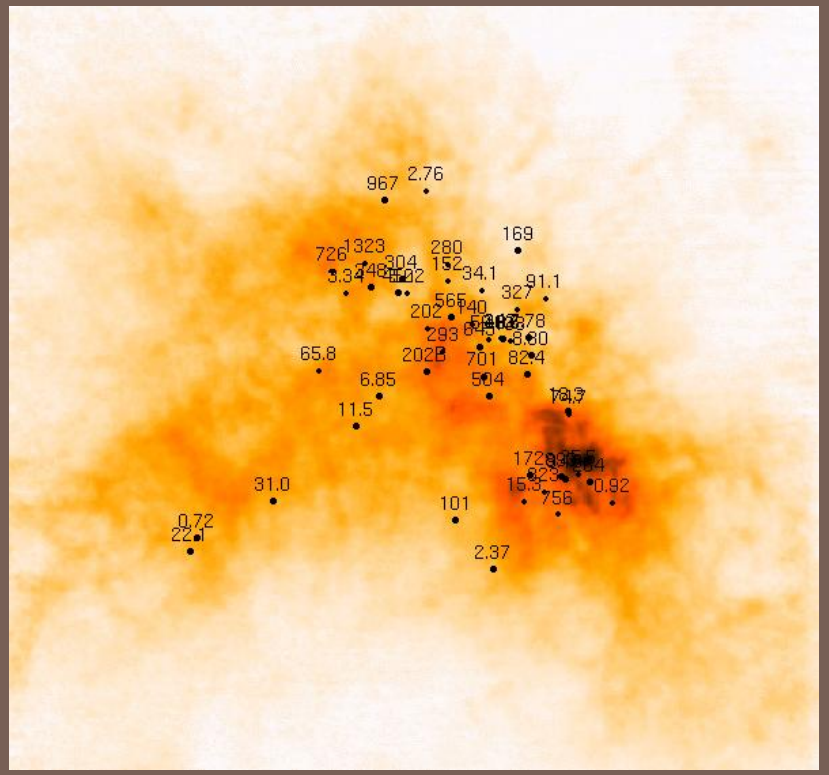
A FIRST LOOK AT THE ORBITAL PARAMETERS OF BE/X-RAY BINARIES IN THE SMC

VALENCIA 2011



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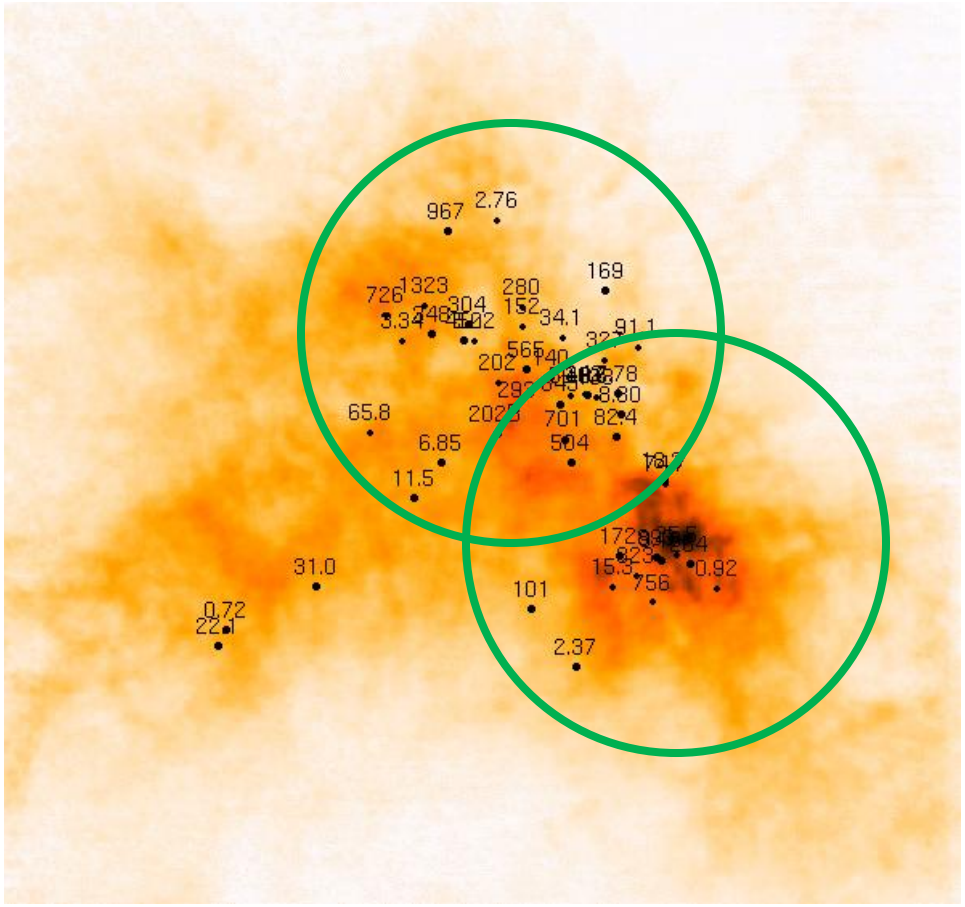
Overview

- The exceptional BeXRB population in the SMC
- Type II outbursts – the SMC sample
- Orbital fitting to X-ray pulsations – how and why?
- Results
  - 5 successful fits
  - Comparison to the Milky Way population
  - The Porb vs. Eccentricity plane
- Summary & Questions

HMXB population in the SMC

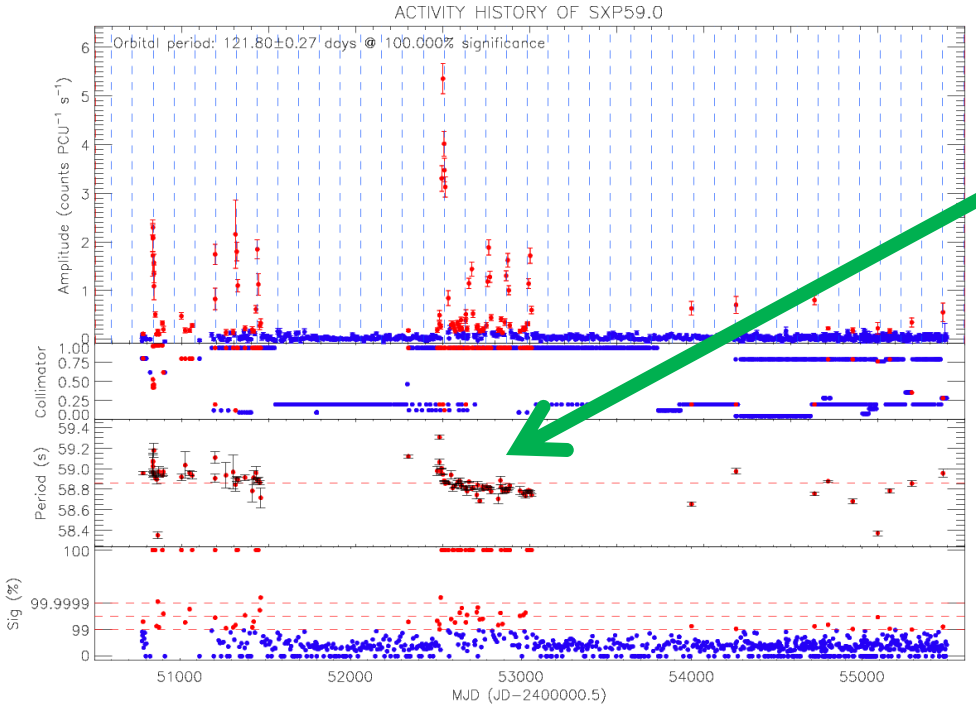


Weekly monitoring of the SMC bar with RXTE (Galache et al., 2008)

→If a pulsar goes into an X-ray outburst, it is almost always seen

Almost all SMC pulsars are found in the bar

Type II outbursts in the SMC – our data sample



Example long-term light curve from our SMC monitoring programme (Galache et al., 2008)

- 13 systems show evidence of a Type II X-ray outburst in their long-term light curves; only 1 of these has Pspin > 100s
- Many are too short or not well sampled, making fitting difficult or impossible
- Some fit these criteria, but still cannot be fit with the model

Orbital Fitting – How and Why?

- Some systems show modulation of their spin periods during an outburst. This is usually a combination of Doppler shifting of the X-ray emission and transfer of angular momentum onto the neutron star

- Combining a spin-up model with a radial velocity code can separate out period changes due to accretion torques and those due to orbital motion

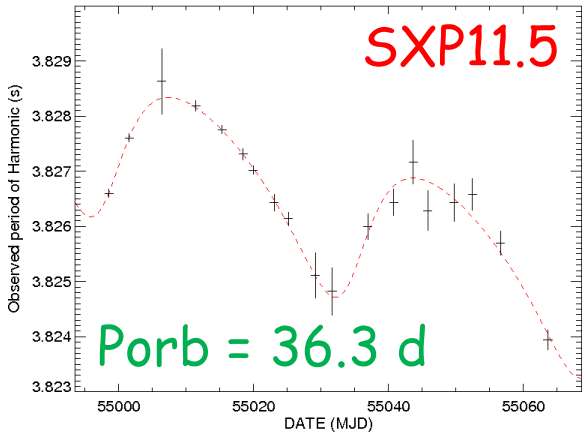
- Knowing orbital periods, eccentricities, and spin-up helps us to understand binary formation and evolution and allows us to probe accretion torques on the NS surface

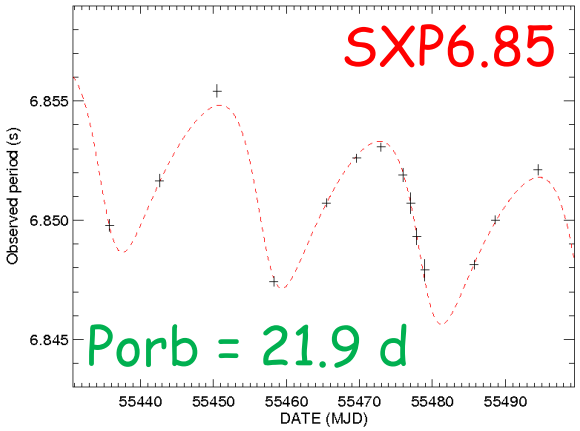
RESULTS

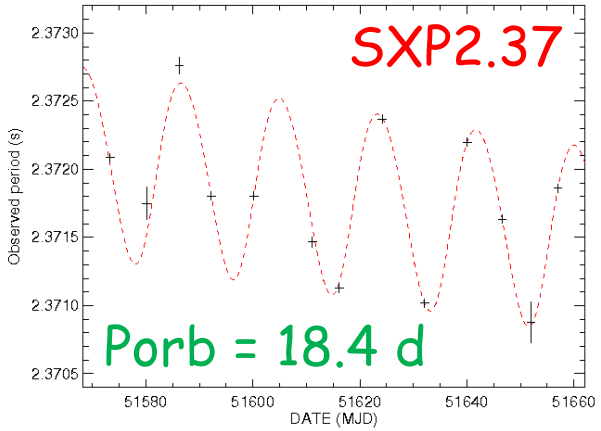
- 5 systems fit with model
- Comparison to Galaxy
- Porb vs. Eccentricity relationship?

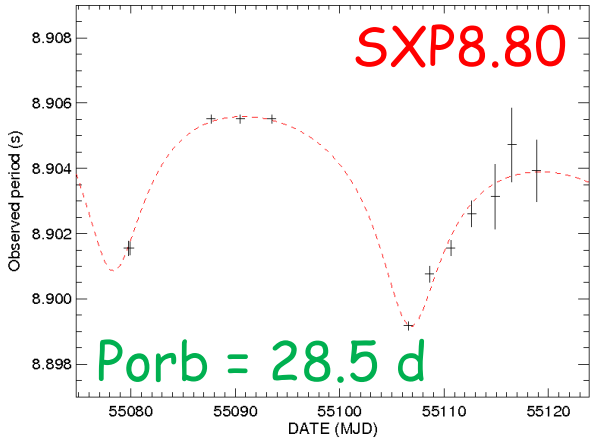
RESULTS

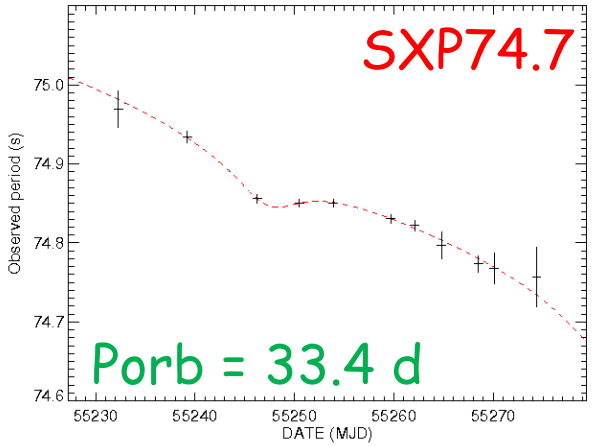
Period







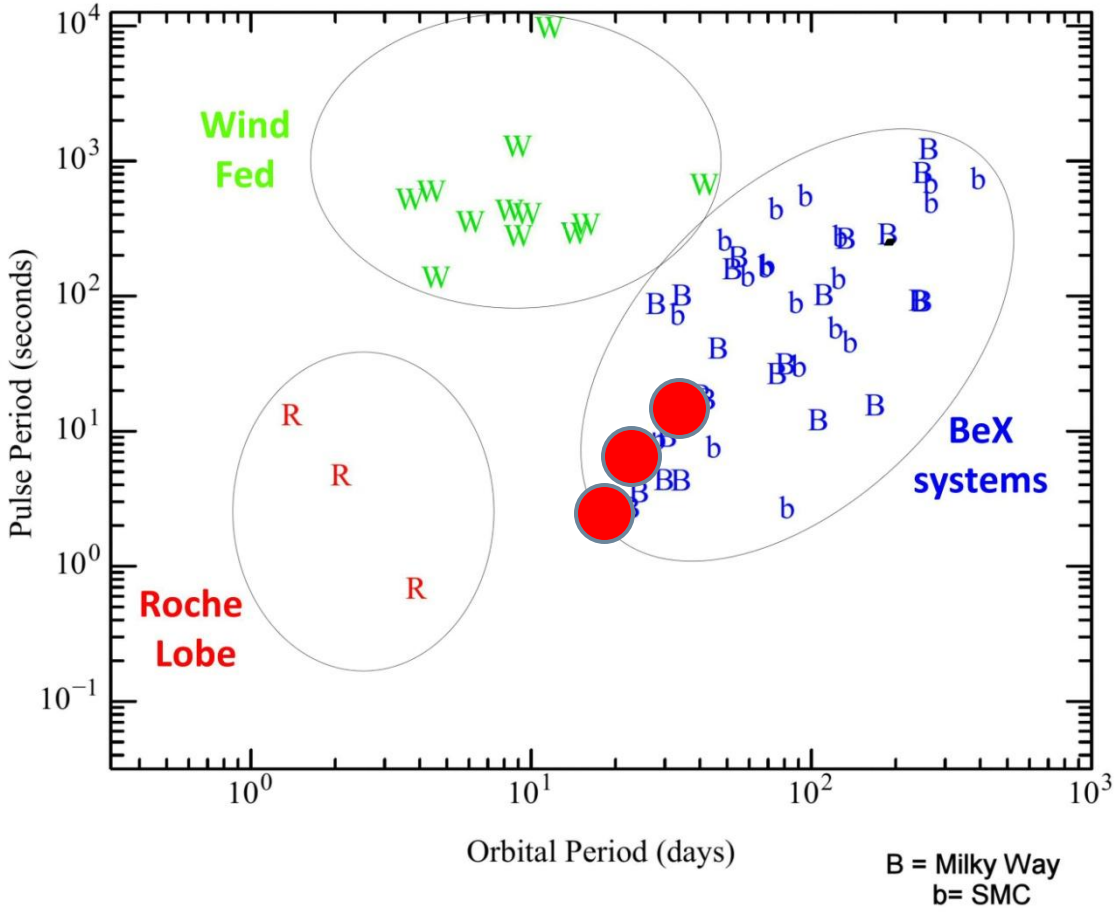




Time

Townsend et al., 2011a, 2011b

Corbet diagram of binary pulsars (adapted from Corbet 1986)



Newly discovered orbital periods place SXP11.5, SXP6.85 & SXP2.37 nicely onto the BeXRB section of the Corbet diagram

→ We must be doing something right!!

Summary of orbital fits

Source	$P_{orbital}$ (d)	$a_x \sin i$ (light-s)	e	$\dot{P}$ (ss^{-1})
SXP11.5	36.3 ± 0.4	167 ± 7	0.28 ± 0.03	$(-4.67 \pm 0.31) \times 10^{-10}$
SXP6.85	21.9 ± 0.1	151 ± 6	0.26 ± 0.03	$(-8.0 \pm 0.5) \times 10^{-10}$
SXP2.37	18.38 ± 0.02	73.7 ± 0.9	0.07 ± 0.02	$(-7.20 \pm 0.15) \times 10^{-11}$
SXP8.80	28.51 *(frozen)*	112 ± 5	0.41 ± 0.04	$(-6.9 \pm 0.6) \times 10^{-10}$
SXP74.7	33.38 *(frozen)*	$147 \pm N/A$	0.40 ± 0.23	$(-6.35 \pm 0.37) \times 10^{-8}$
SXP18.3	17.79 *(frozen)*	75 ± 3	0.43 ± 0.03	$(-5.67 \pm 0.35) \times 10^{-10}$

Most Be systems have Porb ~10-500 d with eccentricities in the range 0.3-0.5 (Bildsten et al. 1997) – we can only probe the low end of this distribution with this method → observational bias

Moderate eccentricity for most systems, though that of SXP2.37 suggests it belongs to the low eccentricity OB transient population (Pfahl et al., 2002)

Huge Pdot of SXP74.7 makes modelling the orbital modulation difficult. The larger spin period means this still agrees with theories of binary accretion (Ghosh & Lamb, 1979)

Mass functions, inclinations & orbital sizes

Mass of the donor based on an error of one spectral type in the published value

Inclination derived from orbital solution with errors from the uncertainty in donor mass

Source	$(M_c/M_\odot)$	$(f_X(M)/M_\odot)$	i (°)	a_x ($R_\star$)
SXP2.37[1]	18–26	1.27 ± 0.05	24^{+2}_{-3}	9
SXP6.85[1]	13–26	7.71 ± 0.92	50^{+20}_{-9}	12
SXP8.80[1]	13–23	1.86 ± 0.25	30^{+6}_{-4}	13
SXP74.7[1]	6–9	3.06 ± 0.94	55^{+20}_{-13}	16
SXP11.5[2]	13–26	3.79 ± 0.48	37^{+11}_{-6}	16
SXP18.3[3]	8–13	1.43 ± 0.17	36^{+5}_{-7}	10

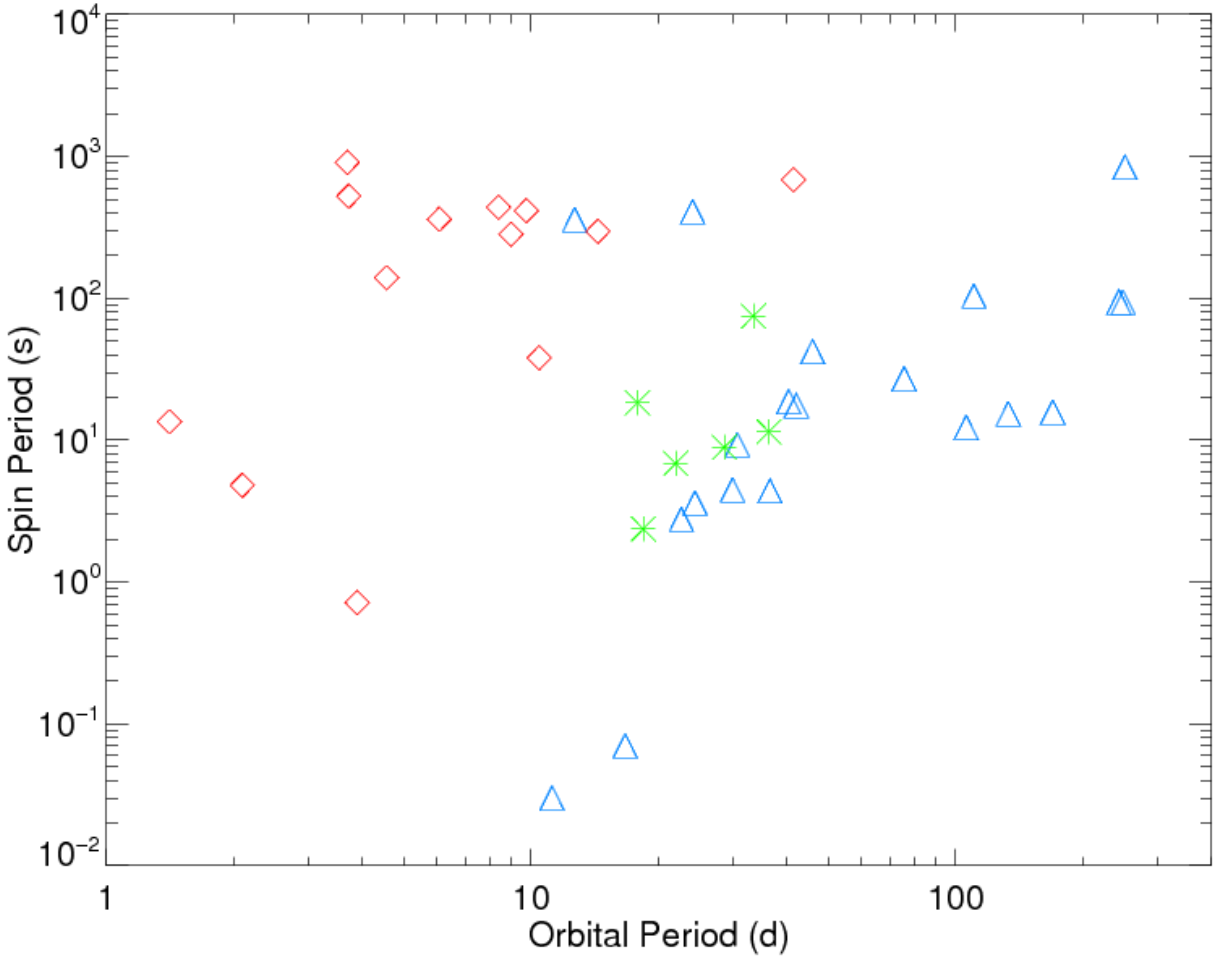
i estimates can be used with Halpha profiles to test for Be disk-orbital plane misalignments

larger orbits tend to be less X-ray active in our sample

Mass function derived from orbital solution

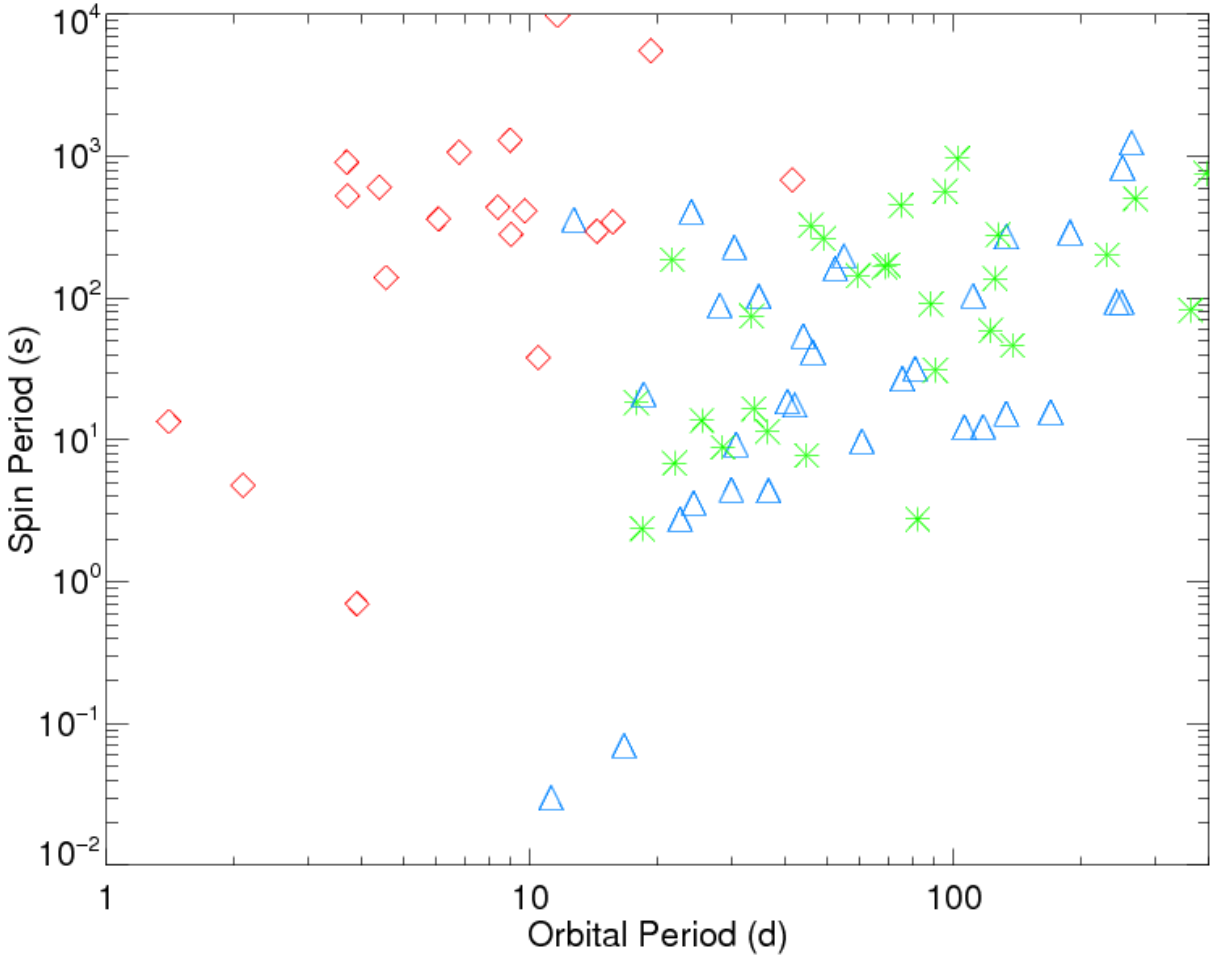
Semi-major axis estimates from most probable mass and radius of donor

Corbet diagram of all high-mass X-ray binaries with an orbital solution



= Galactic Be
= SMC Be
= All supergiant

Corbet diagram of all high-mass X-ray binaries



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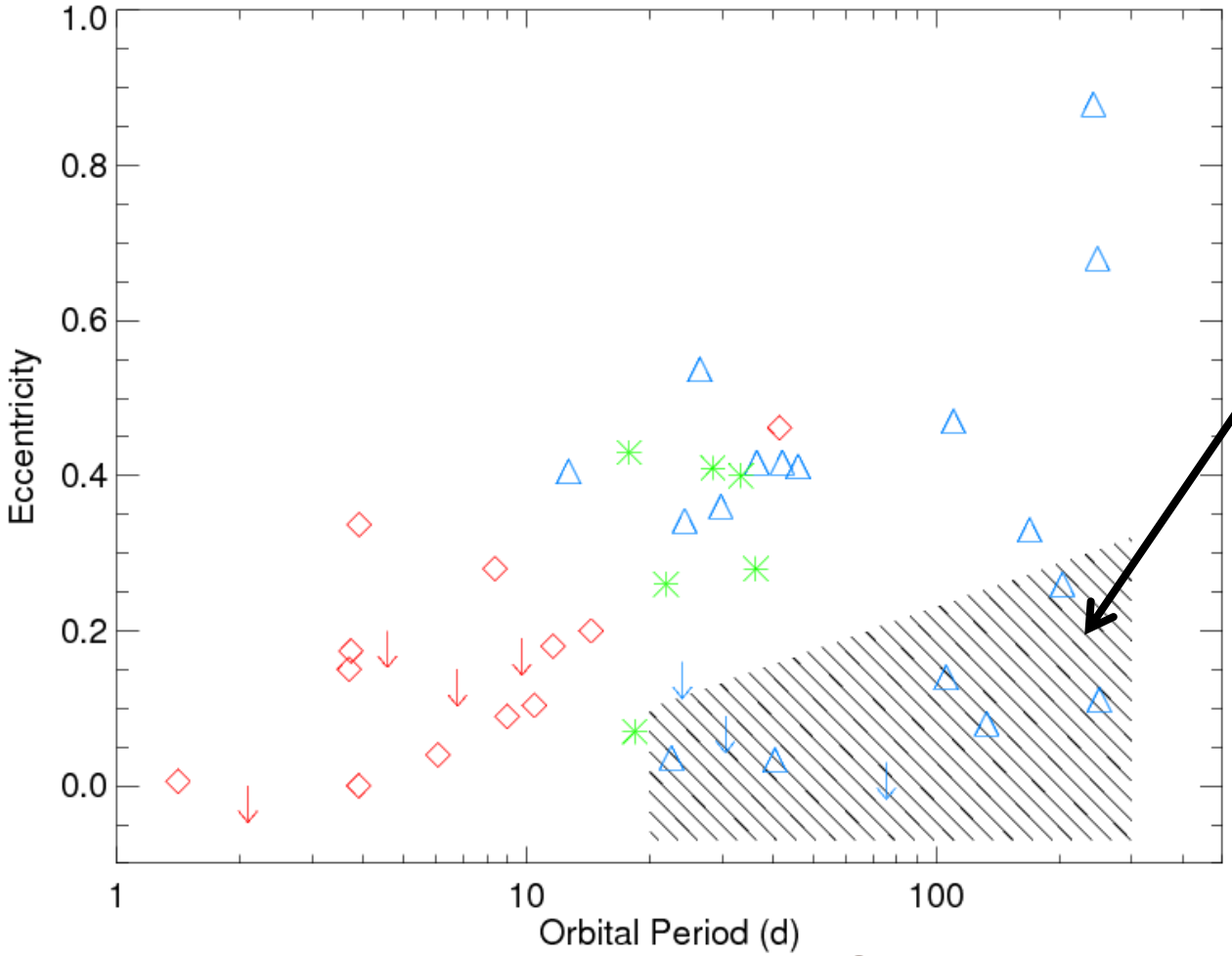
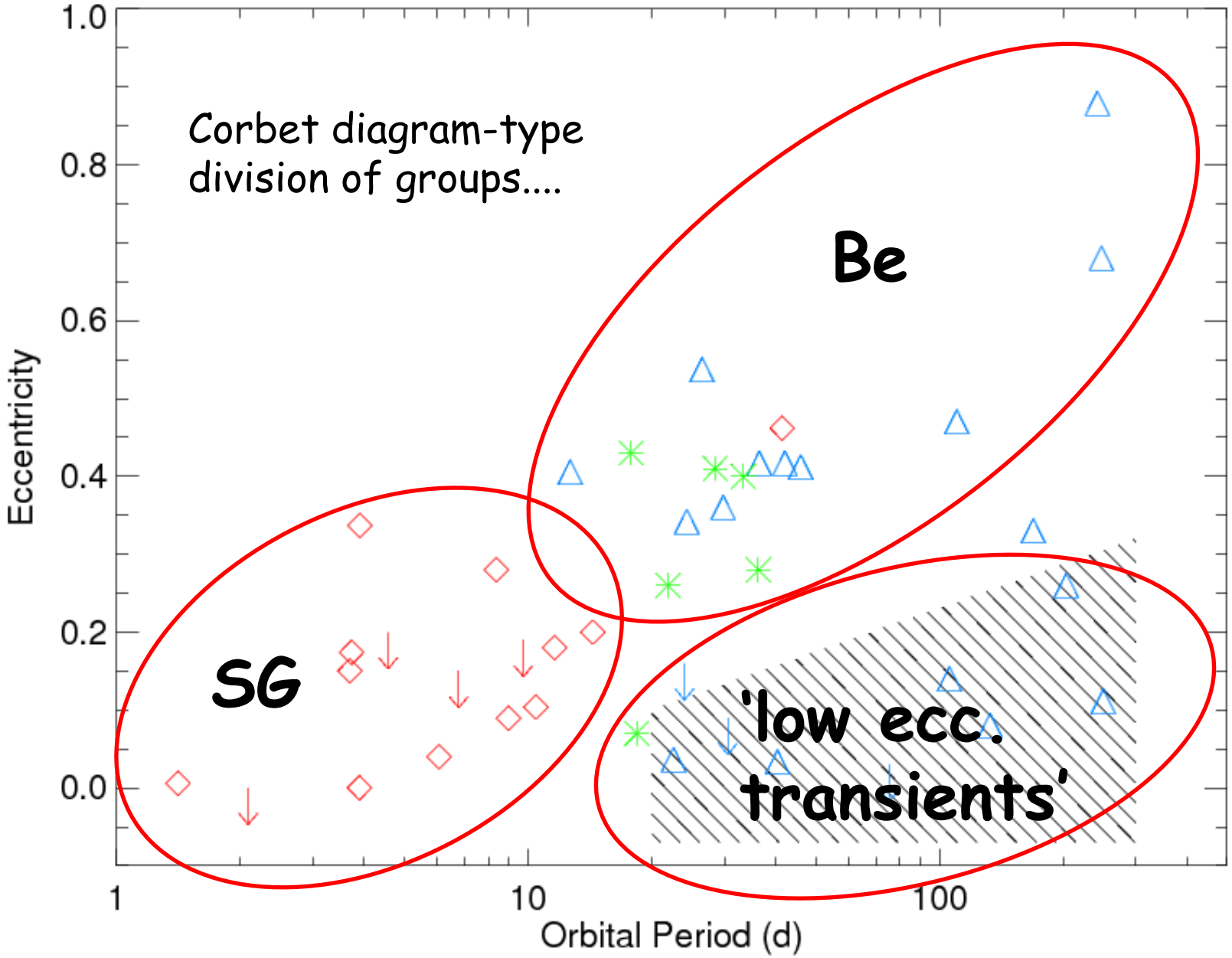
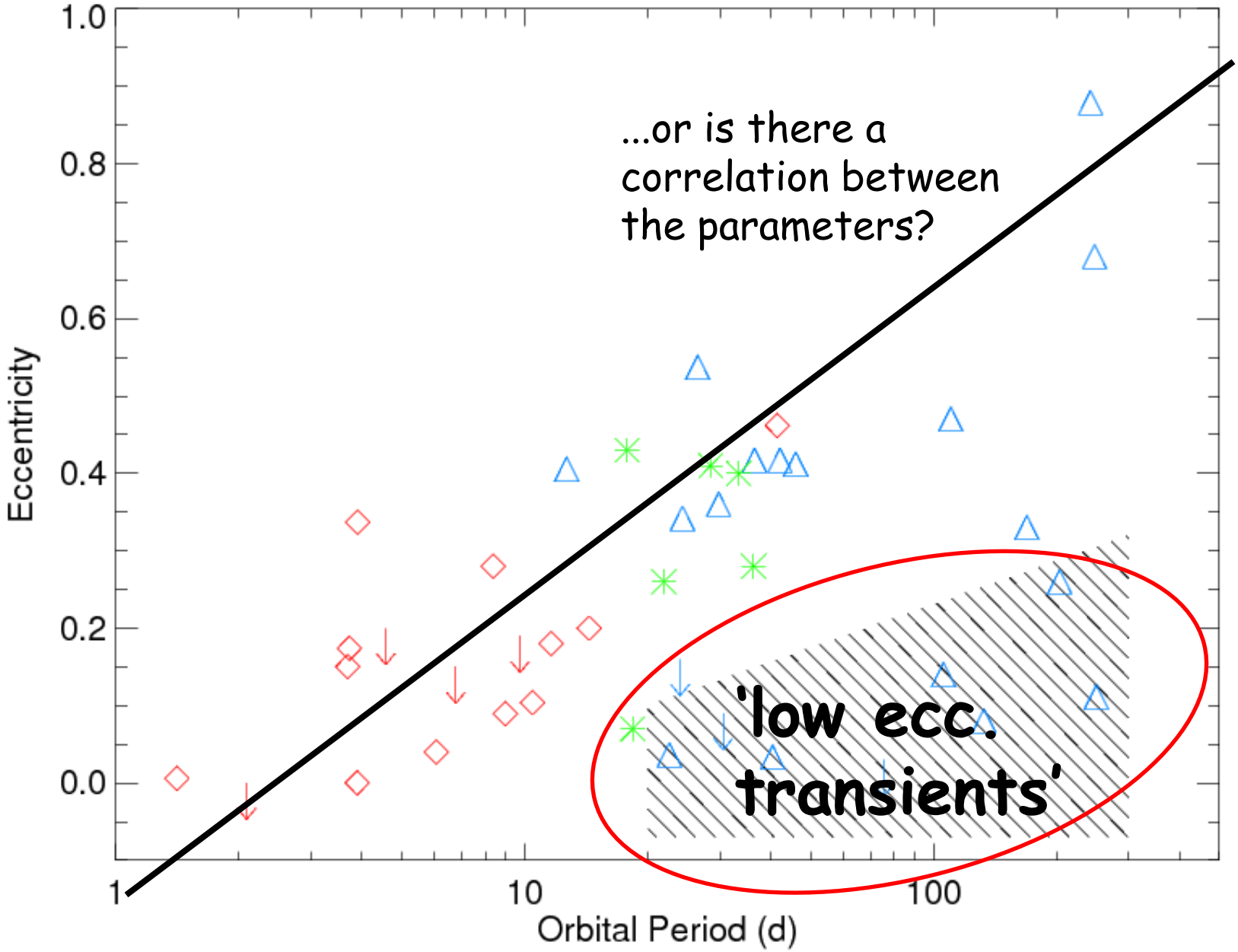
An eccentric analogy to the Corbet diagram?



Proposed group of long orbit, low eccentricity OB transients (Pfahl et al, 2002)


Corbet diagram-type
division of groups....
Be
SG
'low ecc.
transients'
Eccentricity
Orbital Period (d)
1.0
0.8
0.6
0.4
0.2
0.0
1
10
100


1.0
0.8
0.6
0.4
0.2
0.0
Eccentricity
1
10
100
Orbital Period (d)
...or is there a correlation between the parameters?
'low ecc. transients'

Implications for binary evolution models

- The growing population of low eccentricity transients is in support of the dichotomous SN kick scenario (e.g. Pfahl et al., 2002, Podsiadlowski et al., 2004) – SXP2.37 shows that these exist in low metallicity galaxies
- Hints that metallicity may not play a huge role in binary formation, though this is far from conclusive with current data
- Confirming or not the Porb-eccentricity relationship is important as it means many SMC systems could have e > 0.5 – this may be supported by the numerous Type I X-ray outbursts and lack of Type II outbursts in systems with Pspin > 100s

Summary

- Good fits to 5 SXP sources have vastly improved the number of systems with well defined binary parameters in the SMC
- This work has allowed a first comparison of Galactic and extra-Galactic populations
- Knowing the orbital parameters in these and future systems will allow a statistical look at binary orbits in the SMC, and help in our understanding of binary formation
- Improvements to the fitting process are being looked at in preparation for future outbursts
- Thoughts from those working on binary formation and evolution are welcome!