Unveiling the disc structure in ultraluminous X-ray source NGC 1313 X-2

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Fabio Pintore, Peter Kosec …

Fero 10 - Finding Extreme Relativistic Objects

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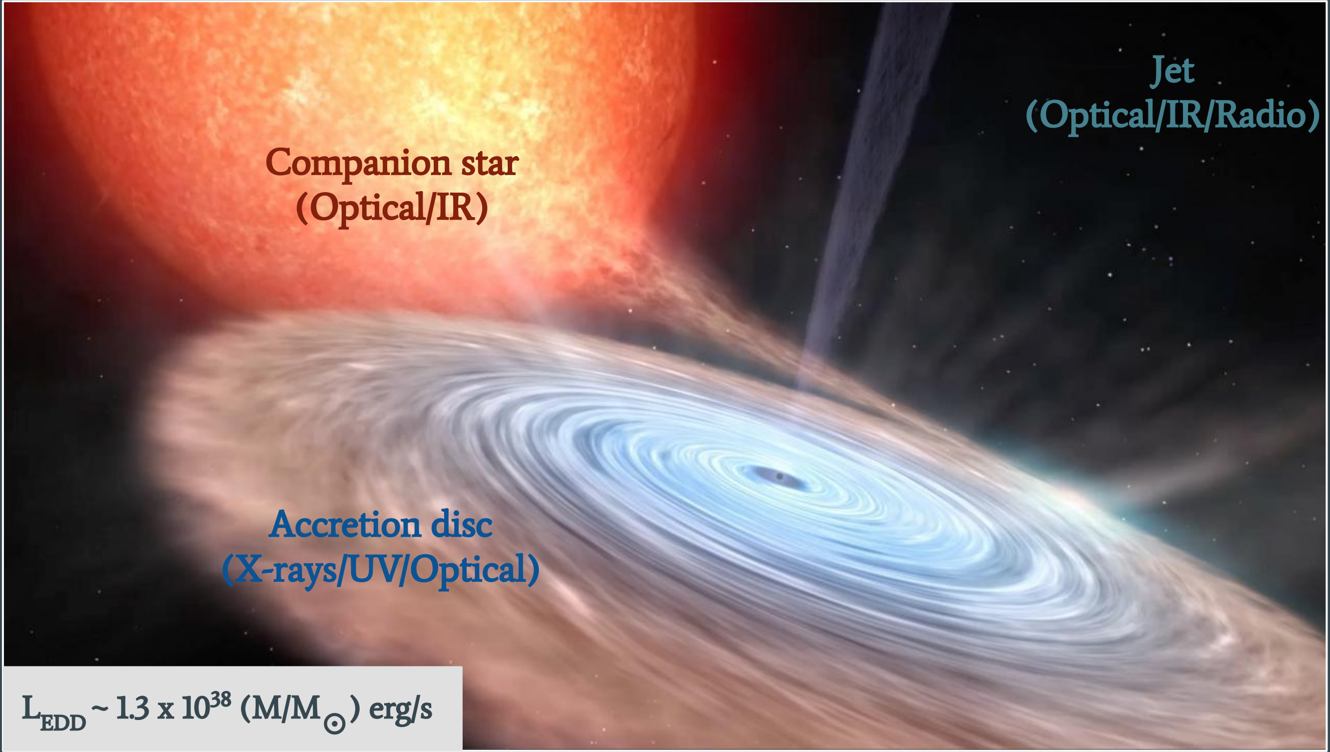
Accretion: the standard picture

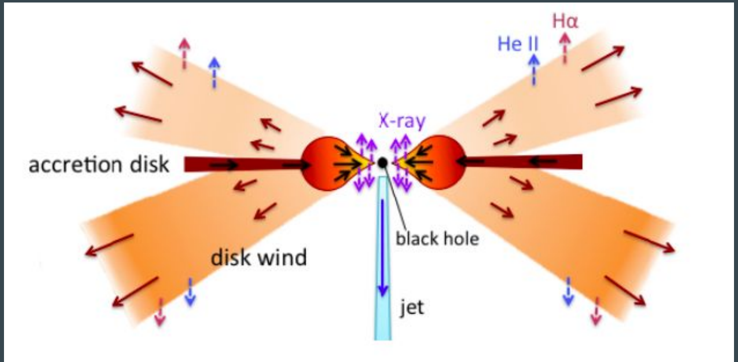


$L_{EDD} \sim 1.3 \times 10^{38} (M/M_\odot)$ erg/s

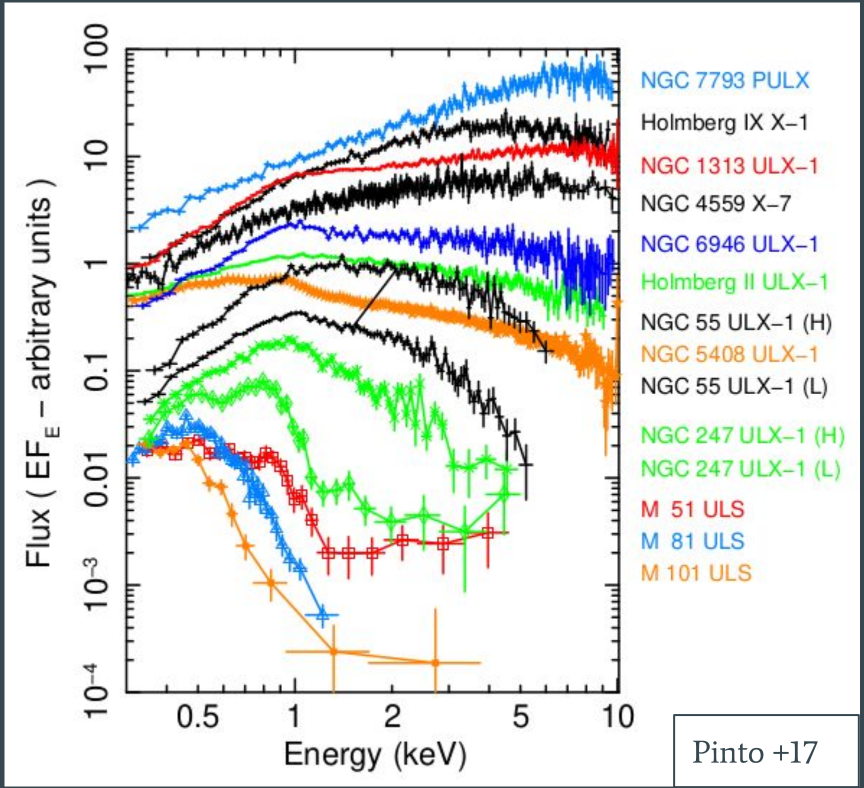
increasing temperature

Ultraluminous X-ray sources

- **X-ray luminosities** that exceed the isotropic Eddington luminosity for a standard black hole (BH) of 10 $M_\odot$
- ULXs are among the **brightest** (10^{39}-10^{41} erg s^{-1}), off-nuclear, X-ray sources in the Universe
- At high mass accretion rates the radiation inflates the disc and launches **winds**



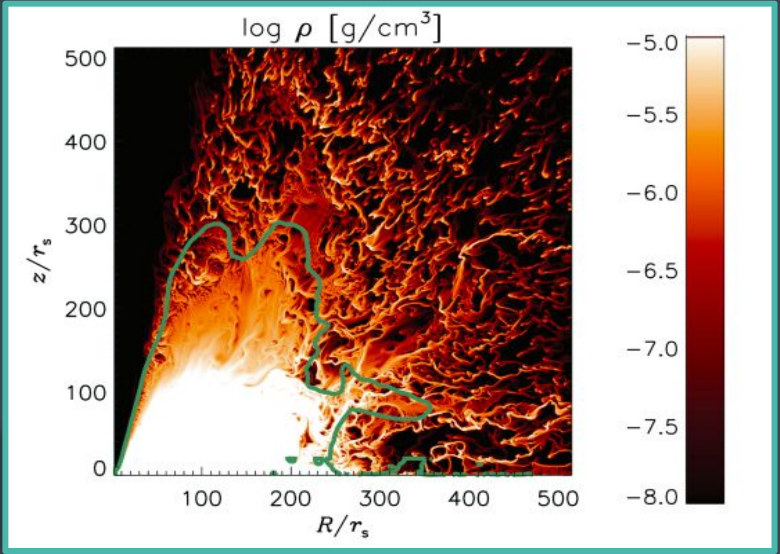
1) The X-ray spectral variability



Pinto +17

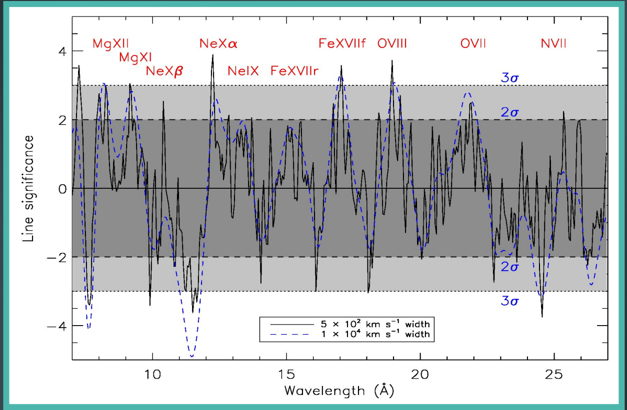
- **Strong curvature** between 2–10 keV
- Often a **soft excess** below 2 keV
- ULXs classified by Sutton+13 as SUL, HUL and BD
- Sub-class of ULXs: **ultraluminous supersoft sources** (ULSs)

2) Powerful outflows



Takeuchi +13

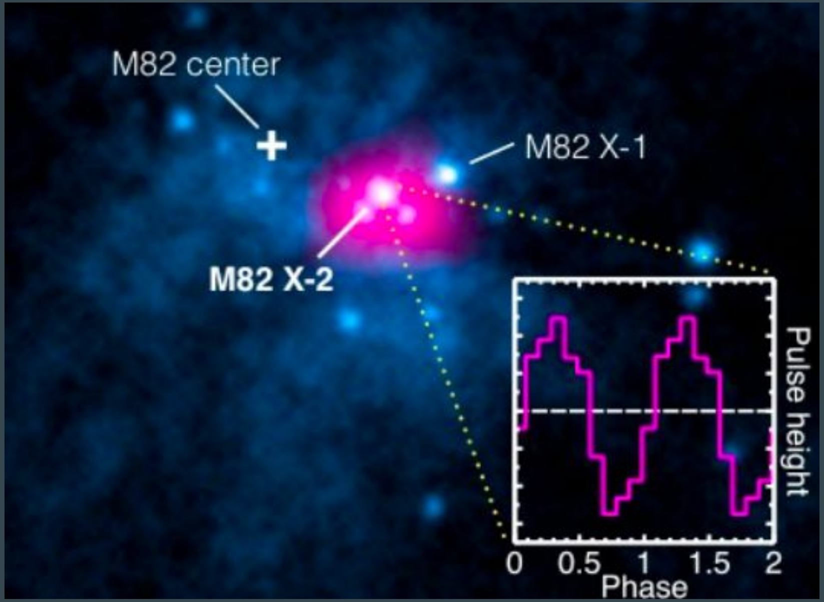
Blueshifted absorption lines and emission lines at laboratory wavelength have been discovered



Pinto +16

Theory predicts powerful winds at super-Eddington accretion rates

3) Discovery of ULX Pulsars



M 82 X-2 (Bachetti+2014)

Around **7 known NS-ULXs**

From all ULXs with sufficient statistics ~25% NSs (Rodriguez-Castillo+20)

- NGC 7793 P13 (Israel+16,Fuerst+16)
- NGC 5907 ULX (Israel+17)
- NGC 300 ULX 1 (Carpano+18)
- NGC 1313 X-2 (Sathyaprakash+19)
- M51 ULX-7 (Rodriguez Castillo+20)
- NGC 7793 ULX-4 (Quintin+21)

Open questions

- Changes in the wind or variations in the accretion rate / geometry responsible for the **spectral transitions** in ULXs?
- What is the **fraction** of matter lost into the wind and, therefore, the **net accretion rate** onto the compact object?
- What is the **fraction of BH-NS** powered ULXs?

ULXs which exhibit strong spectral variability are the ideal targets to tackle them

Sample studied

Study the structure of the accretion disc in super Eddington regime

NGC 1313 ULX-2 → Spectral variability and L/T trends unveil the presence of winds

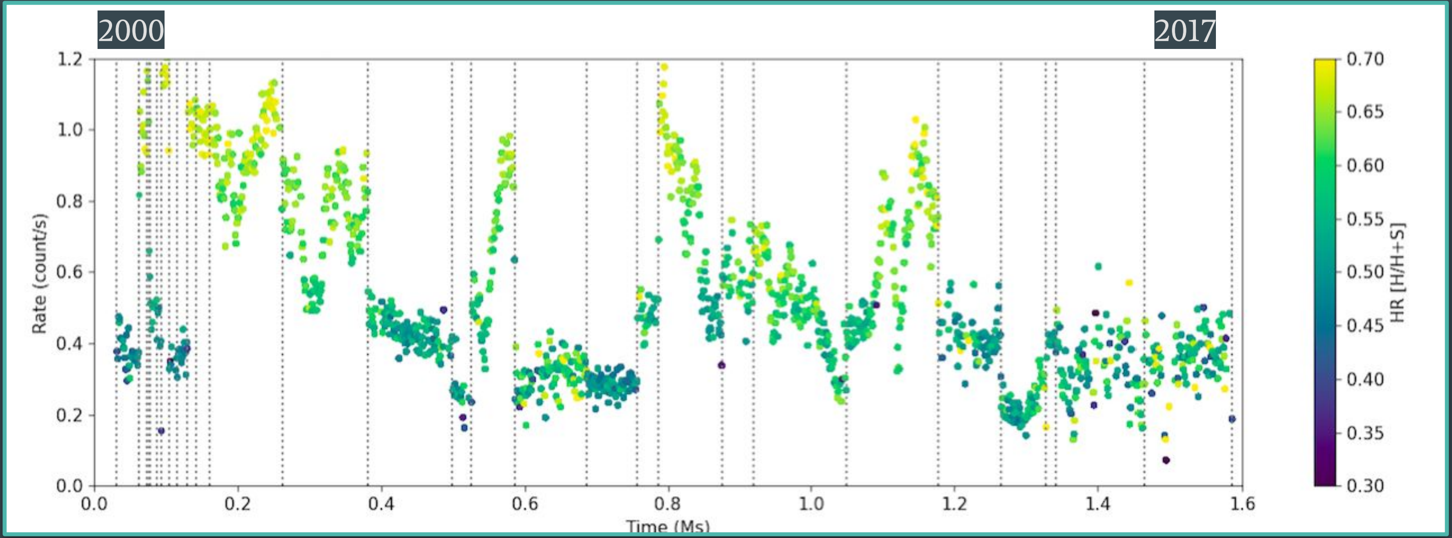
NS-ULX

NGC 55 ULX-1/ NGC 247 ULX-1 → Comparison between these two sources
Dipping activity

BH-ULX ?

NGC 55 ULX-2 → Report the identification of a new ULX candidate (NGC 55 ULX-2)

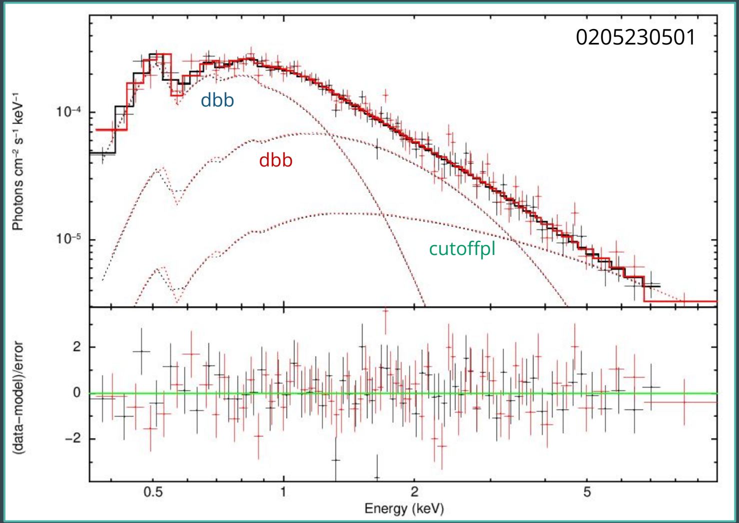
Study of accretion disc structure: NGC 1313 X-2



Hardness Ratio (HR) = 1.2 - 10 keV / 0.3 - 10 keV

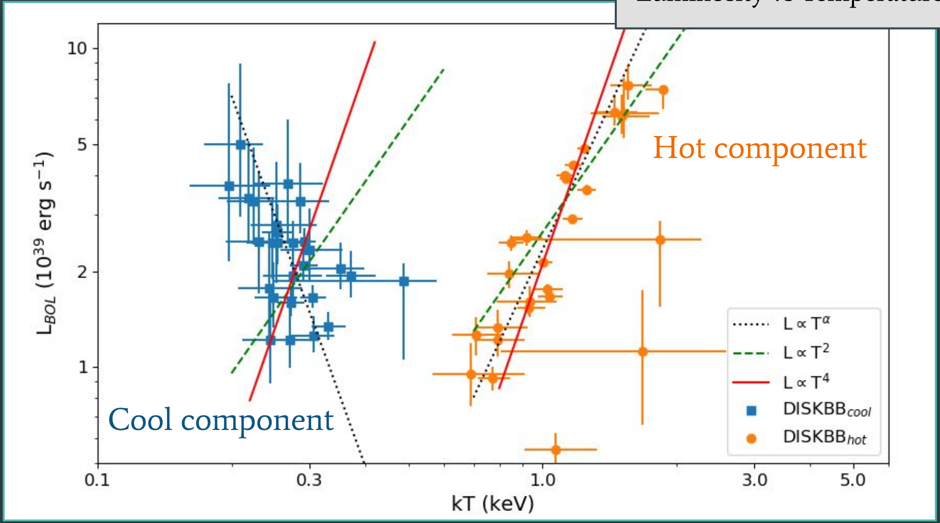
Robba et al. 2021, A&A, vol 652, pages A118

Study of accretion disc structure: NGC 1313 X-2



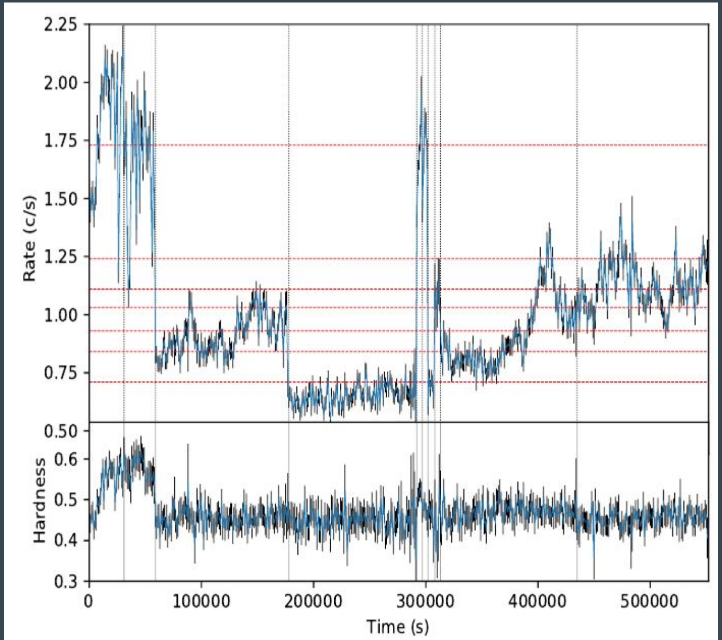
model: TBabs * (dbb + dbb + cutoffpl)

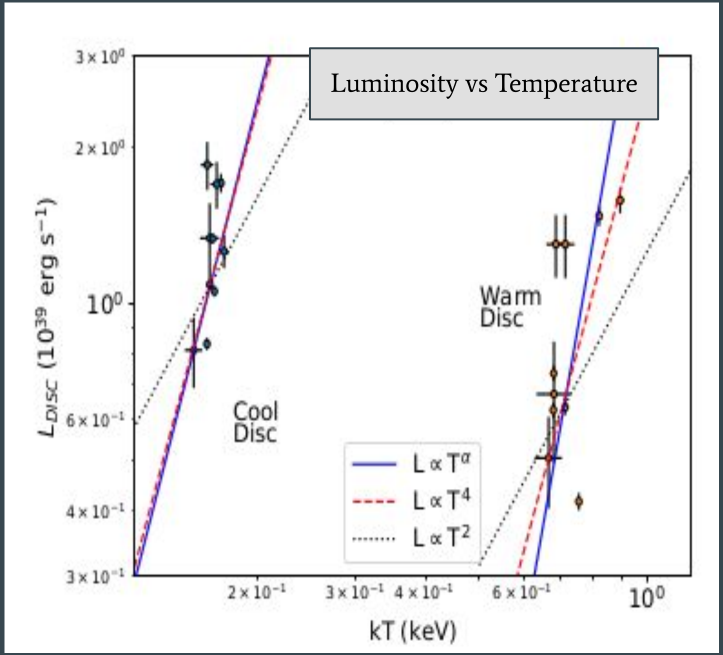
Luminosity vs Temperature



Robba et al. 2021, A&A, vol 652, pages A118

NGC 55 ULX-1

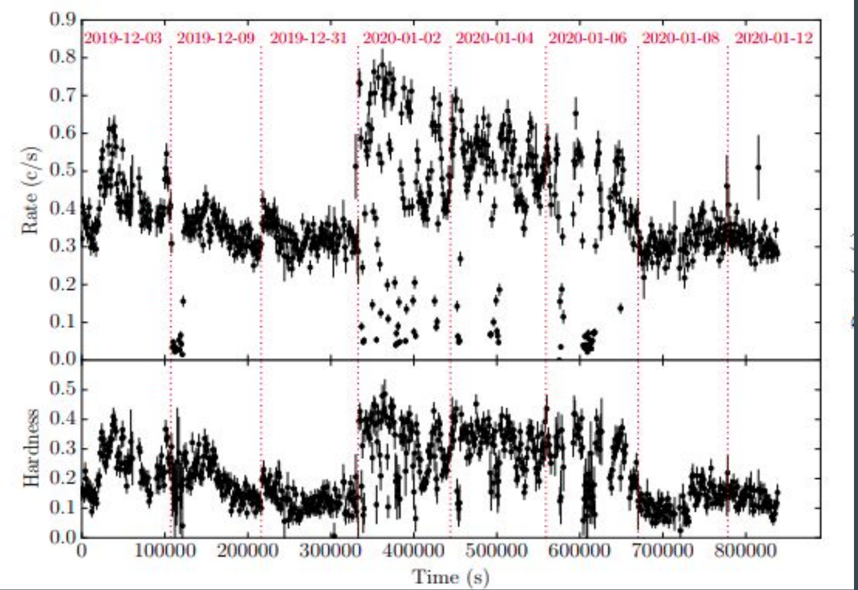


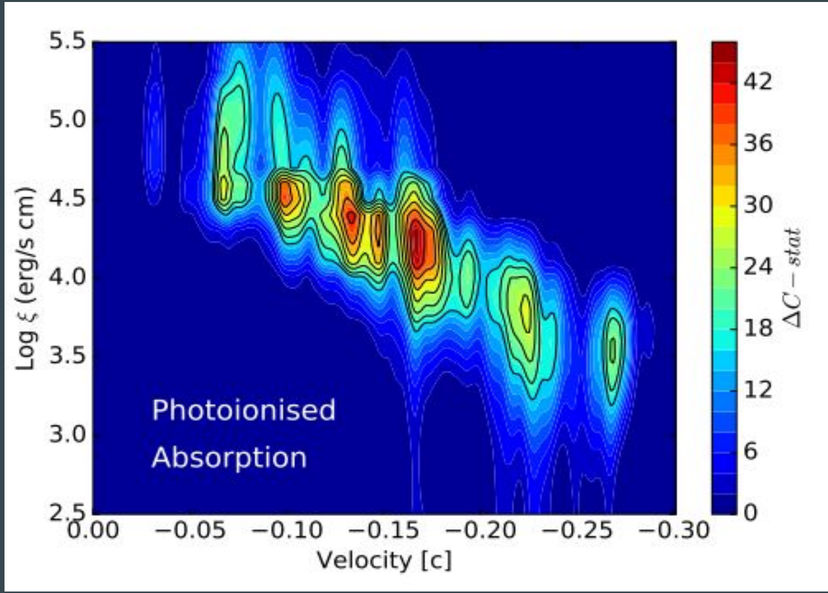


Barra et al. , *submitted to MNRAS*

NGC 247 ULX-1

Pinto +2021



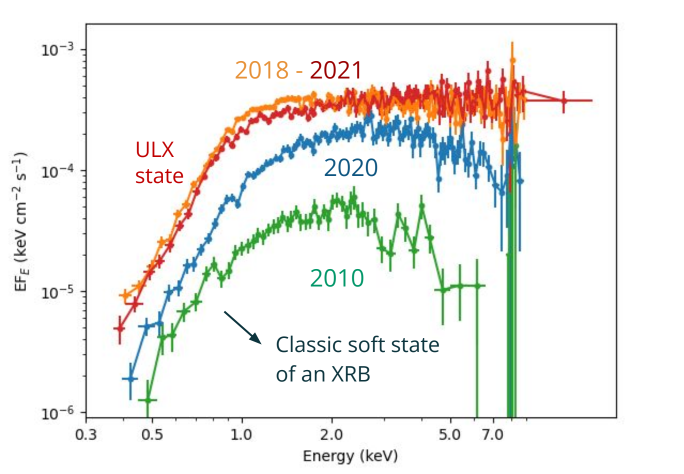


Remarkable variability was observed in source flux with strong dipping activity during the brightest observations

Unambiguous evidence of a wind in the form of emission and absorption lines

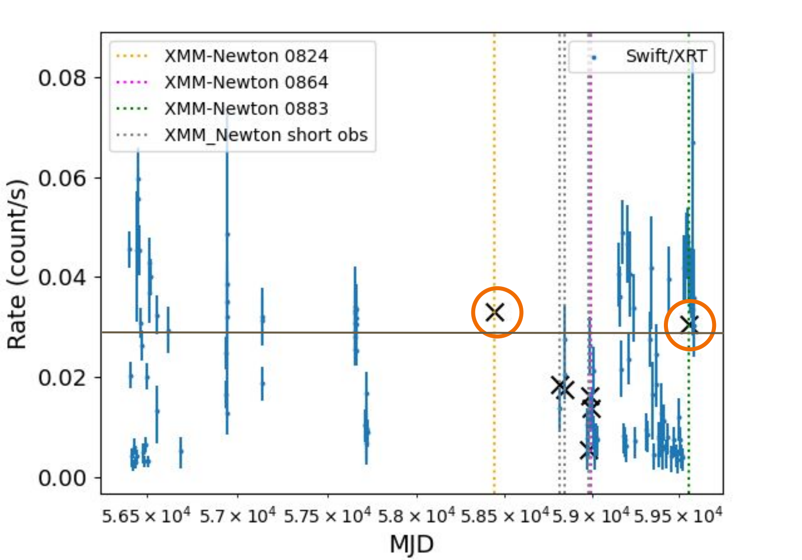
NGC 55 ULX-2: spectral variability

Spectral shape



no detection in obs 00280101 - 201 (November 2001)

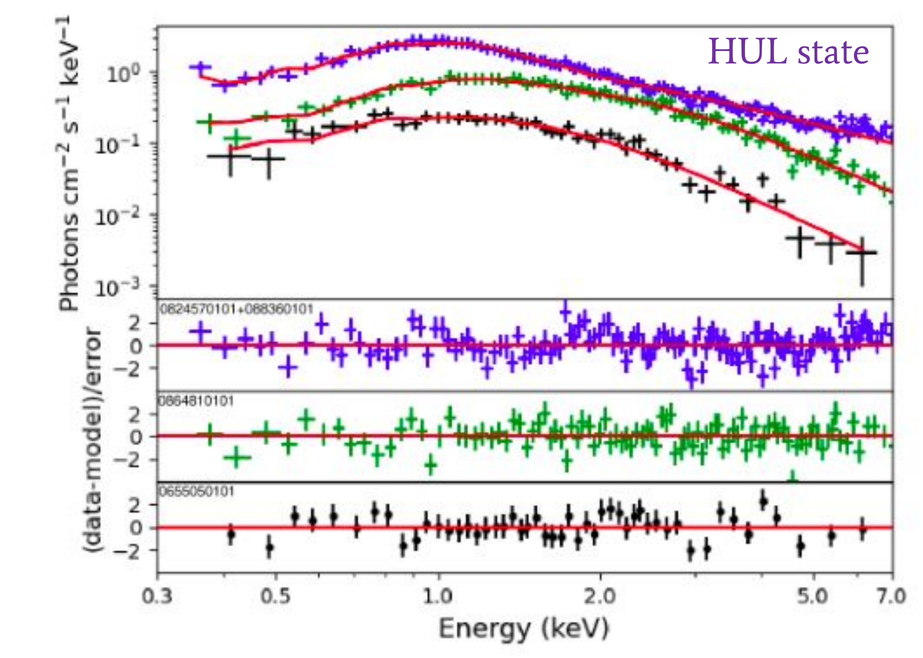
Swift/XRT Light curve



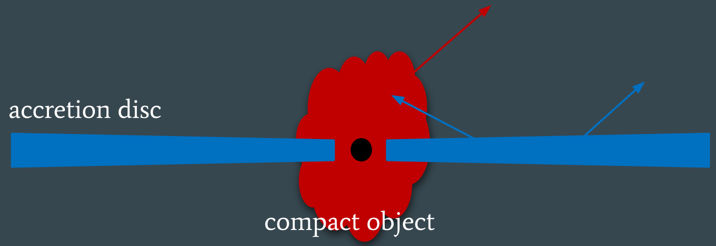
April 2013 → January 2022

Robba et al. , *submitted to MNRAS*

NGC 55 ULX-2: spectral analysis



model: hot * (dbb + comt)



Robba et al. , *submitted to MNRAS*

Summary

- **NGC 1313 X-2** spectral evolution of the cool component agrees with the prediction of super-Eddington accretion
- **NGC 55 ULX-1** deviations of the cool component trend imply an expansion of the disc or a contribution to the emission from the wind
- **NGC 247 ULX-1** shows strong dipping activity during the brightest observations and evidence of wind
- **NGC 55 ULX-2** identification of a new ULX candidate
- **Timing & Spectral evolution** of ULXs is a tool to understand the super-Eddington accretion mechanism

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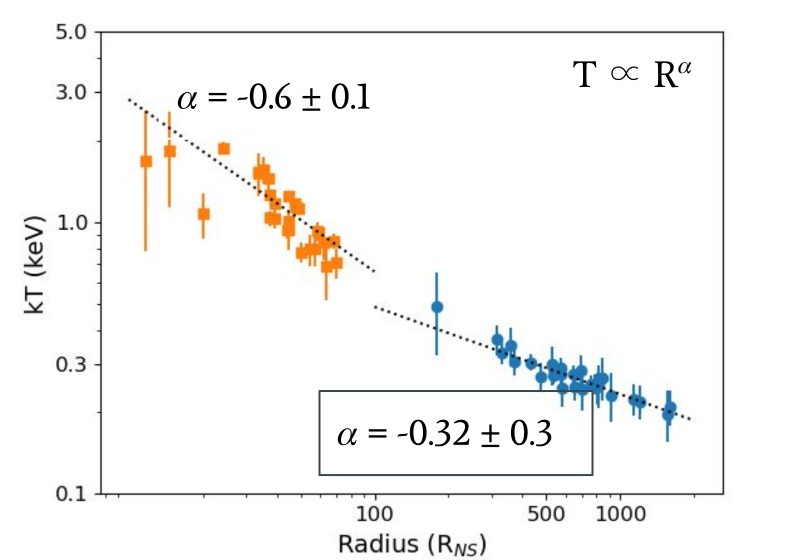
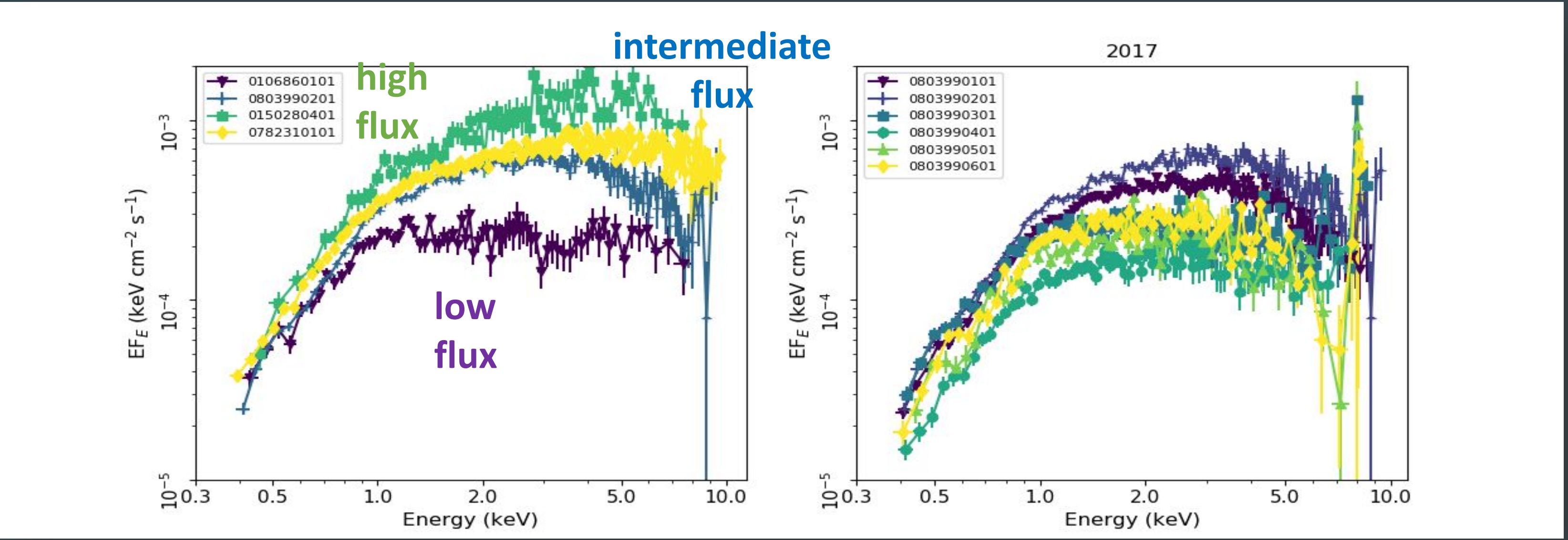
Thank you for your attention!

NGC 1313 X-2 - Temperature/Radius

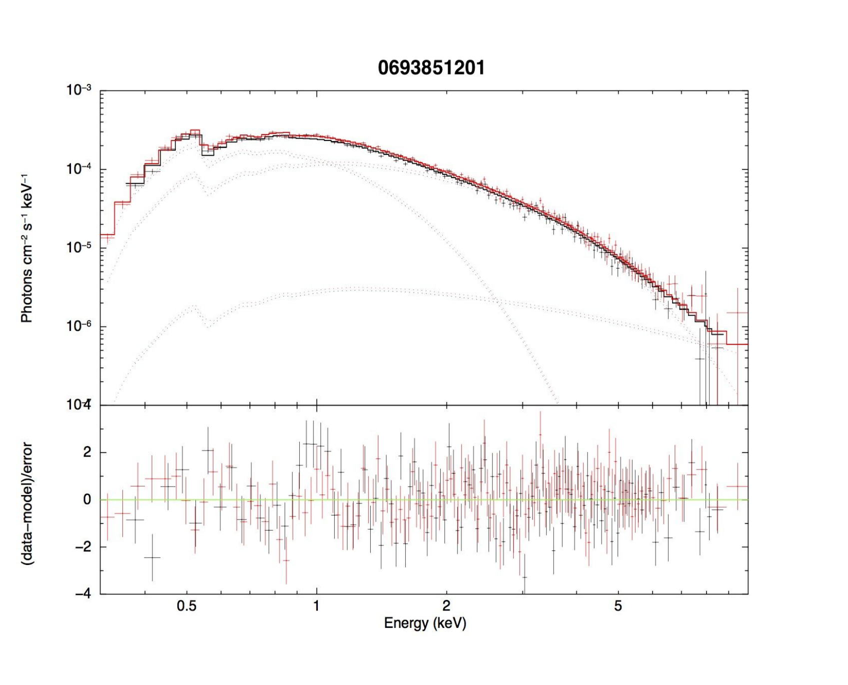
Temperature vs Radius



NGC 1313 X-2: spectral variability



NGC 1313 X-2: example fit



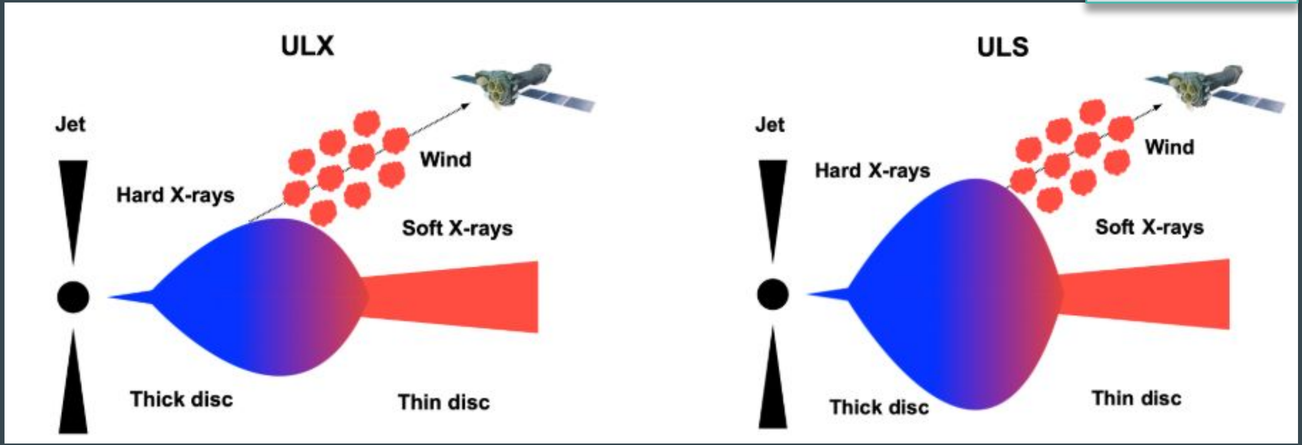
TBABS*(DISKBB+DISKBB+CUTOFFPL)			
Model component	Parameter	Unit	
TBABS	N_H	$[10^{22}\mathrm{cm}^{-2}]$	0.218 ± 0.013
DISKBB	T_{in}	[keV]	0.31 ± 0.02
	norm		$0.046^{+0.009}_{-0.008}$
DISKBB	T_{in}	[keV]	$1.01^{+0.05}_{-0.04}$
	norm		$4.3^{+1.8}_{-1.2}$
CUTOFFPL	PhoIndex		0.59 (fixed)
	HighECut	[keV]	7.9 (fixed)
	norm		$0.00005^{+0.000002}_{-0.000003}$
χ^2/dof			1.1311 (235)

Photoindex = 0.59 keV (fixed)
HighECut = 7.9 keV (fixed)

Brightman +16
Walton +18

Possible scenario for dips: ULX-ULS transitions

Pinto +2021



The source is observed at a viewing angle that is high enough that the inner disc is already partly obscured by the wind (soft ULXs)

High accretion rate → Increase of the scale-height of the disc and the optically-thick base of the wind → near-total obscuration of the inner regions (ultraluminous supersoft source, ULS)

Luminosity / Temperature trends

NGC 1313 ULX-2 → $\alpha_{\mathrm{cool}} = -3.9 \pm 1.0$

$\alpha_{\mathrm{hot}} = 3.0 \pm 0.35$

NGC 55 ULX-1 → $\alpha_{cool} = 4.2 \pm 1.9$

$\alpha_{hot} = 6.1 \pm 2.3$