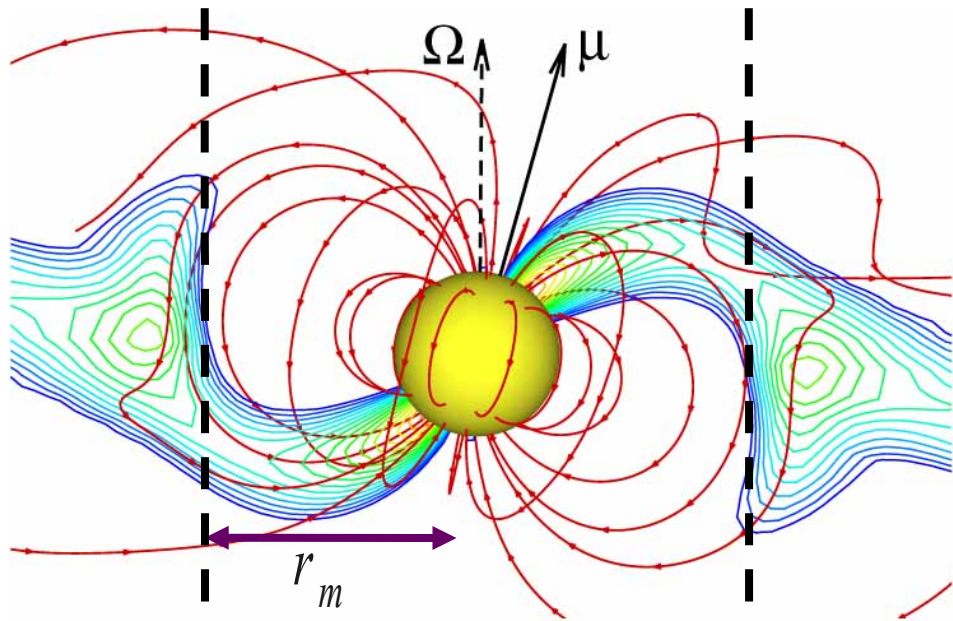


# Accreting Millisecond X-ray Pulsars

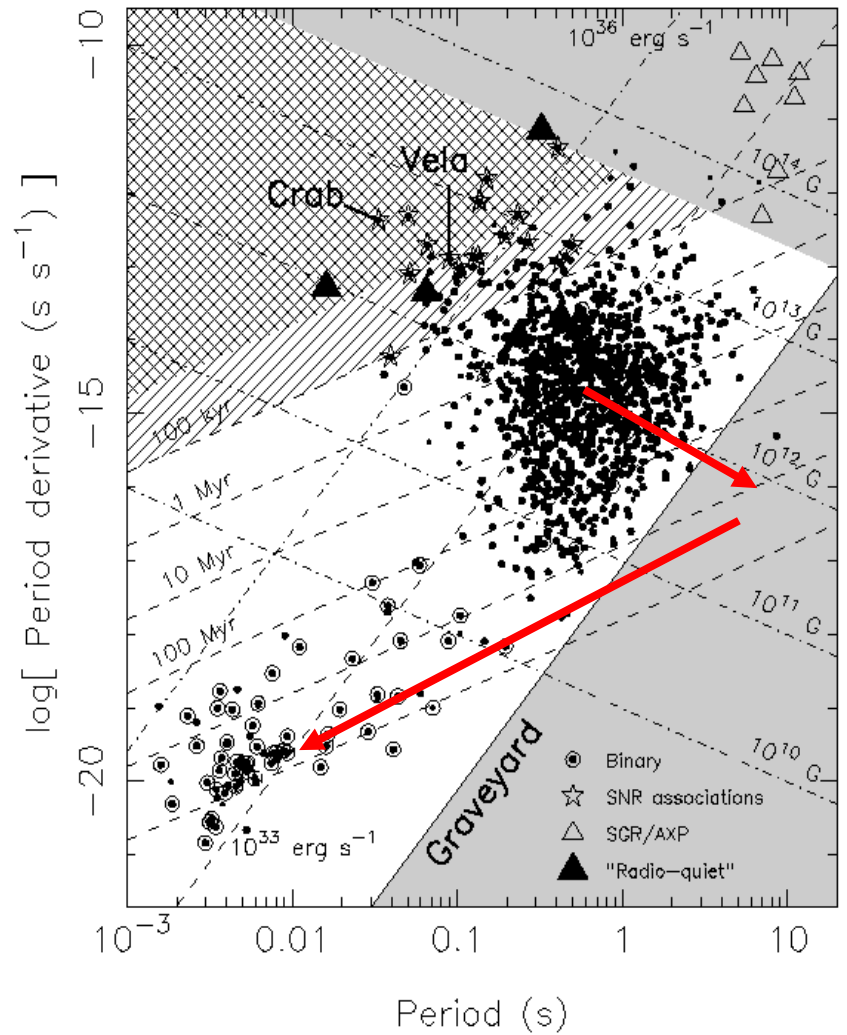
*Alessandro Patrino*

Astronomical Institute "A. Pannekoek"  
University of Amsterdam

# The disc-magnetosphere boundary



$$P_{mag} = \frac{B^2}{8\pi} \gg (P_{gas}, P_{ram})$$

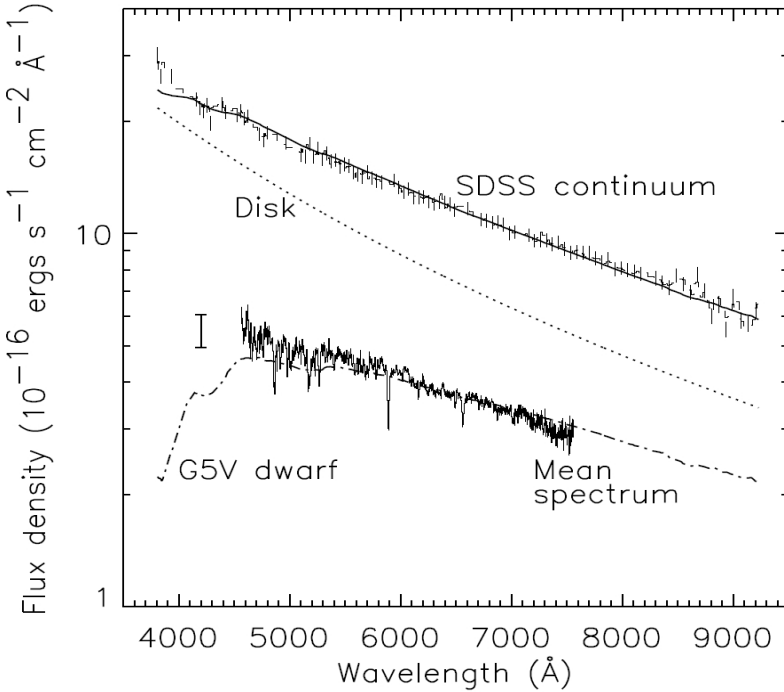


Taken from "Handbook of Pulsar Astronomy" by Lorimer & Kramer

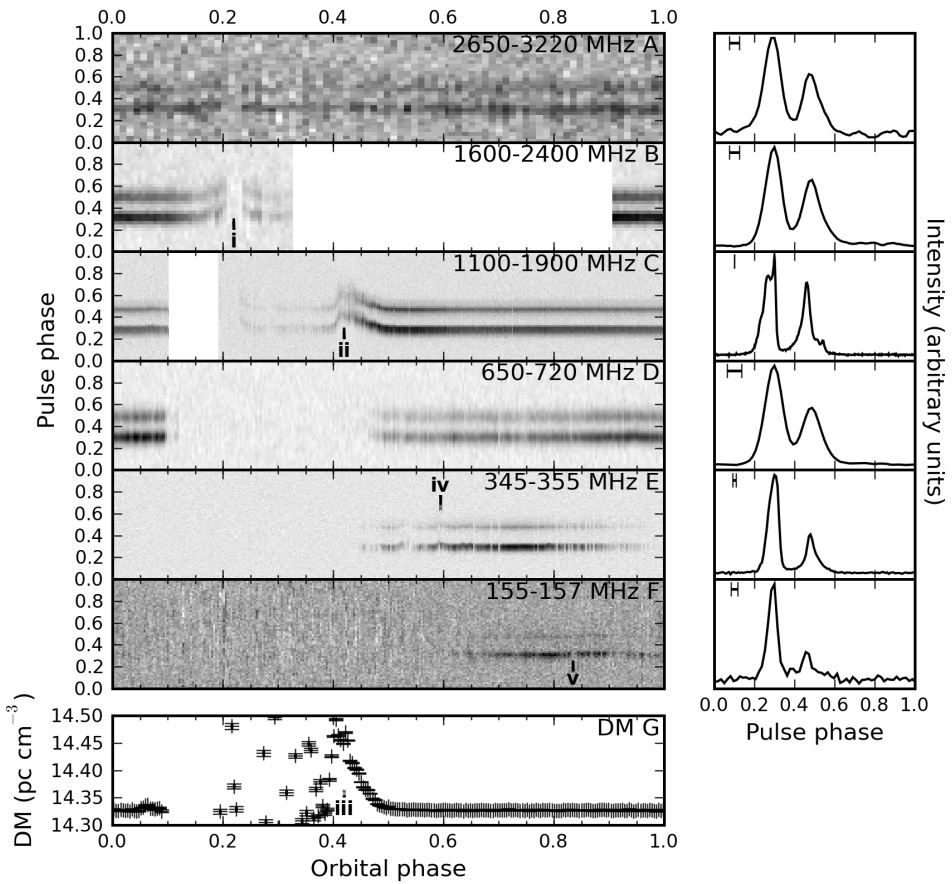
# Radio ms pulsar with an accretion disc ?

## Pulsar Parameters

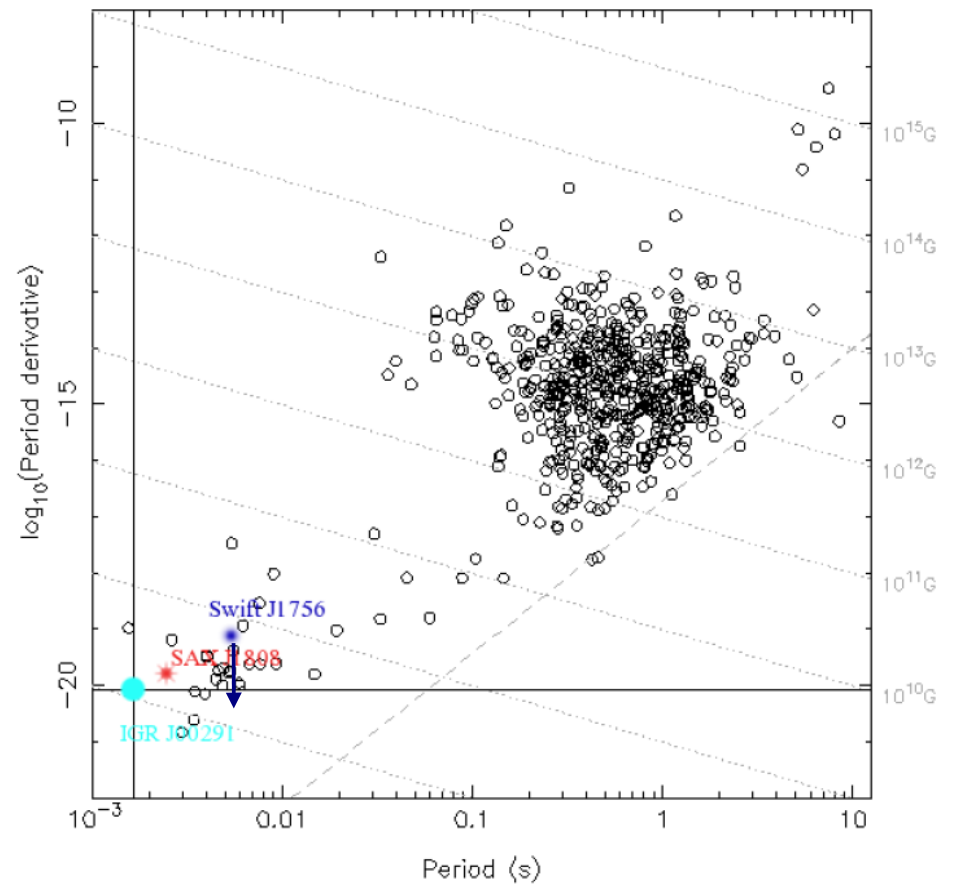
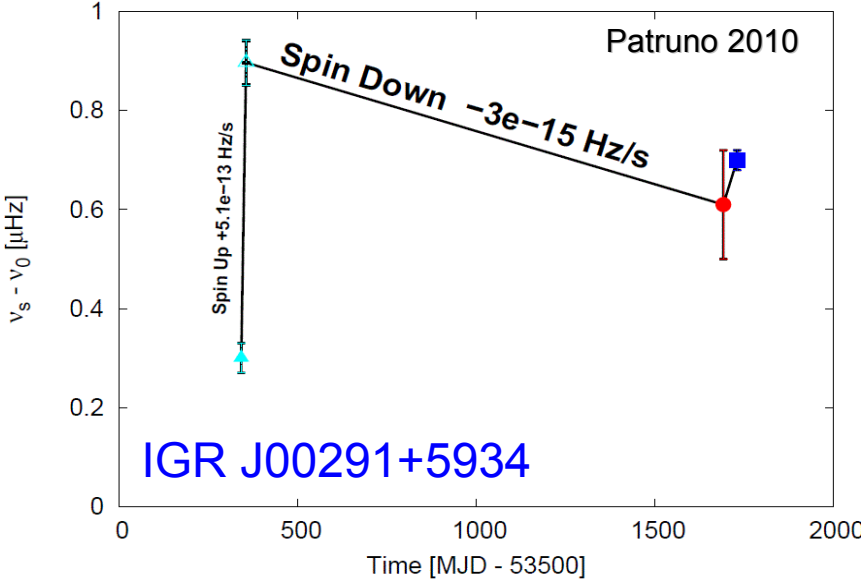
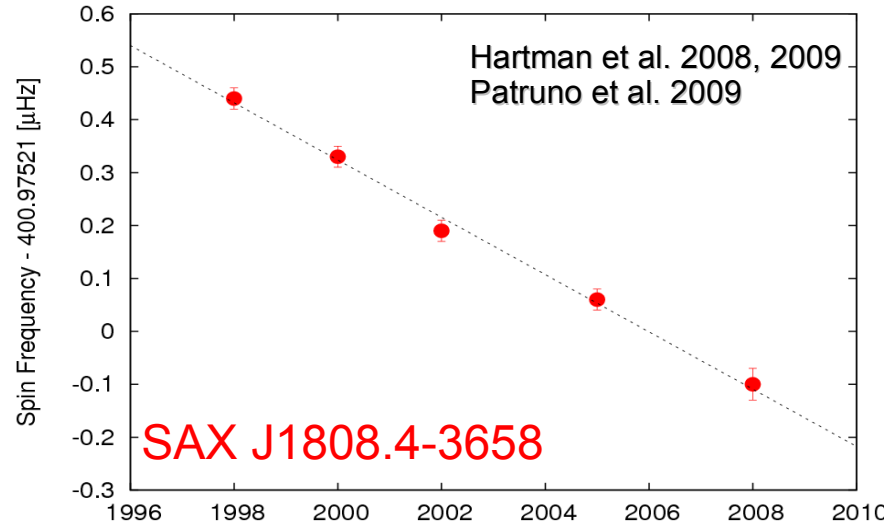
- 1.69 ms spin period
- 4.8 hr orbital period
- 0.2 Msun companion



## PSR J1023+0038

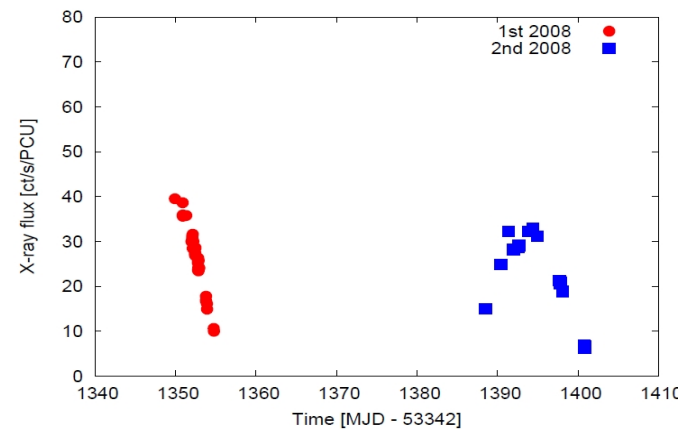
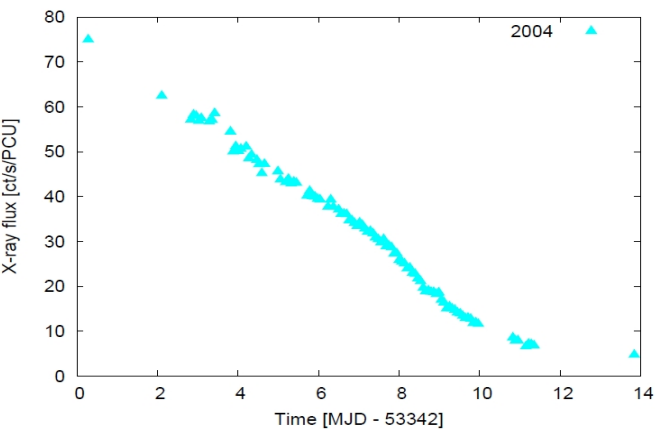


# Recycling scenario in two AMXPs



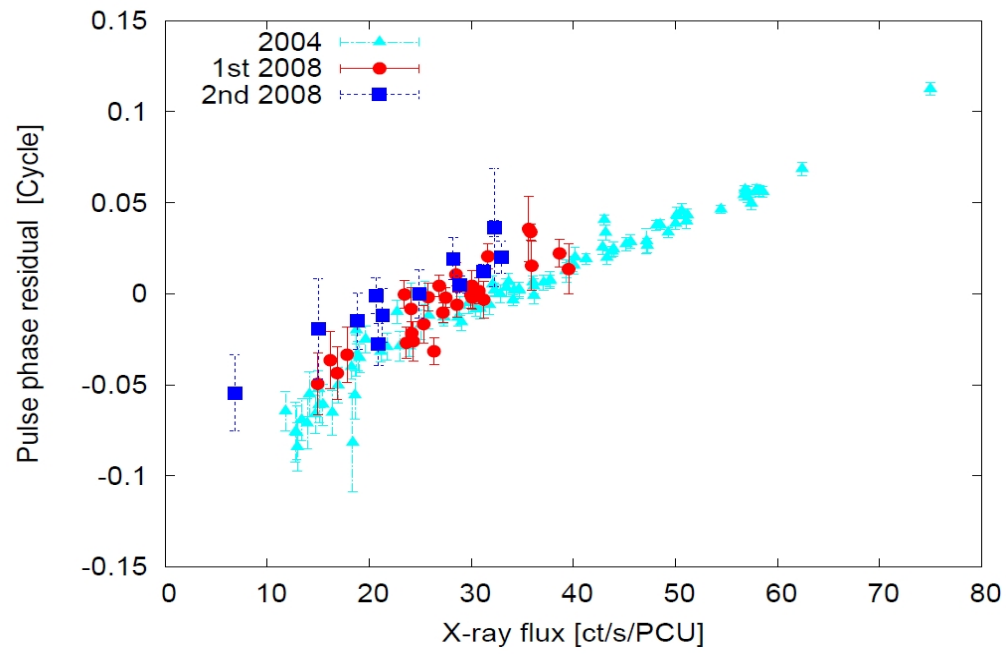
IGR J00291+5934	$1.5 - 2.0 \times 10^8 \text{ G}$
SAX J1808.4-3658	$2.0 - 2.8 \times 10^8 \text{ G}$
Swift J1756.9-2508	$0.4 - 9 \times 10^8 \text{ G}$

# Moving Hot Spot ?



Spin frequency: 599 Hz

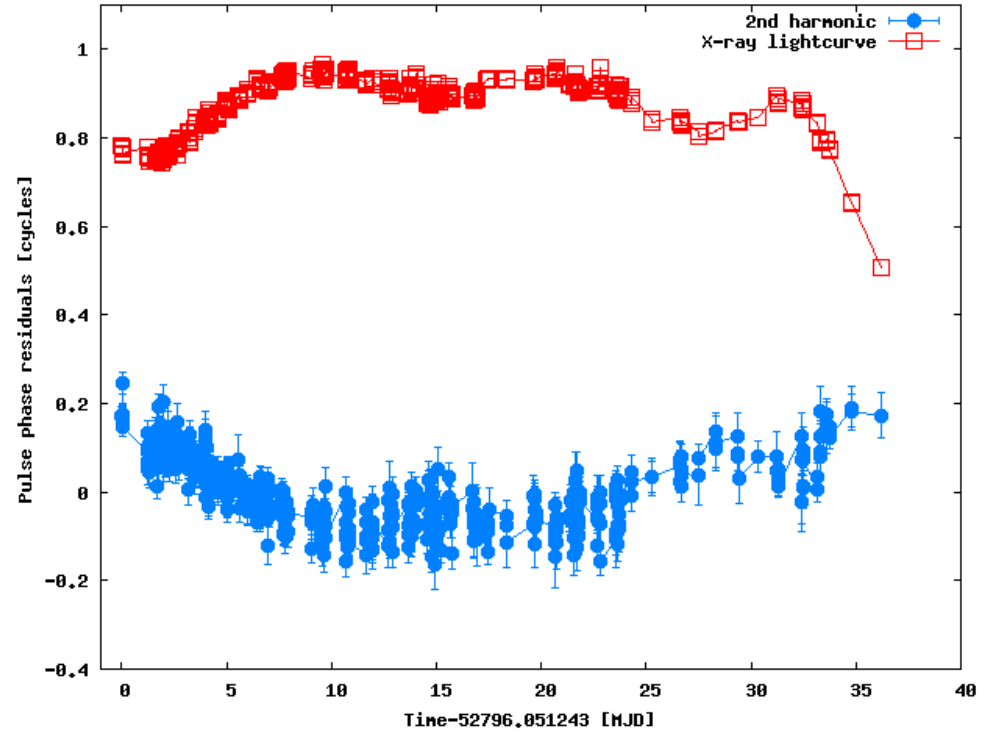
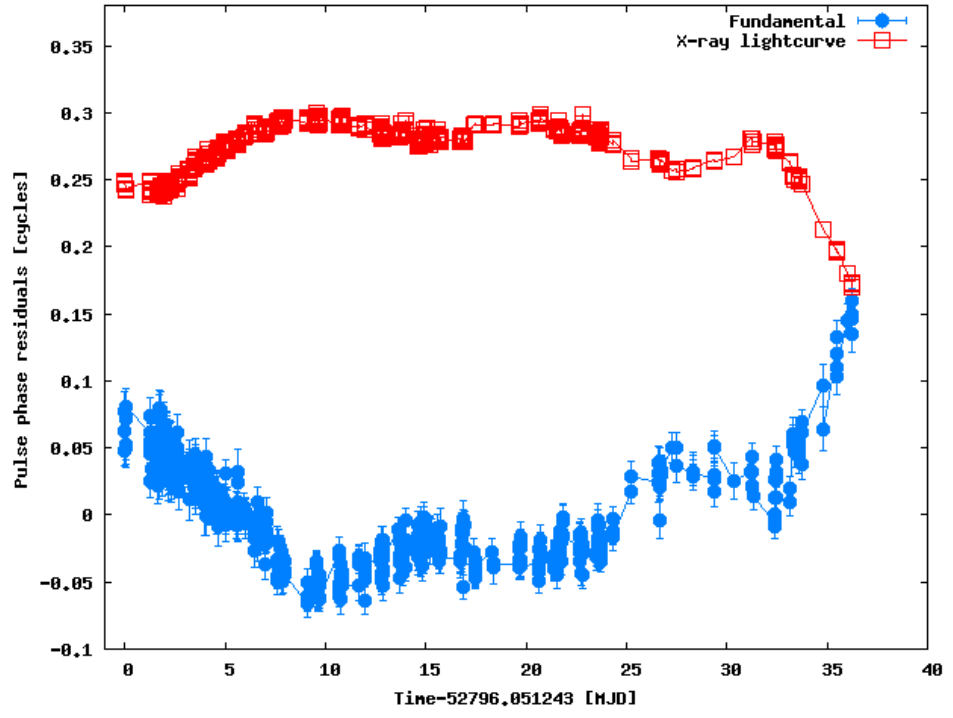
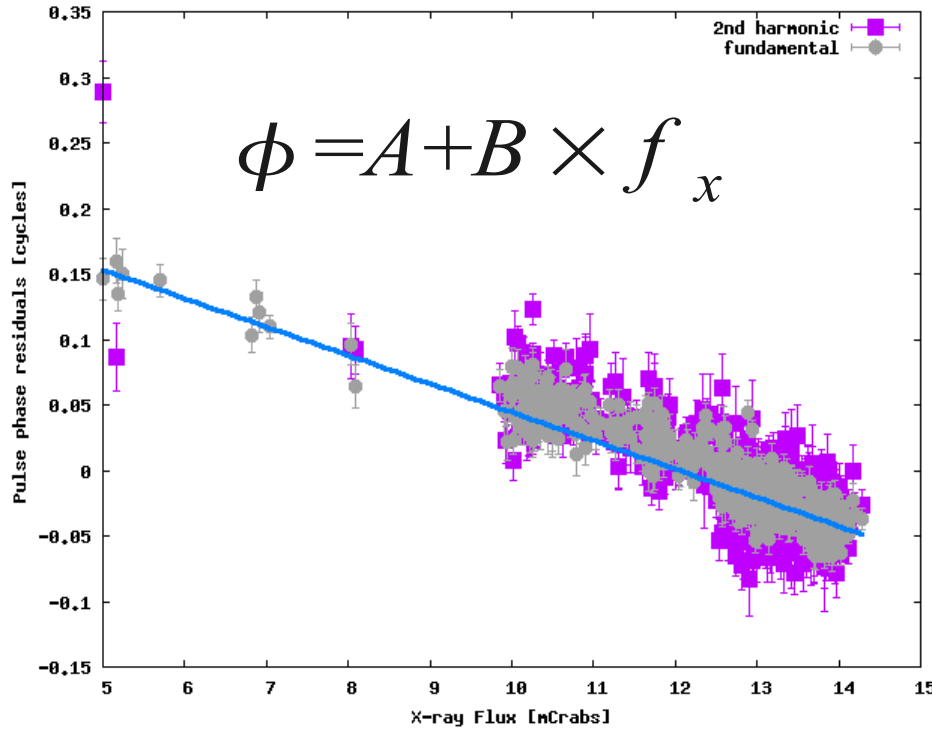
Ordered process is present in all outbursts and manifests itself with the *same* effect of X-ray flux on pulse phases



# XTE J1814-338

$$\phi(t) = \phi_0 + \nu(t - t_0)$$

$$\dot{\nu} = \frac{d^2 \phi}{dt^2}$$



# Torques in accreting millisecond X-ray pulsars

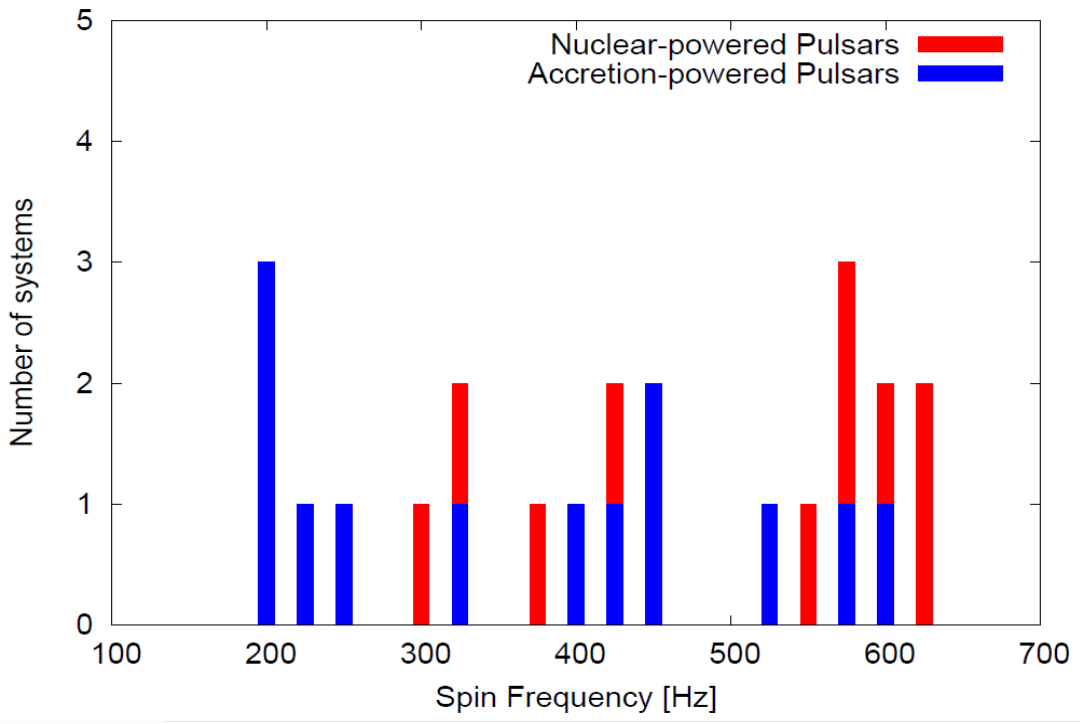
$$N = \dot{M} \sqrt{GM r_m} = 2\pi I \dot{\nu} \propto f_x^{6/7} \xrightarrow{\text{Expected}} \dot{\nu}_{1814} \approx 10^{-13} \text{ Hz s}^{-1}$$

$$\phi = A + B \times f_x \xrightarrow{\text{Corrected}} \dot{\nu}_{1814} < 10^{-14} \text{ Hz s}^{-1}$$

**EVIDENCE THAT ACCRETION TORQUES ARE MUCH SMALLER THAN EXPECTED ?**

- Pulsar close to spin equilibrium ?
- Negative Torques balancing Accretion Torques ? (e.g., GWs ?)

# IGR J00291+5934: close to spin equilibrium ?

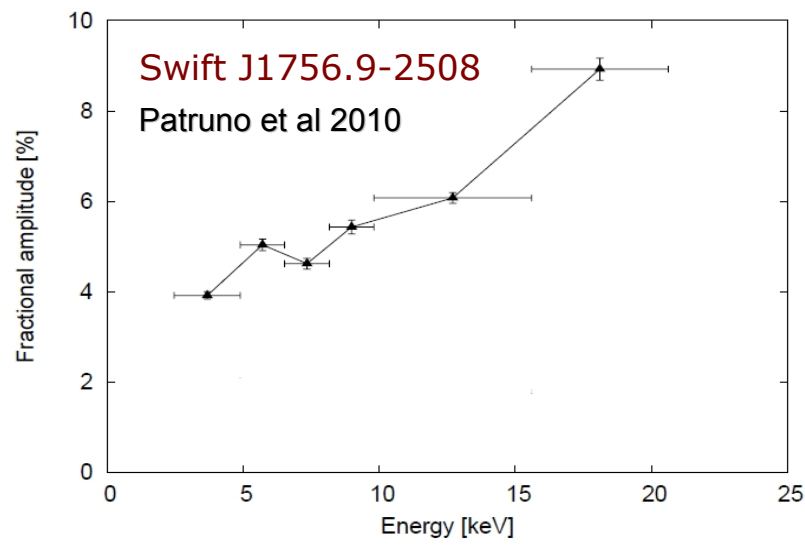
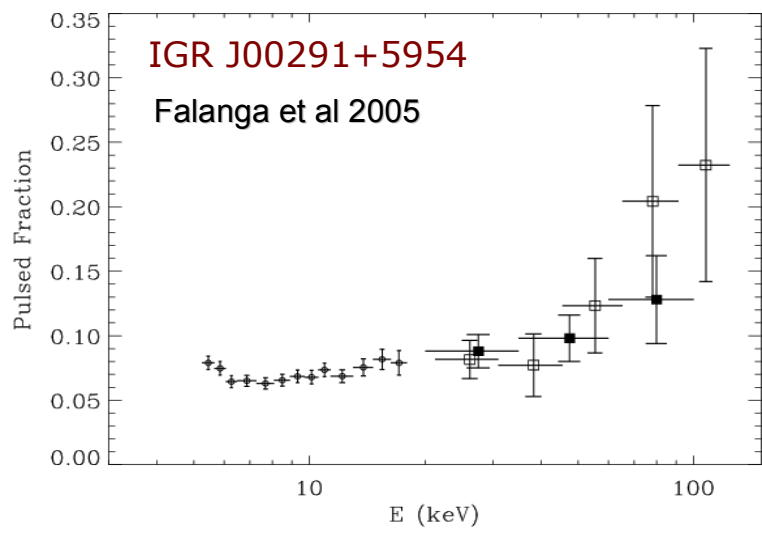
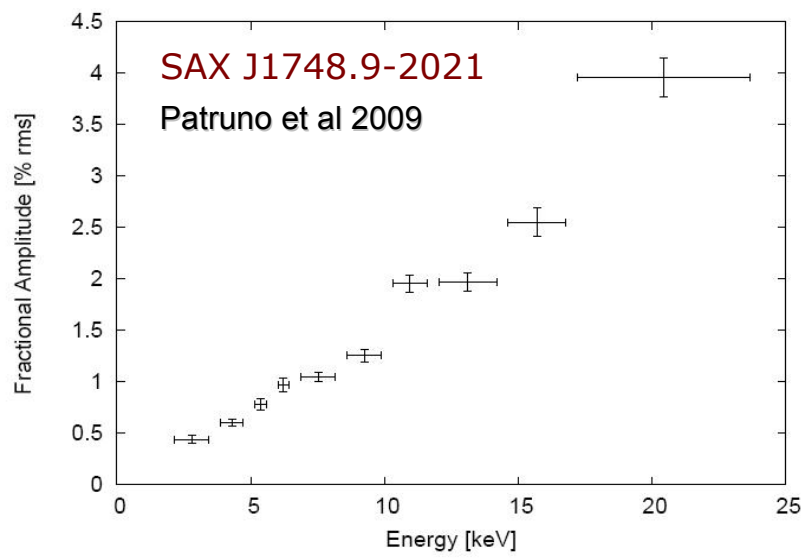
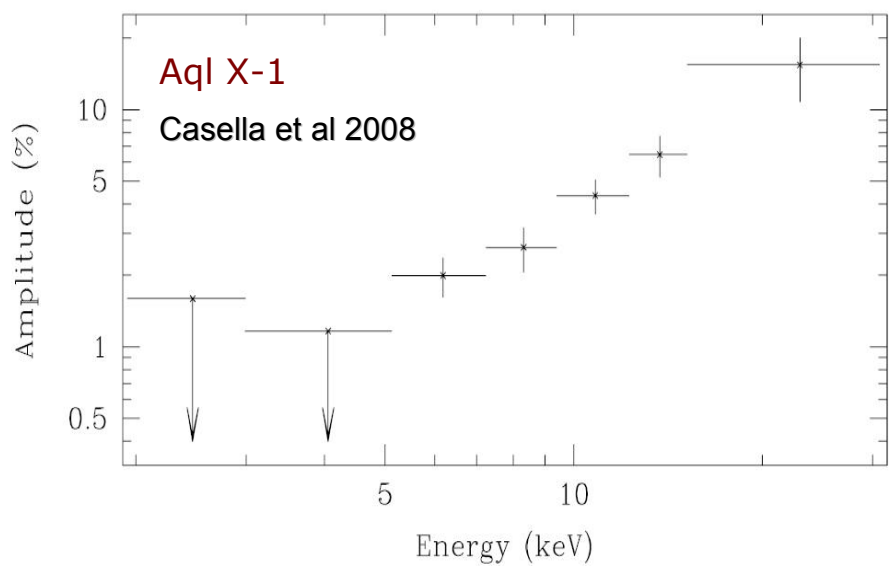


**REMARKABLE POINT:**

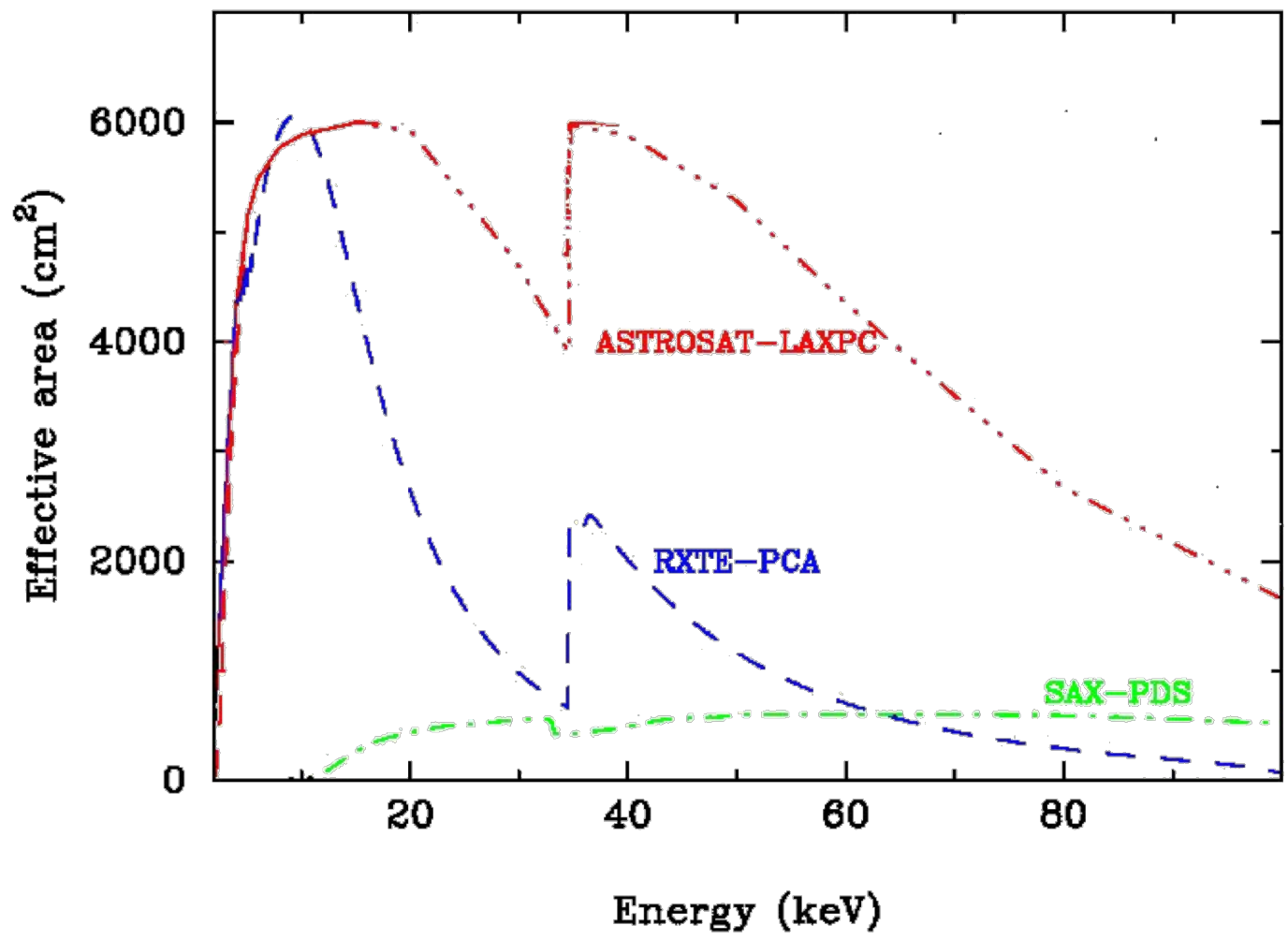
*Cutoff distribution still at ~730 Hz after increasing sample size by a factor 3*

Is there any hope to find sub-ms pulsars ?

# Increase of signal strength at high energies



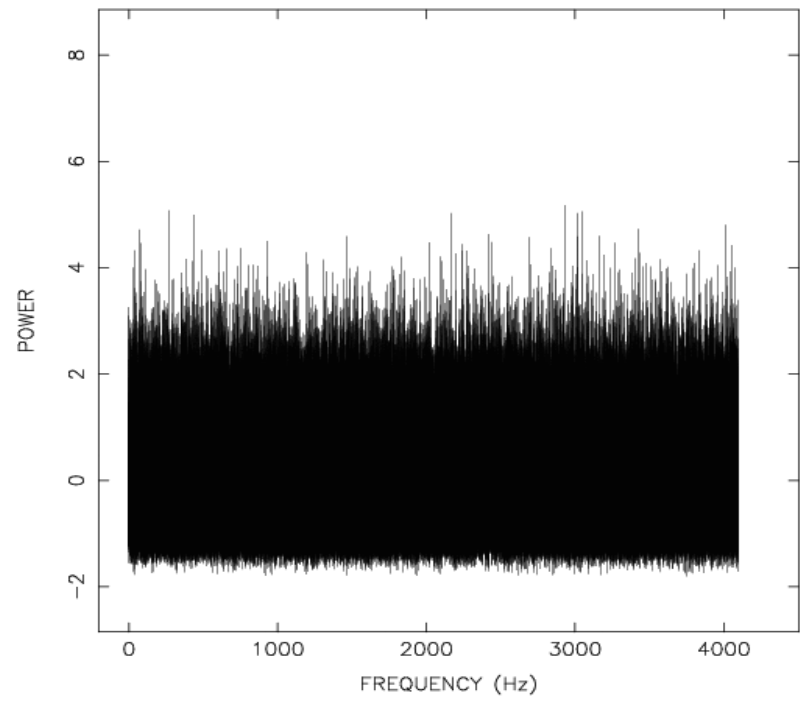
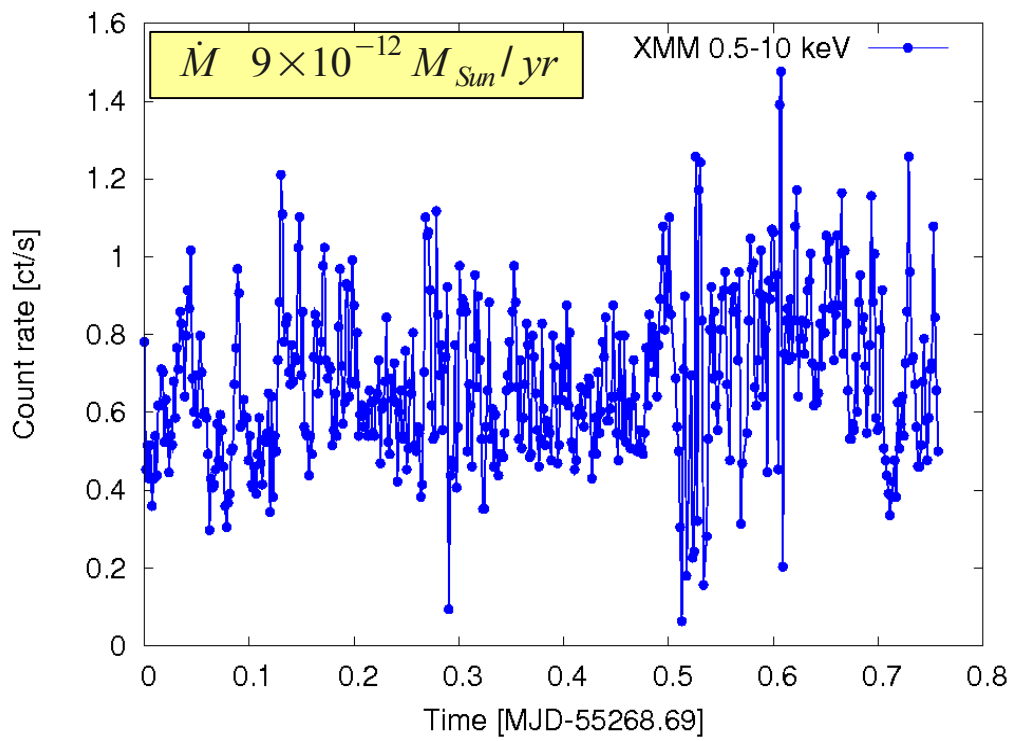
# ASTROSAT vs. RXTE



# Conclusions

- Evidence that AMXPs are progenitors of radio ms-pulsars is close to final.
- Some AMXPs show no evidence of accretion torques. GW torques ? Spin equilibrium ?
- ASTROSAT will be crucial to find new AMXPs and to study long term spin evolution

# The Very Faint source 1RXSJ171824.2-40293



~65 ks of *continuous*  
on-source observation

**OPTIMAL OBSERVATION FOR  
SIDEBAND SEARCH**

No pulsations detected with  
upper limits of a few % rms