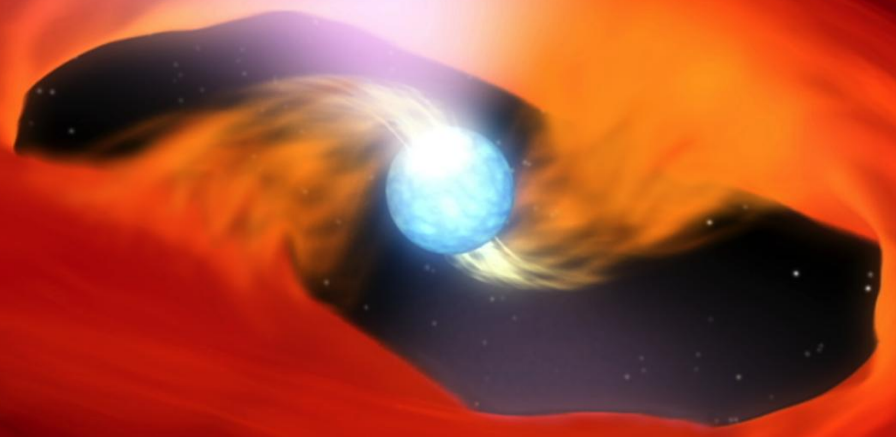
A Potential CRSF in NGC300 ULX1



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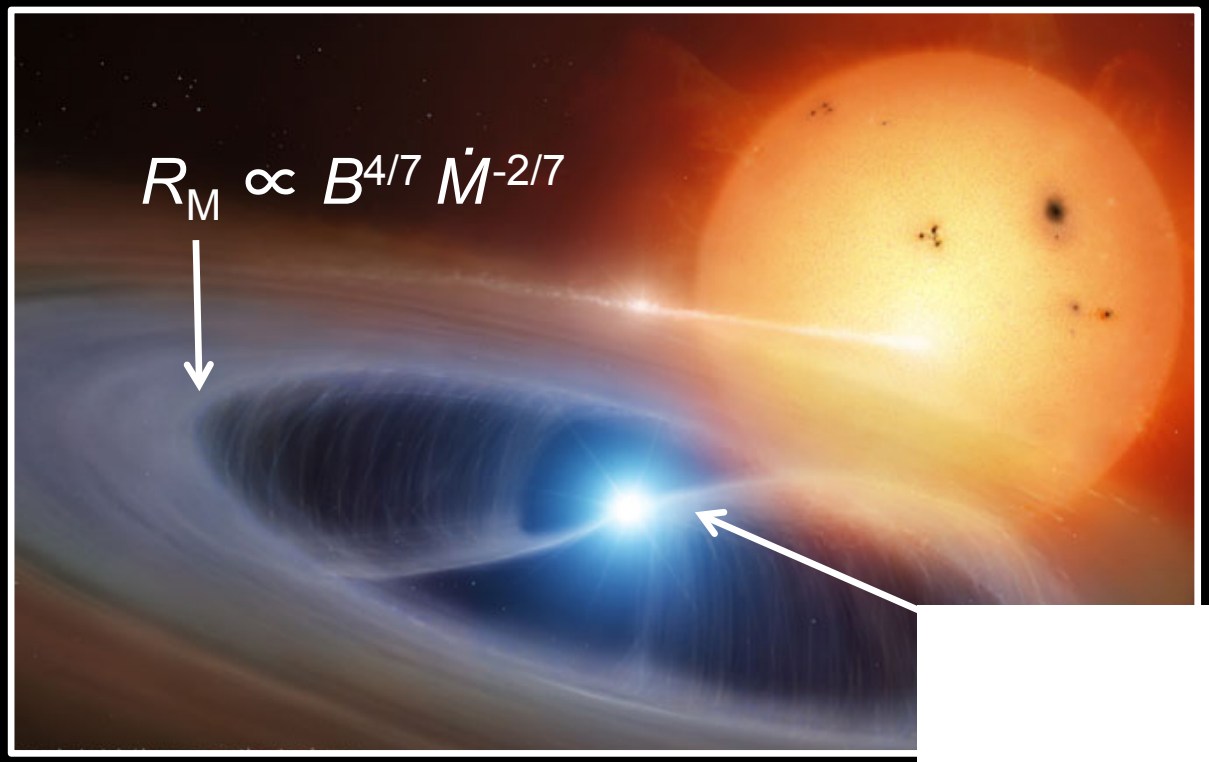
Bachetti, Furst, Barret, Brightman, Fabian, Grefenstette, Harrison, Heida, Kennea, Kosec, Lau, Madsen, Middleton, Pinto, Steiner, Stern, Webb

Magnetic Accretion



Very strong mag. field ($B \sim 10^{14}$ G) can also suppress interaction between photons and matter

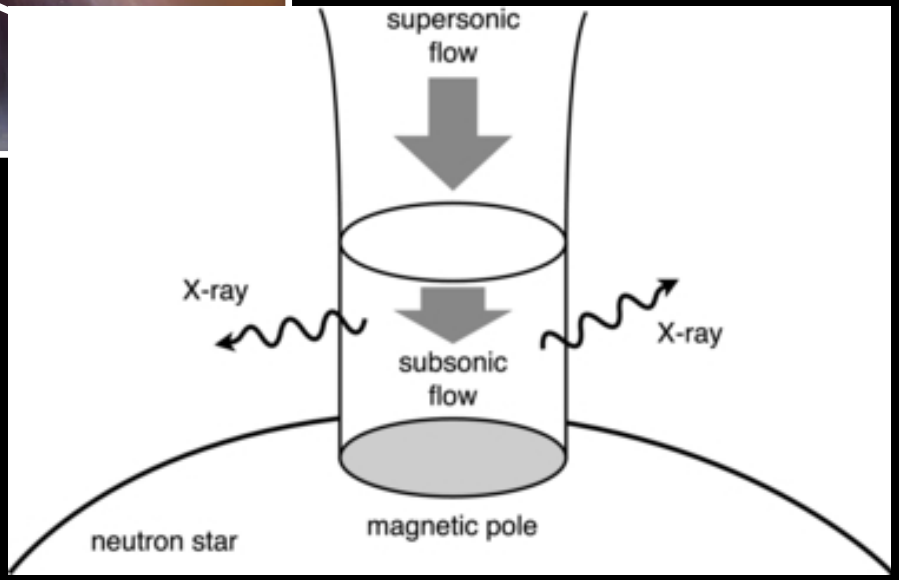
↓

Higher effective L_E

Magnetically channeled accretion is necessarily anisotropic ('beamed')

↓

Assuming isotropy can overpredict L



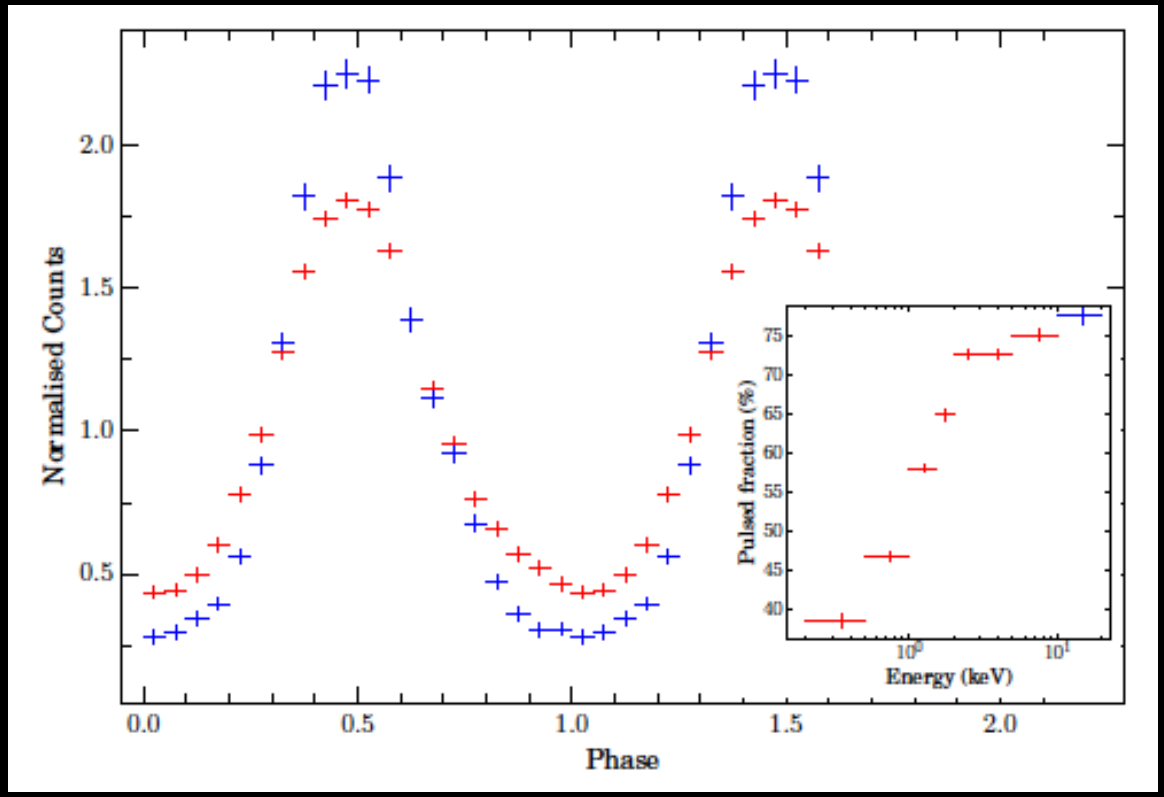
NGC 300 ULX1

Discovered to be the 4th ULX pulsar by Carpano+18 (*XMM+NuSTAR* obs)

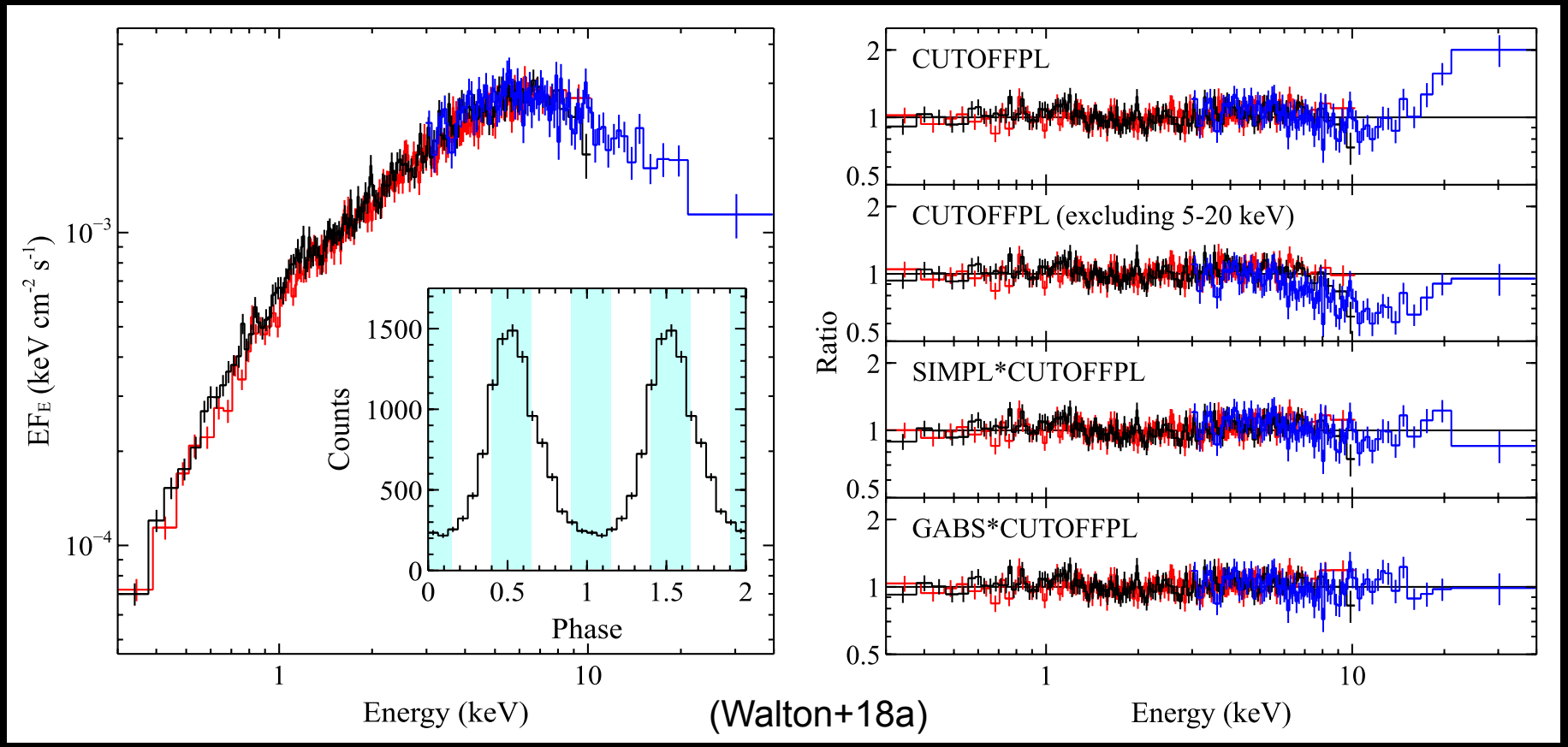
Peak luminosity ~3×10^{39} erg/s

Broad pulse profile (relatively similar to other ULX pulsars)

Very high pulsed fraction, reaching > 75% (other ULX pulsars, have peak PFs ~ 20-30%)



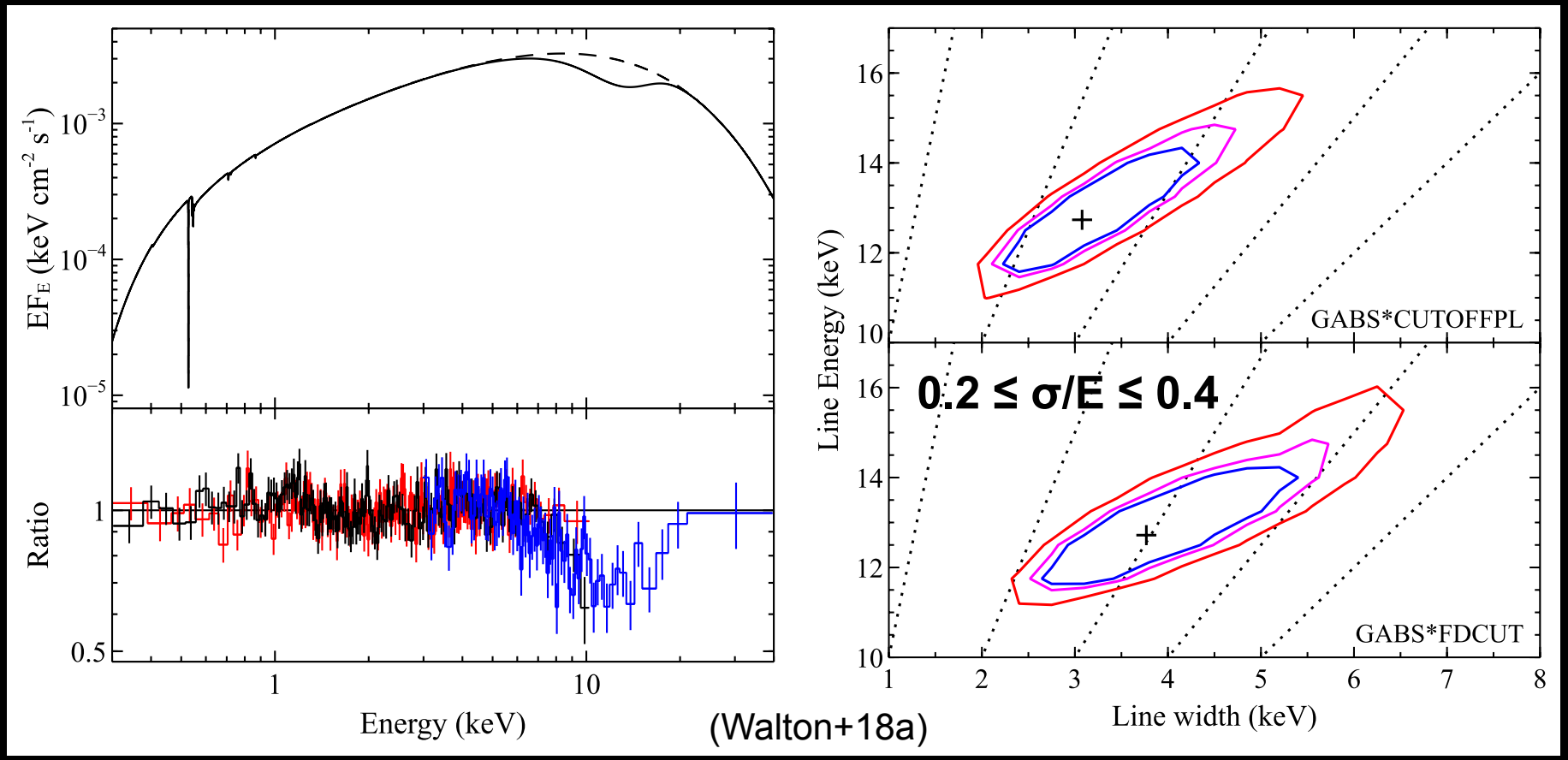
Pulse-Resolved Spectroscopy



(Walton+18a)

Broadband pulsed spectrum (peak – trough) shows structure not currently seen in any other ULX pulsars

Cyclotron Resonant Scattering Feature?



Structure well fit with an **electron** CRSF, line energy implies $B \sim 10^{12}$ G

Similar to B-field estimated from spin-up rate ($B \sim 3 \times 10^{12}$ G; Carpano+18)

M51 ULX8

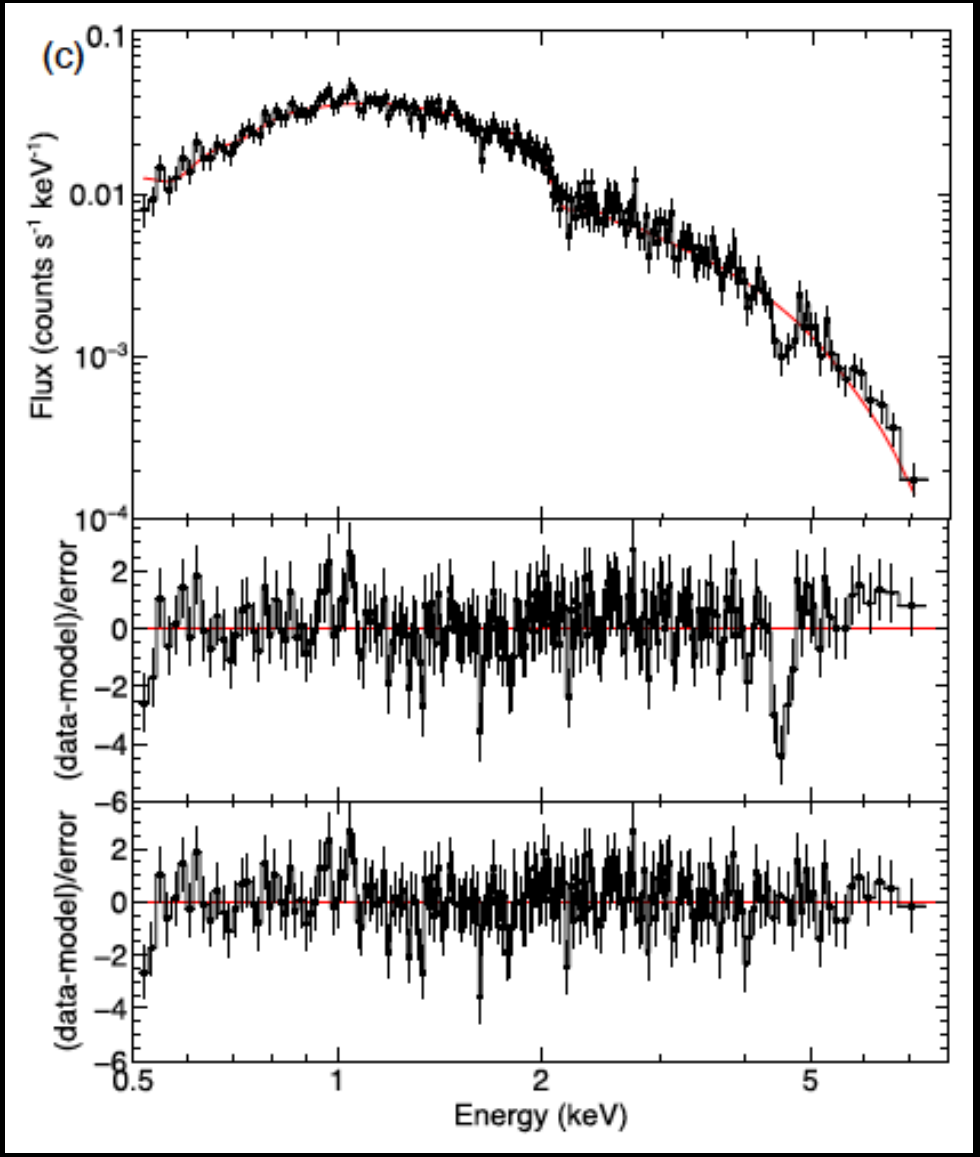
Potential **proton** CRSF seen in M51 ULX-8 (Brightman+18)

(electron and proton CRSFs distinguished by line width)

Line energy implies $B \sim 7 \times 10^{14}$ G

No pulsations seen to date (although limits are not strong)

Peak luminosity ~ 10^{40} erg/s



Implications

- ULX cyclotron magnetic field measurements:

NGC300 ULX1:	$B \sim 10^{12}$ G	$L_{X,peak} \sim 3 \times 10^{39}$ erg/s
M51 ULX8:	$B \sim 7 \times 10^{14}$ G	$L_{X,peak} \sim 10^{40}$ erg/s

- Results are consistent with *B*-field playing a role in producing higher luminosities
- However, *B*-field can only enhance flux from the accretion column
- Super-Eddington accretion almost certainly required in addition (producing the extreme outflow observed)

If high-B required to reach $L_X \geq 10^{40}$ erg/s, other ULX pulsars should also have fields similar to M51 ULX8

The ‘Propeller’ Effect

Co-rotation radius (R_{co}) – the point at which the disk rotates at the same rate as the NS, set by P_{pulse}

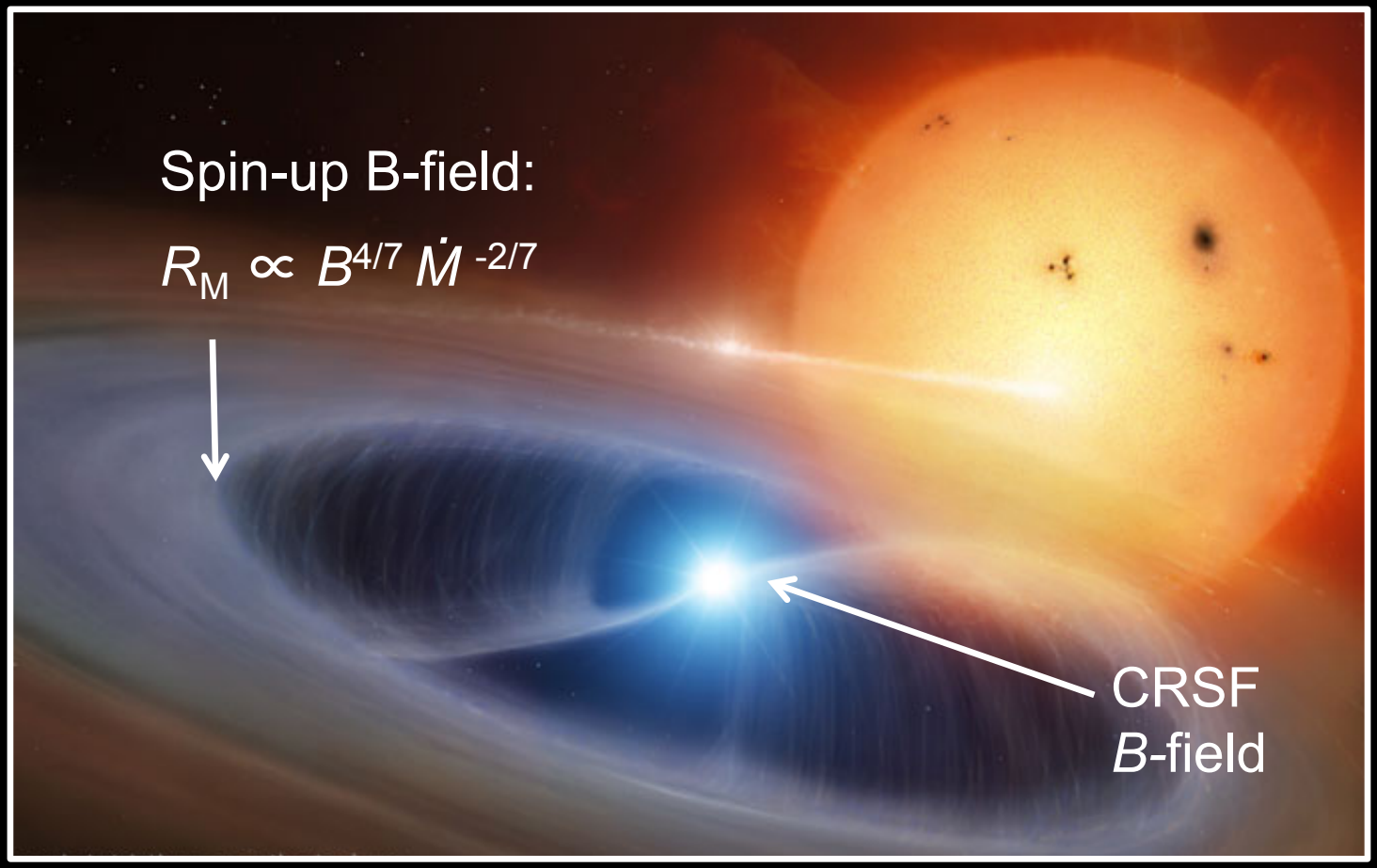
$R_M < R_{co}$: accretion proceeds as normal
$R_M > R_{co}$: magnetic field acts as a barrier to accretion (propeller effect)

For dipole field with $B \sim 10^{14}$ G, pulsar ULXs with $P_{spin} \sim 1$s would be in the propeller regime

We know accretion must be occurring (high luminosity, observed spin-up)

Multipolar fields?

Magnetic Accretion

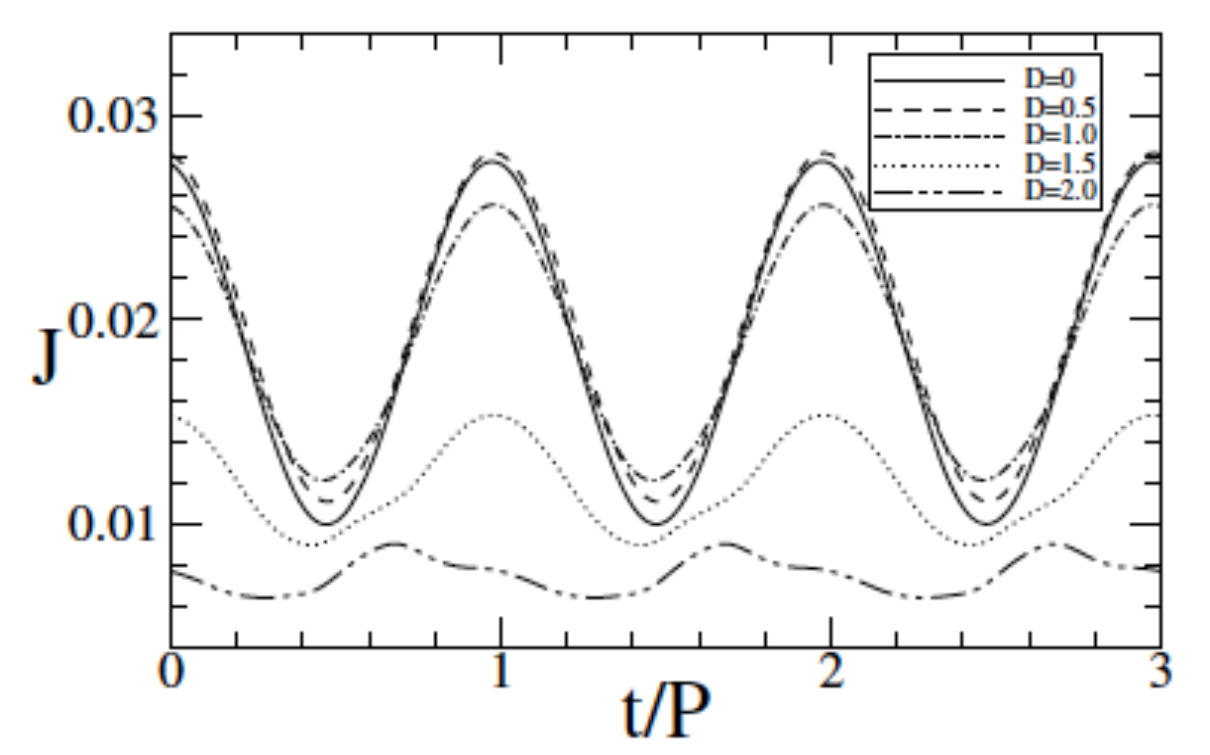


If spin-up and CRSF both imply fields of ~10^{12} G, there is no room for a strong multipolar component

Pulse Fractions

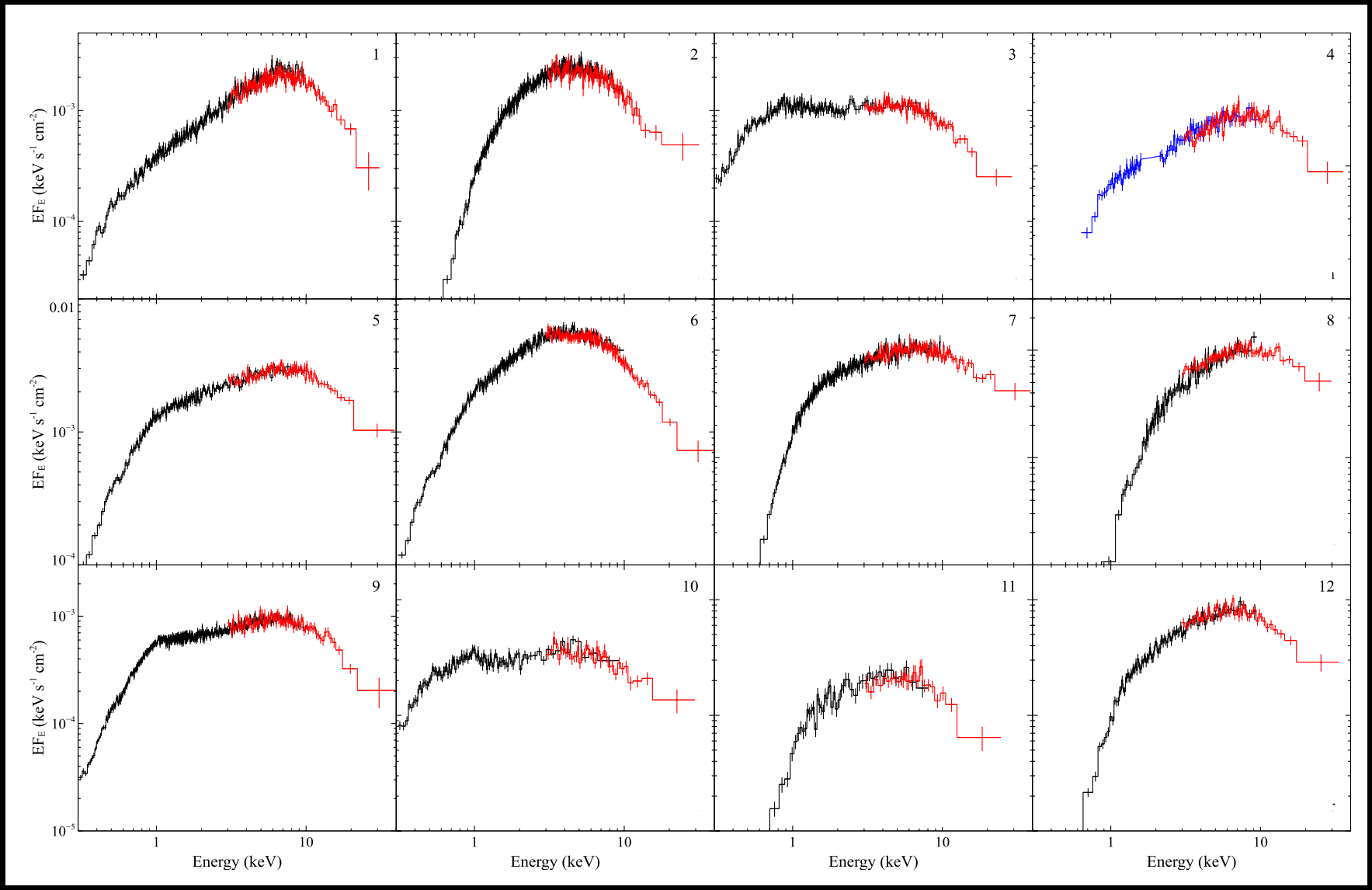
Potential distinction between NGC300 ULX1 and the other ULX pulsars could be the presence of a strong quadrupolar field

Could also explain the large difference in pulsed fraction (Long+08)



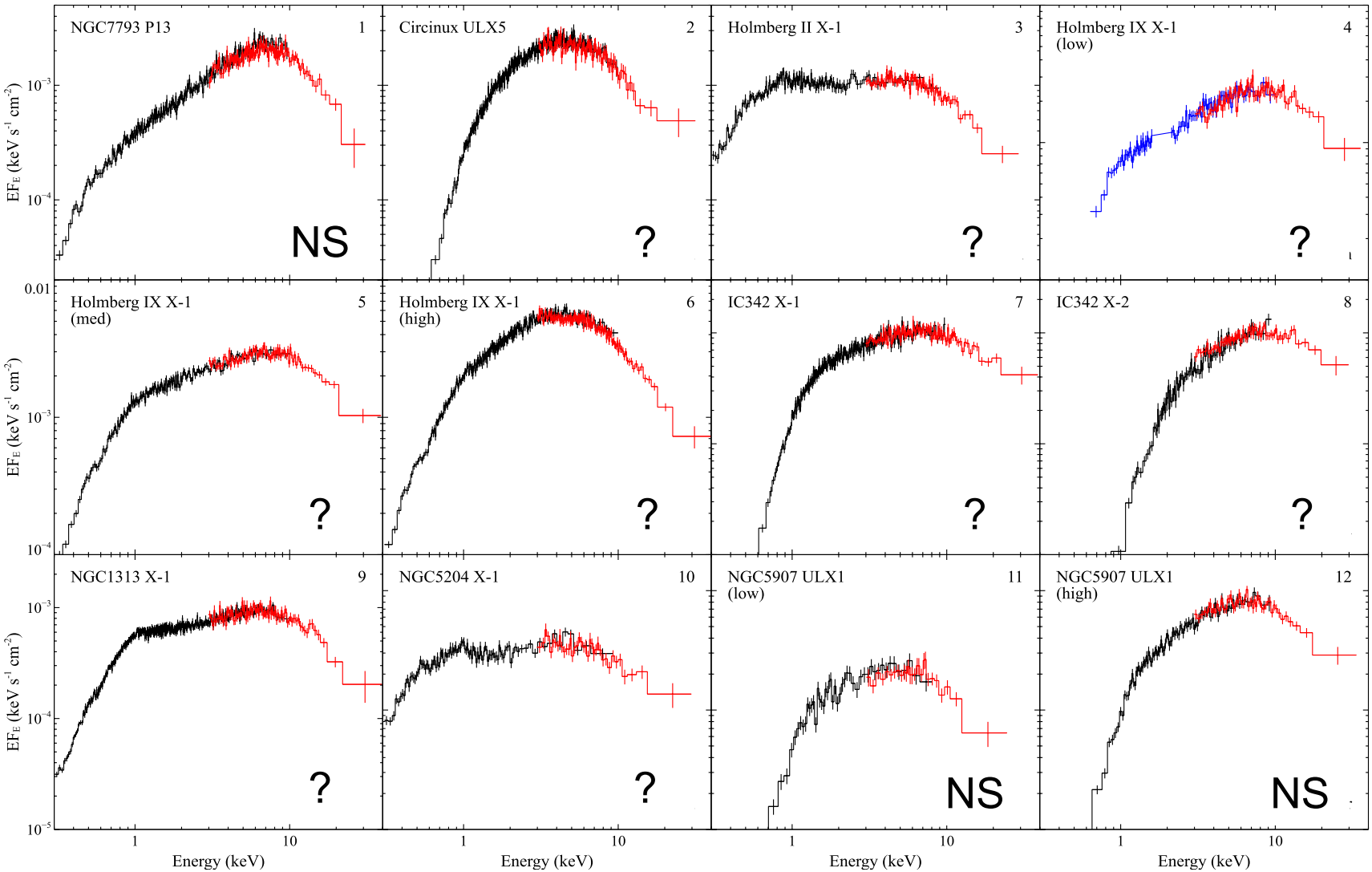
(Increasing D means increasing quadrupolar contribution)

Spot the Neutron Star(s)



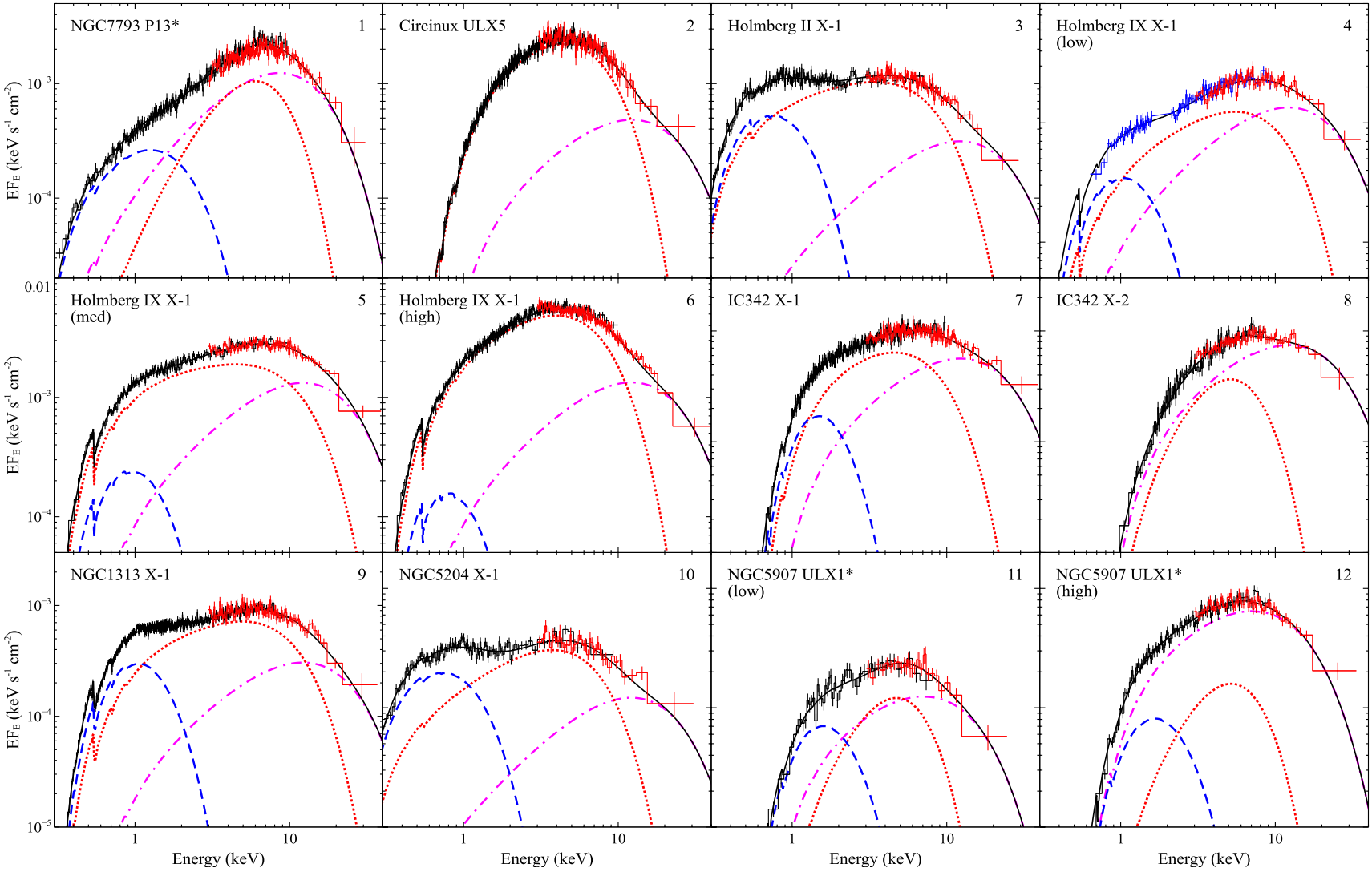
(adapted from Walton+18b,c)

Spot the Neutron Star(s)



(adapted from Walton+18b,c)

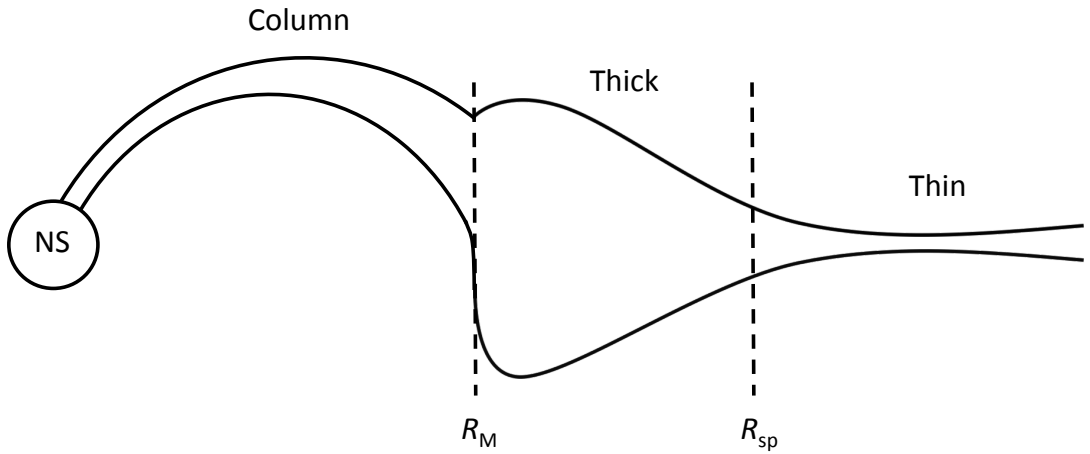
Accretion Columns?



(adapted from Walton+18b,c)

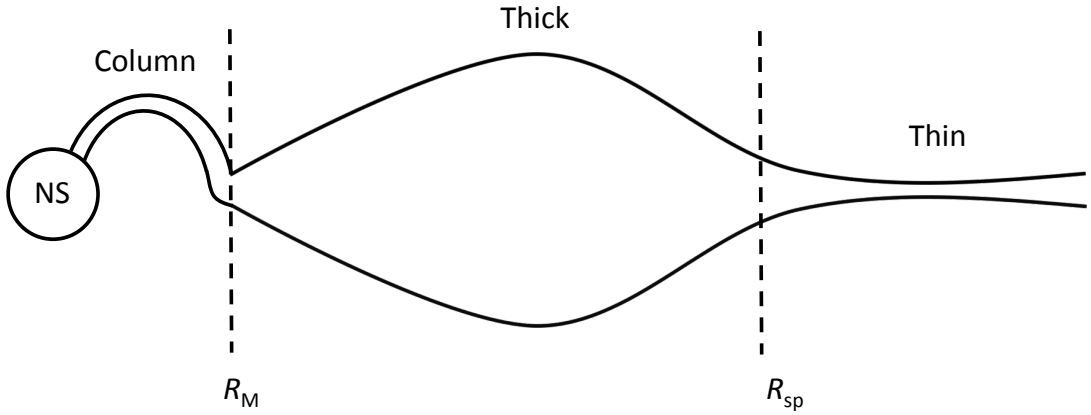
Non-Pulsing ULXs?

Pulsations detected:



- $R_M \lesssim R_{sp}$
- Inner disk ($R_M \leq R \leq R_{sp}$) well fit with a BB
- Lower T_{hot}/T_{cool}
- Higher F_{col}/F_{tot} so pulsations easier to observe

Pulsations diluted:



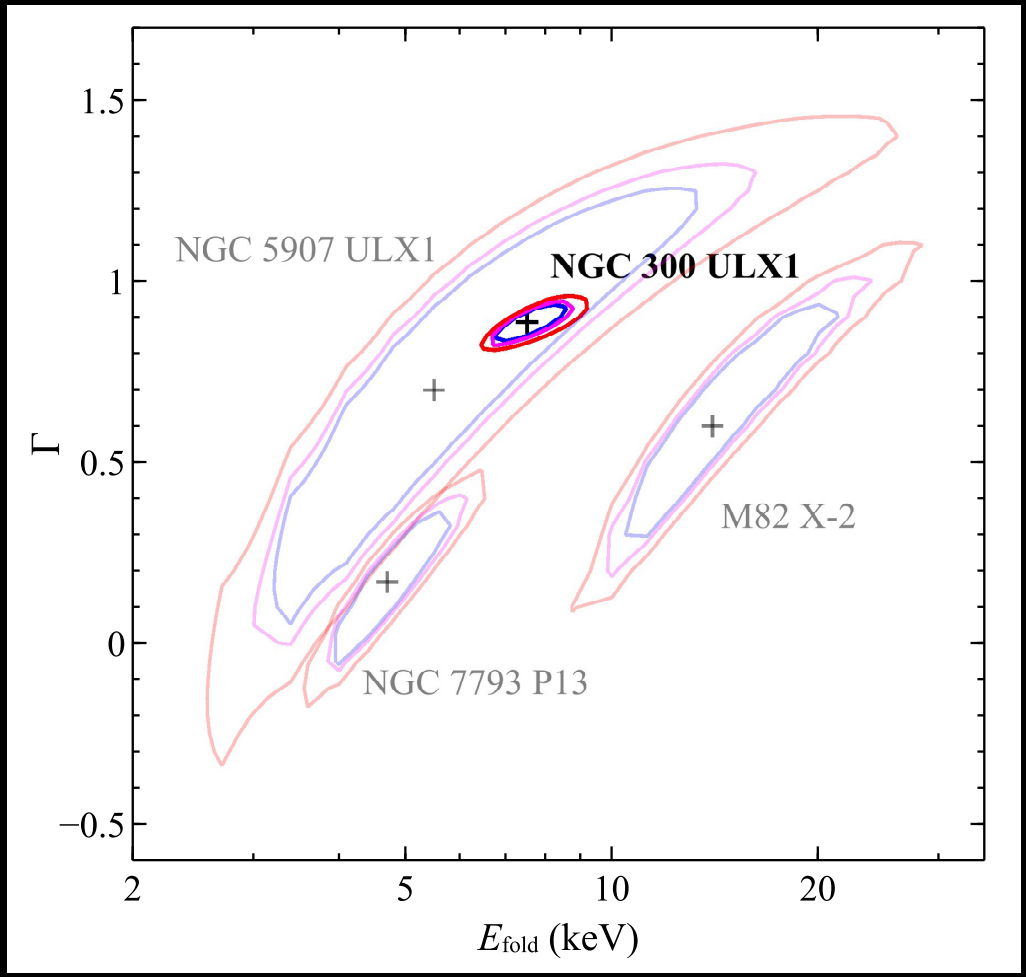
- $R_M << R_{sp}$
- Inner disk ($R_M \leq R \leq R_{sp}$) needs DISKPBB with $p < 0.75$
- Higher T_{hot}/T_{cool}
- Lower F_{col}/F_{tot} so pulsations harder to observe

Summary

- NGC300 ULX1, the 4th known ULX pulsar, shows evidence for a eCRSF implying $B \sim 10^{12}$ G.
- CSRF B-field broadly consistent with that implied by spin-up ($B \sim 3\text{x}10^{12}$ G)
- Contrasts with the potential pCRSF seen in M51 ULX8, implying $B \sim 7\text{x}10^{14}$ G (Brightman+18)
- Results suggest *B*-field could play some role in producing high luminosities, but this cannot be the whole story; accretion must also be super-Eddington
- The ULX population could potentially be dominated by NS accretors, even where pulsations have not (yet) been detected

Supplementary Material

Pulsed Spectra



Continuum parameters for the pulsed spectra are similar for all ULX pulsars

(after modeling the CRSF; Brightman+16, Walton+18a,b,c)