Constraining The Ages Of X-ray Binaries In The Ring Galaxy NGC 922

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Abstract

We present age constraints on 13 X-ray binaries located within the drop-through ring galaxy NGC 922. Star-formation is ongoing within NGC 922 as a result of a shock-wave propagating through the galaxy, caused by a collision between NGC 922 and a neighbouring dwarf galaxy ~ 330 Myrs ago. The majority of the X-ray sources are associated with ongoing star-formation, which is occurring in both a ring close to the edge of the galaxy, and in a region close to the galactic nucleus. By qualitatively estimating the ages of the clusters coincident with these sources, we find that those associated with star-formation are likely to be no more than 10 Myrs old, agreeing with expectations of X-ray binary population models. We intend to confirm these findings by applying more quantitative methods of age estimation.

Introduction

- NGC 922
  - Peculiar morphology
    - C-shaped ring of optical emission (c.f., Fig. 2)
    - Block et al. (2001) => disc-obscured grand design spiral galaxy
    - Wong et al. (2006) => drop-through ring galaxy
      - Off-centre collision with neighbouring dwarf galaxy ~ 330 Myrs ago
  - 13 X-ray binaries within NGC 922 (Prestwich et al. *in prep*), 8 ULX candidates
    - 7 located in ring of optical emission
    - 3 located in optical emission close to galactic nucleus
    - 3 not apparently associated with optical emission
- NGC 922 (high metallicity) vs. the Cartwheel galaxy (low metallicity)
  - X-ray binary luminosity functions (Prestwich et al. *in prep*)
    - same slope
    - source number scales with star-formation rate
    - results agree with models of X-ray binary formation
  - **The goal of this work: X-ray binary ages**
    - do the ages of both galaxies agree with X-ray binary formation models, given their differing metallicities?

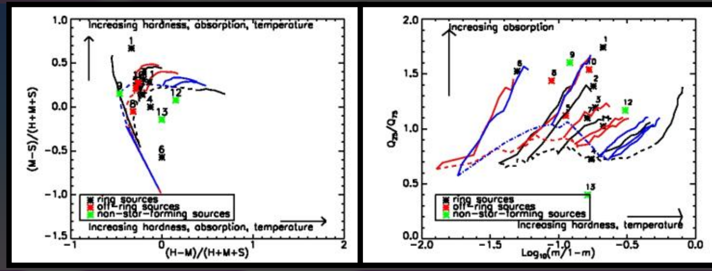

Figure 1. The X-ray 3-colour analysis (Prestwich et al. 2003) and quantile analysis (Hong et al. 2004) plots (left and right, respectively) of the 13 X-ray sources. The curves represent colours/quantiles that were computed using XSPEC (Arnaud 1996) simulated absorbed and unabsorbed power-law, disc blackbody, and bremsstrahlung models. Statistical uncertainties on both the colour and quantile results prevent us from making any statements about the nature of the sources. However, we note that almost all of the sources appear to be heavily absorbed.

HST Observations

In order to constrain the X-ray source ages, we wanted to compare them to the stellar cluster population in the galaxy. We assumed an association between clusters and X-ray source, given the inherent stellar density of clusters, and therefore the higher probability of X-ray sources formation within them. In order to identify the cluster population of NGC 922, we obtained *HST* WFPC2 *UBVI* and WFC3 Hα images. An offset was found between these images and the *Chandra* X-ray source positions. To correct for this, we referred to the *United States Naval Observatory* (*USNO*) archive, where we found the X-ray coordinates of three background galaxies positioned outside NGC 922 that were also detected in our *UBVI* images. Using these sources, we calculated the offset between the optical and X-ray coordinates, and adjusted the coordinates of the 13 X-ray sources accordingly. The source positions, as well as the positions of the three *USNO* reference objects, can bee seen the composite *BVI* image in Fig. 2. The source coordinates can be seen in Tab.1.

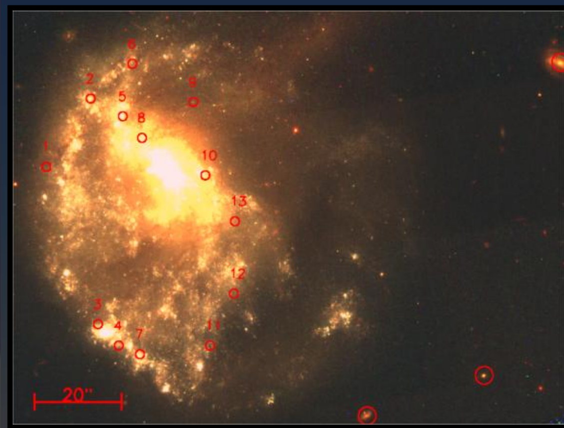

Figure 2. A three colour image of NGC 922, created using the *HST* WFPC *BVI* observations that were used in this analysis. The 439W band is shown in blue, the F547M image is shown in green and the F814 image is shown in red. The X-ray source positions are represented by the centre of the red circles (c.f., tab. 1). The radii of the circles are set to 2σ position uncertainty, as defined by the *Chandra* ACIS instrument. The three circles outside the galaxy represent the positions of the background *USNO* galaxies which were used to calculate the offset between the X-ray source positions and the optical images.

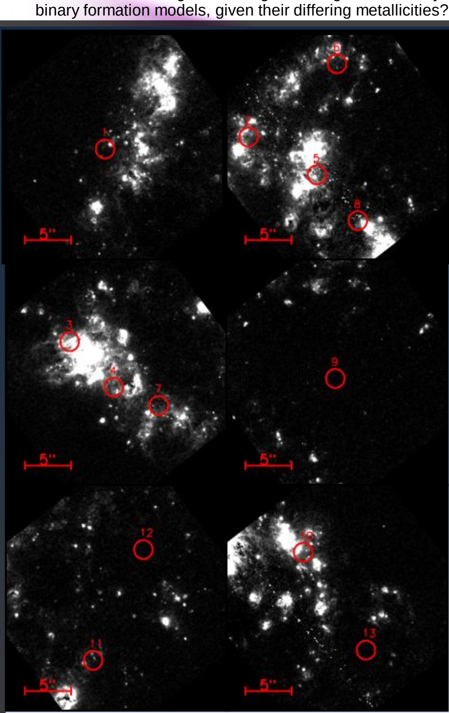

Figure 3. Zoomed in emission-subtracted Hα images of NGC 922, showing the locations of the X-ray sources within circular regions of radius 2σ. It can be seen that 10 of the 13 X-ray sources are associated with Hα emission. This tells us that the majority of the X-ray sources are associated with recent star-formation. Thus, we would expect the source ages to be quite low. It is worth noting that the X-ray analysis told us that most of the sources are heavily absorbed (c.f., fig.1). Given their absorption, and their locations within dusty regions of the galaxy, it is possible that the sources are associated with stars that have not yet blown away their natal debris, and are therefore extremely young (< 10 Myrs).

X-ray source	RA	Dec	Closest cluster U-B	Closest cluster V-I	Distance[a]
1	02:25:06.479	-24:47:16.58	-1.32	0.34	245
2	02:25:05.731	-24:47:01.17	-1.06	0.55	15
3	02:25:05.607	-24:47:51.97	-1.42	0.13	166
4	02:25:05.256	-24:47:56.80	-1.56	0.09	234
5	02:25:05.188	-24:47:05.18	-1.24	0.35	15
6	02:25:05.28	-24:46:53.37			
7	02:25:04.899	-24:47:58.75	-1.27	0.41	55
8	02:25:04.863	-24:47:10.05	-0.84	0.73	243
9	02:25:03.995	-24:47:01.97			
10	02:25:03.794	-24:47:18.47	-1.35	0.67	48
11	02:25:03.711	-24:47:56.84	-1.30	0.69	174
12	02:25:03.311	-24:47:45.09			
13	02:25:03.295	-24:47:28.84			

Table 1. X-ray binaries and closest associated stellar clusters data. Notes: [a] Distance between the X-ray source and its closest associated stellar cluster, measured in parsecs.

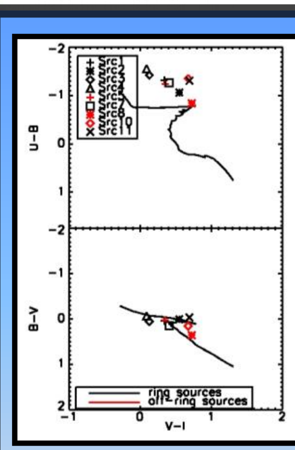

Figure 4. Optical 2-colour (V-I vs. U-B upper; V-I vs. B-V lower) diagrams of the closest clusters associated with the X-ray sources, within 2σ uncertainty. We found that all of the X-ray sources, less the three sources not associated with Hα emission and one other source, have associated stellar clusters (c.f. tab.1 for the closest associated cluster U-B and B-V colours as well as the distances between the X-ray sources and clusters). The solid lines represent synthetic stellar population models (Bruzual & Charlot 2003). These models represent the colour evolution of synthetic stellar populations from 1 Myr to ~ 15 Gyrs, given a Salpeter initial mass function (Salpeter 1955), and a metallicity value of Z = $Z_{\odot}$(see Wong et al. 2006). Our next goal is to constrain the ages of these clusters by χ^2 fitting their colours against these models.

Discussion and Future work

NGC 922 has an extremely interesting morphology. *UBVI* and Hα emission is most concentrated in a C-shape ring close to the edge of the galaxy, as well as in regions closer to the galactic nucleus (c.f., Fig. 2, Fig.3). X-ray source detection indicates that 13 X-ray sources exist within the galaxy, 10 of which appear to be associated with the optical emission (c.f., Fig.2, Fig.3, Tab.1). X-ray colour and quantile analysis implies that the majority of the sources are highly absorbed (c.f., Fig. 1). This high absorption could imply that the 10 sources located in dusty Hα regions of the galaxy are associated with very young stars, and are indeed very young themselves (< 10 Myrs, c.f., Fig.3).

The remaining three sources appear to be isolated from the bulk of bright optical emission. Given that they have no associated Hα emission or stellar clusters, we hypothesise that the ages of these sources are considerably higher than those of the other sources (i.e.,> 10 Myrs). However, this may not be true. The X-ray analysis of these sources indicated high levels of absorption in two of the three cases (c.f., Fig.1) . This implies the possibility that the sources are actually associated with clusters and/or Hα emission that is hidden by absorbing material.

Our next step is to constrain the ages of the X-ray binaries more quantitatively by chi squared fitting the source colours against the Bruzual & Charlot (2003) models. We will then compare these constraints to those of the Cartwheel galaxy in order to determine whether they agree with X-ray binary population models.

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