IOWA STATE UNIVERSITY
Physics & Astronomy Department

The X-ray Universe 2011
27-30 June, 2011

Vallia Antoniou (ISU), Andreas Zezas (SAO, U. of Crete), Vicky Kalogera (Northwestern Univ.)

Young X-ray Binary Populations in Low Metallicity Star-Forming Galaxies

1. Motivation-Objectives

The Magellanic Clouds (MCs) are our two nearest star-forming galaxies, which, through their well characterized stellar populations, provide an excellent testbed for understanding how the HMXB have formed and evolved with time. They have experienced an extended period of star-formation (SF) with recent bursts at ~60 Myr for the Small Magellanic Cloud (SMC; Harris & Zaritsky 2004, AJ, 127, 1531) and at ~12 and 100 Myr for the Large Magellanic Cloud (LMC; Harris & Zaritsky 2009, AJ, 138, 1243 [HZ09]).

In particular, the SMC Bar hosts stellar populations with ages <100 Myr and the vast majority of the SMC pulsars (Galache et al. 2008, ApJS, 177, 189). Shtykovskiy & Gilfanov (2007, AstL, 33, 437) found that the number of HMXBs reaches its maximum ~20–50 Myr after the SF event, while McSwain & Gies (2005, ApJS, 161, 118) observed a strong evolution in the fraction of Be stars with age up to 100 Myr, with a maximum at ~25–80 Myr. On the other hand, the LMC has received much less attention, with most X-ray observations focusing on previously known objects.

These results motivated us to investigate the connection between the spatially resolved SF history in the MCs and the number and spatial distribution of their HMXB populations. The study of the X-ray source populations in the MCs in the context of their stellar populations will address the following questions:

- What are the properties of the overall young XRB population and the relative contribution of their various components?,
- What is the effect of metallicity on the formation and evolution of HMXBs?,
- What is the formation rate of young XRBs as a function of metallicity and post-starburst age?

In the past decade, the study of the X-ray source population properties in our nearest star-forming galaxies has been revolutionized thanks to the detection of increasing numbers of sources and their more precise localization. The results from these systematic and detailed studies will be used to perform comparisons with state-of-the-art XRB population synthesis models, that will allow us to constrain XRB evolution channels and identify the parameters that are most critical for their formation and evolution (e.g., metallicity, SF history, mass transfer, initial mass function etc). This well defined framework of XRB evolution will be then applied to other galaxies, even outside our Local Group.

2. The HMXB population of the Magellanic Clouds

SMC (~1/5 Z⊙)

There are > 100 known HMXBs (e.g., Antoniou et al. 2009, ApJ, 707, 1080; Liu et al. 2005, A&A, 442, 135; Coe et al. 2005, MNRAS, 356, 502; Haberl & Pietsch 2004, A7A, 414, 667):

✓ all but 1 of the spectroscopically confirmed systems (~70) have an Oe or Be III-V star as an optical counterpart, i.e. they are Be-XRBs

✓ there is only 1 known supergiant XRB (located in the SMC Wing (SMC X-1)

✓ so far, no BH-XRBs have been detected

✓ there are 63 known X-ray pulsars (based on the online census of M. Coe), which are mostly confirmed Be-XRBs

LMC (~1/3 Z⊙)

We now know 41 HMXBs (e.g., Antoniou et al. 2011, in prep.; Liu et al 2005):

✓ only 10 Be-XRBs have been confirmed spectroscopically

✓ there are 2 known supergiant XRBs

✓ LMC X-1 and X-3 are candidate BH-HMXBs

✓ so far, we know 9 X-ray pulsars (only 5 of those have been confirmed as Be-XRBs)

3. Young Stellar Parent Populations of HMXBs in the Magellanic Clouds

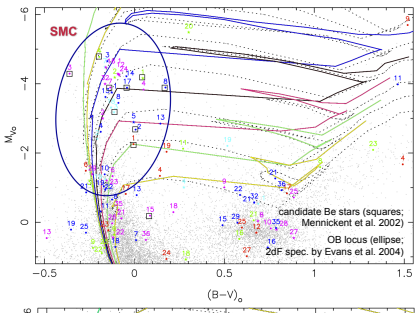

Fig.1a Colour-Magnitude Diagram for all single (★) and brightest of multiple (•) OGLE-II matches (r_{min}=1.5") of our *Chandra* shallow survey sources color coded for detections in different fields (Antoniou et al. 2009, ApJ, 697, 1695). Overlaid are the isochrones (solid lines) and stellar evolutionary tracks (dotted lines) from Geneva database (Lejeune & Schaerer 2001) for ages of 8.7, 15.5, 27.5, 49.0, 87.1, 154.9, and 275.4 Myr; and initial stellar M of 12, 9, 7, 5, 4, and 3 M⊙ (top to bottom).

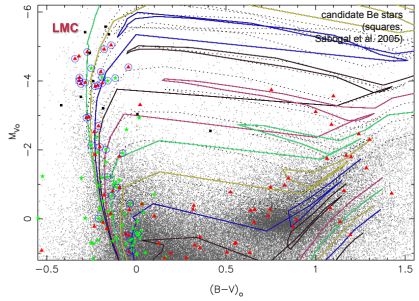

Fig.1b Colour-Magnitude Diagram for all MCPS matches within 5" (▲) and 10" (★) of all known HMXBs (Antoniou et al. 2011, in prep.). The most likely counterpart is marked with an open circle. Overlaid are the isochrones (solid lines) and stellar evolutionary tracks (dotted lines) from Geneva database (Lejeune & Schaerer 2001; same as in Fig. 1a, but for the ~1/3Z⊙ LMC metallicity).

4. Star-formation history of HMXBs in the SMC

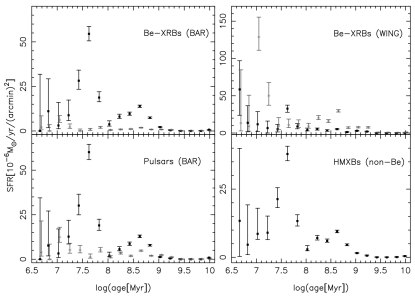

Fig.2 Average SF history (using data from Harris & Zaritsky 2004) of regions with and without various XRBs (black and gray points, respectively) in different locations of the SMC (Antoniou et al. 2010, ApJL, 716, 140).

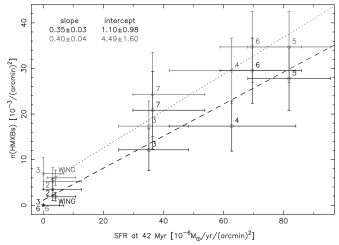

Fig.3 Number of observed Be-XRBs and HMXBs (black and gray, respectively) in the *Chandra* (') and *XMM-Newton* fields (★; marked with their IDs) of the SMC vs. the SF rate ~42 Myr ago. The slope (given in the inset) gives the XRB formation rate. This is its first *direct* calibration based on the HMXBs' parent stellar populations (Antoniou et al. 2010).

5. Star-formation history of HMXBs in the LMC

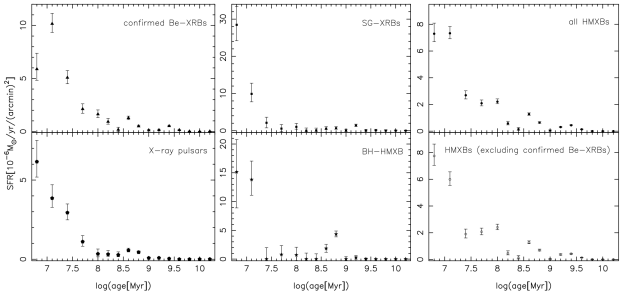

Fig.4 Average SF history (using data from [HZ09]) of regions with and without various XRBs in different LMC locations (Antoniou et al. 2011, in prep.). Notice the different y-axis scales in Figs. 2, 4.

6. Results

SMC (Antoniou et al. 2010, ApJL, 716, 140)

✧ A significant number of Be-XRBs and/or pulsars are connected with a burst of SF ~25–60 Myr ago, while regions with weak SF at ~42 Myr, such as the SMC Wing, show low numbers of Be-XRBs.

✧ Based on the spatial correlation between the SF activity and the XRBs, a limit on the kick velocity imparted on the compact object during the supernova explosion of ~15-20 km/s is set (there is strong observational indication for velocities of even a factor of 2 lower).

✧ A Be-XRB production rate of ~1 system per 3 × 10^{-3} M⊙/yr is estimated.

LMC (Antoniou et al. 2011, in prep.)

✧ In contrast to the SMC, the LMC Be-XRB population is connected with a burst of SF ~6–25 Myr ago.

✧ All regions that host the 9 known X-ray pulsars in the LMC show a peak in their SF history, similar to the one observed in the SMC Bar, but shifted to earlier ages (≤10 Myr instead of ~40–60 Myr for the SMC), thus challenging current population synthesis models.

✧ The 2 known supergiant XRBs have been detected in regions with similar young ages.

✧ Based on the lower SF rate of the parent stellar populations in the LMC, a lower number of Be-XRBs and X-ray pulsars is expected.

The similarity of these ages with the age of maximum occurrence of the "Be phenomenon" (~40 Myr) indicates that the presence of a circumstellar decretion disk plays a significant role in the number of observed XRBs in the 10–100 Myr age range.

Acknowledgements
This material is based upon work supported by the National Aeronautics and Space Administration under Grant No. NNX10AH47G issued through the Astrophysics Data Analysis Program.