The Chandra Galactic Bulge Survey

Tom Maccarone (Texas Tech) on behalf of a large consortium

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Surveys of X-ray binaries

Belczynski et al. 2011; see also Farr et al. 2011; Ozel et al. 2010; Kreidberg et al. 2012

Lattimer & Prakash 2007
Populations of X-ray binaries

From Lamb 2006

Andreas Irrgang web page
Severe biases from using transients!


Chen, Shrader & Livio 1997
Shallow and out of the Plane...

Sources easier to follow-up (c.f. Muno field)

Optimize ratio of X-ray binaries to everything else! (c.f. ChamPlane)
Source classes

X-ray binaries -- NS LMXBs often X-ray bright

Cataclysmic variables -- hard to separate from BHs without spectra; both are mostly foreground objects and should be UV bright

Normal stars/active binaries -- optically bright, OGLE variability

Background objects -- AGN at these X-ray fluxes will be radio bright

Surprises -- millisecond pulsars, or protostars?
Classifying the sources

<table>
<thead>
<tr>
<th>Class</th>
<th>Fx/Fopt</th>
<th>He4471/Hbeta</th>
<th>He6678/Hbeta</th>
<th>He II 4686/Hbeta</th>
<th>Radio</th>
<th>Variability</th>
<th>UV</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV</td>
<td>0.01-1</td>
<td>0.22</td>
<td>0.1-0.5</td>
<td>&lt;0.4</td>
<td>None</td>
<td>flickering, orbital period, DNe</td>
<td>WD surface</td>
</tr>
<tr>
<td>Mag. CV</td>
<td>0.1-10</td>
<td>0.17</td>
<td>0.1-0.5</td>
<td>&gt;0.4</td>
<td>None</td>
<td>flickering, pulsation, DNe</td>
<td>WD surface</td>
</tr>
<tr>
<td>qLMXB NS</td>
<td>0.1-1</td>
<td>~0</td>
<td>0.12</td>
<td>~0</td>
<td>None</td>
<td>flickering, ellipsoidal</td>
<td>None (BG)</td>
</tr>
<tr>
<td>qLMXB BH</td>
<td>0.01-1</td>
<td>~0</td>
<td>0.12</td>
<td>~0</td>
<td>faint</td>
<td>flickering, ellipsoidal</td>
<td>some (FG)</td>
</tr>
<tr>
<td>LMXXB</td>
<td>&gt;100</td>
<td>&lt;0.1</td>
<td>0.3</td>
<td>0.8</td>
<td>bright</td>
<td>flickering, ellipsoidal, bursts</td>
<td>if not extincted</td>
</tr>
<tr>
<td>Star</td>
<td>&lt;0.001</td>
<td>none</td>
<td>none</td>
<td>some</td>
<td>usually</td>
<td>some</td>
<td>usually</td>
</tr>
<tr>
<td>AGN</td>
<td>~1</td>
<td>redshifted</td>
<td>redshifted</td>
<td>redshifted</td>
<td>Usually</td>
<td>yes</td>
<td>probably absorbed</td>
</tr>
</tbody>
</table>

Primarily from Britt et al. 2013, supplemented by Maccarone et al. 2012, Fielder et al, in prep
Get good enough optical data!

- $F_X/F_{opt} \approx 0.1$ for accretion powered sources
- $F_X/F_{opt} \approx 0.001$ for coronally active stars
- Past surveys, with very deep X-ray coverage and very shallow OIR coverage detect mostly coronally active stars!
- To avoid this, we need wider, shallower X-ray data and deeper optical data than past groups have used for similar projects
Multi-wavelength coverage

Optical photometry: r’, i’, Halpha to 23rd in 2006
r’ variability survey in 2010
r’ variability survey in 2013

Optical spectroscopy: numerous runs, about half of sources now covered

UV - Swift survey of part of region

Radio: 11 hours GBT time - ongoing
Multi-wavelength for free!

Infrared - Vista Variables in the Via Lactea, Spitzer GLIMPSE, WISE

Radio - NVSS
UV-Galex

WFIRST should cover about $\frac{1}{3}$ of it!
Some results

From Britt et al. 2013

From Hynes et al. 2013
Identifications to date

Sources: about 1600
Tycho stars: 69 (Hynes et al. 2012)
OGLE variables: 209 (Udalski et al. 2012)
AGN: 12 (Maccarone et al. 2012)
CVs: ~20 (Britt et al. 2013; Torres et al. 2013)
LMXB candidates: ~10 (Torres et al. 2013)
A bizzarre transient

From 2006

From 2010
What’s next?

- GBT survey -- sources with no IR counterpart and low reddening are good MSP candidates
- EVLA survey -- to propose
- Starting to exploit this for real science -- e.g. correlation between X-rays and dwarf nova rate (Britt et al., in prep)
- Classifying more of the objects, finding the black holes and neutron stars

This is very much work in progress, but we are already finding exciting things!