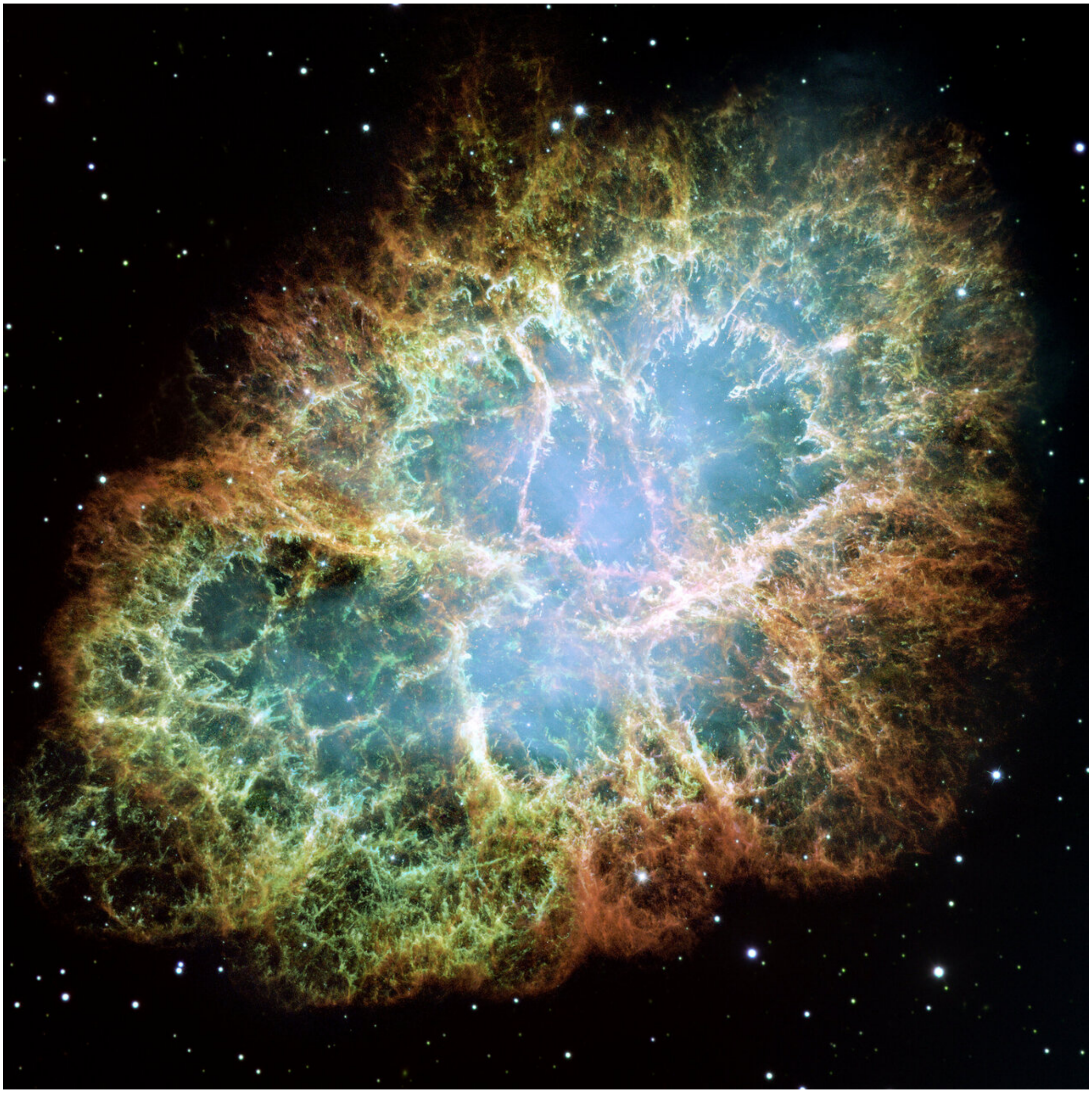
Shock waves from stellar explosions take preferential direction

July 8 2020, by Simon Schmitt



Crab Nebula, a supernova remnant. Credit: public domain

In a paper published in the *Astrophysical Journal*, a team led by researchers at École Polytechnique have paved the way to unraveling the mystery as to why many supernova remnants that we observe from Earth are axisymmetric (elongated along one axis) rather than spherical.

A supernova happens when a star runs out of fuel and dies, generating a huge explosion that causes shock waves in the surrounding medium. These shock waves, known as supernova remnants, spread out for thousands of years across vast distances. If close enough to the Earth, they can be studied by astronomers.

The best models to date predict that these remnants ought to be spherically symmetric, as energy is flung out in all directions. However, telescopes have taken many images which differ from our expectations. For example, the supernova remnant dubbed G296.5+10.0 (not yet well-known enough to warrant a catchier name) is symmetric along its vertical axis. Researchers have come up with many hypotheses to explain these observations, but up until now, it has been difficult to test them.

Paul Mabey, a researcher at École Polytechnique—Institut Polytechnique de Paris and his international collaborators from the University of Oxford, Helmholtz-Zentrum Dresden-Rossendorf (HZDR), and the French Alternative Energies and Atomic Energy Commission (CEA) reproduced this astrophysical phenomenon at a smaller scale in the lab in order to explain this mystery. To do this, the team made use of high-power pulsed lasers at the Intense Lasers Lab (LULI) located on the École Polytechnique campus.

The team also used a large magnetic field, around two hundred thousand times stronger than the one produced by the Earth, to test out different hypotheses. They found that, when this field was applied, the shock wave became elongated along one direction. The results support the idea that a large-scale magnetic field is present around G296.5+10.0 and is responsible for its current shape.

The extreme magnetic fields, which reach a strength of 10 Tesla, originate from a so-called Helmholtz coil, which was jointly developed and built by scientists from Dresden High Magnetic Field Laboratory and the Institute of Radiation Physics at HZDR and which generates nearly uniform magnetic fields. The coil was fed by a high-voltage pulse generator, which was also developed at HZDR and permanently placed at LULI. It is, above all, the technological development of these unique instruments that makes such extreme conditions possible, which are otherwise only found in the vastness of the universe: It enables researchers to study phenomena such as supernova explosions, or novel applications in laboratory astrophysics.

The astrophysicists now hope to use current and future observations of supernova remnants to determine the strength and direction of magnetic fields throughout the universe. In addition, the team has already begun planning future experiments at LULI to study these systems in the laboratory.

More information: P. Mabey et al. Laboratory Study of Bilateral Supernova Remnants and Continuous MHD Shocks, *The Astrophysical Journal* (2020). DOI: 10.3847/1538-4357/ab92a4

Provided by Helmholtz Association of German Research Centres