**What are Anomalous X-ray Pulsars (AXPs)?**

An AXP is a highly magnetized neutron star (typical fields are 10^{12} G) spinning in place.

- Most pulsars are detectable because they emit coherent radio emission (spinning magnetosphere);
- However, these AXPs emit no radio waves, making them difficult to observe.

The emission from most pulsars is powered by the loss of rotational kinetic energy; a few, in binary systems powered by accretion, have others emit thermal X-rays as they cool.

- Few pulsars are observable whose radio luminosity is too great to be powered by spin-down (they are fairly slow) and cannot be explained as thermal X-ray-powdered radiation.

These were dubbed Anomalous X-ray Pulsars.

Approximately nine are currently known (as of late 2004).

- The currently favored explanation is the “braking index” phenomenon, which explains the evolution of the neutron star’s spin as being powered by the decay of an extremely strong magnetic field.

External fields are typically 10^{12}-10^{13} G and spin periods are on the order of 5-10 s.

- X-ray pulsations in AXPs can be interpreted as some form of coherent emission by neutron stars, though the nature of the emission remains uncertain.

- Many others exhibit glitches (sudden spin-up events), bursts (flux increases on a second timescale), and timing irregularities.

- The Millisecond Pulsar (PSR J1048+5837) has been known to have experienced several glitches in a year monitoring campaign in an effort to understand these objects. Observations are taken approximately weekly.

**Pulsar timing**

- Since the pulsars from pulses are due to Doppler shifts they can be expected to be somewhat regular, and they can be used to extract information about the neutron star’s rotation.

- A simple model predicts that the star should spin at a steady rate, experiencing only a drag due to dipole radiation. This energy loss actually takes the form of coherent radiation at radio wavelengths.

- This produces a linearly-decreasing frequency.

- A more sophisticated model takes into account the fact that the energy loss decreases as the frequency decreases, leading to a non-linear spin-down. The non-linearities are described by a “braking index”

- Dipolar models predict the braking index to be -3, but measured braking indices are -2 or -3. Pulsars are complicated objects, which may be expected to have significant deviations from this simple model.

- A more complicated model can account for the acceleration by gravity and the emission of gravitational radiation. These were dubbed Anomalous X-ray Pulsars.

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**Measuring timing**

- For each observation, an integrated pulse profile is computed, and an arrival time (“TOA”) is calculated for a single pulse, the middle of the observation.

- A single model is used to predict the arrival time of the nearest pulse, and the two are subtracted to obtain a “residual”.

- The residual is each spin-down model is adjusted to obtain a match of the preceding data.

- Many residuals are used to observe the second derivative of the spin period to another object due to “timing noise”.

**Results**

- The AXP 1E 1048.1-5937 is the best studied of the AXPs.

- The best fit model is then used to generate many monte carlo data sets.

- The distribution of points shows the covariance of the amplitude and exponential coefficient.

**Questions**

- Why do many sources have the same exponential, and that exponential vary?

- What affects the amplitude of timing noise? Why does it appear to vary in some sources? Why do AXPs appear to have unusually strong timing noise?

- Do deterministic braking indices be extracted even in the presence of timing noise?

- Is timing noise connected to glitches or other variable behaviour?

- Can we distinguish between the different explanations for timing noise?