Clues to the mysterious origin of cosmic rays: Very Large Telescope probes remains of medieval supernova

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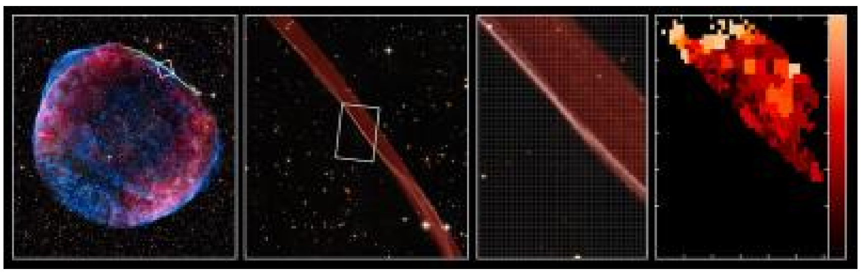

Very detailed new observations with ESO's Very Large Telescope of the remains of a thousand-year-old supernova have revealed clues to the origins of cosmic rays. The image on the left shows the entire SN 1006 supernova remnant, as seen in radio (red), X-ray (blue) and visible light (yellow). The second panel, corresponding to the small square region marked at the left, is a NASA/ESA Hubble Space Telescope close up view of the remarkably narrow region of the shock front, where the material from the supernova is colliding with interstellar medium. The third panel shows how the integral field unit of the VIMOS instrument splits up the image into many small regions, the light from each of which is spread out into a spectrum of its component colors. When these spectra are analyzed, maps of the properties of the underlying object can be derived. The example shown here at the right is a map of one property of the gas (the width a spectral line), which is surprisingly variable, and implies, along with other indicators, the presence of very high-speed protons. Credit: ESO, Radio: NRAO/AUI/NSF/GBT/VLA/Dyer, Maddalena & Cornwell, X-ray: Chandra X-ray Observatory; NASA/CXC/Rutgers/G. Cassam-Chenaï, J. Hughes et al., Visible light: 0.9-metre Curtis Schmidt optical telescope; NOAO/AURA/NSF/CTIO/Middlebury College/F. Winkler and Digitized Sky Survey.

In the year 1006 a new star was seen in the southern skies and widely recorded around the world. It was many times brighter than the planet Venus and may even have rivaled the brightness of the Moon. It was so bright at maximum that it cast shadows and it was visible during the day. More recently astronomers have identified the site of this supernova and named it SN 1006. They have also found a glowing and expanding ring of material in the southern constellation of Lupus (The Wolf) that constitutes the remains of the vast explosion.

It has long been suspected that such supernova remnants may also be where some cosmic rays—very high energy particles originating outside the Solar System and travelling at close to the speed of light—are formed. But until now the details of how this might happen have been a long-standing mystery.

A team of astronomers led by Sladjana Nikolić (Max Planck Institute for Astronomy, Heidelberg, Germany) has now used the VIMOS instrument on the VLT to look at the one-thousand-year-old SN 1006 remnant in more detail than ever before. They wanted to study what is happening where high-speed material ejected by the supernova is ploughing into the stationary interstellar matter—the shock front. This expanding high-velocity shock front is similar to the sonic boom produced by an aircraft going supersonic and is a natural candidate for a cosmic particle accelerator.

For the first time the team has not just obtained information about the shock material at one point, but also built up a map of the properties of the gas, and how these properties change across the shock front. This has provided vital clues to the mystery.

The results were a surprise—they suggest that there were many very rapidly moving protons in the gas in the shock region. While these are not the sought-for high-energy cosmic rays themselves, they could be the necessary "seed particles", which then go on to interact with the shock front material to reach the extremely high energies required and fly off into space as cosmic rays.

Nikolić explains: "This is the first time we were able to take a detailed look at what is happening in and around a supernova shock front. We found evidence that there is a region that is being heated in just the way one would expect if there were protons carrying away energy from directly behind the shock front."

The study was the first to use an integral field spectrograph to probe the properties of the shock fronts of supernova remnants in such detail. The team now is keen to apply this method to other remnants.

Co-author Glenn van de Ven of the Max Planck Institute for Astronomy, concludes: "This kind of novel observational approach could well be the key to solving the puzzle of how cosmic rays are produced in supernova remnants."

Provided by ESO

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