Long Term X-Ray Timing of the Double Pulsar PSR J0737-3039

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Collaborators

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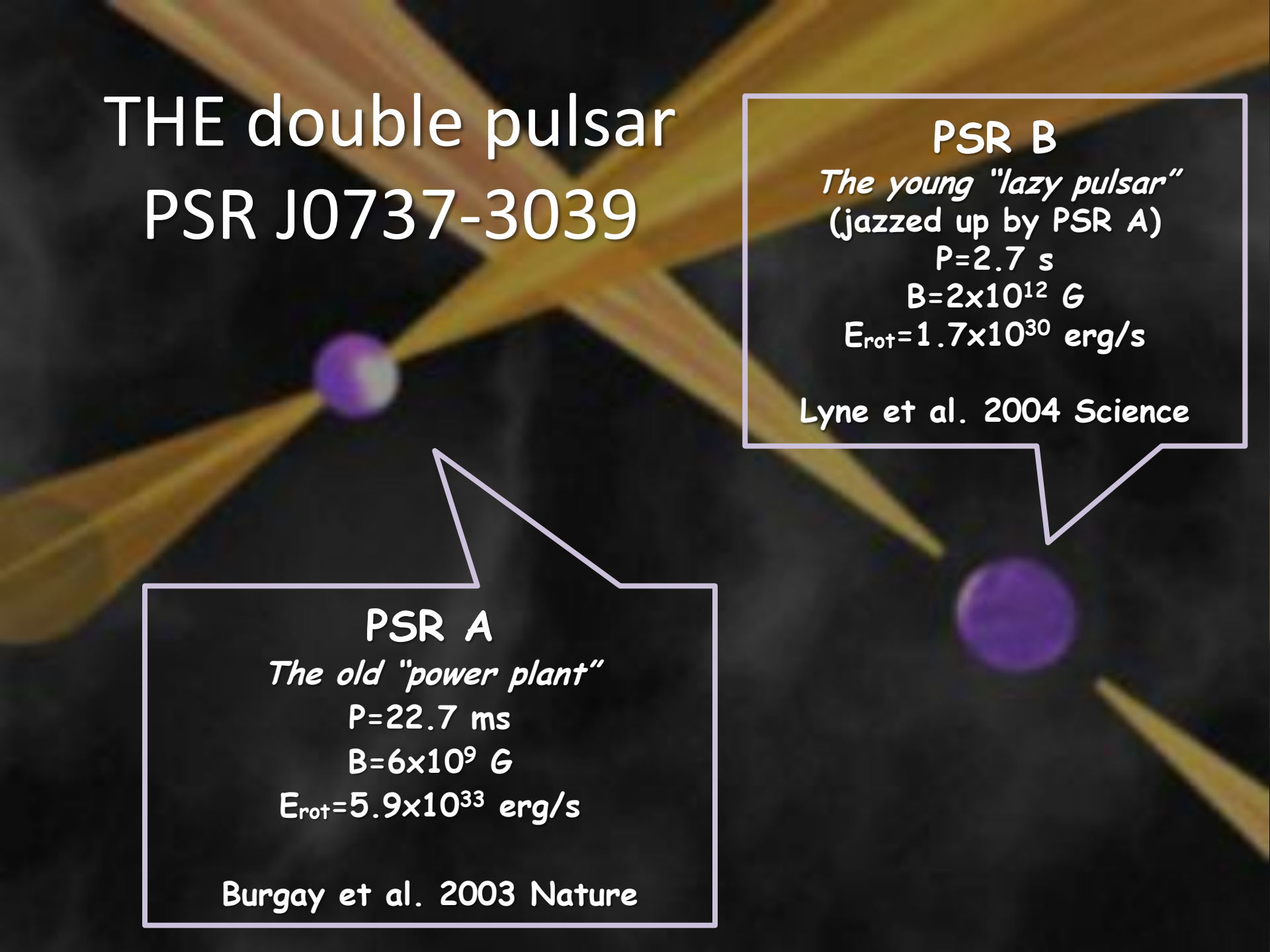
THE double pulsar PSR J0737-3039



PSR B

The young "lazy pulsar"

(jazzed up by PSR A)

P=2.7 s

B=2×10^{12} G

$E_{rot}=1.7 \times 10^{30}$ erg/s

Lyne et al. 2004 Science

PSR A

The old "power plant"

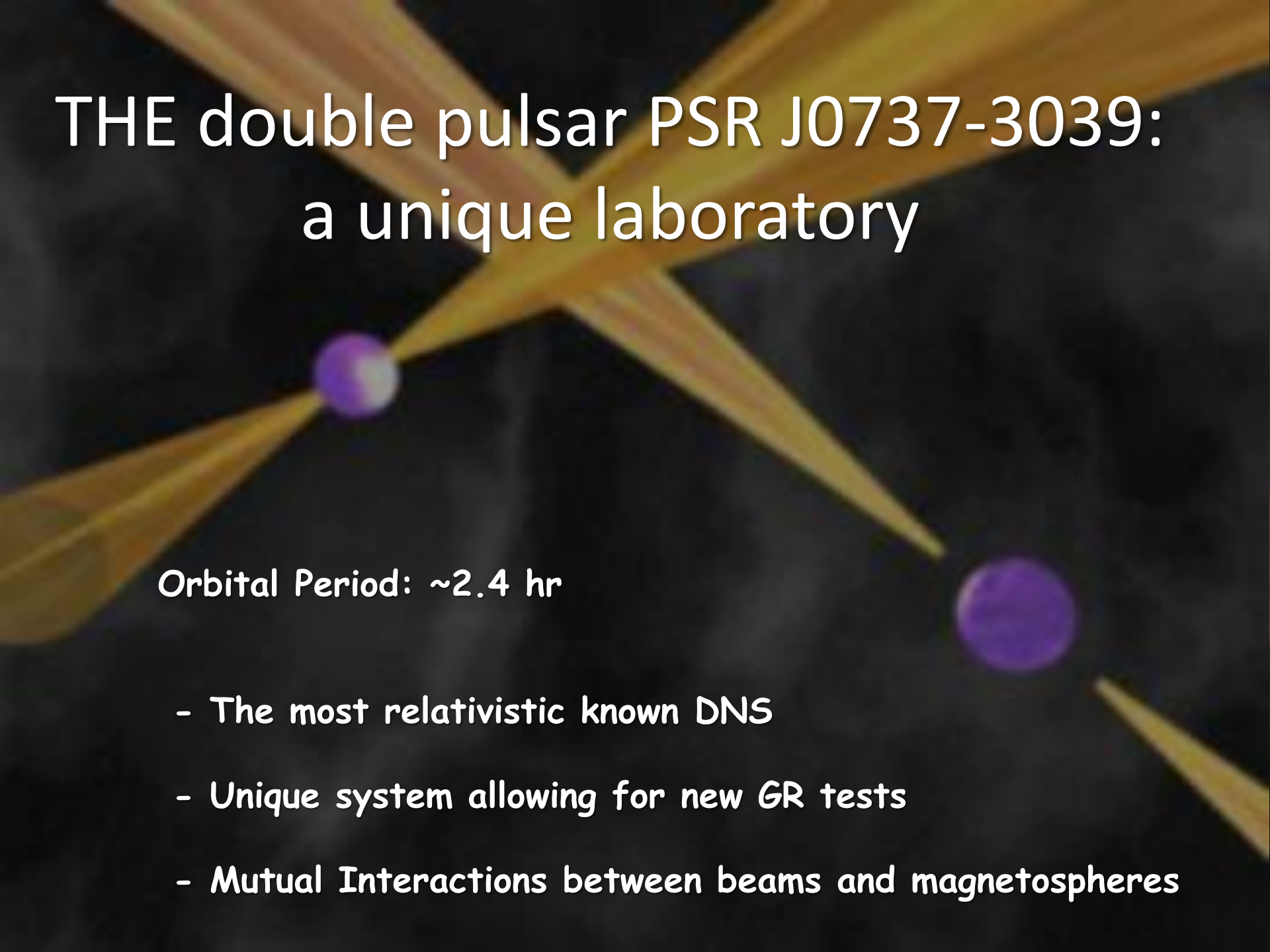
P=22.7 ms

B=6×10^{9} G

$E_{rot}=5.9 \times 10^{33}$ erg/s

Burgay et al. 2003 Nature

THE double pulsar PSR J0737-3039: a unique laboratory



Orbital Period: ~2.4 hr

- The most relativistic known DNS
- Unique system allowing for new GR tests
- Mutual Interactions between beams and magnetospheres

The two XMM-Newton Large Programs

Large program	year	XMM-Newton orbits	Instrument	P.I.	Duration
1	2006	2	PN + MOS	A. Pellizzoni	~230 ks ~26 binary orbits
2	2011	3	PN + MOS	A. Pellizzoni	~360 ks ~41 binary orbits

Total	**5**		~600 ks ~67 binary orbits

Datasets analyzed separately and combined

The data analysis

Extraction process:

- Data were extracted with SAS version 11.0.0
- Extraction parameters:

  PN → 18″ rad - 5σ cleaning

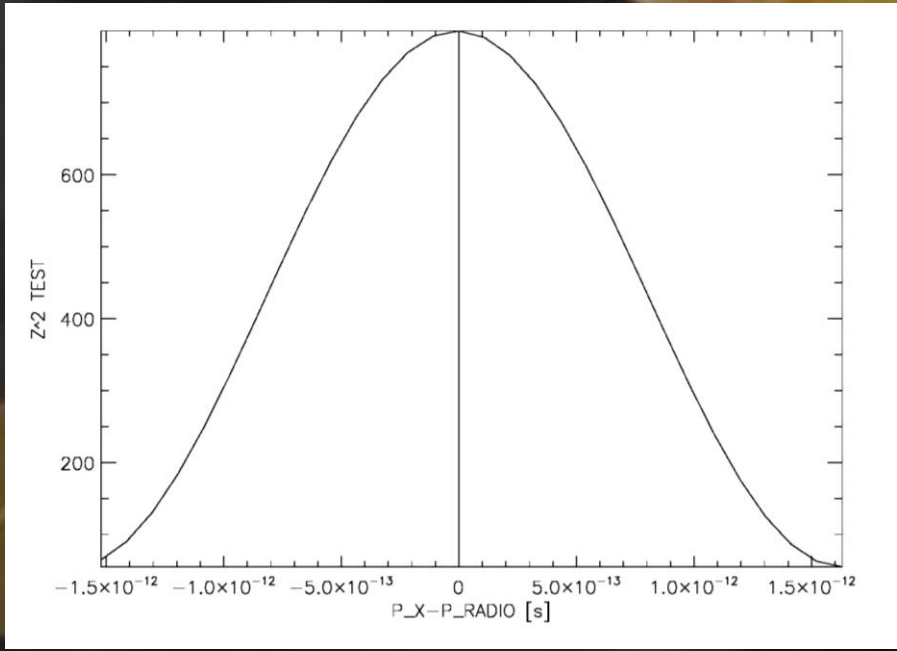
  MOS → 15″ rad - 3σ cleaning

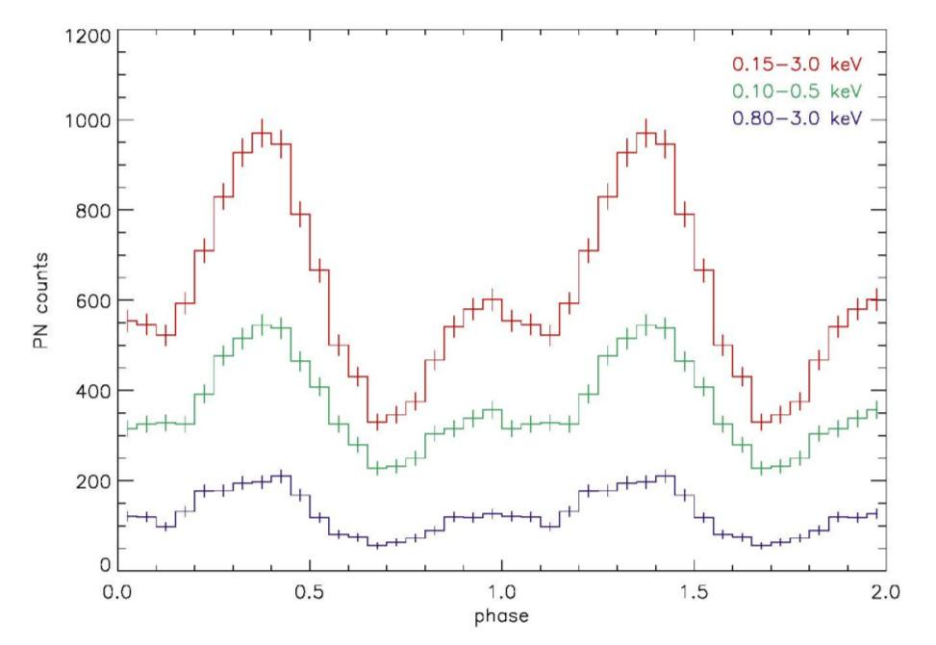
Folding:

- SS barycentered with JPL DE405 (*SAS-barycen*)
- Binary barycentered (according to B&T…)
- Folded in a range centered at the radio period

Ephemeris: Kramer et al. 2006

The total PSR A pulsed profile





Significance Z^2_1 test peaks precisely at the radio spin period

Little modulation in high energy band

$\nu_{S,radio}$ = 44.054069392744(2) Hz

$\nu_{S,XMM}$ = 44.0540693928(2) Hz

Geodetic precession

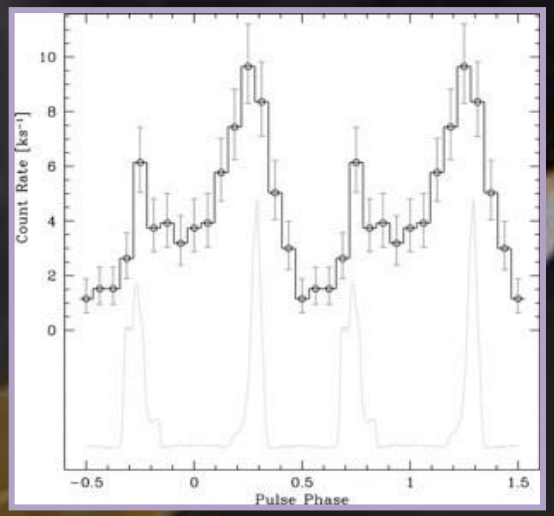
- Relativistic binary systems undergo spin axis precession around the binary angular momentum

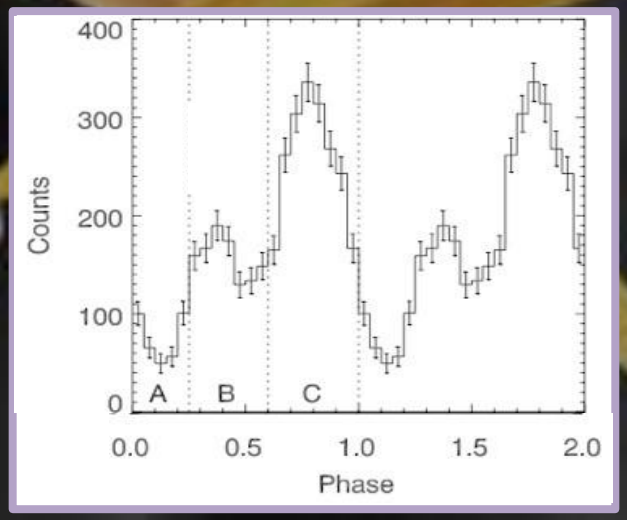
- It results in a change in the pulsed profile shape

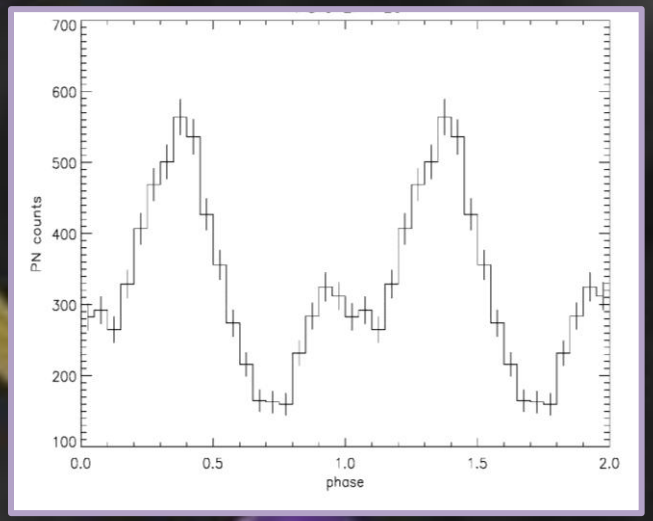
Effects on the radio pulsed profiles:

- PSR A: no evidence for variation in the integrated profile
- PSR B: radio emission not detected since November 2008

The PSR A pulsed profile







2006 – Chandra

Chatterjee et al. 2007

~400 ph
~90 ks

2006 - XMM Newton

Pellizzoni et al. 2008

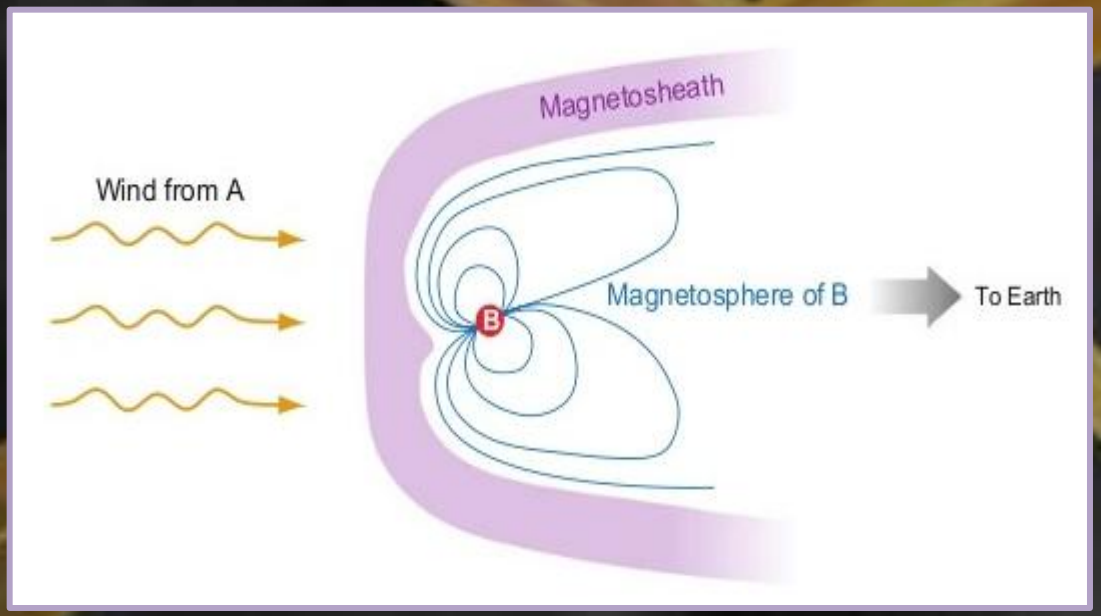
~5000 ph
~230 ks

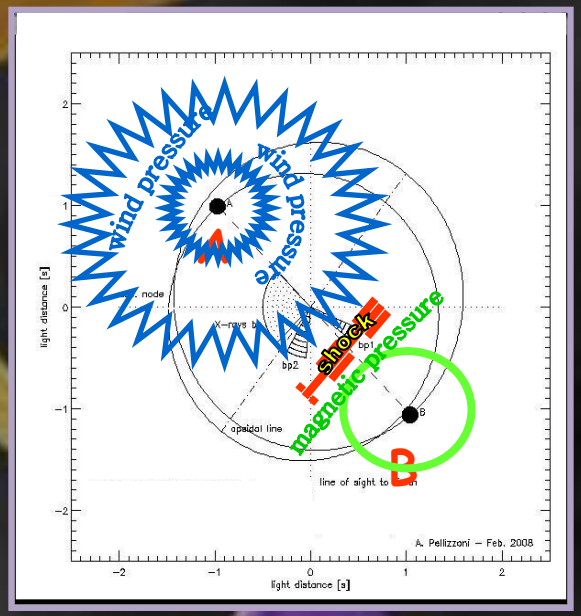
2011 – XMM Newton

Iacolina et al. 2013
in prep.

~8000 ph
~360 ks

High energy emission





Particle wind from PSR A reaches the PSR B magnetosphere. The balancing point between pressures is inside B's magnetosphere

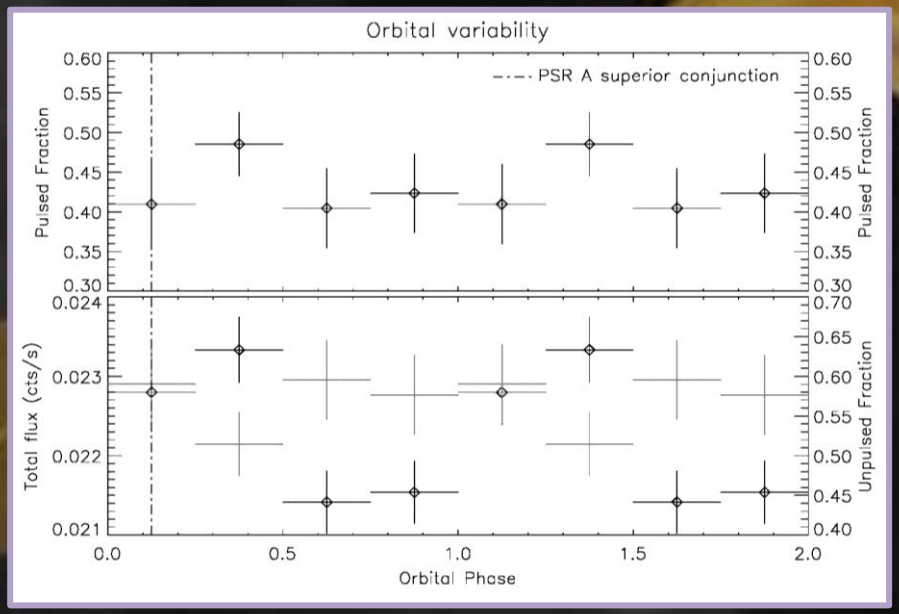
High energy emission from:

- Bow shock → expected X/γ-rays from synchrotron (+inverse compton)
- Pulsed thermal emission from the PSR B surface

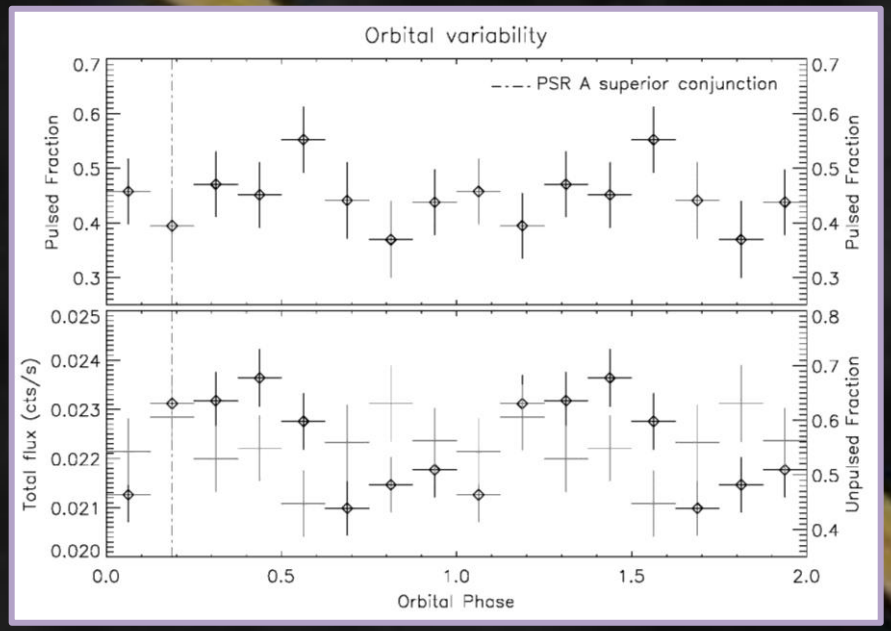
Orbital modulation

Marginal detection of orbital modulation

Four orbital phase intervals ~40 min



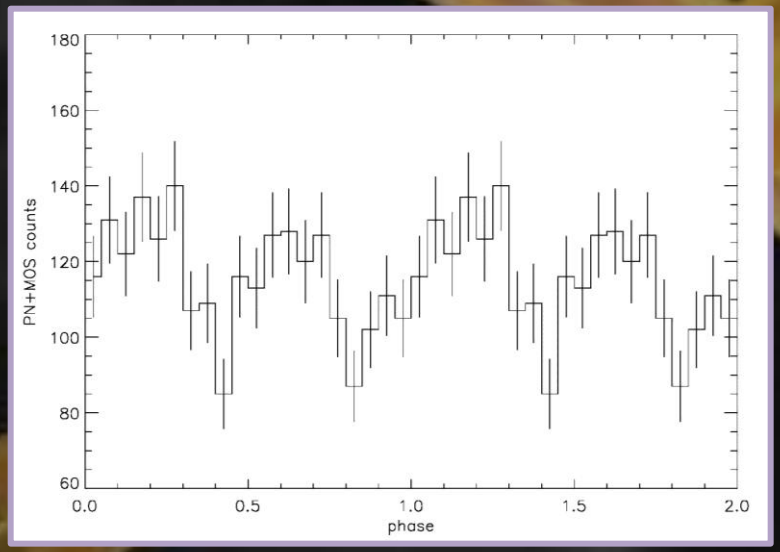
Total flux
χ^2_{red} ~ 3
Null hypotesis prob = 0.3%

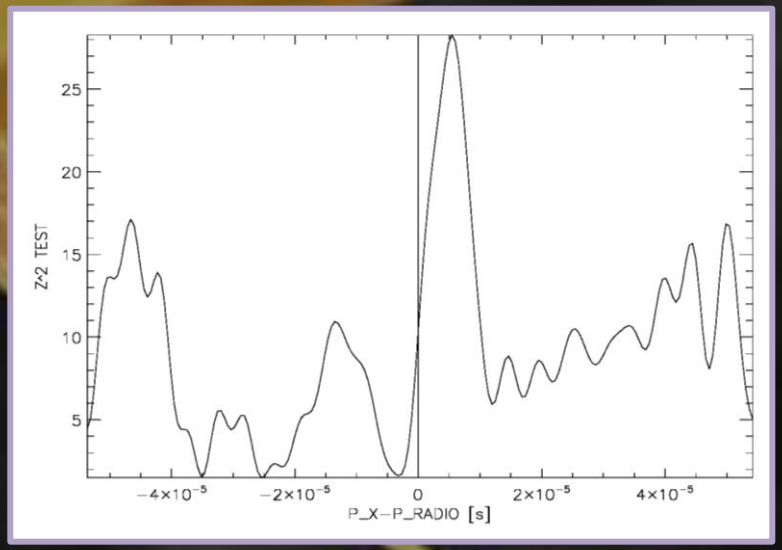


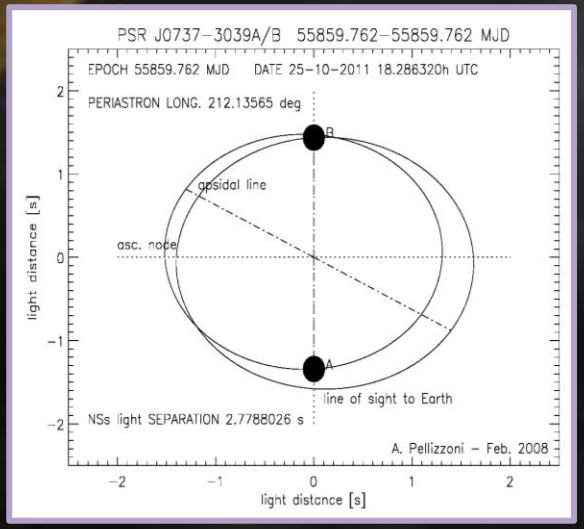
Total flux
χ^2_{red} ~ 5
Null hypothesis prob = 0.01%

Eight orbital phase intervals ~20 min

2011 detection of PSR B







- PSR B detected in 0.35 – 0.55 phase
- PSR B sup conjunction phase → 0.39

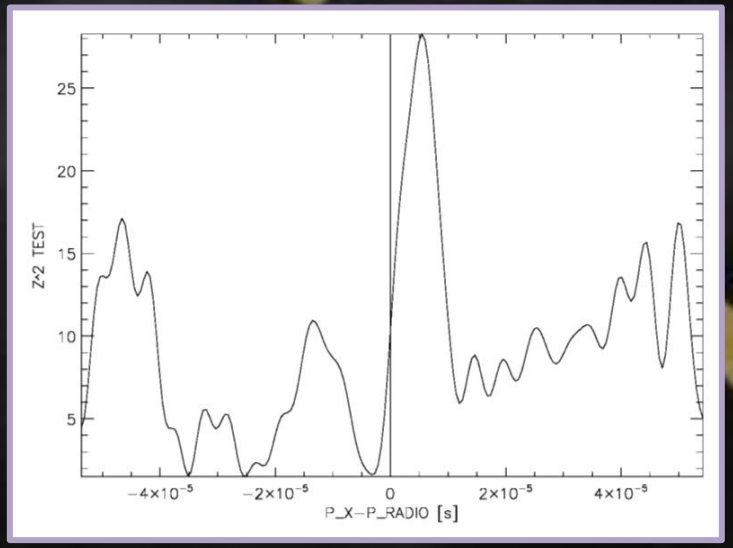
2006 detection confirmed

2011 detection of PSR B

- Frequency shift 6×10^{-6} (also observed in the 2006 data) possibly due to emission located in the upper part of the magnetosphere or in a shock region at some distance from the surface

- The orbital motion of the emission point is perhaps not perfectly corrected by the barycentering software, which however works well in the case of PSR A, as demonstrated by the Z^2 test and light curve

- This shift allows us to evaluate the altitude of the emission (work in progress…)




Thank you