photons from relativistic electrons accelerated in the misaligned radio jet (Fig. 1, Lenain et al. 2010, Lamastra et al. 2018)

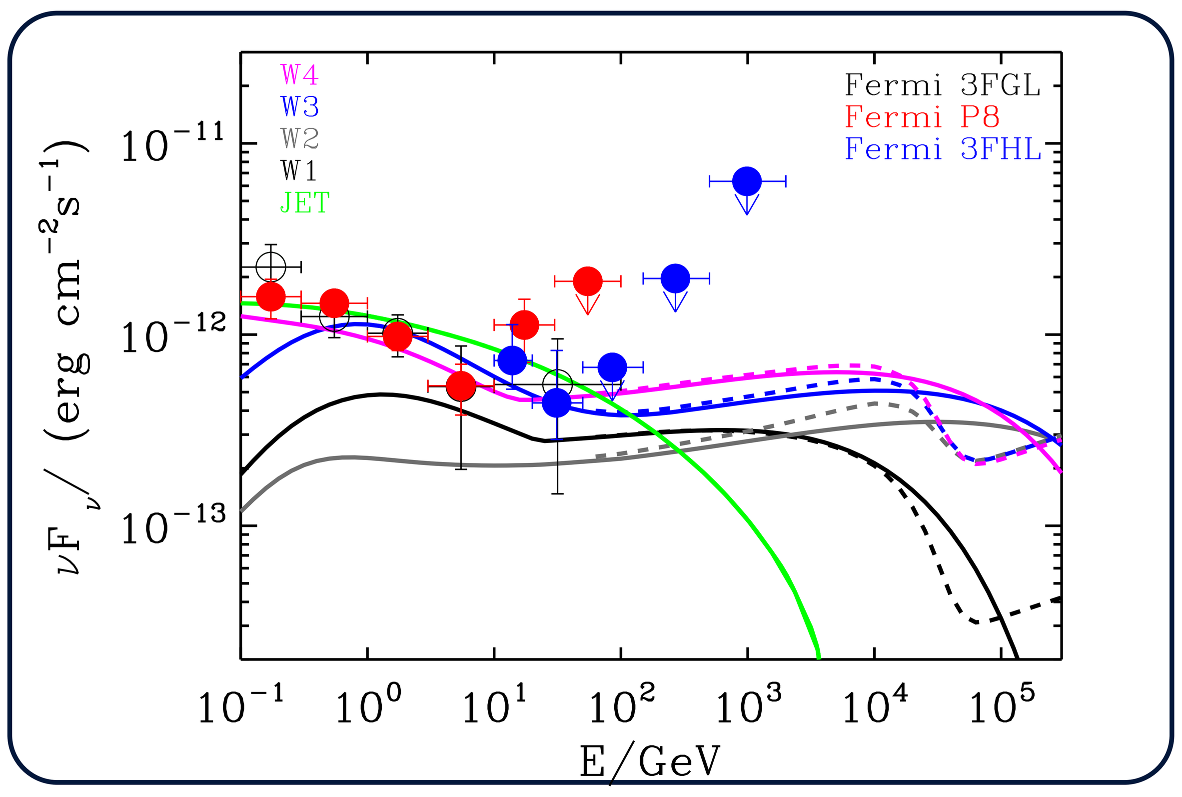

Fig. 1: SED of NGC 1068. The data points are from Acero et al. 2015 (3FGL), from Lamastra et al. 2016 (P8), and from Ajello al. 2017 (3FHL). The green solid line shows the AGN jet model. The black, grey, blue, and magenta solid (dashed) lines show the AGN wind model predictions for different value of particle acceleration efficiency, ISM density, and magnetic field derived by Lamastra et al. 2016 (Lamastra et al. 2018).

SIMULATION

We performed simulations of observations of NGC 1068 using CTOOLS (Knodlseder et al. 2016) and the public CTA instrument response files (Fig. 2). The source is located at RA(J2000) = 40.669583 deg, Dec(J2000) = −0.013333 deg, so it is visible from both CTA sites.

RESULTS

We find that with 50 hours of observation with CTA the spectra predicted by the AGN jet and AGN wind models can be detected up to energies $E \simeq 3$ TeV and $E \simeq 100$ TeV, respectively. Thus, CTA can be effectively used to constrain the two different acceleration models. In fact, a detection at $E>10$ TeV will provide a strong evidence for the existence of a hadronic component in the gamma-ray spectrum of NGC 1068.

At energies $E \gtrsim 10$ TeV the simulations indicate that we will measure with good accuracy the normalization and the position of the high energy cut-off of the gamma-ray spectrum which provide fundamental insights into the physics governing the acceleration of particles in non-relativistic AGN-driven winds. In particular, the detection of a high energy cut-off provides information on the maximum energy of accelerated particles, which depends on the shock properties, and on the magnetic field strength in the shock region.

The all-sky coverage and good sensitivity of the CTA full array will provide an unprecedented opportunity to improve our understanding of the gamma-ray emission in Seyfert and starburst galaxies (Fig. 3), that is crucial to constrain source population models of the extragalactic gamma-ray and neutrino backgrounds.

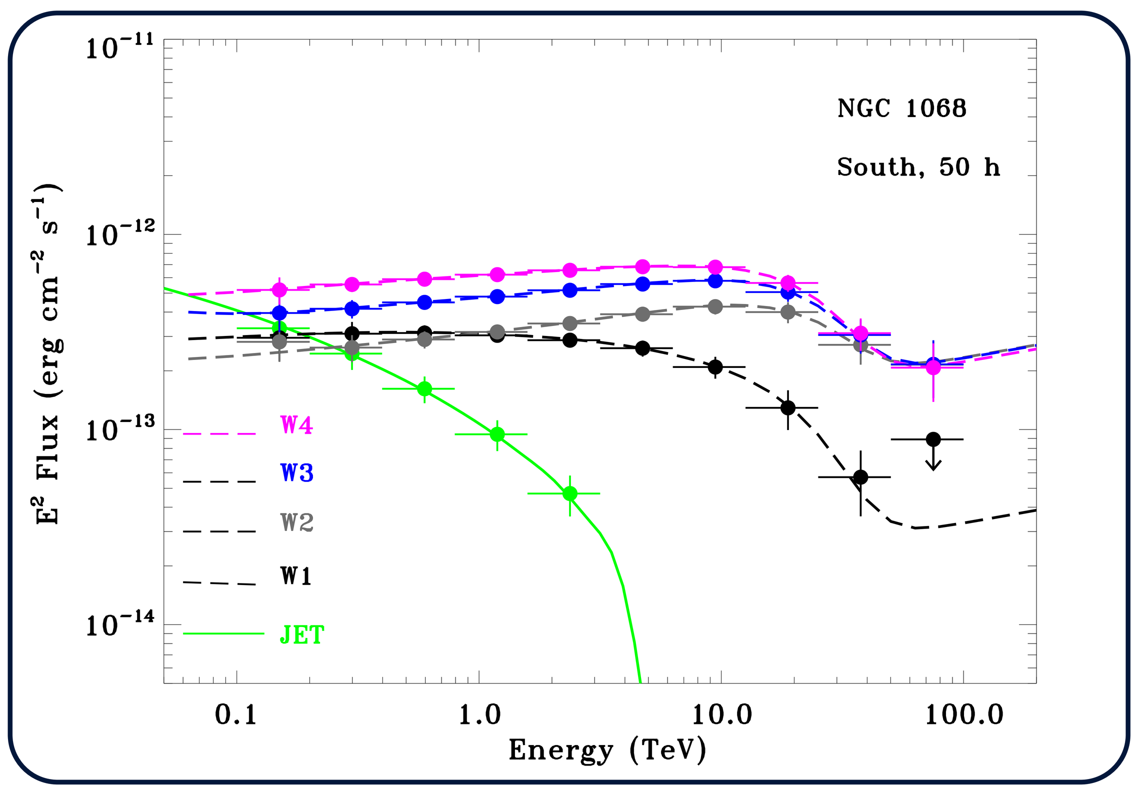

Fig. 2: Simulated spectra of NGC 1068.

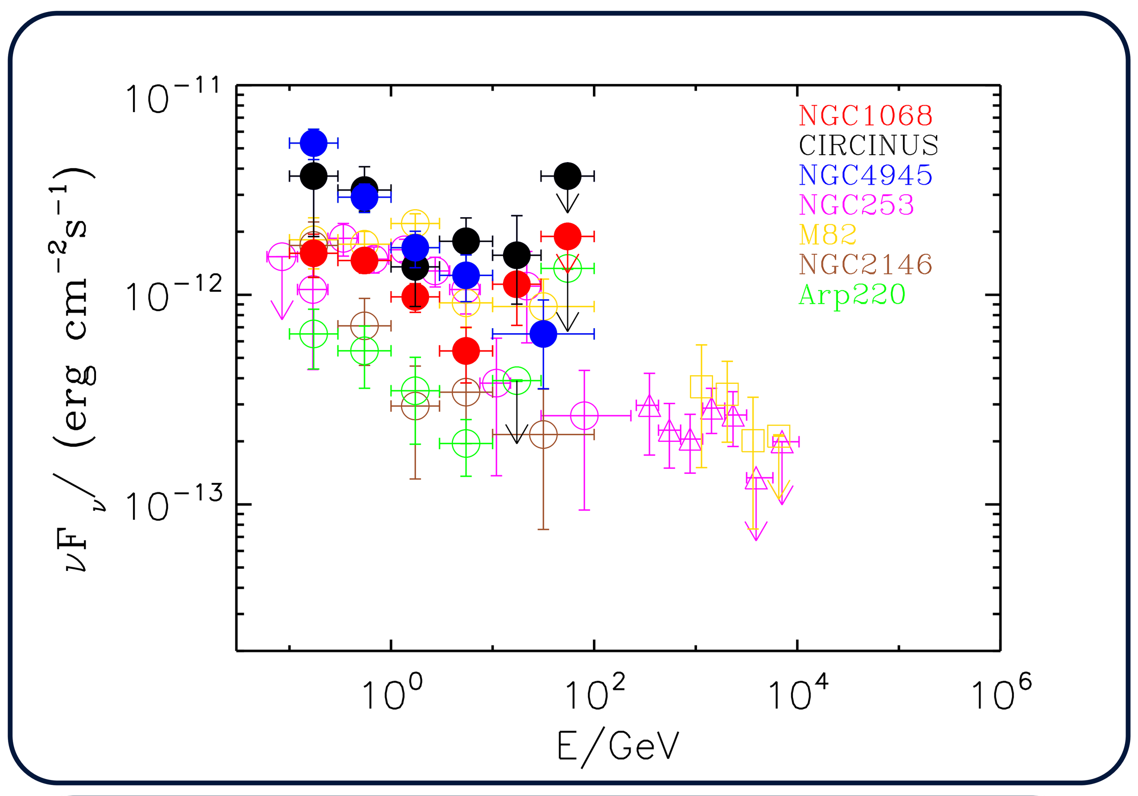

Fig. 3: SED of Seyfert galaxies (filled symbols) and starburst galaxies (open symbols) detected by *Fermi*-LAT and IACTs. The data points are from Ackermann et al. 2012; Acero et al. 2015; Lamastra et al. 2016; Ajello et al. 2017; Wojaczynski & Niedźwiecki 2017; Hayashida et al. 2013; Acciari et al. 2009; Tang et al. 2014; Peng et al. 2016; Abdalla et al. 2018.

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