Very large zenith angle observations with the MAGIC telescopes

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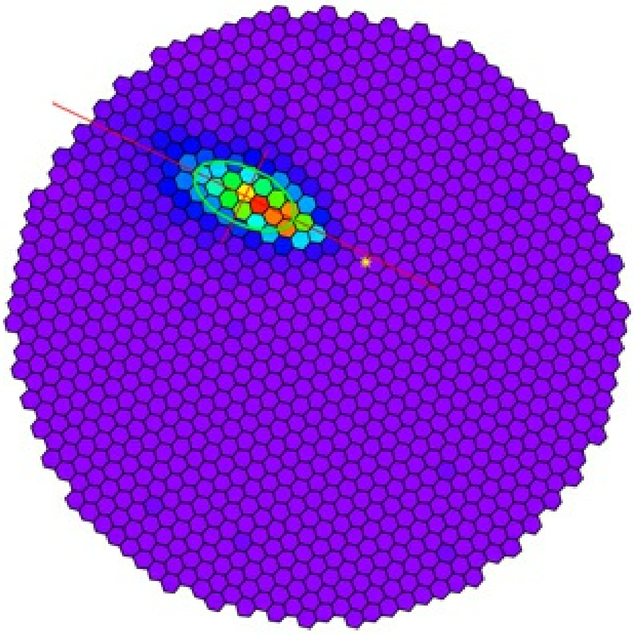
The MAGIC telescopes at the Observatorio del Roque de los Muchachos on La Palma (Canary Islands). Credits: Daniel López, IAC.

Astrophysics has evolved in time as higher energies became accessible, relating progressively more to particle physics. Energies and directions of traced events represent crucial observables.

Measuring these requires stopping incoming particles within a detecting material whose size increases with energy. Due to the rarefied environment of space, satellites are preferred, but eventually their volume becomes excessive for dealing with the highest energies. At this point do Imaging Atmospheric Cherenkov Telescopes (IACTs) come into play.

Exploiting the very high energy (VHE) gamma rays impacting our atmosphere, the two Major Atmospheric Gamma Imaging Cherenkov telescopes (MAGIC) monitor the night sky from the Canary Island of La Palma. The atmosphere plays a key role: particles propagate through it as showers generated by cosmic rays impacting on its upper layer. Charged particles in the showers, electrons and positrons in particular, can be superluminal and cause the emission of Cherenkov radiation. As a consequence, each shower generates a front of Cherenkov photons triggered by a single initial event.



Example of a gamma-like signal from a Monte Carlo simulation. Credits: MAGIC collaboration.

The MAGIC telescopes work in pair, making stereoscopic images of such showers, usually focusing on the ones induced by gamma rays. Light is projected by the mirrors into the corresponding cameras, where photons are converted into electrical impulses by photomultipliers. Information about the primary particles is recovered from statistical analysis of the projected images. This is how IACTs, like MAGIC, operate.

IACTs have pushed gamma-ray astrophysics beyond the energies effectively accessible from space; such energies are of great interest to current physics, especially because of the energy limits of ground-based particle accelerators. How could we reach even higher energies ?

Given its density profile, the amount of crossed atmosphere varies along the zenith angle, from overhead towards the horizon. The shower properties also change as we observe toward the ground, allowing to filter higher-energy events - albeit with a greater effort. Ongoing research by the MAGIC collaboration deals with the largest zenith angle observations ever made, and with the ensuing challenges to be met in order to optimise the data analysis.

Atmosphere monitoring is usually operated via a laser which provides differential absorption measurements along the shooting direction. However, limited power prevents it to cover long distances at very large angles. Infrared thermal radiation can be used to make an integral measure of the same quantity: in this case measurements suffer from the amount of medium itself, which contributes significantly and non-linearly as while approaching the ground.

Optical astronomy provides a possible alternative: absorption can be measured using starlight as reference, correcting data for the atmospheric effects.

The MAGIC collaboration is improving in all these directions, also thanks to dedicated analysis techniques under development, aiming to understand some relevant systematics and to increase the energy capabilities accessible to current IACTs.

(*) On behalf of The Magic Collaboration.