Prospective Science with the Cherenkov Telescope Array

Active Galactic Nuclei

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THE UNIVERSITY of ADELAIDE

TeVPA Sydney
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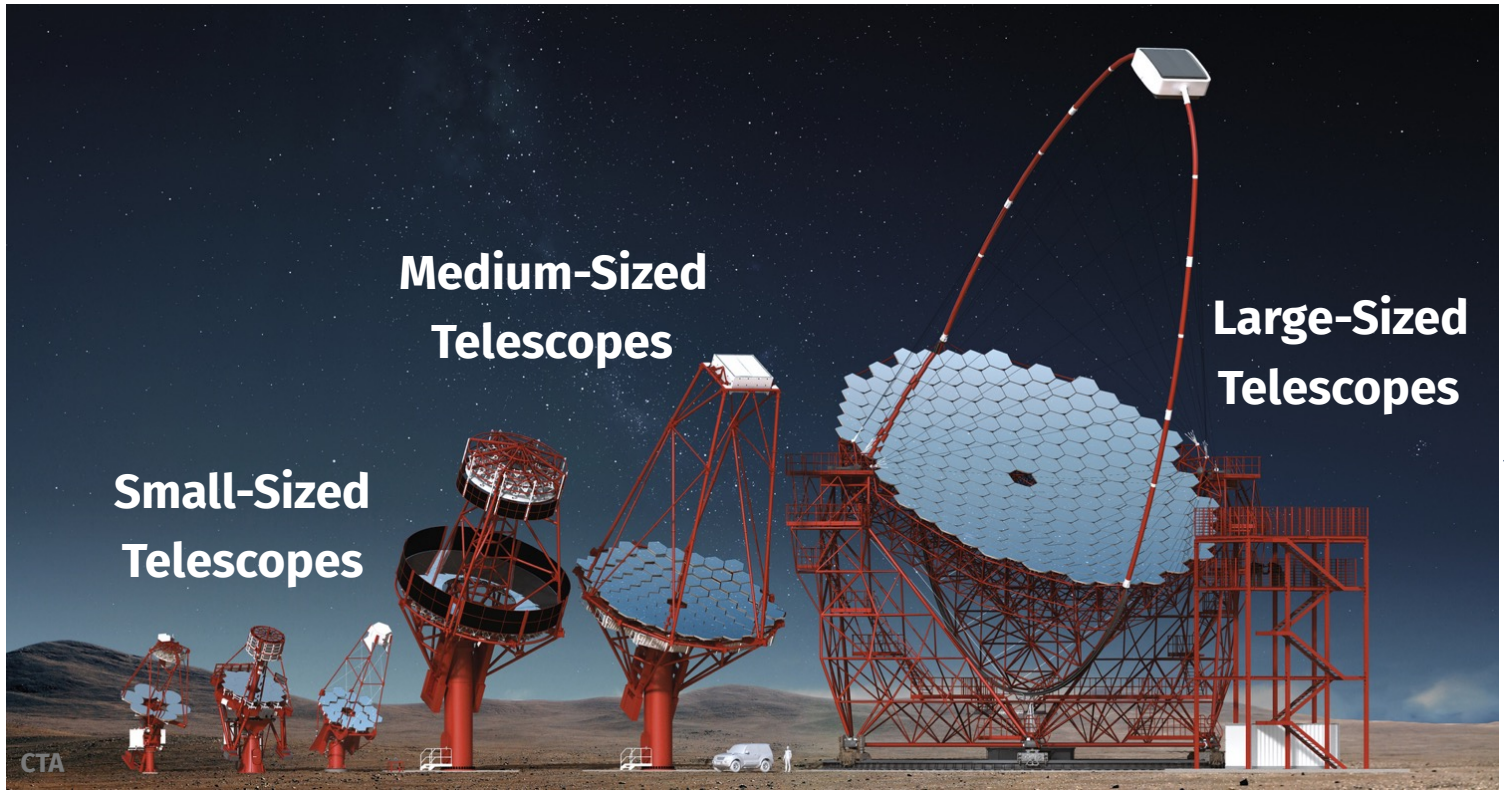
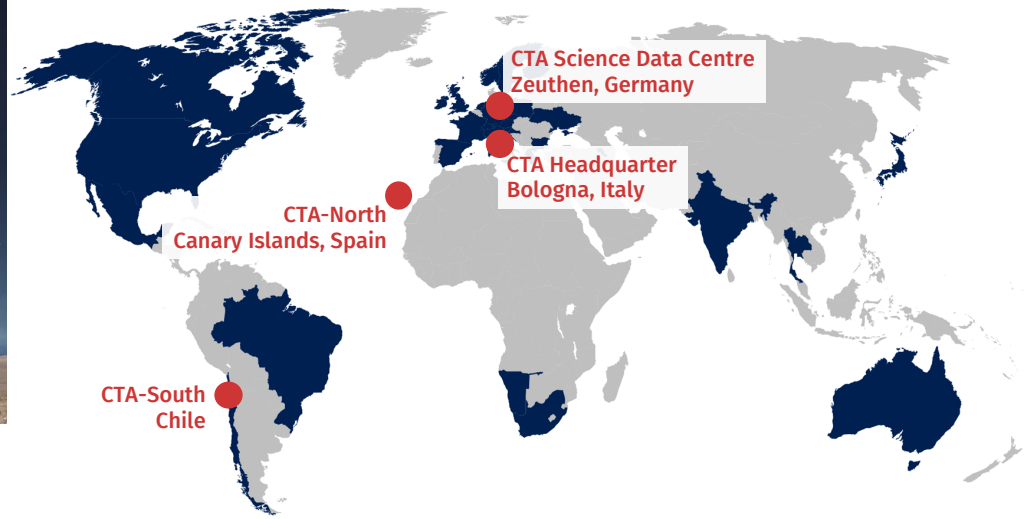
cta cherenkov telescope array — the observatory for ground-based gamma-ray astronomy

The Cherenkov Telescope Array



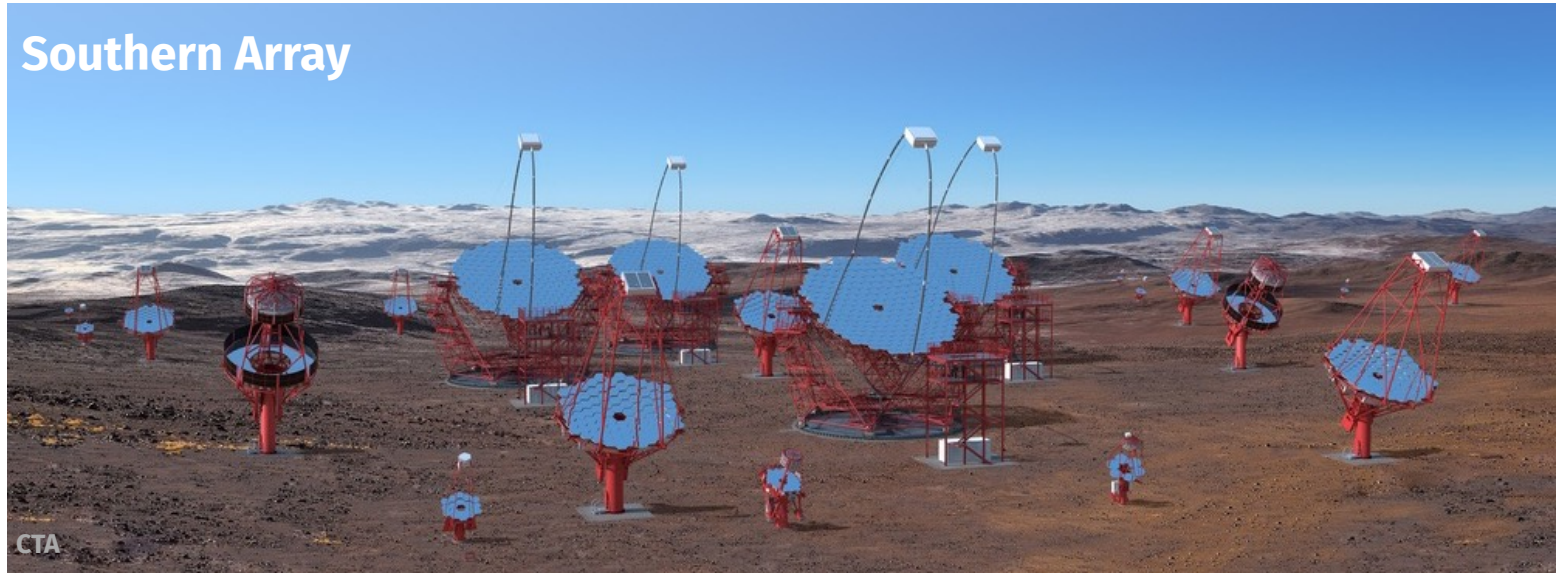
CTA Consortium

- 31 countries
- Over 200 institutes
- Over 1400 members



Friday 9am:
Roberta Zanin, *The Cherenkov Telescope Array: A New Eye on the TeV Sky*

The Cherenkov Telescope Array



Southern Hemisphere

- European Southern Observatory (ESO) Paranal, Chile
- 4 Large-Sized Telescopes
- 25 Medium-Sized Telescopes
- 70 Small-Sized Telescopes

Northern Hemisphere

- Observatorio del Roque de los Muchachos La Palma, Spain
- 4 Large-Sized Telescopes
- 15 Medium-Sized Telescopes

CTA's Themes

Understanding the Origin and Role of Relativistic Cosmic Particles

- What are the sites of high-energy particle acceleration in the Universe?
- What are the mechanisms for cosmic particle acceleration?
- What role do accelerated particles play in feedback on star formation and galaxy evolution?

Probing Extreme Environments

- What physical processes are at work close to neutron stars and black holes?
- What are the characteristics of relativistic jets, winds and explosions?
- How intense are radiation fields and magnetic fields in cosmic voids?

Physics Frontiers

- What is the nature of Dark Matter?
- Are there quantum gravitational effect on photon propagation?
- Do axion-like particles exist?

Science with CTA

Key Science Projects

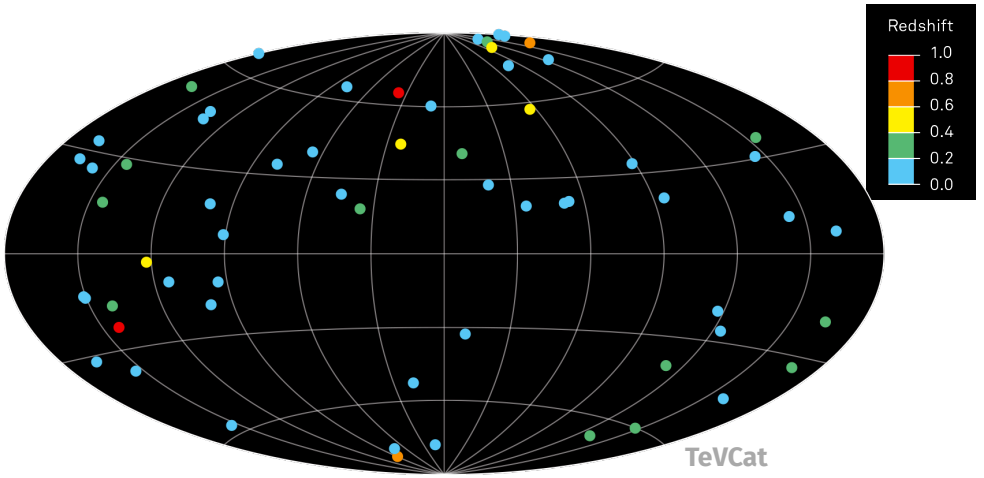
- Dark Matter Programme
- Galactic Centre
- Galactic Plane Survey
- Large Magellanic Cloud Survey
- Extragalactic Survey
- Transients
- Cosmic-Ray PeVatrons
- Star-forming Systems
- Active Galactic Nuclei
- Cluster of Galaxies
- Beyond Gamma Rays

Current Status: Active Galactic Nuclei

- Variable radiation across entire electromagnetic spectrum up to multi-TeV
- Fluctuations on timescales from several years down to a few minutes
- Sources detected at VHE: ~40% AGN
- Non-thermal multi-wavelength emission of blazars characterised by two broad spectral peaks (frequency of peaks defines subclass)

Very-High-Energy (VHE): GeV - TeV

- Population of ~80 VHE AGN:
  - 5 nearby radio galaxies
  - Blazars: 7 FSRQ, 2 LBL, 8 IBL, 38 HBL, 14 EHBL
- Highest redshift of z~0.9



➡ Coverage of different source classes and redshift of VHE AGN limited

➡ CTA will improve this coverage substantially

Key Science Project: Active Galactic Nuclei

Long-Term Monitoring

- Coverage of all known types of VHE AGN: EHBL, HBL, IBL, LBL, FSRQ, radio galaxies
- ~30min per week per target with full array

➡ Spectra on weekly or monthly basis for bright sources

➡ Long-term VHE light curves

➡ Total exposure: ~180h per year (132h CTA-North, 48h CTA-South)

Source Class	Potential Targets
EHBLs	1ES 0229+200, 1ES 1426+428, 1ES 1101-232
HBLs	Mrk 421, Mrk 501, PKS 2155-304
IBLs	1ES 1011+496, 3C 66A, W Comae
LBLs	AP Librae, BL Lacertae
FSRQs	PKS 1510-089, PKS1222+216
Radio Galaxies	M87, NGC 1275

Targeted Science

- Slow variability (annual timescales)
  - ➡ Duty cycle of source
  - ➡ Binary black holes, jet precession, accretion disk processes
- Intermediate variability (timescales of days, weeks, months)
  - ➡ Emission region in AGN jet
  - ➡ Acceleration and emission processes

Key Science Project: Active Galactic Nuclei

AGN Flare Programme

- Follow-up of external alerts: ~10-15 per year with full array
- Follow-up of internal alerts from long-term monitoring targets
- Follow-up of alerts from snapshot observations with full array

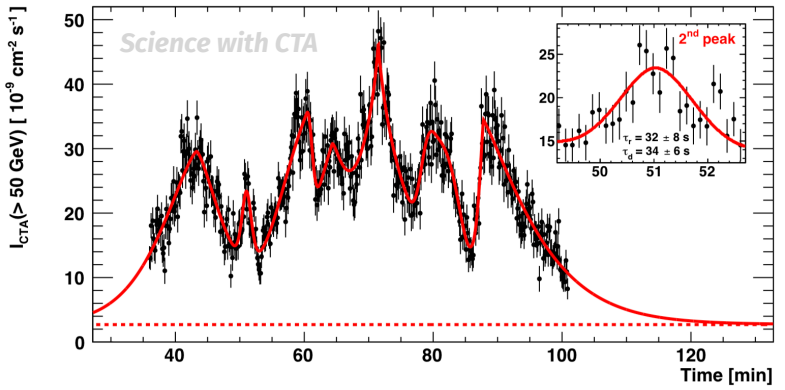
➡ Total follow-up time for all triggers (external, internal, snapshot): 200h

Snapshot observations

- Very short exposure of ~80 targets
- CTA-N / year: 300h LSTs, 22h MSTs
- CTA-S / year: 100h LSTs, 11h MSTs

Targeted Science

- Rapid variability (timescales of hours, minutes)
  - ➡ Constraints on Doppler factor, particle acceleration, cooling processes
  - ➡ Constraints on emission region and light-crossing time
- Detection of FSRQs in flaring states
  - ➡ Link between FSRQ and other blazars
  - ➡ Particle acceleration and emission within blazar jets
  - ➡ Extragalactic Background Light

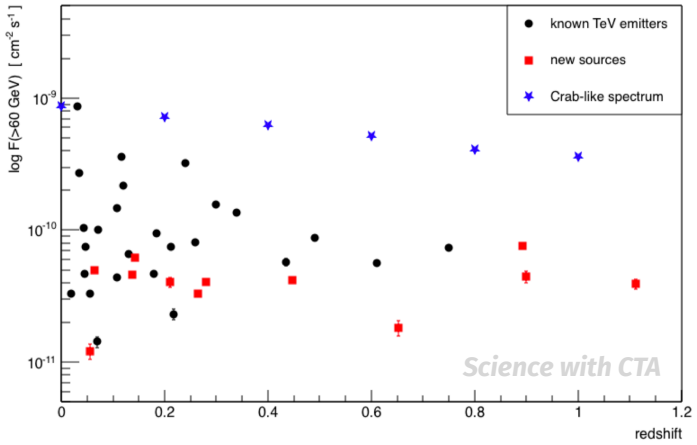


Key Science Project: Active Galactic Nuclei

High-Quality Spectra: Coverage of redshift and AGN classes

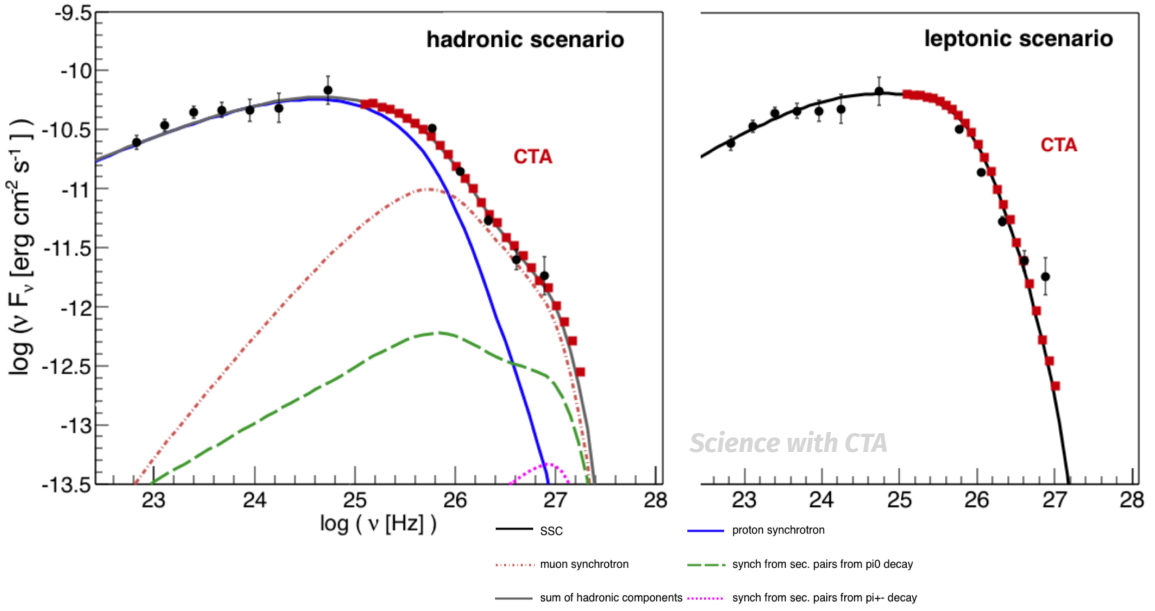
- Source selection criteria: Expected significance above 5σ in 20h
- Observations within one month to avoid mixing different states

➡ Total exposure: ~343h CTA-N, ~283 CTA-S with full array



Targeted Science

- Sources of different classes with different redshift
  - ➡ Leptonic / hadronic emission scenarios
  - ➡ Evolution of blazars with redshift
  - ➡ Precision measurement of Extragalactic Background Light
- Hard-spectrum, high-redshift sources
  - ➡ Search for Axion Like Particles
- Deep observation of hard-spectrum sources
  - ➡ Lorentz Invariance Violation



Key Science Project: Active Galactic Nuclei

High-Quality Spectra: Deep exposures of two radio galaxies

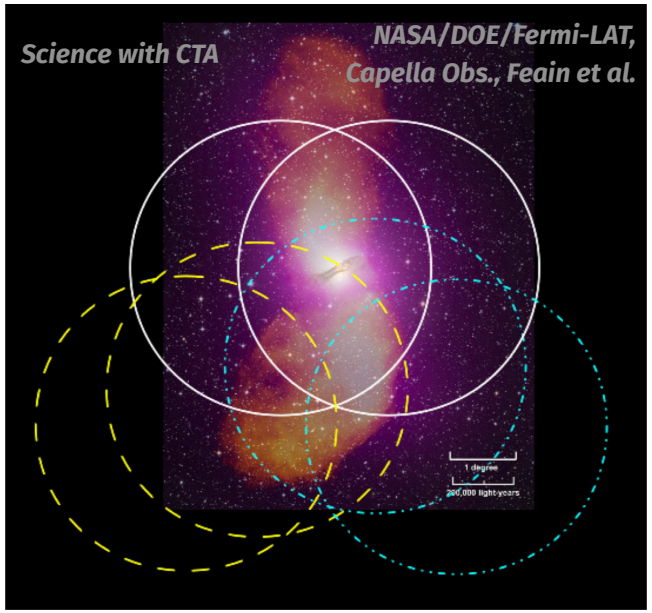
- Nearest radio galaxies known as TeV emitters

➡ Exposure of 150h with CTA-S full array (Cen A)

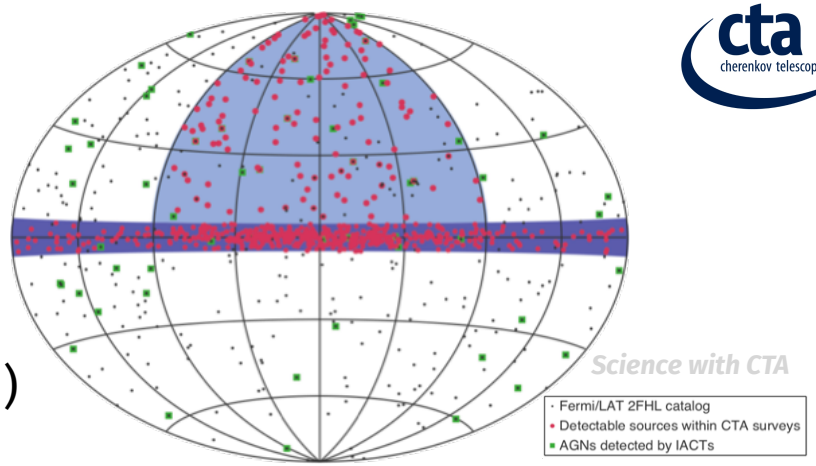
➡ Exposure of 100h with CTA-N full array (M87)

Targeted Science

- Spectra of radio galaxies
  - ➡ Extended emission from radio lobes or kpc jet
  - ➡ Unification of blazars and radio galaxies
  - ➡ VHE emission region of radio galaxies
  - ➡ Leptonic / hadronic emission scenarios
- Time-dependent spectra
  - ➡ Different emission regions for different episodes of VHE flare



Key Science Project: Extragalactic Survey



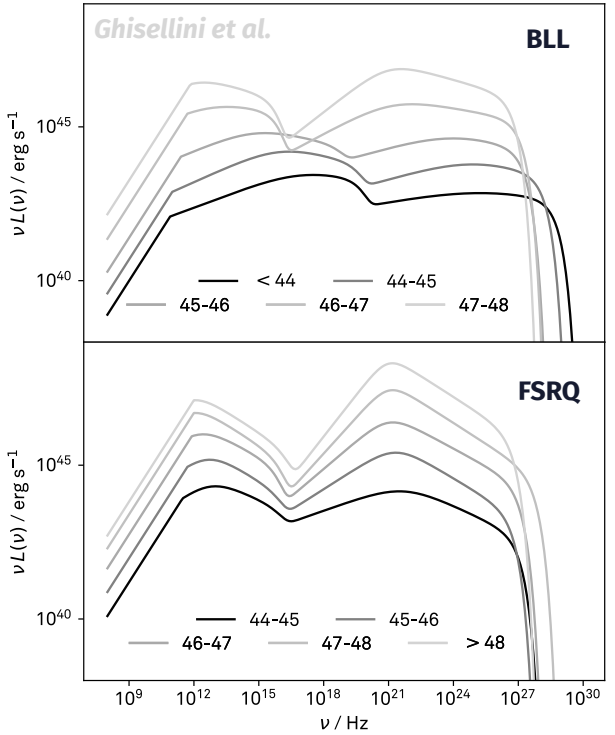
Blind Survey of 25% of Sky

- One of main legacies of CTA

➡ Exposure of 400h for 15% of sky (CTA-S) and 600h for 10% of sky (CTA-N)

Targeted Science

- Unbiased VHE catalog at ~6mCrab
  - ➡ Luminosity distribution and redshift dependence
  - ➡ Gamma-ray production mechanisms
  - ➡ Population studies
  - ➡ New source classes (e.g. Seyfert galaxies, ULIRGs)
- High-resolution map of extragalactic sky between 50GeV and 10 TeV
  - ➡ Discovery of dark sources / dark matter annihilation
  - ➡ Large-scale electron anisotropy
- Search for unexpected and serendipitous VHE phenomena
  - ➡ GRB in prompt phase



Key Science Project: Clusters of Galaxies

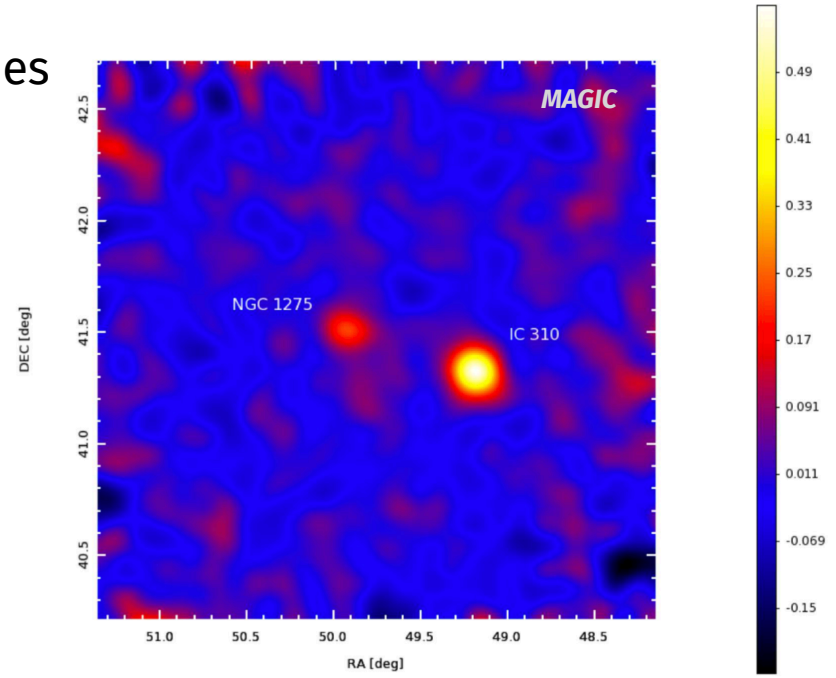
Deep Observation of Perseus Cluster

- Target selected based on distance, mass, ICM density and simulations

➡ Exposure of 300h with full array (CTA-N)

Targeted Science

- First detection of diffuse gamma-ray emission from clusters of galaxies
  - ➡ Cosmic-ray proton content of clusters
  - ➡ Cosmic-ray proton acceleration, propagation and confinement
  - ➡ Radio-emitting electrons and particle acceleration
  - ➡ Magnetic field distribution in clusters
- Detailed morphology study
  - ➡ Point-like vs. diffuse emissions
  - ➡ Extension of parameter space of theoretical models
- Radio galaxy NGC 1275 and HBL IC 310



Key Science Project: Transients

Follow-up Observations

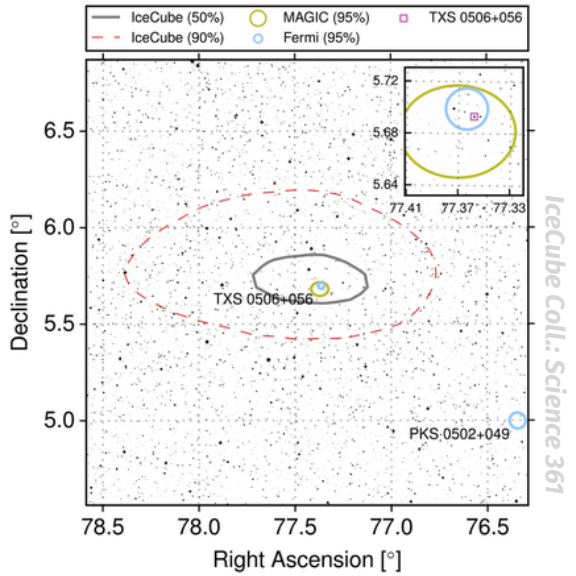
- High-energy neutrino transients:
  Follow-up on well-reconstructed and high-confidence high-energy neutrino alerts

➡ Exposure of 20h (5-10h) per year per site for early phase (afterwards)

- VHE transient survey: Divergent pointing, together with Extragalactic Survey

Targeted Science

- Multi-messenger studies
  - ➡ Origin of hadronic cosmic rays
  - ➡ Correlation to AGNs / emission processes in AGNs
- Unbiased VHE transients
  - ➡ New classes of transients



Connection to CTA's Themes

Understanding the Origin and Role of Relativistic Cosmic Particles

- Probe of gamma-ray emission processes in AGN through comparison of leptonic and hadronic emission models against steady and time-resolved spectra over wide energy range
- Search for ultra-high-energy cosmic rays through high-quality VHE spectra of source population

Probing Extreme Environments

- Comprehensive understanding of different blazar types and their supposed parent population of radio galaxies through exploitation of high-quality spectra and light curves from different classes
- Precise measurement of Extragalactic Background Light through AGNs over large range of redshifts
- Constraint on strength of intergalactic magnetic field

Exploring Frontiers in Physics

- Search for Lorentz invariance violation and axion-like particles

We gratefully acknowledge financial support from the agencies and organisations listed here: www.cta-observatory.org/consortium_acknowledgments