Galactic Bulge Survey

Peter Jonker  (SRON & CfA)
Cees Bassa  (SRON & RU Nijmegen)
Gijs Nelemans  (RU Nijmegen)

for the GBS team (15 active people)
see http://www.sron.nl/~peterj/gbs
What is the Galactic Bulge Survey?
Chandra+Blanco r',i', Hα imaging of 12-sq.deg
Science goals

• Find eclipsing low-mass X-ray binaries
  
  Model independent mass measurements
  black hole formation & neutron star EoS

• Constrain common envelope evolution via number count
  Cataclysmic variables and ultra-compact low-mass X-ray binaries

• Use quiescent LMXBs to map the Galactic structure
  
  X-ray binaries trace stellar mass distribution
  (modulo kick)

Cartoon image of a low-mass X-ray binary

Compact object: neutron star or black hole

Accretion disc
Jet
X-ray heating
Hot spot
Accretion stream
Disc wind
Companion star

BinSim R. Hynes
Population synthesis of LMXBs

Details of Galactic model: Nelemans et al. 2004

~400 qLMXBs predicted ≥10 eclipsing
Mapping Galactic structure?

Figure from Weidenspointner et al. 2008

511 keV line flux

LMXB distribution
Neutron star or black hole mass measurement:

\[
\frac{P_{\text{orb}} K^3}{2\pi G} = \frac{M_{NS} \sin^3 i}{(1 + q)^2}
\]

Outburst system, partial eclipse

Jonker et al. 2005

K = 99.1 ± 3.1 km/s
Measure rotational line broadening

\[
\frac{P_{\text{orb}}K^3}{2\pi G} = \frac{M_{\text{NS}} \sin^3 i}{(1 + q)^2}
\]

\[
\frac{v \sin i}{K} = 0.46[(1 + q)^2 q]^{1/3}
\]

\[
v \sin i = 32.9 \pm 0.8 \text{ km s}^{-1}
\]

\[
M_X = 1.44 \pm 0.10 M_\odot
\]
Neutron star or black hole mass measurement:

\[ \frac{P_{\text{orb}} K^3}{2\pi G} = \frac{M_{NS} \sin^3 i}{(1 + q)^2} \]

\[ \frac{v \sin i}{K} = 0.46[(1 + q)^2 q]^{1/3} \]

\[ \Delta \phi^2 = \left( \frac{0.49 q^{2/3}}{0.6 q^{2/3} + \ln(1 + q^{1/3})} \right)^2 - \left( \frac{\cos i}{1+q} \right)^2 \]

Horne 1985

Best results: quiescent eclipsing systems

EXO 0748-676 \( \tau = 504 \pm 5 \) s
Chandra results

A_i'
Number of Chandra sources as a function of detected counts (in 1 cnt bins)
Chandra localisation accuracy vs offset and # of cnts

Net Counts (STD Dev)

\[
\begin{align*}
\triangle 909 (30) \\
\times 91 (3) \\
\Diamond 44 (3) \\
+ 18 (1) \\
\square 9 (1) \\
\star 6 (1)
\end{align*}
\]

95% PSF

95% error radius (arcsec)

offset (arcmin)

Hong et al. 2005
Stellar density image Northern GBS strip

Northern strip:
801 X-ray sources
556 sources with optical counterpart
Chandra localisations + CMD (instrumental)
First spectroscopic observations: Hydra

• Three dark nights of CTIO 4m Blanco telescope time in June 2008

• Hydra: multi-object fiber-fed spectrograph.
  • 40 arcmin diameter FOV
  • 138 fibers (2 arcsec diameter)
  • Minimum fiber-to-fiber distance: 25”
  • Setup: slitless + KPGL3 grating
  • Useful ~4000-6900 A and 5 A FWHM

• We targeted bright (<18 mag) stars from UCAC and USNO B1.0 catalogs within < 5 arcsec from the position of an X-ray source
Initial Hydra results

X-ray selected sdB star
Initial Hydra results (ii)

GBS selected CV

Flux (erg cm$^{-2}$ s$^{-1}$ Å$^{-1}$) vs Wavelength (Å)

- Hα
- HeII
- Hβ
- HeI

Lots and lots of optical follow-up needed

- Three more nights of Hydra in July 2009

- IMACS: Inamori Magellan Areal Camera and Spectrograph (proposal pending)
  - Multislit spectroscopy
  - 27.4 arcmin diameter FOV
  - Setup: 1 arcsec slit + 300 g/mm grating. Useful interval 3900-7000 with 7 Å FWHM
  - s/n of 10 at Halpha in 30 min for r’=20

- VIMOS for identification the faint sources 20 < r’ < 23
  - to be proposed: in total needs ~170 pointings \(\rightarrow\) 300 hours

- FORS2 + X-shooter for phase resolved spectroscopic obs
  - 24 hours of X-shooter GTO time awarded

- Photometric follow-up to determine variability (orbital periods)
  - Strategy: re-observe the whole GBS area 15-30 times in r’
Optical follow-up photometry

- 30 epochs over 10 nights
  - $\sigma_r = 0.1$
  - $A_r = 0.25$

- 15 epochs over 5 nights
  - $\sigma_r = 0.1$
  - $A_r = 0.25$
Finally:

Much more to be done with the data collaborations welcome (spare fibers, slitlets etc)

We will help raise the oversubscription rate for VIMOS