The Cherenkov Telescope Array

The next-generation gamma-ray observatory

Gernot Maier
Astronomy at very-high energies

rapid growth in number of sources and sources classes in the past decade

\( \approx 120 \) sources at energies > 100 GeV

2nd generation instruments

\[ \nu F(\nu) \text{ (erg cm}^{-2}\text{ s}^{-1}) \]

gamma-ray signatures of particle accelerators

**synchrotron radiation**

**\( \pi^0 \)-decay**

**Inverse-Compton**

\[ \text{radio} \quad \text{keV} \quad \text{GeV} \quad \text{TeV} \]
Cherenkov light from air showers: weak, short (~ns), blue flash of light
<table>
<thead>
<tr>
<th>Instrument</th>
<th>Lat</th>
<th>Long</th>
<th>Alt</th>
<th>#</th>
<th>Telescopes</th>
<th>Pixels</th>
<th>FoV</th>
<th>Thresh</th>
<th>Sensitivity</th>
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<tbody>
<tr>
<td></td>
<td>(°)</td>
<td>(°)</td>
<td>(m)</td>
<td></td>
<td>Area (m²)</td>
<td>Total (m²)</td>
<td>FoV (°)</td>
<td>(TeV)</td>
<td>(% Crab)</td>
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<td>H.E.S.S.</td>
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<td>16</td>
<td>1800</td>
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<td>107</td>
<td>428</td>
<td>5</td>
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<td>MAGIC I+II</td>
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<td>18</td>
<td>2225</td>
<td>2</td>
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<td>468</td>
<td>3.5</td>
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<td>137</td>
<td>160</td>
<td>3</td>
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<td>172</td>
<td>4</td>
<td>0.4</td>
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<td>2300</td>
<td>1</td>
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<td>1650</td>
<td>1</td>
<td>17.8</td>
<td>17.8</td>
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</tr>
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</table>

The CTA Consortium 2010 (arXiv:1008:3703)
The Cherenkov Telescope Array

10x sensitivity improvement over current instruments

plus wider energy range, improved energy resolution & wider field of view, flexibility of operation

substantially better angular resolution

The step to CTA can be compared to the move from ASCA to XMM
CTA: The Project
Baseline: 50-100 imaging Cherenkov telescopes
open observatory
(external proposals, peer-review selection process, standard analysis tools provided)

EU funded (€5.2 M) Preparatory Phase 2010-2013
CTA: The Array

Low energies
limitation: photon collection
large telescopes with >20 m diameter
energy threshold: some 10 GeV

Midsize telescopes
limitation: gamma/hadron separation
telescopes with ~12 m diameter
energy range: 100 GeV - 10 TeV

High-energy section
limitation: effective area
telescopes with ~4-6 m diameter
energy range: > 5 TeV
**CTA: Event Confinement**

- Majority of effective area is inside the array.
- Improved angular resolution and better background rejection.

**E = 4.290 TeV**

- **Ground view**
- **Camera view**

The CTA Consortium 2010 (arXiv:1008.3703)
CTA: Sites

two sites - North and South
site selection until 2012
Midsize Telescopes: Optimization and Prototyping
Understanding the origin of cosmic rays and their role in the Universe

Energy spectrum of charged cosmic rays

Energies and rates of the cosmic-ray particles

RXJ1713.7-3946
Abdo et al 2011 (Fermi-LAT)

Tycho
Molmino&Capriolo 2011

Suzaku
Radio

FermiLAT
VERITAS
**Shell-type SNRs as seen with CTA**

Spectro-imaging analyses of RX J1713.7-3946

**CTA simulations:**
using spatial image of XMM with best-fit values on the joint Fermi-LAT/H.E.S.S. spectrum:

\[
dN/dE = N_0 E^{-\Gamma} \times \exp \left( - \left( \frac{E}{E_{\text{max}}} \right)^{\beta} \right)
\]

\[\beta = 1.00 \pm 0.035\]

\[\beta = 2.41 \pm 0.20\]

Box size = 0.05°

after M.Renau (2011)
CTA Science Drivers II

Understanding the nature and variety of particle acceleration around black holes

broadband SED during all states probably key to understanding of non-thermal emission from AGN (now: most AGN are detected in their high-states only)

W Comae (Acciari et al 2009)

Swift AGILE VERITAS

no detection during low state

high-state detection
**CTA: Variability Studies**

Slewing in <1 minute to anywhere on the sky 4-9° FoV

**Huge Opportunity** for short-timescale phenomena:
- Gamma-ray bursts,
- AGN & Microquasars, ...

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**Fermi**
- 1 min
- 1 hour
- 10 hours
- 100 hours

**CTA**
- 1 year

Ex integral flux sens. (erg cm⁻² s⁻¹)

30 GeV

Log₁₀ (Energy/TeV)
whole Universe visible: AGN population study

precision studies morphology

\( \gamma \gamma \rightarrow e^+ e^- \)
CTA Science Drivers III

Understanding the nature of dark matter

DM annihilation $\sim \rho^2$

DM decay / Astrophysical sources $\sim \rho$

Milky Way Halo

Galactic center

Dwarf Galaxies

$\log S (M_{\odot}^2 \text{kpc}^{-5} \text{sr}^{-1})$

CTA Science Drivers III

Understanding the nature of dark matter

DM annihilation $\sim \rho^2$
DM decay / Astrophysical sources $\sim \rho$


Buckley et al 2008
CTA Science Drivers IV

survey: large part of the sky >100 GeV unexplored
population studies of SNR, PWN, AGN

Fermi LAT all sky survey

VERITAS survey of the Cygnus region

H.E.S.S. Survey of the inner Galaxy

CTA: North + South Array
8° field of view
Design Concepts for the Cherenkov Telescope Array

CTA

An Advanced Facility for Ground-Based High-Energy Gamma-Ray Astronomy

The CTA Consortium

May 2010

astro-ph/1008.3703

www.cta-observatory.org