Press release

The engine of the Crab Nebula

MAGIC telescopes observe a pulsar at the highest energies yet achieved and strongly challenge current theories for the emission.

The pulsar at the heart of the famous Crab nebula is bursting with energy. This was just confirmed by the MAGIC (**M**ajor **A**tmospheric **G**amma-Ray **I**maging **C**herenkov) collaboration operating two large telescopes on the Canary island La Palma. The MAGIC telescopes have been used to observe the pulsar in gamma rays above 50 GeV, an inaccessible energy for most high energy instruments, and have detected periodic pulsed emission at energies as high as 400 GeV. This is 50-100 times higher than predicted by current theoretical models.

The central star in the Crab nebula is a neutron star and one of the best known pulsars. It rotates 30 times per second and has an intense magnetic field, 100 million Tesla -- 1000 billion times stronger than the Earth's. The pulsar and the nebula, located at a distance of about 6000 light years from Earth in the constellation of Taurus, are the remnants of the supernova that exploded in the summer of 1054 AD that was visible to the naked eye even in the day sky for months.

Neutron stars are extremely dense objects with masses around that of the Sun but with diameters of only about 10 km. They are like atomic nuclei the size of a small city. They rotate extremely rapidly and regularly, with periods between 1/1000th of a second and 10 seconds.
Their combined fast rotation and super--strong magnetic fields produce intense electrical potentials at the neutron star that continuously generate charged particles, mainly electrons and positrons (positively charged anti-electrons). These particles stream outward along the magnetic field lines that rotate with the star, emitting beamed radiation throughout the electromagnetic spectrum from radio waves to gamma rays. Whenever the beam crosses our line of sight we see a pulse of emission, much like a lighthouse seen from a distance.

The Crab pulsar and its surrounding nebula are the only case for which the violent birth originating event was observed and for which the age is certain so it is THE essential test of all of our understanding of the properties neutron stars.

A few years ago the MAGIC telescope discovered gamma rays from the Crab pulsar at energies above 25 GeV, which was a big surprise. Scientists concluded that this radiation had to be produced at least 60 km above the neutron star's surface, because the high energy photons are shielded very effectively by the magnetic field of the star. As a consequence, a source of gamma rays located very close to its surface could not be detected at such high energies, which ruled out one of the main theories of the periodic emission from the Crab pulsar.

About one and a half years ago MAGIC detected gamma-rays at higher energy, 100 GeV.
Only half a year ago, the VERITAS collaboration detected pulsed gamma rays with energies above 100 GeV that, again, far exceeded expectations. Now, after the analysis of data collected over the last two years, the MAGIC collaboration presents the most detailed and precise measurement of the periodic emission throughout the energy range of 50 - 400 GeV and shows that the duration of pulses is only one thousandth of a second.

The recent measurements by MAGIC, together with those of the orbiting *Fermi* satellite at much lower energies, provide an uninterrupted spectrum of the pulses from 0.1 GeV to 400 GeV. These clear observational results create major difficulties for most of the existing pulsar theories that predict significantly lower limits for highest energy emission.

A new model explains the phenomenon by a cascade-like process producing secondary particles that potentially overcome the barrier of the pulsar magnetosphere. Another explanation, recently reported in the journal Nature, connects our observations with the equally puzzling physics of the pulsar wind – an outflow composed of electrons, positrons and electromagnetic radiation that merges into and powers the surrounding nebula. But although these new models may explain the extreme high energies and the short duration of the pulses, further refinements are necessary to reproduce the observational results and, clearly, future observations are needed to solve the puzzle.

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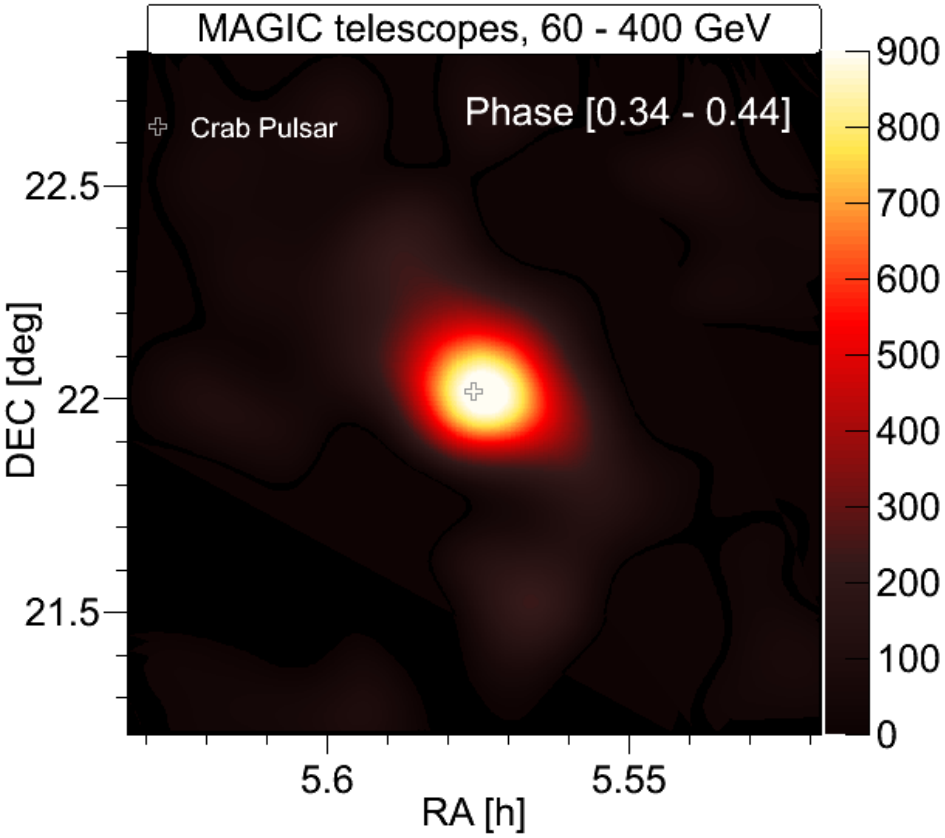
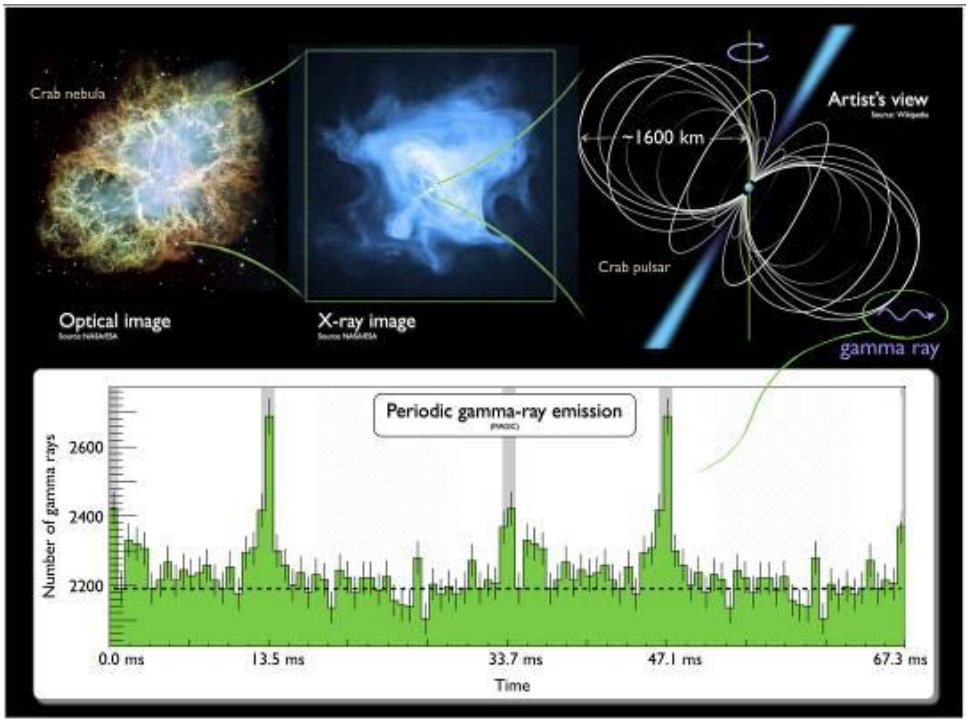
Astronomy & Astrophysics, 30. March 2012

Figures and figure captions



Cosmic lighthouse: The Crab pulsar emits gamma-ray pulses with a maximum measurable energy of up to 400 GeV. This is 50-100 times more than expected from theory. The Animation shows the pulsed emission measured with the system of the two MAGIC telescopes (graphics: S. Klepser, MAGIC Collaboration).



Observations at different wavelengths: the photo shows the Crab nebula in visible spectrum (upper left) and in X-rays (upper center). Also a graphical sketch of the pulsar magnetosphere is shown (upper right). The light curve (below) shows the periodic emission of gamma-rays, two pulses in every 0,0337 seconds; the same period is shown twice for clarity (Graphic: NASA, ESA, J. Hester, A. Loll, CXC, SAO, F. Seward et al., MAGIC Collaboration).

The MAGIC Project

MAGIC is located in the *Roque de los Muchachos* European North Observatory (2200m a.s.l.) on the Canary island of La Palma.
The system of two MAGIC telescopes, each of 17m in diameter, is currently the worldwide largest instrument for measuring very high energy gamma rays from cosmic sources in the energy range 25GeV-50TeV.

The neutral gamma rays impinge onto the earth's atmosphere and produce avalanches of secondary particles that emit bluish Cherenkov light. MAGIC is measuring the gamma rays by collecting and analyzing this Cherenkov light.

MAGIC has been built with the joint efforts of a largely European collaboration that includes about 160 researchers from Germany, Spain, Italy, Switzerland, Poland, Finland, Bulgaria, Croatia and Japan.

MAGIC is operating since 2004 and has discovered the most distant sources of

very high energy gamma rays. Also, it has discovered pulsed gamma-ray emission from the Crab pulsar at energies ≥ 25 GeV.

Photo of the two MAGIC telescopes on the Canary island of La Palma. The two 17m diameter telescopes measure the ultra-short flashes of bluish Cherenkov light, produced by the avalanches of secondary particles. These are produced by cosmic gamma rays that bombard the earth's atmosphere.

(photo: R. Wagner, Max-Planck-Institut für Physik).

Further information:

MAGIC Collaboration homepage
http://wwwmagic.mpp.mpg.de/

Material for media and press release in other languages:
http://wwwmagic.mpp.mpg.de/physics/recent/Crab-Pulsar/