Chameleon pulsar baffles astronomers

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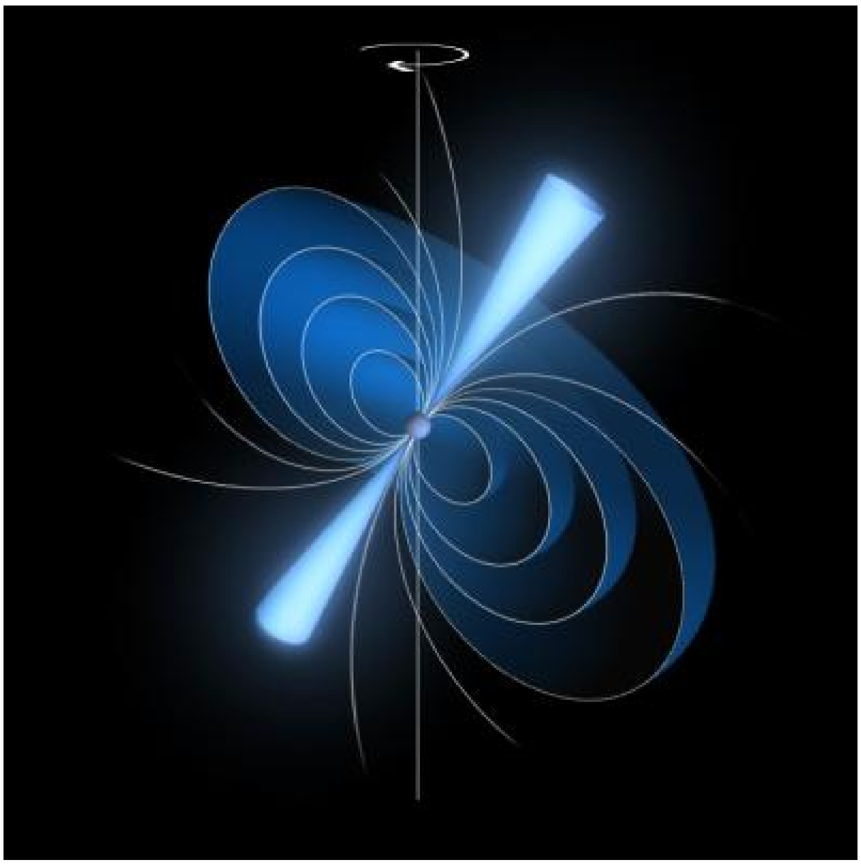


This illustration shows a pulsar with glowing cones of radiation stemming from its magnetic poles -- a state referred to as "radio-bright" mode. Credit: ESA/ATG medialab

A pulsar that is able, without warning, to dramatically change the way in which it shines has been identified by an international team of astronomers.

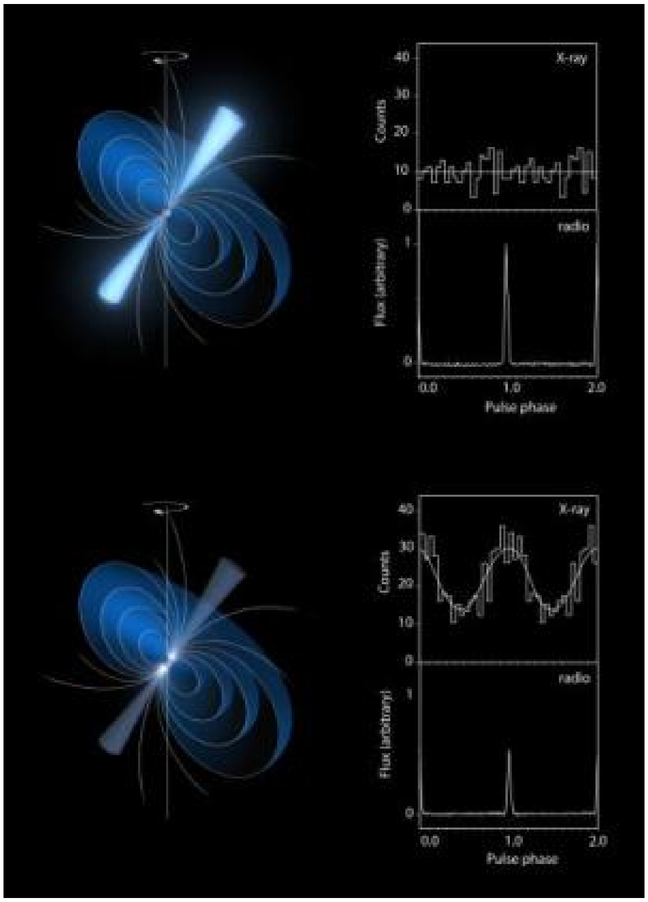
Using a satellite X-ray telescope combined with terrestrial radio telescopes the pulsar was found to flip on a roughly half-hour timescale between two extreme states; one dominated by X-ray pulses, the other by a highly-organised pattern of radio pulses.

The research was led by Professor Wim Hermsen from The Netherlands Institute for Space Research and the University of Amsterdam and will appear in the journal *Science* on the 25th January 2013.

Researchers from Jodrell Bank Observatory, as well as institutions around the world, used simultaneous observations with the X-ray satellite XMM-Newton and two radio telescopes; the LOw Frequency Array (LOFAR) in the Netherlands and the Giant Meter Wave Telescope (GMRT) in India to reveal this so far unique behaviour.

Pulsars are small spinning stars that are about the size of a city, around 20 km in diameter. They emit oppositely directed beams of radiation from their magnetic poles. Just like a lighthouse, as the star spins and the beam sweeps repeatedly past the Earth we see a brief flash.

Some pulsars produce radiation across the entire electromagnetic spectrum, including at X-ray and radio wavelengths. Despite being discovered more than 45 years ago the exact mechanism by which pulsars shine is still unknown.



An international team has made a tantalizing discovery about the way pulsars emit radiation. The emission of X-rays and radio waves by these pulsating neutron stars is able to change dramatically in seconds, simultaneously, in a way that cannot be explained with current theory. It suggests a quick change of the entire magnetosphere. In their research the team combined observations from the X-ray space telescope XMM-Newton and the radio telescope LOFAR (among others). Credit: ASTRON

It has been known for some time that some radio-emitting pulsars flip their behaviour between two (or even more) states, changing the pattern and intensity of their radio pulses. The moment of flip is both unpredictable and sudden. It is also known from satellite-borne telescopes that a handful of radio pulsars can also be detected at X-ray frequencies. However, the X-ray signal is so weak that nothing is known of its variability.

To find out if the X-rays could also flip the scientists studied a particular pulsar called PSR B0943+10, one of the first to be discovered. It has radio pulses which change in form and brightness every few hours with some of the changes happening within about a second.

Dr Ben Stappers from The University of Manchester's School of Physics and Astronomy said: "The behaviour of this pulsar is quite startling, it's as if it has two distinct personalities. As PSR B0943+10 is one of the few pulsars also known to emit X-rays, finding out how this higher energy radiation behaves as the radio changes could provide new insight into the nature of the emission process."

Since the source is a weak X-ray emitter, the team used the most sensitive X-ray telescope in existence, the European Space Agency's XMM-Newton on board a spacecraft orbiting the Earth. The observations took place over six separate sessions of about six hours in duration. To identify the exact moment of flip in the pulsar's radio behaviour the X-ray observations were tracked simultaneously with two of the largest radio telescopes in the world, LOFAR and the GMRT.

What the scientists found was that whilst the X-rays did indeed change their behaviour at the same time as the radio emission, as might have been expected, in the state where the radio signal is strong and organised the X-rays were weak, and when the radio emission switched to weak the X-rays got brighter.

Commenting on the study's findings the project leader Wim Hermsen says: "To our surprise we found that when the brightness of the radio emission halved, the X-ray emission brightened by a factor of two! Furthermore the intense X-rays have a very different character from those in the radio-bright state, since they seem to be thermal in origin and to pulse with the neutron star's rotation period."

Dr Stappers says this is an exciting discovery: "As well as brightening in the X-rays we discovered that the X-ray emission also shows pulses, something not seen when the radio emission is bright. This was the opposite of what we had expected. I've likened the changes in the pulsar to a chameleon. Like the animal the star changes in reaction to its environment, such as a change in temperature."

Geoff Wright from the University of Sussex adds: "Our observations strongly suggest that a temporary "hotspot" appears close to the pulsar's magnetic pole which switches on and off with the change of state. But why a pulsar should undergo such dramatic and unpredictable changes is completely unknown."

The next step for the researchers is to look at other objects which have similar behaviour to investigate what happens to the X-ray emission. Later this year there will be another round of simultaneous X-ray and radio observations of a second pulsar. These observations will include the Lovell telescope at Jodrell Bank Observatory.

More information: Synchronous X-ray and Radio Mode Switches: a Rapid Transformation of the Pulsar Magnetosphere will be published in *Science* on Thursday 24 January.

Provided by University of Manchester