Spin-Powered Pulsars

- Radio
- High Energy
- RRATs
- Magnetars
- XDINS

Thanks to Maura McLaughlin
A Multiwavelength Approach

✓ Understanding the nature of the engine of Pulsars
Pulsar Electrodynamics
Pulsar Electrodynamics

Watters et al. 2009

- Polar Cap
- Two Pole Caustic
- Outer Gap

Peak Multiplicity:
- No peaks
- One peak
- Two peaks
- Three peaks
- Four peaks

Magnetic Inclination $\alpha$
A Multiwavelength Approach

✓ Understanding the nature of the engine of Pulsars
✓ Clarifying the real nature of peculiar signals
Peculiar Signals: RRATs

- Repeating Single dispersed Pulses in Parkes Pulsar Surveys Data
  - Repeating Radio Transients

- Underlying periodicity found through time difference studies

- Persistent pulsation found from X-ray observations
  - Rotating Radio Transients!

- Population studies including radio surveys selection effects
  - 4 times more RRATs than persistent pulsars

McLaughlin et al. 2006
Reynolds et al. 2006
A Multiwavelength Approach

✓ Understanding the nature of the engine of Pulsars
✓ Clarifying the real nature of peculiar signals
✓ Establishing a link between different classes of NSs
The NSs Connections

- **Radio**
- **High Energy**
- **RRATs**
- **Magnetars**
- **XDINS**

X-ray observations of RRATs
Radio observations of XDINS
Radio observations of magnetars...

Camilo et al. 2006
A Multiwavelength Approach

- Understanding the nature of the engine of Pulsars
- Clarifying the real nature of peculiar signals
- Establishing a link between different classes of NSs
- Having a complete picture of specific objects of interest
The Double Pulsar
J0737-3039A

22.7 ms pulsar in the Parkes High-Latitude Survey
2.4 hr orbit around a second NS
The most relativistic DNS known allowing for precise tests of GR

Burgay et al. 2003 Nature
Kramer et al. 2006 Science
The Double Pulsar J0737-3039B

Discovery of 2.7 s pulsations from companion NS
Unique system allowing for new GR tests
Mutual Interactions between radio beams and magnetospheres

Lyne et al. 2004 Science
Breton et al. 2008 Science

jpl.nasa.gov
The Double Pulsar in X-rays

The balancing point between pressures inside B’s magnetosphere

Shock emission expected: X/γ-rays from synchrotron (+inverse Compton)
The Double Pulsar in X-rays

**X-ray observations:**

- **Chandra ACIS-S, 10.0 ks: 64 counts, spatial analysis**  
  (McLaughlin et al 2004, Campana et al. 2004)

- **XMM MOS-1+2 47.2 ks: 432 cts spectral and timing analysis**  
  (Campana et al. 2004, Pellizzoni et al. 2004, Kargalstev et al. 2006)

- **Chandra HRC-S 53.5 ks: 250 cts, spatial and timing analysis**  
  (Chatterjee et al. 2007)

- **Chandra HRC-S 35.8 ks: 167 cts, spatial and timing analysis**  
  (Chatterjee et al. 2007)

- **Chandra ACIS-S 79 ks: 529 cts, spatial, spectral and timing analysis**  
  (Possenti et al. 2008)

- **XMM MOS+pn 230 ks: 5000 cts, spatial, spectral and timing analysis**  
  (Pellizzoni et al. 2008)
The Double Pulsar
in X-rays: Timing

Pulsations found at A’s period
Double peaked
$P_f \sim 75\%$

McLaughlin et al 2004, Campana et al. 2004,
Pellizzoni et al. 2004, Chatterjee et al. 2007,
Possenti et al. 2008, Pellizzoni et al. 2008
The Double Pulsar
in X-rays: timing

Pulsations found at B's period in 0.41 – 0.66 orbital phase

Pellizzoni et al. 2008
The Double Pulsar in X-rays: Spectra

PL (or BB+PL) or BB+BB equally ok
Standard emission from A
Quite soft

230 ks XMM:
Phase averaged: PL+BB or BB+BB
Phase & energy resolved spectra:
✧ Off-pulse softer
✧ Pf increases with energy

Off pulse: shock? Pulsar B?

Pellizzoni et al 2008
The Double Pulsar in X-rays: Spectra

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Pellizzoni et al 2008
The Double Pulsar in X-rays: spectra

Too soft for shock
No orbital variations
$L_{\text{shock}} < 10^{29}$ erg/s

Gives limit on A’s wind magnetization parameter

Off pulse: not shock. Pulsar B!
The Double Pulsar in X-rays: spectra

Three component spectral model:

- Power law ($\Gamma = 3.3$) $\rightarrow$ PSR A pulsed
- "Hot" BB (134 eV, 100 m) $\rightarrow$ PSR A
- "Cold" BB (32 eV, 15 km) $\rightarrow$ PSR B

Delay between radio and X-ray emission phases can constrain thermal inertia of NS surface
Multiwavelength observations are fundamental tools for:

✧ Have a deeper knowledge of the pulsar emission mechanisms

✧ Understand possible connections between classes of NSs

✧ Have a better understanding of peculiar objects such as
  
  ✧ RRATs (NSs population)
  
  ✧ The Double Pulsar (emission mechanisms, plasma physics...)

✧ ...

Summary
Thanks!