Discovery of coherent X-ray pulsations in the sub-luminous disk state of XSS J12270-4859

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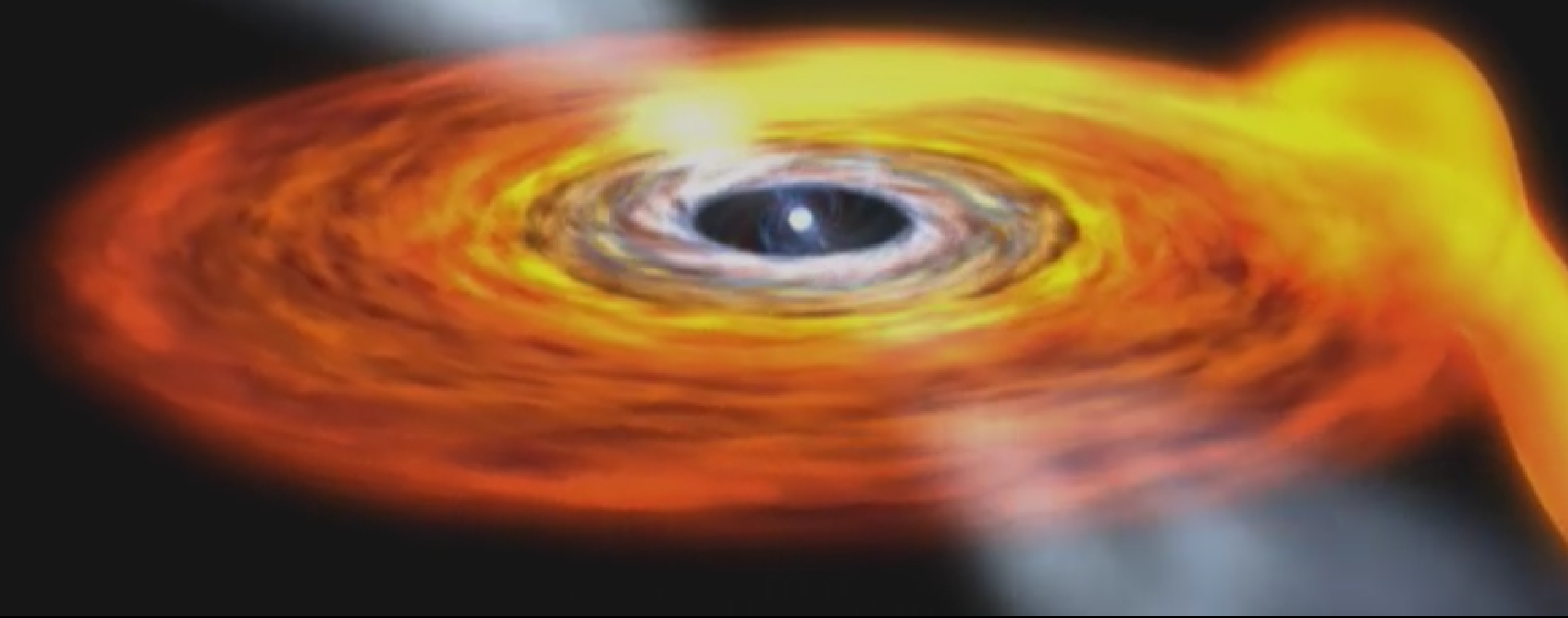
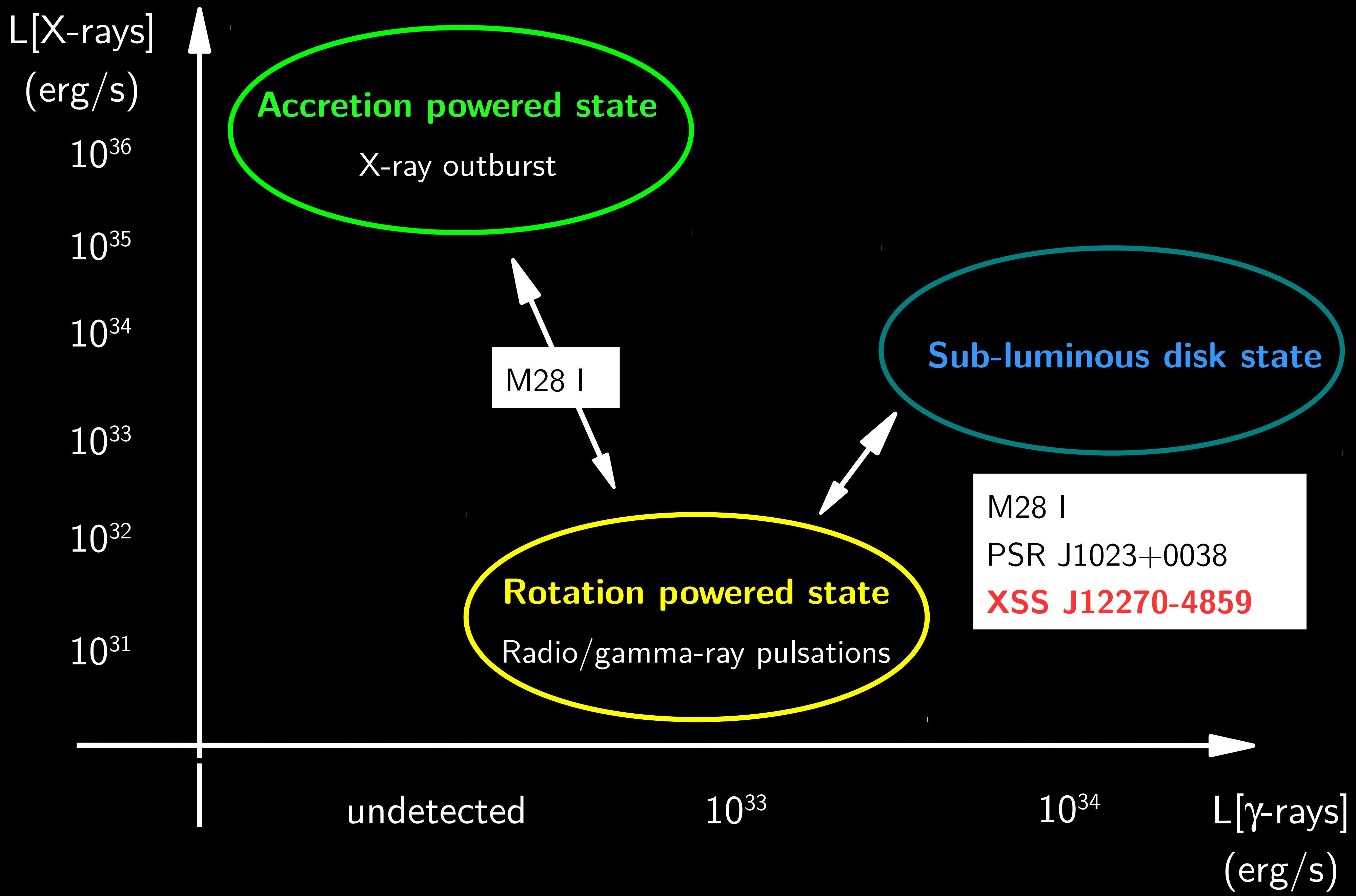


25.6.2015 – NS at the crossroads: X-ray binaries and transitional ms pulsars
EWASS 2015 – La Laguna, Tenerife, Spain

The three states of millisecond pulsars



The sub-luminous disk state

Accretion disk (Hα broad line);

X-ray luminosity $\sim 10^{33} - 10^{34}$ erg/s, variable,
Spectrum described by a power law with $\Gamma\sim1.5$. No cut-off up to ~80 keV;

Radio bright emission with flat spectrum;

Gamma-ray ($>$0.1 Gev) luminosity $\sim 10^{34}$ erg/s; 5-10 times brighter than in radio pulsar state;

Systems can persist in the sub-luminous state for a decade.

What is powering the emission? Accretion or rotation power?

XSS J12270-4859

Sub-luminous disk state

X-ray luminosity ~10^{34} erg/s

Fermi gamma-ray counterpart

same state during 2003-2013

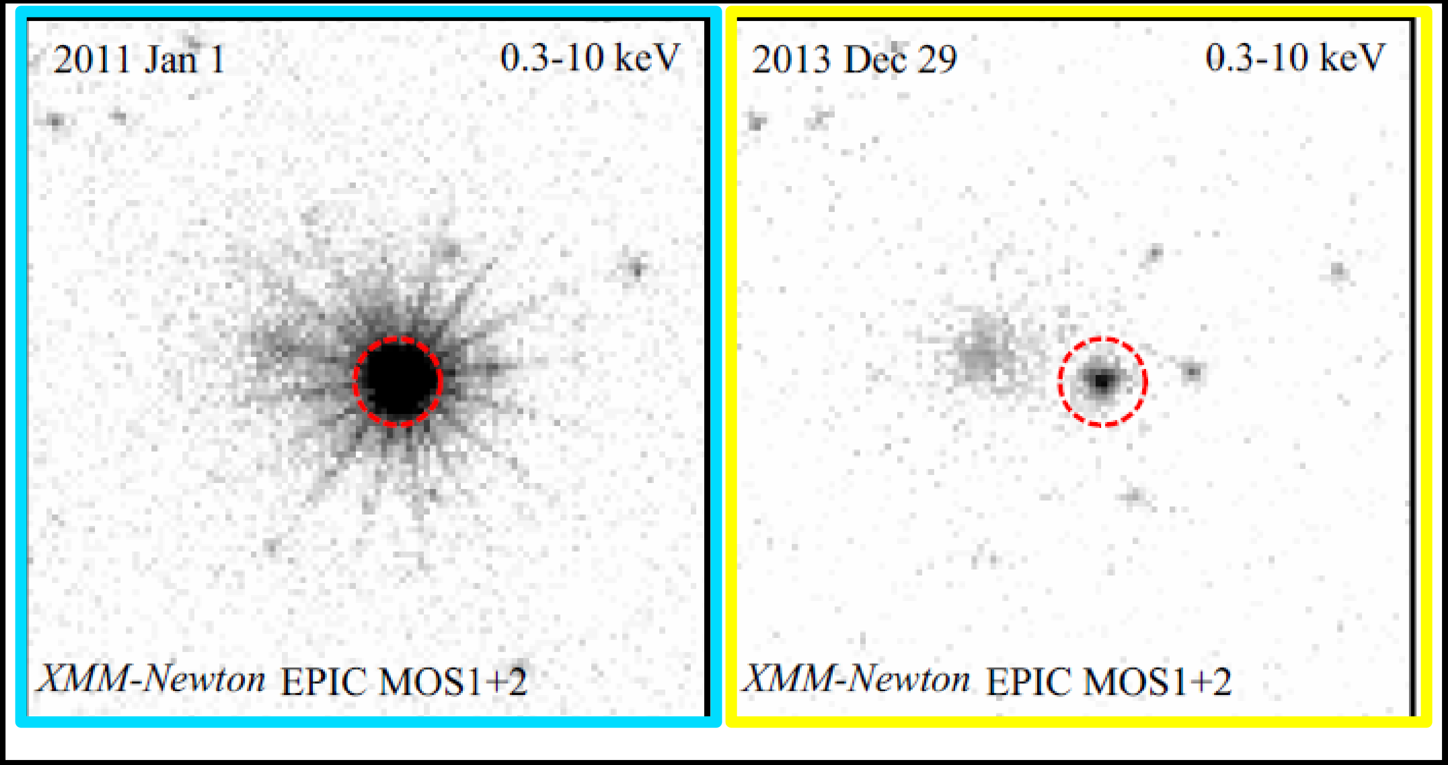
[De Martino+2010,2013; Saitou+2010; Hill+2011]

Radio PSR state

Very faint in X-rays (~10^{32}) erg/s

No disk

[Bassa+2014, Bogdanov+2014, Roy+ 2014]



Sub-luminous disk state: X-ray pulsations

XMM-Newton detection of pulsations at the 1.7 ms spin period by performing a search around the radio PSR ephemerides

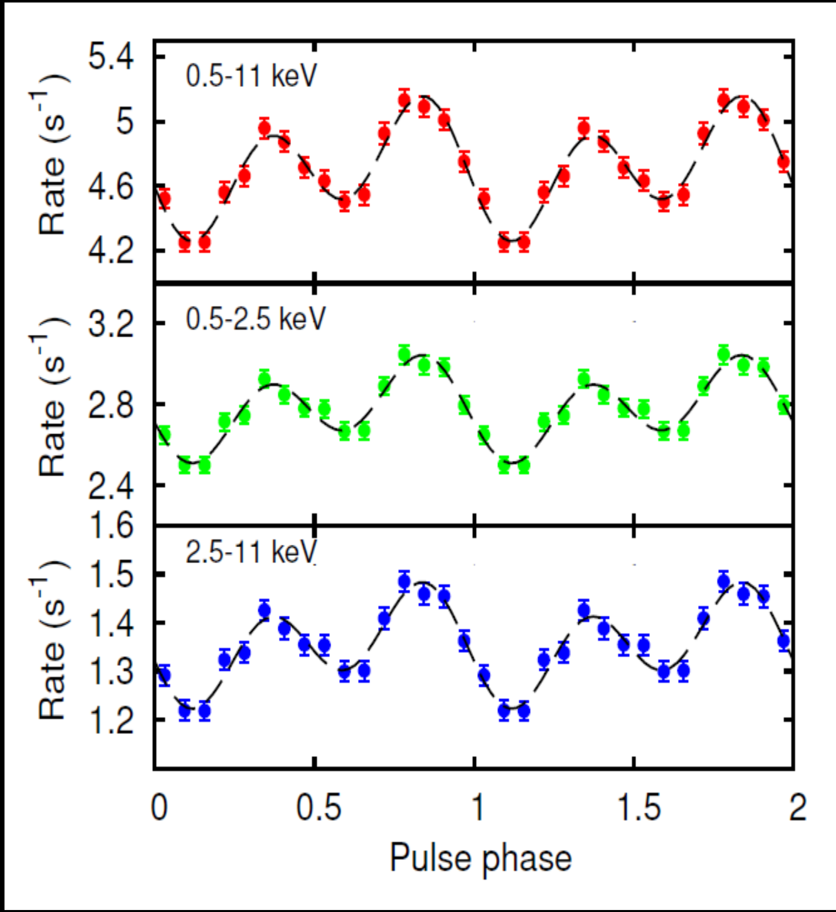
$A_{RMS}=(7.7 \pm 0.5)\%$

$A_{2nd}/A_{1st} = 1.8$

Pulsations not detected in radio PSR state ($A_{RMS}<7\%$)

Pulsed flux ≥ 10 times larger than during radio PSR state → **accretion origin**

Similar pulse shape in soft (0.5-2.5 keV) and hard (2.5-11 keV) XMM band



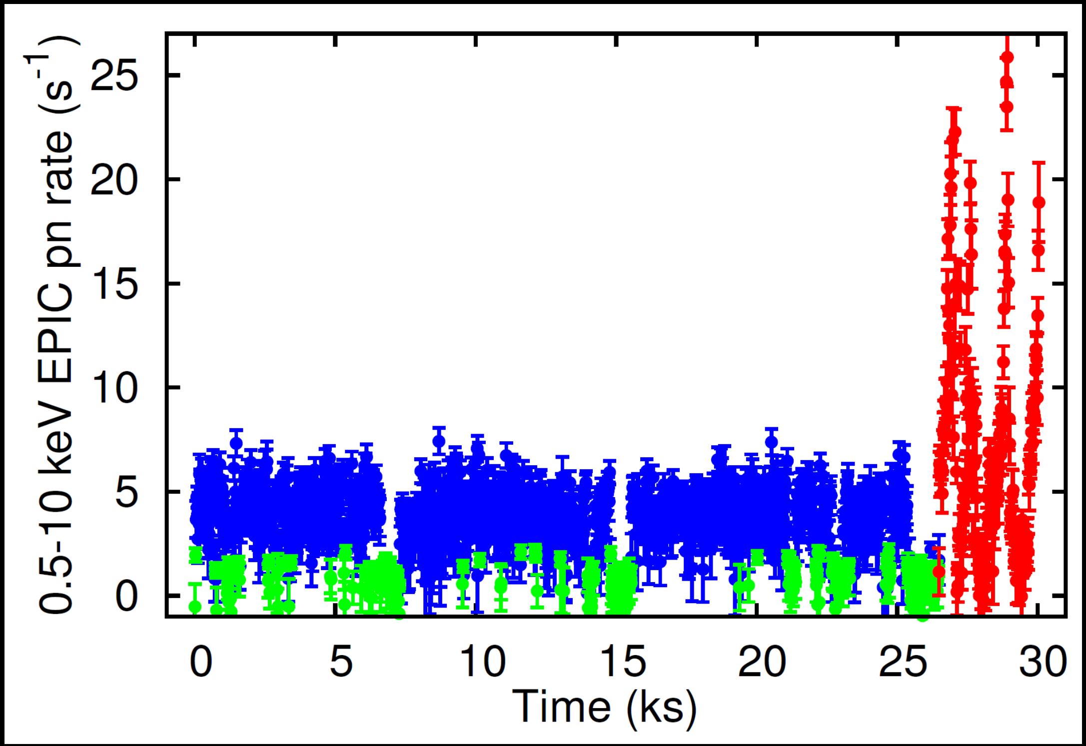
Papitto et al. 2015, MNRAS, 449, L26

Sub-luminous disk state: X-ray pulsations

Pulsations detected only in **high state**

In **low** ($A_{RMS} < 5.8\%$) and **flaring state** ($A_{RMS} < 2.7\%$) no detection

Very similar behavior observed from PSR J1023+0038 in the sub-luminous disk state [Archibald et al. 2015]



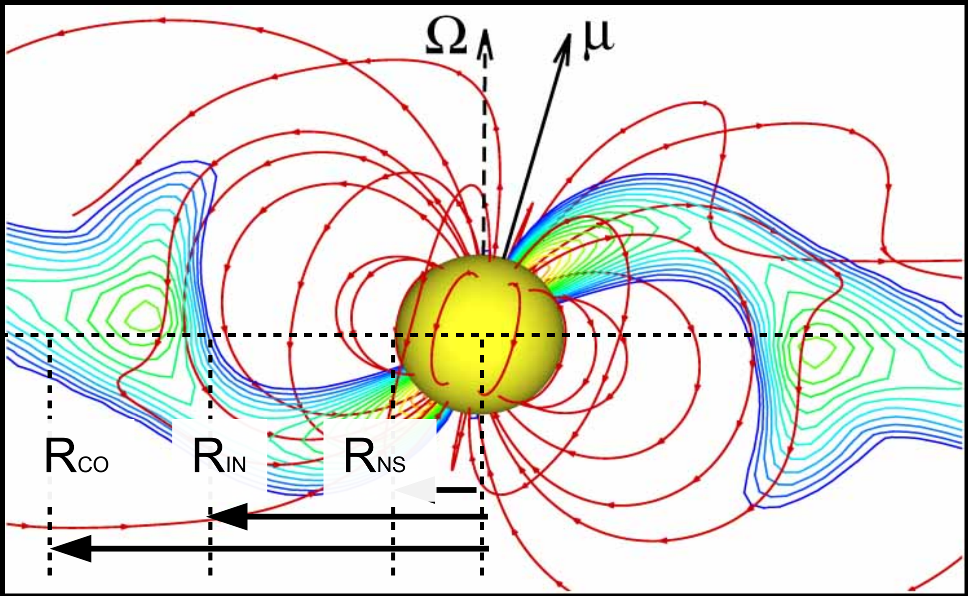
Papitto et al. 2015, MNRAS, 449, L26

Implications of X-ray pulsations

Pulsations detected at L_X=5x10^{33}erg/s

~100-1000 times lower than AMSPs

$$R_{\rm in} = k_m R_{\rm A} = k_m \left[\frac{\mu^4}{2GM_* \dot{M}_d^2} \right]^{1/7}$$

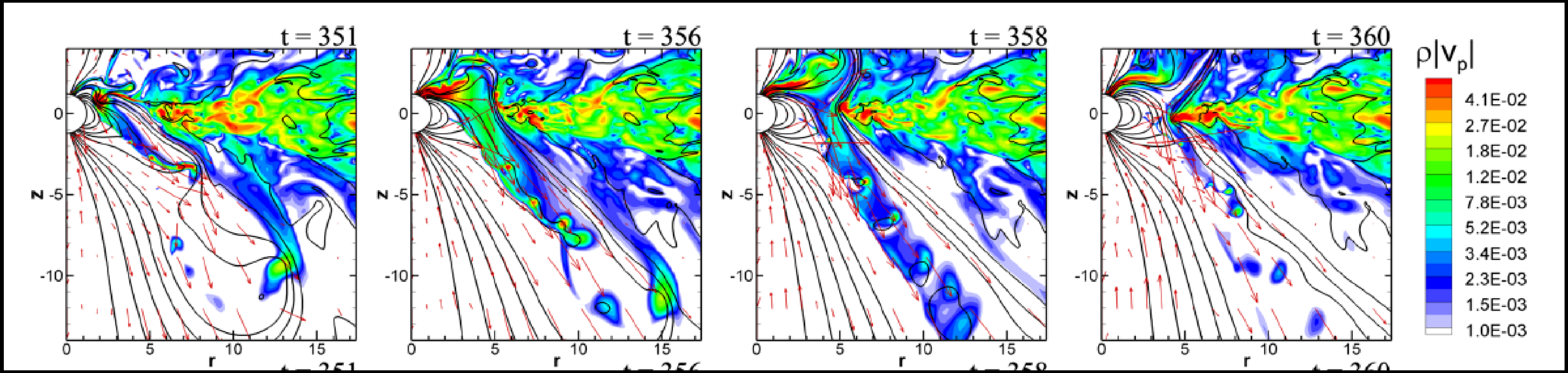


The mass accretion rate on the NS surface is 100 times smaller than the one required to keep the magnetosphere inside the corotation radius.

$(dM/dt)_{disk} \sim 100\ (dM/dt)_{NS}$ to have Rin ~ Rco

More than 95% of the inflowing mass ejected (e.g. through the propeller effect) or accumulated in the disk.

Propeller outflows



3d MHD simulations of propeller ejection of matter

Lii, Romanova+ 2014 – for a disk terminated close to the corotation surface, part of the inflowing mass manages to accrete and part is launched in an outflow.

→ Accretion and outflows can coexist

The gamma-ray emission

Ecut ~ few GeV

→ radio pulsar models, GeV electrons of magnetospheric origin

→ propeller model, electrons accelerated at the turbulent disk-magnetospheric boundary

Propeller hypothesis:

→ **synchrotron** (up to MeV)

→ **self-synchrotron Compton** (up to GeV)

A solution found for:

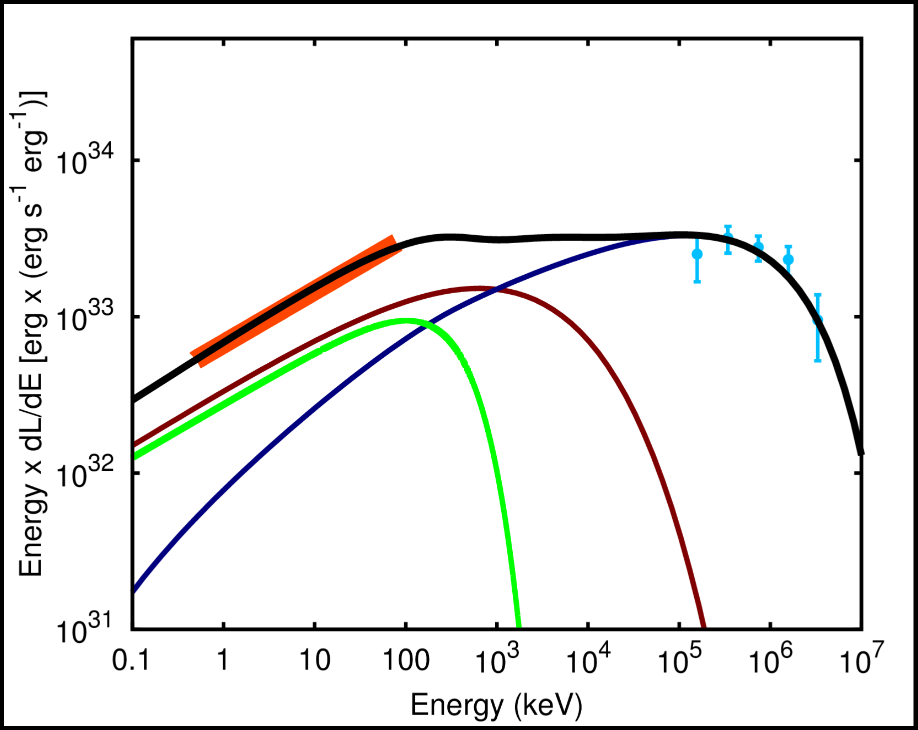
Rin = 1.8 Rco

$(dM/dt)_{disk} = 2.4\times10^{-11}$ Msun/yr ~30 $(dM/dt)_{NS}$

Papitto & Torres 2015, ApJ, in press

Papitto, Torres, Li, 2014, MNRAS,

(see Diego Torres talk later this morning)



Discussion & Conclusions

Possible scenarios for the sub-luminous disk state:

- a **rotation powered pulsar**:
  X-ray pulsations unlikely (not observed in the radio pulsar state);
  Bolometric luminosity too high (close to or larger than spin down power);

- a **purely accreting pulsar**:
  X-ray luminosity too low (predicted inner disc radius $\sim$ 5 Rco);

- a **propeller model** (with a fraction of the mass accreted) accounts for the bolometric high energy luminosity and qualitatively explains the radio and the gamma-ray emission;

- **Are all sub-luminous accretors pulsars? (need for new instruments)**

A parallel session on X-ray binaries and pulsars

Abstract submission before September 15 at
https://indico.cern.ch/event/336103/