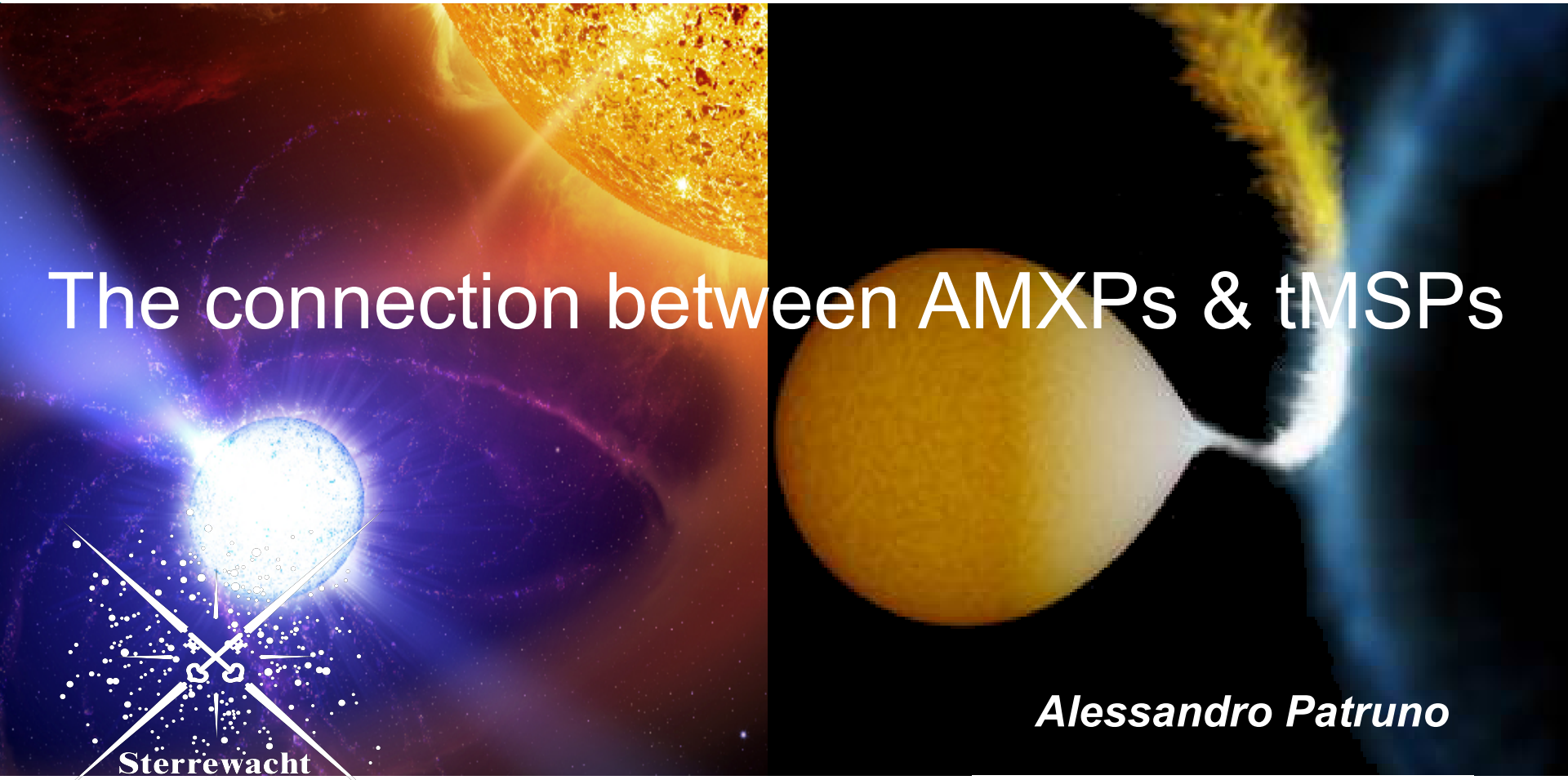
The connection between AMXPs & tMSPs



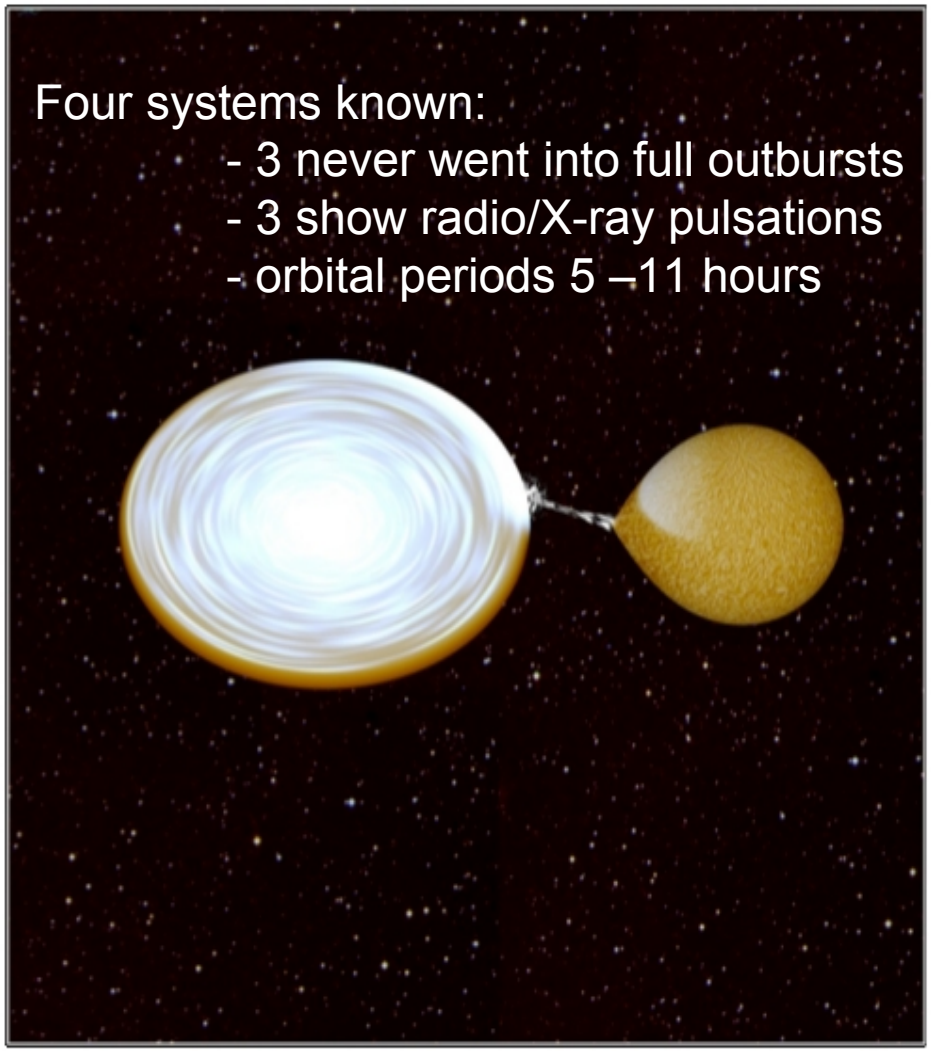
Alessandro Patruno

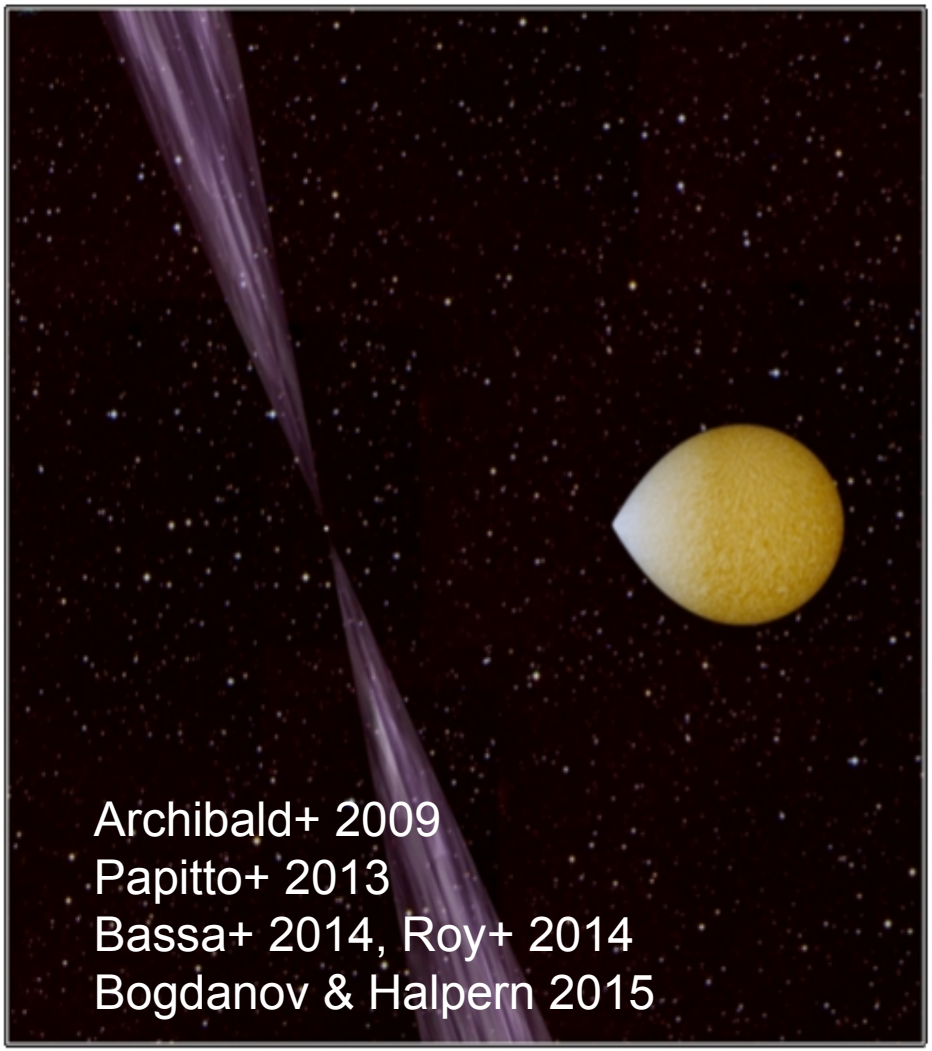
Sterrewacht Leiden

ASTRON
Netherlands Institute for Radio Astronomy

Universiteit Leiden
The Netherlands

Transitional MSPs



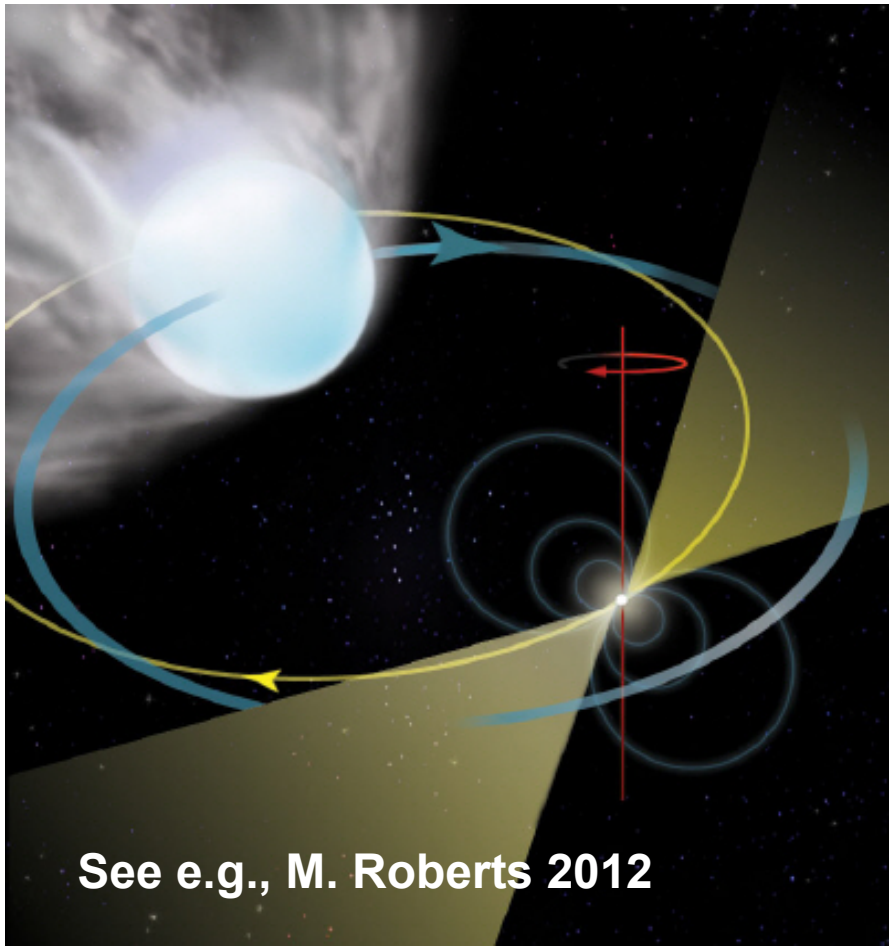


Redbacks

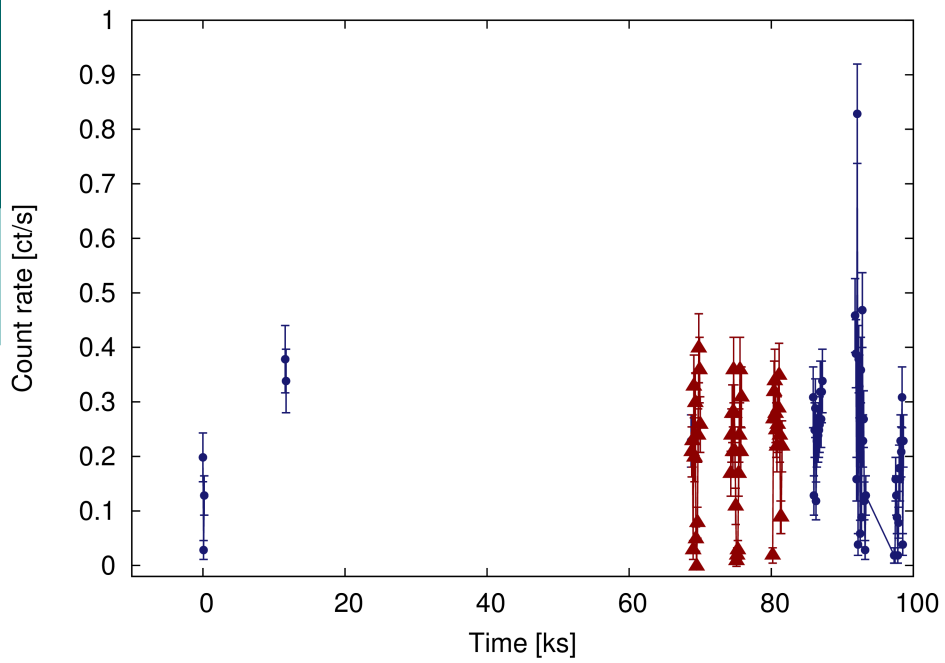
Black widows:
(semi)-degenerate companion

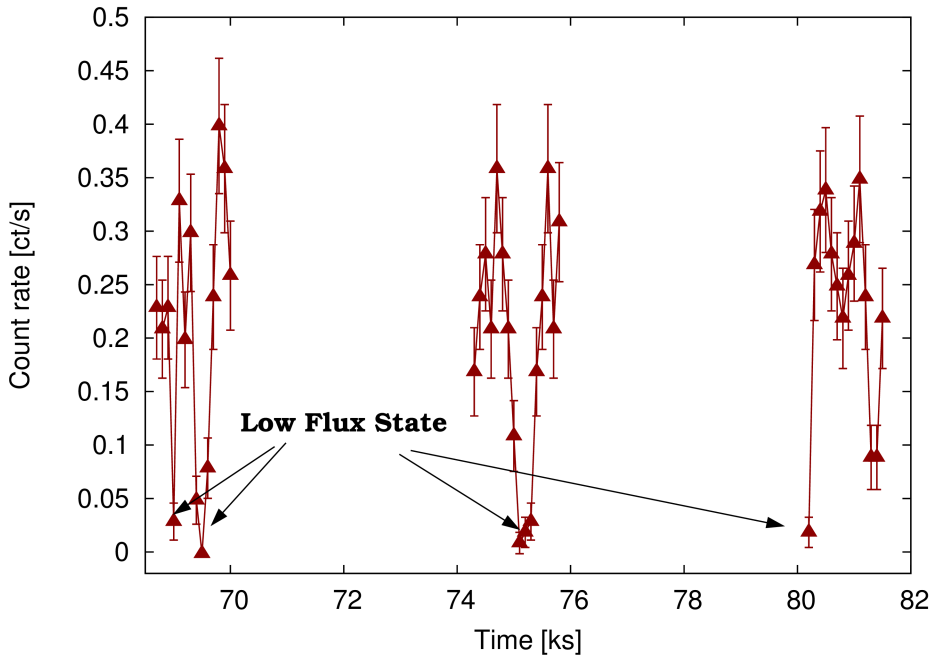
Redbacks:
non-degenerate companion

All 4 tMSPs belong to the Redback class



Unexplained Flickering

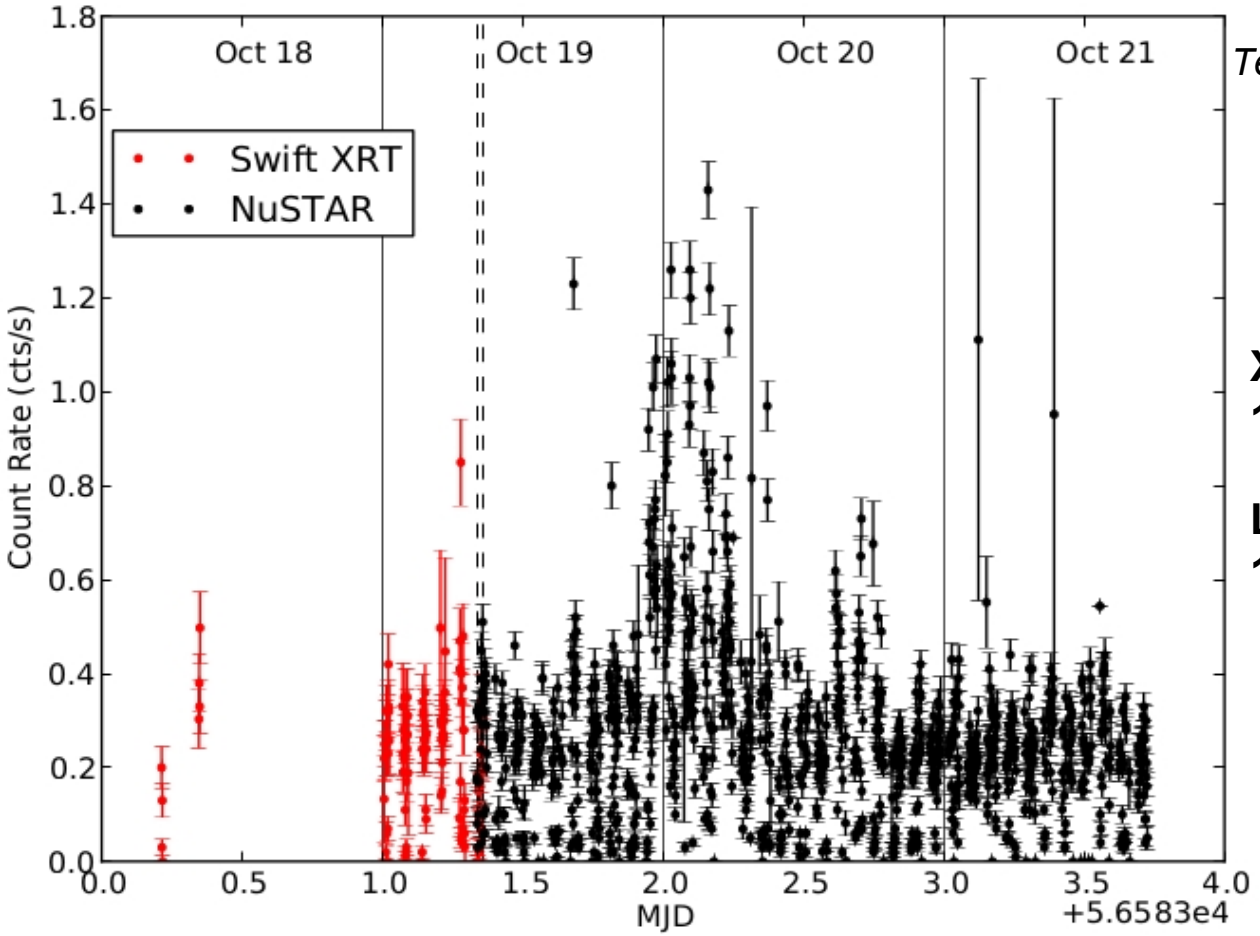




Swift/XRT 0.3-10 keV

Patruno+ 2014
Kong 2014
Takata+ 2014

Unexplained Flickering



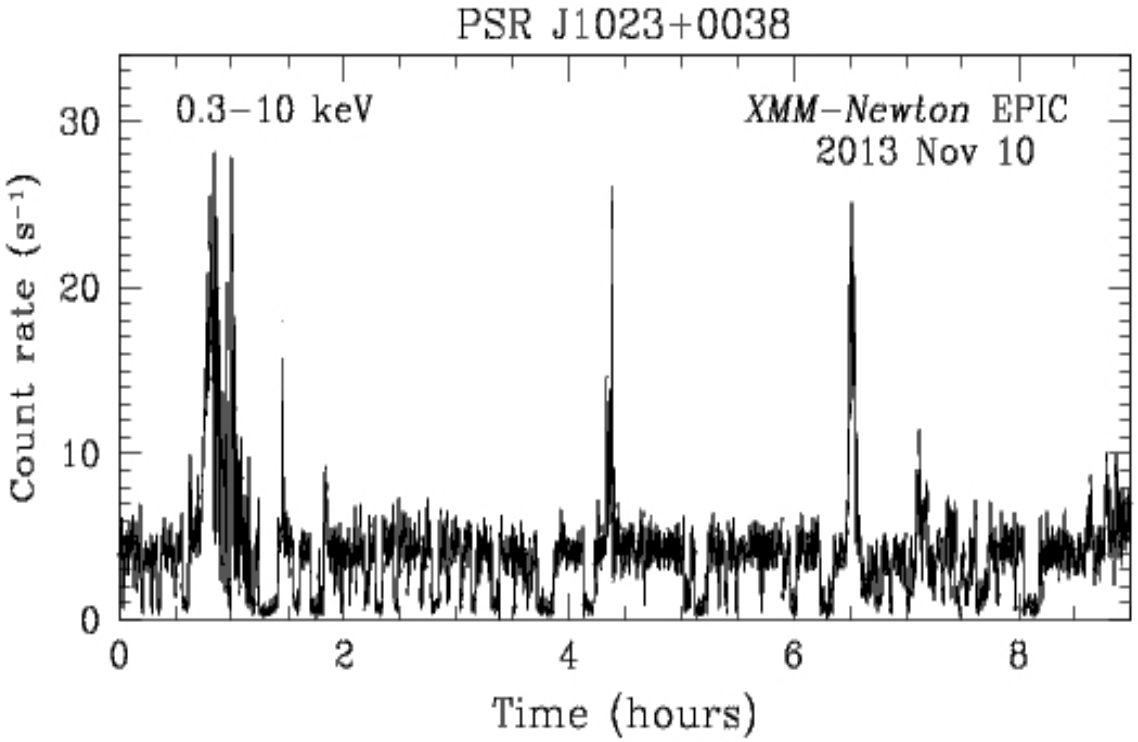
Tendulkar+ 2014

X-Ray Flickering: 10-1000 s

Luminosity: 1e32 – 1e34 erg/s

qLMXB?

Unexplained Flickering



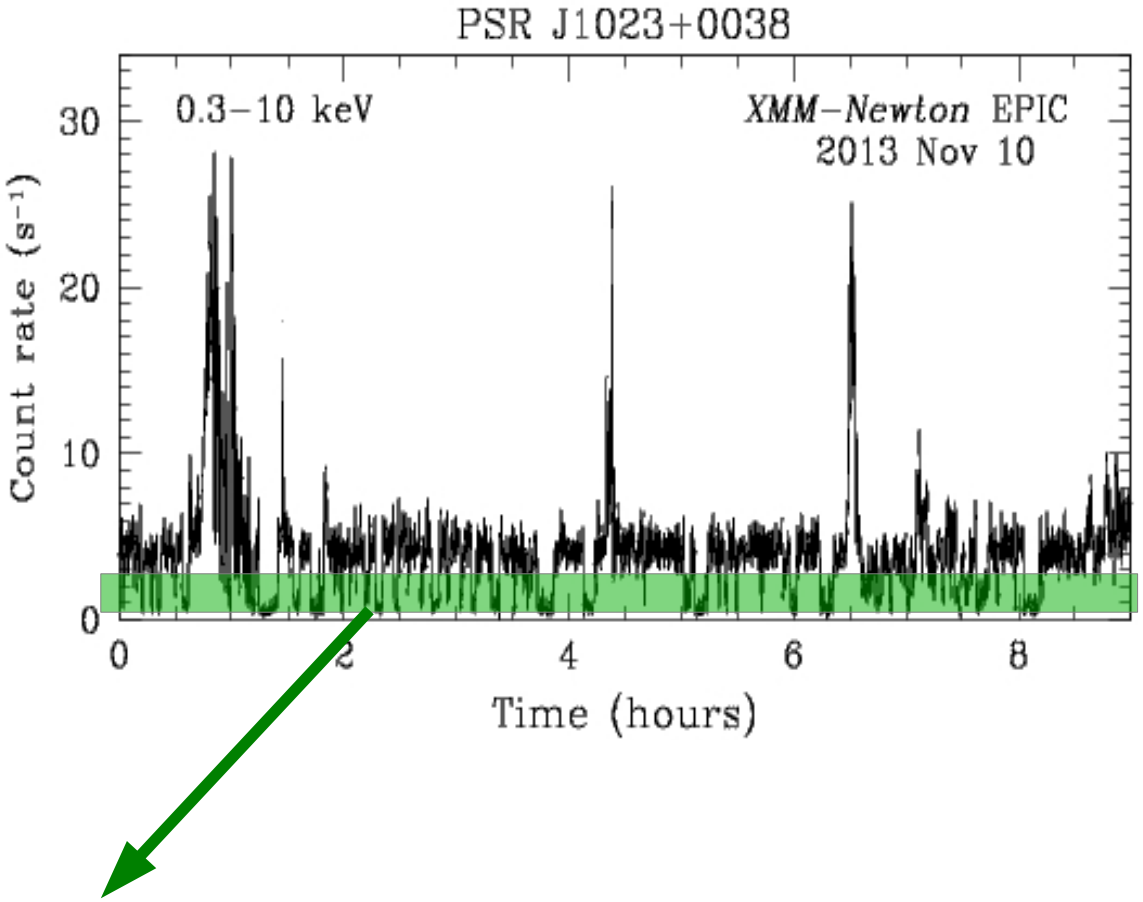
Bogdanov+ 2015

X-Ray Flickering:
10-1000 s

Luminosity:
1e32 – 1e34 erg/s

qLMXB?

Unexplained Flickering



Bogdanov+ 2015

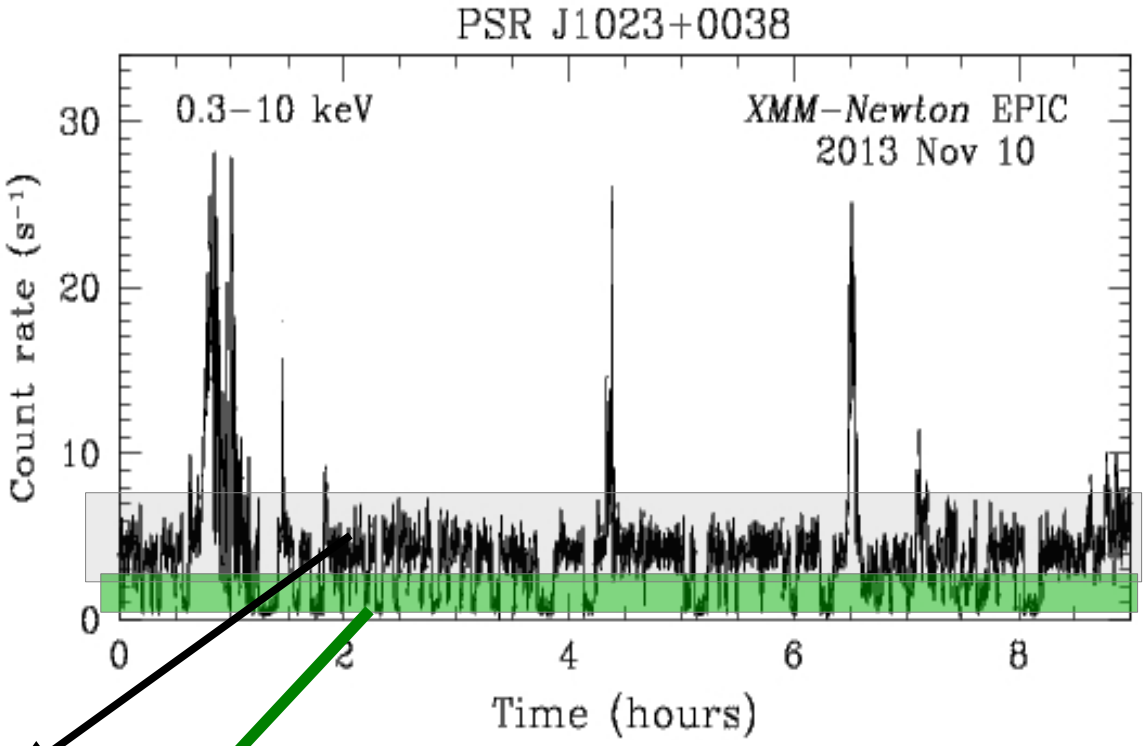
X-Ray Flickering:
10-1000 s

Luminosity:
1e32 – 1e34 erg/s

qLMXB?

Low Mode 10^32 erg/s

Unexplained Flickering



Bogdanov+ 2015

X-Ray Flickering:
10-1000 s

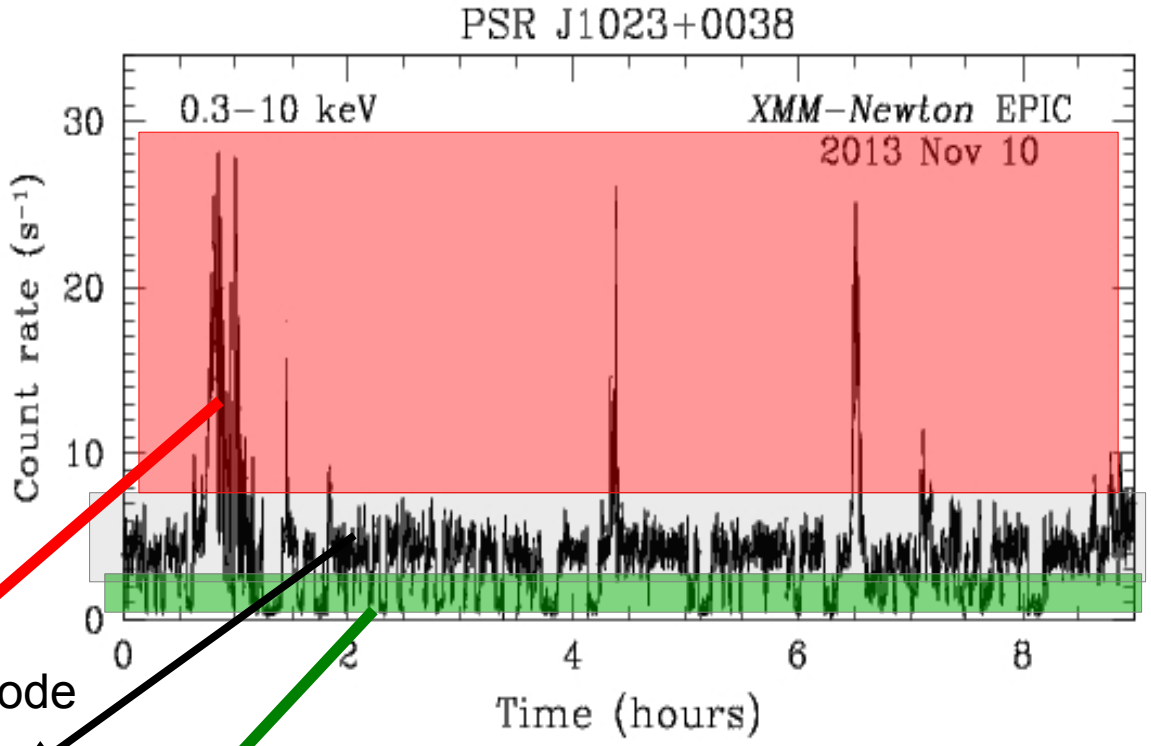
Luminosity:
1e32 – 1e34 erg/s

High Mode 10^33 erg/s

Low Mode 10^32 erg/s

qLMXB?

Unexplained Flickering



Flaring Mode

High Mode 10^33 erg/s

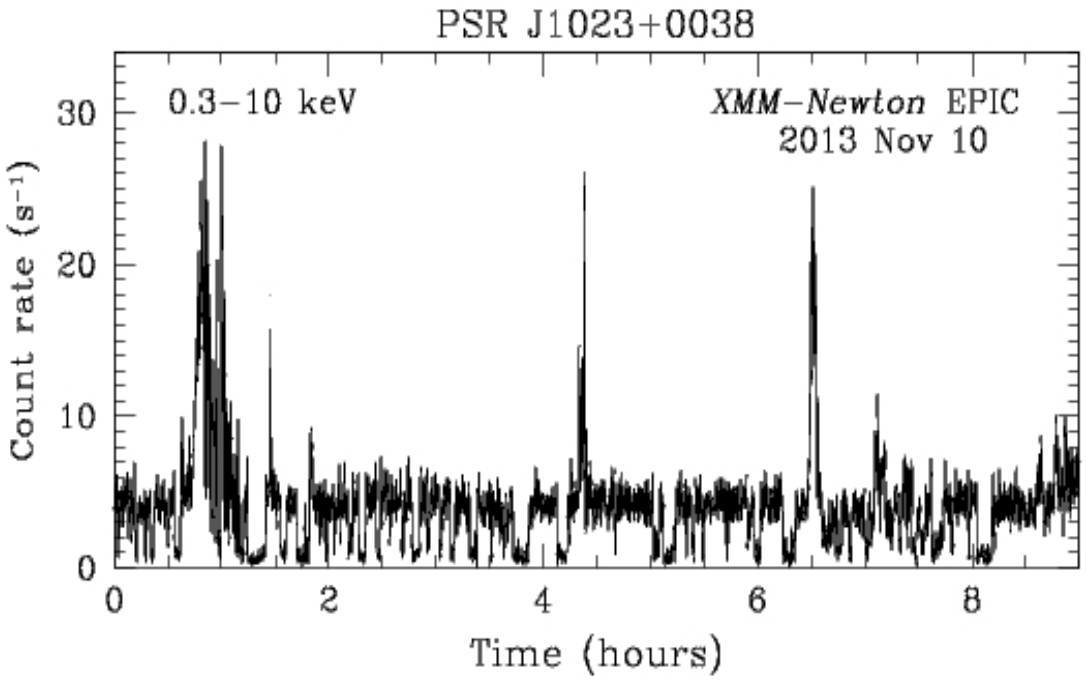
Low Mode 10^32 erg/s

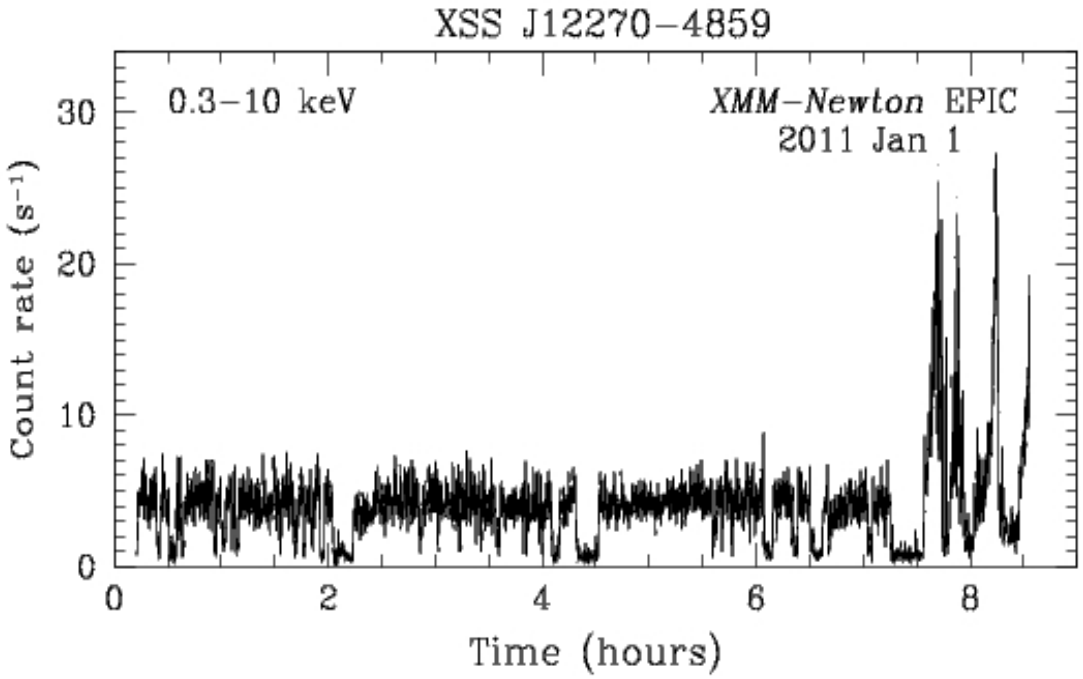
Bogdanov+ 2015

X-Ray Flickering: 10-1000 s

Luminosity: 1e32 – 1e34 erg/s

qLMXB?





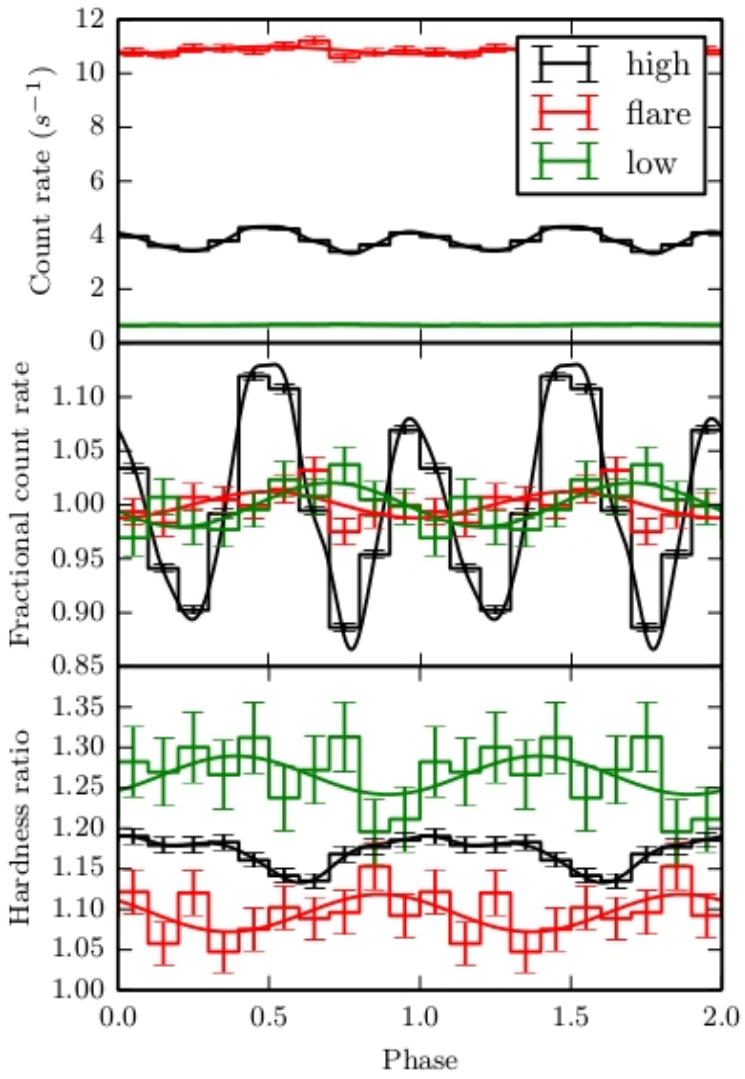
Patruno+ 2014
Kong+ 2014
Tendulkar+ 2014
Bogdanov+ 2015
De Martino+ '10,'13
Bassa+ '14

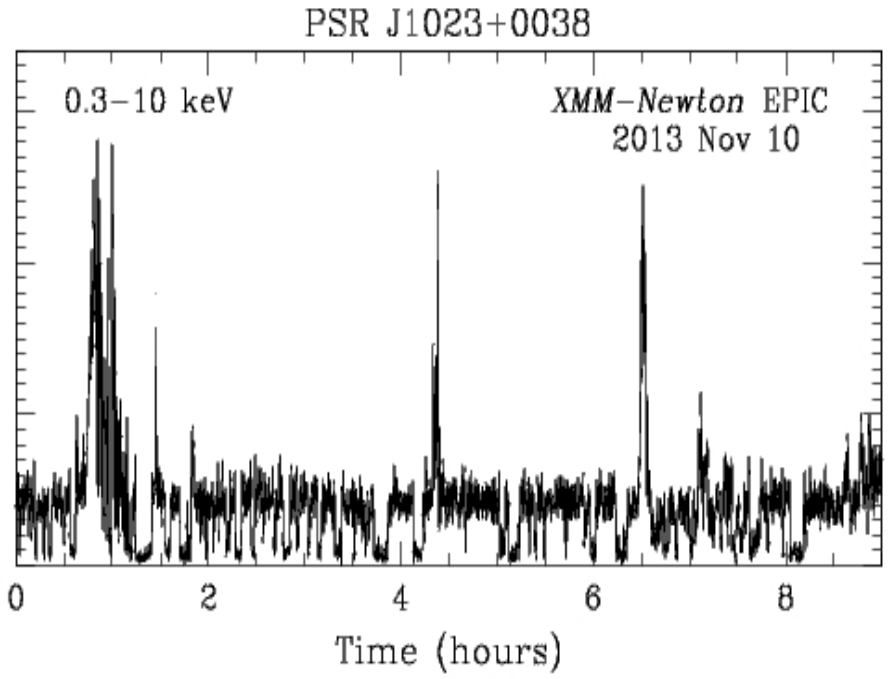
X-Ray Flickering:
10-1000 s

Luminosity:
1e32 – 1e34 erg/s

qLMXB?

The first accretion powered **quiescent** LMXB



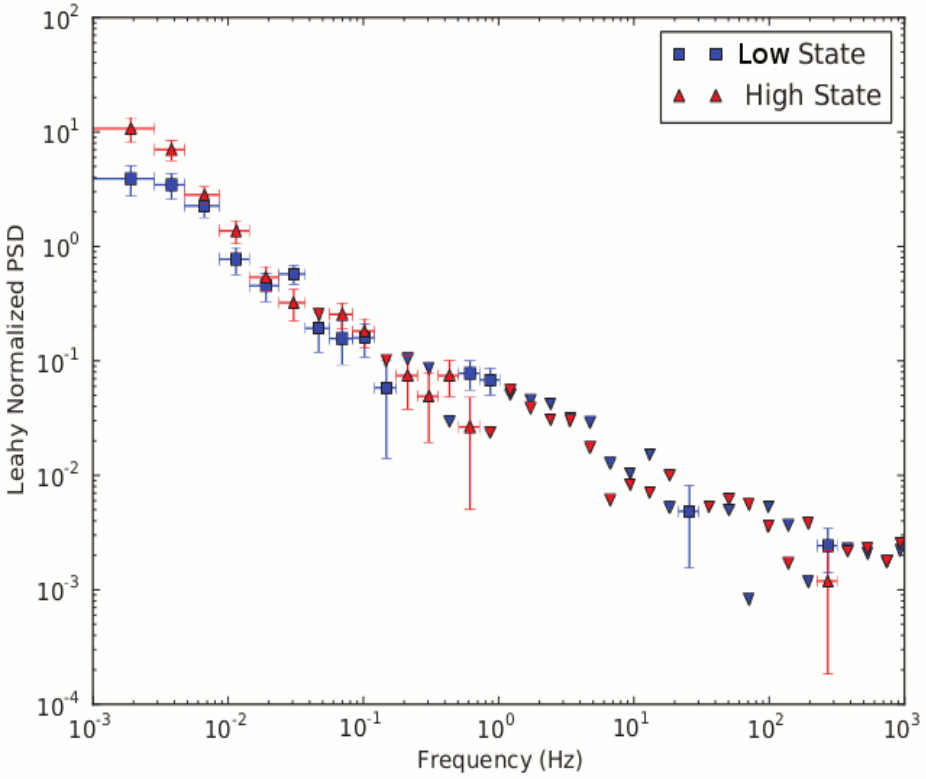


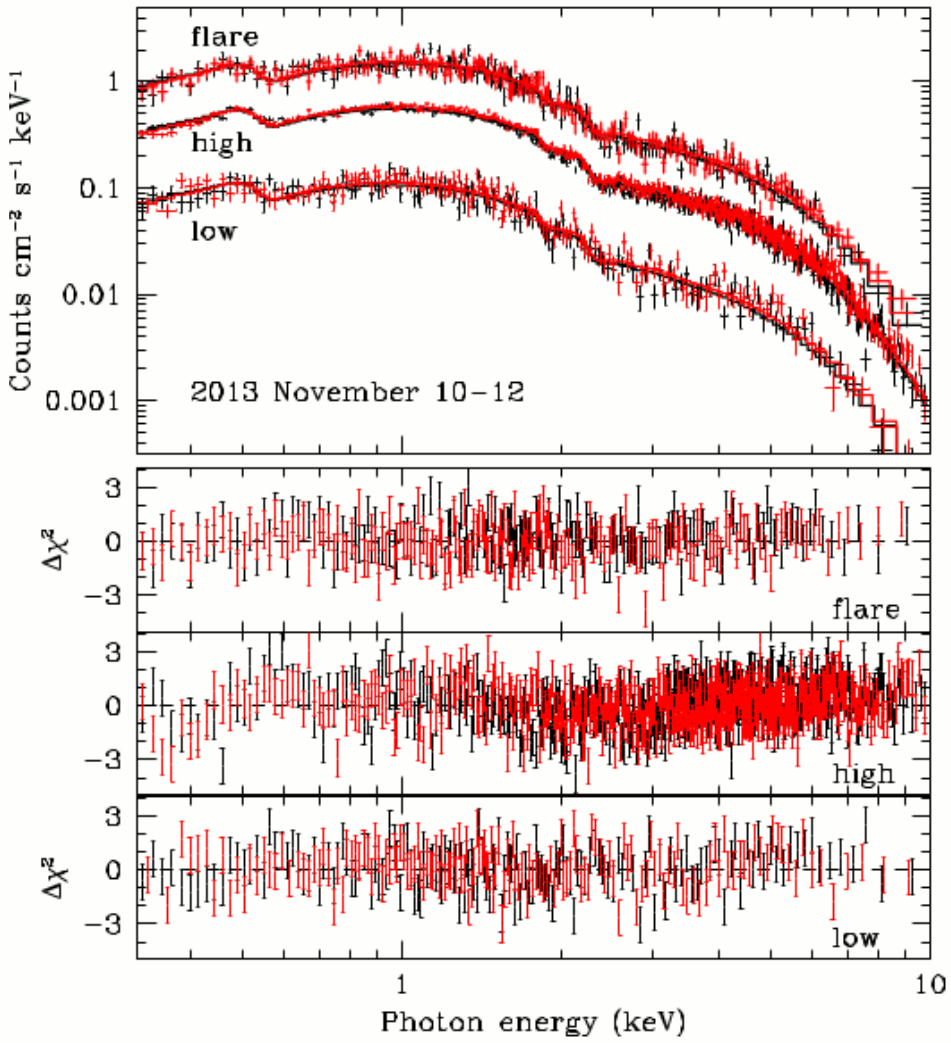
Intermittent Pulses!

Archibald+ '14

(See talk of A. Papitto for XSS J12270)

PSR J1023+0038 Energy and Power Spectra

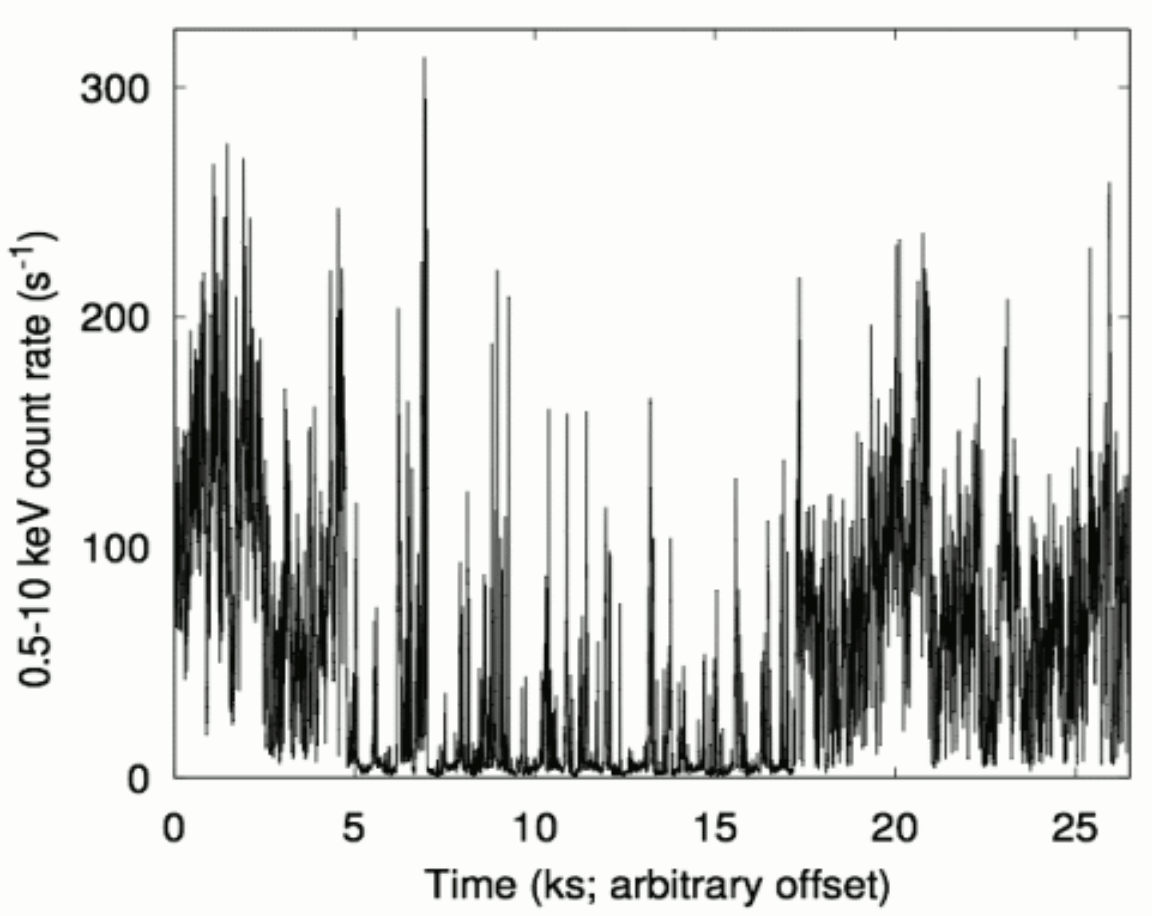




- Identical power spectra
- Very similar energy spectra

Tendulkar+ 2014
Bogdanov+ 2015

M28I: The First AMXP/Radio Pulsar

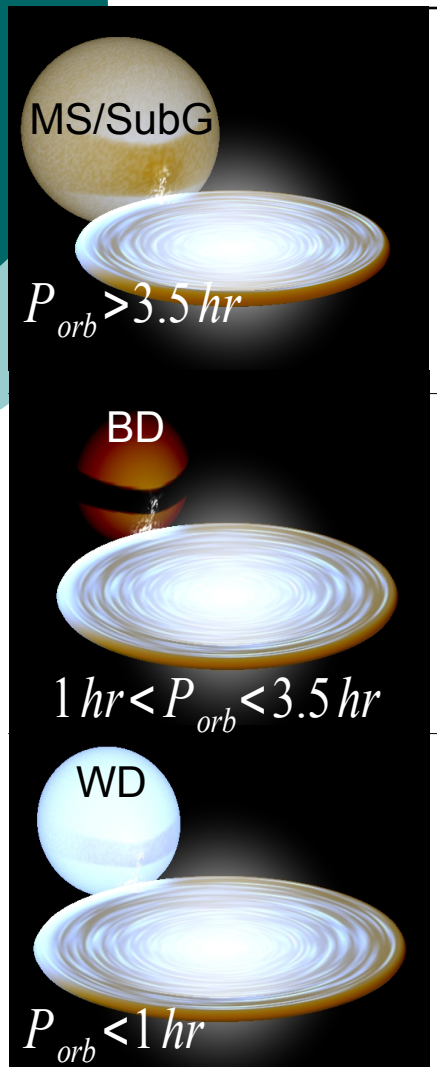


Completely different luminosity scale!

Papitto+ 2013
Ferrigno+ 2014

Pulsations always present

AMXP Family (tMSP excluded!)



XTE J1814-338
AQL X-1
SAX J1748.9-2021
IGR J17511-3057
Swift J1749.4-2807
IGR J17498-2921

Redback-like

SAX J1808.4-368
HETE J1900.1-2455
IGR J00291+5934

Black-Widow like

XTE J1751-305
XTE J0929-314
XTE J1807-294
Swift J1756.9-2508
NGC 6440 X-2

(Patruno & Watts 2012 for a review)

Similarities/Differences

tMSPs	**Redback like AMXPs**
MS companion star	MS companion star
Pb ~ 5-10 hours	Pb ~ 4-20 hours
B~10^8-10^9 G	B~10^8-10^9 G
Flickering in outburst	No Flickering
Flickering in quiescence	No Flickering (Obs. Bias?)
Radio Pulsations	No Radio PSR (yet?).

Radio pulsar search in AMXPs

Source Name	$P_{\rm orb}$ (hr)	Dist. (kpc)	Type
SAX J1808.4−3658	2.0	~ 3	BW
IGR J00291+5934	2.5	~ 5	BW
XTE J1814−338	4.3	~ 8	RB
IGR J17511−3057	3.5	< 5	RB
Swift J1749.4−2807	8.8	~ 7	RB
IGR J17498−2921	3.8	~ 8	RB

By far the deepest radio pulsar search so far (1.6-2.4 GHz) (Jaodand, Patruno, Hessels in prep.)

(See other searches by Iacolina+ 2010 at 4.8-8.4 GHz)

Radio pulsar search in AMXPs

Source Name	$P_{\rm orb}$ (hr)	Dist. (kpc)	Type
SAX J1808.4−3658	2.0	~ 3	BW
IGR J00291+5934	2.5	~ 5	BW
XTE J1814−338	4.3	~ 8	RB
IGR J17511−3057	3.5	< 5	RB
Swift J1749.4−2807	8.8	~ 7	RB
IGR J17498−2921	3.8	~ 8	RB

Preliminary results → no radio pulsations
(Jaodand, Patruno, Hessels in prep.)

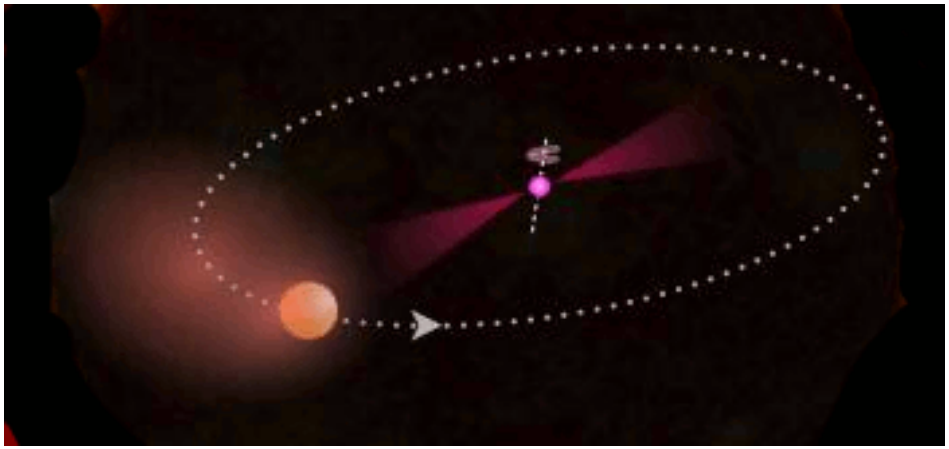
What about BW-like AMXPs?

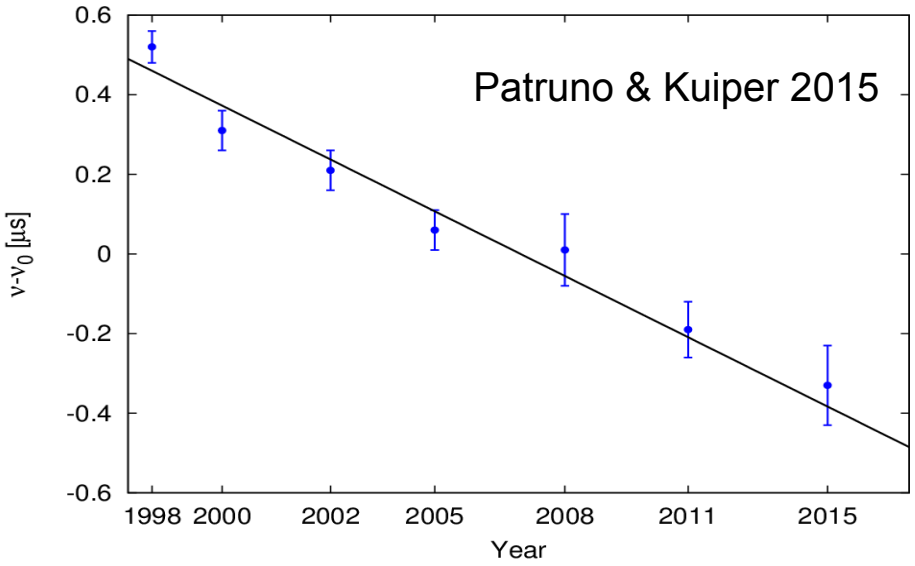
SAX J1808.4-3658 behaves exactly as a BW:

1. shows anomalies in the orbital evolution

2. shows spin down compatible with magnetic dipole radiation in quiescence

3. indirect evidence for a radio pulsar (in quiescence)

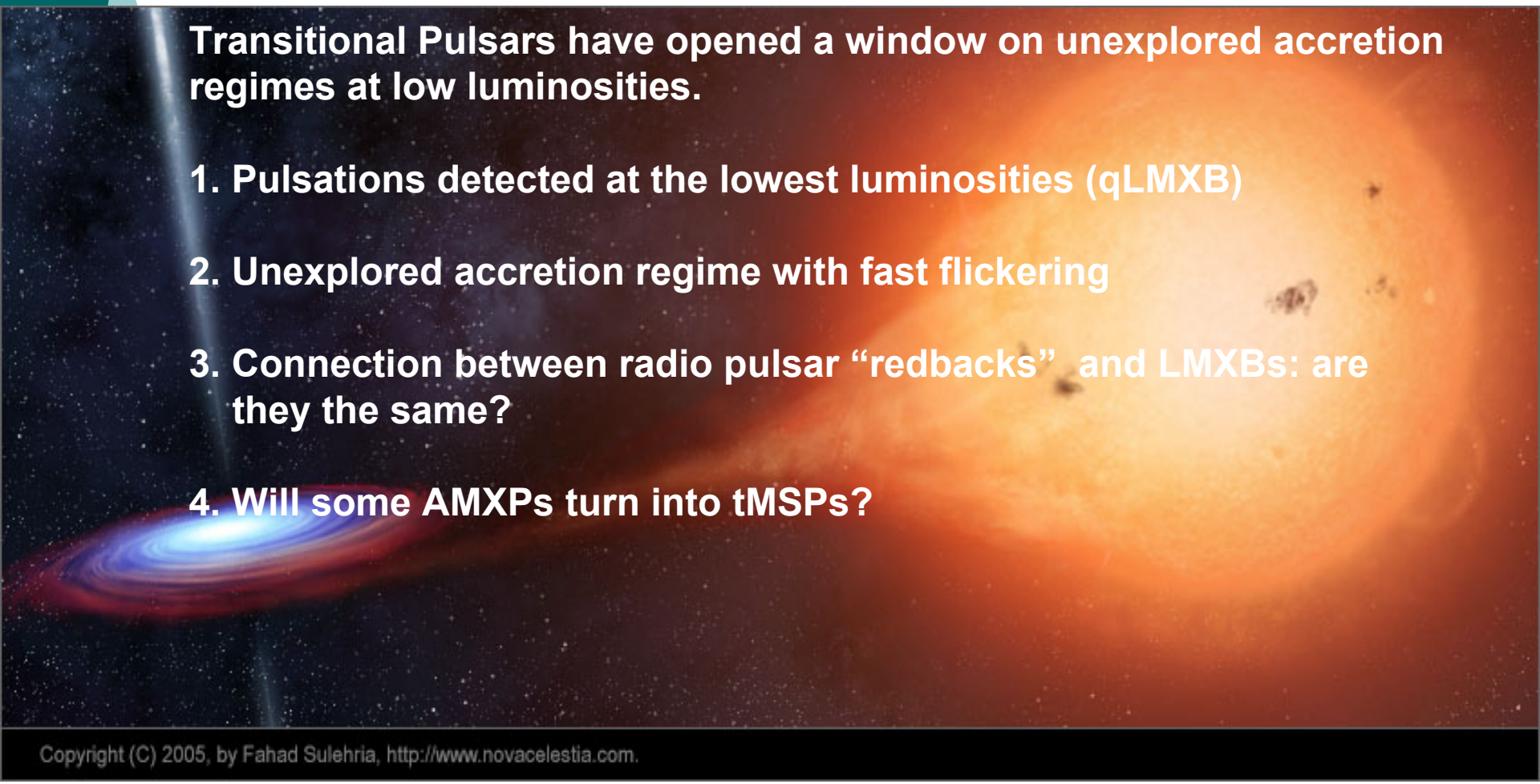




Still no radio pulsar (and no BWs ever turned into LMXBs!)

Homer+ (2001); Burderi+ (2003); Campana+ (2004); Deloye+ (2008); Wang+ (2009)

Conclusions



Transitional Pulsars have opened a window on unexplored accretion regimes at low luminosities.

1. **Pulsations detected at the lowest luminosities (qLMXB)**
2. **Unexplored accretion regime with fast flickering**
3. **Connection between radio pulsar "redbacks" and LMXBs: are they the same?**
4. **Will some AMXPs turn into tMSPs?**