Accretion geometry and variability of ULX pulsars

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and the NuSTAR ULX working group

Properties of the three known PULX

	M82 X-2	NGC 7793 P13	NGC 5907 ULX1
Pulse Period	1.37s	0.42s	1.1s
Spin-up ($\dot{P}$)	2×10^{-10} s/s	3.5×10^{-11} s/s	8×10^{-10} s/s
Orbital Period	2.5 d	64d?	5.3 d
Superorb. P.	63.8 d	?	78 d
Max. Luminosity	2×10^{40} erg/s	6×10^{39} erg/s	$>10^{41}$ erg/s
Min. Luminosity	$<2.5\times10^{38}$ erg/s	$\sim4\times10^{37}$ erg/s	$<4\times10^{38}$ erg/s
Optical Comp.	$M > 5\ M_\odot$	SG B9I	$M \lesssim 3\ M_\odot$
References	Bachetti et al. 2014; Brightman et al. 2017; Dall'Osso et al. 2015	Fürst et al. 2016; Israel et al. 2017a	Israel et al. 2017b; Fürst et al. 2017; Walton et al. 2015

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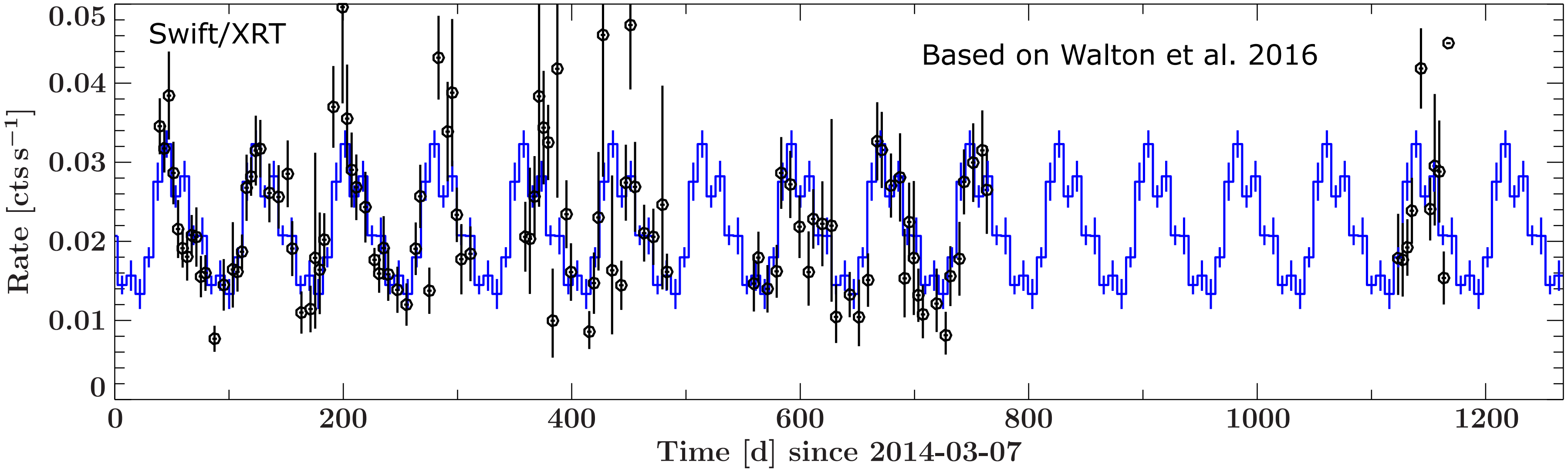
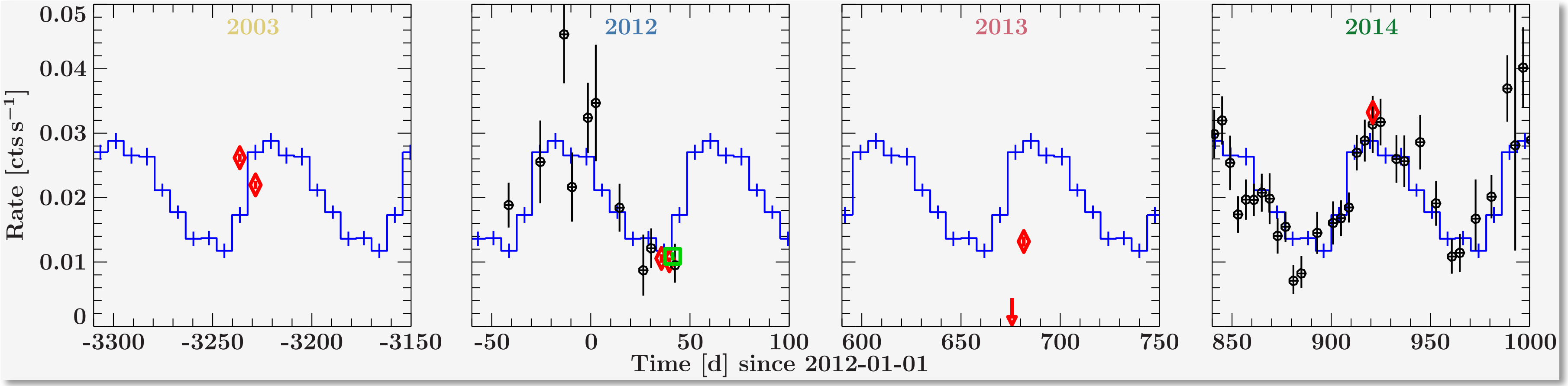
Super-obital period in NGC 5907 UXL 1



NGC 5907 ULX 1 has stable 78d period (Walton et al. 2016).

→ super-orbital, as orbit is known from pulsar timing to be ~5d

XMM observations as function of SO phase



Rising high phase

Minimum

Off-state and recovery + *NuSTAR*

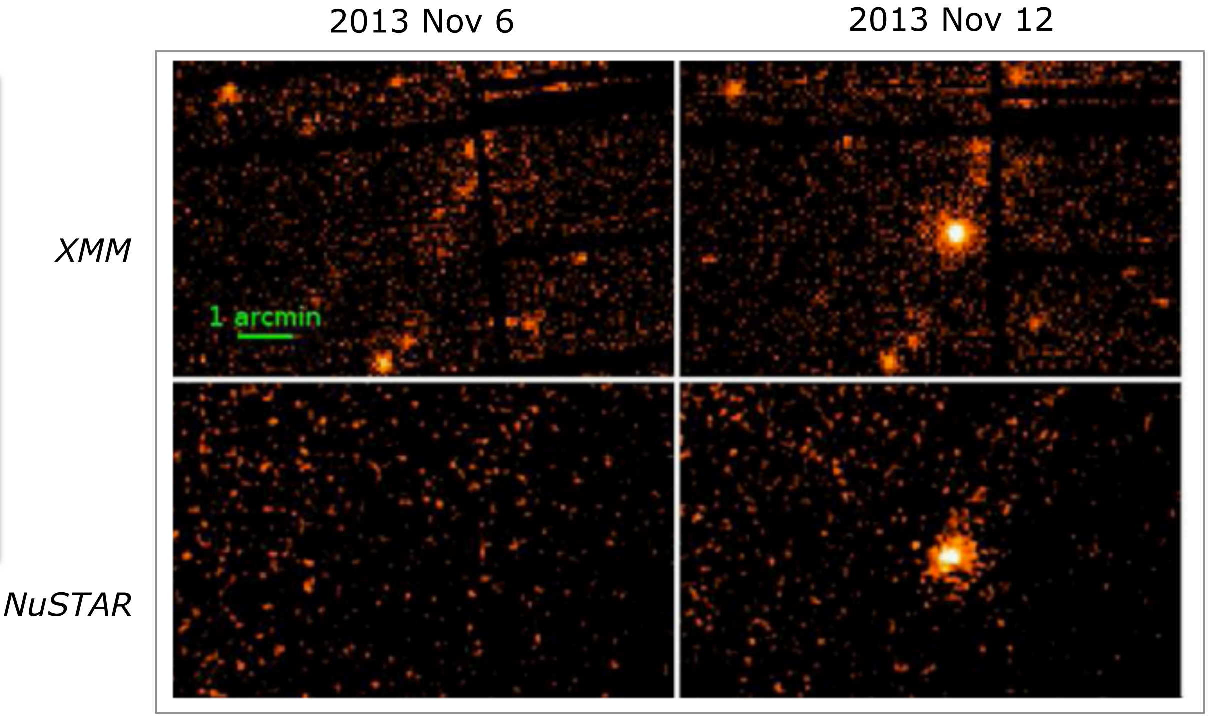
Maximum + *NuSTAR*

Fürst et al., 2017, ApJ 834, 77

Off-states: sources disappear suddenly

NGC 5907 was "off" during first observation, and appeared at 1.6×10^{40} erg s^{-1} only 4 days later.

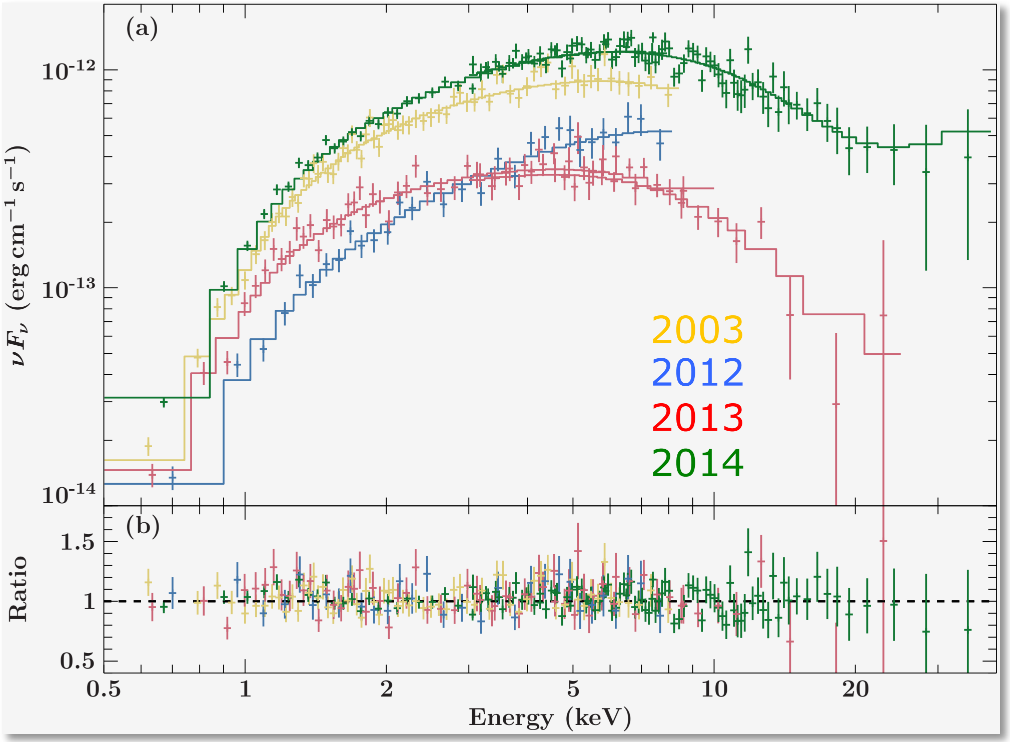
→ Obscuration event or shut-off of accretion?



Walton et al. 2015

Spectral variations over time

Fitted with typical diskpbb model (multi-temperature blackbody with variable temperature gradient)
+
powerlaw hard excess in bright phase

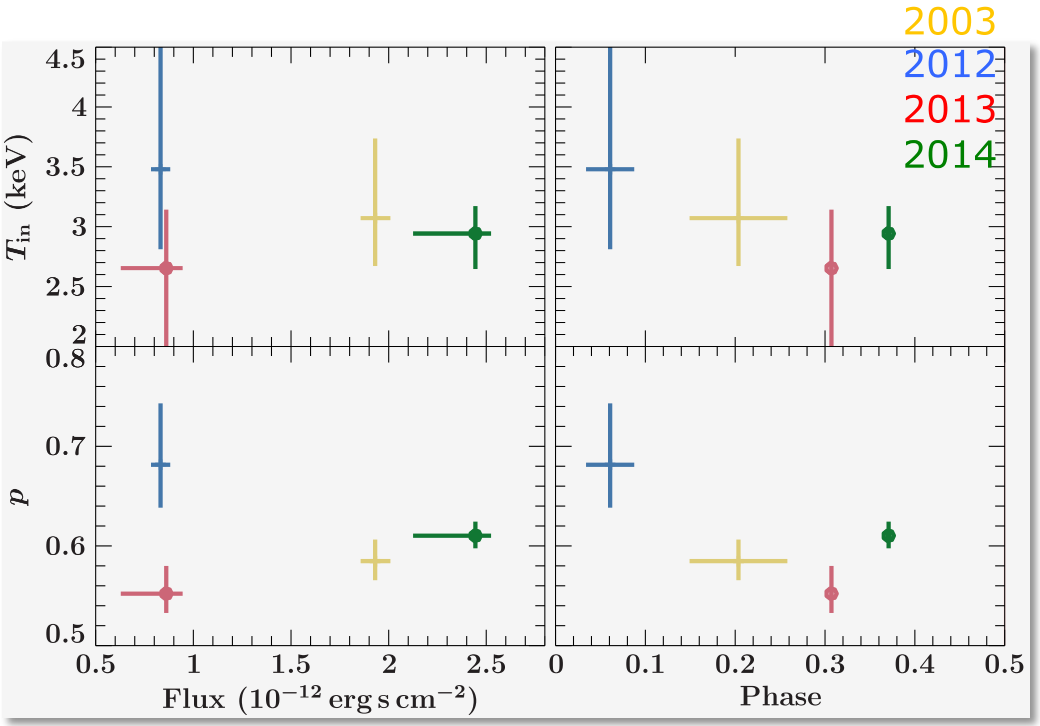


Fürst et al., 2017

Spectrum varies with super-orbital phase

Variations are more clearly separated as function of **super-orbital phase** than as function of flux.

→ Precessing accretion disk?



Fürst et al., 2017

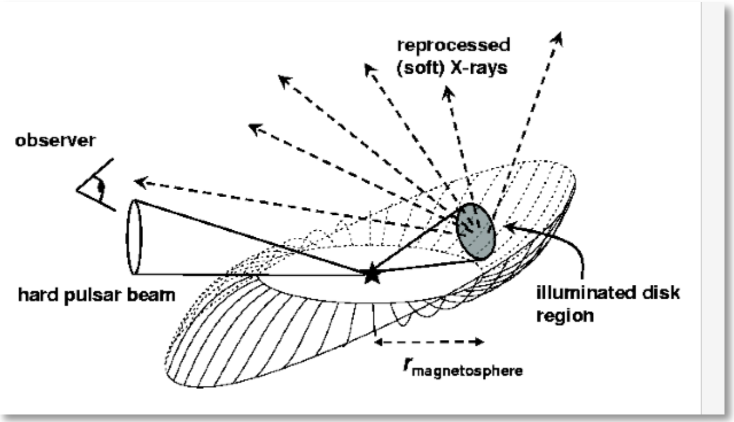
Accretion disk precession in galactic sources

Some local X-ray binaries show super-orbital periods (Her X-1, SMC X-1, LMC X-4).

Periods seen in light-curve, pulse profile shape, spectral shape

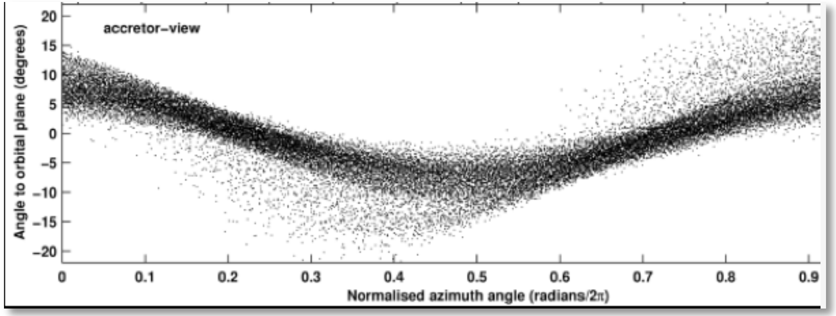
Warped and precessing accretion disk calculated also by hydro simulations.

→ But unclear how that would look in super-Eddington case!



SMC X-1, Hickox et al. 2005

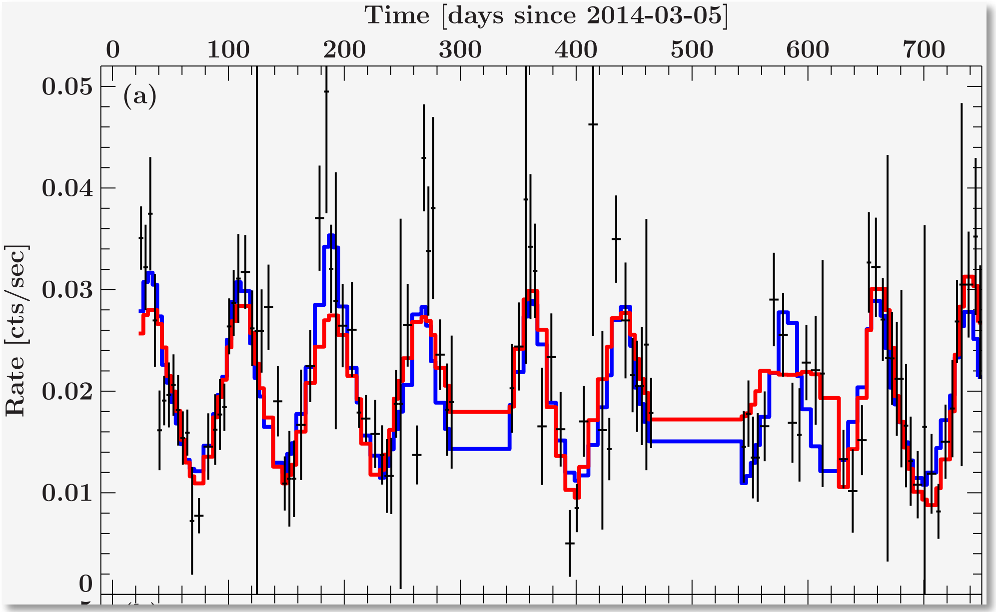
Foulkes et al. 2005



Collimation and scattering

Dauser et al. (2017) use a simple model of multiple scatterings within a narrow cone of a puffed up accretion disk

Together with precession, modeling of super-orbital variability of NGC 5907 possible! (but requires very narrow opening angle)



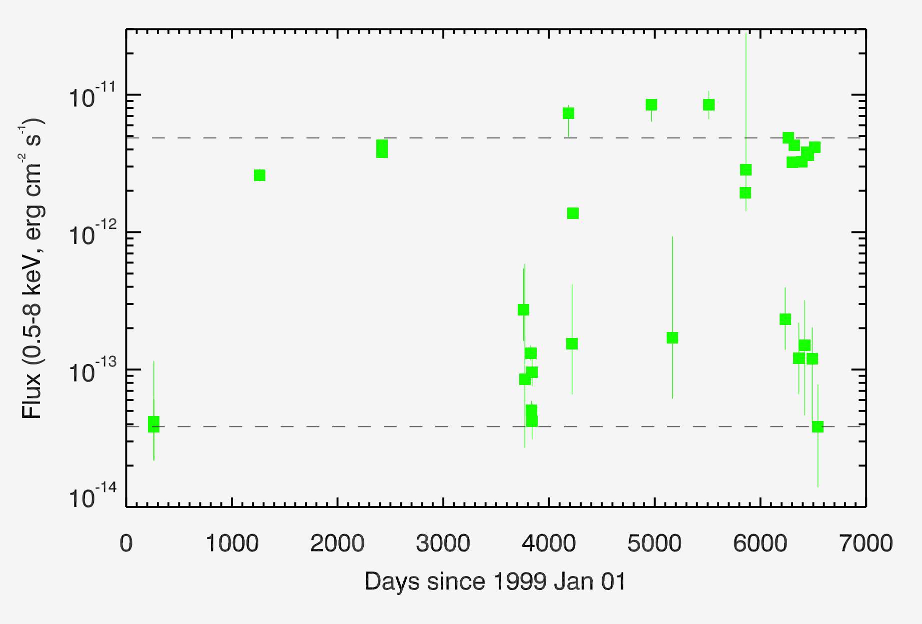
Dauser et al. 2017

M82 X-2: super-orbital variation is larger

Flux variation of M82 X-2 in *Chandra*

→ Consistent with 68d period (Brightman et al., in prep.)

→ Dynamic range is ~100x, much larger than in NGC 5907!



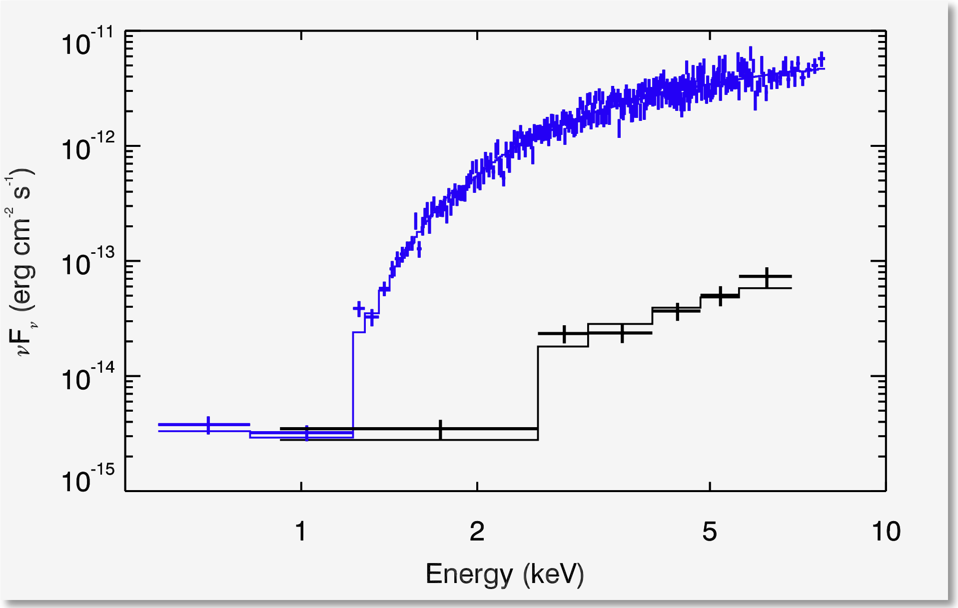
Brightman et al., in prep.

M82 X-2: no spectral variation with SO phase

Chandra spectra do not reveal any significant change

→ Definitely not very soft or thermal, as expected from "propeller state"

→ Variation due to precessing accretion disk also seems unlikely



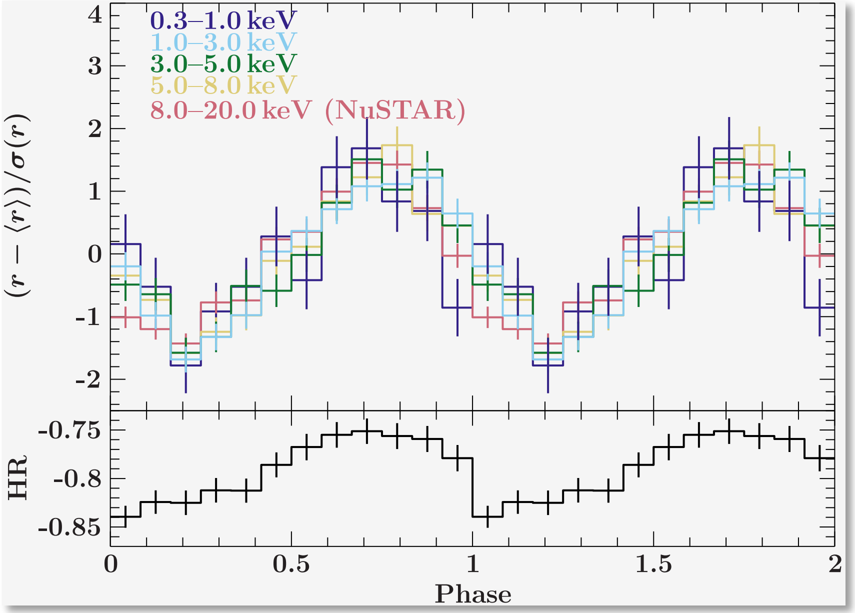
Brightman et al., in prep.

NGC 7793 P13: pulse profile

Pulse profiles are very sinusoidal

Shape is independent of energy

Very different to Galactic (sub-Eddington sources!)
→ Different emission geometry?



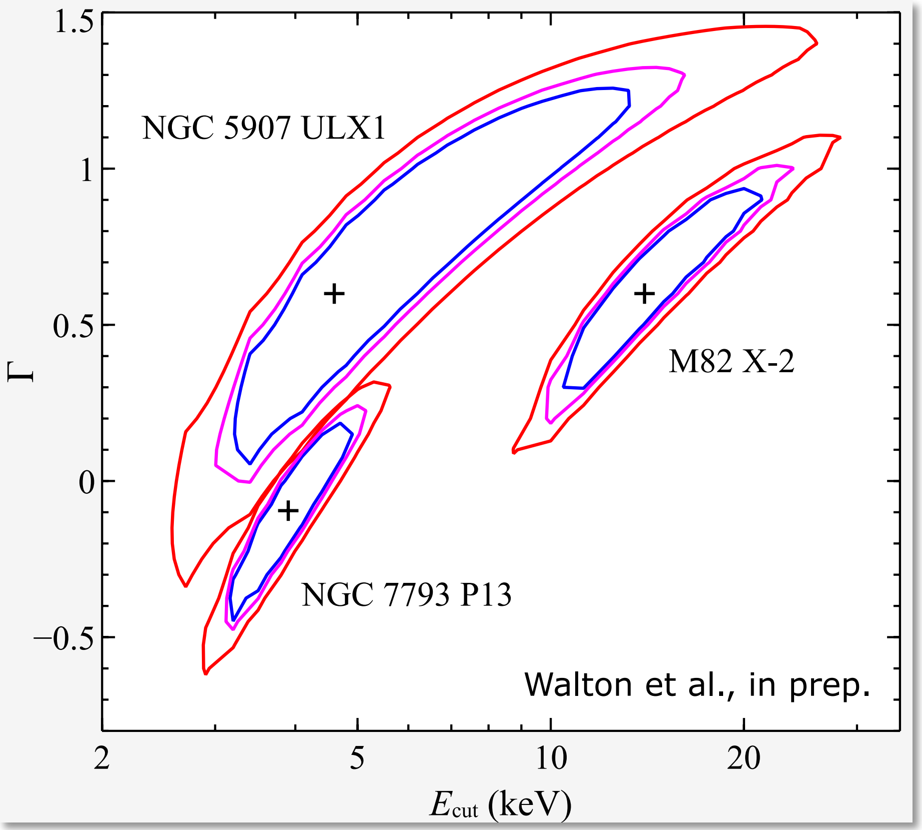
Fürst et al., 2016

On-off difference spectroscopy

Subtracting off-phase from on-phase to study spectrum of the pulsed component only

→ all sources well fit by just a cutoffpl

→ spectral parameters are similar, but significantly different!



Summary

Pulsating ULXs show spectral variations as super-orbital and pulse phase. But what are the physics behind these variations? #twittersummary

Only 3 PULXs are currently known, with very similar *observational* properties.
Their *physical* properties are still investigated.