

Neutron Star Spins Down

Topic:

Neutron stars

Concepts:

Pulsars, magnetic fields, pulsar timing

Missions:

Swift, Fermi

Coordinated by

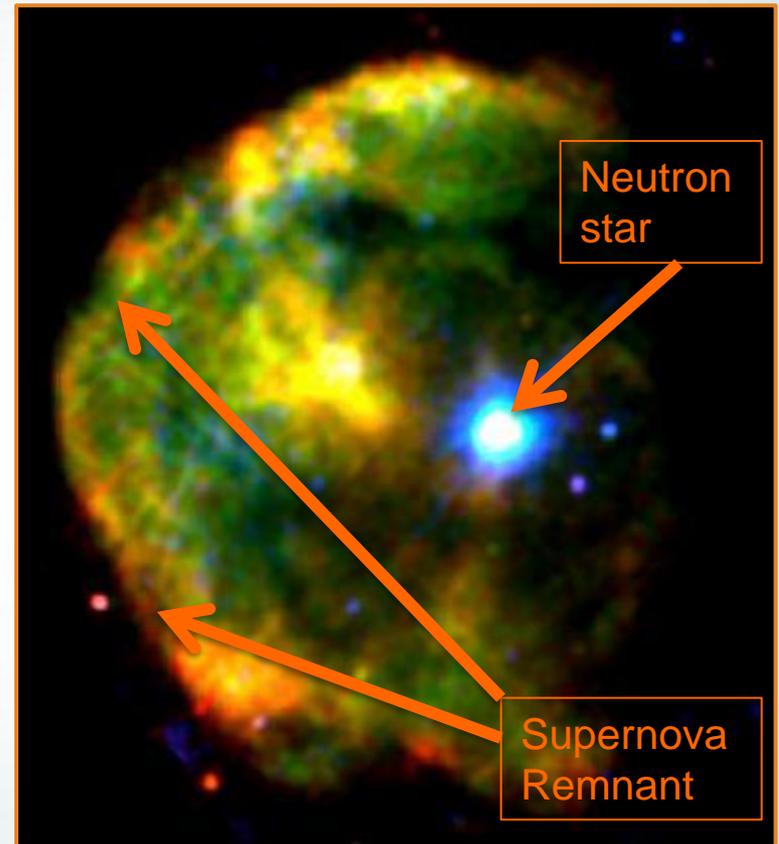
the NASA Astrophysics Forum

An Instructor's Guide for using the slide sets is available at the ASP website

<https://www.astrosociety.org/education/resources-for-the-higher-education-audience/>

The Discovery

- X-ray observations by NASA's Swift satellite showed a sudden slow-down in the spin of a highly magnetized neutron star known as 1E 2259+586 .
- The discovery creates a puzzle for astronomers because usually they see neutron stars (the collapsed cores of massive stars that end their lives as supernovae) suddenly speed up – this is the first time they've seen one slow down.



Neutron star 1E 2259+586 shines in blue-white in this X-ray image of the CTB 109 supernova remnant. (Credit: ESA/XMM-Newton/M. Sasaki et al.)

How Was the Discovery Made?

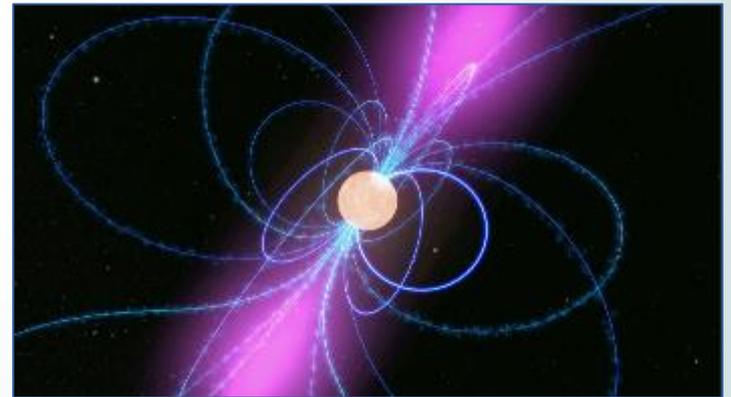
- The Gamma-ray Burst Monitor on NASA's Fermi Gamma-ray Space Telescope observed a brief but intense outburst from IE 2259+586 on April 21, 2012.
- Data from the X-ray Telescope on *Swift* showed that the spin rate of IE 2259+586 decreased abruptly on April 28, 2012 – just a week after the outburst.
- The spin rate of once every seven seconds decreased by 2.2 millionths of a second – a tiny but significant change for a neutron star.



An artist's rendering of an outburst from a highly-magnetized pulsar, which is a fast-spinning neutron star. (Credit: NASA/GSFC)

The Big Picture

- Neutron stars contain twice the mass of our Sun crushed into a sphere about 12 miles across.
- Pulsars are rapidly rotating neutron stars that emit a beam of radiation (directed along their magnetic poles) and sweep it across our line-of-sight. Much like a lighthouse, we observe a pulse every time the beam sweeps past us.
- Astronomers have observed “glitches” in many neutron stars – these are sudden increases in the rate of rotation of the pulsar.
- This new observation showed an “anti-glitch” – or a sudden **decrease** – in the rotational frequency of 1E 2259+586.



Top: A neutron star has the mass of about two suns in a sphere the size of Manhattan.

Credit: NASA's Goddard Space Flight Center

Bottom: A pulsar emits light beams (magenta) that we see as pulses as it rotates. Pulsars also have super-strong magnetic fields (blue lines illustrate magnetic fields lines; the beams are emitted along the magnetic poles). **Credit:** NASA

How Does this Discovery Change our View?

- The internal structure of neutron stars is a long-standing puzzle in astronomy. The current view is that a neutron star has:
 - an *interior* containing oddities that include a **neutron superfluid** (which is a state of matter without friction)
 - a *crust* of **electrons and ions**
 - a *surface* where **streams of high-energy particles are accelerated** through the star's powerful magnetic field
- Current theory holds that a glitch occurs when streaming particles drain energy from the crust causing the crust to spin down. The fluid inside the crust resists this change. Under the strain, the crust fractures, which results in an X-ray outburst and a speedup kick from the faster-spinning interior.
- Processes that would lead to a sudden slow-down in the spin pose a new theoretical challenge!



A composite optical (red) and X-ray (blue) image of the environment near the Crab Nebula pulsar (center), a pulsar from which multiple glitches have been observed. (Credit: NASA/HST/CXC/ASU/J. Hester et al.)

Resources

Press releases

- NASA press release
http://www.nasa.gov/mission_pages/swift/bursts/new-phenom.html
- Penn State press release <http://science.psu.edu/news-and-events/2013-news/Kennea5-2013>

Scientific article

- Archibald, R. F., et al. 2013, Nature, 497, 591
<http://www.nature.com/nature/journal/v497/n7451/full/nature12159.html>
(subscription required)

Multimedia:

- Visit the Interactive Fermi Pulsar Explorer
<http://www.nasa.gov/externalflash/fermipulsar/>
- Additional stories/visuals on pulsars available at NASA/Goddard Space Flight Center's Science visualization Studio:
<http://svs.gsfc.nasa.gov/cgi-bin/search.cgi?sortby=relevance&value=pulsar>

Collected Instructor's Notes

"The Discovery" (page 2 in this PDF)

Neutron Star = the collapsed core of a massive star that ended its life as a supernova.

This neutron star, 1E 2259+586, is located about 10,000 light-years away toward the constellation Cassiopeia.

It is in a class of neutron stars known as **Magnetars**, which have very powerful magnetic fields and occasionally produce high-energy explosions or pulses.

"How Was the Discovery Made?" (page 3 in this PDF)

Initial spin rate = once every seven seconds

Decrease in spin rate was tiny but significant: slowed by 2.2 millionths of a second

"The Big Picture" (page 4 in this PDF)

This neutron star is considered a pulsar because we see beams of radiation from it. The beams are created at the surface where streams of high-energy particles are accelerated by the star's intense magnetic field.

Pulsars' magnetic fields can be millions of times that of Earth.