The population of high-mass X-ray binaries in the SMC: pulsars vs. non-pulsars

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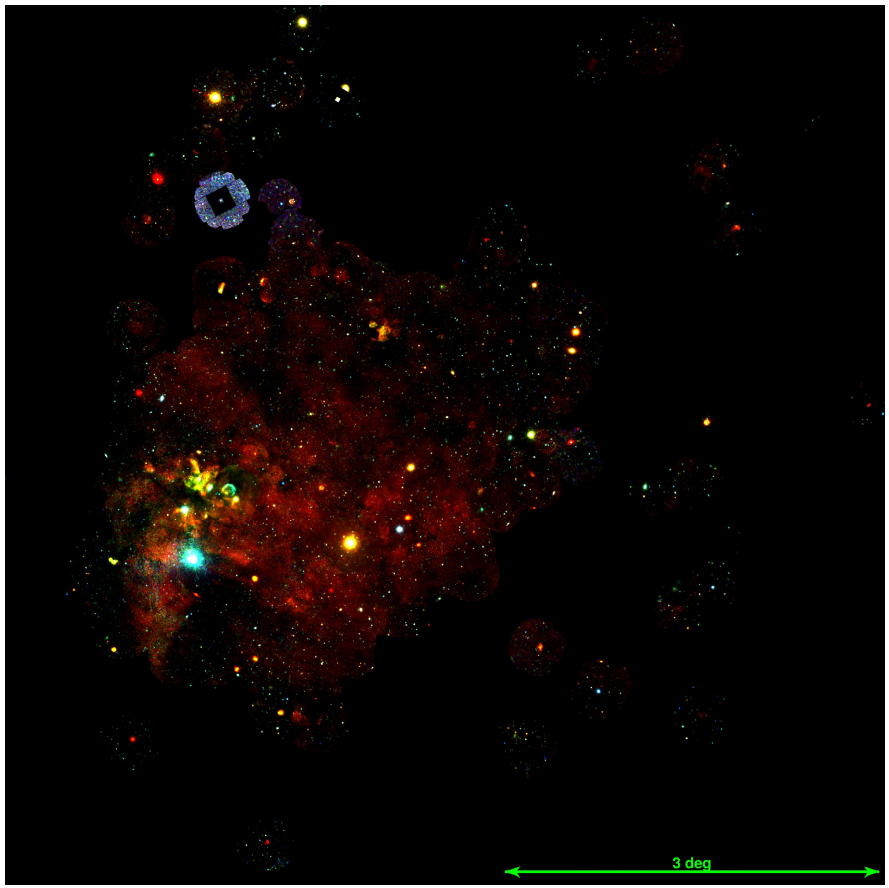
- XMM-Newton surveys of the Magellanic Clouds
  New HMXBs in the SMC
- The current census
  Statistical population studies
- eROSITA outlook
- Summary

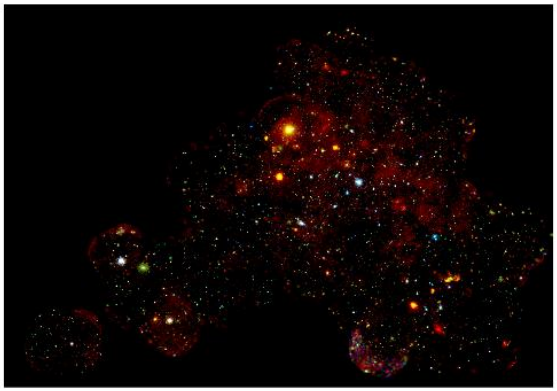
XMM-Newton Surveys of the Magellanic Clouds



The Large Magellanic Cloud
A large population of SNRs
70 pointings (1.8 Ms) + archival
Typical exposure 20 ks

High-mass X-ray binaries (HMXBs)
Supernova remnants (SNRs)
Diffuse emission (hot ISM)

The Small Magellanic Cloud
A unique population of HMXBs
40 pointings (1.2 Ms) + archival
Typical exposure 25 ks



HMXBs – X-ray spectral classification

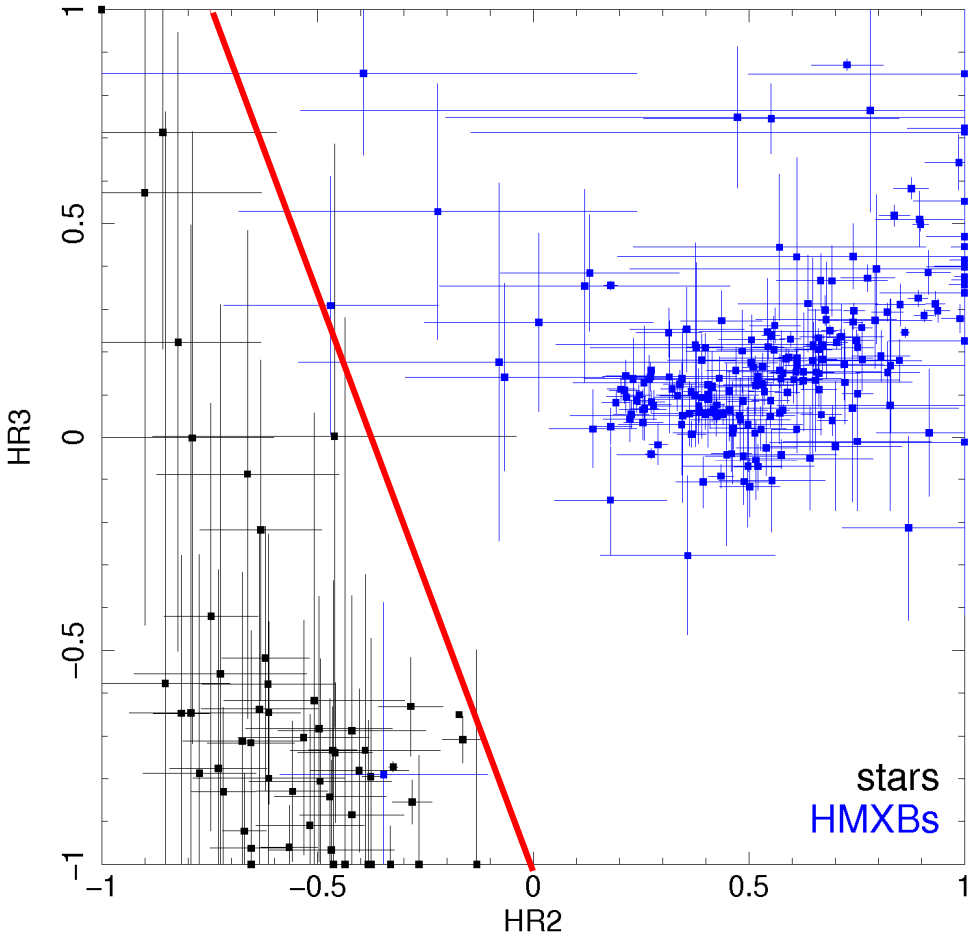
Hardness ratios:

$$HR_i = \frac{R_{i+1} - R_i}{R_{i+1} + R_i}$$

⇒ 2711 hard sources

⇒ 945 very hard sources

i	Energy band
1	(0.2 – 0.5) keV
2	(0.5 – 1.0) keV
3	(1.0 – 2.0) keV
4	(2.0 – 4.5) keV
5	(4.5 – 12.0) keV



Sturm et al. 2013, A&A, 558, 3

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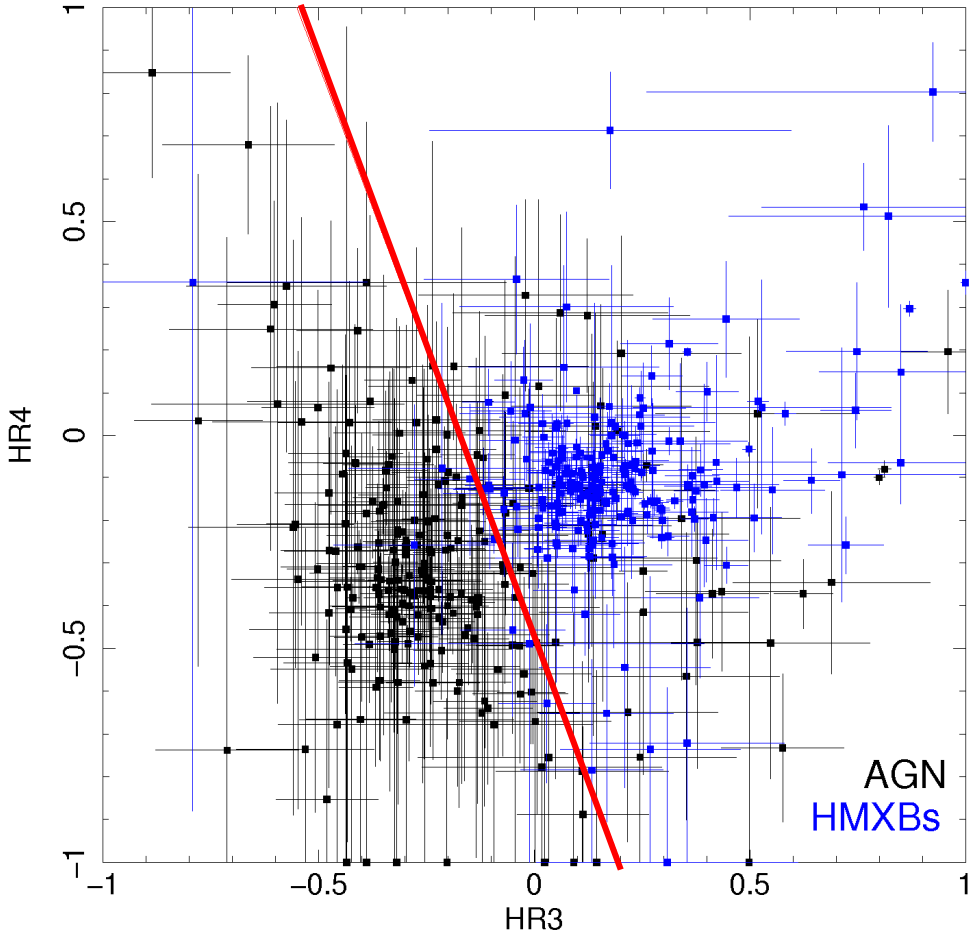
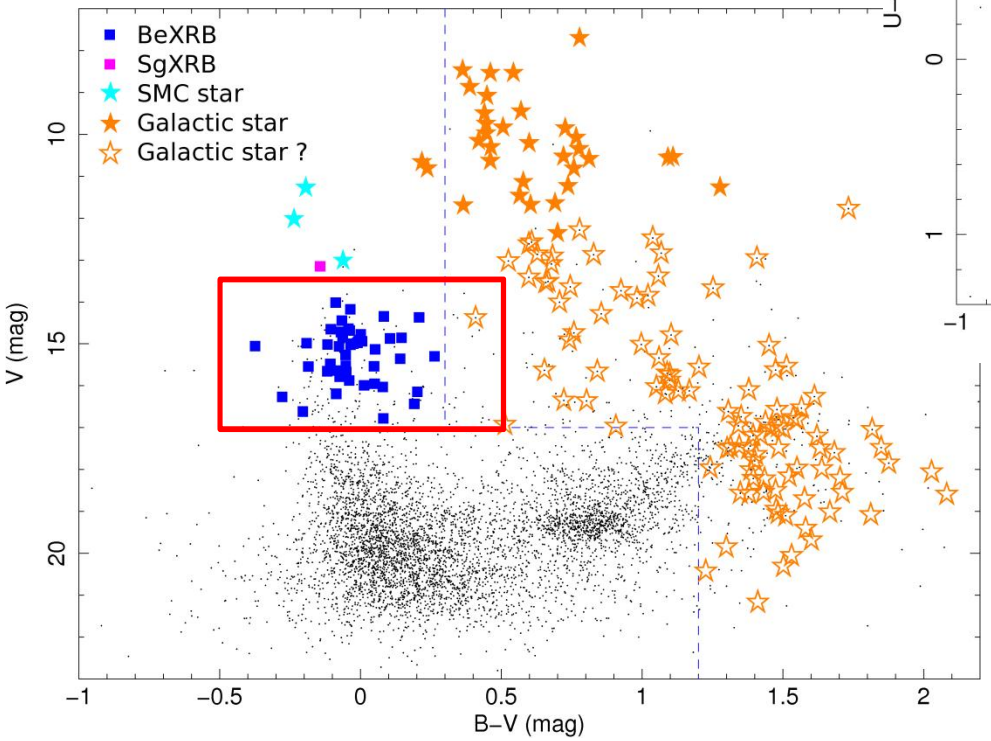
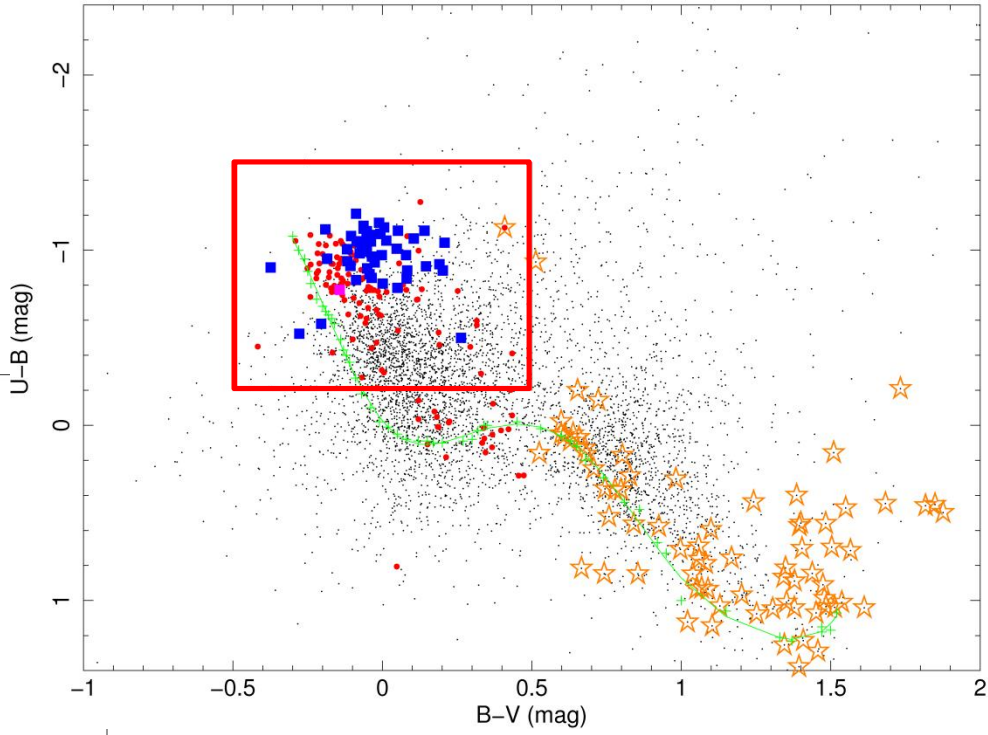


Sturm et al. 2013, A&A, 558, 3

HMXBs - Optical counterpart , CMD





45 new HMXB candidates

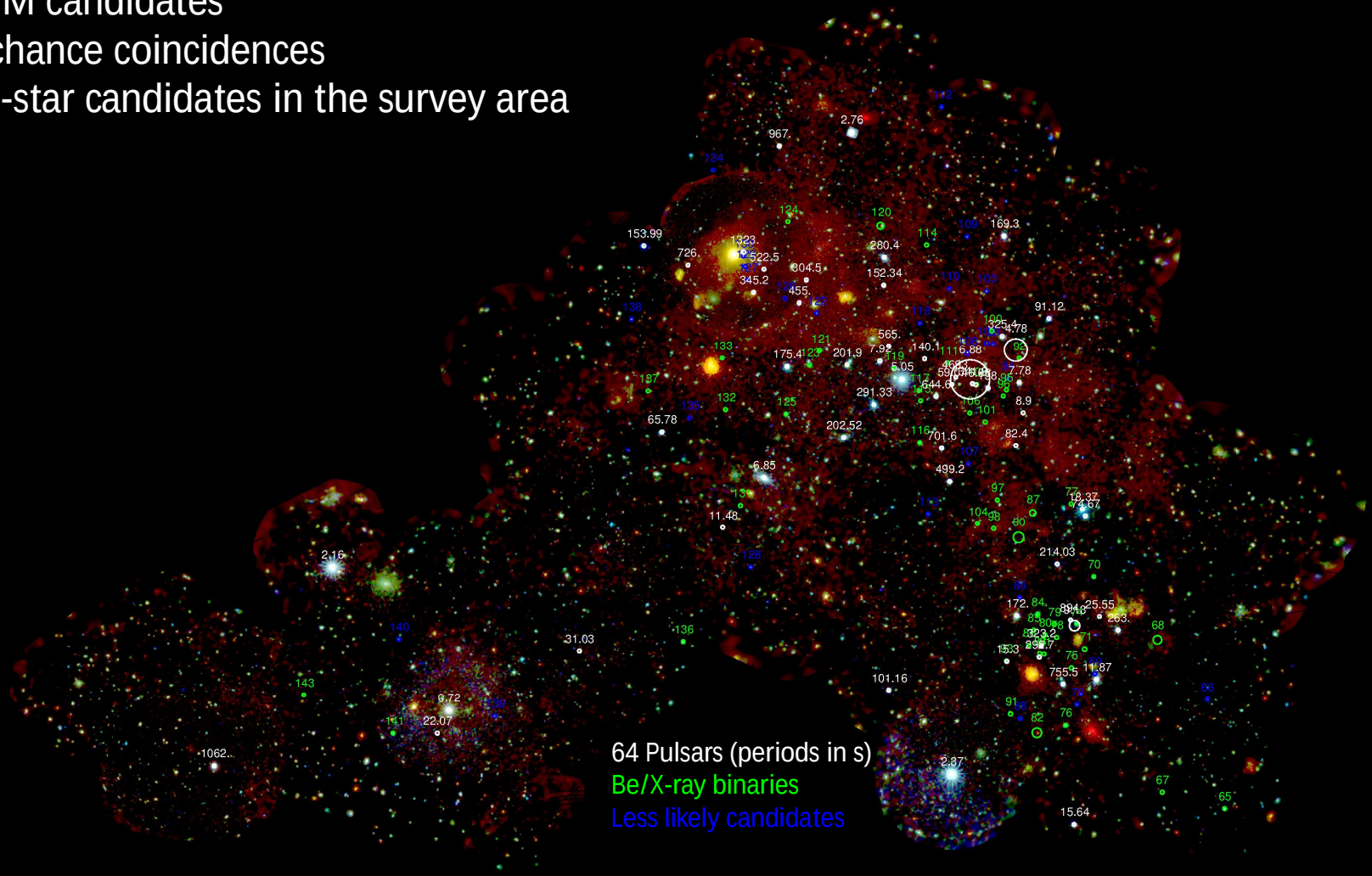
10^{-14} erg s^{-1} cm^{-2}

$5 \cdot 10^{33}$ erg s^{-1} at SMC distance

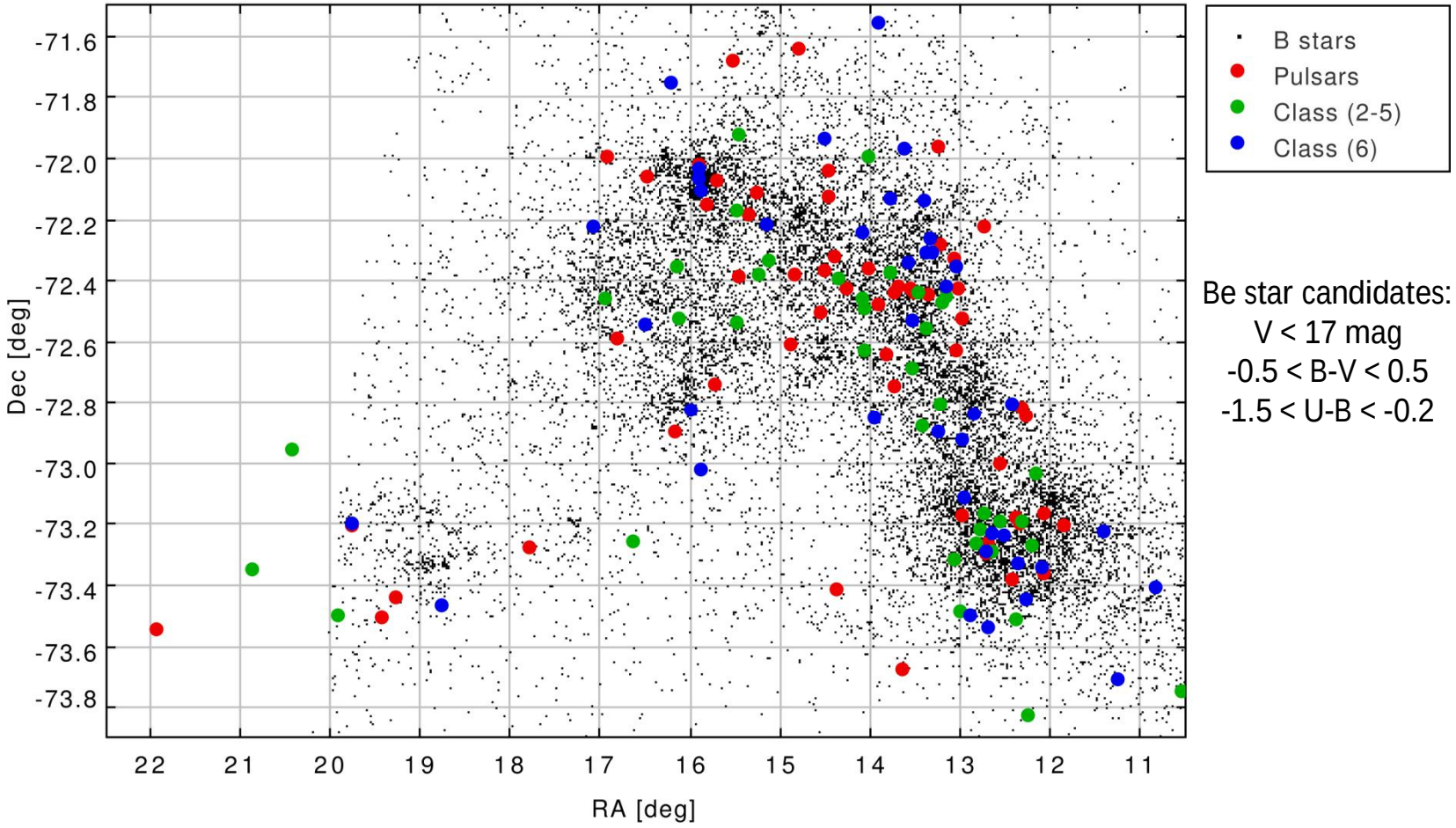
Sturm et al. 2013, A&A, 558, 3

High mass X-ray binaries in the SMC

Sturm et al. 2013:
45 new XMM candidates
16.6 ± 3.4 chance coincidences
~16.600 Be-star candidates in the survey area



HMXB and candidates – spatial distribution

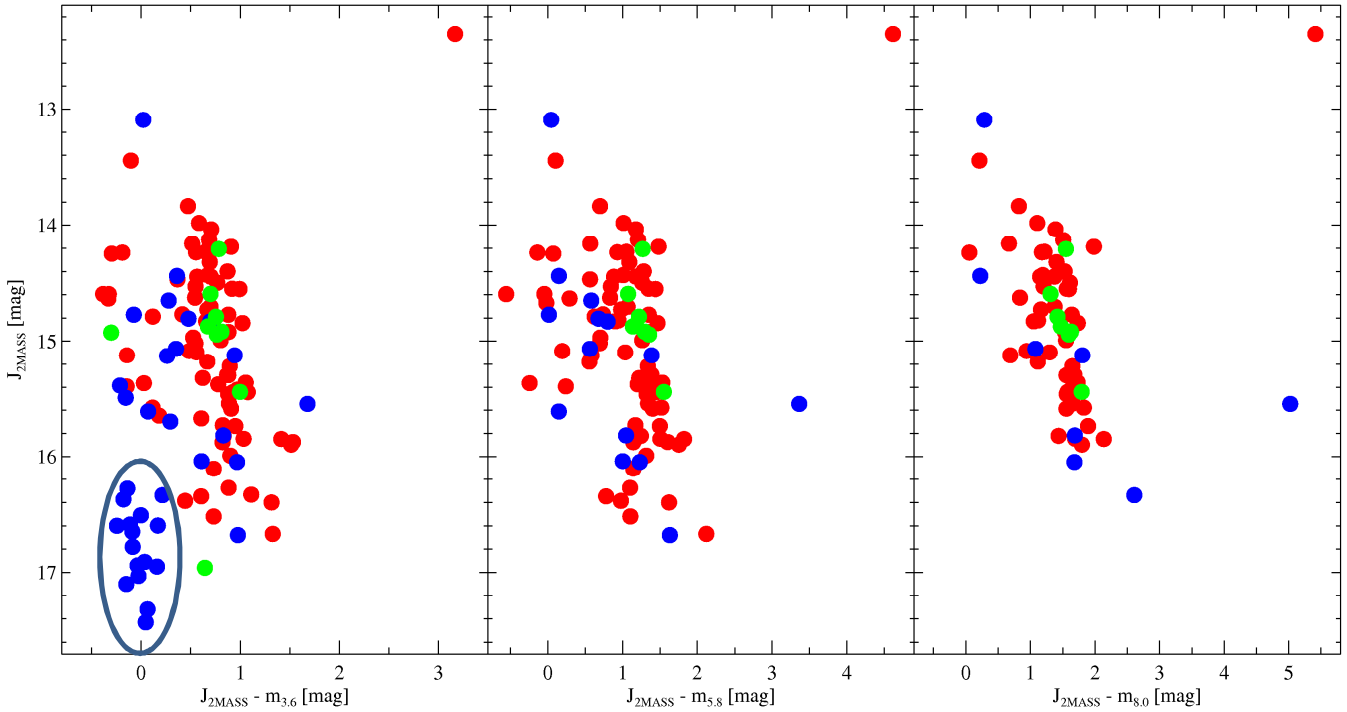


Be star candidates:
V < 17 mag
-0.5 < B-V < 0.5
-1.5 < U-B < -0.2

Haberl & Sturm 2016:
catalogue of 148 (candidate) HMXBs
(literature + XMM)

64 pulsars
57 HMXBs without pulsations
27 less likely candidates

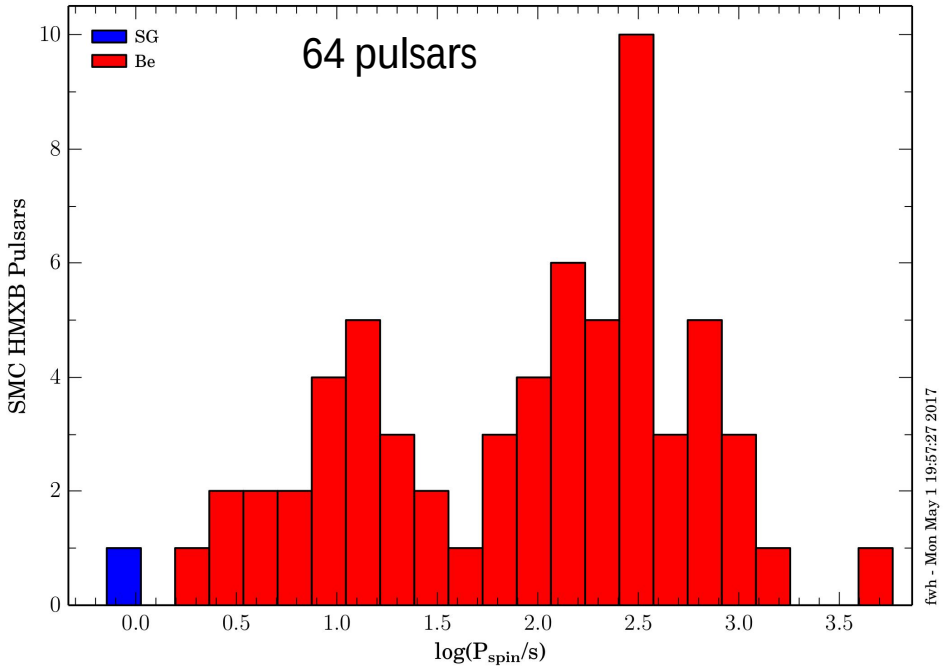
HMXB candidates – NIR

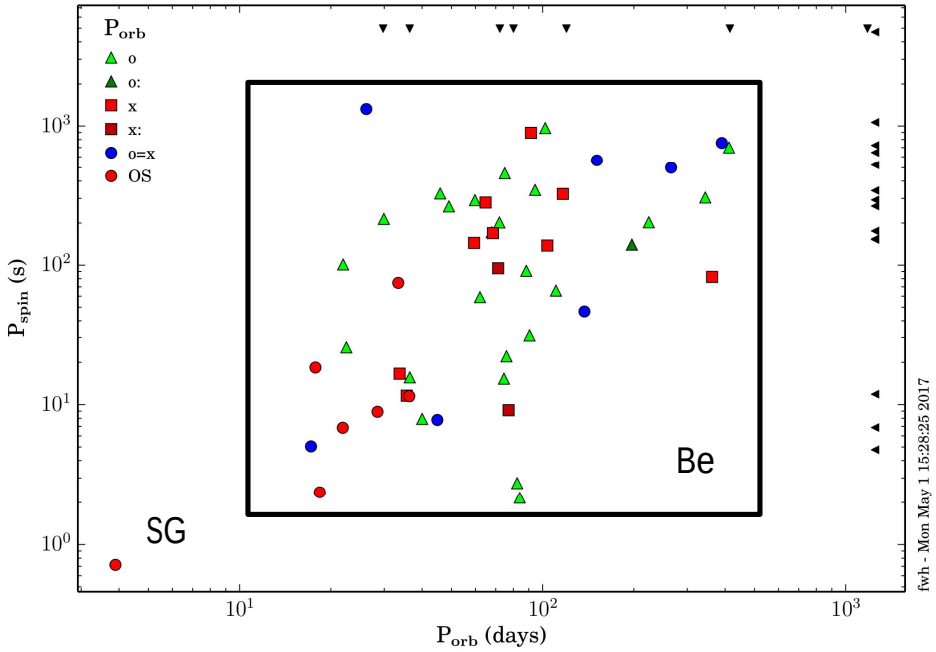


Class (6)
Class (4)
Others with secure ID

Infrared excess using 3 IRAC mag. at 3.6, 5.8 and 8.0 μm and J-band from 2MASS
Following Bonanos et al. (2010): photometric Be star classification: $J-m_{3.6} > 0.5$
16 (from 44) class (6) objects have $J>16$ and $J-m_{3.6} < 0.3$
Their Q-values are > -0.91
14 are from the XMM-Newton candidates (16.6 ± 3.4 chance coincidences)
2 are Chandra sources from Laycock et al. (2010) with error > 5" (and not in CSC)
Most likely not Be stars!

The HMXB population in the SMC – Be/X-ray binary pulsars





- Knigge et al. 2011: Two different types of SNe
  1) Capture of electrons by Ne/Mg nuclei in a lower-mass O/Ne/Mg core: short spin-periods, short orbital periods, low eccentricities
  2) Iron-core collapse of high-mass star
- Cheng et al. 2014: Two different accretion modes
  1) disc accretion during type-II outbursts
  2) advection dominated/quasi-spherical accretion in case of normal (type I) outbursts

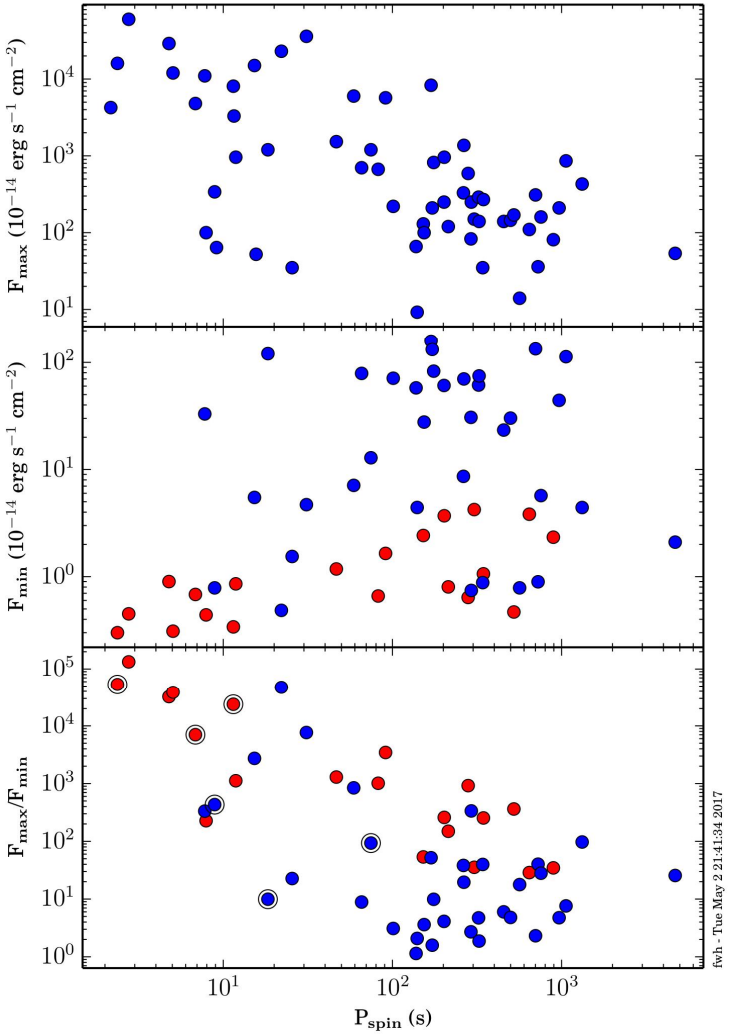
Loose correlation
Many systems not in equilibrium

SXP1223: Carpano et al. (Session binary VI)

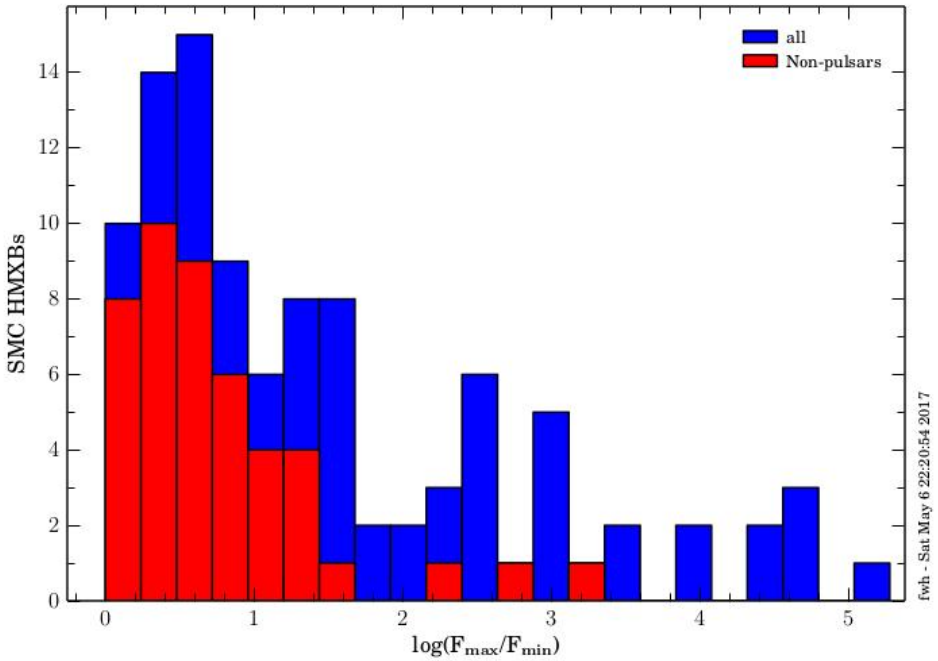
SXP1062: associated with SNR

Haberl & Sturm 2016

Non-pulsating Be/X-ray binaries ?



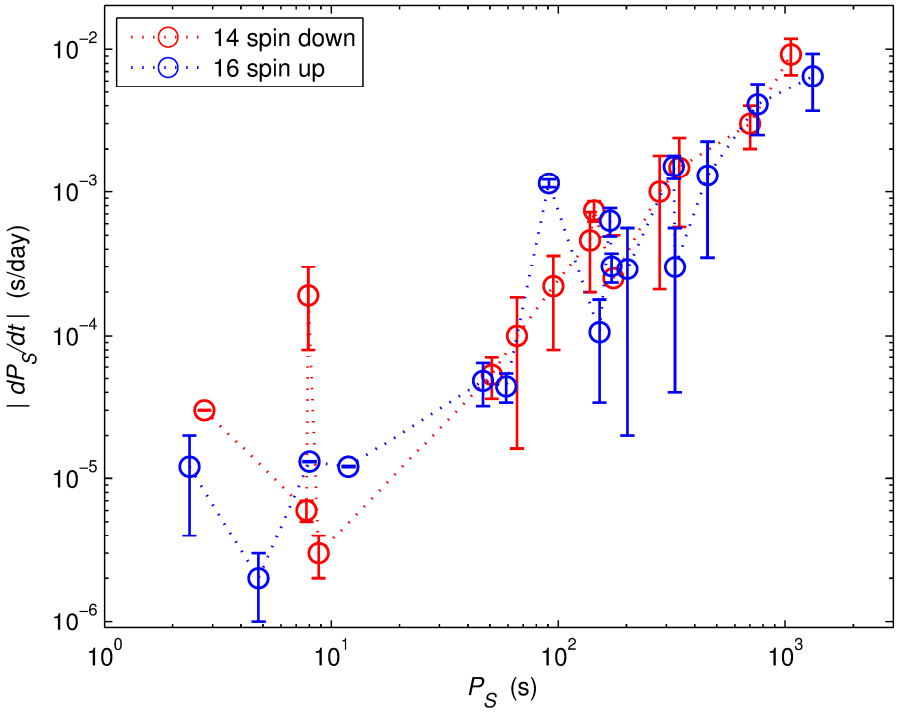
Variability amplitude anti-correlated to Spin period



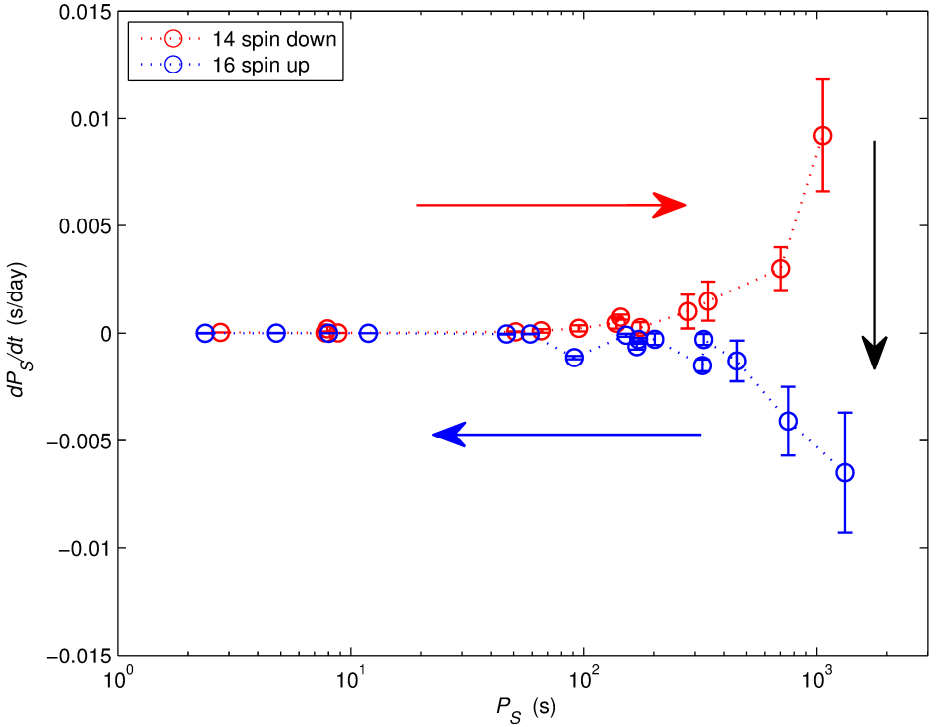
- Non-pulsars: low variability amplitude
- Long spin periods expected for non-pulsars
  - Observational bias?
  - Alignment of rotation / magnetic axes?

Haberl & Sturm 2016

The Be/X-ray binaries in the SMC – spin evolution



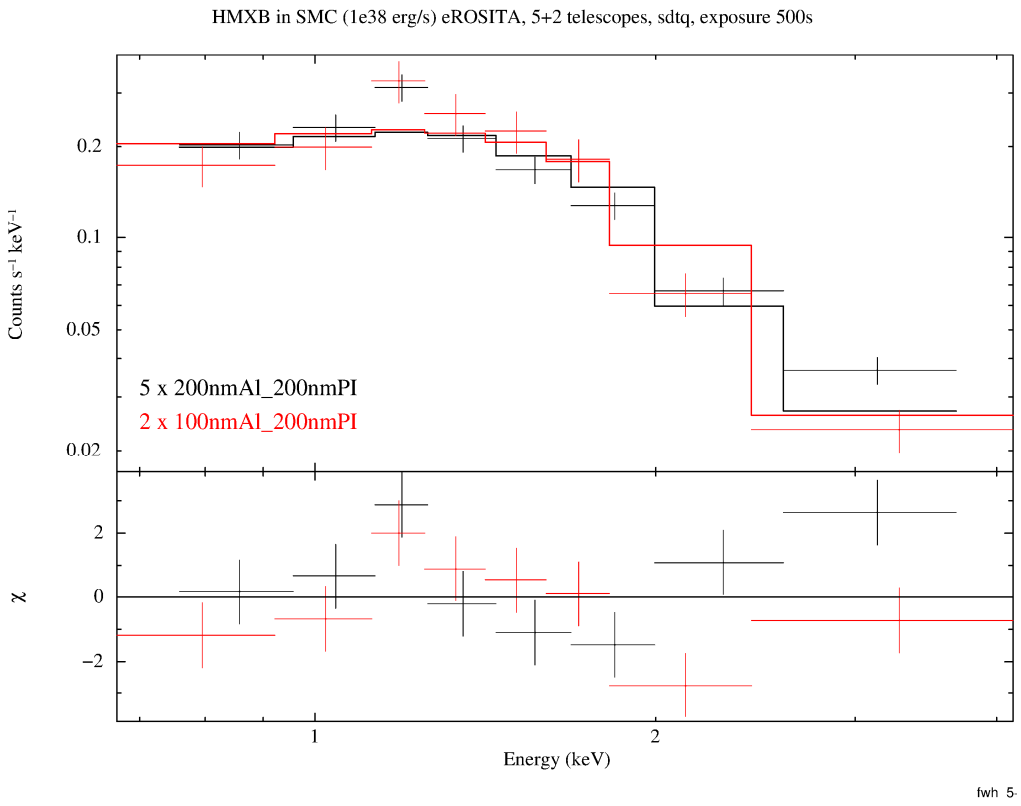
~20 years of SMC observations
RXTE – Chandra – XMM-Newton



|spin-up| = |spin-down|
Both caused by accretion!
No magnetar model required for strong spin-down
Retrograde accretion disks ?

Christodoulou et al. 2017

SMC sources in the eROSITA survey



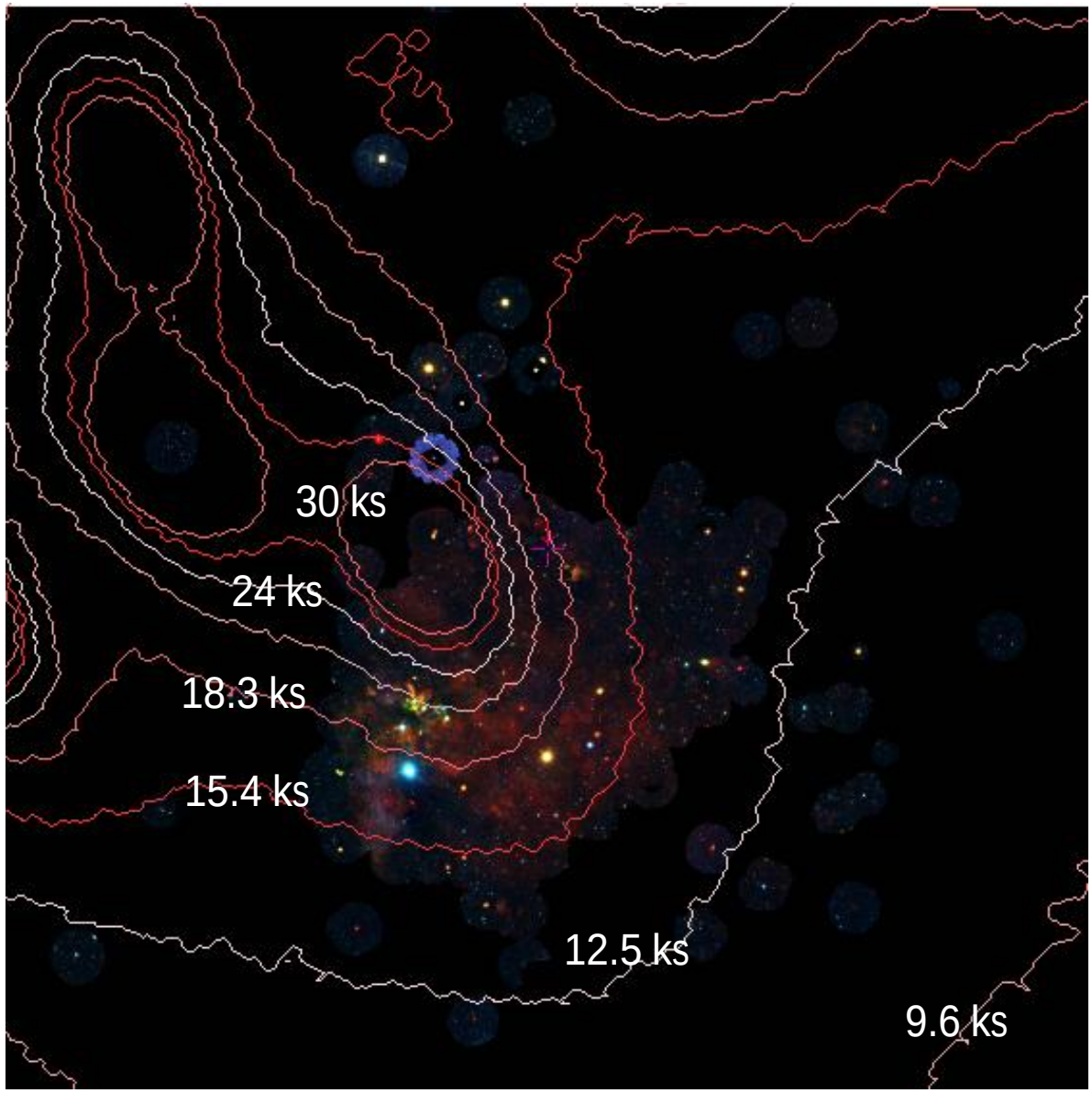
A bright hard transient
10^{38} erg s^{-1}
powerlaw γ=0.9
(+/-0.3)

One day visit:
500 s exposure
2 x 0.33 cts/s
5 x 0.32 cts/s
1130 counts

10 counts for 10^{36} erg s^{-1}

LMC: a factor of 4-10 more exposure!

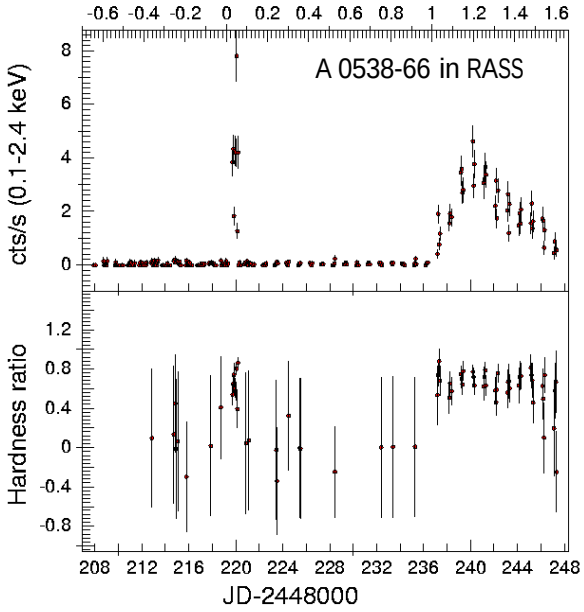
eROSITA survey of the Magellanic Clouds



LMC

eROSITA survey:

- Complete coverage
- Multiple coverage
- Similar exposure after 4 years

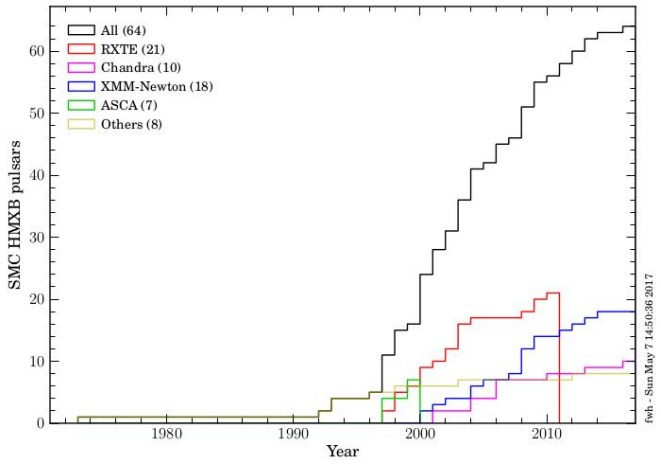


Mavromatakis+ 1993

Summary – HMXBs in the SMC (MCs)

- Magellanic Clouds ideally suited for population studies (distance, foreground absorption)
  XMM-Newton survey SMC (6deg^2, ~10^{-14} erg cm^{-2} s^{-1}, $5 \cdot 10^{33}$ erg s^{-1})
  Chandra deep survey (1.2deg^2, 10^{32} erg s^{-1}) (Zezas et al. this session)

- Catalogue of HMXBs in the SMC
  Extraordinary large population, 121 HMXBs
  64 pulsars (1 SG, 63 BeXRB)
    Bimodal spin period distribution
    Cutoff @ 1500s
    Fast spin period evolution beyond
    Retrograde accretion?
  57 BeXRBs with no spin period detection
    low variability
    long spin periods?



- Known population of BeXRBs in the SMC still rises
  Future observations: XMM-Newton, Chandra, Swift, eROSITA, ...