LST-1 and CTA
Questions & Answers

Artistic Rendering of CTA Northern Hemisphere Site, La Palma (credit: Gabriel Pérez Diaz, IAC)

What is the intended use for the new Large-Sized Telescope?

The Large-Sized Telescope (LST) is the largest telescope type in the future Cherenkov Telescope Array (CTA), a ground-based gamma-ray observatory that will be located on two sites in the northern and the southern hemispheres. With a mirror of 23 meters in diameter and a reflective surface of 400 square meters, the LST is one of the largest Cherenkov telescopes ever built. Four LSTs are planned for the centre of both CTA arrays.

The LST is focused on the low-energy range of CTA, with sensitivity down to 20 gigaelectronvolts (GeV). Along with this low energy threshold, the LST's ability to reposition in less than 20 seconds turns it into an optimal instrument to observe transient events, within our Galaxy or beyond. These kinds of sources are associated with extreme environments, such as those in the vicinity of neutron stars or black holes. Thus, the LSTs will allow us to explore sources like gamma-ray bursts, some types of active galactic nuclei (black holes in the center of distant galaxies) and different Galactic transients.

What is the Cherenkov Telescope Array (CTA)?

CTA (www.cta-observatory.org) is a large-scale, global project to build the world's most powerful instrument for ground-based gamma-ray astronomy. It will be not only the largest and most sensitive high-energy gamma-ray observatory ever built, but also the first observatory open to the world-wide astronomy and physics communities as a facility devoted to high-energy astronomy. The project started in 2005, when scientists around the world proposed the first design concept for a next-generation gamma-ray facility, and we currently estimate the observatory to be completed in 2025.

The observatory will be located on two sites: at the Instituto de Astrofísica de Canarias' (IAC's) El Roque de los Muchachos Observatory on the island of La Palma (Spain) and near the European Southern Observatory's (ESO's) Paranal Observatory in the Atacama Desert (Chile).

Besides the Large-Sized Telescopes, CTA will host Medium-Sized Telescopes (MSTs) and Small-Sized Telescopes (SSTs) to cover a wide range of gamma radiation reaching from 20 GeV up to 300 teraelectronvolt (TeV). The plan for the northern site includes 4 LSTs and 15 MSTs, while the southern site will feature all three telescope types – 4 LSTs, 25 MSTs and 70 SSTs.

More than 1,400 scientists and engineers from 31 countries are engaged in the scientific and technical development of CTA. The planning for the construction of the Observatory is managed by the CTAO gGmbH, which is governed by Shareholders and Associate Members from a growing number of countries.

What kinds of observations and insights do scientists hope to achieve with CTA?

Ground-based gamma-ray astronomy is a young field with enormous scientific potential. The current instruments H.E.S.S., MAGIC and VERITAS have already demonstrated the huge scientific potential of astrophysical measurements at TeV energies, with more than 150 sources detected and a wide range of high impact scientific results. But these are most likely just the tip of the iceberg.

CTA will be sensitive to the highest-energy gamma rays, making it possible to study the physical processes at work in some of the most violent environments in the Universe. Thus, CTA will be able to detect hundreds of objects in our Galaxy, the Milky Way, including among others:

- Remnants of supernova explosions (SNR) and new pulsar wind nebulae (PWNe), which will allow us to delve into the origin of cosmic rays
- New binary systems – composed of two stars or formed by a star and a compact object (lika neutron star or black hole) – which will permit us to study steady or variable gamma-ray emission at different timescales

Beyond the Milky Way, CTA will be able to detect:

- The most luminous cosmic explosions, named gamma-ray bursts, in their initial phases
- Active galactic nuclei (AGNs), some of which are still undetected in the gamma-ray regime (such as Seyfert galaxies), and observe very rapid flares
- Star-forming galaxies, including so-called star-burst galaxies
- Clusters of galaxies, which are promising targets to detect dark matter, as well as to investigate cosmic-ray acceleration

Moreover, CTA will observe transient phenomena occurring in our own galaxy and beyond. These transient sources form a population of diverse astrophysical objects that explode, flare up or intensify activity in an unpredictable manner. Many transients emit very high-energy gamma rays and are related to neutron stars and black holes that manifest the most extreme physical conditions in the Universe.

Another hot topic in gamma-ray astronomy is the origin of cosmic rays. Cosmic rays are energetic particles that arrive from outside our atmosphere, mainly protons and Helium nuclei. Until recently, the cosmic machines that accelerate the particles to energies in the petaelectronvolt (PeV) range, have not been known. Recent scientific results achieved in a multi-messenger observation provided strong hints that a blazar, a special kind of AGN, might be possible source of cosmic rays. However, there are still interesting unsolved questions about cosmic rays that CTA may be able to answer, for example, if supernova remnants are the main contributor of cosmic rays in our Galaxy.

Dark matter is thought to account for a large part of the total mass of the Universe, but its nature remains one of the greatest mysteries in science. CTA will be a dark matter discovery instrument of unprecedented sensitivity and will potentially provide a tool to study the particle physics and astrophysical properties of the as-yet-unidentified dark matter particles. CTA will attempt to find dark matter by looking for the gamma rays produced when dark matter particles (believed to be weakly interacting massive particles, or WIMPs) annihilate one another when they interact. Gamma rays detected with CTA may also provide evidence for deviations from Einstein's theory of special relativity and definitive answers to the contents of cosmic voids, the empty space that exists between galaxy filaments in the Universe. More about CTA study topics.

How does the LST work?

Gamma rays, the most energetic radiation in the electromagnetic spectrum, are blocked by the atmosphere so they cannot reach the Earth's surface. Nevertheless, they can be detected by telescopes like CTA – via the production of Cherenkov light. When gamma rays interact with the atmosphere, they produce subatomic particle cascades. Charged particles in these cascades travel faster than the speed of light (possible in surroundings other than vacuum) emitting very faint bluish light known as Cherenkov light. CTA's large telescope mirrors and ultra-high-speed cameras can then collect and record the nanosecond flash of light so that the incoming gamma ray can be tracked back to its cosmic source.

To collect the faintest traces of gamma rays, the first LST prototype, named LST-1, features a mirrored surface of about 400 square meters. Although the LST-1 stands 45 metres tall and weighs around 100 tonnes it is able to re-position within 20 seconds to capture brief, low-energy gamma-ray signals. Thus, scientists have a chance to register even very short gamma-ray flares.

The camera weighs about two tonnes with a total of 1,855 photomultiplier tubes (PMTs) grouped in 265 modules with easy access for maintenance. The PMTs are detectors that convert light into an electrical signal. Each module has a readout board to save the data coming from the attached PMTs.

The camera has a total field of view of about 4.3 degrees and has been designed for maximum compactness and low weight, cost and power consumption while providing optimal performance at low energies.

The camera trigger strategy is based on the shower topology and the temporal evolution of the Cherenkov signal produced in the camera. The analogue signals from the photosensors are conditioned and processed by dedicated algorithms that look for extremely short but compact light flashes. Furthermore, all future LST cameras will interconnect in order to form an on-line coincidence trigger among the telescopes. More about how CTA works.

Who built the LST-1?

The Large-Sized Telescope (LST) project team consists of more than 200 scientists from ten countries: Brazil, Croatia, France, Germany, India, Italy, Japan, Poland, Spain and Sweden. In this truly international effort, the design and management leadership was shared among LAPP, Annecy, France; Max Planck Institute for Physics, Munich, Germany; INFN, Italy; ICRR, University of Tokyo, Japan; and IFAE, Barcelona and CIEMAT, Madrid, Spain. Once the LST-1, a prototype for the other three telescopes to be constructed in La Palma, undergoes a critical design review to verify that the design complies with CTA science goals, operational needs, safety standards, etc., it will become CTA's first telescope on site.

What is the status of the CTA project?

The project to build CTA is well advanced: prototypes now exist for all the proposed telescope designs and significant site characterization has been undertaken. The first phase of the detailed design of the La Palma site's infrastructure, which includes the design and construction of the remaining LST foundations and of the first MST foundation, is expected to be completed by the middle of 2019 with work on site beginning before the end of 2019. Negotiations for the southern site agreement are expected to conclude before the end of 2018, which would allow site work to begin in 2019.