Beyond Fermi: Prospects for Very High-Energy Gamma-Ray Observations with CTA

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For the CTA Consortium
http://www.cta-observatory.org
The CTA Concept

Arrays in northern and southern hemispheres for full sky coverage
4 large telescopes in the center (LSTs)
  Threshold of $\approx 30$ GeV
$\geq 25$ medium telescopes (MSTs) covering $\approx 1$ km$^2$
  Order of magnitude improvement in 100 GeV–10 TeV range
Small telescopes (SSTs) covering $>3$ km$^2$ in south
  $>10$ TeV observations of Galactic sources
Construction begins in $\approx 2015$
From current arrays to CTA

Light pool radius
$R \approx 100-150 \text{ m}$
$\approx$ typical telescope spacing

Sweet spot for best triggering and reconstruction:
Most showers miss it!

Large detection area
More images per shower
Lower trigger threshold
Why a large array?

Sufficiently large and capable MST array is the primary goal of the US groups
- Contribution of 36 telescopes
- Developing novel design w/ secondary mirror & excellent angular resolution

Color scale: number of triggered telescopes for 500 GeV showers
Site candidates

Two sites to cover full sky at 20º-30º N, S

Warning: map not quite accurate
Recommended by relevant roadmaps ...
Differential sensitivity

Achieved with current telescopes, simple “Hillas” analysis

Detection with 5σ in each bin of 0.2 decade in energy

E.g. using advanced analysis algorithms
Simulated Galactic Plane surveys

H.E.S.S.

CTA, for same exposure

Expect ~1000 detected sources over the whole sky
Resolving complex sources

SN 1006

CTA compared to Fermi – steady sources

Funk & Hinton

Differential Flux $E^2 \frac{dN}{dE}$ (erg cm$^{-2}$ s$^{-1}$)

Photon Energy (MeV)

Funk & Hinton
CTA compared to Fermi – transient sources

Field of view, duty cycle also matter
A simulated GRB (E > 30 GeV)

Simulation of GRB 080916C seen by GBM + LAT

from
Gamma-Ray Burst Science in the Era of Cherenkov Telescope Array
(Astroparticle Physics special issue article)
Susumu Inoue et al.
In the following, we explore the sensitivity of CTA to the DM particle. If such WIMPs annihilate to provide clues about the nature of the dark matter (DM), evaluating different possible array layouts (see Fig. 1), based on the expected performance of the instrument as obtained from Monte Carlo simulations.

The introduction of CTA, aiming to improve on the current factor for Segue 1 is shown for comparison.

Fig. 1: CTA layout for different array layouts. We explore several observational strategies and classes of targets.

Fig. 2: Cherenkov Telescope Array for indirect dark matter searches.

Fig. 3: Minimum value of the astrophysical factor required for detection after 100 h of observations, versus the WIMP cross section as a function of the WIMP mass from 100 h observation, with the different targets indicated by the black horizontal line.

Fig. 4 shows that for deep exposures and an additional DM component, we find the 4 Fermi combined DSG analysis, 10 years sensitivity by populating the arrays with 36 unresolved sources, but some fraction of the same observation time.

CTA will constitute the most sensitive instrument to DM signals at masses thought to be primarily composed of extragalactic dwarf spheroidal galaxies (e.g., Fornax, the Galactic plane, etc). Disregarding the intrinsic gamma-ray background can be excluded (see Fig. 5).

The extragalactic dwarf spheroidal galaxy Segue 1 dSph (channel i) is a prime target for DM searches with Fermi and CTA. Assuming the b b-bar decay channel, the Fermi LAT 2-year result from Ackermann et al. 2011, Phys. Rev. Lett. 107, 241302.

The Fermi combined DSG analysis, 2 years, Fermi combined DSG analysis, 10 years, Galactic Halo, 100 h, CTA array B (Ring Method), Fornax Cluster, 100 h, CTA array B (f_{max} = 1.0^\circ), Segue 1 DSG, 100 h, CTA array B.

VHE instruments are therefore possibly on the way to activity related to the BL Lac phenomena, but at weaker level dayscale variability. Indeed, IC 310 was already mentioned as the first option appears favored because of the detection of far-infrared line of sight to the galaxy with the capability to recognize a population of low luminosity or misdirected BL Lacs, different sections of the jet and the core. There is a growing evidence that relativistic jets are not on-axis, namely the problem of “missing BL Lac” and the question of AGN unification which is difficult to identify at lower energies, and thus “bridge the gap” between genuine BL Lacs and FRI radiogalaxies.

Dynamical modeling suggests that BL Lac are FR I radiogalaxies seen along their jet axis, namely the problem of “missing BL Lac” and the question of AGN unification which is difficult to identify at lower energies, and thus “bridge the gap” between genuine BL Lacs and FRI radiogalaxies. Generally speaking, nearby radio galaxies are likely core-dominated gamma-ray sources, although some could have the capability to recognize a population of low luminosity or misdirected BL Lacs, diholes.

Seyfert galaxies are radio-loud (RL) and show flat spectra to high energies, and thus “bridge the gap” between genuine BL Lacs and FRI radiogalaxies. Confirmed by the detection of a small number of RL-NLS1s (PMN J0948−2.8, which makes the detection of intracluster gas (59). Astrometric and angular resolution created by interaction of the fast moving host galaxy with the internal kpc jet structures are potentially resolvable by CTA, enabling us to look for possible VHE radiation from large scale inner kpc jet structures. CTA should be able to resolve Cen A (Abdo et al. 2010, Science 328, 725). Fermi LAT >200 GeV background-subtracted counts map of Cen A.

- Fermi LAT PSF at 10 GeV
- CTA PSF at 100 GeV (≥2 images)
- CTA PSF at 300 GeV (≥10 images)

(68% containment)
For the first time in this energy band:
Open observatory

- Open formats and tools following astronomy standards (FITS) to represent and analyse data and instrument response functions (IRFs)
- User-oriented data center & Virtual Observatory interfaces
CTA will enhance the Fermi legacy

- Guaranteed science – much of it with Fermi sources
- Discovery potential
- Proven technology combined with judicious innovation
- Will serve a large and diverse community
- Initial operations will potentially overlap with Fermi
- A natural way to extend Fermi science