X-ray spectral variability in the ULX population of NGC 4485 and NGC 4490

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The nearby Sd galaxy NGC 4490 is remarkable in that its hosts one of the most numerous ULX populations within 10 Mpc, only bettered by M51 and M82. Here, we examine the X-ray spectral and temporal variability of these sources over the course of four *Chandra* and *XMM-Newton* observations spanning the years 2000-2004. We detect all 5 previously identified ULXs in NGC 4490 and that in the tidal tail of NGC 4485. We also find one new transient ULX in the system. The spectral variability is generally characterized by a hardening of the source spectra as their luminosities increase. The sources show a variety of long-term light curves; however, short-term (intra-observational) temporal variability is conspicuous by its absence.

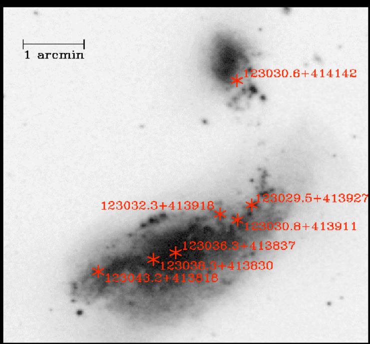

Figure 1: NGC 4485 (top) and NGC 4490 with positions of ULXs marked.

Ultraluminous X-ray Sources (ULXs) are point like, non-nuclear X-ray sources situated outside the nucleus of their host galaxy, that have X-ray luminosities in excess of 10^{39} erg s^{-1}. Various studies have been carried out on these sources since their discovery ~25 years ago, but their true nature remains uncertain. Here we study X-ray spectral variability of the ULXs in the nearby NGC 4485/90 galaxy pair.

Three *Chandra* observations were available to us, one of which was reported in Roberts et al (2002), who noted the presence of 6 ULXs in the galaxy pair. Two further observations were obtained in 2004 (PI: Roberts). One archival observation was available in the *XMM-Newton* database (observed in 2002), which we also include in our analysis.

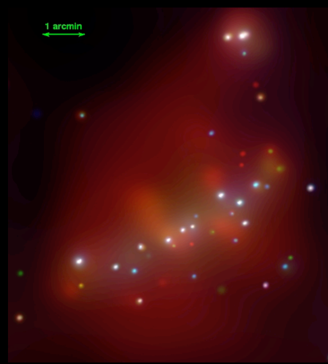

Figure 2:*Chandra* true-colour image of NGC4485 and NGC 4490

We extracted and analyzed the spectra of the 6 ULXs associated with these galaxies that were visible in each available observation. One new ULX (J123038.3+413830) was observed in the most recent exposure. The position of each has been marked in figure 1. The source names are *Chandra* IDs (labeled as CXOU J followed by coordinates). Figure 2 shows a true-colour *Chandra* image of the interacting galaxy pair created by combining all 3 images (totaling ~100ks), where the colours represent emission in the 0.3-1 keV (red), 1-2 keV (green) and 2-8 keV (blue) bands. This shows clearly a population of luminous point sources and extensive diffuse emission, whilst giving the first possible evidence of outflows from the nucleus of NGC 4490.

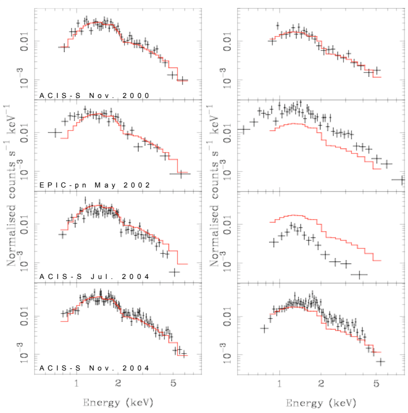

Figure3: Example X-ray spectra from two ULXs, CXOU J123030.6+414142 (left) and CXOU J123036.3+413837 (right). Spectra are shown in chronological order (top to bottom)

The four observations provided us with an opportunity to explore temporal variations in the X-ray spectra. The spectrum for each source was fit with an absorbed power-law continuum and a multi-colour disc blackbody model (MCDBB) in each epoch. Clear examples of variability are shown in figure 3. Here we present the spectral data for two ULXs, CXOU J123030.6+414142 (left) and CXOU J123036.3+413837 (right) in chronological order (from top to bottom), with each panel showing the spectral data points in black compared to the best fitting absorbed power law continuum from the first epoch.

The resulting parameters from spectral fitting are plotted against ULX luminosity in Figure 4. For clarity, each source is represented by a different symbol and colour. The best fitting model is shown with solid error bars, while dashed bars represent the poorer fit. All data for statistically acceptable fits are shown for the original 6 ULXs. We find that the majority of data points are clustered in parameter space. Those spectra best fit by a disc exhibit a hardening, or increase in temperature, as the luminosity increases. This relation is not as obvious in the power law sources. The general trends shown in figure 4 agree with findings of previous ULX studies (e.g. Fabbiano et al 2003, Roberts et al 2006), demonstrating an extension of the $L \alpha T^4$ behaviour observed from galactic black hole binaries (cf. Stobbart et al 2006).

Results for the best fitting parameters are n the range Γ~ 1.7 - 2.7 for the power law model and kT_{in} ~ 0.8 - 1.7 keV for the MCDBB model, which is very typical of Chandra data for ULXs (cf Swartz et al 2004) . We also find, in general, these ULXs are more frequently better fitted by a MCDBB than a power law (12/20 datasets). Three of the sources are best fitted by differing models at different epochs, with the trend appearing to show that power laws give better fits at lower observed luminosities (≤ 1.9x10^{39} erg s^{-1}), whereas the MCDBB model fits to higher luminosities; this could indicate a change in accretion state from power law dominated VHS to a super-Eddington "ultraluminous" state as matter is accreted on to a stellar mass black hole in these sources.

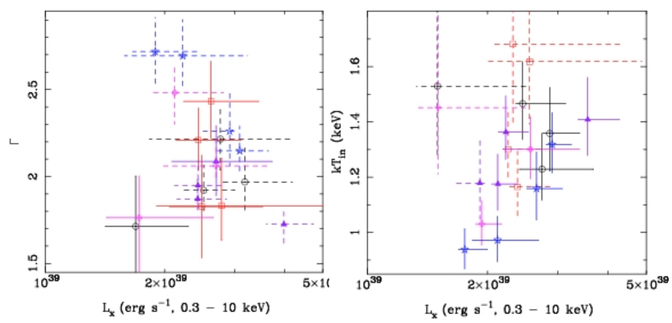

Figure 4: Parameter vs observed luminosity plots for the four observations. Spectra show a general trend of hardening/ increasing in disc temperature as the luminosity increases.

Details presented in this poster will be published in Gladstone & Roberts (2008) *in prep.* For more information on this subject, please email j.c.gladstone@durham.ac.uk.