Investigating the Dynamics of Polar-cap Heating and Pair Plasma Generation In Pulsar B0823+26 Using NASA's NICER X-ray Observatory and Arecibo Observatory

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Background & Significance

Provide an introduction that provides background context and NASA significance for the study. 150 words maximum.

Neutron stars are fantastically exotic astronomical objects. Formed in the throes of a star's death, neutron stars are imbued with intense magnetic fields (>10^9 Tesla) and densities greater than atomic nuclei, whilst their exterior is enshrouded by dense electron position plasma. Serving as excellent extreme physics laboratories, those that produce observable electromagnetic radiation are termed pulsars. Some pulsars undergo *mode changing*, where the pulsar's emission properties alter between a number of defined states. This often results in the radio beam's shape changing or completely ceasing. These changes arise as a result of unknown mechanisms in the pulsar's near and/or internal environment. While most mode changing events occur in radio, a handful of pulsars exhibit joint radio and X-ray mode changes. These rare hybrids allow us the opportunity to probe the intrinsic connections between pulsar radio and X-ray emission, and in turn, the properties of emission mechanisms.

Project Goals

Concisely describe the specific goals of the project. 150 words maximum.

B0823+26, the most recently discovered radio/X-ray mode changing pulsar, was chosen as our source of study. We initially outlined a joint radio/X-ray observation campaign, with a particular focus on studying the correlations between radio and X-ray emission. Unfortunately, due to the competitive nature of proposals, we were unable to secure observation time with NICER. However, we were awarded 20+ hours of Arecibo radio telescope time, which we used to collect over 20 separate rise-to-set observations of B0823+26. Our specific goals in analyzing this data set were to

- Ascertain the properties of each mode.
- Determine the classification of each beam shape as related to known beam shape phenomenology.
- Determine how the beam shape changes between the two modes.
- Determine where in the magnetosphere the radio emission arises from.
- Infer physical conditions of the radio/X-ray's source plasma

Summary of Key Findings

Describe the key outcome of your work in terms suitable for an educated, but non-expert reader. 300 words maximum.

B0823+26 has two modes. In it's bright mode, the beamed emission is consistently visible in both radio and X-ray. This contrasts with it's quiet mode, where the X-ray emission has disappeared and radio remains mostly off with short bursts/flickers of emission that last about 1-5 rotation periods. The pulsar spends at least 12 hours in each mode, but no greater than 3 days (limitations set by known observations). A rare feature is the appearance of a quasi-stable bright mode. This has only been detected once previously, interrupting the quiet mode for about 6 minutes. Our re-detection confirms this as a feature of the quiet mode, and not an isolated event.

In both modes we found evidence for quasi-periodicities in the emission. The bright mode modulates on a timescale of 5 rotation periods, while the quiet mode's flickers occur about every 20 rotation periods. These periodicities suggest that the plasma producing radiation is undergoing a quasi-periodic process in both modes.

In this pulsar, we also identified a majority of the radio emission arising from near the surface, while a small portion comes from substantially higher heights. We found the bright mode to be dominated by low altitude emission whereas the quiet mode is strictly high altitude emission (indicating low altitude emission disappears in the quiet mode). X-ray emission also arises near the surface. The disappearance of low altitude emission in the quiet mode suggests a large scale reconfiguration of the plasma in the pulsar's near environment. As well, the physical mechanism by which plasma is produced appears to differ in the low and high altitude regimes. Understanding the connections between this pulsar, and the many more known ones will help us in better understanding how pulsars work.

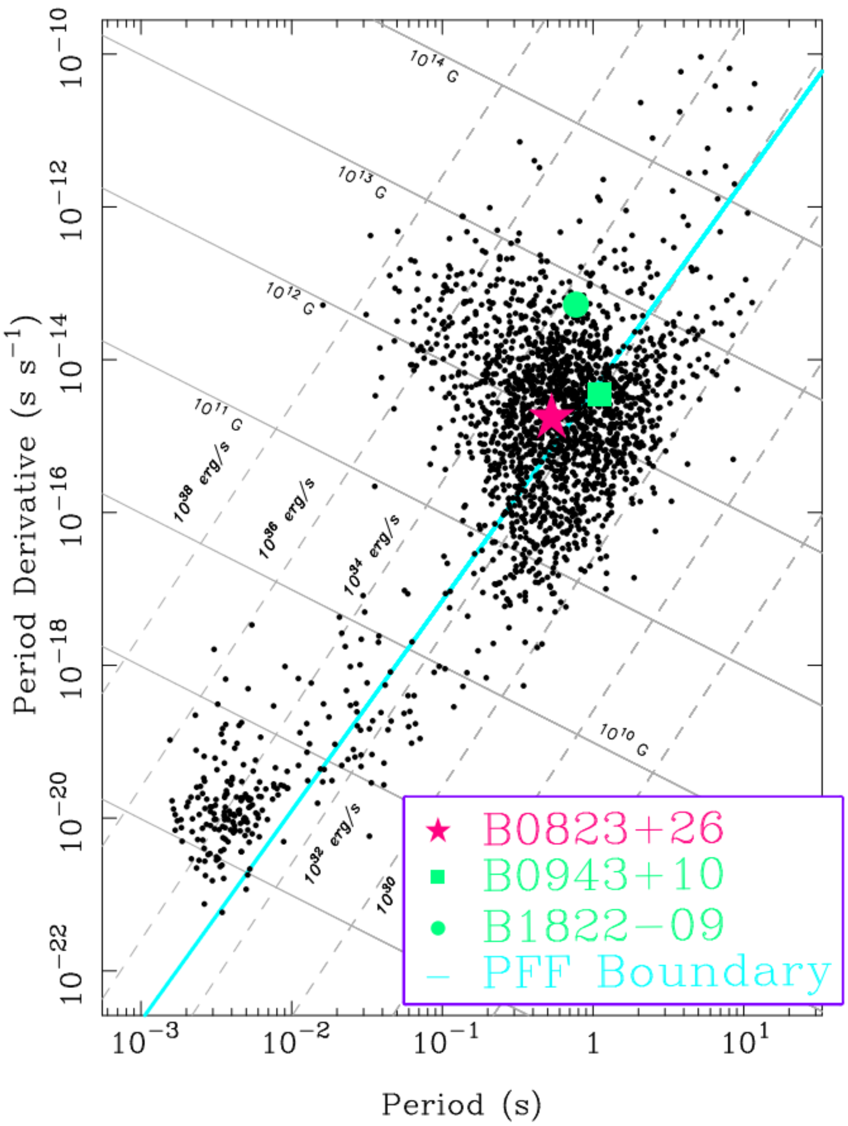

Figure 1: Pulsar's rotate in many different ways. While all pulsars ideally slow down with age, some pulsars are born with naturally slow rotations or get sped up faster by accretion. Plotting a pulsar's change of period vs period gives us a way to naturally distinguish populations. B0823+26 lies in what we call the "normal" pulsar population. Three mode changing pulsars have been plotted and are indicated by the star, square, and circle respectively. The cyon blue line represents a death line (where plasma generation can no longer be self-sustained) for a postulated theoretical emission mechanism.