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Simulations of the evolution of the X-Ray properties of a young stellar population

M. Eracleous[1], M. S. Sipior[1]†, S. Sigurdsson[1] and H. Flohic[1]

[1]Department of Astronomy & Astrophysics, The Pennsylvania State University, 525 Davey Lab, University Park, PA 16802, USA

Abstract. We present an X-ray binary population synthesis model, and use it to simulate the evolution of X-ray binaries formed in a burst of star formation of duration 20 Myr and star-formation rate 10 $M_\odot$ yr^{-1}. We find that the X-ray luminous phase persists long after the star-formation episode has ended. The 2-10 keV X-ray luminosity can reach values of 10^{40}–10^{41} erg s^{-1}, comparable to those of some Seyfert galaxies. These models are directly applicable to starburst galaxies as well as LINERs powered by vigorous star formation.

1. Introduction

In our quest for the power source of LINERs we have found, through observations with the *Chandra* X-ray observatory, that a significant fraction of objects host clusters of luminous ($L_x \sim 10^{38}$ erg s^{-1}) X-ray binaries in their nuclei. The X-ray binary luminosity functions are flatter than those of elliptical galaxies and resemble those of star-forming and starburst galaxies (Eracleous et al. 2002; Flohic et al. 2004). This suggests the presence of high-mass X-ray binaries formed in a recent episode of star-formation. To understand the origin and properties of these X-ray binaries and to relate them to star-formation activity in the LINER nuclei, we have constructed binary population synthesis models and used them to predict the integrated X-ray properties of the population.

2. Methodology

We used a modified version of the code of Pols & Marinus (1994) to follow for 2 Gyr the evolution of binaries from a 20 Myr star-formation episode with $SFR = 10\ M_\odot\ \mathrm{yr}^{-1}$. Our modifications include: a mapping of progenitor to black hole mass based on recent collapse simulations (Fryer 1999), an up-to-date supernova kick distribution, semi-analytic mass transfer prescriptions at different evolutionary stages (Hurley et al. 2002), magnetic braking, and accretion-disk instabilities and duty cycles. Details are given in Sipior et al. (2004). We explored two binary mass fraction distributions (flat and low-biased) and two IMFs (Salpeter and Miller-Scalo).

3. Results and Discussion

Our primary result, the evolution of the integrated X-ray luminosity luminosity of the population (assuming a low-skewed mass ratio distribution and a Salpeter IMF), is shown in Figure 1. This result is not sensitive to the assumed mass ratio distribution or IMF. There is a prolonged X-ray luminous phase, which may last 100 Myr past the end of star formation. During this phase, the X-ray luminosity is sustained by successive generations

† Present address: Astronomical Institute "Anton Pannekoek" and Section Computational Science, University of Amsterdam, Kruislaan 403, 1098 SJ Amsterdam, Netherlands.

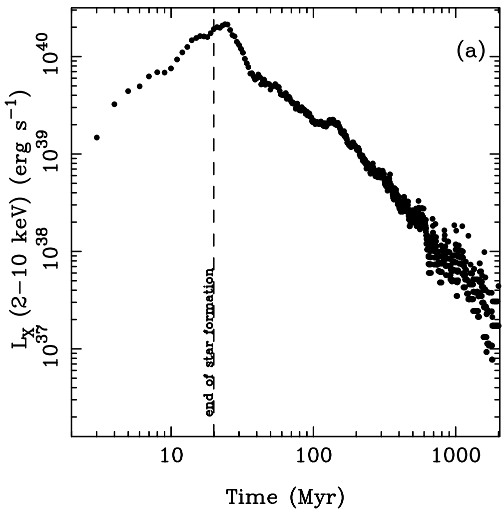

Figure 1. The evolution of the total 2–10 keV X-ray luminosity of a simulated population, such as that described in §2. For this simulation we assumed a Salpeter IMF with a low-skewed binary mass ratio distribution.

of X-ray binaries, which rise and fall at different times, depending on the masses of the donnor stars. At its peak, the X-ray luminosity is 3×10^{40} erg s^{-1}, and should scale with SFR. The power-law index of the *cumulative* luminosity function, $N(> L) \propto L^{-\beta}$, evolves from $\beta \approx 0.8$ at 10 Myr to $\beta \approx 3$ at 100 Myr. The models reproduce the empirical relation between SFR and X-ray luminosity, $SFR = 2\ (L_{\rm x}/10^{40}\ {\rm erg\ s^{-1}})\ {\rm M_{\odot}\ yr^{-1}}$ (e.g., Ranalli et al. 2003), to better than a factor of 2. They also reproduce the slope of the cumulative luminosity function of star-forming galaxies (e.g., Colbert et al. 2004) and its steepening with time. At late times, after the demise of OB stars (post-starburst phase), the late B and post-AGB stars provide enough ionizing photons to power line emission with luminosities and line ratios as observed in LINERs (Binette et al. 1994; Magris et al. 2003). Such objects would have X-ray spectra and luminosities similar to weak AGNs, even though they are powered by star formation.

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