THE BIRTHPLACE OF LMXBS: FIELD VS. GLOBULAR CLUSTER POPULATIONS IN EARLY-TYPE GALAXIES

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ABSTRACT

Recent *Chandra* studies of low-mass X-ray binaries (LMXBs) within early-type galaxies have found that LMXBs are commonly located within globular clusters of the galaxies. However, whether all LMXBs are formed within globular clusters has remained an open question. If all LMXBs formed within globular clusters, the summed X-ray luminosity of the LMXBs in a galaxy should be directly proportional to the number of globular clusters in the galaxy regardless of where the LMXBs currently reside. We have compared these two quantities over the same angular area for a sample of 12 elliptical and S0 galaxies observed with *Chandra*, and found that the correlation between the two quantities is weaker than expected if all LMXBs formed within globular clusters. This indicates that a significant number of the LMXBs were formed in the field, and naturally accounts for the spread in field–to–cluster fractions of LMXBs from galaxy to galaxy. We also find that the "pollution" of globular cluster LMXBs into the field has been minimal within elliptical galaxies but there is evidence that roughly half of the LMXBs originally in the globular clusters of S0 galaxies in our sample have escaped into the field.

Key words: LaTeX; ESA; X-rays.

1. INTRODUCTION

While it was expected that *Chandra* would resolve many low-mass X-ray binaries (LMXBs) in nearby galaxies, it was quite unexpected that such a large percentage of LMXBs would reside within globular clusters of the host galaxies. Also unexpected was the variation in the fraction of LMXBs within globular clusters from galaxy to galaxy, ranging from almost 70% in NGC 1399 to a more modest 18% in NGC 1553 (Angelini et al. 2001; Sarazin et al. 2003).

Given the much higher ($>$ 100 times) efficiency of creating LMXBs within globular clusters than in the field, it is natural to ask if *all* (or nearly all) LMXBs are formed within globular clusters. In this scenario, the LMXBs found presently in the field actually formed within globular clusters, but escaped to the field at a later time, either through interactions within the globular cluster or through the tidal disruption or destruction of the globular cluster over time. This was first suggested by Grindlay (1984) for the case of Galactic X-ray bursting binaries, and extended to LMXBs within early-type galaxies by White, Sarazin, & Kulkarni (2002).

To address this issue we have compared the total X-ray luminosity emanating from LMXBs in a galaxy to the number of globular clusters in the galaxy for a sample of galaxies. If all LMXBs formed within globular clusters, there should be a linear relation between these two quantities regardless of where the LMXBs currently reside. On the other hand, if there is a significant population of LMXBs created in the field, the relation between the number of LMXBs and globular clusters should be weaker, as the field component becomes more dominant in galaxies with fewer globular clusters. This would also predict that the fraction of LMXBs found within globular clusters is larger for galaxies with more globular clusters per unit light, which could account for the measured spread in the fraction of LMXBs within globular clusters from galaxy to galaxy.

2. THE DATA REDUCTION

We have determined L_X, the total X-ray luminosity emanating from LMXBs in a given galaxy. L_X was determined by summing the individual X-ray luminosities of the detected sources and adding to this an estimate of the unresolved LMXB emission (determined by the amount of diffuse emission in hard energy channels, where gaseous X-ray emission should be minimal). This was done for a sample of 12 galaxies for which good estimates of the total number of globular clusters per unit light (the globular cluster specific frequency, S_N) could be obtained from the literature. For each galaxy, L_X was normalized by the optical luminosity of the galaxy in order to compare galaxies of different sizes. We were careful to determine L_X/L_{opt} only over the same angular area of the *Chandra* detector for which S_N was determined from optical data (primarily *HST* WFPC2 data), since S_N can vary substantially with galactic radius. We also eliminated all X-ray sources with X-ray luminosities exceeding 5×10^{38} ergs s^{-1} from the study to avoid the few brightest X-ray sources from dominating L_X.

3. RESULTS

Figure 1 shows the relation between L_X/L_{opt} vs. S_N for our sample of 12 galaxies. Although there is a clear relation between the two quantities, the best-fit relation does *not* go through the origin. If it had gone through the origin, this would imply that a galaxy without any globular clusters would not contain any LMXBs – this is expected if *all* LMXBs formed within globular clusters. However, the non-zero $y-$intercept (significant at the 8.0σ level) implies that there is indeed a component to the LMXB population that forms in the field (and are not simply LMXBs that escaped from globular clusters).

If we fit a linear relation to the data of the form $(L_X/L_{opt})_{total}$ = $(L_X/L_{opt})_{GC}$ + $(L_X/L_{opt})_{Field}$ = A * S_N + B, we can use the best-fit constants A and B to predict the fraction of LMXBs that formed within globular clusters. That is, the fraction of LMXBs formed in globular clusters is (A * S_N)/(A * S_N + B) for each galaxy. This is not to be confused with the *present-day* fractions of LMXBs within globular clusters, which can be substantially lower than the initial fraction if some LMXBs were lost from globular clusters over time. For the elliptical galaxies in our sample, the predicted (initial) fraction is consistent with or only slightly less than the measured (present-day) fraction. Conversely, for the three S0s in the sample, the initial fractions were much greater than the present-day fraction. This indicates that LMXBs within globular clusters of S0 galaxies have been removed from globular clusters at a much higher rate than within elliptical galaxies. It is possible that this is due to the tidal disruption (but not destruction) of globular clusters within S0 galaxies. Such an effect is expected to be more pronounced within S0 galaxies than in elliptical galaxies, owing to the presence of disks in S0s that are lacking in ellipticals. Gravitational shocks caused by the passage of a globular cluster through a disk are much stronger than passage through a bulge distribution (Fall & Zhang 2001), leading to a greater number of LMXBs ejected from globular clusters in S0s than in ellipticals. Clearly, more observations are needed to confirm this hypothesis.

4. CONCLUSIONS

Our main conclusions are that (1) LMXBs can be formed in the field of early-type galaxies, despite the fact that it is much easier to form them within globular clusters – a galaxy without any globular clusters would still contain LMXBs, and (2) it appears that some LMXBs within S0 galaxies have escaped from globular clusters into the field to join the LMXBs that were truly formed in the field. This effect is not seen (or to a much lesser extent) in elliptical galaxies, possibly due to the fact that elliptical galaxies lack a disk that might be necessary to tidally disrupt globular clusters to the point where they could lose their LMXBs into the field.

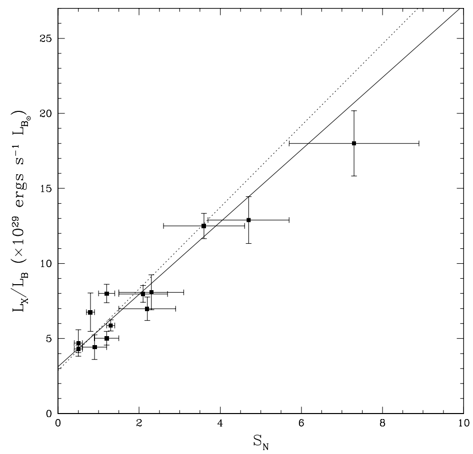

Figure 1. Relation between L_X/L_{opt} vs. S_N for a sample of 12 galaxies. The fact that the best-fit relation does not pass through the origin indicates that there is a population of LMXBs in each galaxy that did not form within globular clusters, but formed in the field instead. The y-intercept represents the fraction of L_X/L_{opt} attributed to field-born LMXBs in each galaxy.

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