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The Cherenkov Telescope Array: status and perspectives

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Abstract. The progress of the ground-based γ-ray Astronomy in the last 10 years (mainly due to instruments such as H.E.S.S., MAGIC and VERITAS) has inspired the scientific community to go for the next step in the evolution of the ground-based Imaging Atmospheric Cherenkov Technique (IACT). CTA has been conceived as an array of Cherenkov telescopes working as an open observatory, covering a wide energy range ($\sim$ 30 GeV to 100 TeV), with an enhanced sensitivity and improved spatial, temporal and energy resolution. The design phase of CTA has been completed and the project is in the middle of its preparatory phase. The begin of the construction is foreseen for 2014. In this paper we describe the status of the project, the technical challenges and we give an insight on the involved physics.

Resumen. El avance de la Astronomía de rayos γ desde Tierra en los últimos 10 años (principalmente gracias a instrumentos como H.E.S.S., MAGIC y VERITAS) ha inspirado a la comunidad científica para dar el próximo paso en la evolución de la Técnica de detección del Cherenkov atmosférico(IACT). CTA ha sido concebido como un arreglo de telescopios Cherenkov para cubrir un amplio rango de energías con una sensibilidad y resolución angular y energética muy superior a la de los instrumentos actuales. La etapa de diseño de CTA ha sido completada y el proyecto se encuentra en la etapa de "preparación" antes del comienzo de la construcción, planificada para 2014. En este trabajo se describe el status del proyecto y de los desafíos tecnológicos que se presentan además de una breve introducción a la física involucrada.

1. Introduction

Very-high energy (VHE) γ-rays are produced in non thermal processes in the universe, namely in galactic objects like pulsars, pulsar-wind nebulae (PWNe), supernova remnants (SNR), microquasars, etc . Among the extragalactic VHE γ-rays sources are active galactic nuclei (AGN), Gamma-Rays Bursts (GRB) and starburst galaxies.

Ground-based γ-ray astronomy has already demonstrated to be a mature scientific technique to probe non-thermal phenomena in the universe. Upon reaching the Earth's atmosphere, VHE γ-rays interact with atmospheric nuclei and generate electromagnetic showers. The charged secondary particles, mostly electrons and positrons, move with ultra-relativistic speed and emit Cherenkov light. This radiation is mainly concentrated in the near UV and optical band and is collected by telescopes mirrors and focused onto multi-pixel cameras that record the shower images.

This field has been impulsed by the Whipple Collaboration, which discovered the first source of TeV γ-rays (the Crab Nebula) in 1989. Since then, results from the latest generations of telescopes have revealed a rich sky with different objects emitting VHE γ-rays (Buckley et al. 2008). More than 100 sources at TeV are known so far, detected with the ground-based instruments as H.E.S.S.[1], MAGIC[2] and VERITAS[3].

In the GeV domain, the Fermi/*LAT*, has discovered more than 1800 bright sources (20 MeV to 100 GeV) during the first 3 years of operation (Nolan et al. 2012).

2. CTA: a new science infrastructure

CTA is formed by two large arrays of Cherenkov telescopes of different sizes, based on proven technology and deployed on an unprecedented scale. See the left panel of Fig.1 for an artistic view of the array configuration. It was conceived as a new facility, with capabilities well beyond the existing instruments and their possible upgrades.

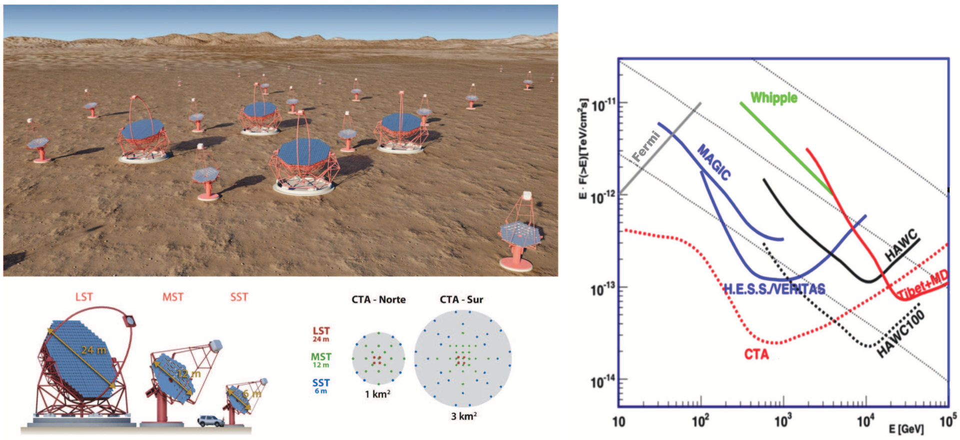

Figure 1. *Left:* Possible layout of the composite CTA Observatory. *Right:* Integral sensitivity for a Crab-like spectrum for several current IACT and expected for CTA (5σ, 50 h) and Fermi/LAT (5σ, 1 yr).

This project unites the main research groups in this field in a common strategy. The Consortium is composed nowadays of 25 countries and more than 100 institutions are implicated. CTA will, for the first time in this field, provide open access via targeted observation proposals and generate large amounts of

[1]http://www.mpi-hd.mpg.de/hfm/HESS/
[2]http://magic.mppmu.mpg.de/
[3]http://veritas.sao.arizona.edu/

public data, accessible using Virtual Observatory tools. CTA aims to become a milestone in a networked multi-wavelength exploration of the high-energy non-thermal universe.

2.1. Science motivation

CTA science prospectives are wide (for more detailed discussion see Actis et al. 2011 and Aharonian et al. 2008), but they are based on three cornerstones:
The origin of cosmic rays (CR) and their role in the Universe. Is commonly said that CR are accelerated in shocks generated by supernova explosions. γ-ray emission is detected in several SNR but the nature of the underlaying processes is not yet wholly understood. A deep CTA survey of the Galactic plane should unveil a handful of PeVatrons (not yet discovered) and of other types of CR accelerators candidates as PWNe, pulsars and binaries. The impact of the accelerated particles on their environment will be studied as CTA will enable detailed mappings of VHE emission around potential CR accelerators (Acero et al. 2013).
The nature of particle acceleration around black holes (BH), in particular inside objects as AGN. CTA will be able to detect a large number of these objects enabling population studies. It will be also possible to probe variability time scales well below minutes, putting constraints on acceleration and cooling times in these types of sources. A detailed study of the Extragalactic background light, and the emission from galaxy clusters and Gamma Ray Burst will be also possible by means of CTA (Sol et al. 2013).
Physics beyond the horizon. It is difficult to speculate about the unknown, and definitely we cannot accurately predict how much CTA will unveil about any physics that is beyond our standard model of the world. γ-rays, however, hold the potential to reveal properties of the elementary particles that make up our Universe because photonic signatures of particle interactions, decays and annihilations show up in this energy range (Martinez 2009, Bertone 2010).

2.2. An instrument of "unprecedented" performance

This observatory aims to provide full-sky view, from a southern and a northern site and to have the following characteristics:
-A sensitivity 10 times greater than any existing instrument. It will allow detection and in-depth study of large samples of known sources and it will be also sensitive to new phenomena. See the right panel of Fig.1.
-Coverage of three to four orders of magnitude in energy range, for distinguish between an hadronic or leptonic origin of VHE emission in different scenarios.
-Angular resolution in the arc-minute range, which is 5 $\times$ better than the typical values for current instruments.
-Time resolution of less than minute, for resolving flaring and variable emission.
-Wide range of configurations for observation, for the study of individual objects with high sensitivity, and the simultaneous monitoring of tens of flaring objects.
-Survey capability dramatically enhanced. For the first time, a full-sky survey at high sensitivity will be possible.

2.3. Technical Challenges

Three sizes of telescopes will be placed in different configurations and covering areas related to the desired sensitivity (see the left panel of Fig. 1: SST –

Small size telescopes of 5-8m diameter–; MST –Medium size telescopes of 10-12m diameter–; and LST –Large size telescopes of 20-30m diameter–.

Few LSTs should observe the sub-100 GeV photons thanks to their large reflective area. They will have a parabolic shape to avoid the intrinsic optical aberrations and will have limited Field of View (4° or 5°). This means the technical challenge of displacing the camera at more than 28 m from the reflector. Several tens of MSTs will perform the bulk TeV search. Different designs are currently under study and the construction of the first prototype is ongoing. Finally, various tens of SSTs will complete the array to perform the super-TeV search. They shall be simple in construction and should have moderate cost. A dual mirror telescope design is under study (Guarino et al. 2009). These telescopes are going to be distributed covering a multi-km^2 area.

A major effort is currently focused on the telescope design, the mirror facets development and the electronic and focal plane instrumentation. Different projects for SSTs, MSTs and LSTs are under design at several institutes to stimulate competition and technological development. Mirrors constitute an important challenge because they contribute to a considerable part of the costs. The focal plane instrumentation also represents a challenge in technology and cost. The efficiency of the collection of Cherenkov photons and their conversion to photoelectrons in the photosensor must be improved. Finally, enlarging the energy range requires appropriate electronics with a sufficiently large dynamic range.

3. Summary

The CTA observatory is the logical next step in the exploration of the high-energy Universe and will promote VHE observations to a public tool for modern astronomy. CTA will explore the VHE domain from several tens of GeV up to more than 10 TeV with unprecedented sensitivity and angular resolution, enabling a comprehensive understanding of cosmic particle acceleration physics at various scales, distances and time scales. CTA is passing through the preparatory phase for the construction and operation, dedicated to the development and prototyping. In about 5 years from now, CTA will produce its first results starting the next era on the VHE γ-rays astronomy.

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References

Acero F., et al., 2013, Astroparticle Physics, 43, 276
Actis M., et al., 2011, Experimental Astronomy, 32, 193
Aharonian F., et al., 2008, Reports on Progress in Physics, 71, 096901
Bertone G., 2010, Particle Dark Matter : Observations, Models and Searches. Cambridge University Press
Buckley J., et al., 2008, ArXiv e-prints
Guarino V. et al. 2009, in APS Meeting, "The Advanced Gamma-ray Imaging System"
Martinez M., 2009, Journal of Physics Conference Series, 171, 012013
Nolan P. L., et al., 2012, ApJS, 199, 31
Sol H., et al., 2013, Astroparticle Physics, 43, 215