Feeding Compact Objects: Accretion on All Scales
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Simulating the X-ray evolution of late-type galaxies with population synthesis

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Abstract. Using an evolutionary population synthesis code, we modeled the global emission of X-ray binaries in late-type galaxies, its relations with other physical properties (i.e., optical luminosity, stellar mass, etc.) of the galaxies, and their evolution with redshift over the cosmic history, which may be investigated further by future high-resolution X-ray and optical observations.

Keywords. Stellar evolution, compact stars, X-ray binaries.

1. Introduction

Using *Chandra* data, Lehmer *et al.* (2008, hereafter L08) found that there is a significant increase (by a factor of about 5−10) in the X-ray-to-optical luminosity ratio ($L_{\rm X}/L_{\rm B}$) and the X-ray-to-stellar mass ratio ($L_{\rm X}/M$) over the red-shift range of z =0−1.4. Based on this, we used an evolutionary population synthesis (EPS) code to investigate the X-ray evolution of late-type galaxy populations and its dependence on the physical properties and star formation history (SFH) of galaxies.

2. Model

We used the EPS code developed by Hurley *et al.* (2000,2002) and updated by Zuo *et al.* (2008) to calculate the X-ray luminosity ($L_{\rm X}$) of X-ray binaries (XRBs), the optical luminosity($L_{\rm B}$), and stellar mass (M) of the host galaxies , and their evolution in different SFH (i.e., constant, starburst and cosmic) cases. We calculate the X-ray luminosity from accreting XRBs (Zuo & Li, 2010). We consider the optical luminosity from both normal stars (both binary and single stars) and accretion disks in XRBs. The stellar mass is the sum of the masses of currently living stars.

We adopt the derived expression of the SFH in Hopkins & Beacom (2006), and an empirical equation $Z/Z_{\odot} \propto 10^{-\gamma z}$ from Langer & Norman (2006) for metallicity evolution in cosmic SF case. We also vary the Kroupa (2001, hereafter KROUPA01) IMF to a steeper one (e.g. Kroupa, Tout & Gilmore 1993, KTG93 for short) and a shallower one (Baldry & Glazebrook 2003, BG03 for short) to examine its effect in this case.

3. Results

Fig. 1 shows the evolution of the X-ray luminosity-to-stellar mass ratio ($L_{\rm X}/M$, left panel) and X-ray-to-B-band luminosity ratio ($L_{\rm X}/L_{\rm B}$, right panel) with red-shift z, respectively. Also shown are the measured values of $\log(L_{\rm X}/M)$ (left panel) and $\log(L_{\rm X}/L_{\rm B})$ (right panel) derived by L08 (squares), Zheng *et al.* (2007, Z07, diamonds) and local samples by Shapley *et al.* (2001, S01, open symbols), respectively.

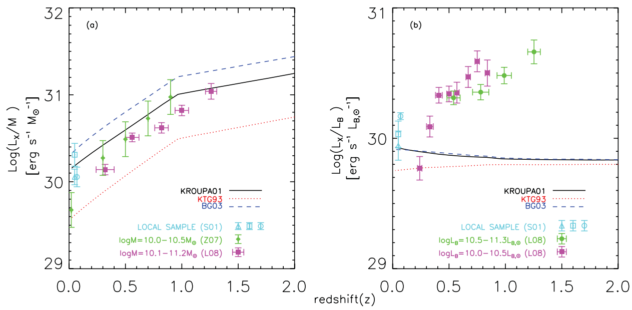

Figure 1. Evolution of the $L_{\rm X}/M$ (left) and $L_{\rm X}/L_{\rm B}$ (right) with red-shift z, respectively.

4. Discussion and Conclusions

Our simulated $\log(L_{\rm X}/M)$ versus z relations (left panel) match the observations quite well. The decrease of $\log(L_{\rm X}/M)$ results from slow evolution of $L_{\rm X}$ of XRBs and the stellar mass accumulation with time in galaxies, without requiring that lower mass galaxies have higher specific SFR than more massive ones as suggested before.

The nearly constant values of $L_{\rm X}/L_{\rm B}$ (right panel) seem to not properly match the observed increase in $L_{\rm X}/L_{\rm B}$ with z. The discrepancy originates from the fact that in our simulations we have roughly $L_{\rm X} \propto L_{\rm B}$, giving a flat $L_{\rm X}/L_{\rm B} - z$ relation, while observationally it was found that $L_{\rm X} \propto L_{\rm B}^{1.5}$, leading to increasing $L_{\rm X}/L_{\rm B}$ with z. The discrepancy may be due to different obscured SF activities in galaxies at higher redshifts. This will be investigated by future high-resolution X-ray and optical observations of galaxies at high redshifts.

We find the $\log(L_{\rm X}/M)$ evolution with time has a common decreasing feature in different cases of SF (i.e., constant, starburst and cosmic SF). The $L_{\rm X}/L_{\rm B}$ ratios in all cases rise rapidly in the first $\sim 10^8$ yr to $\sim 10^{30}$ erg s$^{-1} L_{{\rm B},\odot}^{-1}$, then stay nearly constant afterward for a given model, and are not sensitive to the SFH details in the galaxies.

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