

An exceptionally powerful trio in the Large Magellanic Cloud

H.E.S.S. discovers three extremely luminous gamma-ray sources in Milky Way's satellite galaxy

Once again, the High Energy Stereoscopic System, H.E.S.S., has demonstrated its excellent capabilities. In the Large Magellanic Cloud, it discovered most luminous very high-energy gamma-ray sources: three objects of different type, namely the most powerful pulsar wind nebula, the most powerful supernova remnant, and a shell of 270 light years in diameter blown by multiple stars and supernovae – a so-called superbubble. This is the first time that stellar-type gamma-ray sources are detected in an external galaxy, at these gamma-ray energies. The superbubble represents a new source class in very high-energy gamma rays.

Very high-energy gamma rays are the best tracers of cosmic accelerators such as supernova remnants and pulsar wind nebulae – end-products of massive stars. There, charged particles are accelerated to extreme velocities. When these particles encounter light or gas in and around the cosmic accelerators, they emit gamma rays. Very high-energy gamma rays can be measured on Earth by observing the Cherenkov light emitted from the particle showers produced by incident gamma rays high up in the atmosphere using large telescopes with fast cameras.

The Large Magellanic Cloud (LMC) is a dwarf satellite galaxy of our Milky Way, located about 160.000 light years away and showing us its face. New, massive stars are formed at a high rate in the LMC, and it harbors numerous massive stellar clusters. The LMC's supernova rate relative to its stellar mass is five times that of our Galaxy. The youngest supernova remnant in the local group of galaxies, SN 1987A, is also a member of the LMC. Therefore, the H.E.S.S. scientists dedicated significant observation to searching for very high-energy gamma rays from this cosmic object.

For a total of 210 hours, the High Energy Stereoscopic System (H.E.S.S.) has observed the largest star-forming region within the LMC called Tarantula Nebula. For the first time in a galaxy outside the Milky Way, individual sources of very high-energy gamma rays could be resolved: three extremely energetic objects of different type.

The so-called superbubble 30 Dor C is the largest known X-ray-emitting shell and appears to have been created by several supernovae and strong stellar winds. Superbubbles are broadly discussed as (complementary or alternative to individual supernova remnants) factories where the galactic cosmic rays are produced. The H.E.S.S. results demonstrate that the bubble is a source of, and filled by, highly energetic particles. The superbubble represents a new class of sources in the very high-energy regime.

Pulsars are highly magnetized, fast rotating neutron stars that emit a wind of ultra-relativistic particles forming a nebula. The most famous one is the Crab Nebula in our Galaxy, one of the brightest sources in the high-energy gamma-ray sky. The pulsar PSR J0537–6910 driving the wind nebula N 157B discovered by the H.E.S.S. telescopes in the LMC is in many respects a twin of the very powerful Crab pulsar in our own Galaxy. However, its pulsar wind nebula N 157B outshines the Crab Nebula by an order of magnitude, in very high-energy gamma rays. Reasons are the lower magnetic field in N 157B and the intense starlight from neighboring star-forming regions, which both promote the generation of high-energy gamma rays.

The supernova remnant N 132D, known as a bright object in the radio and infrared bands, appears to be one of the oldest – and strongest – supernova remnants still glowing in very high-energy gamma rays. Between 2500 and 6000 years old – an age where models predict that the supernova explosion front has slowed down and it ought no longer be efficiently accelerating particles – it still outshines the strongest supernova remnants in our Galaxy. The observations confirm suspicions raised by other H.E.S.S. observations, that supernova remnants can be much more luminous than thought before.

Observed at the limits of detectability, and partially overlapping with each other, these new sources challenged the H.E.S.S. scientists. The discoveries were only possible due to the development of advanced methods of interpreting the Cherenkov images captured by the telescopes, improving in particular the precision with which gamma-ray directions can be determined.

“The LMC is a great laboratory to study such objects,” says Manami Sasaki, Emmy Noether research group leader at the Institute for Astronomy and Astrophysics Institute in Tübingen and expert of the LMC. “We have been able to do this in the X-ray waveband since some time now, and it is great to see that Cherenkov telescopes meanwhile also have reached the sensitivity to study sources in our neighboring galaxy in the light of very high energy gamma-rays.”

One object in the LMC presented a surprise because it did not show up in the H.E.S.S. gamma-ray image, in contrast to theoretical predictions: the young supernova remnant SN 1987A. “Luckily, with the new H.E.S.S. II 28 m telescope that the collaboration recently installed at the H.E.S.S. site in Namibia, the sensitivity of the H.E.S.S. telescope system was significantly improved,” explains Andrea Santangelo, head of the High Energy Astrophysics Section of the Faculty of Science in Tübingen. “After already such a deep exposure, more sensitive observations are only feasible with a higher performance instrument.”

And in the more distant future, the planned Cherenkov Telescope Array (CTA) will provide even deeper and higher-resolution gamma-ray images of the LMC. Gerd Pühlhofer, who is coordinating the section’s high energy gamma-ray activities, adds “In the plans for science with CTA, extensive investigations of the LMC are already identified as a “Key Science Project”, one of the major observational goals that the CTA consortium wants to achieve.”

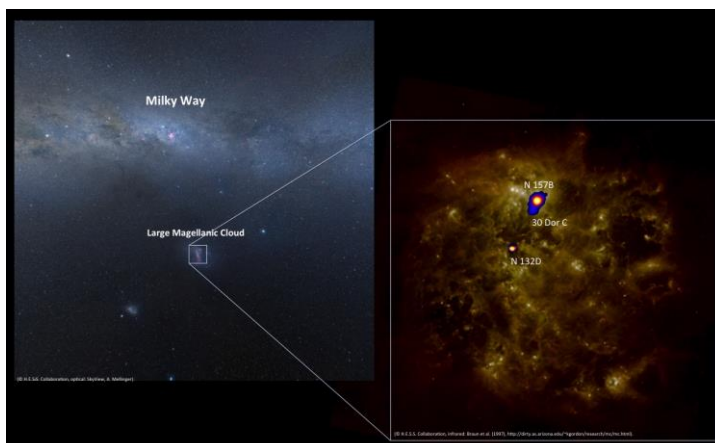


Figure: Optical image of the Milky Way and an infrared zoom into the Large Magellanic Cloud with superimposed H.E.S.S. sky maps. (Milky Way image: © H.E.S.S. Collaboration, optical: SkyView, A. Mellinger; LMC image © H.E.S.S. Collaboration, infrared: M. Braun et al. (1997), <http://dirty.as.arizona.edu/~kgordon/research/mc/mc.html>)

The H.E.S.S. Telescopes

The collaboration: The High Energy Stereoscopic System (H.E.S.S.) team consists of scientists from Germany, France, the United Kingdom, Namibia, South Africa, Ireland, Armenia, Poland, Australia, Austria, Sweden, and the Netherlands, supported by their respective funding agencies and institutions. The University of Tübingen is part of the H.E.S.S. collaboration through the High Energy Astrophysics Section of the Institute for Astronomy and Astrophysics Tübingen (IAAT), financially supported by the Federal Ministry for Education and Research.

The instrument: 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 13 m diameter telescopes – recently complemented with the huge 28 m H.E.S.S. II telescope – is one of the most sensitive detectors of very high-energy gamma rays. These are absorbed in the atmosphere, where they create a short-lived shower of particles. The H.E.S.S. telescopes detect the faint, short flashes of bluish 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. telescopes have been operating since late 2002; in September 2012 H.E.S.S. celebrated the first decade of operation, by which time the telescopes had recorded 9415 hours of observations, and detected 6361 million air shower events. H.E.S.S. has discovered the majority of the about 150 known cosmic objects emitting very high-energy gamma rays. In 2006, the H.E.S.S. team was awarded the Descartes Prize of the European Commission, in 2010 the Rossi Prize of the American Astronomical Society. A study performed in 2009 listed H.E.S.S. among the top 10 observatories worldwide.

Original publication:

The exceptionally powerful TeV gamma-ray emitters in the Large Magellanic Cloud, H.E.S.S. Collaboration (corresponding authors: j.vink@uva.nl, nukri.komin@wits.ac.za, chia-chun.lu@mpi-hd.mpg.de, michael.mayer@physik.hu-berlin.de, stefan.ohm@desy.de), Science 347 (2015), 406-412

Web:

H.E.S.S. home page: www.mpi-hd.mpg.de/HESS

H.E.S.S. instrument: www.mpi-hd.mpg.de/HESS/pages/about/

Institute for Astronomy and Astrophysics Tübingen home page: <http://www.physik.uni-tuebingen.de/institute/astronomie-astrophysik/institut/astronomie/astronomie-hochenergieastrophysik.html>

H.E.S.S. II press release at Tübingen University: [http://www.uni-tuebingen.de/en/1369?tx_ttnews\[tt_news\]=10160](http://www.uni-tuebingen.de/en/1369?tx_ttnews[tt_news]=10160)

Press release about recent BMBF grants for CTA and other astroparticle physics experiments: <http://www.uni-tuebingen.de/en/news/newsfullview-aktuell/article/19-millionen-euro-fuer-tuebingen-astroteilchenphysiker.html>

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