Multi-component X-ray Spectral Analysis of the Double Pulsar System J0737-3039

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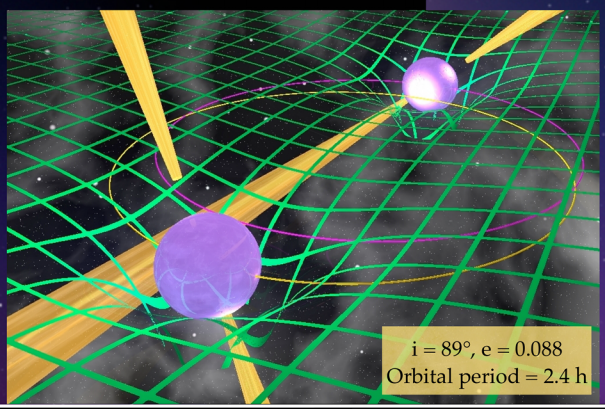
Discovered in 2003, PSR J0737-3039 is a rare and amazing system since two radio pulsars orbit each other. The high-energy study of such system is extremely interesting for understanding the physics of the magnetospheric emissions/interactions of both neutron stars.
We present the results of the spectral analysis of the 235 ks jointly with the 360 ks large-program observations performed by XMM-Newton in 2006 and 2011, respectively, using the EPIC-PN, MOS1 and MOS2 data. Multi-component models are required to properly account for the magnetospheric and surface emission from both pulsars and their interactions. Different possibilities are discussed in the frame of the complex multiwavelength model of the Double Pulsar.

PSR J0737-3039

PSR A

Fast, mildly recycled, old pulsar

P = 22.7 ms
M = 1.3381(7) M_{sol}
B = $6.3*10^9$ G
E_{rot}=$5.9*10^{33}$ erg/s
Age = 210 Myr



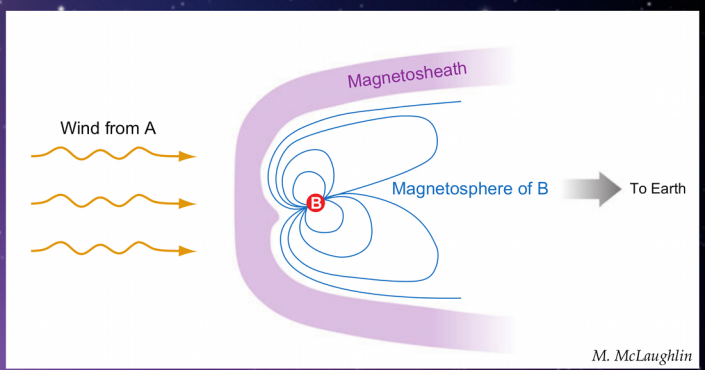
PSR B

Slower, young, «lazy» pulsar

P = 2.77 s
M = 1.2489(7) M_{sol}
B = $1.2*10^{12}$ G
E_{rot}=$1.7*10^{30}$ erg/s
Age = 50 Myr

High energy emission

The high energy observation of the double pulsar allows us to better understand the physics of magnetospheric emissions and their interactions.



Two large XMM-Newton programs

2006: 26 revolutions of the binary system => 235 ks

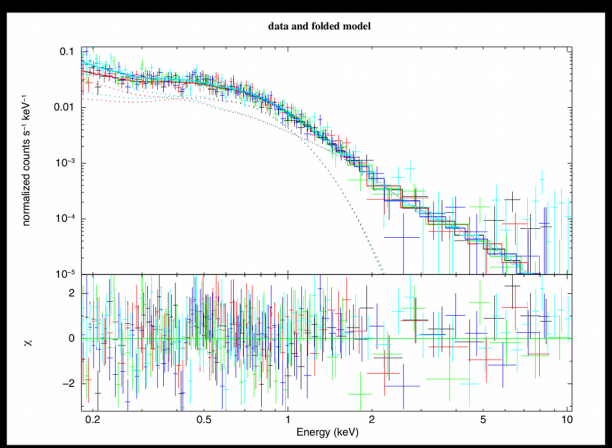
2011: 41 revolutions => 367 ks

Total: 15 spectra (5 PN and 10 MOS)

EPIC-PN/MOS cameras operated in the Small Window mode.
We used pattern = 0 for E < 0.4 keV and pattern = 0-4 for E > 0.4 keV in order to reduce the background.

The X-ray flux is about $F_{0.2\text{-}10keV}$= $4.3*10^{-14}$ erg/cm²/s which corresponds to an unabsorbed bolometric luminosity $L_X = 1.4*10^{30}\, d^2_{0.5}$ erg/s.

Results



Top panel: 2006 + 2011 EPIC-pn data points of PSR J0737-3039.
Bottom panels: Comparison of the residuals (Data−Model) in units of sigmas.
The model consists of: phabs*(power law + bbody). The χ^2_{red} associated is 1.04 (368).

At the moment, the best models able to fit simultaneously the 2006 and 2011 EPIC/PN and MOS data are phabs*(power law + bbody), with a soft photon index of 3.0 and k_BT=157.eV, and phabs*(bbody + bbody + bbody), where k_BT_1=108 eV, k_BT_2=222 eV and k_BT_3=989 eV. The X^2_{red} associated are 1.012 (566) and 1.009 (564).

Interesting features are visible in all of the EPIC/pn spectra:
- an absorption line at 0.4 keV ?
- an absorption line at 2.4 keV ?
- a component at higher energies (E > 5 keV) ?

The most relativistic binary system PSR J0737-3039 presents a variety of observational and theoretical properties. The high energy study of the double pulsar provides interesting information about the interactions of the magnetospheres of both neutron stars, and testifies of its complex X-ray phenomenology. Multi-component models are necessary for fitting the XMM-Newton data, and lead to different interpretations to explain the X-ray emission. X-ray photons may originate from heated polar cap(s), inverse Compton processes in the pulsar magnetosphere, and/or from the interaction between PSR A' wind and PSR B's magnetosphere.