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Discovery of a new type of very high energy gamma-ray emitter

The H.E.S.S. (High Energy Stereoscopic System) collaboration reports the discovery of a new type of energetic gamma-ray source, probably related to supersonic winds from massive stars in a young open stellar cluster. Dr. Olaf Reimer of the Hansen Experimental Physics Laboratory and Kavli Institute for Particle Astrophysics and Cosmology of Stanford University presents the result at the First GLAST Symposium in Palo Alto, California, on behalf of a large team of international astrophysicists operating the H.E.S.S. array of gamma-ray telescopes in Namibia. For the first time, high energy gamma-ray emission could be convincingly associated with a stellar cluster characterized by ongoing star formation and presence of massive stars near the end of their life cycle but prior to their explosion as supernovae, known as Wolf-Rayet stars. Extreme particle acceleration connected with stellar winds is becoming a phenomenon more widely observed at high energies than previously thought, and offers a hint for cosmic ray particle acceleration in other sources besides the major candidates, the relics of supernova explosions.

An international team of astrophysicists from the H.E.S.S. collaboration has announced the discovery of a new type of very-high-energy (VHE) gamma ray source. Combining data obtained during a systematic survey of the Galactic Plane and dedicated pointed observations of the telescope array revealed energetic gamma radiation coincident with the stellar cluster Westerlund 2, which is embedded in the giant ionized hydrogen cloud RCW49. The new VHE source, HESS J1023-575, is a first indication of extreme particle acceleration associated with a young open stellar cluster, an ensemble of stars which are particularly interesting due to ongoing star formation and the existence of extremely massive stars, known as Wolf-Rayet (WR) stars. One of these, WR 20a, a close binary systems of two WR stars orbiting each other, is the most massive of all confidently-measured binaries presently known in our Galaxy.

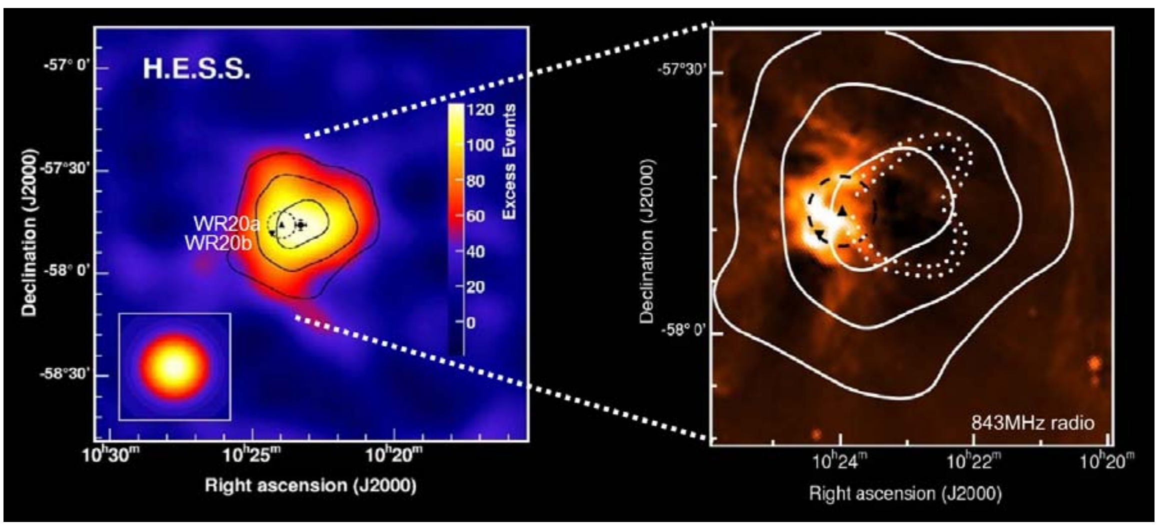
Wolf-Rayet stars (named for their discoverers) are evolved, massive stars near the end of their stellar live-cycle, when they are rapidly losing their mass by means of supersonic stellar winds. In the Westerlund 2 cluster, the Wolf-Rayet winds have literally blown bubbles around their stellar hosts, clearly visible in infrared and radio images of the region. Integrated over their lifetime, the wind energy output of Wolf-Rayet stars is not too far from the kinetic energy released in supernova explosions, and shocked winds are well suited to accelerate particles to high energy.

The energetic gamma radiation discovered by the H.E.S.S. telescopes, however, is neither point-like nor centered at the locations of the Wolf-Rayet stars, but appears extended compared to the point spread function of the telescopes, on scales beyond the extent of the stellar cluster, with constant emission over time.

What can we conclude about the origin of these gamma rays? With a projected angular size of milliarcsecond scale, the WR 20a binary system, including its colliding wind zone, would appear as a point source for observations with the H.E.S.S. telescope array. “Unless there are extreme differences in the spatial extent of the particle distributions producing radio, X-ray, and VHE gamma-ray emission”, says Olaf Reimer, Senior Research Scientist at Stanford University, “scenarios based on the colliding stellar winds in the WR 20a binary system face the severe problem of accounting for a source extension of 0.2 degrees in the VHE waveband.”

On the other hand, at the nominal distance of WR 20a of 8 kpc, this source extension is equivalent to a diameter of about 28 pc for the emission region, consistent in size with theoretical predictions of bubbles blown from massive stars into the interstellar medium. Shocks and turbulent motion inside a bubble can efficiently transfer energy to cosmic rays, providing a plausible mechanism for particle acceleration. In size and location, the gamma-ray source resembles the so-called "blister" as reported by Whiteoak & Uchida 1997, where the bubble opens up and the wind expands into the low-density ambient medium. Shock acceleration at the boundaries of the blister may enable particles to diffusively re-enter into the dense medium, thereby interacting in hadronic collisions and producing γ-rays. Similar scenarios were outlined over twenty years ago for supernova-driven expansion of particles into a low density medium. If one accepts such a scenario here, it might give the first observational support of energetic gamma-ray emission due to diffusive shock acceleration from supersonic winds in a wind-blown bubble created by WR 20a, or by the ensemble of hot and massive stars in Westerlund 2.

Further observations with the H.E.S.S. telescope array, and other sensitive ground-based gamma-ray telescopes, and the Gamma Ray Large Area Space Telescope (GLAST) satellite will ultimately clarify whether high energy gamma-ray emission is a common property to young stellar clusters or a distinctive feature of Westerlund 2 and its remarkable ensemble of massive stars. GLAST is due for launch in late 2007.



Left side: H.E.S.S. gamma-ray sky map of the Westerlund 2 region, smoothed to reduce the effect of statistical fluctuations. The inlay in the lower left corner shows how a point-like source would have been seen by H.E.S.S. The WR stars WR 20a and WR 20b are marked as filled triangles, and the stellar cluster Westerlund 2 is represented by a dashed circle.

Right side: Significance contours of the gamma-ray source HESSJ1023-575 (corresponding 5, 7 and 9 sigma), overlaid on a radio image from the Molonglo Observatory Synthesis Telescope (MOST). The wind-blown bubble around WR 20a, and the blister to the west of it can be seen as depressions in the radio continuum map. The blister is indicated by white dots as in Whiteoak and Uchida (1997), and appears to be compatible in direction and location with HESSJ1023-575.

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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, Ireland, the Czech Republic, Poland, 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 13 m 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 Guirab, 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.