The Unusual Broadband X-ray Continuum Variability seen from ULXs (well, NGC1313 X-1)

Dom Walton

Rutherford Fellow
IoA, Cambridge

Nearby barred spiral galaxy, hosts two well-known ULXs with peak $L_X \sim 10^{40}$ erg/s
Ultraluminous X-ray Sources

Ultraluminous X-ray sources (ULXs) are off-nuclear point sources with luminosities in excess of $10^{39}$ erg s$^{-1}$ ($\sim L_E$ for a 10 M$_{\odot}$ black hole)

Explanations for these extreme luminosities include:

- Larger black holes (possibly ‘intermediate mass’ black holes with $M_{\text{BH}} \sim 10^{3-4} M_{\odot}$)
- Super-Eddington accretion onto stellar remnants

Now believe most ULXs are super-Eddington accretors

$L_X \sim 2 \times 10^{40}$ erg s$^{-1}$

100x $L_E$ for a Neutron Star!
Ultrafast Outflows in ULXs

NGC1313 X-1: an ultrafast outflow with $v_{\text{out}} \sim 0.25c$ seen in a ULX for the first time, combining XMM-Newton and NuSTAR

Strong outflows a ubiquitous prediction of super-Eddington accretion
NGC 1313 – 2017 Campaign

Major observational program in 2017 to study variability in the wind seen in X-1:

XMM-Newton – 750 ks, performed as 3x250 ks observations spread over ~6 months
Chandra – 500 ks, spread over the same period (using HETG)
NuSTAR – 375 ks, coordinated with XMM-Newton and Chandra; 5x75 ks

Combined with XMM-Newton + NuSTAR observations in the archive, we now have nine distinct broadband spectra of X-1
NGC1313 X-1 – Winds

Current wind analysis has focused on XMM-Newton data (Nowak to lead Chandra).

Lower velocity/ionisation component is present in the new data, not significantly detected seen in the archival data.

The wind in NGC1313 X-1 is complex, components vary with both time and flux.

\( \Delta C \sim 20 \Rightarrow \sim 3\sigma \) significance (MCMC sims); Pinto et al. 2019 (in prep.)
High-energy (>10 keV) NuSTAR data shows remarkable consistency

Powerlaw model gives $\Gamma \sim 3.2$ with flux variations at the ~50% level (10-40 keV), despite changes by up to a factor of ~3 at energies below 10 keV.
Very similar to the behaviour seen from Holmberg IX X-1!
(Walton+17)
NGC1313 X-1 – Continuum Modeling

Fit the data with standard models used previously, allowing for the possibility of both a BH and NS accretor; both scenarios work similarly well.

BH case: high-energy = corona  \[\text{model} = \text{DISKBB} + (\text{SIMPL} \times \text{DISKPBB})\]

NS case: high-energy = column  \[\text{model} = \text{DISKBB} + \text{DISKPBB} + \text{CUTOFFPL}\]

(cutoffpl params set to average seen from known ULXPs in the NS model: \(\Gamma = 0.6\), \(E_{\text{cut}} = 8\text{ keV}\))
Fit the data with standard models used previously, allowing for the possibility of both a BH and NS accretor; both scenarios work similarly well.

**BH case:** high-energy = corona

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- **model = DISKBB + (SIMPL x DISKPBB)**
- **model = DISKBB + DISKPBB + CUTOFFPL**

(cutoffpl params set to average seen from known ULXPs in the NS model: $\Gamma = 0.6$, $E_{\text{cut}} = 8$ keV)
Luminosity vs temperature results for DISKPBB (the dominant thermal component) cluster into two groups for both models.

Each appears to follow its own $L \propto T^4$ track!

Implies two distinct, stable radii, which differ by a factor of $\sim 4$

(assuming no change in inclination or colour correction; Walton et al. 2019, in prep.)

What does this mean?!
NGC1313 X-1 – L vs T

Geometric obscuration

Scattering (by wind?)

Object of ~3x10^{24} cm^{-2}
NGC1313 X-1 – L vs T

Geometric obscuration

Scattering (by wind?)

Hard to explain constant $R_{\text{outer}}$

Need constant $N_H$ of $\sim 3 \times 10^{24} \text{ cm}^{-2}$
Summary

- We undertook a major observing program on NGC1313 in 2017 to study its ULXs (X-1 and X-2, both of which have $L_{X,\text{peak}} \sim 10^{40}$ erg/s), including: XMM-Newton (750 ks), Chandra (500 ks) and NuSTAR (400 ks).

- The new observations show clear evidence that the extreme wind seen in NGC1313 X-1 is complex, showing multiple velocity components that vary with time and/or flux (Pinto+19; poster 239).

- Lower energy (<10 keV) data for X-1 shows strong variations, while higher energies (>15 keV) remain reasonably stable (similar to Holmberg IX X-1).

- Application of disc models reveals that NGC1313 X-1 shows evidence for two stable radii which differ by a factor of ~4.

- Difficult to simultaneously explain these two radii and the stability of the high-energy emission if the latter arises close to the accretor (i.e. in a compact corona or an accretion column).