2A 1822-371 as a Super-Eddington Source

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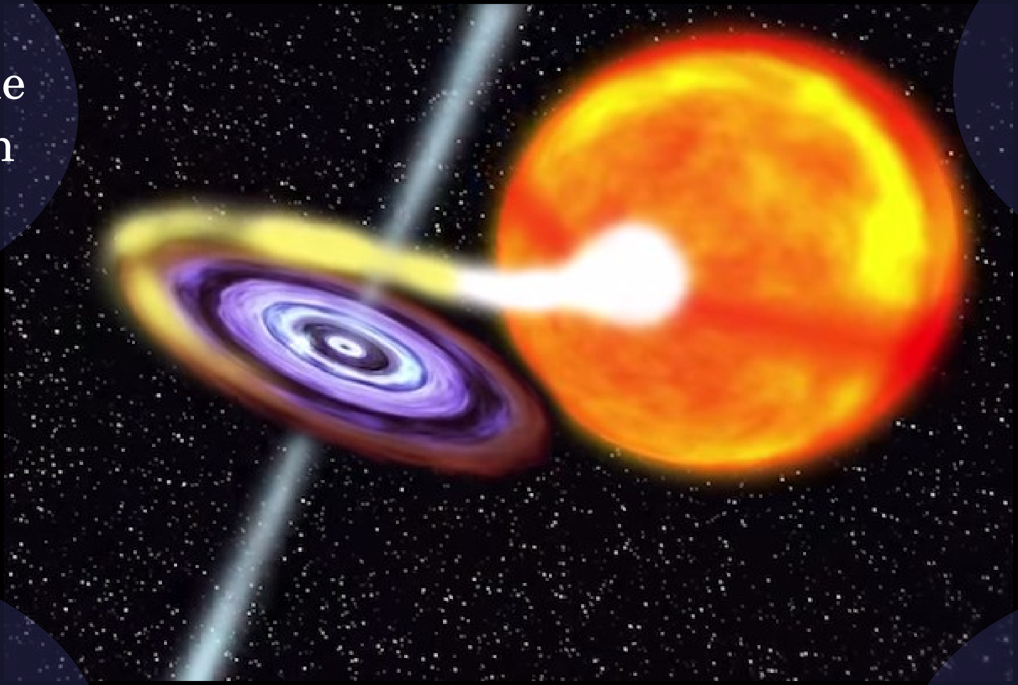
Bonn 11. December 2017

Summary

1) The surface of the pulsar is never seen

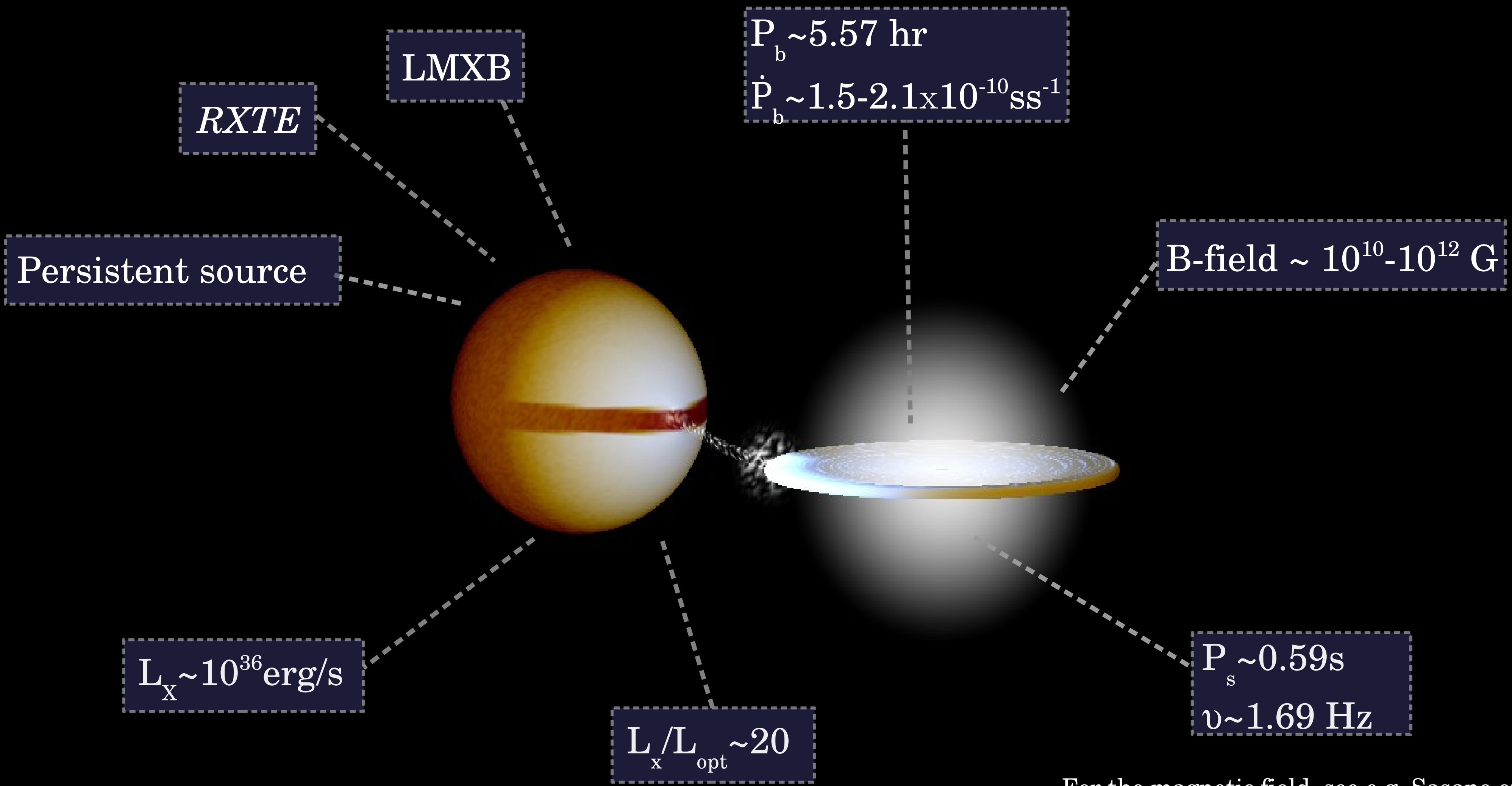


4) Super-Eddington source ($B \sim 10^{10}$G)

2) Optically thin Accretion disc corona (ADC)

3) Similar Long-term and Short-term spin up

Meet 2A 1822-371



For the magnetic field, see e.g. Sasano et al. 2014 and Iaria et al. 2015. For $\dot{P}_b$ see e.g. Burderi et al. 2010

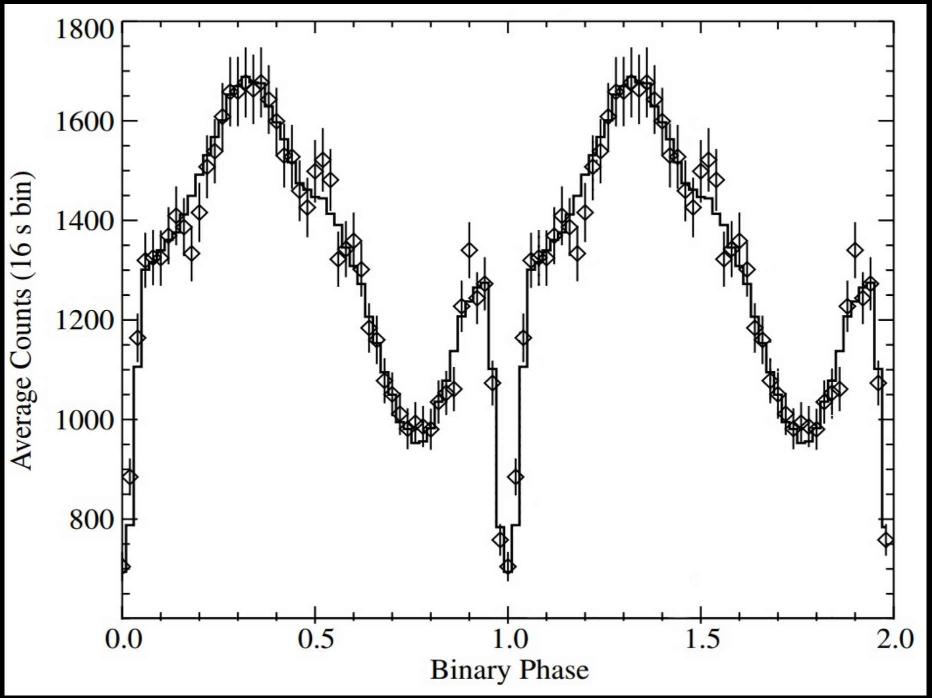
1) The Light curve

Eclipsed LMXB

Edge on view

50% eclipsed

Extended X-ray emitting region → wide eclipses, partially eclipsed



Heinz et al. 2001

1) The surface of the NS is never seen

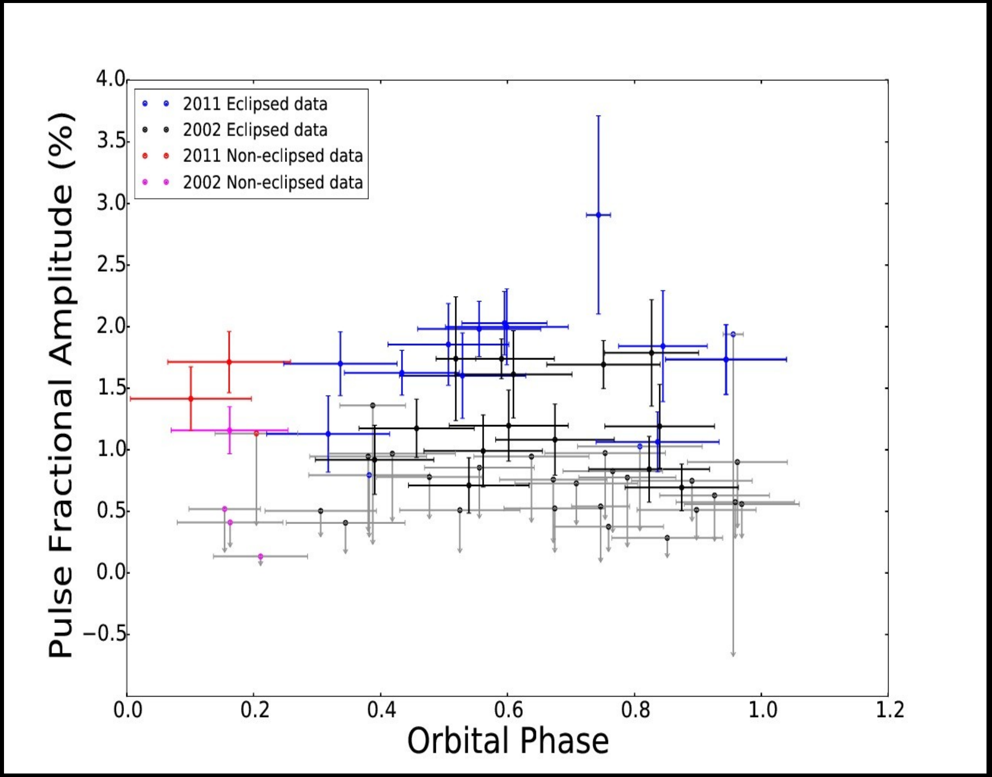
Is the surface seen?

→ Fractional amplitude vs. orbital phase

→ Eclipsed vs. non-eclipsed data

No difference in eclipsed/non-eclipsed

→ Surface of NS never seen



Bak Nielsen et al. 2017

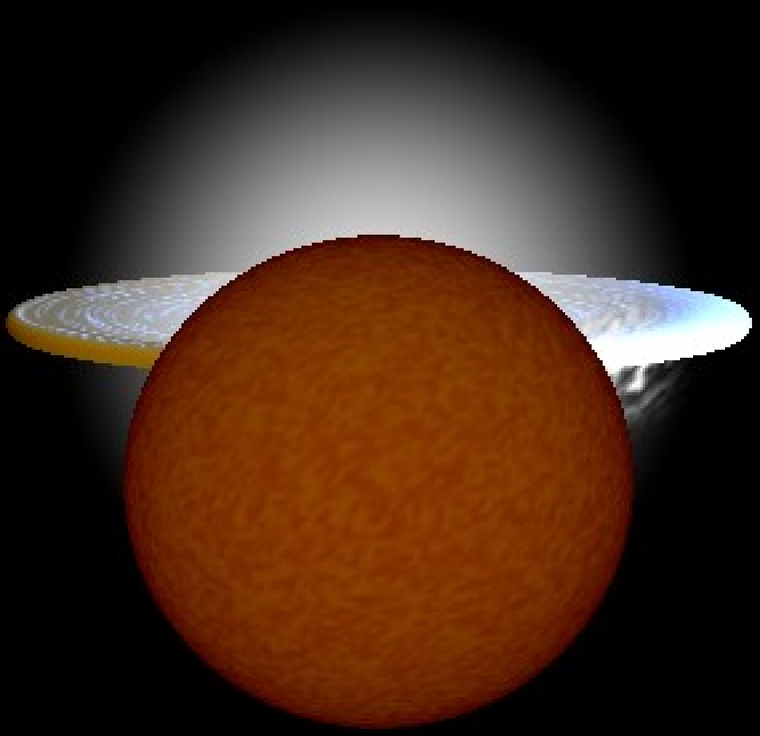
For more details on the light curve and eclipses see e.g. Heinz & Nowak 2001 & Parmar et al. 2000

2) The Accretion Disk Corona

Edge on, inclination ~ 83°

Spectral analysis:

- → Extended x-ray emitting region
- → ADC
- → Evaporated material
- → Very opaque corona



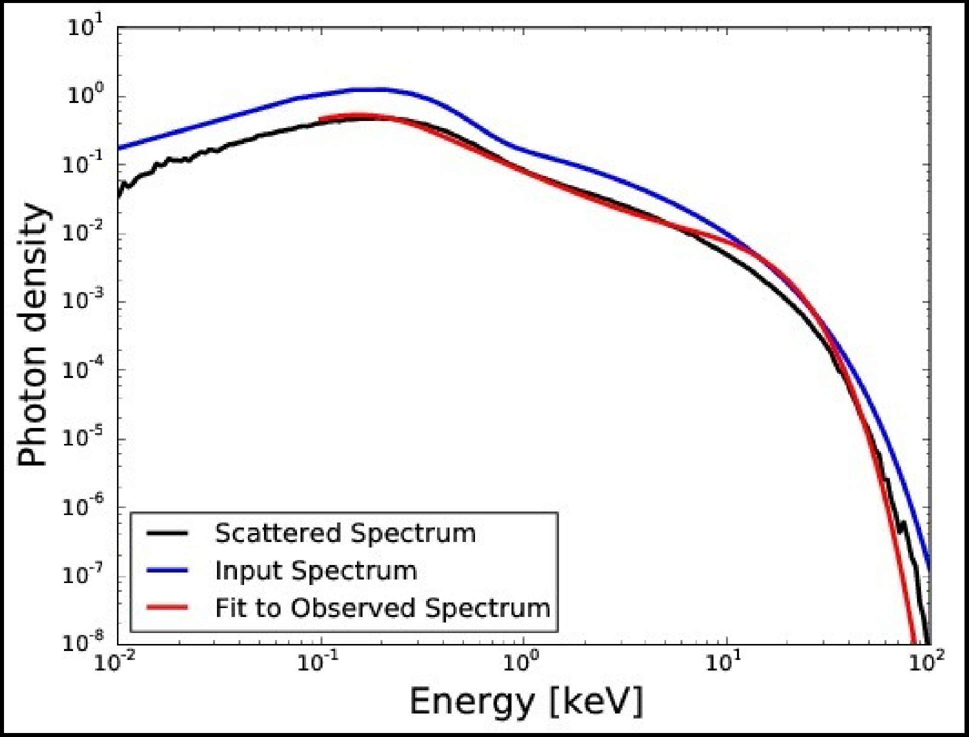
For other discussion on ADC see e.g. White & Holt 1982 and Iaria et al. 2013. For discovery of pulsations see Jonker & van der Klis 2001.

2) The Accretion Disk Corona

Previously → ADC optically thick (τ~10-20)
(post 2001)
→ Problem
→ coherent pulsations

Model:
→ BB + Power law
→ inverse compton up-scattering code
(Monte Carlo)

Results:
→ Possible non opaque medium (Opt. thin)
→ ADC (τ~1) (norm rms deviation of 28%)



Bak Nielsen et al. 2017

For other discussion on ADC see e.g. White & Holt 1982 and Iaria et al. 2013. For discovery of pulsations see Jonker & van der Klis 2001. MC Compton code see Giannios & Spruit 2004.

3) Long-term spin-up

2A 1822-371 shows spin-up over 13 years

$$\dot{\nu} = 7.6(8) \times 10^{-12}\ \mathrm{Hz\,s^{-1}}$$

υ ~ 1.69 Hz

P_s ~ 0.59 s

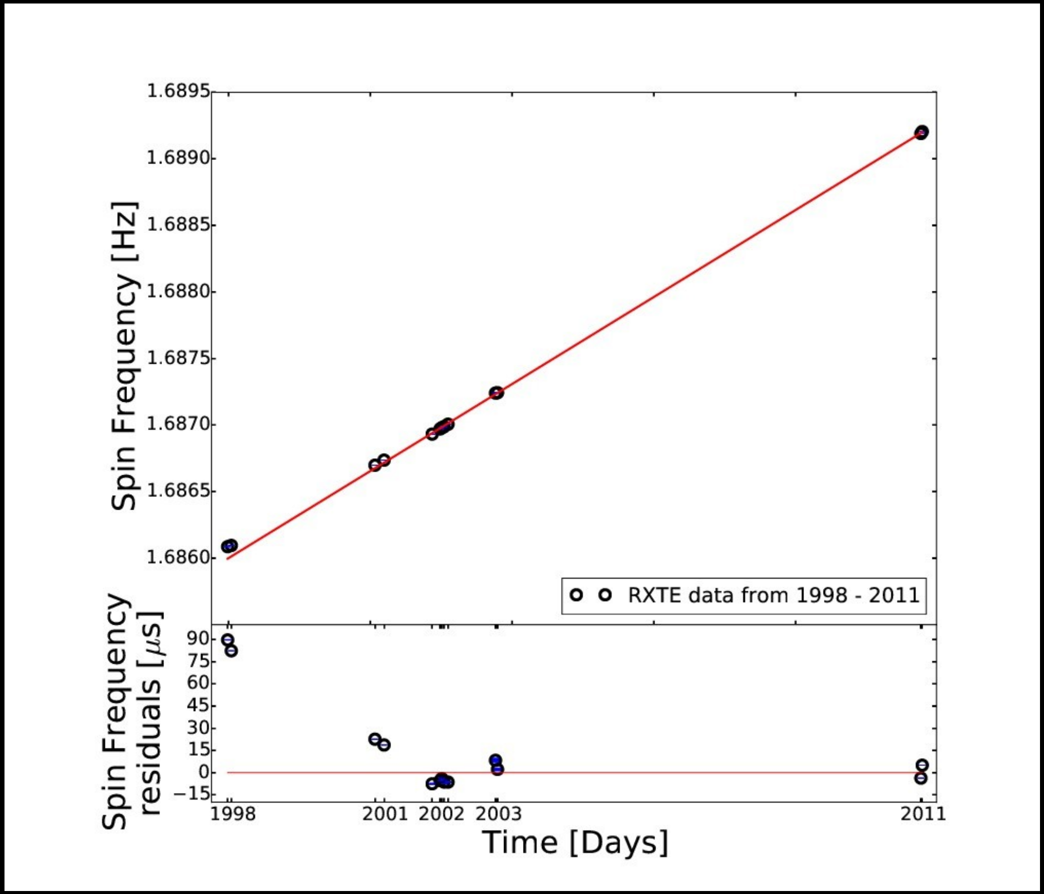
→ Varying residuals – short term changes?

Short-term spin-up

- Phase connected
- Length of 8-10 days
  - ~1-11 July 2001
  - ~ 2-9 August 2002

$$\dot{\nu} = 6.7(4) \times 10^{-12}\ \mathrm{Hz\,s^{-1}}$$

$$\dot{\nu} = 8.2(5) \times 10^{-12}\ \mathrm{Hz\,s^{-1}}$$



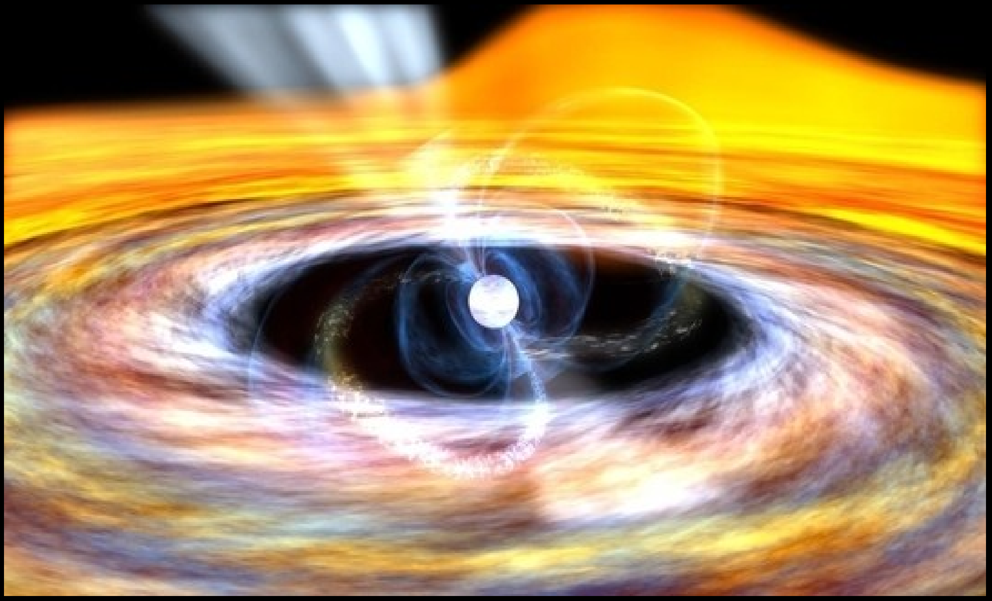
Bak Nielsen et al. 2017

4) A Super-Eddington source

Weakness of model

- → Needs Eddington limited accretion
- → Orbital period evolution not explained by conservative mass transfer
- → $\dot{P}_b$ possibly due to huge mass loss
- → Or donor star out of thermal equilibrium

- → $\dot{M}_{tr}$ not via Ang. Momentum loss (magnetic breaking/Grav. radiation)



Mass transfer proceeds on thermal timescale

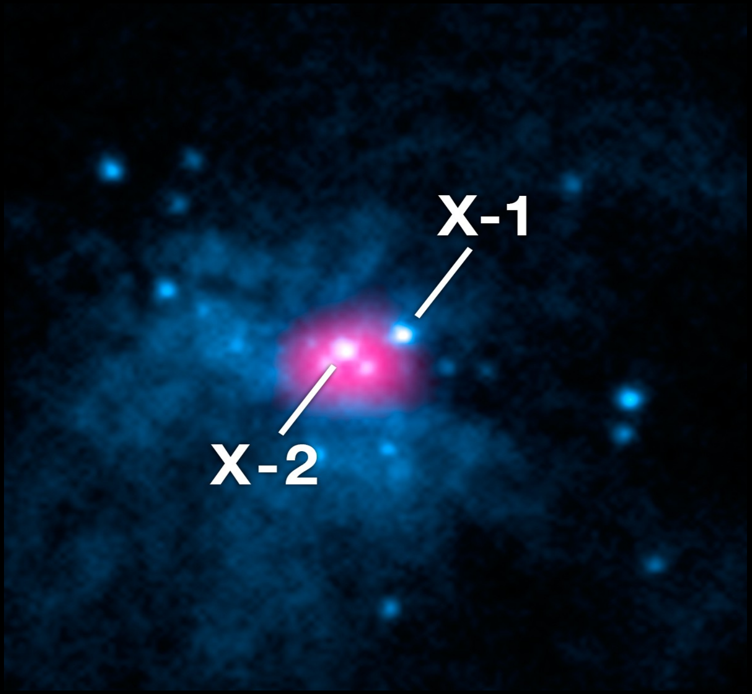
- → $\tau \sim 10^7$yr
- → So $\dot{M}_{tr} \sim 10^{-7} M_\odot$/yr
- → $\dot{M}_{Edd} \sim 10^{-8} M_\odot$/yr

4) A Super-Eddington source

Test if $\dot{M}_{tr}$ explains the orbital evolution
→ $\dot{a}/a \sim 2\dot{P}_b/3P_b$
→ Similar to within an order of magnitude

$\dot{M}_{tr}$ super Eddington → close to idea for ULX
→ King & Lasota 2016 idea for ULX as NS

Following King & Lasota 2016, we find:
→ $R_{sph} \sim 10^7$cm
→ $R_m \sim 10^6$-10^7cm
→ B-field $\sim 10^{10}$G (at poles)



Img. Credit: NASA

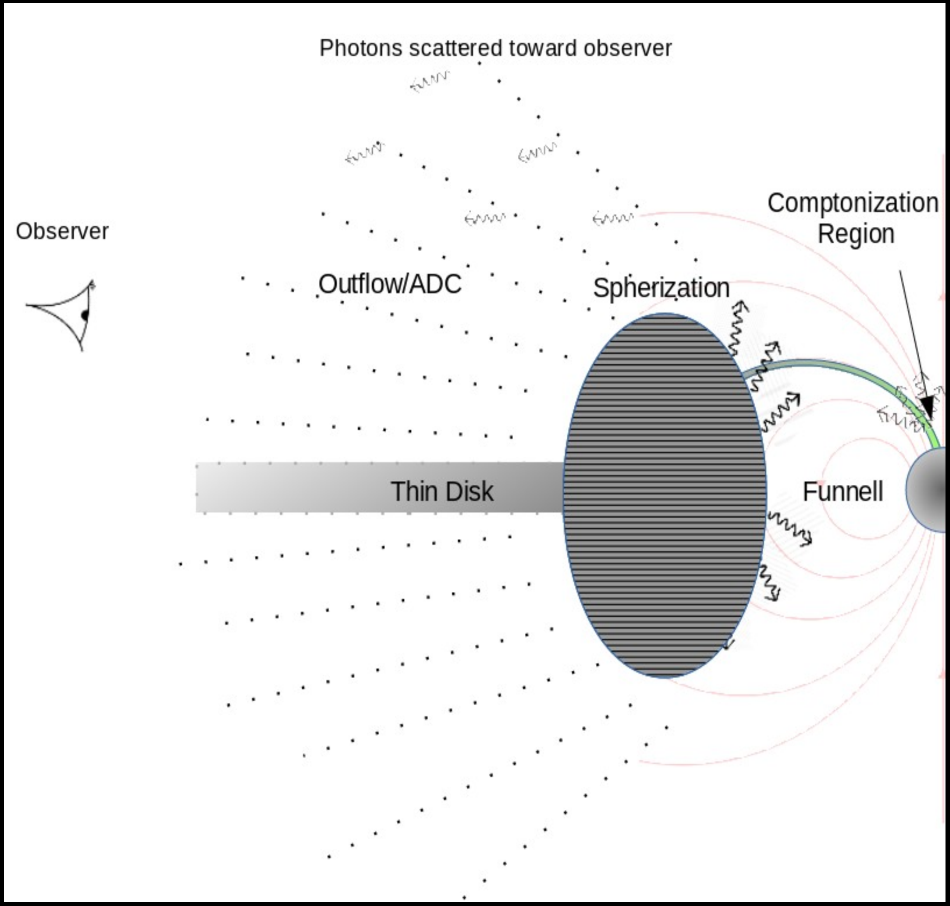
4) A Super-Eddington source

Where $R_m \sim R_{sph}$
Inner disk puffed up

Outflow created by Super Eddington $\dot{M}_{tr}$

See pulsations in the outflow

See around disk/inner part of disk



Bak Nielsen et al. 2017

Geometrically thick inner disk

Beaming of emission → possibly Jet/Outflow

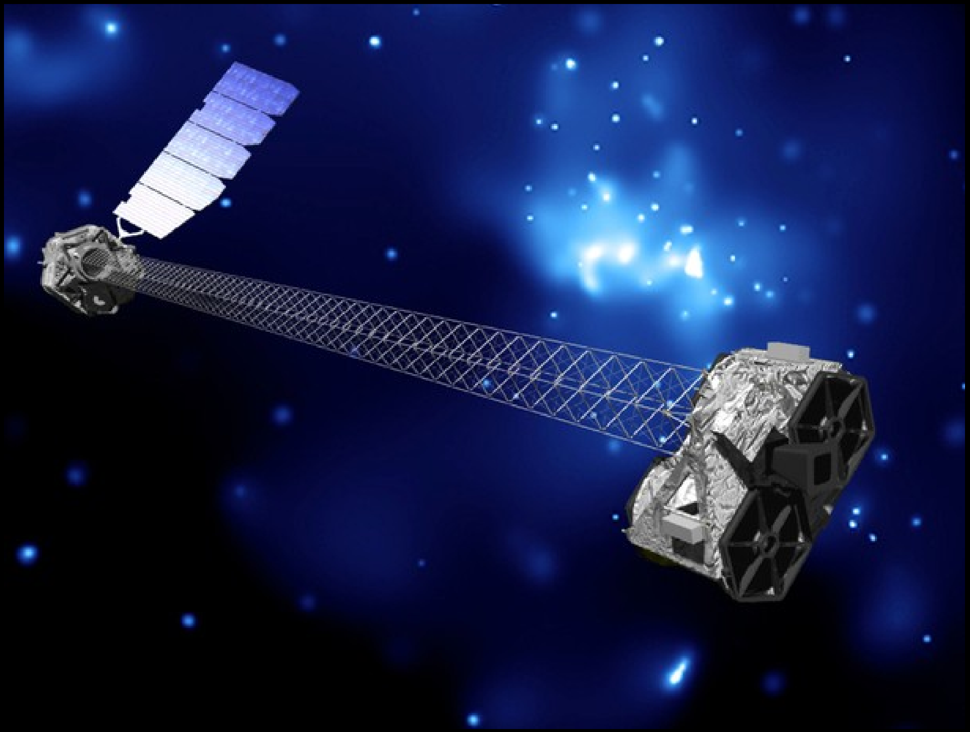
B-field ~ 10^{10}G

4) A Super-Eddington source - Tests

Tests:
- Is the magnetic field ~ 10^{10}G
  → NuStar observation confirm/contradict 10^{12}G B-field

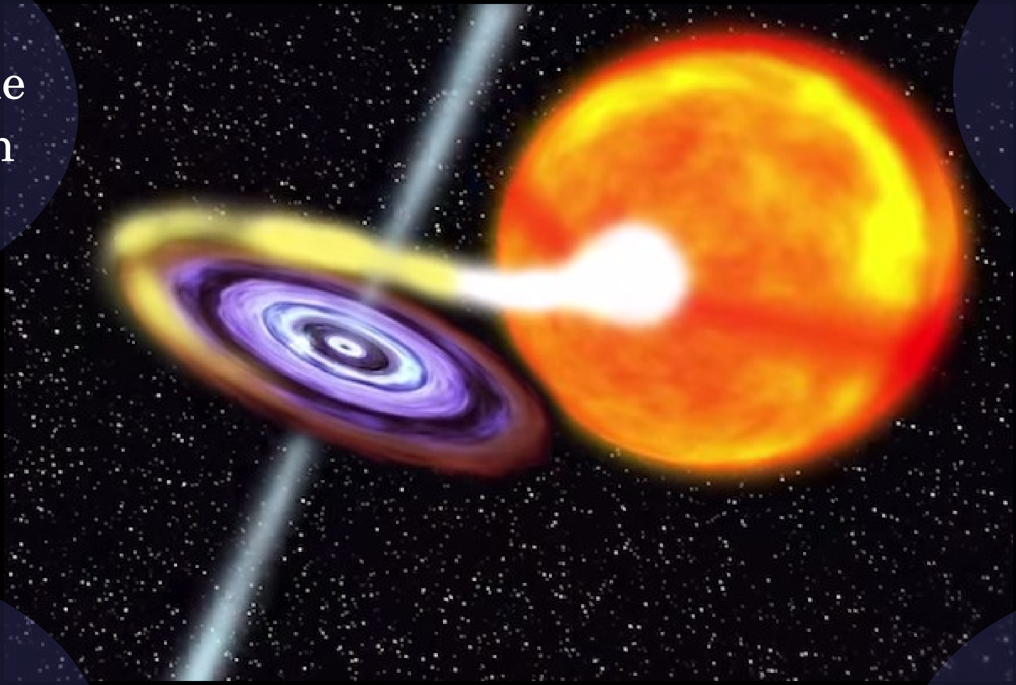
- Source should not show Torque reversal
  → Similar to what 4U 1626-67 or GX1+4 does

- A Jet/outflow should be present (Radio)
  → If beaming is present



Img. Credit: NuStar

Summary



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2) Optically thin Accretion disc corona (ADC)

3) Similar Long-term and Short-term spin up

4) Super-Eddington source ($B \sim 10^{10} G$)

Summary

1) The surface of the pulsar is never seen

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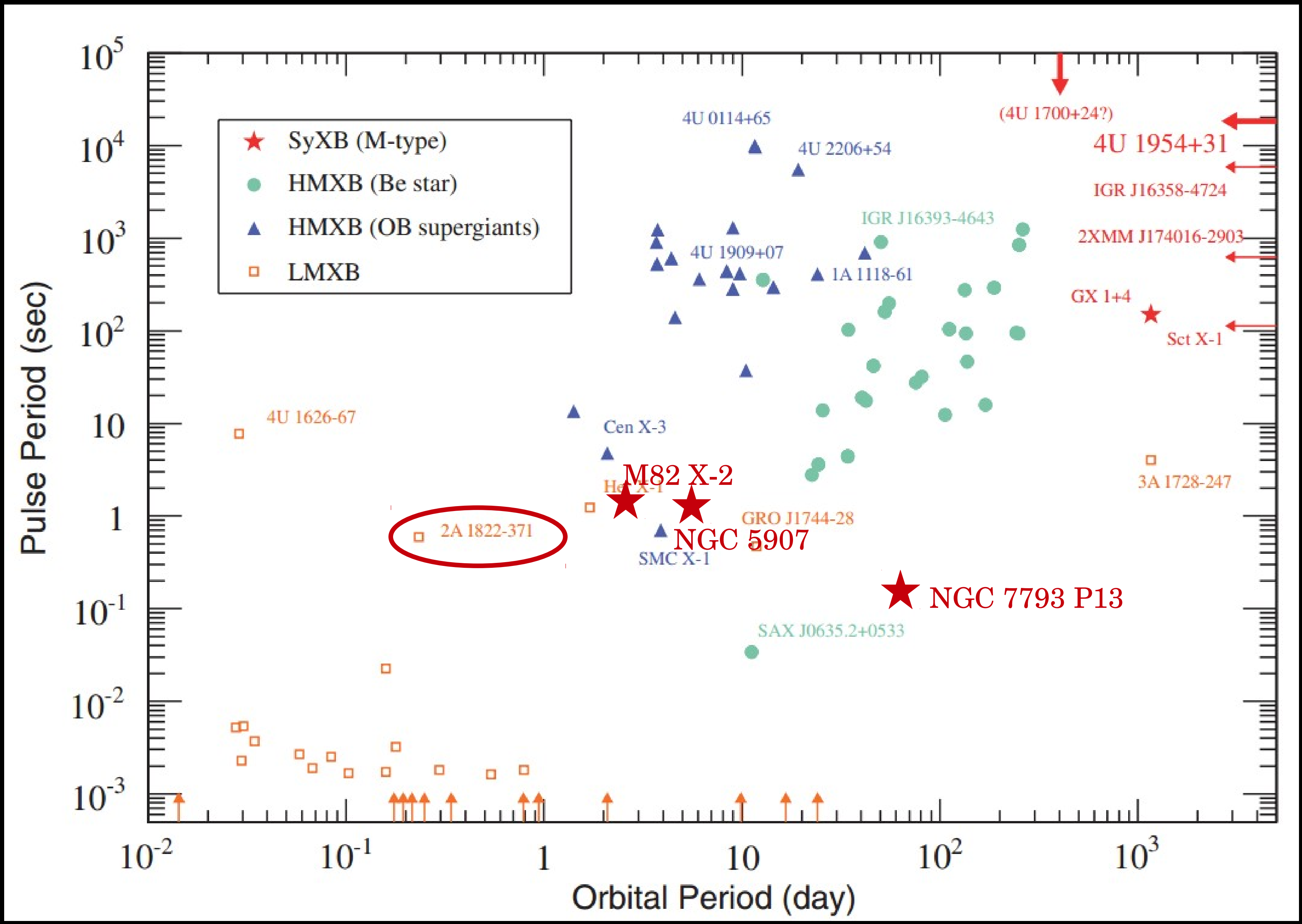
3) Similar Long-term and Short-term spin up

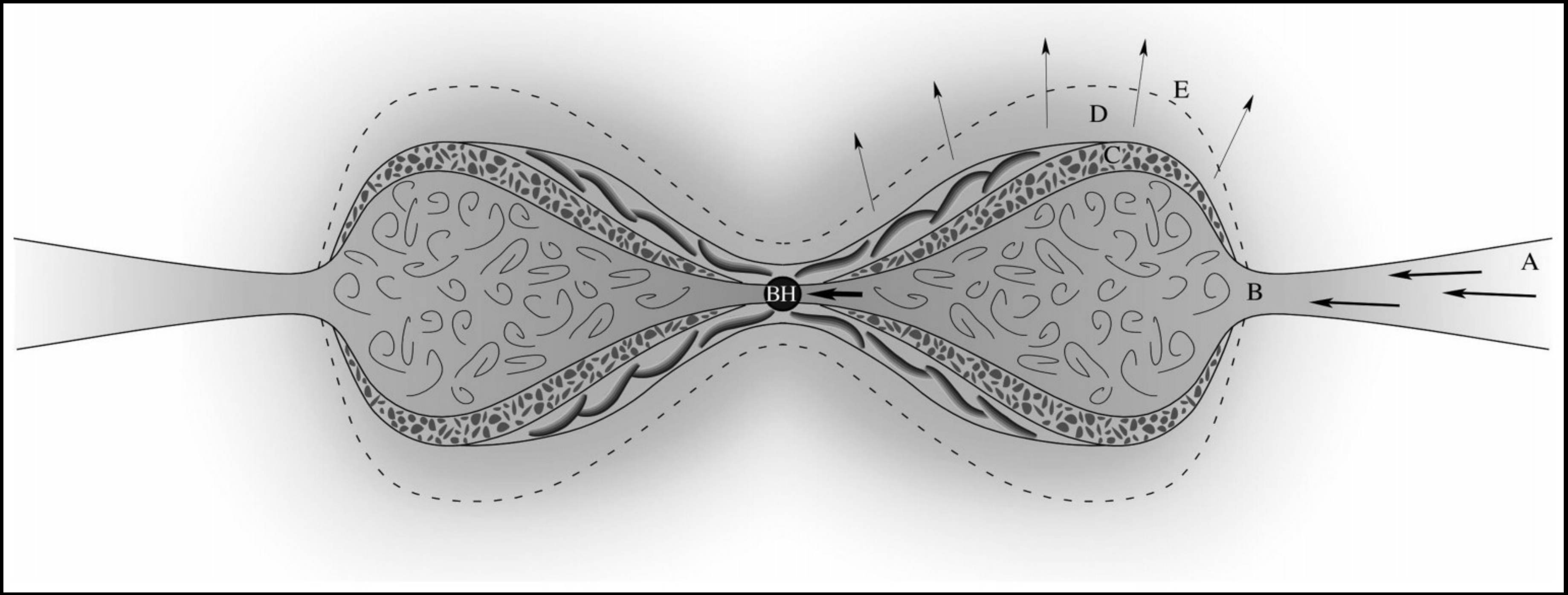
4) Super-Eddington source (B~10^{10}G)

Extra Slides

5) Comparison to ULX sources



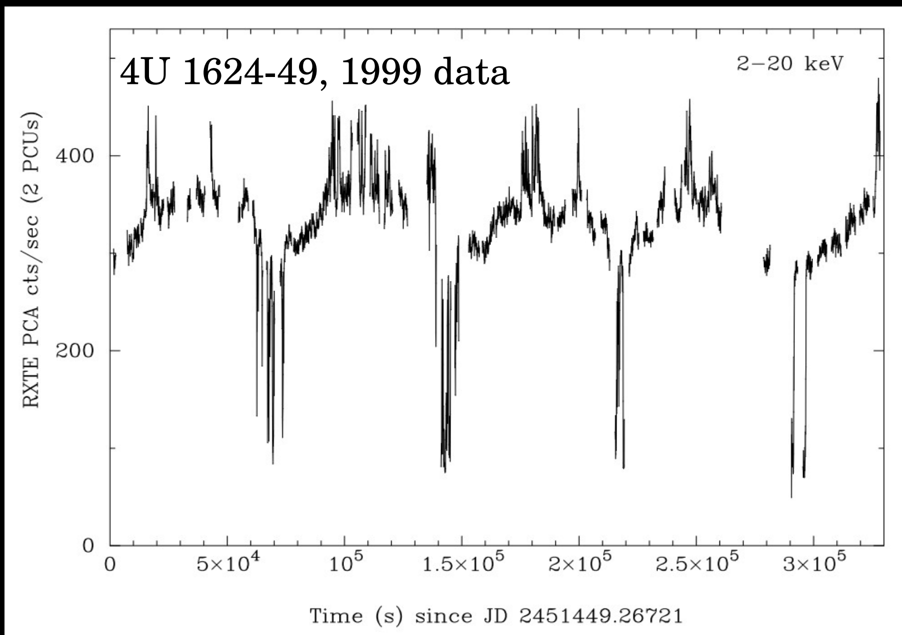
5) Comparison to ADC sources



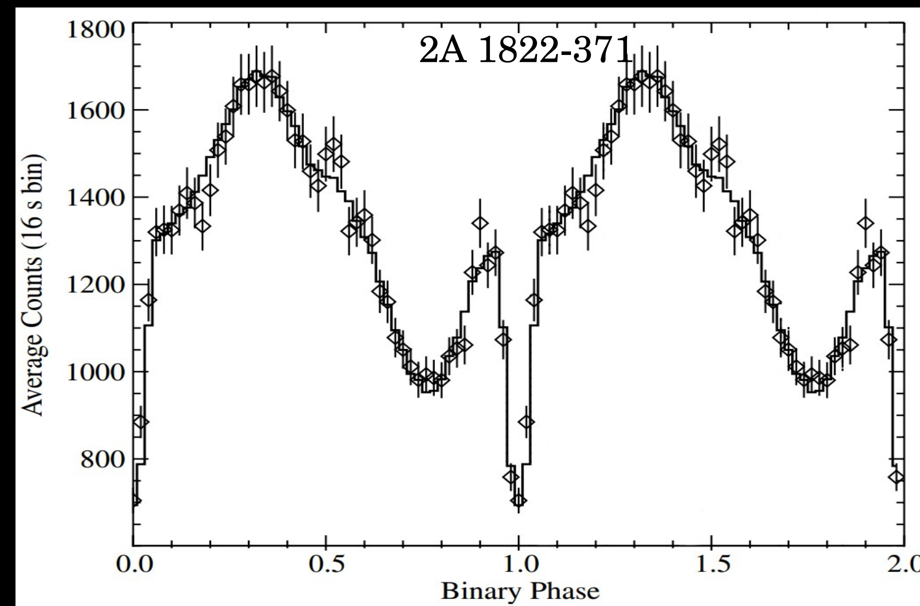
Dotan et al. 2011

SS 433 similar geometry to 2A 1822-371

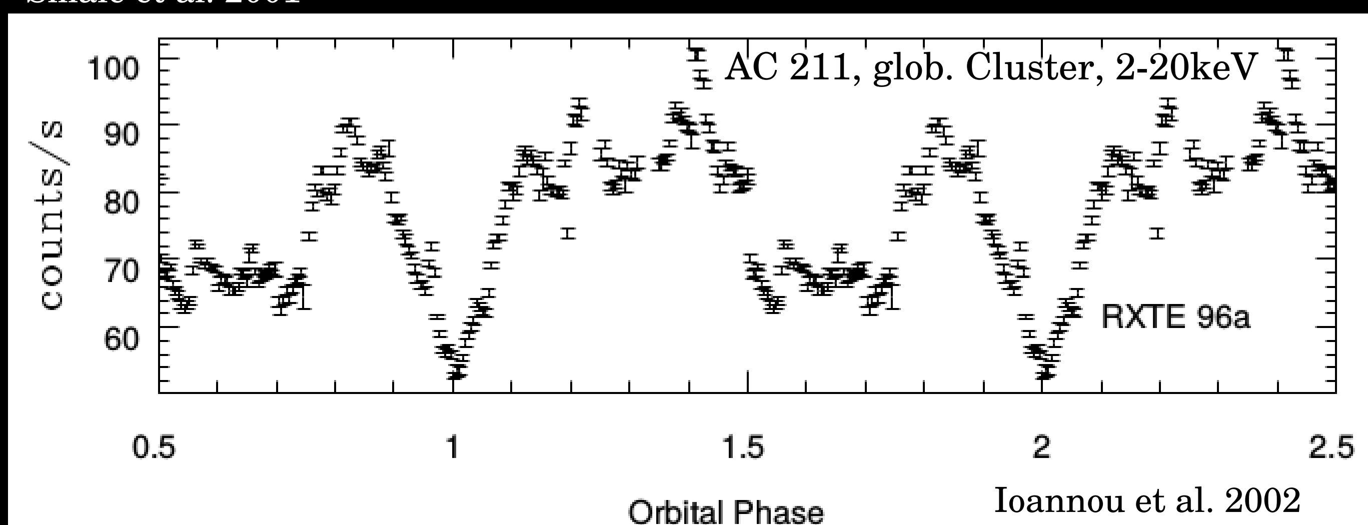
5) Comparison to ADC sources



Smale et al. 2001



Heinz et al. 2001

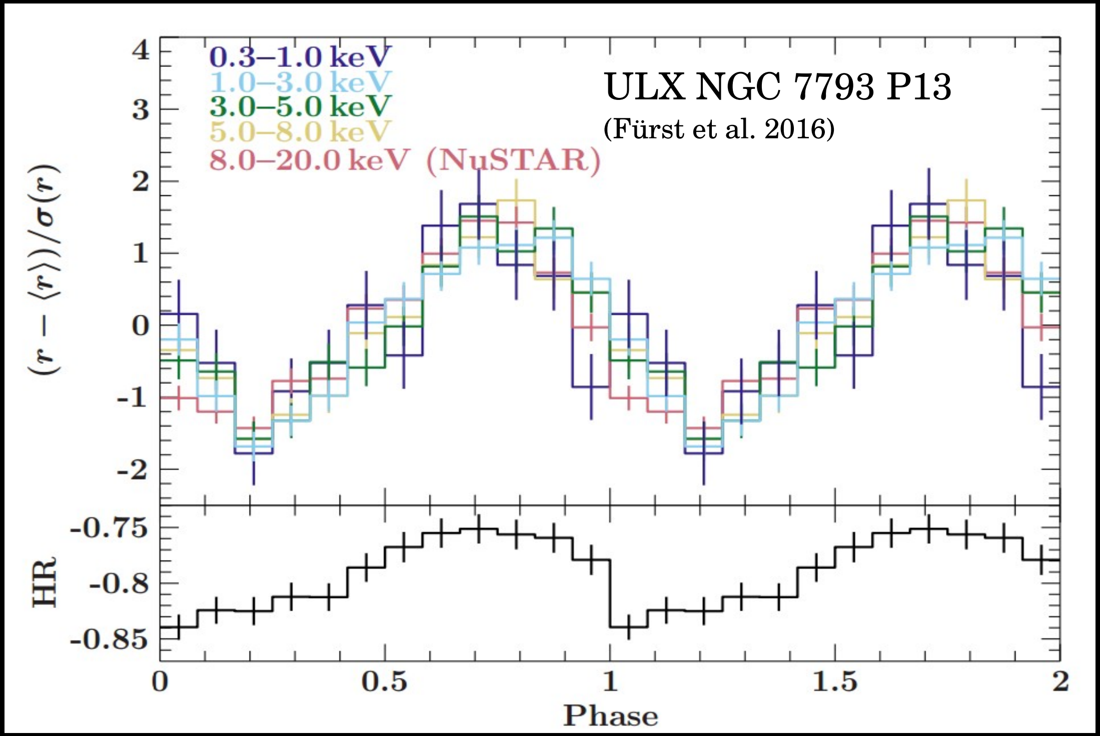


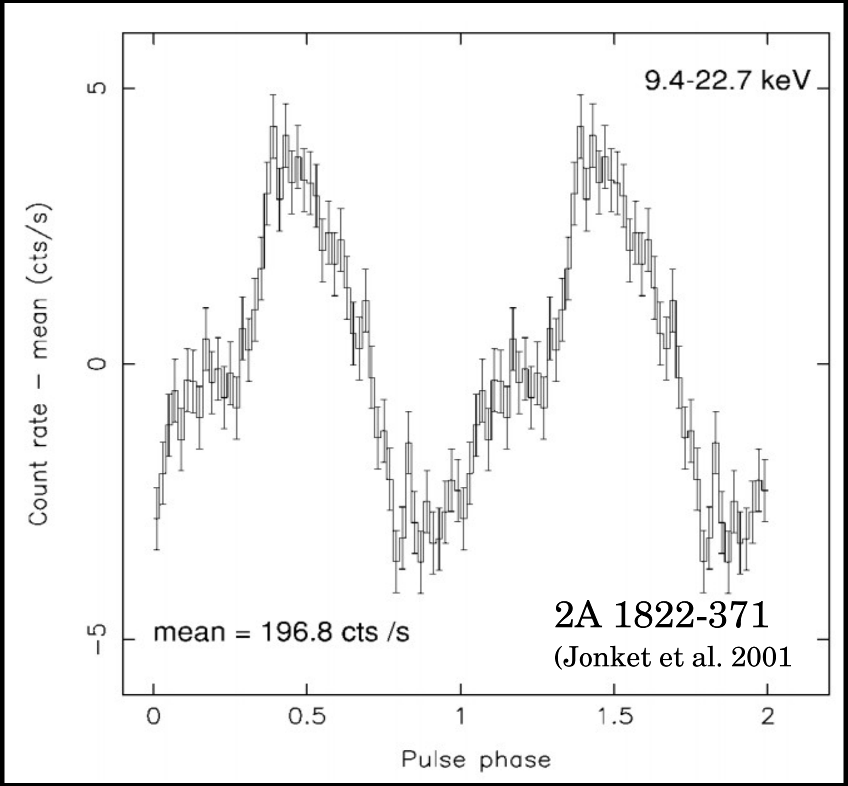
Ioannou et al. 2002

5) Comparison to ULX sources

3 know ULX-pulsars, M82 X-2, NGC 7793 P13, NGC 5907

→ Sinusoidal pulse profiles





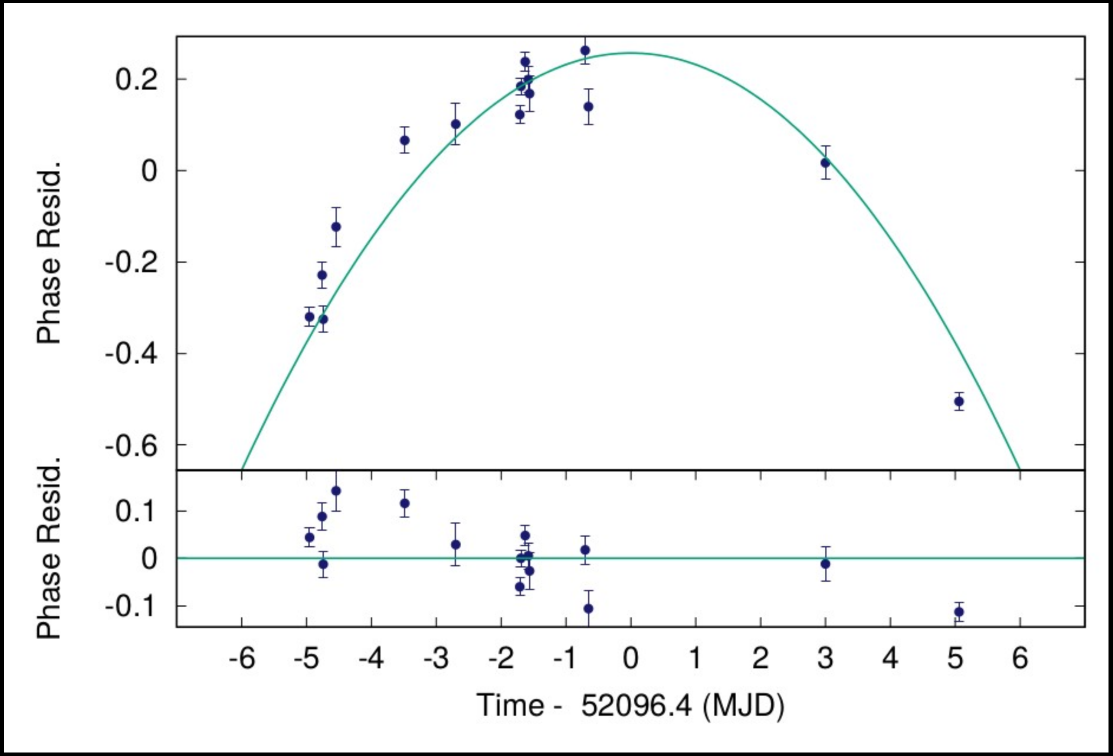
3) Short-term spin-up

Short-term spin-up
- 2 data segments
- Phase connected
- Length of 8-10 days
  - ~1-11 July 2001
  - ~ 2-9 August 2002

$$\dot{\nu}=6.7(4)\times 10^{-12}\ \mathrm{Hz\,s^{-1}}$$

$$\dot{\nu}=8.2(5)\times 10^{-12}\ \mathrm{Hz\,s^{-1}}$$

Figure shows 1-11 July 2001 data



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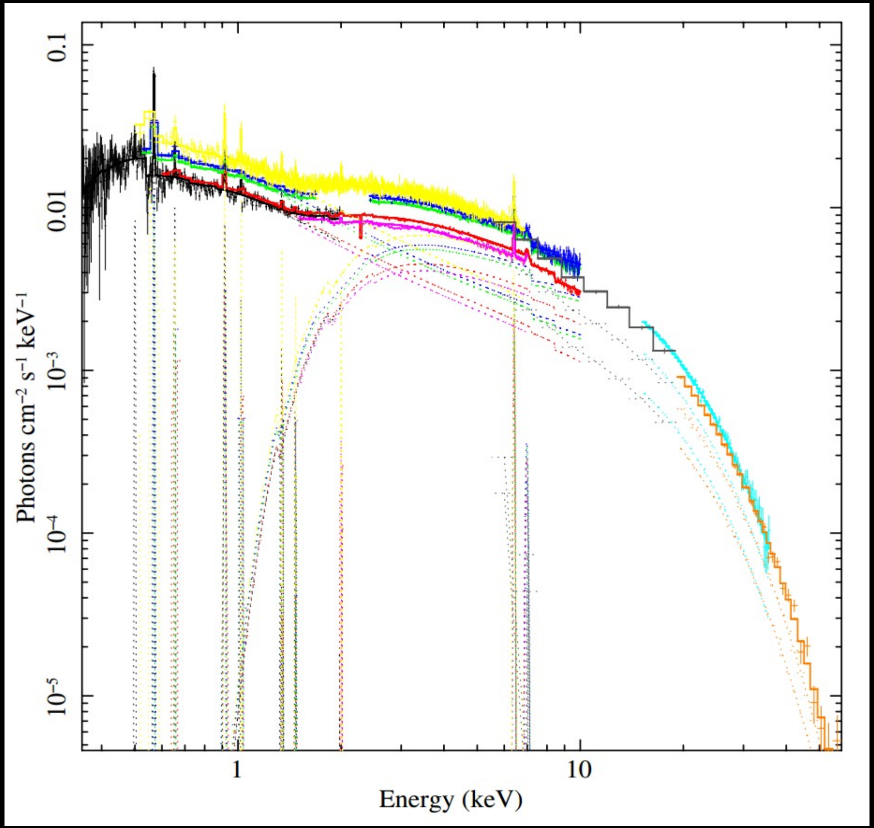
5) Comparison to ADC sources

Some ADC sources have spectra that drop off at ~ 8-12keV

→ 4U 1624-49

→ 2S 0921-630 (?)

4U 1624-49, AC 211, MS 1603+2600 have little info on spectra or spectra does not seem to show cut-off



Iaria et al. 2015

Meet the telescope

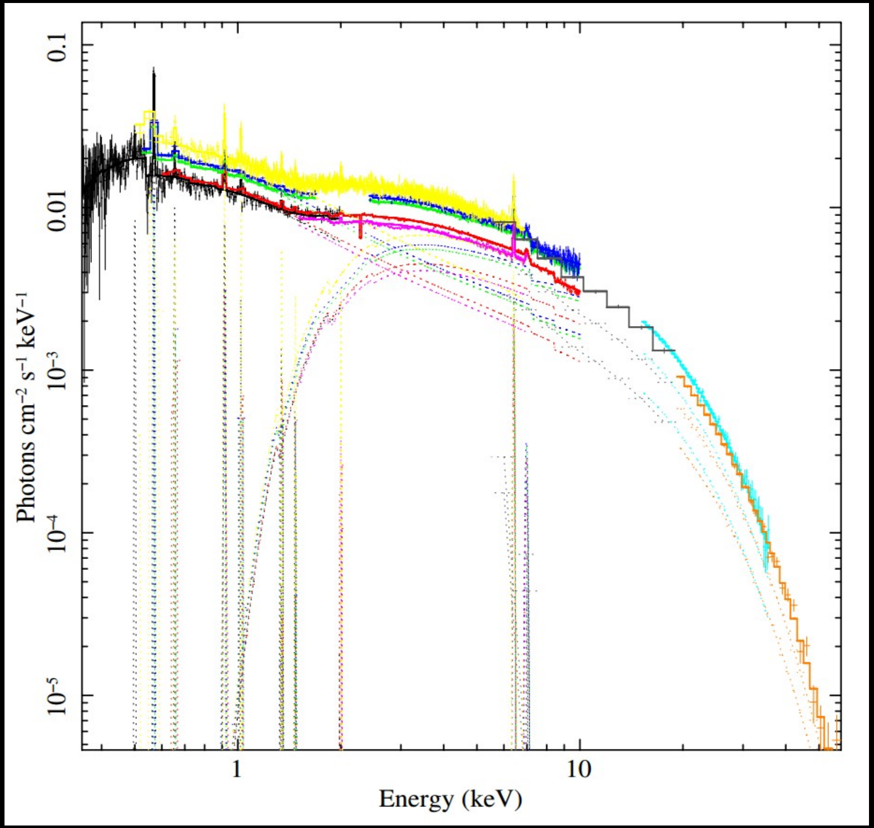
Rossi X-ray Timing Explorer (RXTE)
Launched in 1995
Operating 1995-2012

2A 1822-371:
28 June 1998 – 30 November 2011

2) The Accretion Disk Corona

Previously → ADC optically thick (τ~10-20)
(post 2001)
→ Problem
→ coherent pulsations

So look at the spectra + models of spectra
→ cut-off PL, BB, compTT …
→ cut-off at ~10keV



Iaria et al. 2015

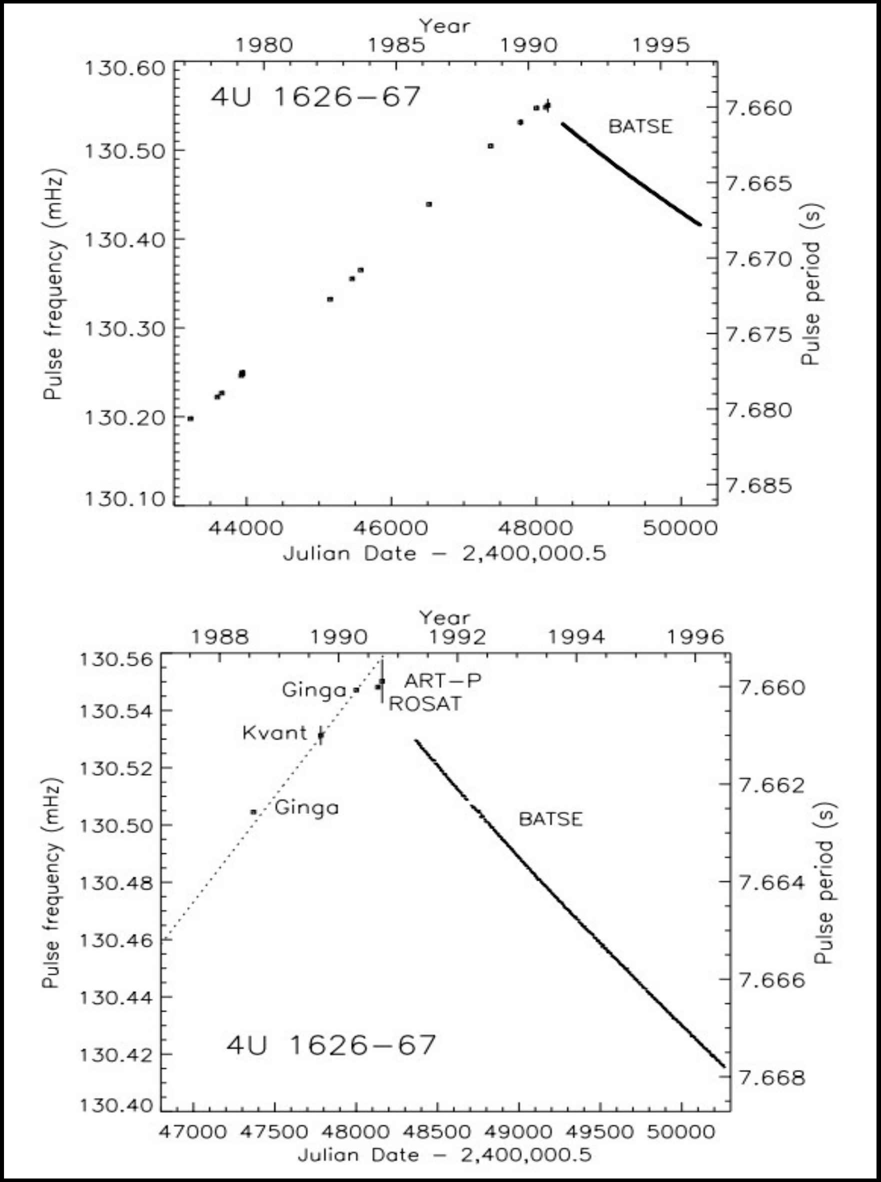
Future of 2A 1822-371

Possible torque reversal system
4U 1626-67
→ spin 7.66s
→ Spin freq. 0.13 Hz
→ P_b~0.69 hr

Spin up over 13 years
Spin down over 18 years
40 years of observation

Show same spin up/down time in both states → 5000yrs

Torque reversal for 2A 1822-371?



Chakrabarty et al. 1997