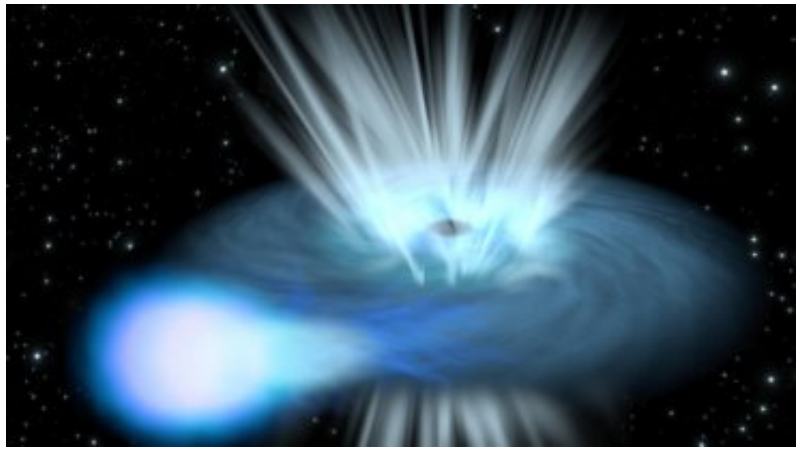
Durham University

A new detection of pulsations from an old ULX



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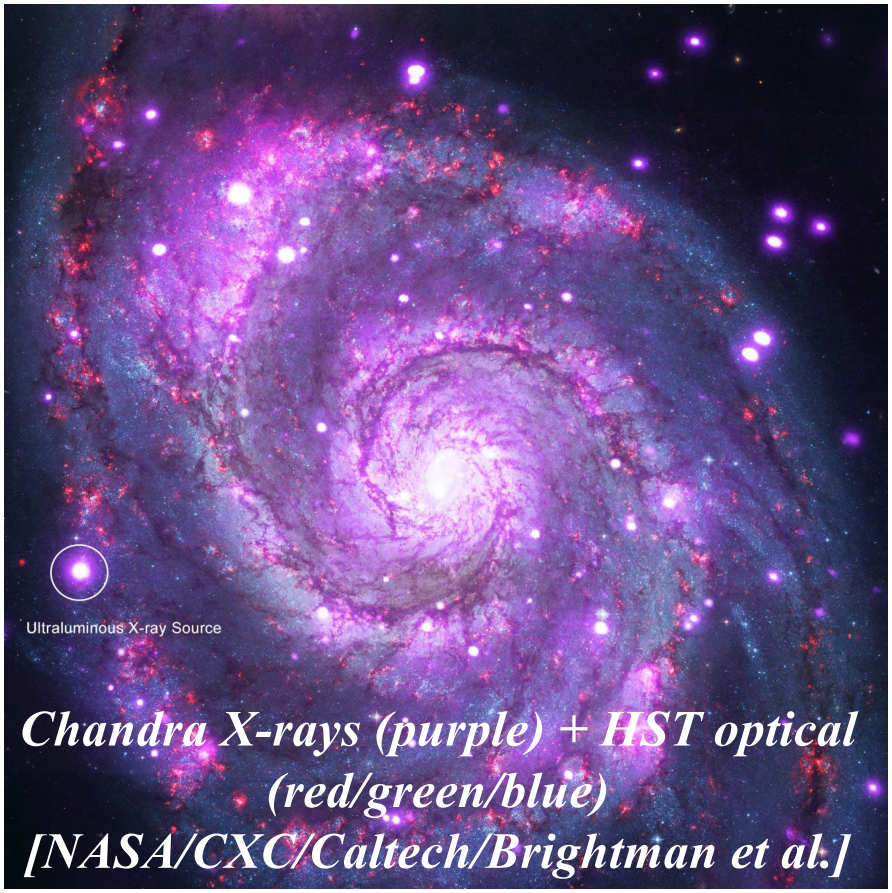
Ultraluminous X-ray sources

Kaaret, Feng & Roberts (2017)

- **ULXs**: point sources in nearby galaxies with $L_x \gtrsim 10^{39}$ erg s^{-1}
- Most luminous extra-nuclear, non-explosive objects
- Eddington limit is

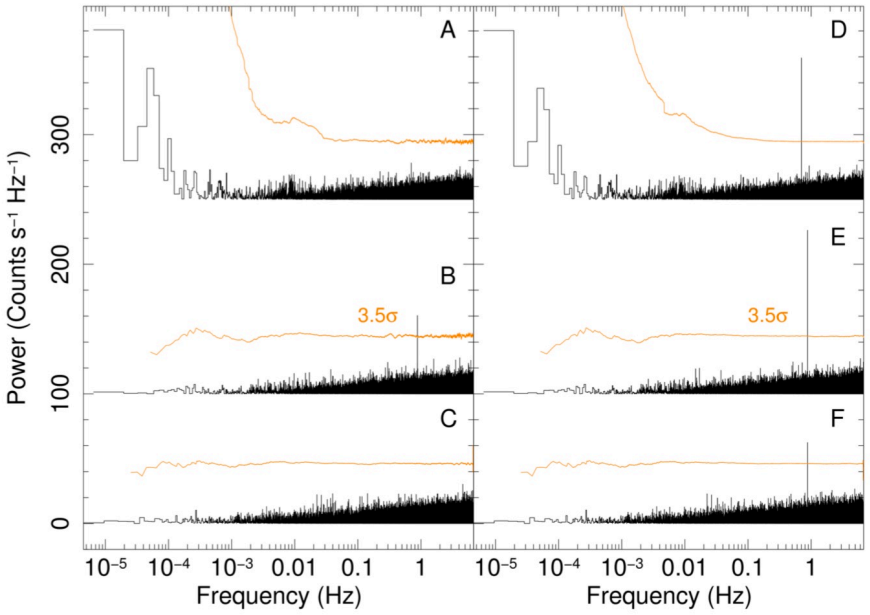
$$L_{Edd} = 1.3\times10^{38}(M/M_\odot) \text{ erg s}^{-1}$$

- **Implies big black holes ($\geq 10\ M_\odot$); or super-Eddington accretion**



Chandra X-rays (purple) + HST optical (red/green/blue) [NASA/CXC/Caltech/Brightman et al.]

It's got a pulse!

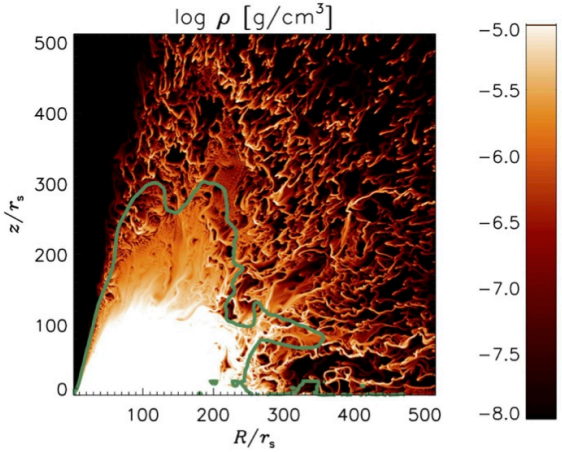


Pulse detection in NGC 5907 (Israel et al. 2017), showing pre- and post-correction for large $\dot{P}$ ($\sim 10^{-9}$ s s^{-1}) in a ULX that goes up to ~ 500 times Eddington

- Detections of pulsating ULXs are a paradigm shift → neutron stars
- Difficult to detect – large $\dot{P}$
- Find sinusoidal pulse profiles, $P \sim 1$s, $\dot{P} \sim 10^{-11} \rightarrow 10^{-7}$ s s^{-1}, pulse fraction higher at high E, transient

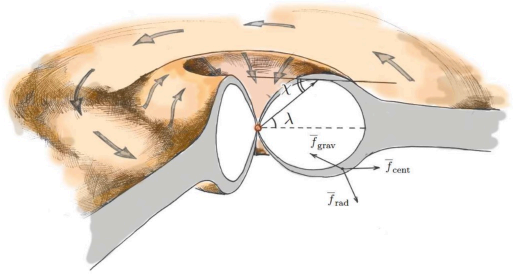
New questions

- Demographics: fraction of ULXs hosting NS?
  - How do we distinguish NS from BHs?
- Physics: how does super-Eddington accretion work for high magnetic field NSs?



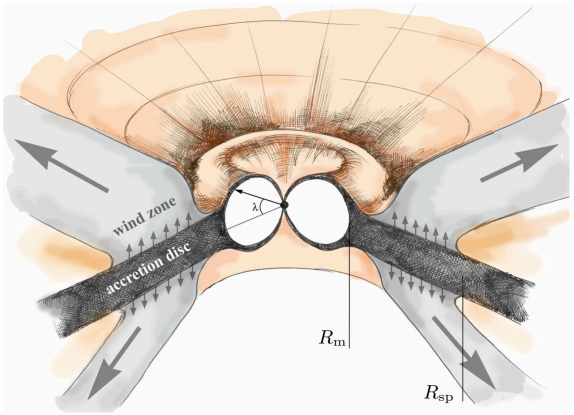
Super-critical disc?
(e.g. Takeuchi et al. 2013)

OR



Magnetospherically-dominated accretion?
(Mushtukov et al. 2017)

OR

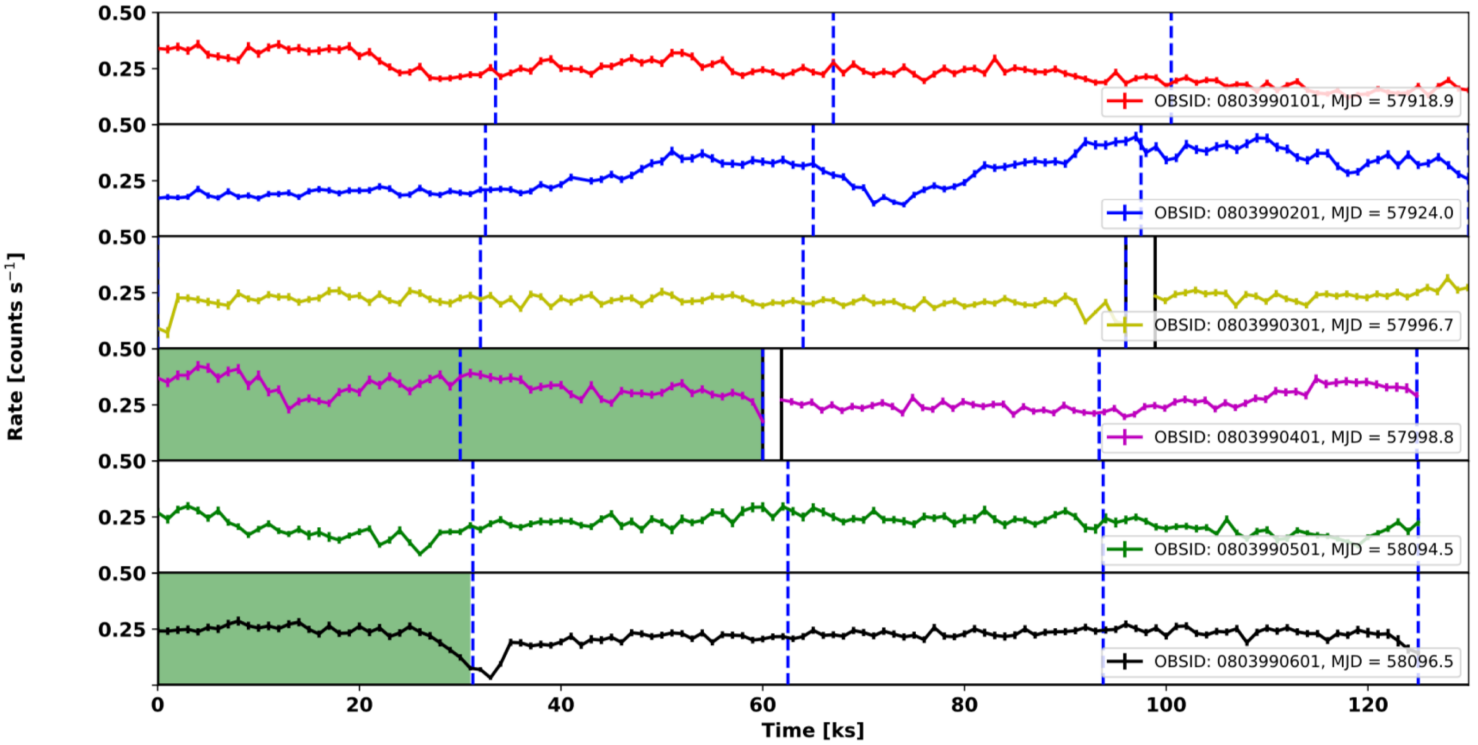


Hybrid model?
(Mushtukov et al. 2018)

XMM-Newton LP for NGC 1313

Sathyaprakash et al. (2019)

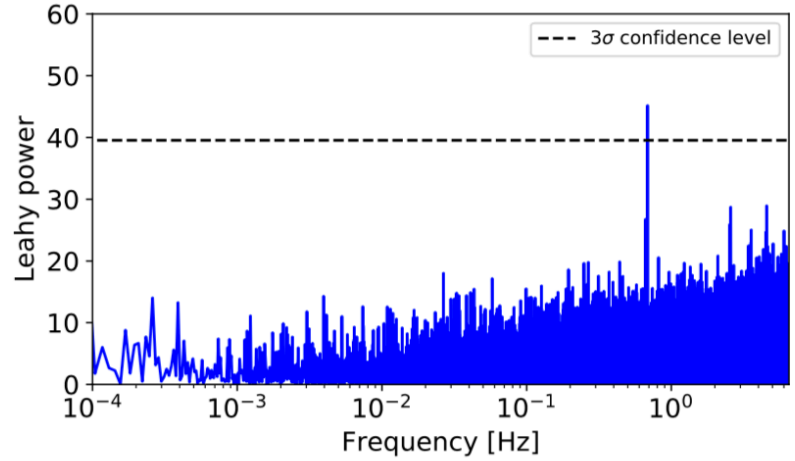
- > 700 ks of data to look for RGS wind signatures (Pinto et al., Walton et al. in prep.)

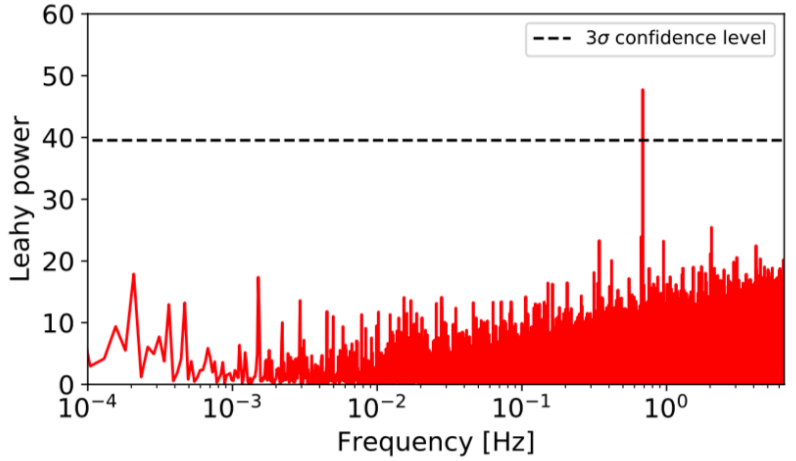


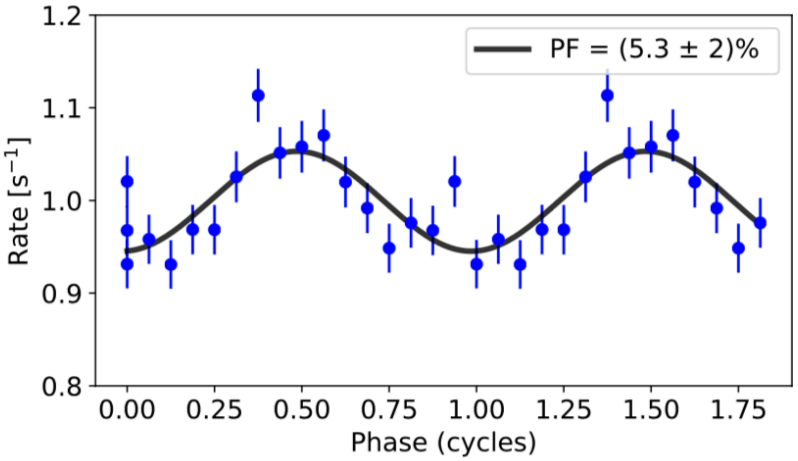
Accelerated pulsations search finds two periods with pulses (green shaded).

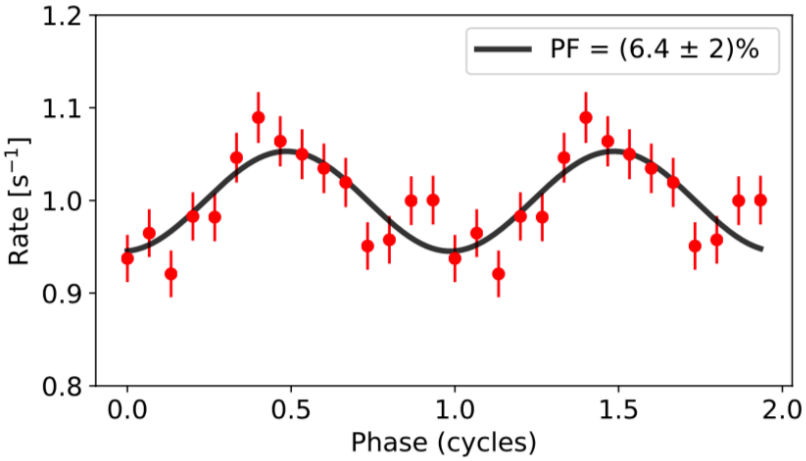
Data is light curve of NGC 1313 X-2, Sathyaprakash et al. (2019)

Weak pulsations



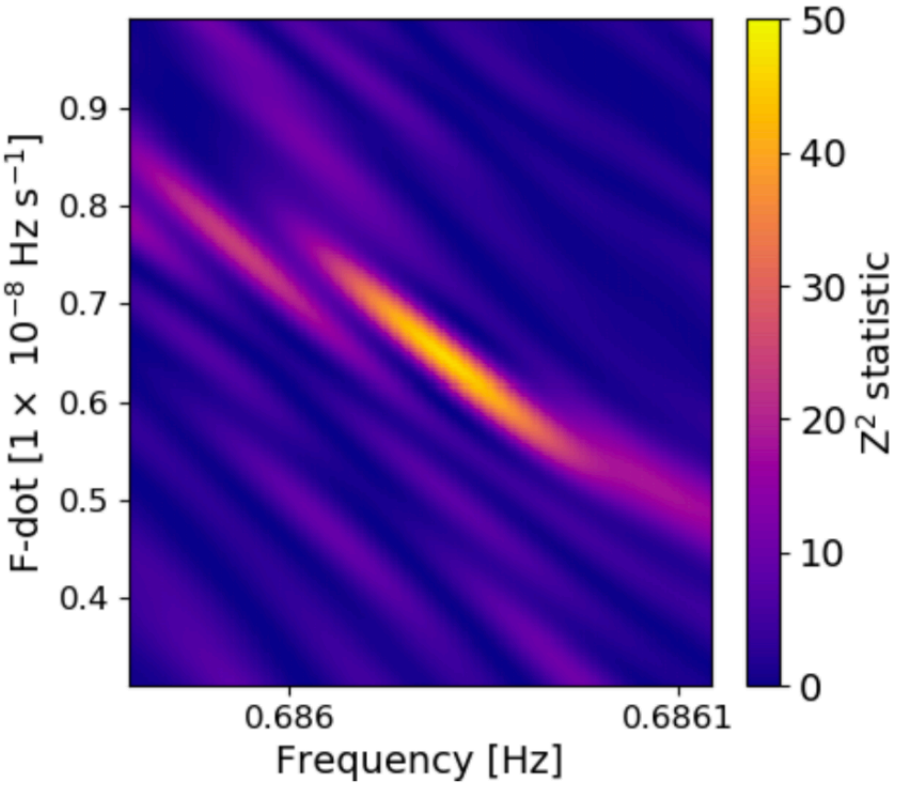






Are they real pulsations?

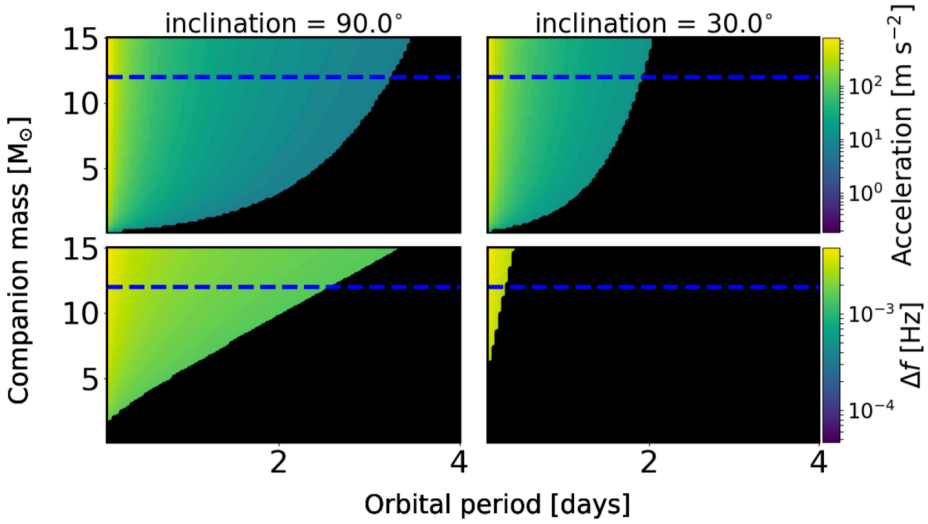
- ***YES***
- Detected by multiple methods
- Pulse period (~1.5s) & profile similar to other PULXs
- Monte Carlo sims – detecting two false periods with same Δf no better than 1 in 10000 occurence



Detection of pulses using epoch folding tool in HENDRICS. ($Z^2 > 40 \equiv 3\sigma$)

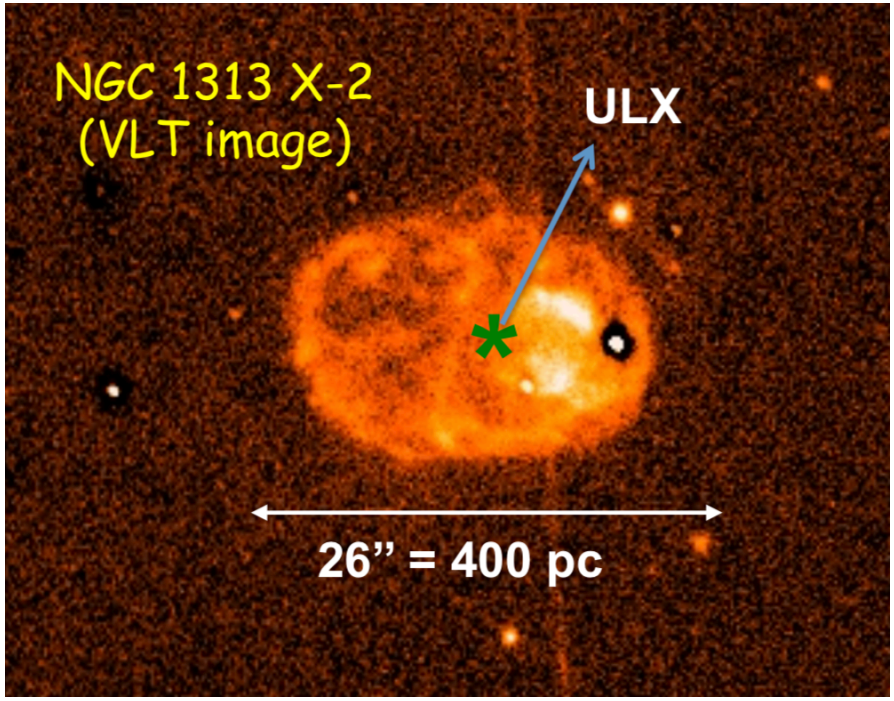
Orbital constraints

- Change in detected $f, \dot{f}$ between two detections is high – assumed orbital
- Can rule out some orbital configurations for a 1.4 $M_\odot$ NS (black)
- X-ray properties suggest face-on – spin-orbit misalignment?



Black regions show $\Delta\dot{f} < 8.5 \times 10^{-9}$ Hz s^{-1} *(top) and* $\Delta f < 1.5 \times 10^{-3}$ Hz *(bottom). Blue line shows upper limit on companion mass from local stellar population*

An old PULX



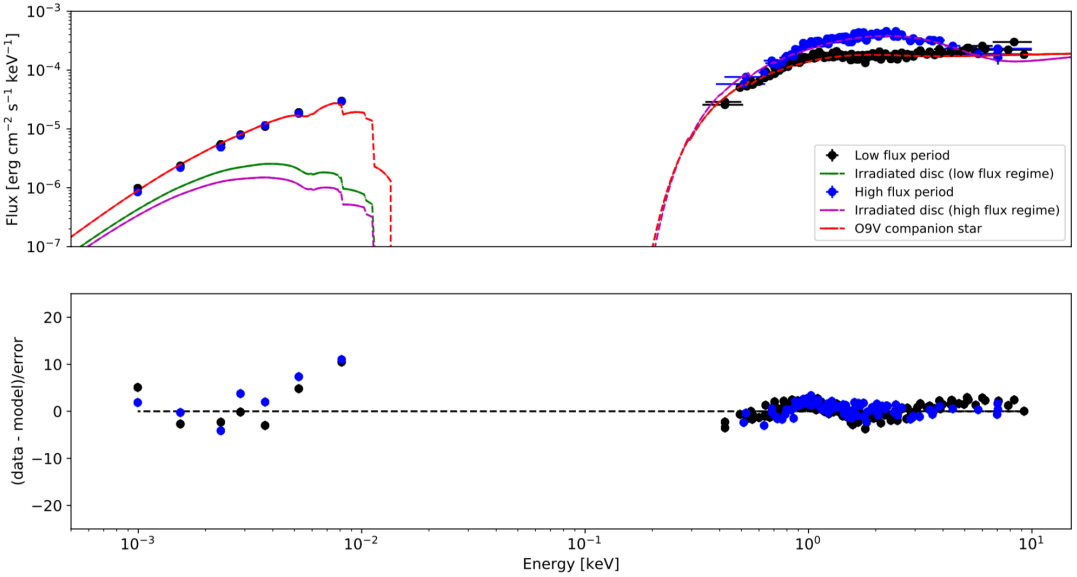
Hα emission from bubble nebula around NGC 1313 X-2 (Pakull, Lorentz Center talk, 2014)

- Large bubble nebula - $L_{mech} \sim 10^{40}$ erg s^{-1} for 10^6 years
- Still pulsing – *B* field survives accretion!
- If $L_{rad} \sim L_{mech}$ then $\gtrsim 1 M_\odot$ accreted: but still NS?
- Most material lost in wind?
- Supports hybrid models

Optical to X-ray SED

Sathyaprakash et al. in prep.

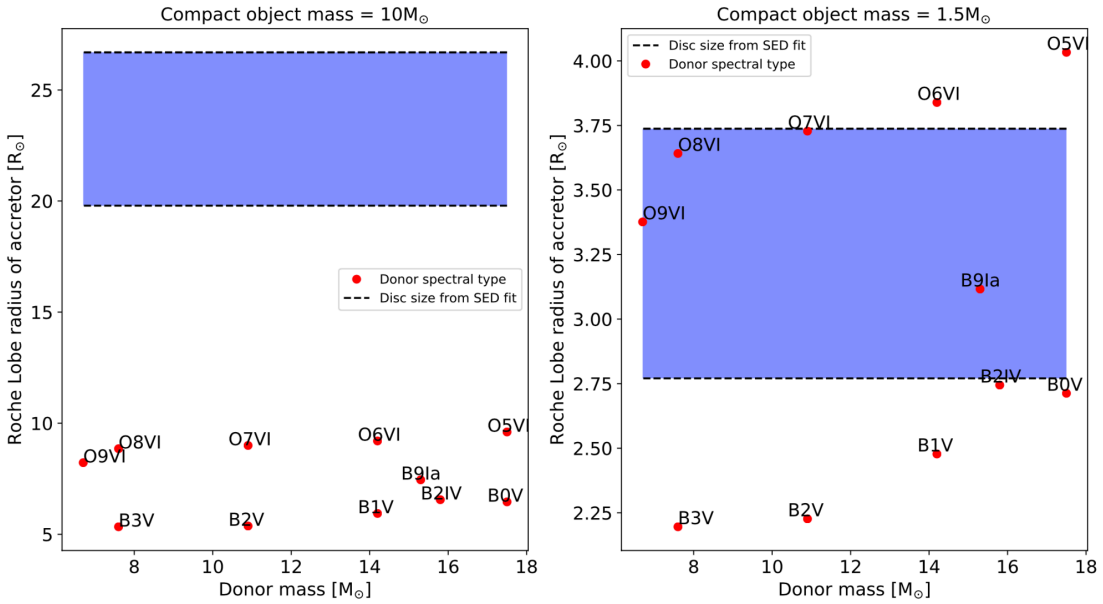
- Simultaneous *HST* & *XMM-Newton* observations for high & low X-ray fluxes
- Optical emission doesn't change
- Dominated by star? Cf. P13, another PULX



Fits show either unusually high reprocessed fraction; or another, likely stellar, component. Note also UV excess – outermost part of wind (cf. Poutanen et al. 2007)?

More orbital constraints

- Reprocessed emission required in fits, out to NIR
- Implies big accretion disc ($10^6\ R_g$)
- Rules out BH accretor (too big for Roche lobe); fits with NS! Consistent with pulsations



Summary

- NGC 1313 X-2 – fifth reported PULX
- Properties similar to other PULXs – but pulsations fainter
- If changes in $f, \dot{f}$ are orbital – possible spin-orbit misalignment
- Bubble nebula says ULX old – but still pulsing so B field not buried, NS not collapsed to BH – material lost in wind? *Hybrid physical model*
- Optical light dominated by companion star