The XMM-Newton survey of the SMC: The Be/X-ray binary population

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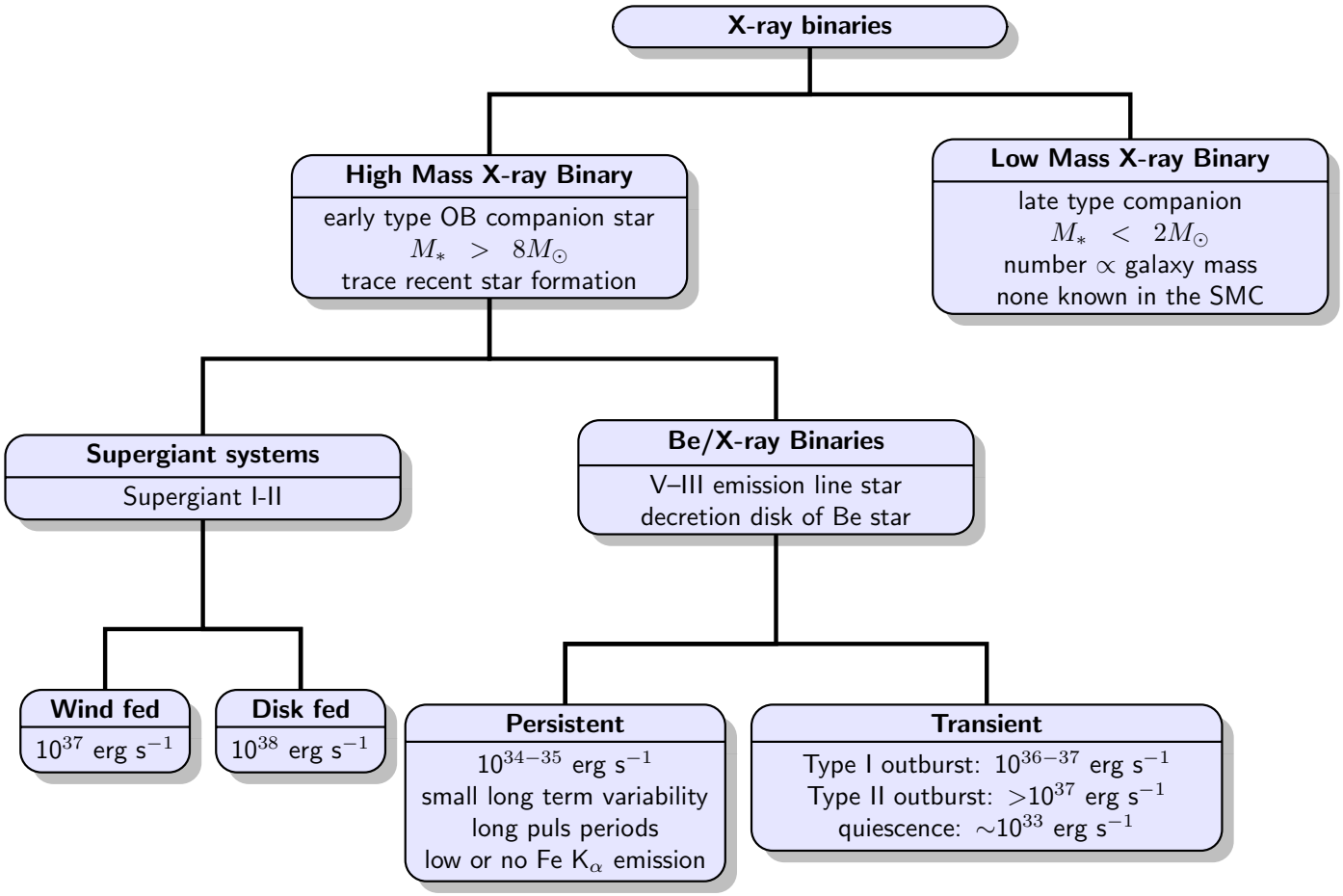
on behalf of the SMC XMM-Newton large project collaboration

Max-Planck-Institut für extraterrestrische Physik

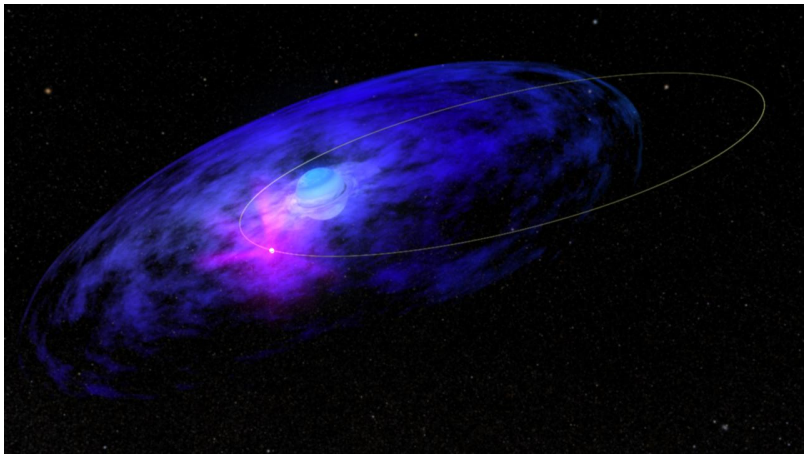
The X-ray Universe 2011
Berlin, 27.06.2011

Neutron Star X-ray Binaries – Classification



Be/X-ray Binaries – Phenomenology

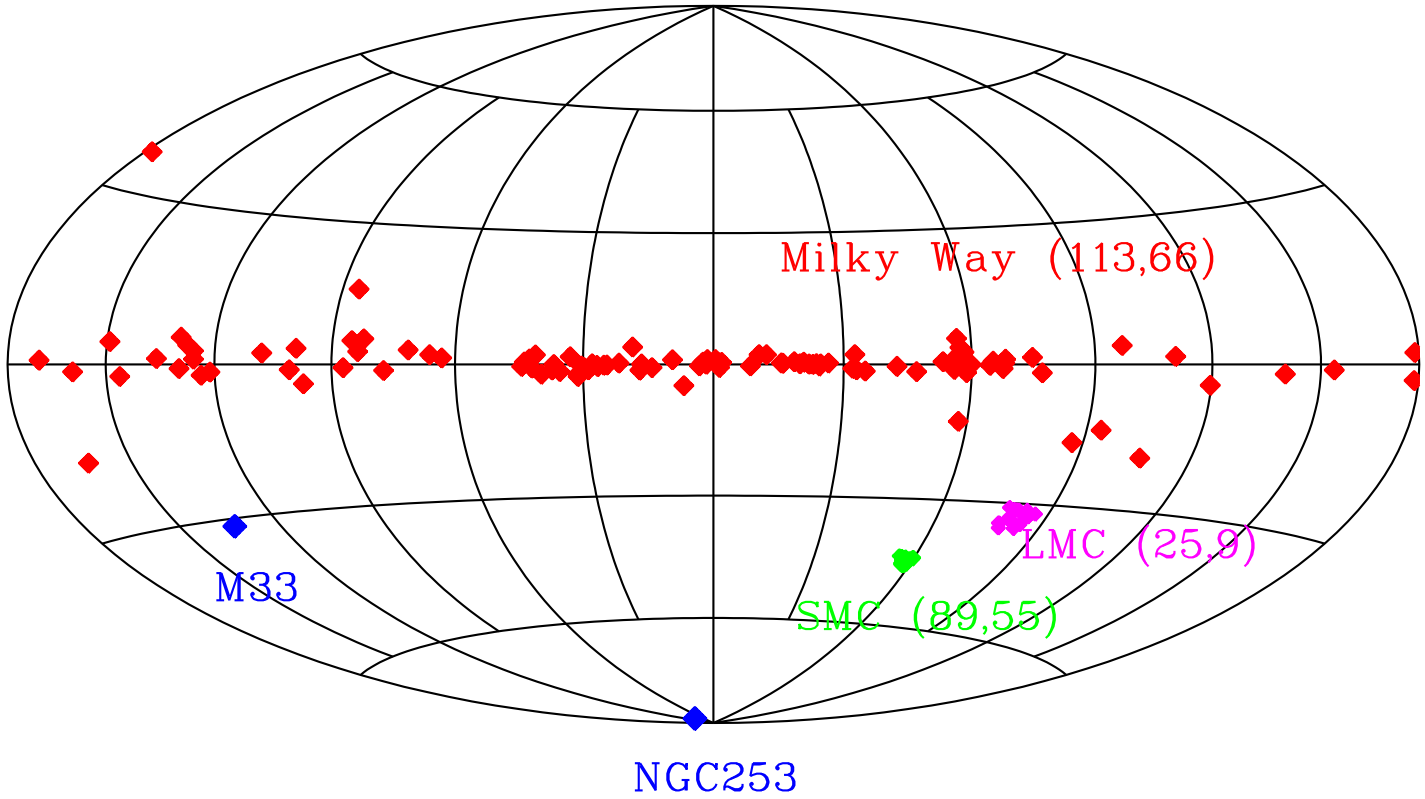
- X-rays powered by accretion of matter from companion star onto a compact object:
  - high variability possible
  - powerlaw like ($\Gamma \sim 0.8$) spectrum
  - soft excess
  - pulsations
- optical & infrared emission dominated by Be star:
  - spectral types O9e–B4e
  - variable emission lines (e.g. Hα)
  - variable IR excess



Credit: Walt Feimer, NASA/Goddard Space Flight Center

HMXBs in the Milky Way and nearby galaxies

227 HMXBs and candidates – 130 pulsars



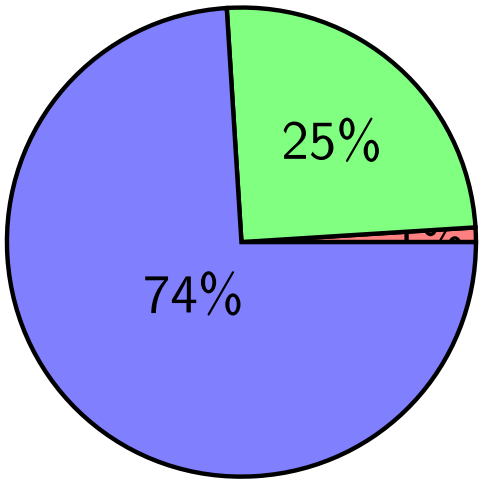
MW: Liu et al. (2006)

SMC: Haberl & Pietsch (2004); Coe et al. (2005) + new discoveries

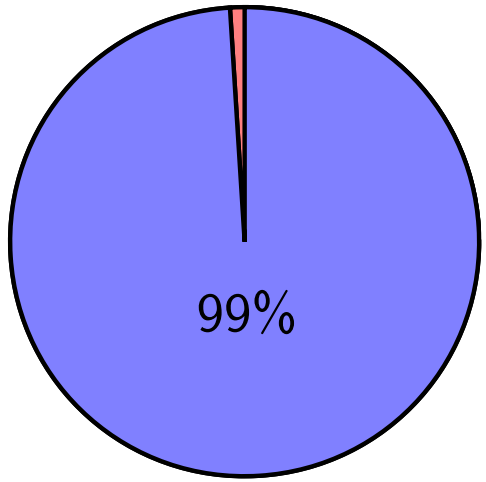
LMC: Negueruela & Coe (2002); Shtykovskiy & Gilfanov (2005) + new discoveries

The Be/X-ray binary population in the SMC

Galaxy



SMC

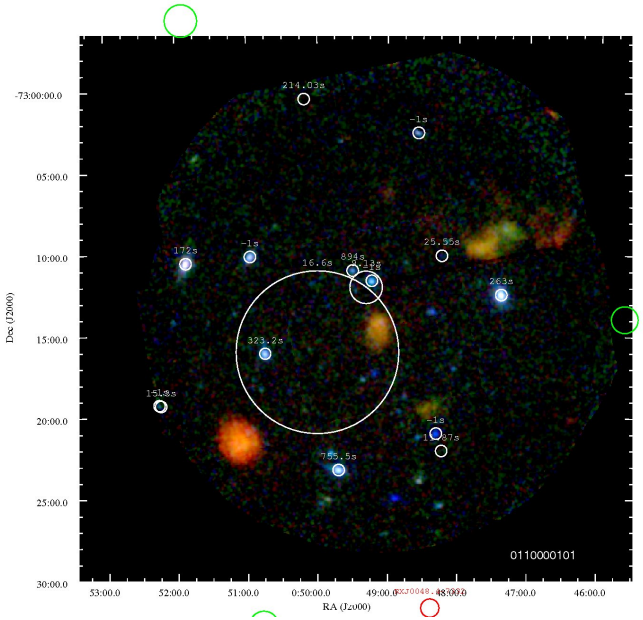


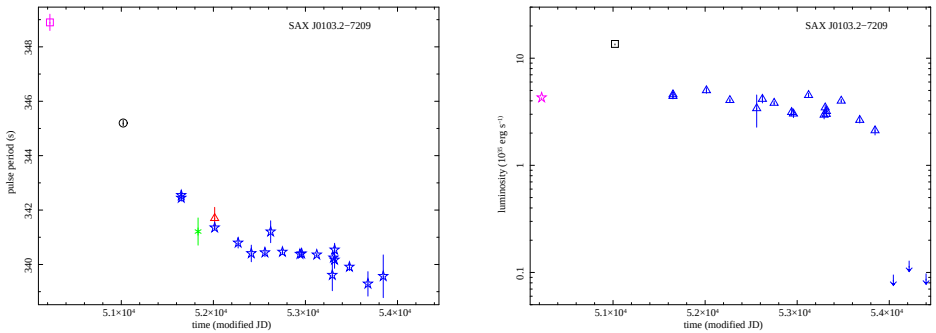
SG HMXB disk
SG HMXB wind
Be/X-ray binary

Over-abundance of HMXBs
No wind accretion powered supergiant system

Why observe HMXB in the SMC?

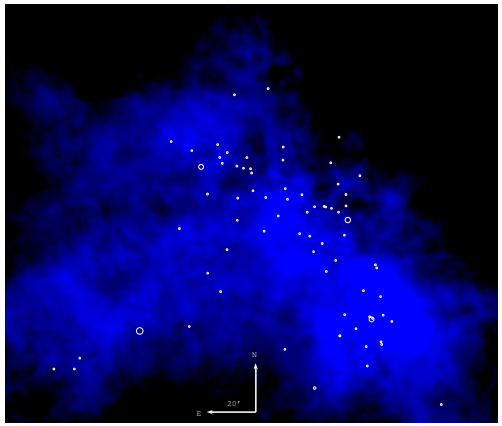
- Galaxy – Physics of individual systems
  - high-resolution spectroscopy and timing
  - accretion process
  - wind structure
- SMC – Statistical studies
  - Observations of many systems simultaneously at similar distance
  - low foreground absorption
  - global properties
  - population studies





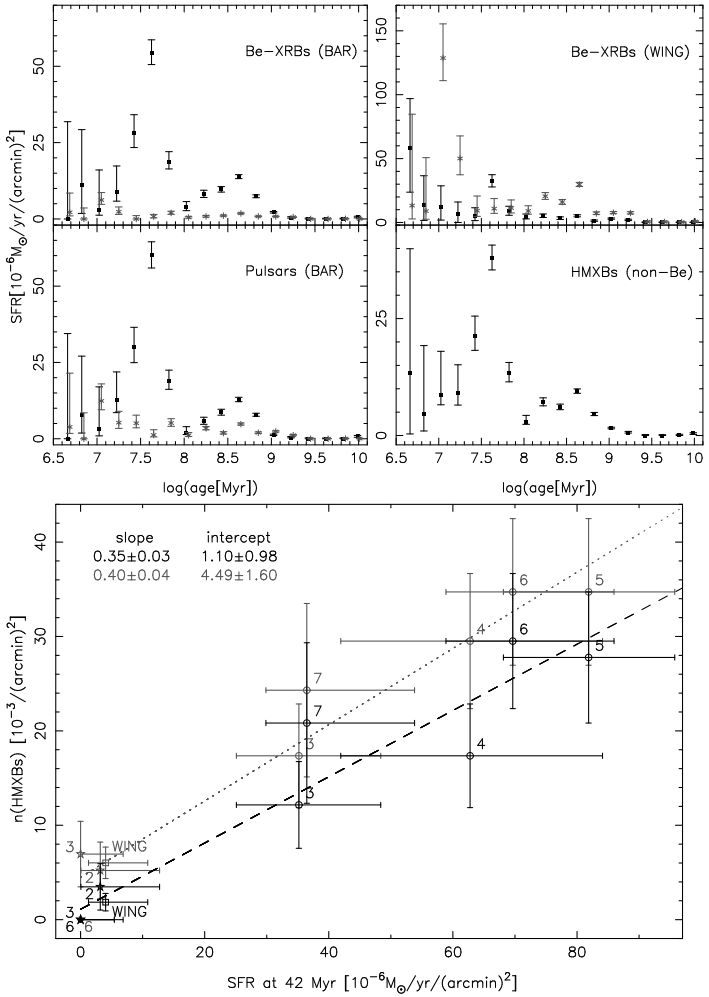
Eger & Haberl (2008)

HMXBs and Star Formation History



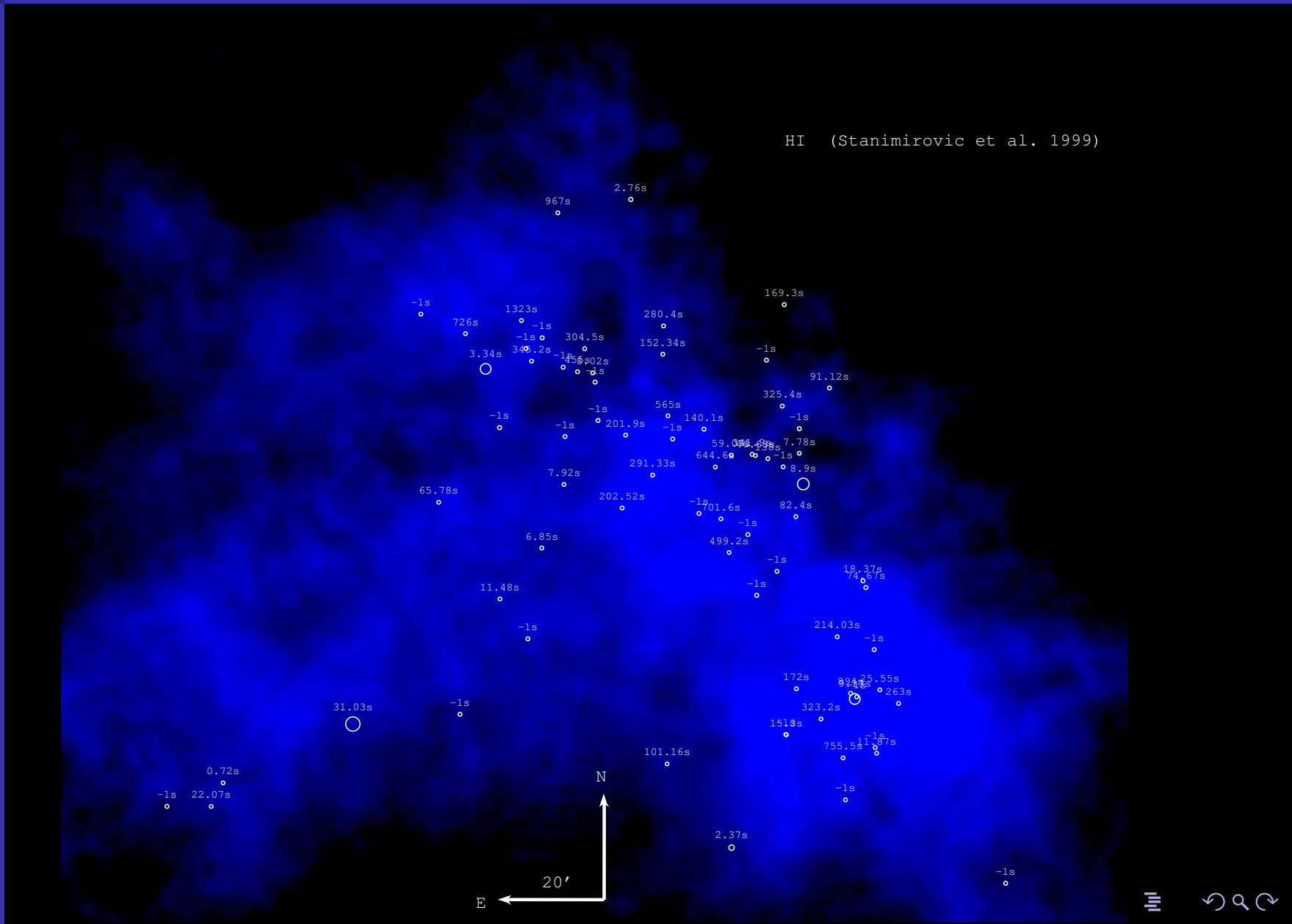
HI map Stanimirovic et al. (1999)

- HMXBs in regions with star formation bursts 25-60 Myr ago
- number of HMXBs correlates with SFR at 42 Myr

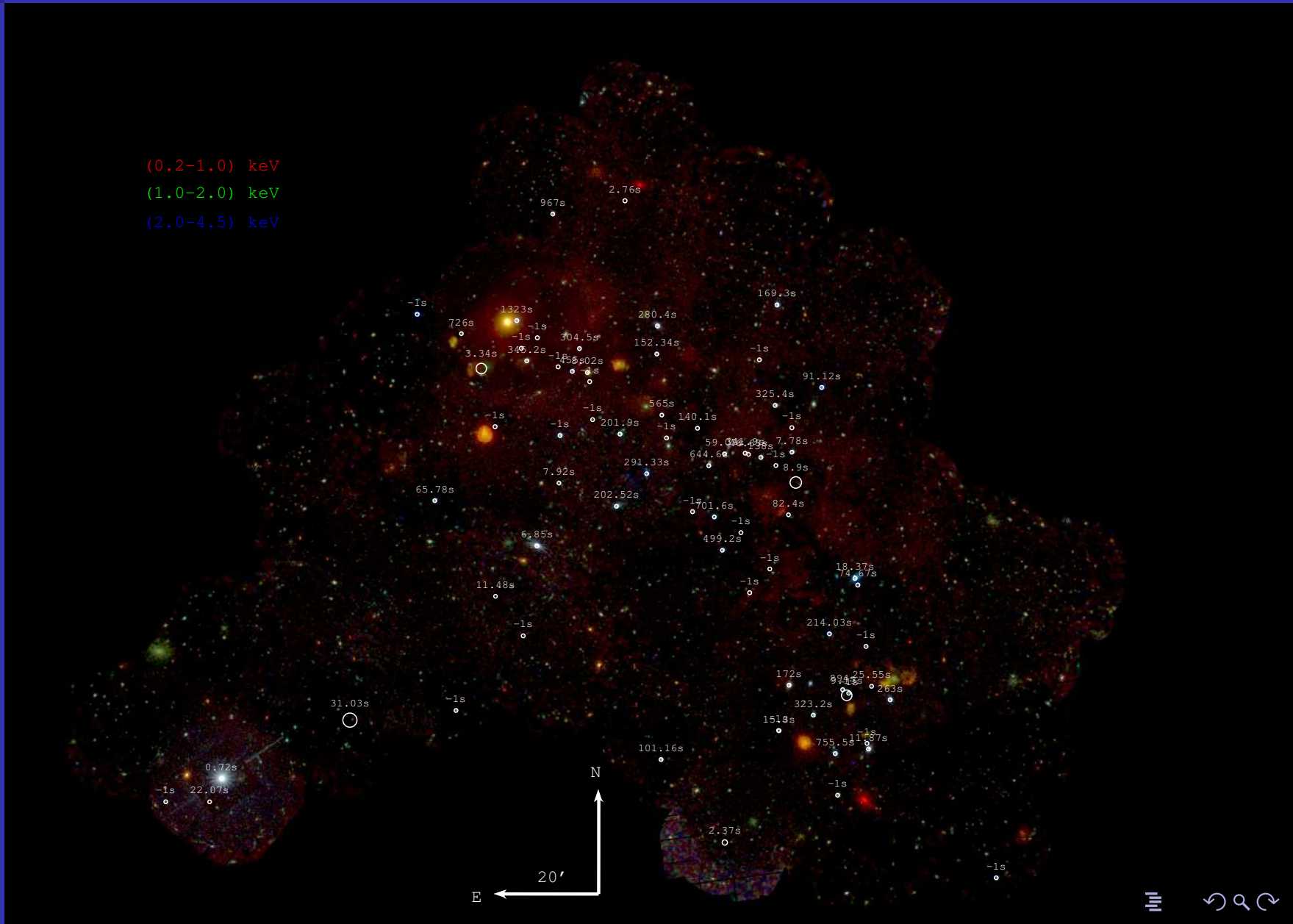


Antoniou et al. (2010)

The SMC in HI

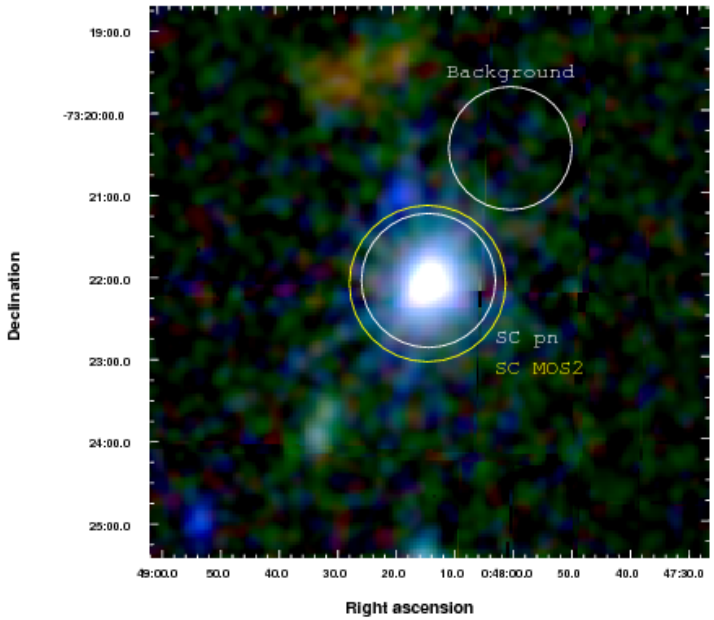


The SMC in X-ray



Discovery of the 11.866 s Be/X-ray binary pulsar

- New X-ray transient
  $L_{\mathrm{X}} = 3.97 \times 10^{36}$ erg s^{-1}
  variability of >560
- Spectrum:
  absorbed power-law
  $\Gamma = 0.53 \pm 0.08$
  indication of soft excess
- Spin period:
  (11.86642 ± 0.00017) s
- Be counterpart
- H_α emission
  $EW = (-3.5 \pm 0.6)$ Å
- NIR excess and variability



Sturm et al. (2011)

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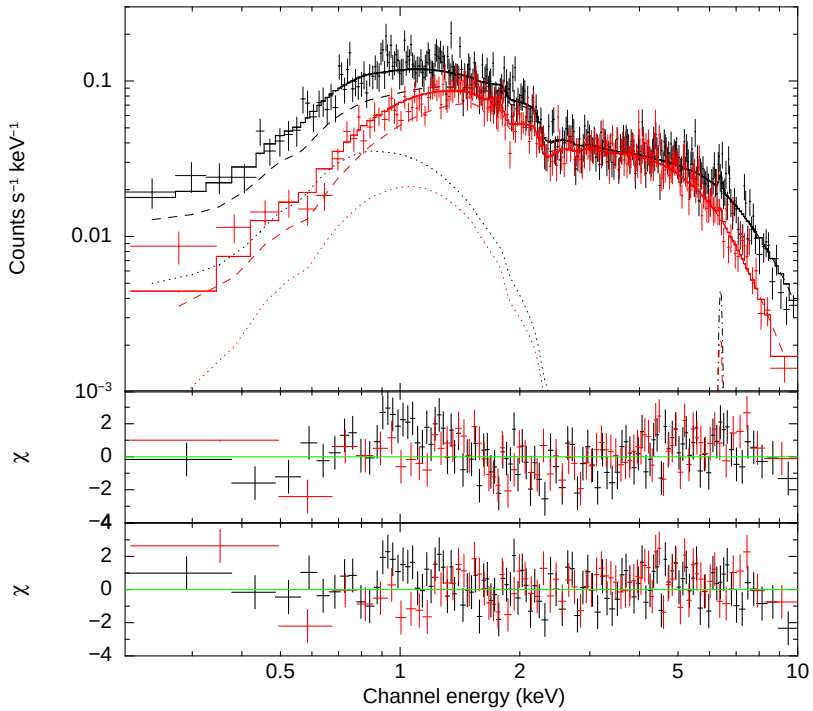

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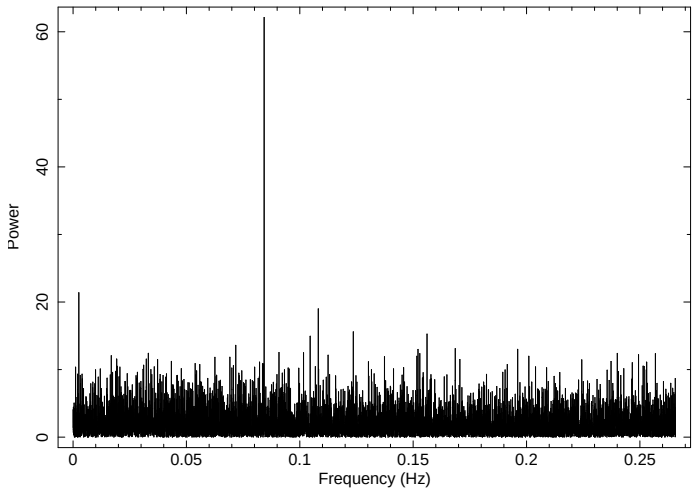

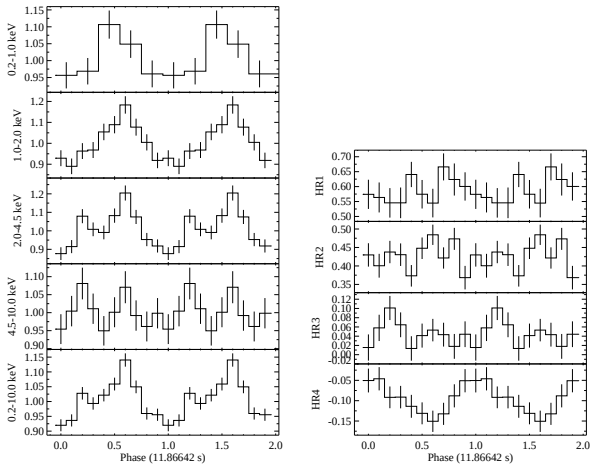

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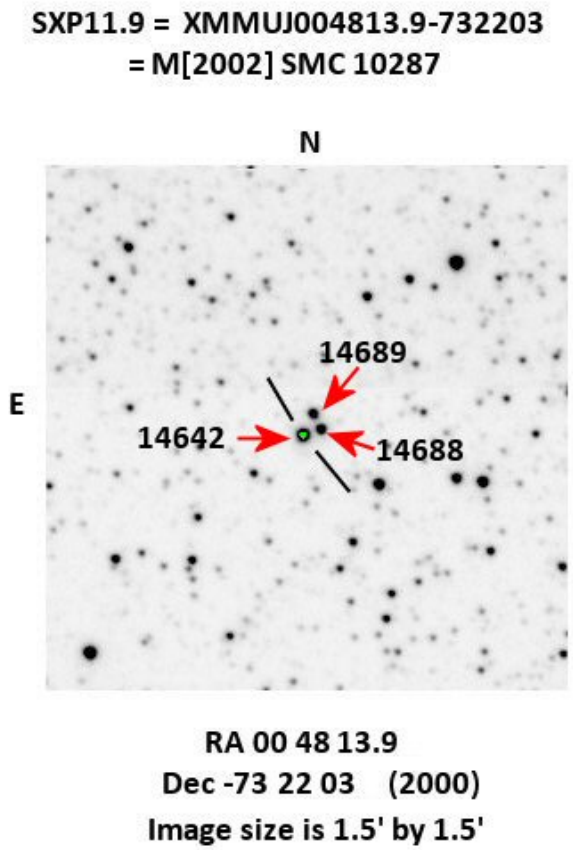

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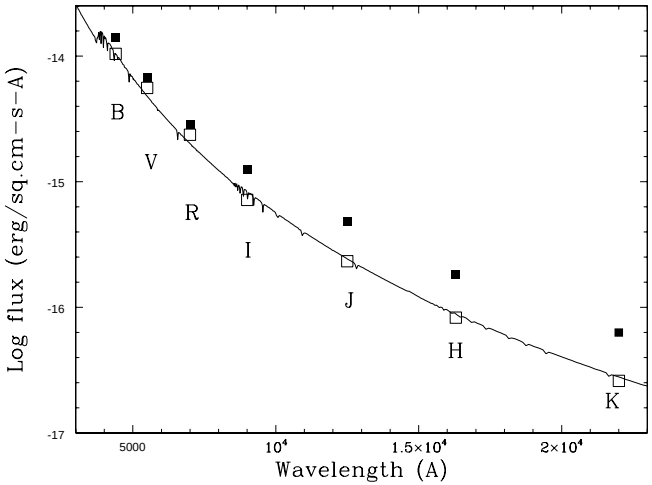

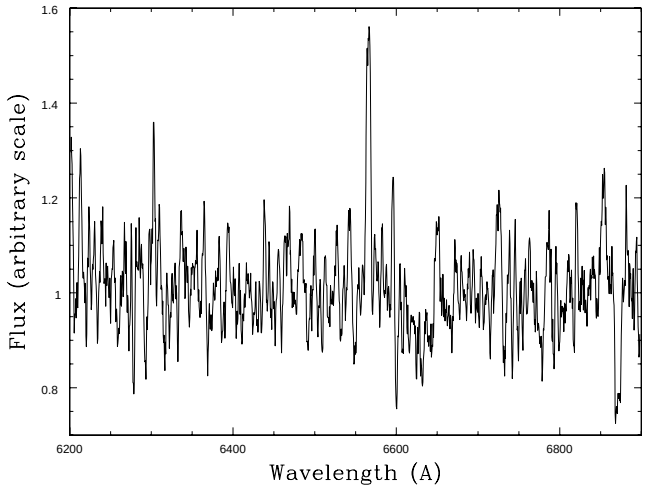

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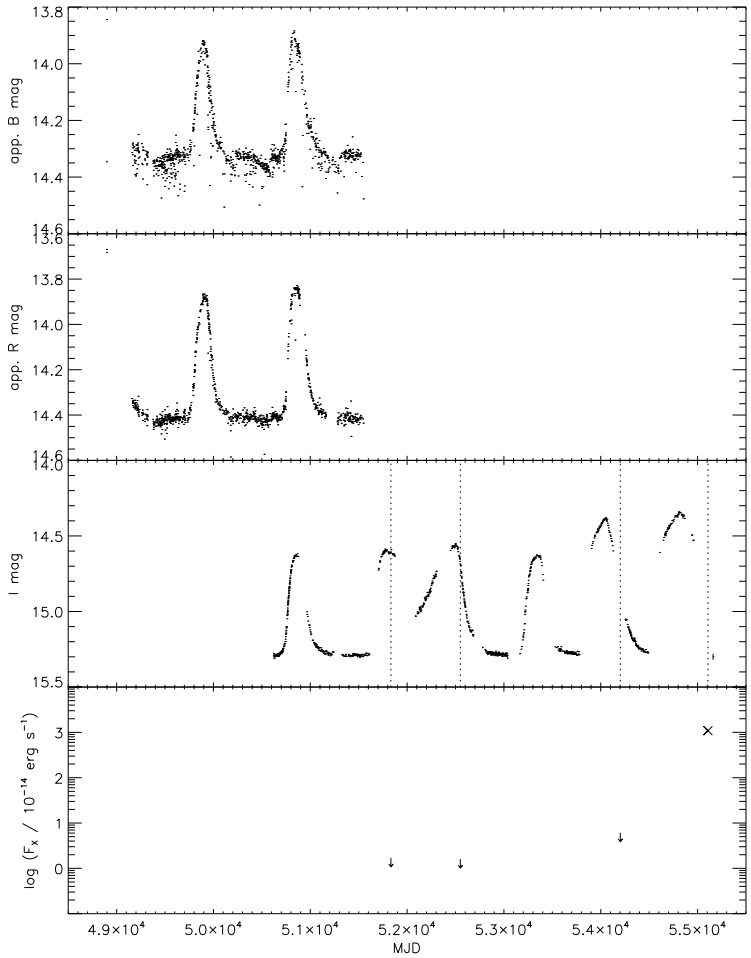
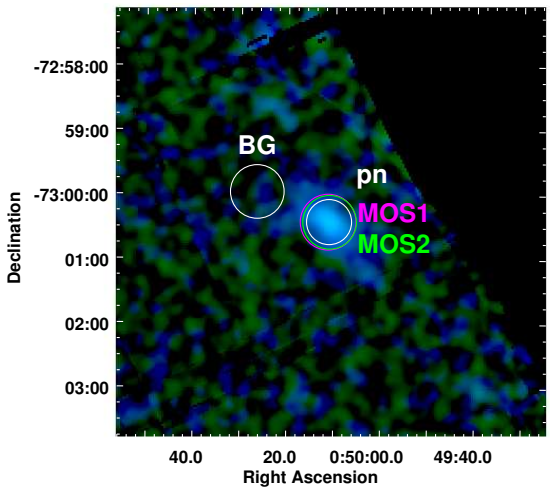
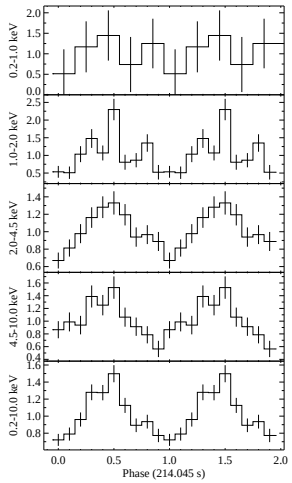
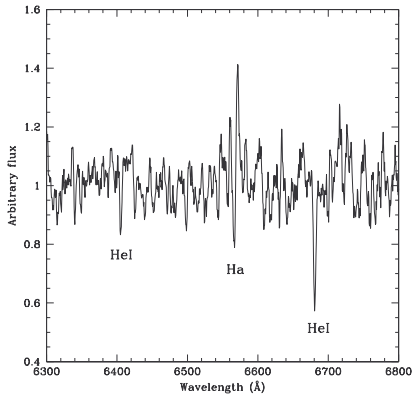


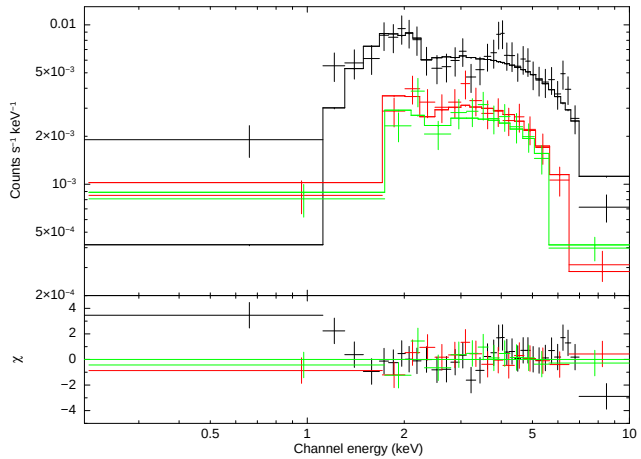
Sturm et al. (2011)

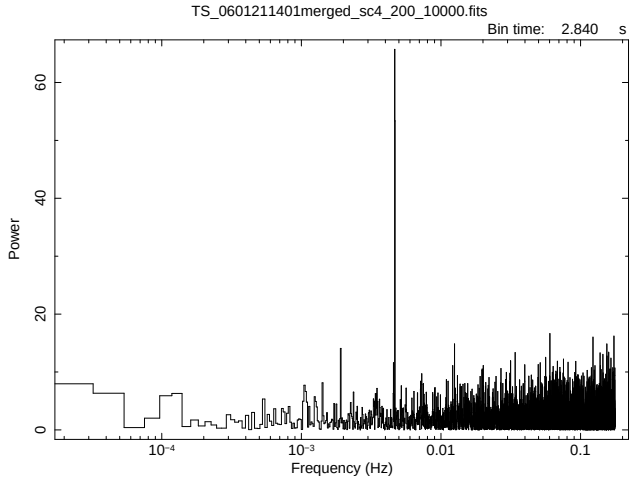
Discovery of the 214 s Be/X-ray binary pulsar







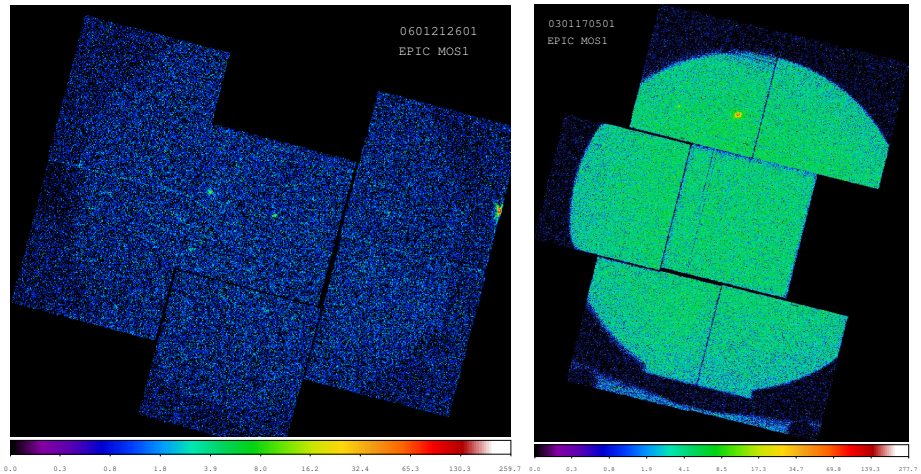




Start Time 15139 22:01:52:914 Stop Time 15140 7:13:30:677

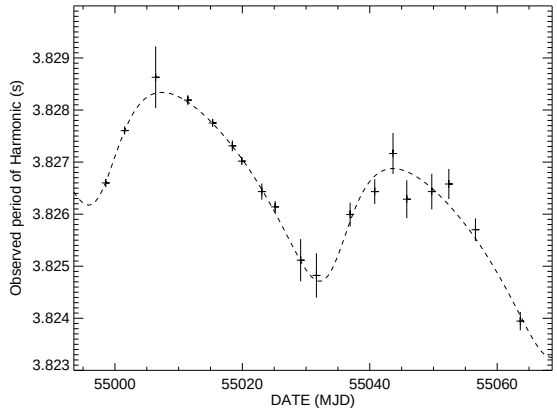
?

Detection of the 11.48 s Be/X-ray binary pulsar

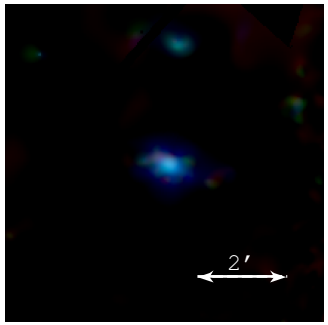


Townsend et al. (2011)

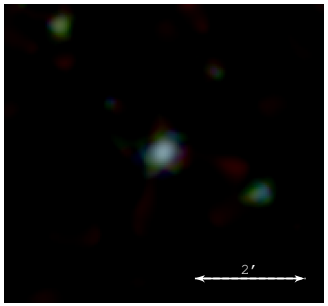
- Discovered by INTEGRAL (IGR J01054-7253)
- Swift follow up
- RXTE found spin period
- XMM-Newton confirmed position and spin
- Orbital solution



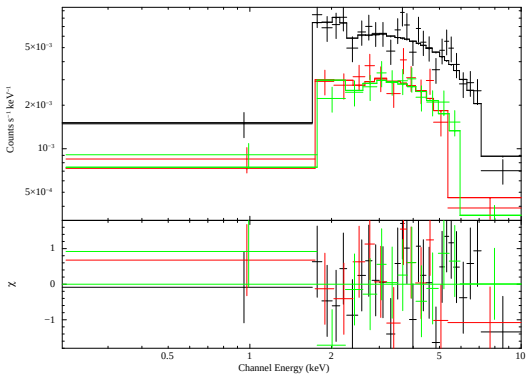
2 further transients in the survey data

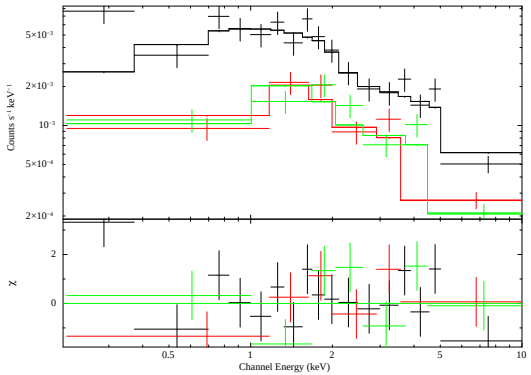


$\Gamma = 0.79 - 1.16$
$N_H = (8 \pm 2) \times 10^{22}$ cm^{-2}
$L_X = 5.6 \times 10^{35}$ erg s^{-1}
double peaked Hα line
$EW = -(33 \pm 3)$ Å

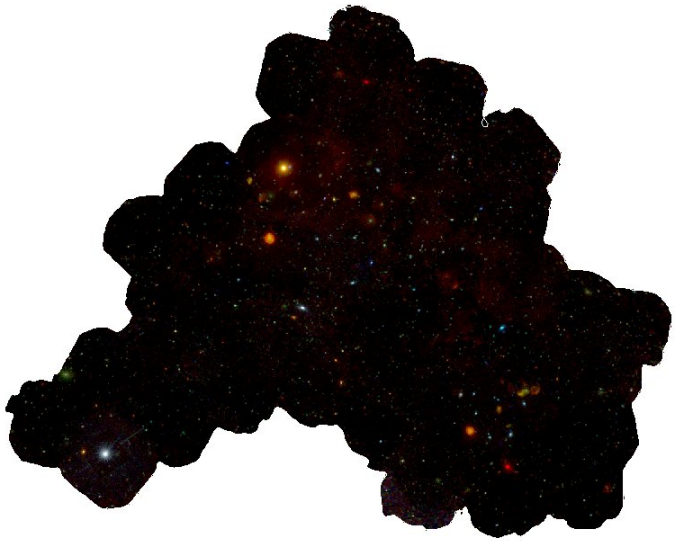


$\Gamma = 0.66 - 0.83$
$N_H < 7 \times 10^{20}$ cm^{-2}
$L_X = 1.1 \times 10^{35}$ erg s^{-1}
correlating with early type emission line star





The search for new candidates



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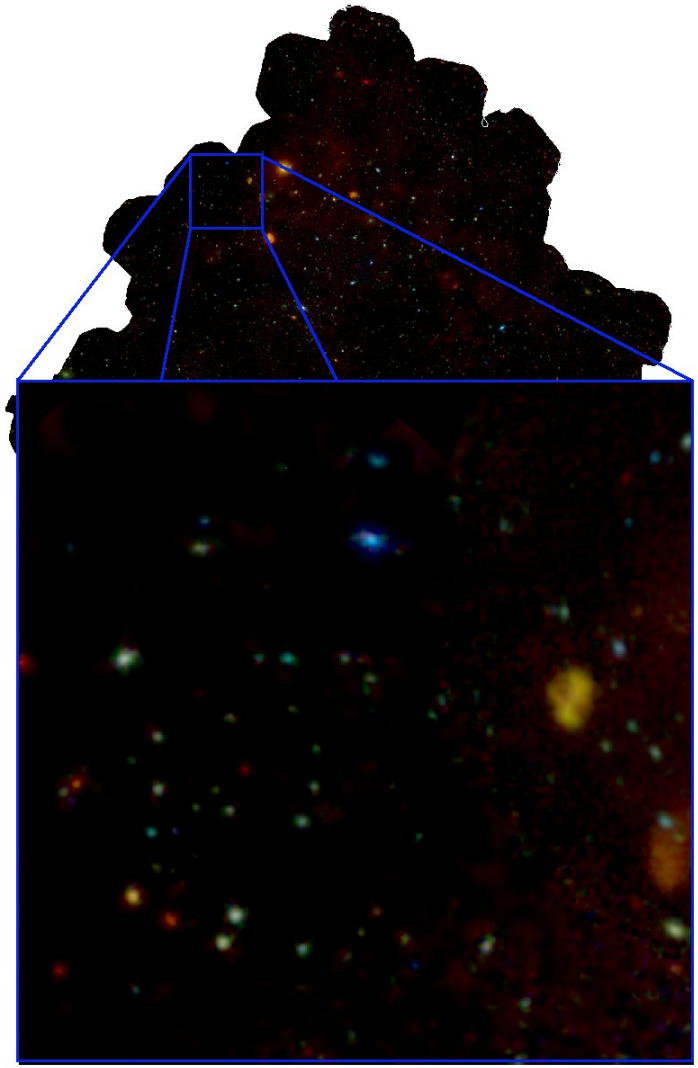

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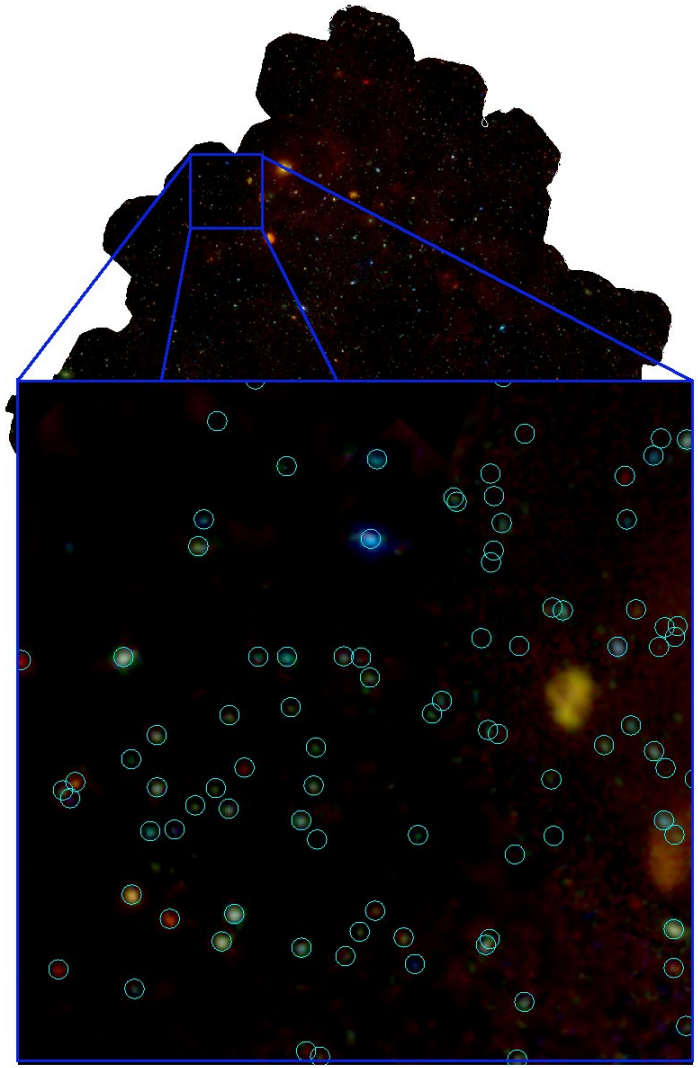

The XMM-Newton point source catalog of the SMC:

(Sturm et al., in preperation)

- 3053 X-ray sources
- 5.7 deg^2 total area
- 95 individual observations
- astrometric improved positions accuracy $\sim$1.42″
- complete to 10^{-14} erg s^{-1} cm^{-2} in the (0.2–4.5) keV band 4.3×10^{33} erg s^{-1} (for the SMC).
- exposure: 10-30 ks (average), $\sim$600 ks (maximum)

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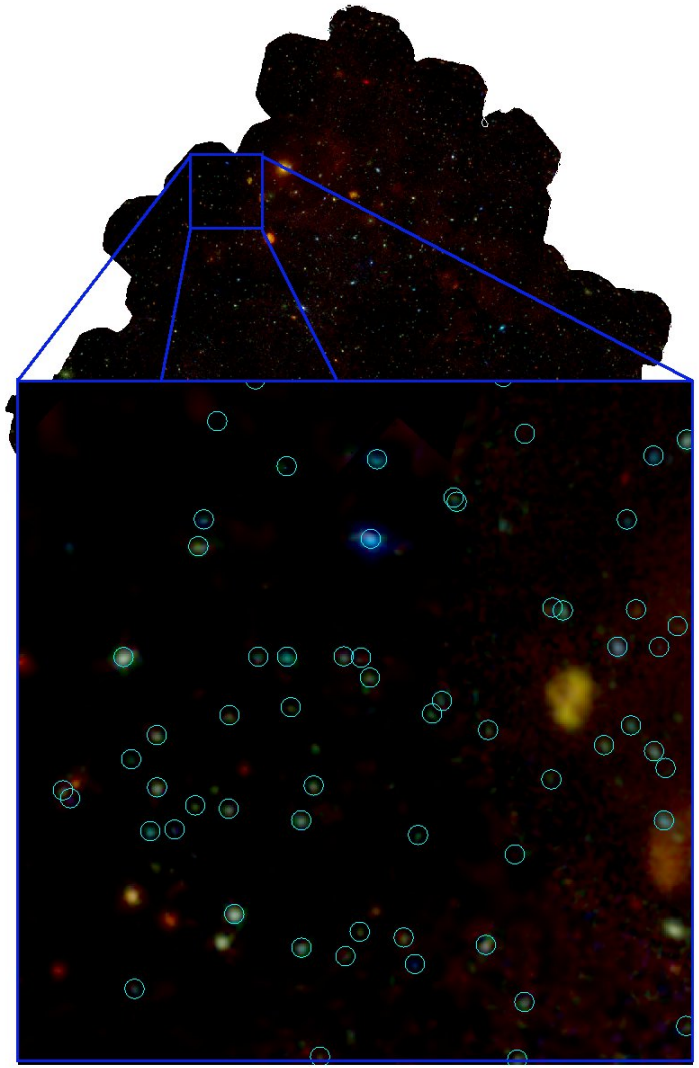
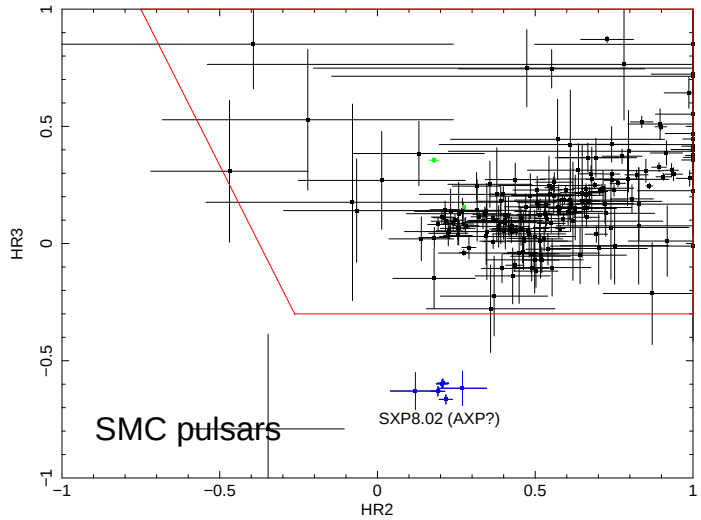
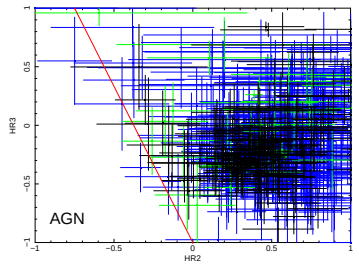
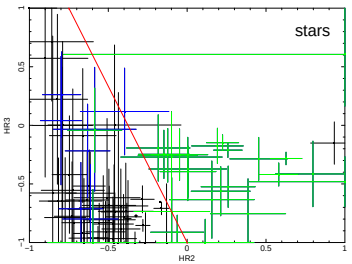


X-ray selection using hardness ratios:







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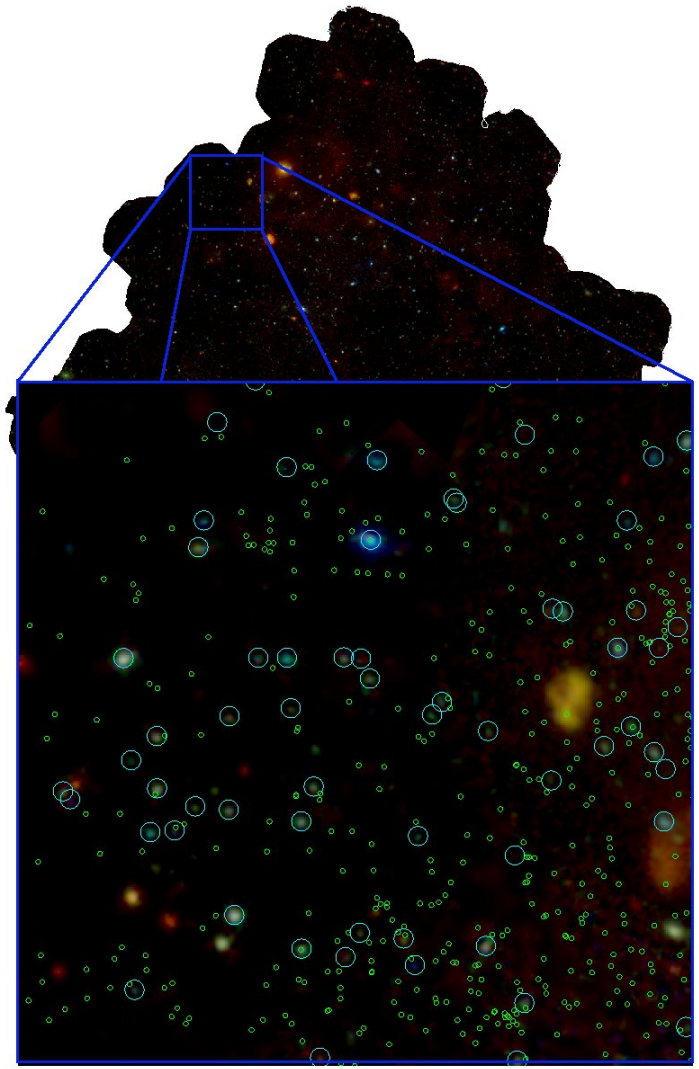
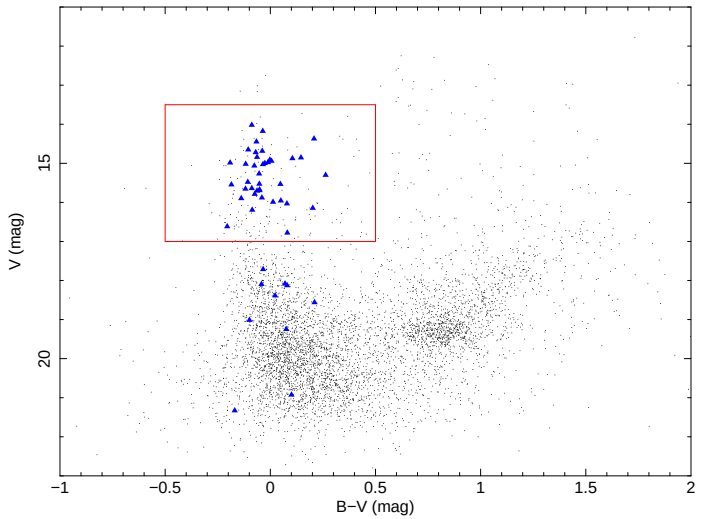


Optical counterpart:

- Magellanic Cloud Photometric Survey (Zaritsky et al. 2002)
- 16605 sources in the XMM-Newton field
- position accuracy $\sim 0.3''$



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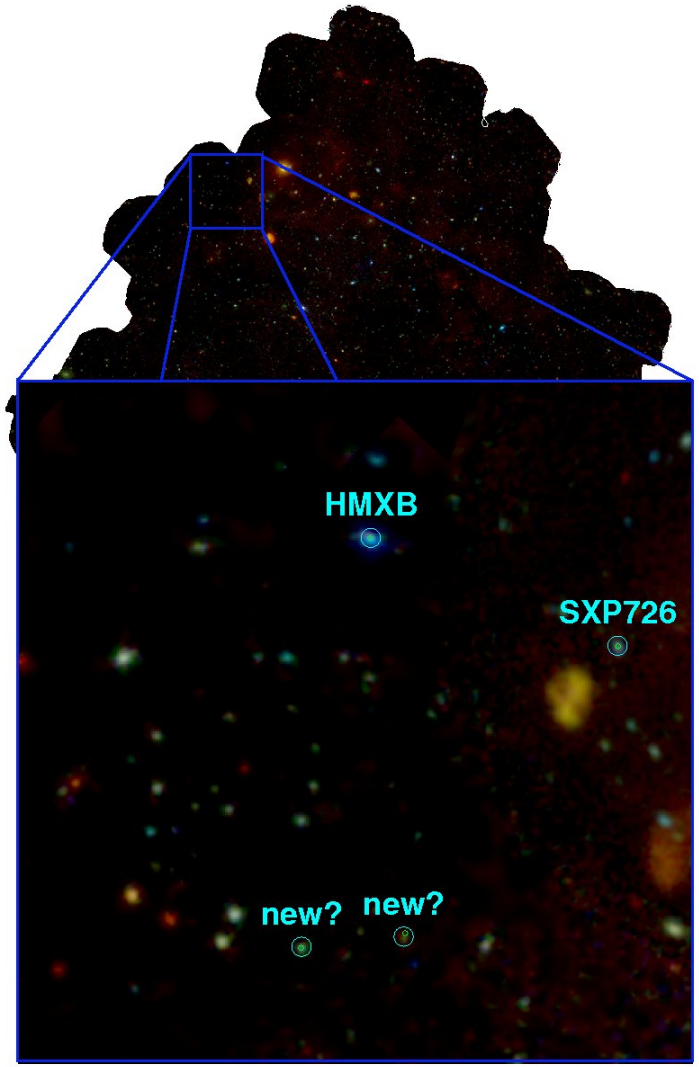

Result:

- 93 X-ray sources
  - 51 known HMXB
  - 10 candidates from previous studies
  - 32 new candidates
- further investigation necessary...

Be/white dwarf systems

- Population synthesis models predict for Be companions

  (Pols et al. 1991; Raguzova 2001)

  - 10% neutron stars
  - 20% helium stars
  - 70% white dwarfs
- expected X-ray properties:
  - Hard X-ray emission during accretion at 10^{29-33} erg s^{-1}
  - Supersoft X-ray emission during thermonuclear surface burning
  - But: absorption and disc truncation
- possible candidates:
  - γ Cas and γ Cas like objects (Haberl 1995; Lopes de Oliveira et al. 2006)
  - one SSS in the LMC (Kahabka et al. 2006)

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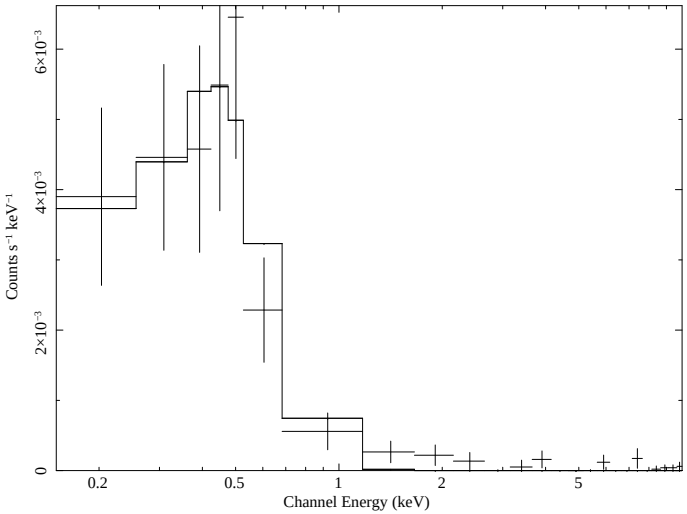
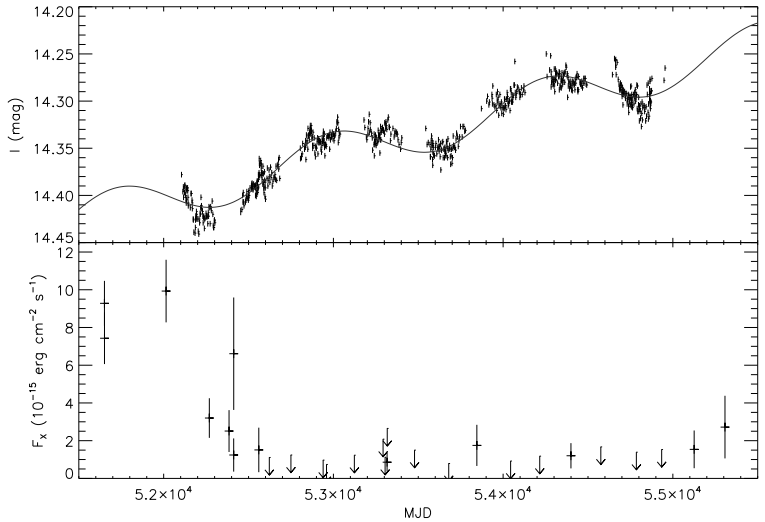
A new candidate in the SMC?

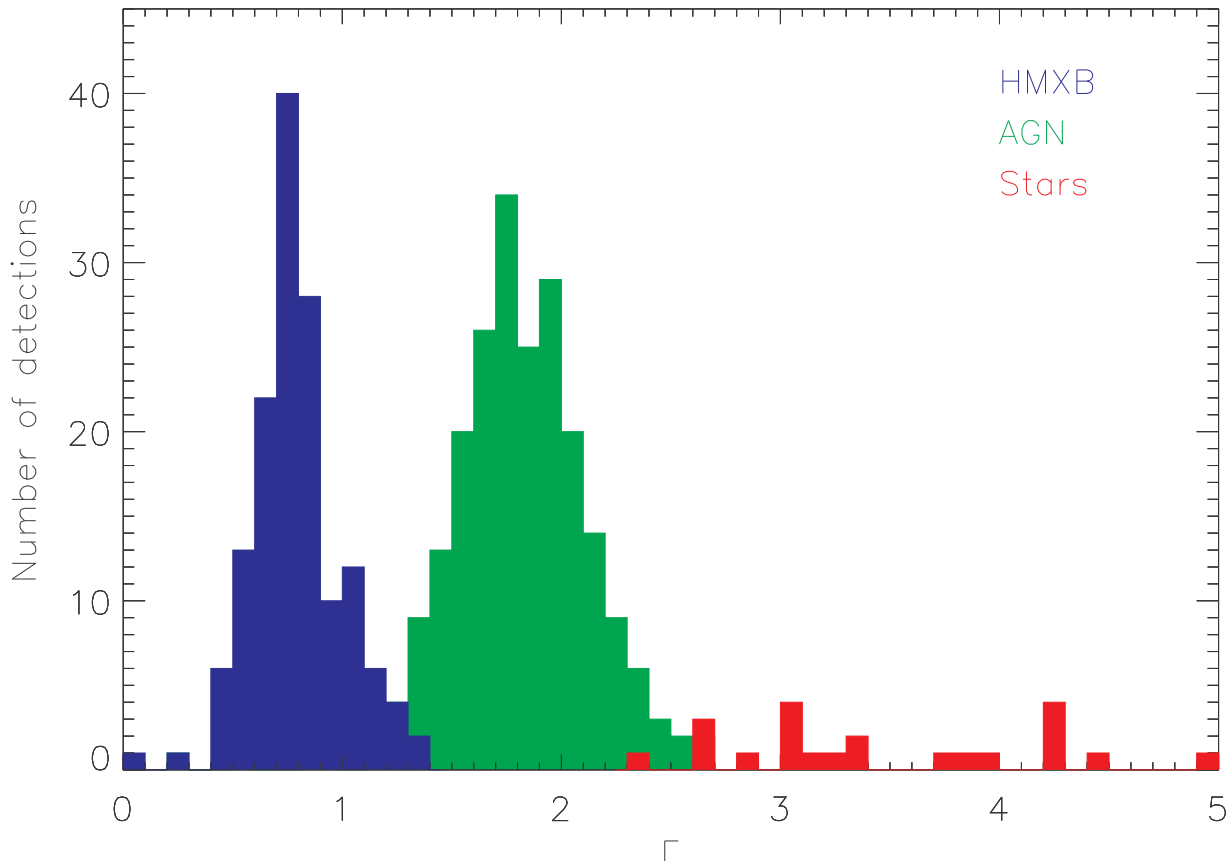
- New Discovery of a faint supersoft X-ray source ($kT = 76^{+3}_{-6}$ eV, $F_{(0.2-1.0)\mathrm{keV}} = 9.4{\times}10^{33}$ erg s^{-1})
- O7III–B0Ie companion star in the SMC

(Sturm et al., in preperation)



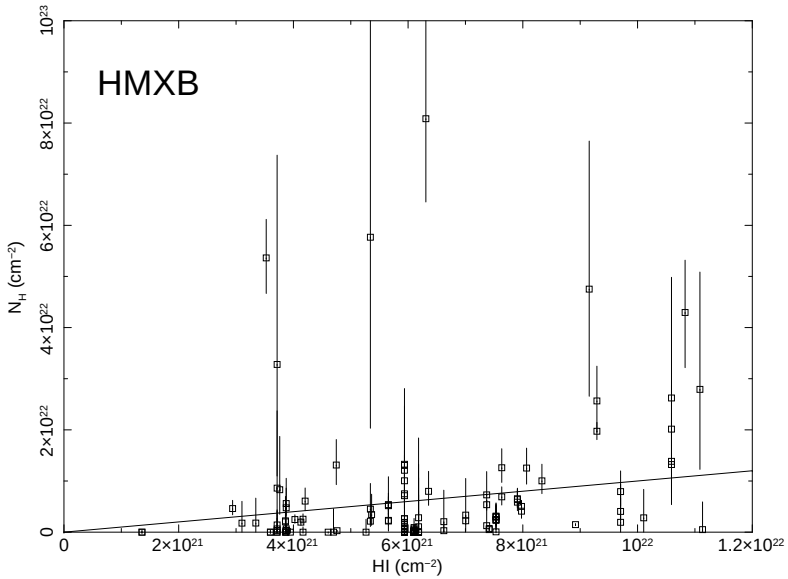


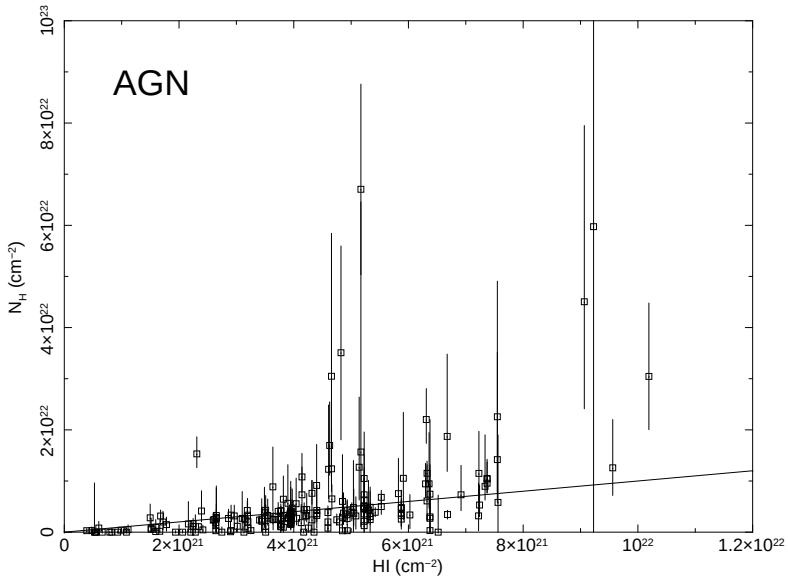
Spectral distribution of Be/X-ray binaries in the SMC



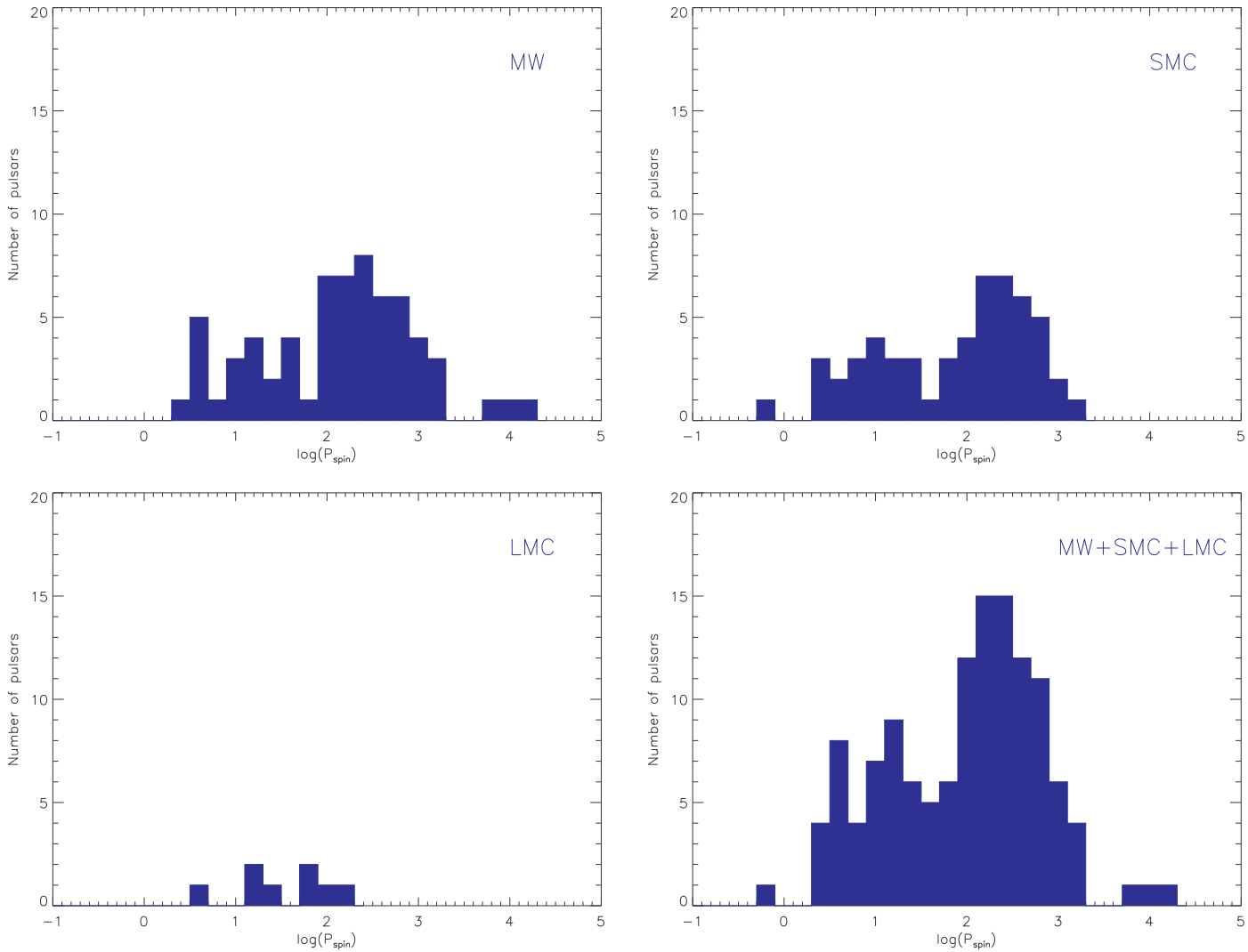
average photon index $\Gamma = (0.79 \pm 0.20)$
spectral confirmation of 3 HMXB candidates

Absorption of Be/X-ray binaries in the SMC



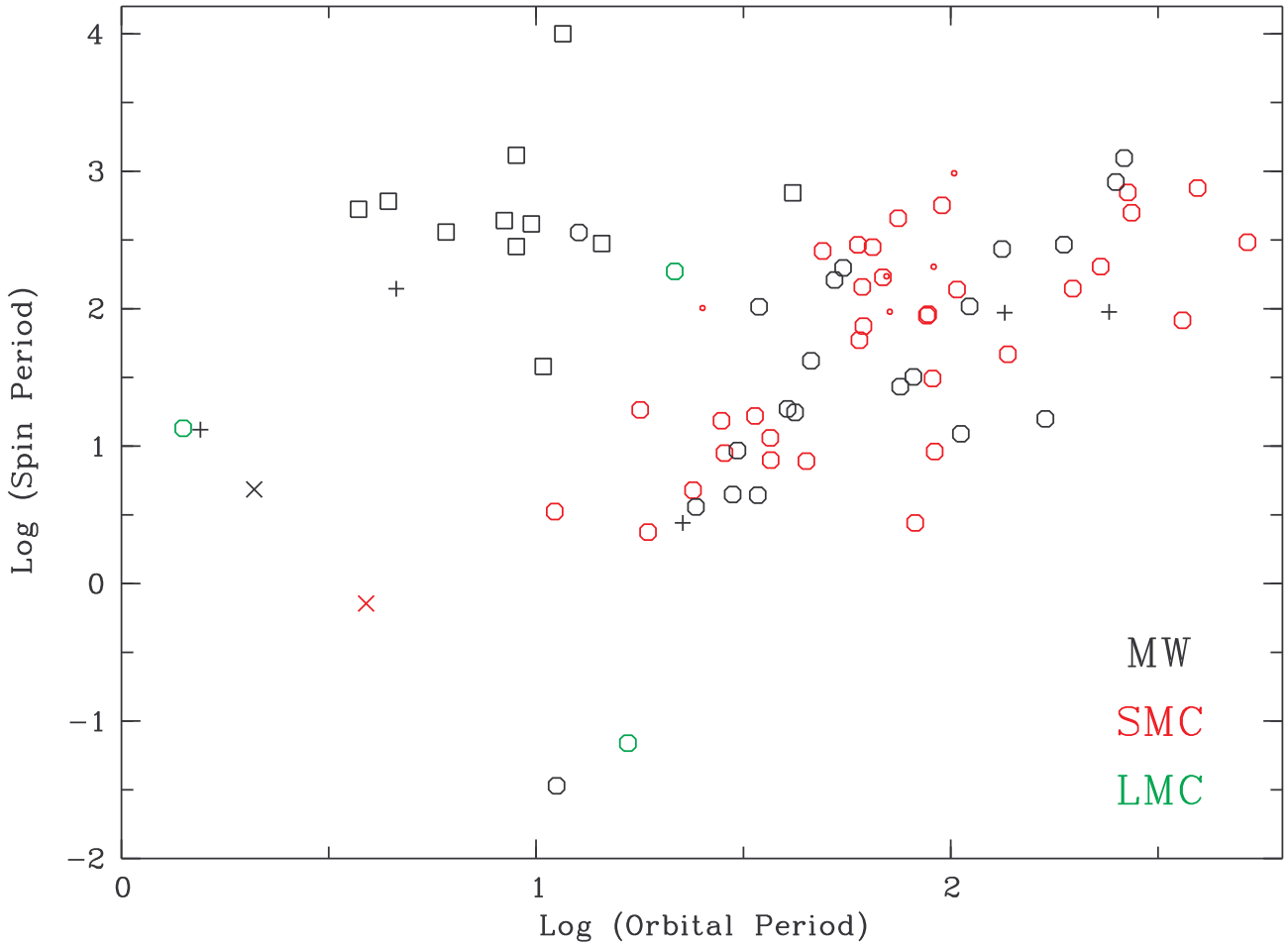


Spin Period distribution



Bimodal distribution in the SMC?
Comparing SMC and MW: KS-Test probability: 46%

The Corbet relation



Summary

- 4 new HMXB in the SMC found during the survey (SXP11.87, SXP214 and two transients)
- XMM-Newton confirmed position and pulsation of SXP11.5
- $\sim$ 29 bright detections of known HMXBs in the survey data (144 in total)
- Spectra of bright sources $\Rightarrow$ confirmation of 3 HMXB candidates
- Hardness ratio selection and correlation with optical catalogs results in $\sim$ 30 new candidates
- One candidate for a Be/white dwarf system found
- to be continued...

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