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Discovery of a spectacular dust spiral around a new star system identifies a unique precursor for cosmic fireworks

Astronomers have discovered a unique binary star system containing a pair of massive 'Wolf-Rayet' stars: a kind believed to explode as supernovae. The system has created an elegant spiral dust cloud whose form can be understood if a star in the system is spinning extremely fast. Such stars have never previously been confirmed, but are thought to produce the most powerful explosions in the Universe, gamma-ray bursts, when they die.

Wolf-Rayet stars represent the final phase in the evolution of the most massive stars, which are about to go supernova. They are the hottest stars in the Universe and blast out powerful winds of hot gas.

When Wolf-Rayet stars pair up to form binary systems, the collision between the winds of the two stars can seed gigantic dust clouds, which take on elegant spiral 'pinwheel' shapes as the stars orbit each other.

At the University of Sydney, lead author Joseph Callingham of the Netherlands Institute for Radio Astronomy (ASTRON) discovered a new, bright star around 8000 light years away, adorned with a beautiful and rare pinwheel.

The authors named the star system, 'Apep', after a serpent deity from Ancient Egyptian mythology that is the mortal enemy of sun god Ra. Co-author Peter Tuthill (Sydney) said: "The name seemed fitting as the sinuous dust plume looks like a coiled serpent doing battle with a central star."

However, when they set out to understand the shape of the dust cloud, they discovered something strange. They used the Very Large Telescope (VLT) in Chile and the Anglo-Australian Telescope (AAT) in Australia to measure the speeds of the spewed-out gas. "This gave us evidence of wind speeds of 12 million kilometres per hour, which is incredibly fast", says Callingham.

One would expect dust seeded from this gas to have a similar speed. But when the astronomers imaged the dust cloud again one year later, the changed shape indicated a much lower expansion speed. Tuthill: "The dust appears to be moving at only 2 million kilometres per hour, almost an order of magnitude slower. How do you reconcile those two numbers? It is like the dust is in the middle of a hurricane, but not moving at all."

"The only way we get such a system to work is if the Wolf-Rayet star is spewing out gas at several speeds", says co-author Benjamin Pope (New York University). From the poles, Apep is emitting fast, hot gas that shows up in the

spectroscopy. But the wind from its equator is much slower and denser. Such 'anisotropic wind speeds' are known to be a product of fast-rotating stars.

Pope: "One way for such different winds to happen is via critical rotation. One of the stars in Apep is rotating so fast that it is nearly ripping itself apart. On its equator, the rotational forces make the gas basically weightless, so it slowly floats off the equator."

Apep's companion star, probably also a Wolf-Rayet star shedding its own gas, meets with the disc only intermittently, explains Tuthill: "You only get dust production when the binary orbit intersects with this disk." This explains the intricate dust cloud shape.

The Wolf-Rayet stage is the last stage before the star explodes in a supernova. In most supernova models, critical rotation is needed for a star's fiery death to be accompanied by the most energetic explosion in the Universe: a long-duration Gamma-Ray Burst (GRB).

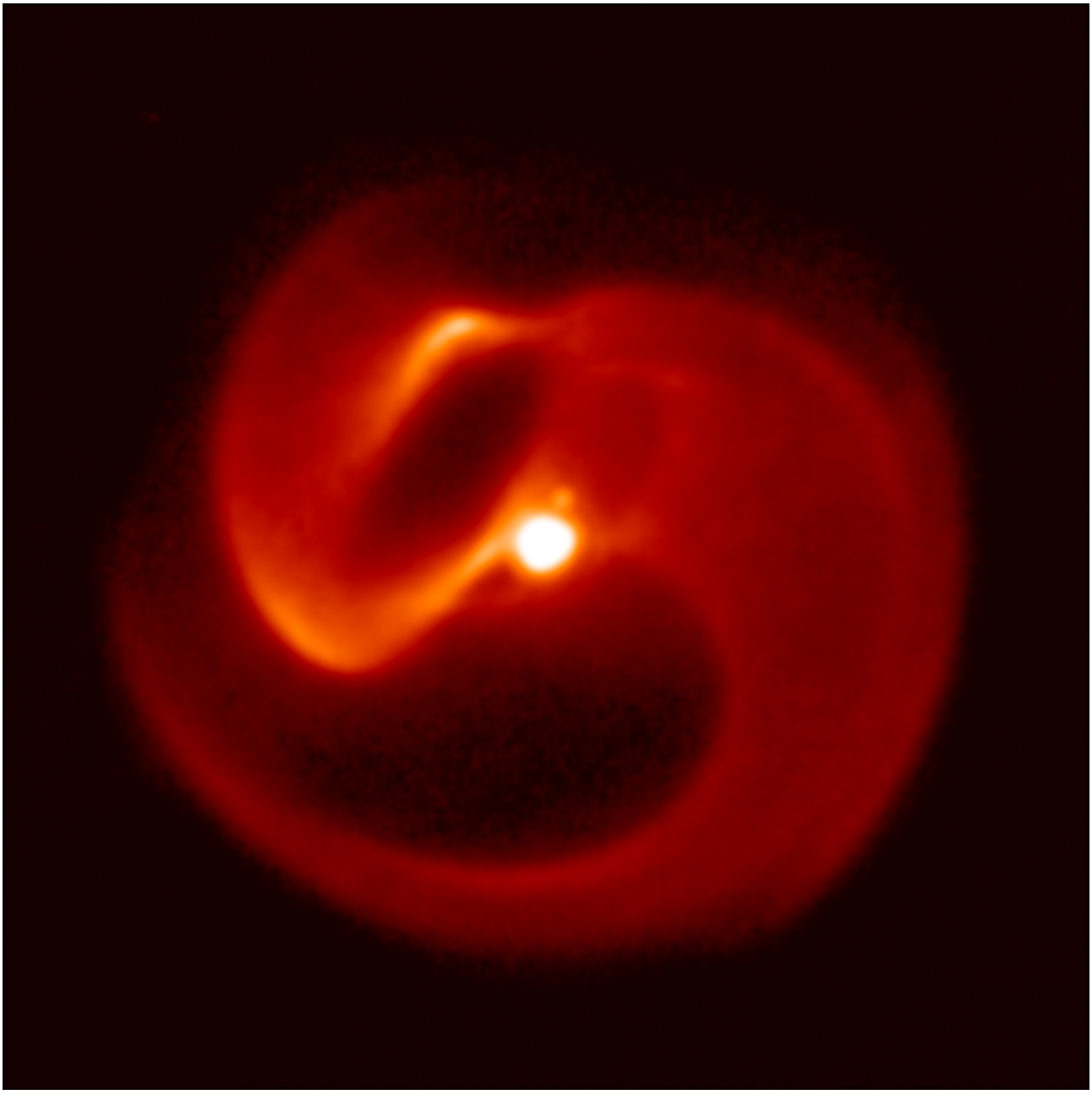
GRBs have only been observed in other galaxies, usually at remote distances, although astronomers have speculated that there may be evidence for past events in our own galaxy encoded in Earth's fossil record. Callingham: "We never thought we would find something like this in our own Milky Way."

This study was conducted by Dr Joseph Callingham from the Netherlands Institute for Radio Astronomy (ASTRON), Prof Peter Tuthill (University of Sydney), Dr Benjamin Pope (NASA Sagan Fellow, New York University), Dr Peredur Williams (University of Edinburgh), Prof Paul Crowther (University of Sheffield), Mr. Mark Edwards (University of Sydney), Dr Barnaby Norris (University of Sydney) and Dr Lucyna Kedziora-Chudczer (University of New South Wales).

E N D O F P R E S S R E L E A S E

More information:

Image of Apep displaying the spectacular dust pattern captured by the Very Large telescope. The binary creating the dust pattern is located in the centre of the image.



Other images and an animation of Apep are available at: www.physics.usyd.edu.au/~gekko/Apep
The animation is an illustration of the motion of Apep as if we had a time-lapse covering approximately 80 years. The pause marks the current epoch.

Joe Callingham, Peter Tuthill and Benjamin Pope wrote a post for the *Behind the paper* blog of Nature about the story of the discovery of Apep and how they came to the understanding of the system outlined in the paper. Read it at https://astronomycommunity.nature.com/users/181582-joseph-callingham/posts/40890-riding-the-serpent-the-discovery-and-study-of-apep (available after the embargo date).

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