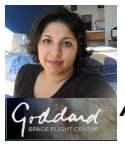

X-ray properties of local Lyman break galaxy analogs

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Introduction

Recent work on local galaxies have found that X-ray luminosity correlates strongly with star formation rate (SFR). Our knowledge of star formation in the distant (z~3) Universe is largely confined to studies in the rest-frame ultraviolet. X-ray properties of the best-studied high redshift, UV-selected galaxies (Lyman break galaxies, LBGs) have been deduced using stacking analyses of large samples of galaxies for long (>30 Ms) effective *Chandra* exposures. A new opportunity provides us with another way to study these star-forming galaxies: GALEX has recently selected a low redshift (z~0.2) LBG population, the Lyman break analogs (LBAs). In this pilot study we observe 3 LBAs using *Chandra* to constrain the high end of the local X-ray/SFR correlation and put the higher-z studies on firmer footing.

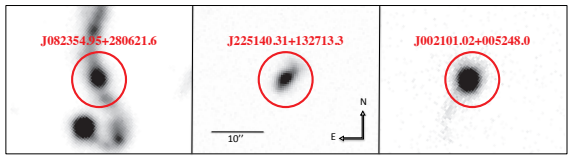


Figure 1 (Above): We show the *g*-band SDSS images of the 0.05< z <0.1 LBAs observed with *Chandra*, with a 5" radius circle drawn for scale. These images are shown with a logarithmic stretch to emphasize faint outer features. LBAs are compact (typical half-light radii in the u and r bands are approximately 1"–2"), high UV surface brightness galaxies, whose stellar light is dominated by recent star formation– sharing several similar properties with z~3 LBGs.

Sample Selection

LBAs are 'pure starburst' galaxies that form an interesting sample to compare with other local galaxy samples. LBAs are selected from SDSS and GALEX cross-matched catalogs. Heckman et al. (2005) and Hoopes et al (2006) have shown that those galaxies **with $L_{FUV} > 10^{10.3}\ L_{\odot}$ and $I_{FUV} > 10^{9}\ L_{\odot}\ kpc^{-2}$** are good LBG analogs. We have conducted *Chandra* observations for three of the nearest LBAs with the highest SFRs and optical emission line ratios characteristic of star-forming (non-AGN) galaxies (See Figure 2) . These emission-line ratios are determined after subtracting off template galaxy spectra and are very sensitive to even low-level AGN activity. We have also used velocity widths to screen against AGN.

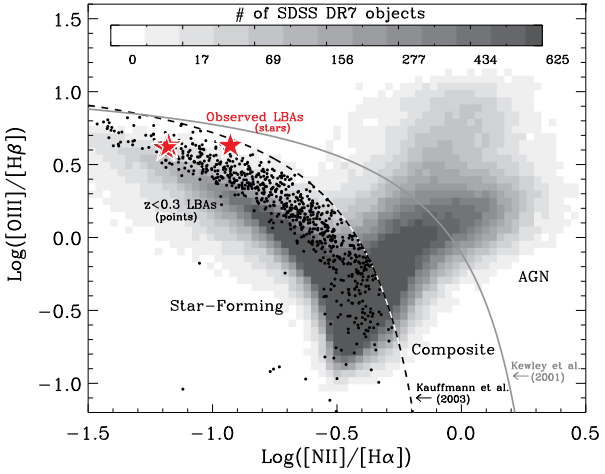
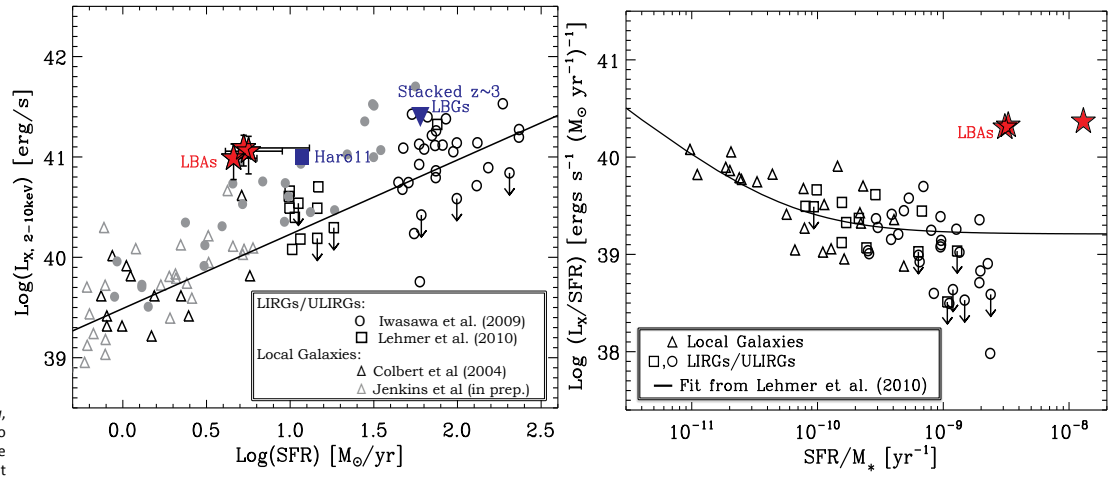


Figure 2 (Right): We show the emission-line ratio diagram for the full SDSS DR7 galaxy sample (background data, with contrast corresponding to numbers shown in upper color bar), complete expanded sample of z<0.3 LBAs (black points; 301 galaxies) and the *Chandra*-observed LBA sample (red stars, 3 galaxies). The two lines in the diagram indicate the theoretical upper limit for star formation (gray upper solid line; Kewley et al. 2001) and the lower line below which AGN are not expected (Kauffmann et al. 2003, black dashed line). Our *Chandra* sample fall well within the star-forming galaxy part of this diagram.



[a] X-ray/SFR correlation **[b] HMXBs dominate L_X at high SFR/M$_*$**

Figure 3 (Above): [a] X-ray/SFR correlation-- We find that the three LBAs (red stars), observed with *Chandra,* are slightly more Xray-luminous per SFR compared to other galaxy populations: local galaxies and LIRGs/ULIRGs. The stacked LBG value (Lehmer et al. 2008) and another LBA, Haro11, appear similarly high with respect to the Xray-SFR correlation (solid black line shows fit to data from Lehmer et al. 2010). [b] We show SFR/M$_*$ versus L_X/SFR for these galaxies: LBAs have high SFR/M$_*$, similar to LIRGs/ULIRGs, and therefore L_X in LBAs is expected to be dominated by HMXBs. However, the LBAs deviate from the curve found by Lehmer et al. (2010), with significantly higher L_X/SFR values compared to LIRGs/ULIRGs.

Discussion

The total X-ray emission from normal galaxies may be written as a linear combination of the young high-mass x-ray binary (HMXB) population associated with SFR and the older low-mass x-ray binary (LMXB) population associated with stellar mass:

$$L_X = \alpha \times M + \beta \times SFR$$ (Colbert et al. 2004; Lehmer et al. 2010)

The parameter α corresponds to the longer-lived (Gyr) LMXB population, which appears to have a universal luminosity function that scales with galaxy stellar mass (Gilfanov et al. 2004). By observing galaxies with well-characterized SF histories we can extract the α (evolved stellar component) and β (SFR) parameters. The curved fit in Figure 3b shows two regimes: at low SFR/M$_*$, L_X/SFR decreases because LMXBs and HMXBs both contribute to the X-ray luminosity; at high specific SFR, the X-ray luminosity per SFR is constant since HMXBs dominate the X-ray luminosity.

Results

- Our preliminary data, along with Haro11, hints towards an intriguing result (See Figure 3a) – all these cases appear to have higher L_X, given their SFR, compared to other galaxy populations. We calculate that the probability for all three LBAs to lie at the edge of the scatter in the X-ray/SFR correlation is ~10^{-3} .
- To investigate the possibility that these are AGN, we estimate the AGN fraction based on Rafferty et al. (2011) as f_{AGN} (L_X>10^{41} erg/s) = 0.06 – 0.15 for SFR ≈ 5 – 10 $M_{\odot}\ yr^{-1}$. Thus the chance that all three cases are AGNs is low (0.001-0.05%).
- Lehmer et al. (2010) argues that the scatter in the ULIRG population (with highest SFR/M$_*$; see Figure 3) may arise from dust attenuation within these galaxies, suppressing the X-ray luminosity. The LBAs, high SFR/M$_*$ galaxies with little expected dust obscuration, deviate significantly from the fit derived by Lehmer et al. (2010).