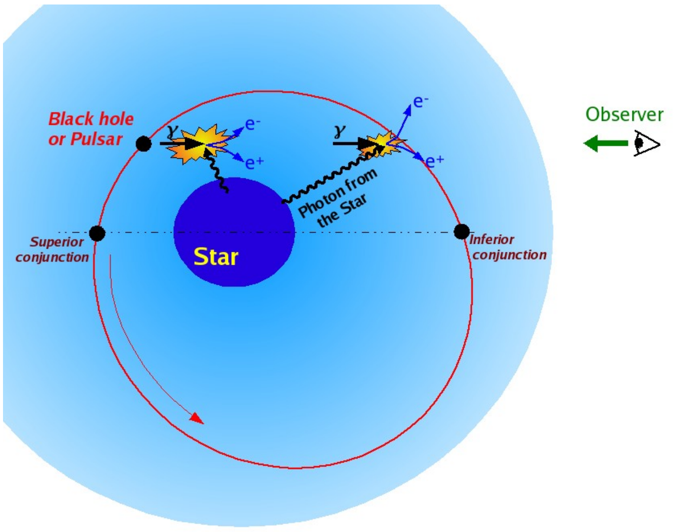
# The H.E.S.S. experiment discovers a cosmic timekeeper

*The first discovery of an orbital clock at gamma-ray energies in our Galaxy*

**Astrophysicists operating the H.E.S.S. gamma-ray telescopes in Namibia have announced the discovery of periodic emission of very-high-energy gamma rays from a binary system. The object which is responsible for this emission is a double system called LS 5039, comprised of a massive blue star (20 times heavier than the Sun) around which an as-yet unidentified compact object (perhaps a black hole) is orbiting. As it dives towards the blue-giant star, the compact companion is exposed to the strong stellar 'wind' and the intense light radiated by the star, allowing on the one hand particles to be accelerated to high energies, but at the same time making it increasingly difficult for gamma rays produced by these particles to escape, depending on the orientation of the system with respect to us. The interplay of these two effects is at the root of the complex modulation pattern. This is the highest energy at which any periodic signal has been observed, nearly 100,000 times higher than previously known.**
**This discovery allows the source of the gamma rays to be better localized in the region within LS 5039, and opens the way to a better understanding of the dynamics of such binary systems.**

The H.E.S.S. international collaboration has announced, in the latest edition of the journal Astronomy & Astrophysics (link to PDF), the discovery of periodic emission of very-high-energy gamma rays coming from a binary system LS 5039. In our Galaxy, more than 80% of the stars are members of multiple systems (double, triple...) made up of several stars in orbit about each other. Isolated stars, such as our Sun, are in the minority. The system LS 5039 (see the adjacent figure) is made up of a massive blue star around which orbits an as-yet unidentified compact object, possibly a black hole.




***The binary system LS 5039***

These two objects are in an extremely tight orbit. Their separation varies between two and four times the radius of the star (which represents about a tenth of the Earth-Sun distance) with an orbital period of 3.9 days, confirmed to a precision better than 0.04% by H.E.S.S.

The H.E.S.S. team showed that the LS 5039 system emits gamma rays with a certain periodicity, with the highest emission when the compact object is in front of the star, and the lowest (but not zero) emission when it is behind (see figure below). "*Additionally, we discovered that the energy distribution of gamma rays varies strongly along the orbit, with an excess of the highest-energy gamma rays in the high-emission state,*" notes H.E.S.S. researcher Gavin Rowell (then working at the Max Planck Institute for Nuclear Physics, MPI-K).

**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.

This gamma-ray emission could be produced by the violent interaction between the compact object and the stellar wind. This wind is the flux of particles accelerated in the star's atmosphere which causes, in the case of our Sun, magnetic storms and the *aurora borealis* or "Northern lights" seen near the Earth's poles. The compact object, in moving along its orbit, acts like a probe of the star's electromagnetic environment: of the intensity of the star's wind and its optical and ultraviolet radiation, and of the magnetic field which changes depending on the distance to the star and which influences the particle acceleration process near to the compact object. Another implication of this discovery is that the particle acceleration responsible for the emission takes place at a short distance from the star, at distances similar to the Earth-Sun distance.

In addition, a geometrical effect adds a further modulation to the flux of gamma rays observed from the Earth. We know since Einstein derived his famous equation ($E=mc^2$) that matter and energy are equivalent, and that pairs of particles and antiparticles can mutually annihilate to give light. Symmetrically, when very energetic gamma rays meet the light from a massive star, they can be converted into matter (an electron-positron pair in this case). So, the light from the star acts like a fog for gamma rays, absorbing them especially when their source – the compact object - is behind the star, and so is partially eclipsed. *"The periodic absorption of gamma rays is a nice illustration of the production of matter-antimatter pairs by light, though it also obscures the view to the particle accelerator in this system"* explains Guillaume Dubus, Astrophysical Laboratory of Grenoble, LAOG.

The modulation seen with H.E.S.S. is therefore likely to be caused both by a variation in the particle-acceleration process along the orbit and also by the geometric effect due to the "light-fog". *"This is the first time in the history of very high energy gamma-ray astronomy that we can observe a repeating, evolving, particle-acceleration experiment in a well-determined environment"* says Mathieu de Naurois, Nuclear and High-Energy Physics Laboratory, LPNHE, Paris.

The discovery by the H.E.S.S. collaboration of this orbital clock, thanks to the precision of the measurements, will open the way to a better understanding of the environment of black holes, neutron stars, and more generally of the sites of particle acceleration in the Universe.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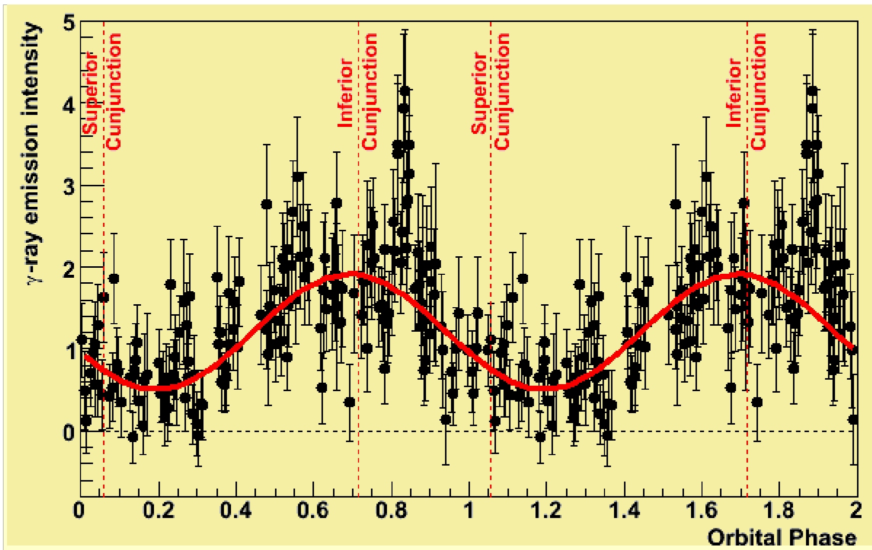


***Modulation of the emission of LS 5039 along its orbit:***
*The H.E.S.S. measurements (each black point integrates a half-hour time-exposure) are distributed on a sinusoid (red curve) along the orbital period, of which two phases are shown for clarity.*

## *Notes on 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)