5.15 MAGIC

People working on MAGIC-II. One person wearing a yellow helmet is near the centre of the picture, just to the left of the circular camera cover. But that puts him only just behind the focal point of the huge mirror, so his reflection (at left) looks as though he's about 8 m (26 ft) high.

Name	Major Atmospheric Gamma-ray Imaging Cherenkov Telescope (MAGIC)
Run by	MAGIC collaboration (23 institutes from Bulgaria, Croatia, Finland, Germany, Italy, Japan, Poland, Spain and Switzerland)
Type	Segmented reflector
Wavelength	Gamma rays (Cherenkov radiation)
Diameter	2 x 17 m
Inaugurated	MAGIC I: 2004 MAGIC II: 2009
Website	http://wwwmagic.mppmu.mpg.de/
Webcam	http://www.magic.iac.es/webcams/

Unlike the other telescopes at the Roque, MAGIC doesn't observe visible light, infrared or ultraviolet. It's a gamma ray telescope. (See *C. The Invisible Rainbow* for an explanation of gamma rays.)

Astronomers worked out that there ought to be cosmic sources of gamma rays in the late 1940s and 1950s, but since the atmosphere blocks gamma rays, they had no way of detecting them until they could send detectors above the atmosphere.

The first gamma ray detector went into orbit in 1961. Other satellites, launched in the late 1960s and early 1970s, were designed to monitor nuclear bombs exploding on Earth. They also found explosions of gamma rays from deep space, lasting from a few seconds to a few minutes. At the time, nobody had a clue what they were.

Well that's guaranteed to get astronomers fascinated, and gamma ray astronomy took off. More satellites were launched to study lower energy gamma rays, and ground based telescopes were developed to observe the highest energy ones. (There are very few of the highest energy rays, so you need a massive detec-

tor to observe them. That makes it impractical to put them into orbit.)

So how do you observe gamma rays on the ground, where gamma rays never reach? You use something called an IACT (Imaging Atmospheric Cherenkov Telescope).

An IACT looks for something called Cherenkov radiation, created by gamma rays hitting the earth's atmosphere 10-30 km up.

Don't panic. If you watch *The Simpsons*, the chances are good that you've already seen Cherenkov radiation.

Homer Simpson works in a nuclear power station. Occasionally you see the rods of nuclear fuel in a water tank, with an eerie blue glow around the rods. That blue glow is Cherenkov radiation.

Gamma rays are so energetic that they smash the atoms in the water around the fuel rods. The subatomic particles then travel faster than light - faster than light in water (but still slower than light in a vacuum). The charged particles disrupt the electromagnetic field as they pass, and that polarizes the air molecules. As the polarized molecules return to their normal state, they emit a blue light called Cherenkov radiation. It's rather like the sonic boom when a plane breaks the sound barrier, but with light instead of sound. Less technically, it's a bit like seeing pieces of car flying through the air and working out where the truck came from.

The MAGIC telescope is looking for Cherenkov radiation made by gamma rays from space smashing atoms in the upper

The two MAGIC telescopes. MAGIC-II is in the foreground The photo was taken in August 2007, before the mirror segments were fitted on the dish structure.

The MAGIC Telescope at night, by R. Wagner
The telescope used to use lasers to align and focus the mirror segments. The laser beams could only be seen on foggy nights.

atmosphere instead of in water. But since the blue flashes are very faint and very brief and 10-20 km above the telescope, the mirrors have to be huge to catch as much of it as possible. In fact each of the two mirrors is 17 m (55ft) across, and they work together like a pair of binoculars. The first thing you notice about the MAGIC is its enormous size.

The second thing you notice is that there's no dome, and the telescopes are out in the open air, like giant baskets on their sides. For one thing, a dome that size would cost a fortune. For another, the telescope isn't taking pictures in the usual way, so the mirror doesn't need to be kept to optical quality. The rain washes any dust off the mirror. Thirdly, it would move too slowly. Gamma ray bursts last for a maximum of three minutes, which is less than the time it takes the WHT dome to rotate to the other side of the sky. Obviously, a dome that took three minutes to rotate towards a burst would be about as much use as a chocolate frying pan. The MAGIC is designed to swing to the other side of the sky in just 40 seconds, even though it weighs about 60 tonnes and has over 16 times the light-collecting area of the WHT. It's a Formula One telescope.

MAGIC I was built in 2004. MAGIC II was added in 2009. Obviously this doubled the amount of light collected. MAGIC II came with newer, better instrumentation, which was also fitted to MAGIC I. This year the camera of MAGIC-I was exchanged to a clone type as used in MAGIC-II.

The cameras are where you'd put your hand on the basket handle. Because these telescopes observe indirectly --looking at the Chrenkov radiation rather than the gamma rays directly -- you can't get a high-quality image, and the cameras only have 1039 pixels each. But it's getting data you couldn't get any other way.

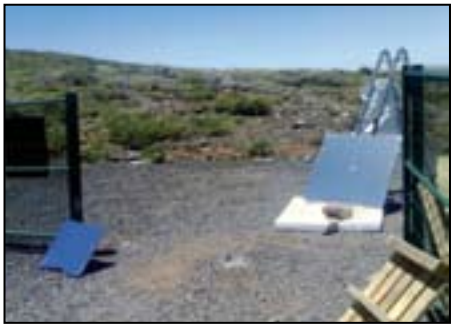
So what does MAGIC look at? Basically at the really high energy stuff -- things the Myth Busters would enjoy.

- **Black holes** in **Active Galactic Nuclei**.
- **Supernova** remnants, partly because they're a source of cosmic rays.
- Other galactic sources such as **pulsar wind nebulae** or

binary stars which emit x-rays.

- Sources identified by the EGRET or Fermi satellites.
- Annihilation of **Dark matter**
- And of course **Gamma Ray Bursts**

A pan of chili con carne being heated by solar power, sitting on the MAGIC telescope
Credit: Carlos Gonzalez..



The two mirror segments being used to heat the chili. The small one (50x50 cm^2) on the left is from MAGIC-I and the larger one (100x100 cm^2) on the right is from MAGIC-II.
Credit: Carlos Gonzalez.

It's not all high tech, though. While they were fitting the mirror segments to MAGIC II, the team used two of the segments to focus the sun onto a pan, and reheat chilli con carne for lunch.

Since two segments will reheat lunch in about 20 minutes, imagine what would happen at the camera focus if the sun hit the whole mirror, all 225 segments of it! I don't think it would be long before the metal of the shutter would glow enough to fry the extremely sensitive camera inside.

The solution is simple - during daylight hours, the telescopes always point north and slightly downwards. Luckily, this means that they're also sideways on to the prevailing wind, which reduces wind resistance.

5.15.1 HEGRA, *the pioneer in the field*

When I first came to La Palma, there was an earlier gamma ray detector installation on the same site. The initial experiment was called AIROBICC (AIRshower Observation By angle Inte-

grating Cherenkov Counters). It looked like an array of beehives. 49 of the beehives (in a 7 x 7 grid) were looking for Cherenkov light overhead. They could only work when the moon was down. Another 48 were added later on. These contained scintillation counters, which detected the secondary particles arriving at ground level.

In 1992 the first IACT was build on the Roque. With the time more telescopes were added and in 1996 an array of five telescopes with 8.5 m^2 mirror area each was finished. The telescope system was collected HEGRA (High Energy Gamma Ray Array). One of them is still there and was just recently refurbished. The telescope is called now FACT (First G-APD Cherenkov Telescope) and its aim is to test the new camera techniques for future IACT generations. And although I never knew it, there were underground detectors counting the arrival of sub-atomic particles called muons.

AIROBIC and HEGRA took data between 1987 and 2002, then both were dismantled and MAGIC was build.

> *Any sufficiently advanced technology is indistinguishable from magic.*
>
> *Arthur C Clark (SF writer, and inventor of the satellite.)*

Florian

Florian Goebel was the project manager for MAGIC-II, the second of the huge Cherenkov telescopes at the Roque de los Muchachos. Shortly before the telescope was due to be inaugurated in September 2008, he somehow fell from the prime focus tower in the dark. The tower is about ten metres (33ft) high, and Florian didn't survive.

I only ever had one conversation with him. He must have been very busy, but he took time out to help me with a magazine article. I always think that's the true test of character: how you treat people who are of no possible use to you.

My husband worked for him for three weeks, fitting mirror segments to MAGIC II, and said several times how nice he was.

After his death the project was renamed to The Florian Goebel MAGIC telescopes.

My sincere sympathies to his family.