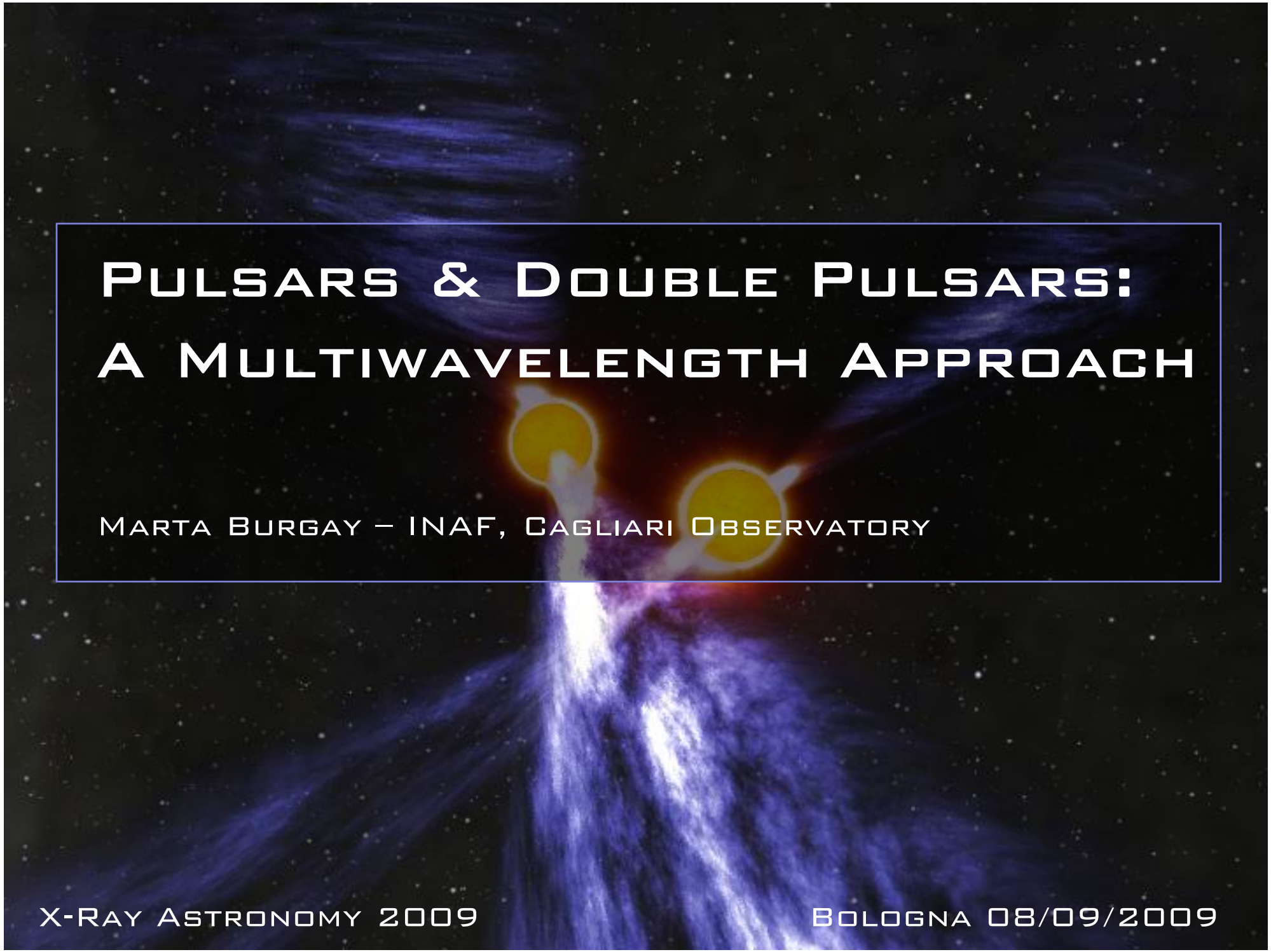


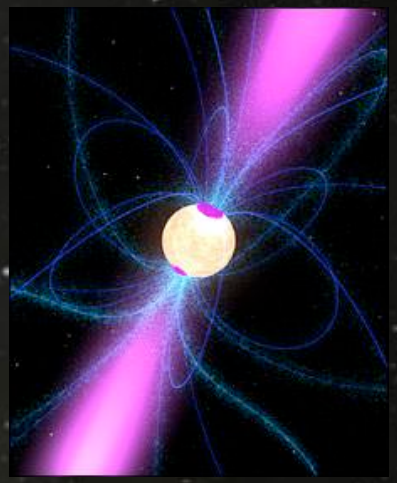
Pulsars & Double Pulsars: A Multiwavelength Approach

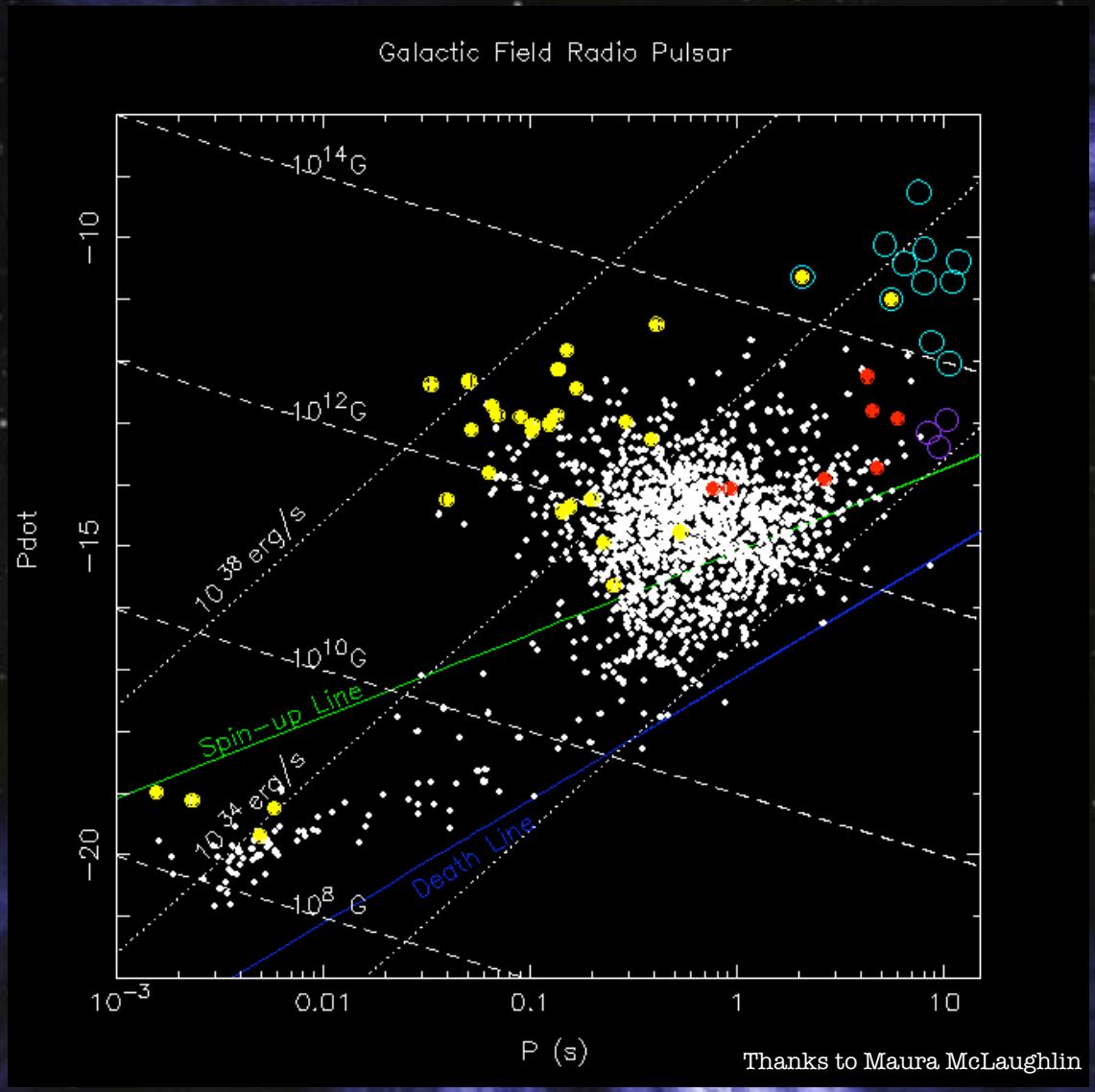
Marta Burgay – INAF, Cagliari Observatory

X-Ray Astronomy 2009 Bologna 08/09/2009

Spin-Powered Pulsars

- Radio
- High Energy
- RRATs
- Magnetars
- XDINs

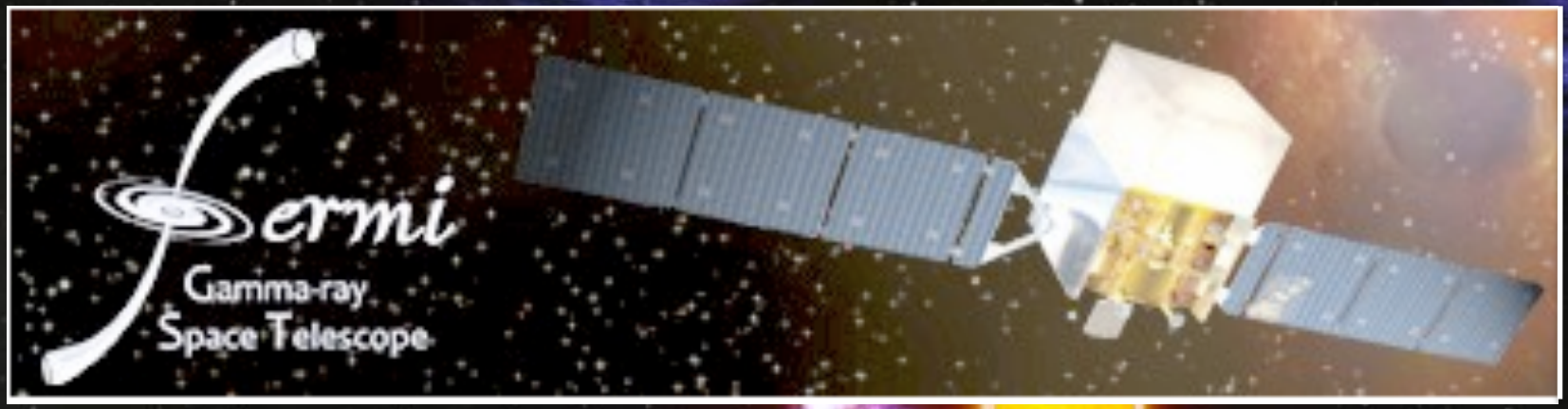


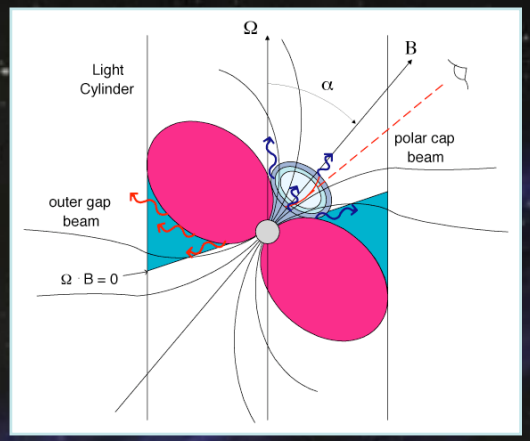


A Multiwavelength Approach

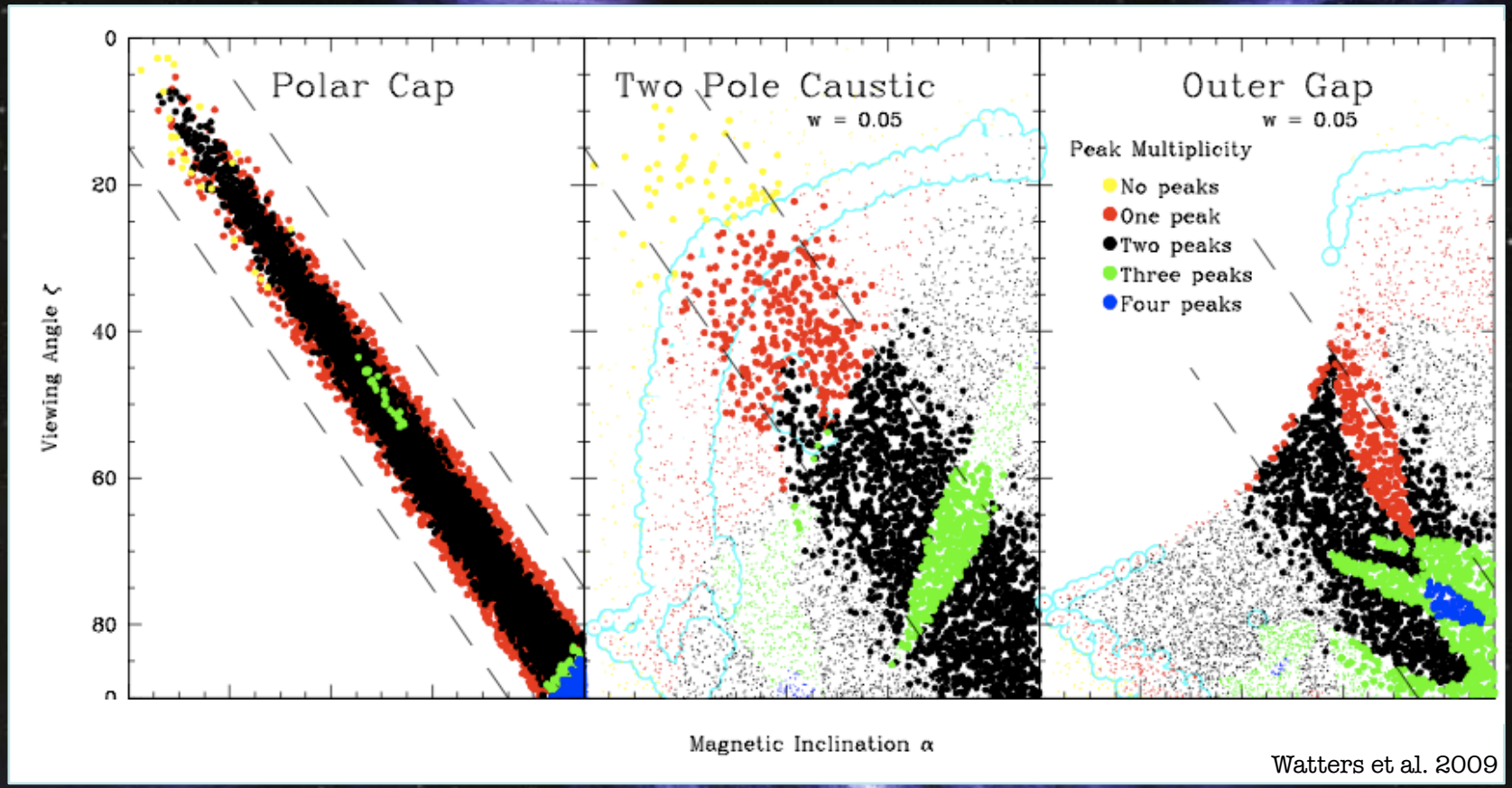
- ✓ Understanding the nature of the engine of Pulsars

Pulsar Electrodynamics





Pulsar Electrodynamics



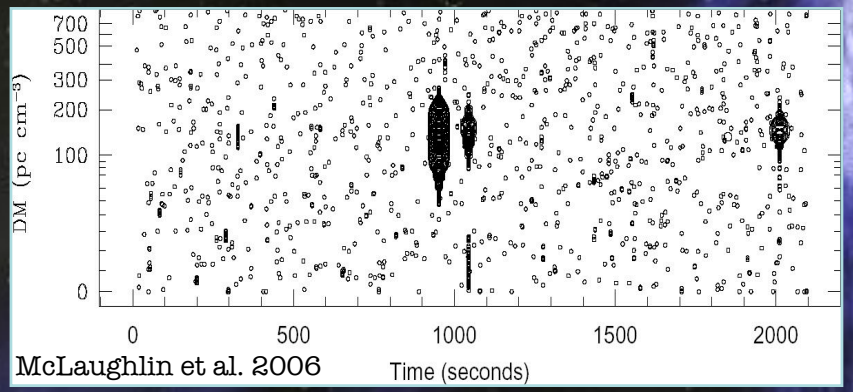
Watters et al. 2009

A Multiwavelength Approach

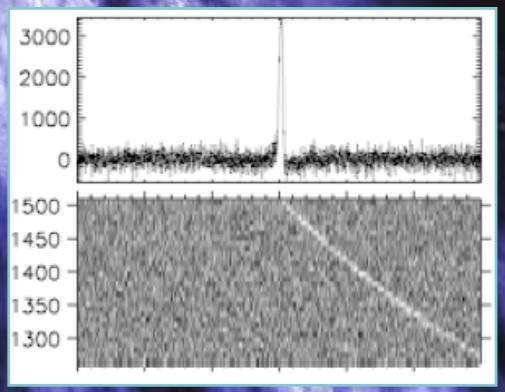
- ✓ Understanding the nature of the engine of Pulsars
- ✓ Clarifying the real nature of peculiar signals

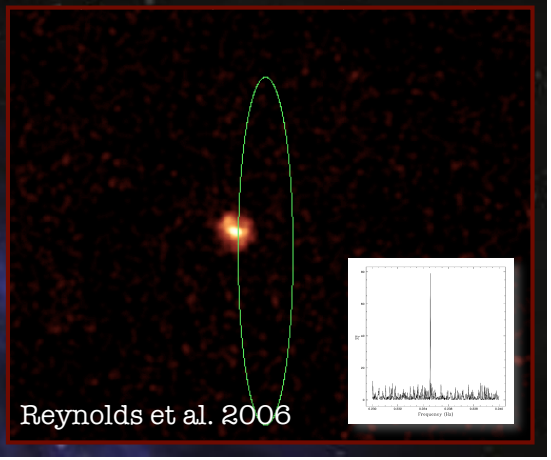
Peculiar Signals: RRATs

- 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



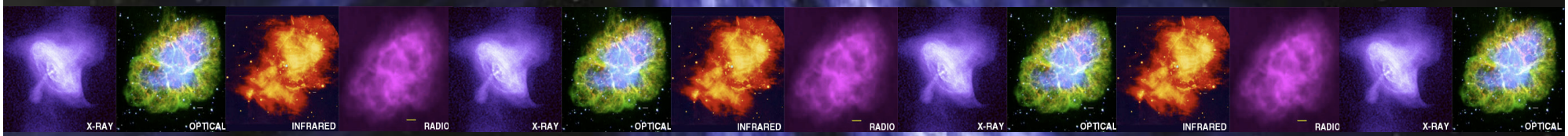
McLaughlin et al. 2006



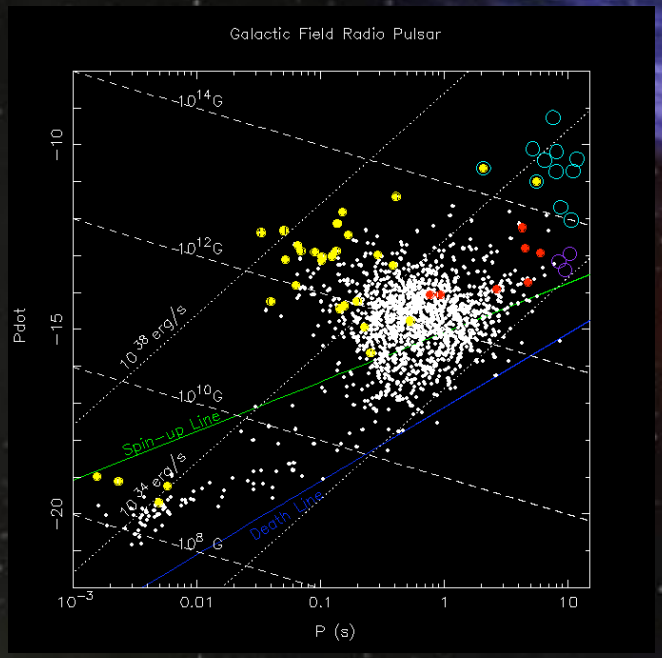

Reynolds et al. 2006

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



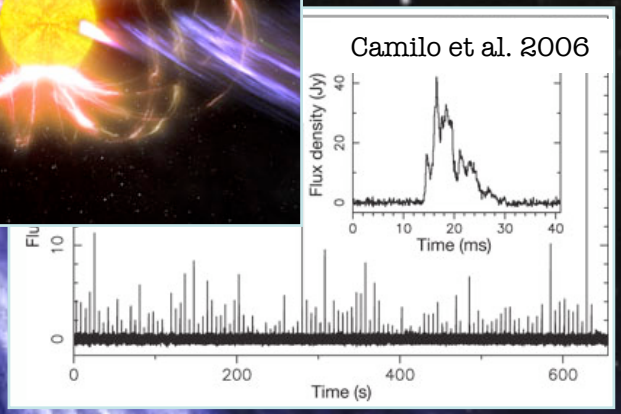
- Radio
- High Energy
- RRATs
- Magnetars
- XDINs

X-ray observations of RRATs

Radio observations of XDINs

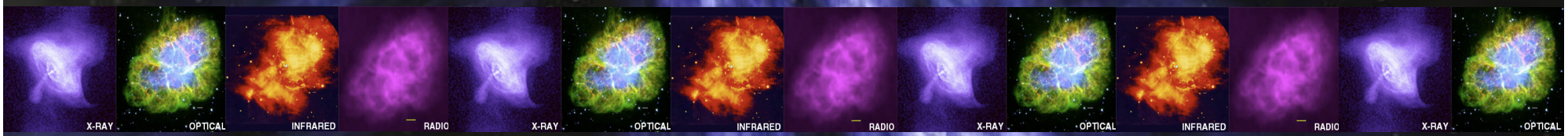
Radio observatons of magnetars

...



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

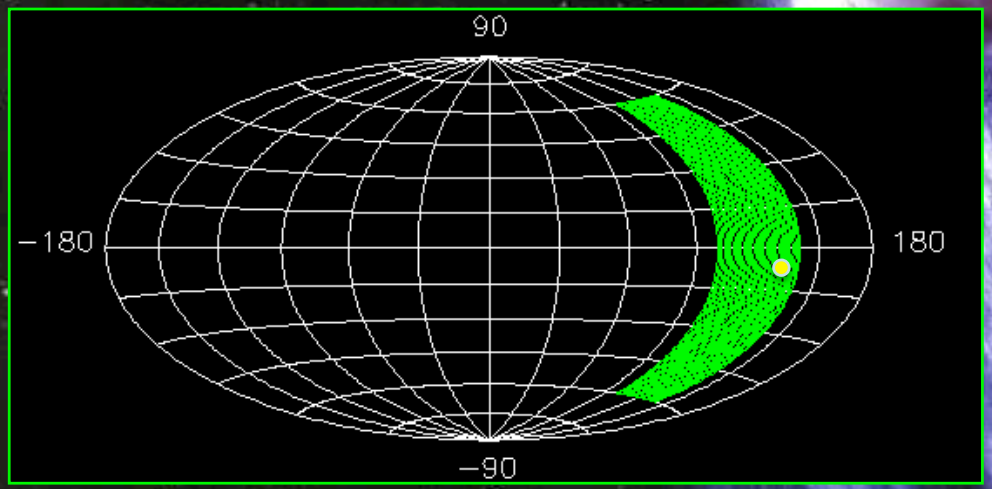


The Double Pulsar J0737-3039A

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



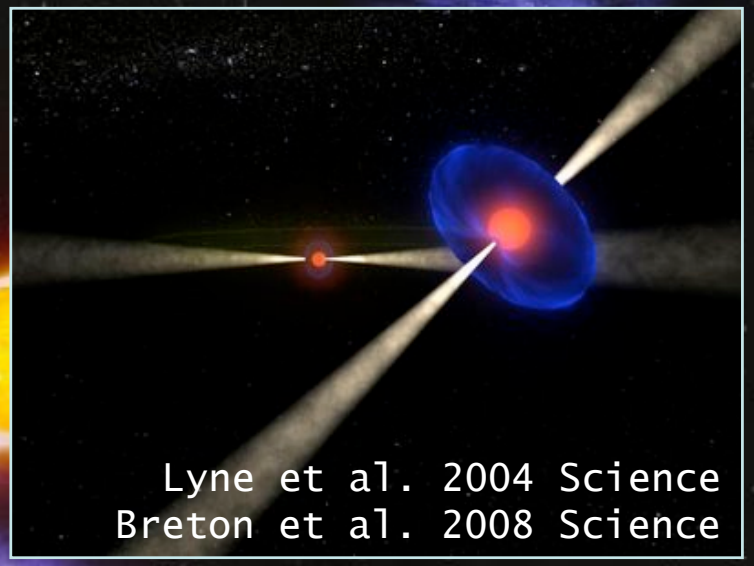
Burgay et al. 2003 Nature
Kramer et al. 2006 Science

The Double Pulsar J0737-3039B

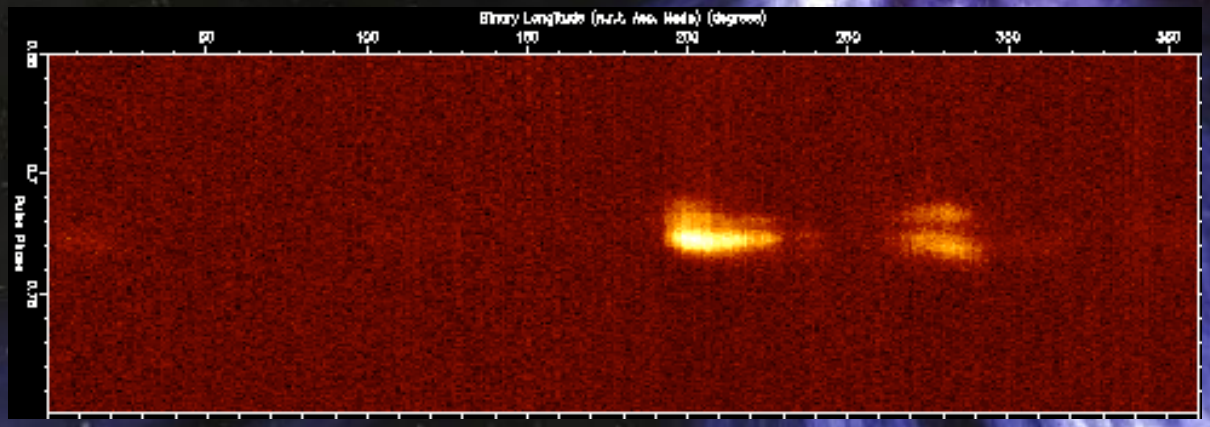
Discovery of 2.7 s pulsations from companion NS

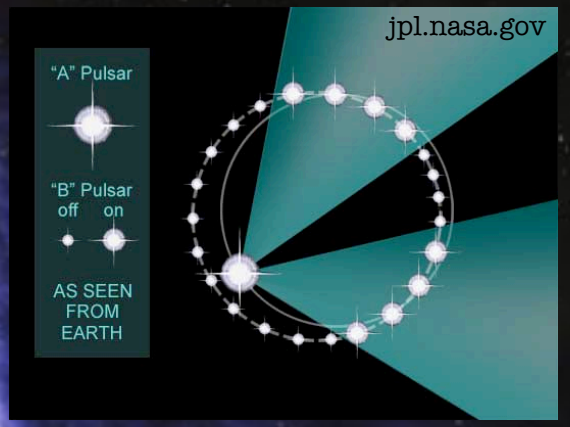
Unique system allowing for new GR tests

Mutual Interactions between radio beams and magnetospheres

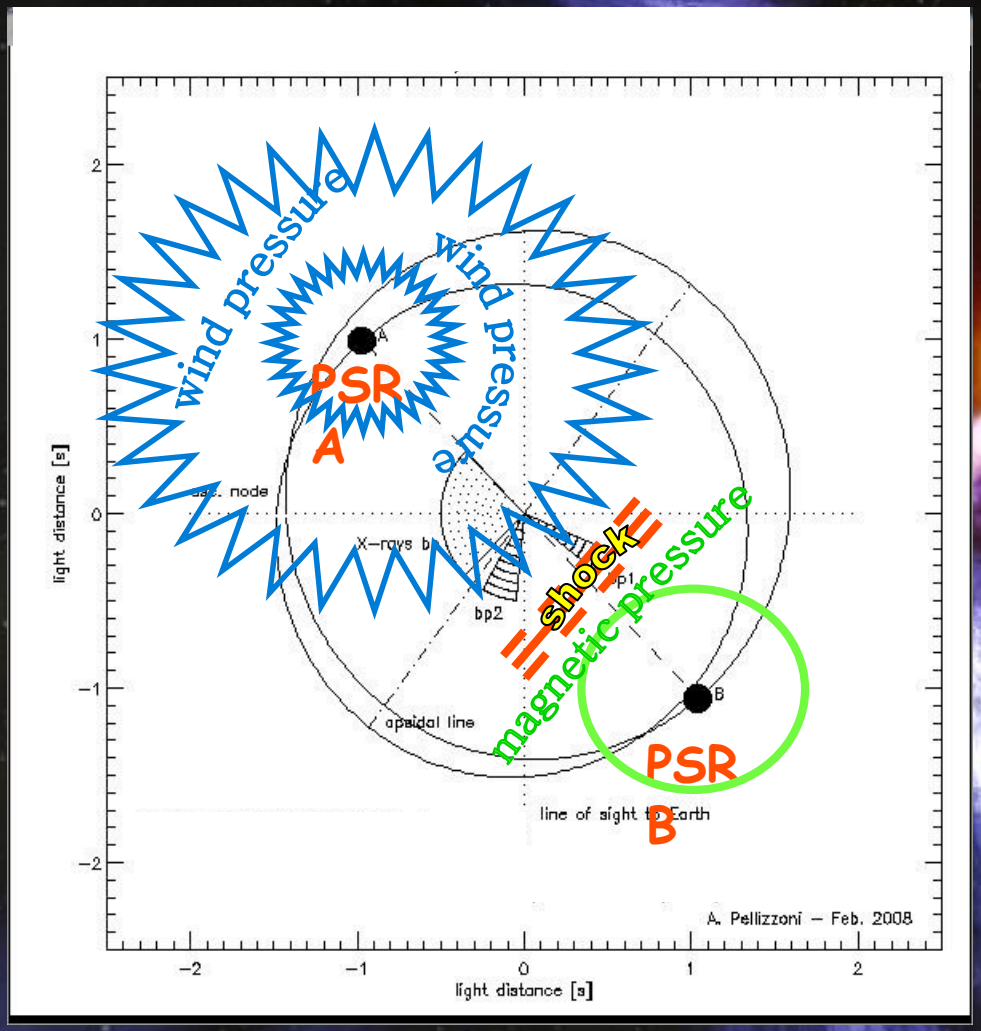


Lyne et al. 2004 Science
Breton et al. 2008 Science





The Double Pulsar in X-rays



The balancing point between pressures inside B's magnetosphere

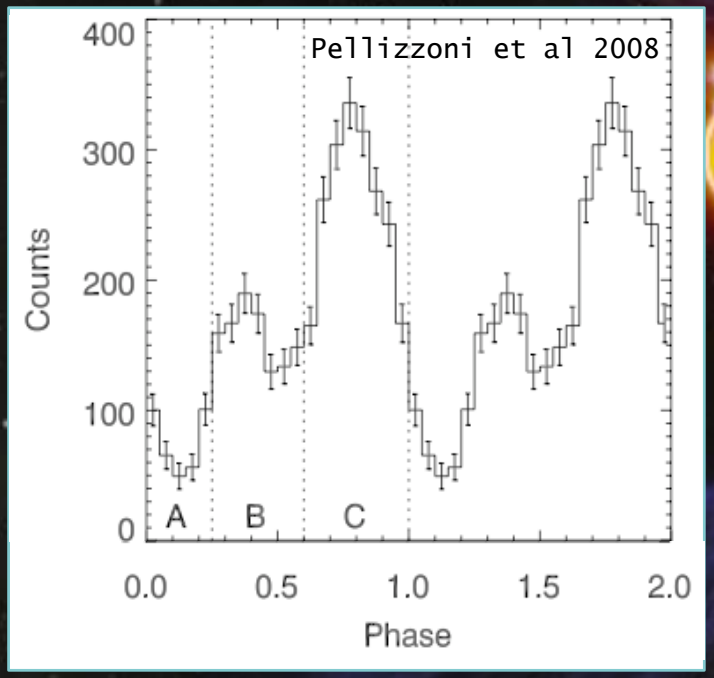
Shock emission expected: X/γ-rays from synchrotron (+inverse compton)

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

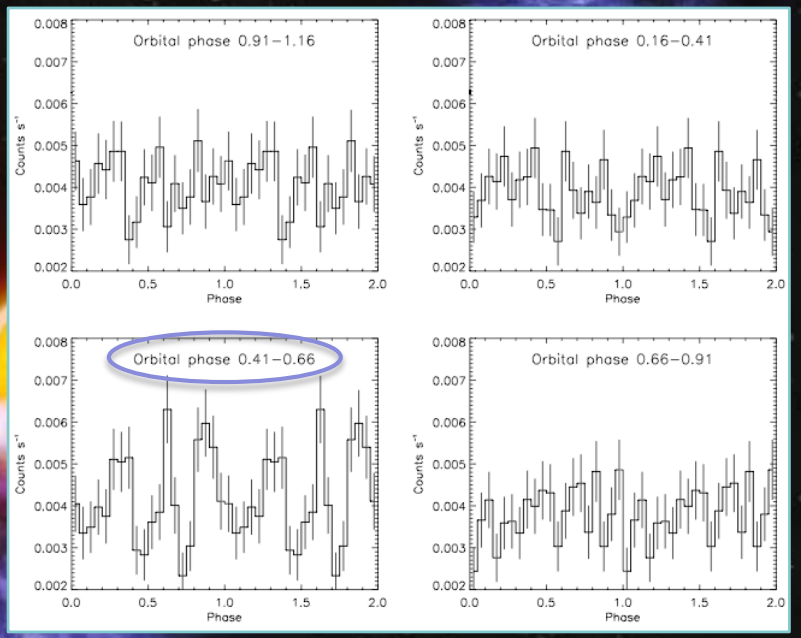
Pf ~ 75%

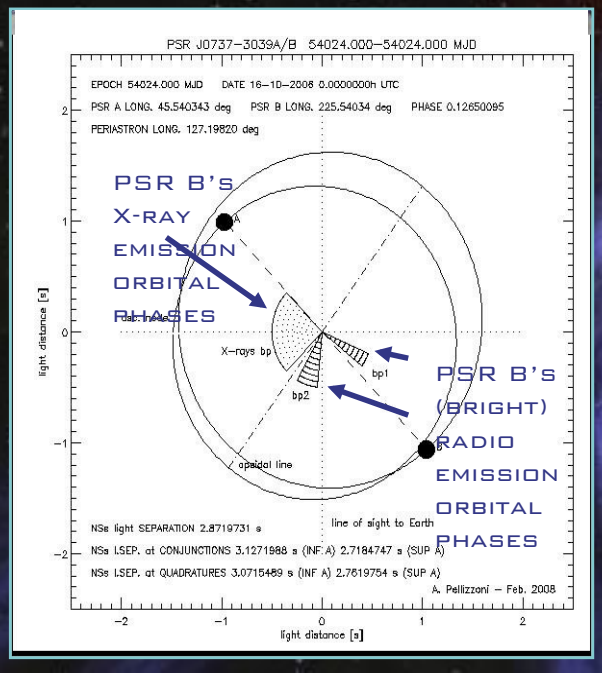
McLaughlin et al 2004, Campana et al. 2004, Pellizzoni et al. 2004, Chatterjee et al. 2007, Possenti et al. 2008, Pellizzoni et al. 2008

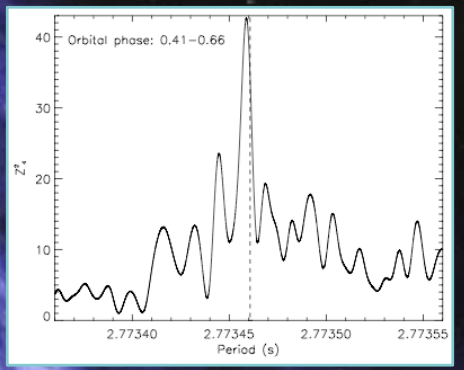
The Double Pulsar in X-rays: timing

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

Pellizzoni et al. 2008





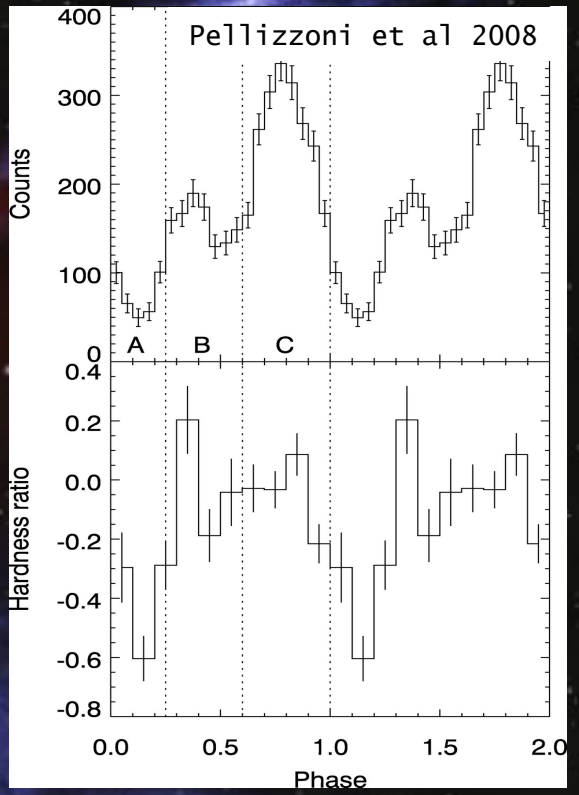


The Double Pulsar in X-rays: spectra

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?



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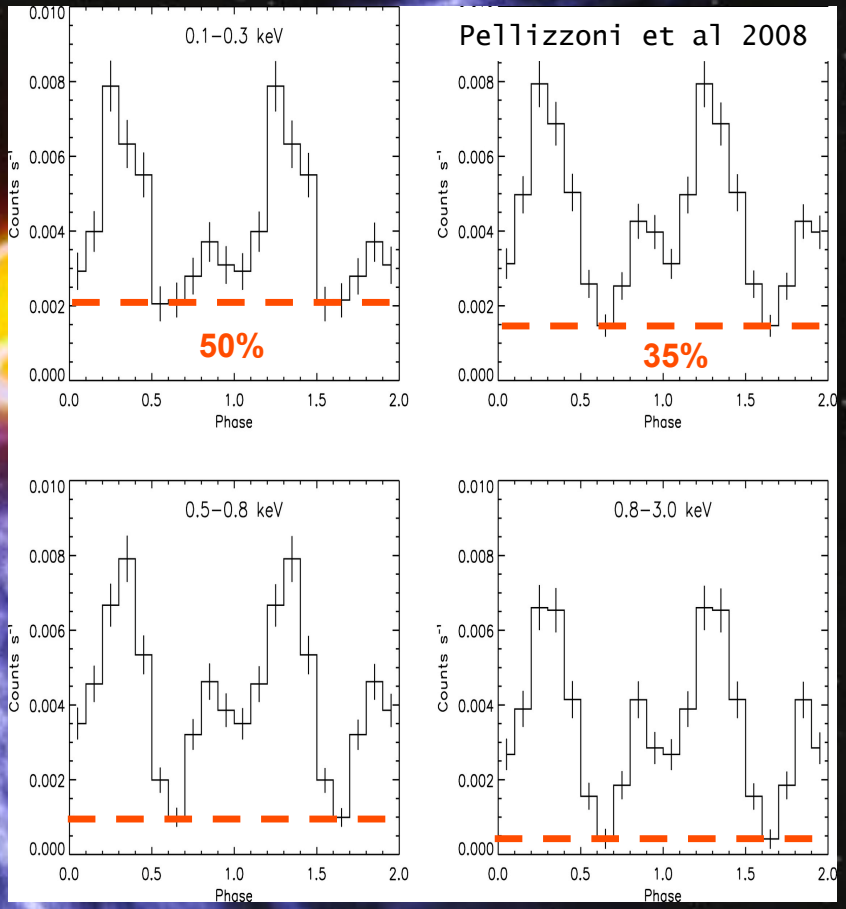
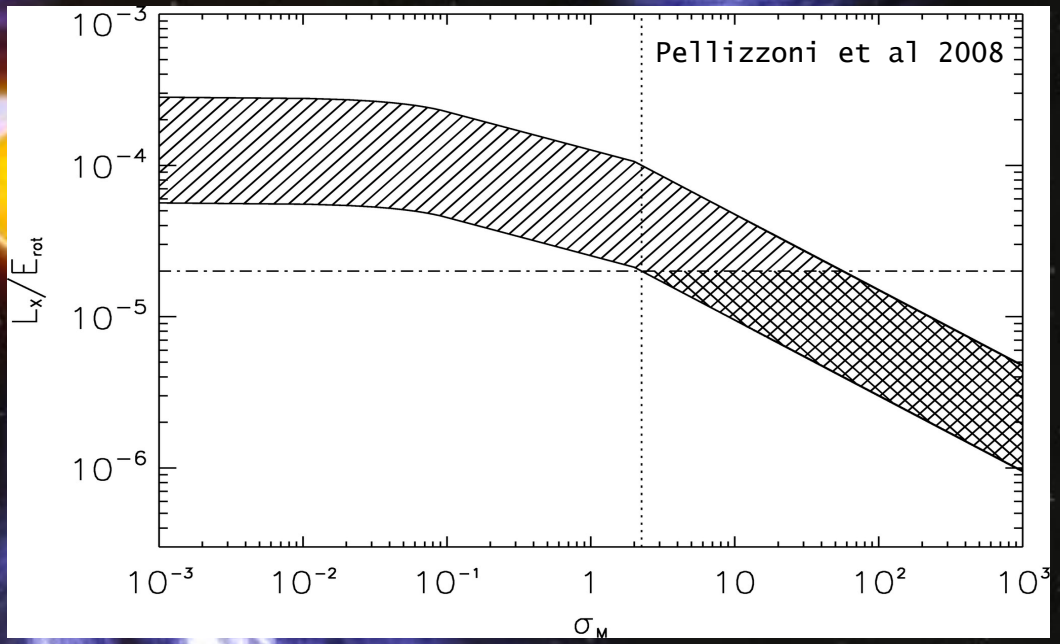


The Double Pulsar in X-rays: spectra

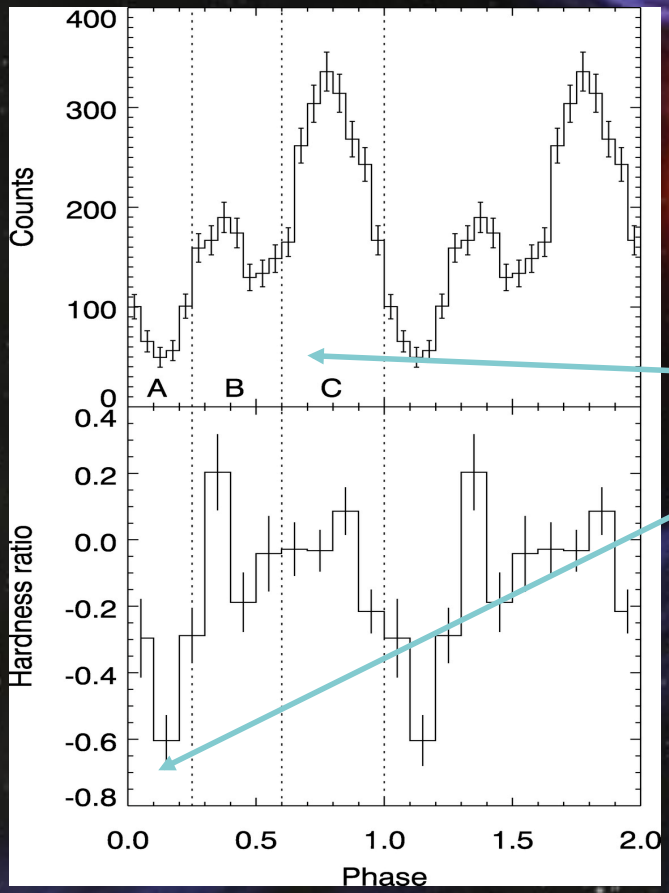
Too soft for shock
No orbital variations
$L_{shock} < 10^{29}$ erg/s

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

Delay between radio and X-ray emission phases can constran thermal inertia of NS surface

Summary

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 undesrtanding of peculiar objects such as
  - RRATs (NSs population)
  - The Double Pulsar (emission mechanisms, plasma physics...)
  - ...


Thanks