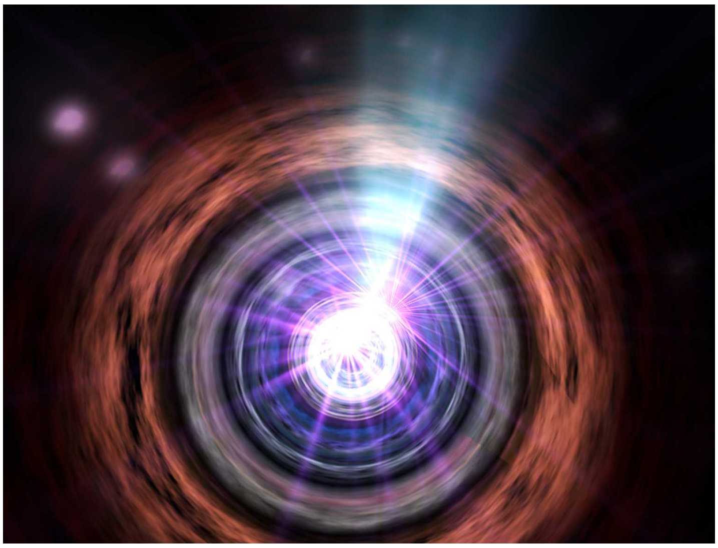
NASA's Fermi Mission, Namibia's HESS Telescopes Explore a Blazar

Collaboration between ground and space

An international team of astrophysicists using telescopes on the ground and in space have uncovered surprising changes in radiation emitted by an active galaxy. The picture that emerges from these first-ever simultaneous observations in visible light, X-rays and gamma rays is much more complex than scientists expected and challenges current theories of how the radiation is generated.



In the heart of an active galaxy, matter falling into a supermassive black hole somehow creates jets of particles traveling near the speed of light. For active galaxies classified as blazars, one of these jets beams right toward Earth. Credit: NASA/Goddard Space Flight Center Conceptual Image Lab *(see animation)*
Credit: NASA/Goddard Space Flight Center Conceptual Image Lab

The galaxy in question is PKS 2155-304, a type of object known as a “blazar”. Like many active galaxies, a blazar emits oppositely directed jets of particles travelling near the speed of light as matter falls into a central supermassive black hole; this process is not well understood. In the case of blazars, the galaxy is oriented such that we're looking right down the jet.

PKS 2155-304 is located 1.5 billion light-years away in the southern constellation of Piscis Austrinus and is usually a detectable but faint gamma-ray source. But when its jet undergoes a major outburst, as it did in 2006, the galaxy can become the brightest source in the sky at the highest gamma-ray energies scientists can detect -- up to 50 trillion times the energy of visible light. Even from strong sources, only about one gamma ray this energetic strikes a square metre at the top of Earth's atmosphere each month.

Atmospheric absorption of one of these gamma rays creates a short-lived shower of subatomic particles. As these fast-moving particles rush through the atmosphere, they produce a faint flash of blue light. The High Energy Stereoscopic System (H.E.S.S.), an array of telescopes located in Namibia, captured these flashes from PKS 2155-304.

Gamma rays: Gamma rays resemble normal light or X-rays, but are much more energetic. Visible light has an energy of about one electronVolt (1 *eV*) of energy in physicist's terms. X-rays are thousands to millions of *eV*. H.E.S.S. detects very-high energy gamma-ray photons with an energy of a million million *eV*s, or Tera-electronVolt energies (TeV). These high energy gamma rays are quite rare; even for relatively strong astrophysical sources, only about one gamma ray per month hits a square metre at the top of the Earth's atmosphere.

Gamma rays at lower energies were detected directly by the Large Area Telescope (LAT) aboard NASA's orbiting Fermi Gamma-ray Space Telescope. “The launch of Fermi gives us the opportunity to measure this powerful galaxy across as many wavelengths as possible for the first time,” says Werner Hofmann, spokesperson for the H.E.S.S. team at the Max-Planck Institute for Nuclear Physics in Heidelberg, Germany.

With the gamma-ray regime fully covered, the team turned to NASA's Swift and Rossi X-ray Timing Explorer (RXTE) satellites to provide data on the galaxy's X-ray emissions. Rounding out the wavelength coverage was the H.E.S.S. Automatic Telescope for Optical Monitoring, which recorded the galaxy's activity in visible light.

Between August 25 and September 6, 2008, the telescopes monitored PKS 2155-304 in its quiet, non-flaring state. The results of the 12-day campaign are surprising. During flaring episodes of this and other blazars, the X- and gamma-ray emission rise and fall together. But it doesn't happen this way when PKS 2155-304 is in its quiet state – and no one knows why.

What's even stranger is that the galaxy's visible light rises and falls with its gamma-ray emission. “It's like watching a blowtorch where the highest temperatures and the lowest temperatures change in step, but the middle temperatures do not,” says Berrie Giebels, an astrophysicist at France's École Polytechnique who works in both the H.E.S.S. and Fermi LAT teams.

“Astronomers are learning that the various constituents of the jets in blazars interact in fairly complicated ways to produce the radiation that we observe,” says Fermi team member Jim Chiang at Stanford University, California. “These observations may contain the first clues to help us untangle what's really going on deep in the heart of a blazar.”

The findings have been submitted to The Astrophysical Journal.

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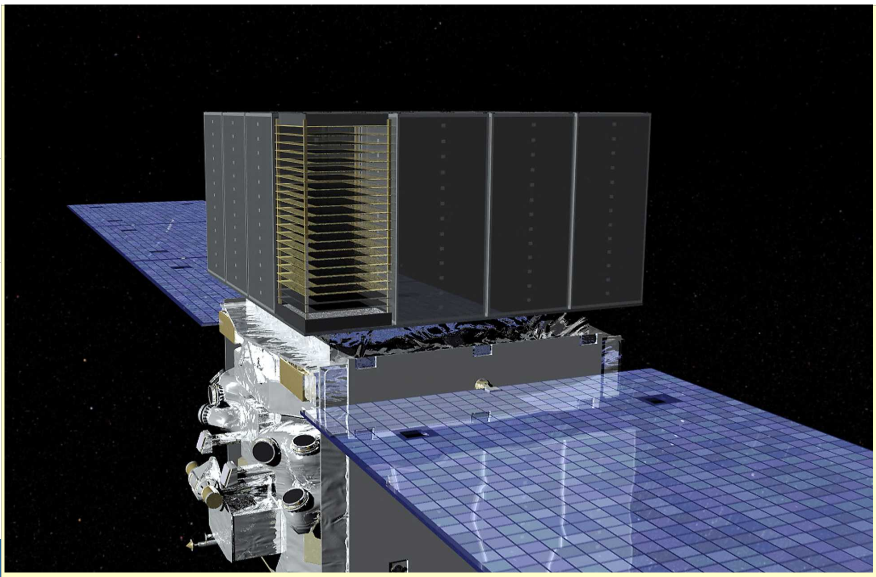
Related links:

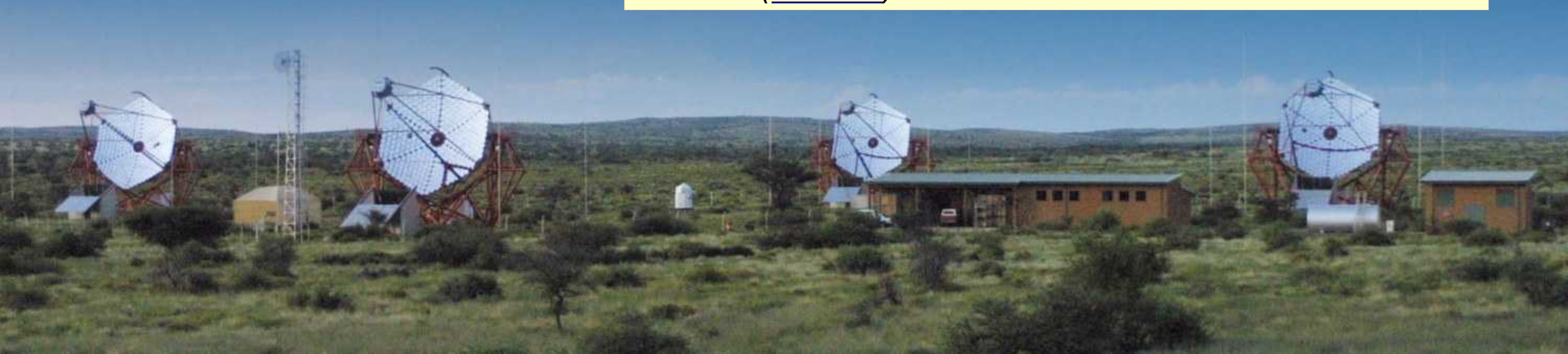
The High Energy Stereoscopic System (H.E.S.S.)
[http://www.mpi-hd.mpg.de/hfm/HESS]

NASA press release
[http://www.nasa.gov/mission_pages/glast/news/blazar.html]

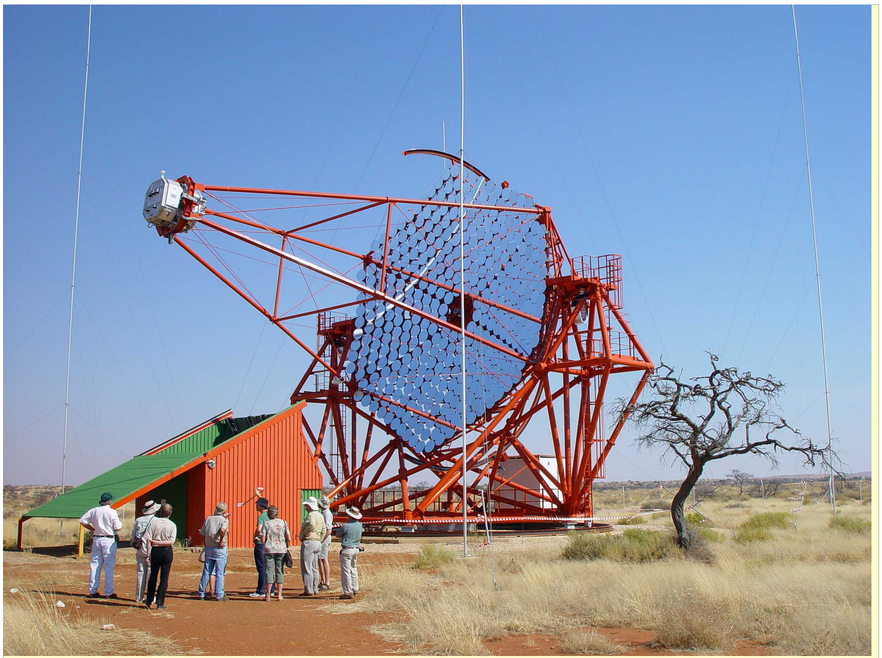
Link to the article
[http://arxiv.org//abs/0903.2924]



Fermi LAT : *Artist's view of the Fermi LAT satellite detector (see link)*



Notes on H.E.S.S.

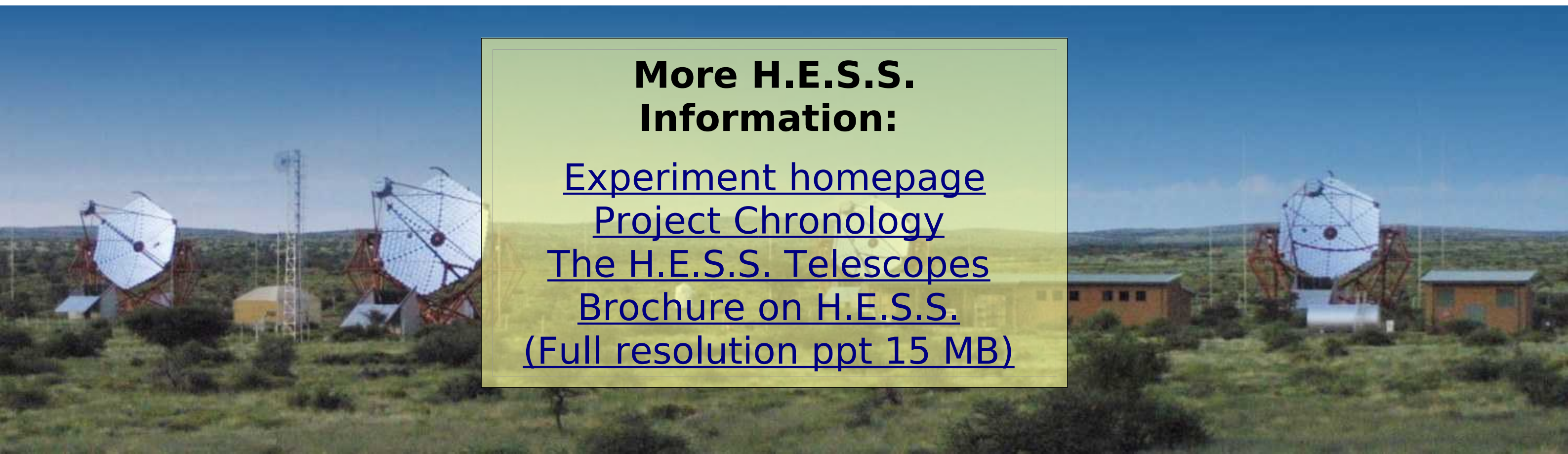

H.E.S.S. Telescopes : *The four identical telescopes of the High Energy Stereoscopic System in Namibia detect faint atmospheric flashes caused by the absorption of ultrahigh-energy gamma rays. Credit: H.E.S.S*

The collaboration: The High Energy Stereoscopic System (H.E.S.S.) team consists of scientists from Germany, France, the UK, Poland, the Czech Republic, Ireland, Armenia, South Africa and Namibia.

The detector: The results were obtained using the High Energy Stereoscopic System (H.E.S.S.) telescopes in Namibia, in South-West Africa. This system of four 13m-diameter telescopes is currently the most sensitive detector of very high energy gamma rays. These are absorbed in the atmosphere, where they give a short-lived shower of particles. The H.E.S.S. telescopes detect the faint, short flashes of blueish light which these particles emit (named Cherenkov light, lasting a few billionths of a second), collecting the light with big mirrors which reflect onto extremely sensitive cameras. Each image gives the position on the sky of a single gamma-ray photon, and the amount of light collected gives the energy of the initial gamma ray. Building up the images photon by photon allows H.E.S.S. to create maps of astronomical objects as they appear in gamma rays.

The H.E.S.S. telescope array represent a multi-year construction effort by an international team of more than 100 scientists and engineers. The instrument was inaugurated in September 2004 by the Namibian Prime Minister, Theo-Ben Gurirab, and its first data have already resulted in a number of important discoveries, including the first astronomical image of a supernova shock wave at the highest gamma-ray energies.

Future plans: The scientists involved with H.E.S.S. are continuing to upgrade and improve the system of telescopes. Construction of a central telescope — a behemoth 30m in diameter — is underway. The improved system, known as H.E.S.S.-II, will be more sensitive and will cover an increased range of gamma-ray energies, so enabling the H.E.S.S. team to increase the gamma-ray source catalogue and to make new discoveries.



More H.E.S.S. Information:

Experiment homepage
Project Chronology
The H.E.S.S. Telescopes
Brochure on H.E.S.S.
(Full resolution ppt 15 MB)