X-ray Source Populations of Local Group Galaxies

Prospects for eROSITA

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(MPE)

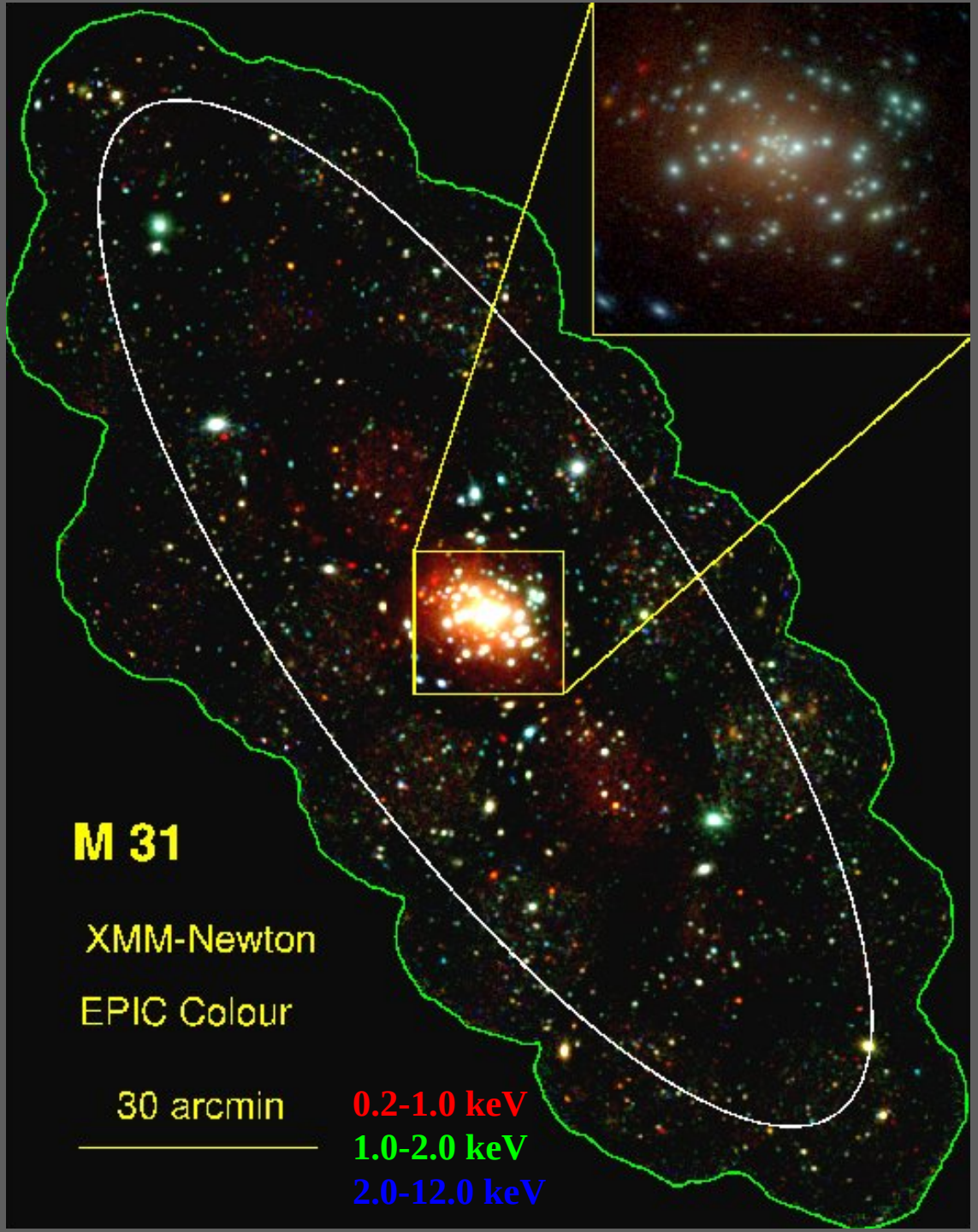
- **Introduction**
- **Transients in M 31**
- **The remarkable HMXB population of the SMC**

First eROSITA International Conference – Garmisch-Partenkirchen, Germany, October 17-20, 2011

What can we learn from observations of local group galaxies?

- Different types of galaxies
- Sources at “same” distance; similar, low foreground absorption accurate luminosity
- Learn more about the source populations in the Milky Way
- Understanding of unresolved emission from distant galaxies
- X-ray source classes
  - X-ray binaries (XRBs)
    - Low and High Mass XRBs
      An exceptionally large population of HMXBs in the SMC
      Time variability - bright transients
  - Supersoft X-ray sources
    - Classical SSSs
      Established as class in the Magellanic Clouds
    - Optical novae
      The major class of supersoft X-ray sources in M31
      Supersoft states last from weeks to years
  - Supernova remnants

    Resolved with eROSITA in SMC and LMC (typical size 2-3 arcmin)
  - Nuclear sources (M33)
  - Ultraluminous X-ray sources (ULXs)
  - Diffuse emission in disk and halo



The Andromeda Galaxy M 31

H. Stiele 2010 PhD Thesis

Stiele et al. 2011, A&A 534, A55

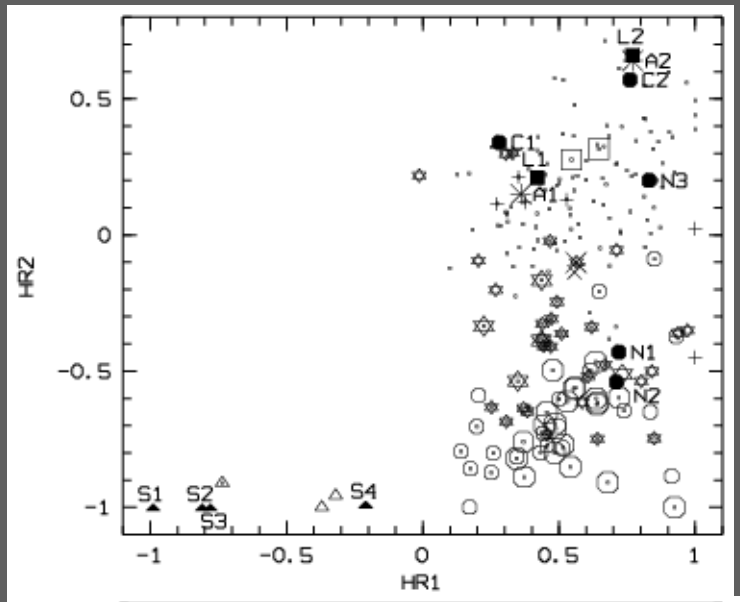
More than 1900 sources

Classification and identification:

- Hardness ratio and time variability
- Correlation with catalogues from other wavelength

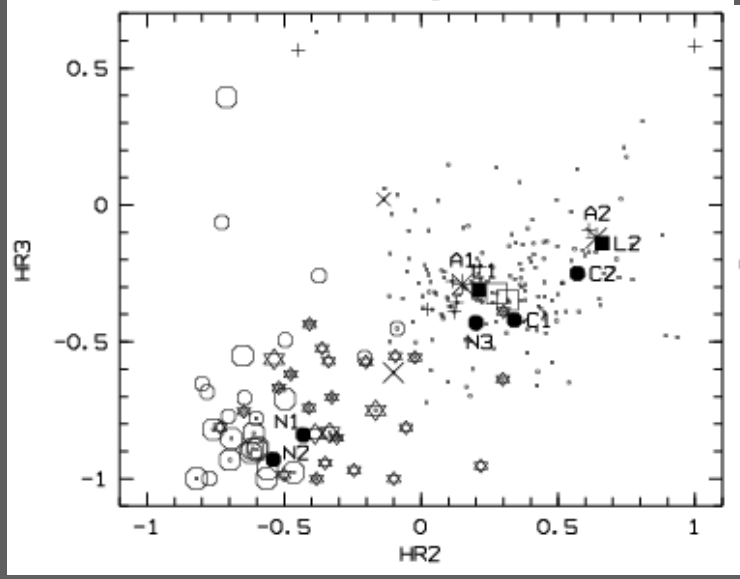
Sb spiral galaxy
Distance ~800 kpc

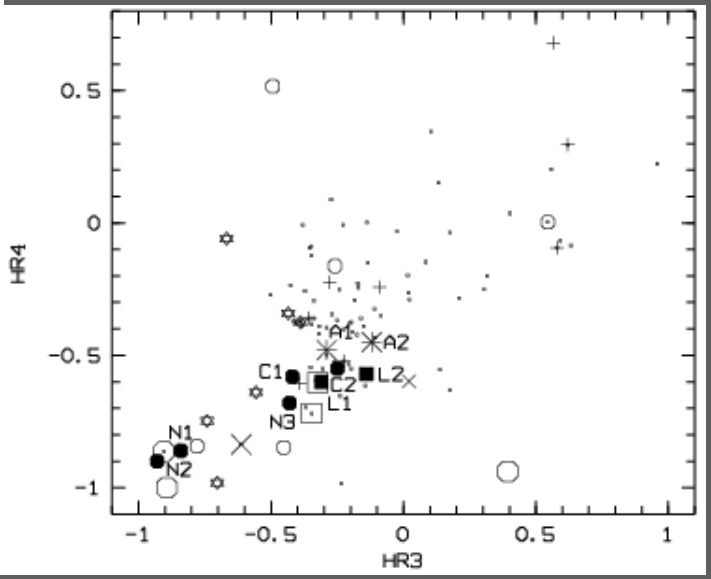
Spectral classification using hardness ratios



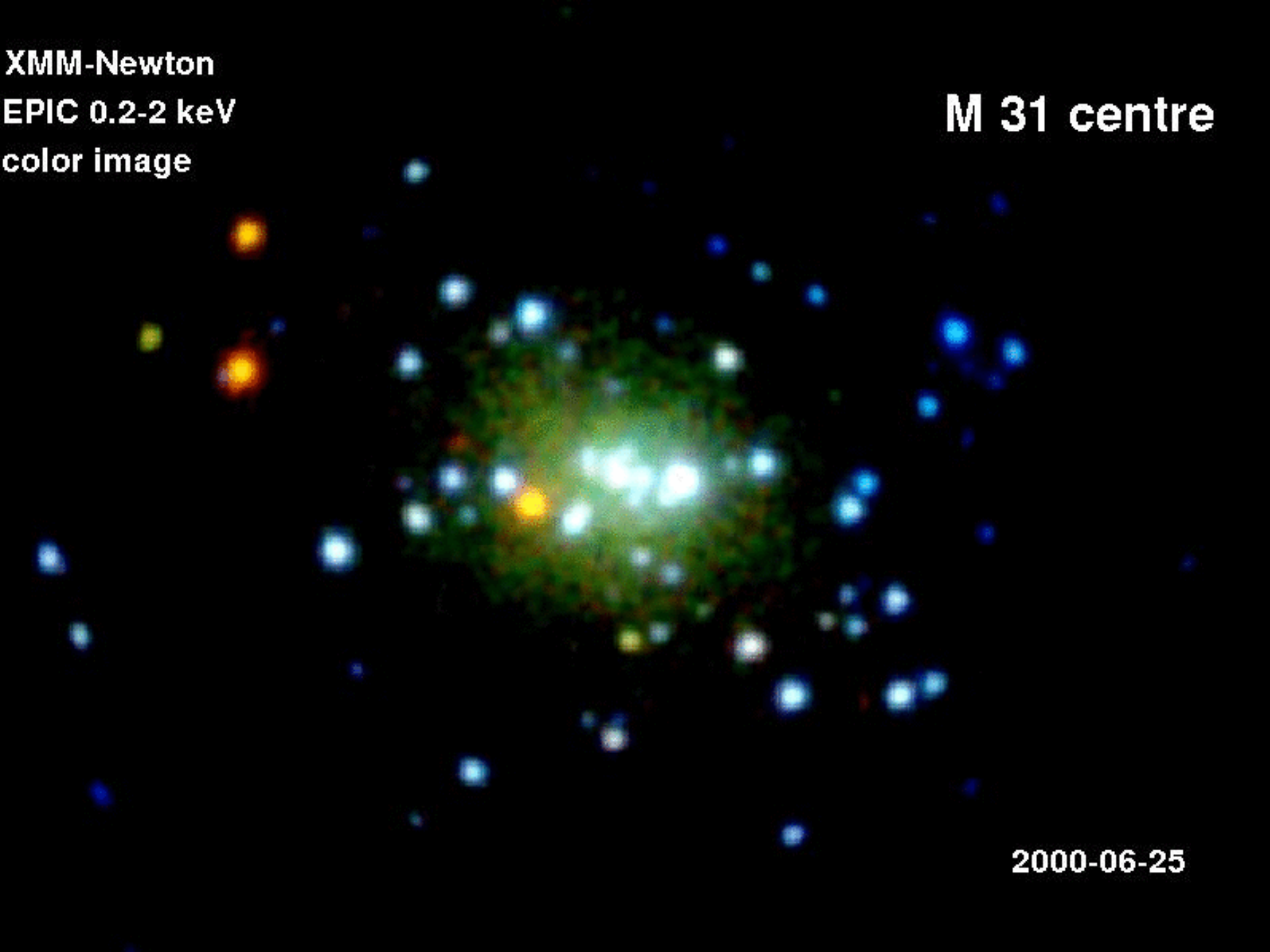
$HR_i = (B_{i+1} - B_i)/ (B_{i+1} + B_i)$

B1: 0.2-0.5 keV
B2: 0.5-1.0 keV
B3: 1.0-2.0 keV
B4: 2.0-4.5 keV
B5: 4.5- 12 keV

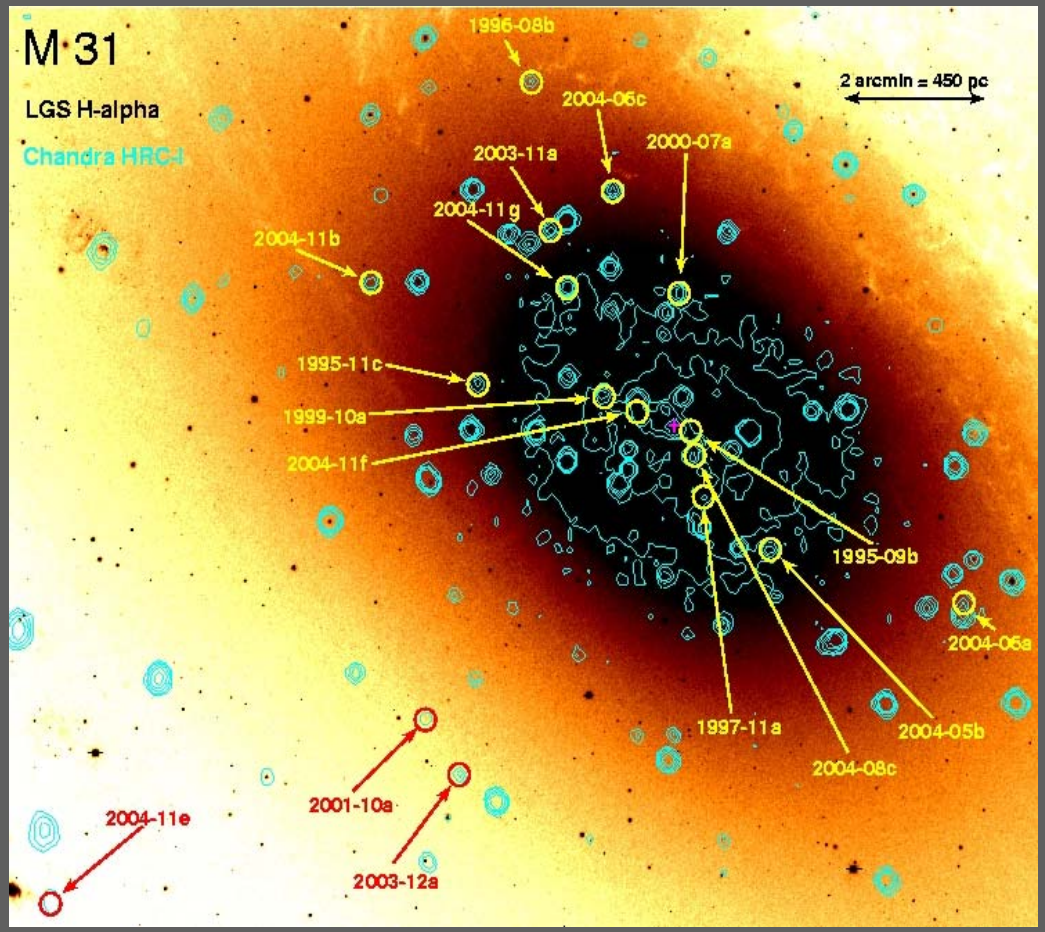


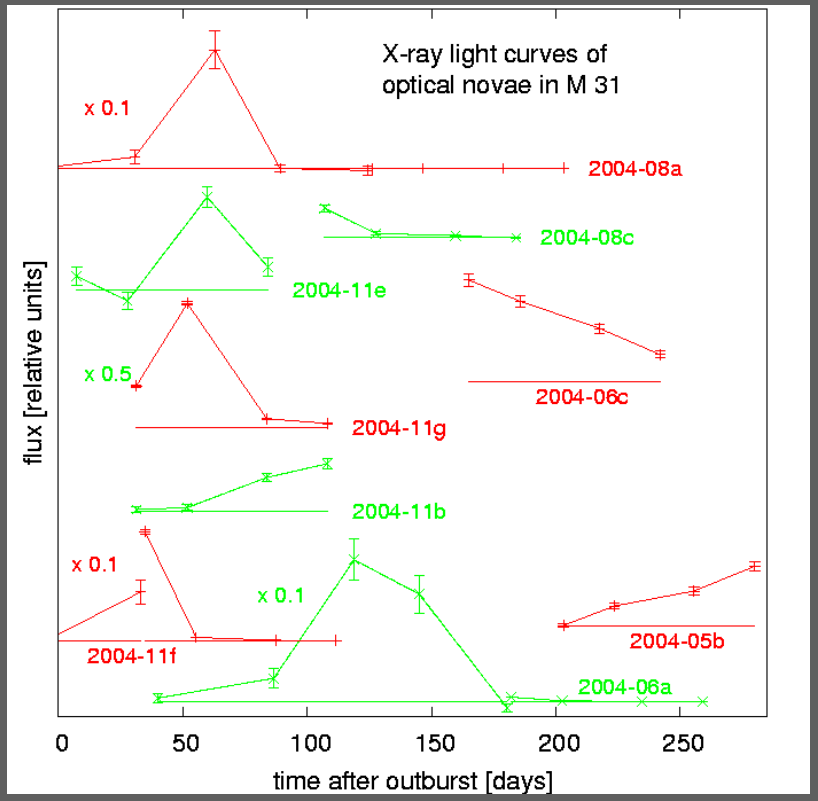


fg-star
AGN
SSS
SNR
XRB


XMM-Newton
EPIC 0.2-2 keV
color image
M 31 centre
2000-06-25

XMM-Newton/Chandra M31 nova detections before 2006





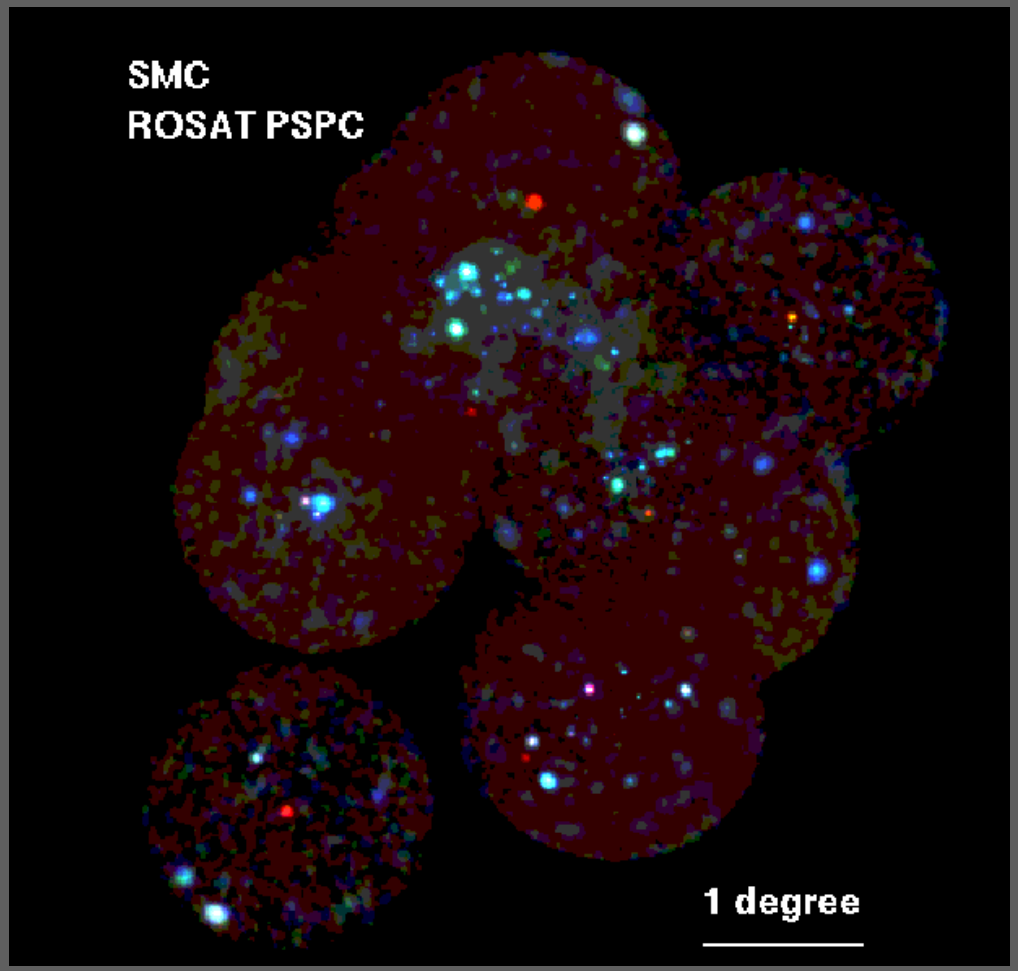
Nova SSS light curves (<250 d)

- **Optical novae: major class of supersoft X-ray sources in M 31**
- **More than 30% of optical novae show SSS state**

Pietsch et al. 2005, A&A 442, 879; Pietsch et al. 2007, A&A 465, 375
Henze et al. 2010, A&A 523, A89; Henze et al. 2011, A&A 533, A52

X-ray surveys of the Small Magellanic Cloud

- Einstein IPC
  70 discrete X-ray sources *(Wang et al. 1991, Wang & Wu 1992)*
- ROSAT PSPC and HRI
  517 sources (PSPC), 121 sources (HRI, 46 additional)
  (Haberl et al. 2000, Sasaki et al. 2000)
  Diffuse emission 10^6-10^7 K (Sasaki et al. 2002)

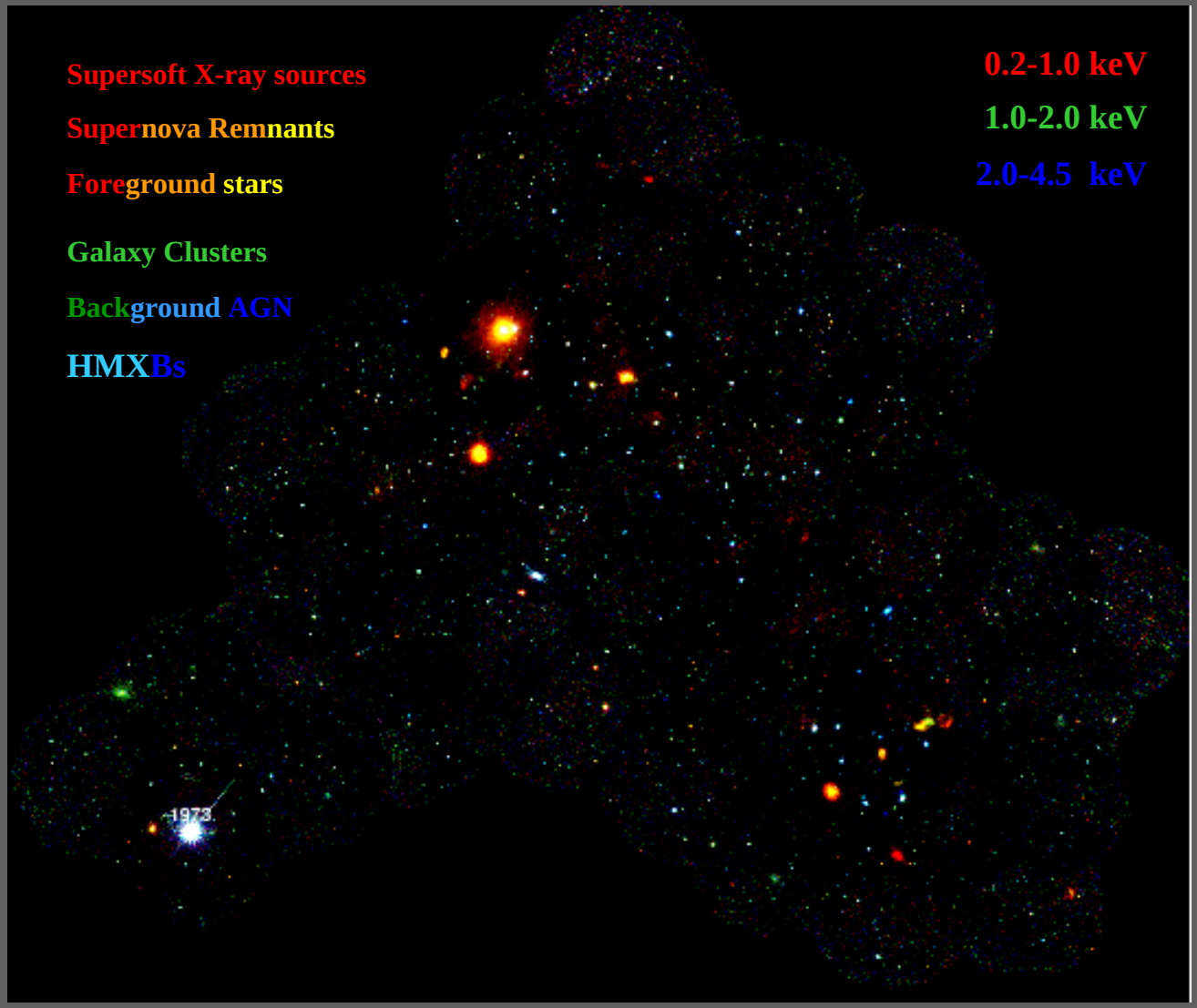


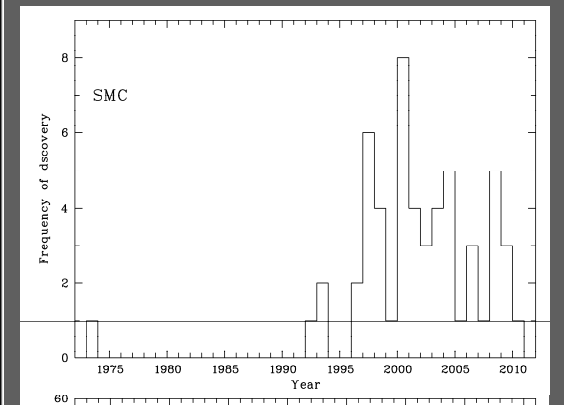
Mosaic of ROSAT pointed observations
large field of view (1 degree radius)
6x6 degree field (~18 square degrees)
0.1-2.4 keV band
moderate energy resolution

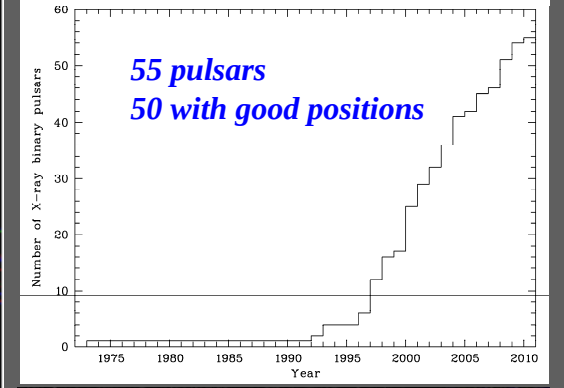
Classification of X-ray sources
Spectral information (hardness ratios)
X-ray to optical flux ratio
Spatial extent
Flux variability

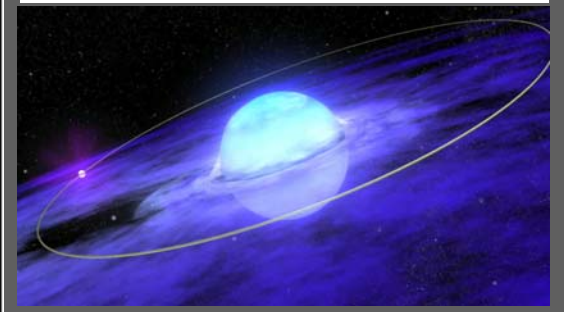
Irregular dwarf galaxy
Distance 60 kpc

An exceptionally large number of HMXBs in the SMC



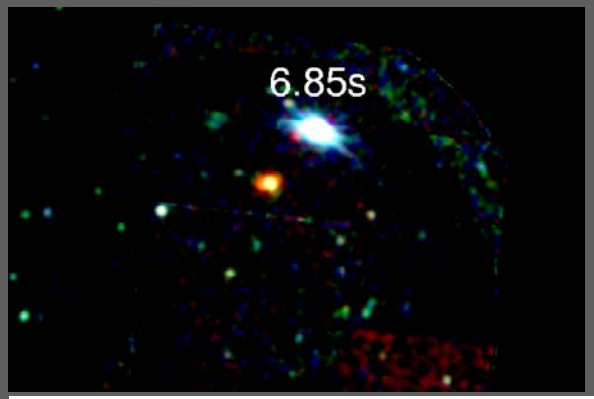




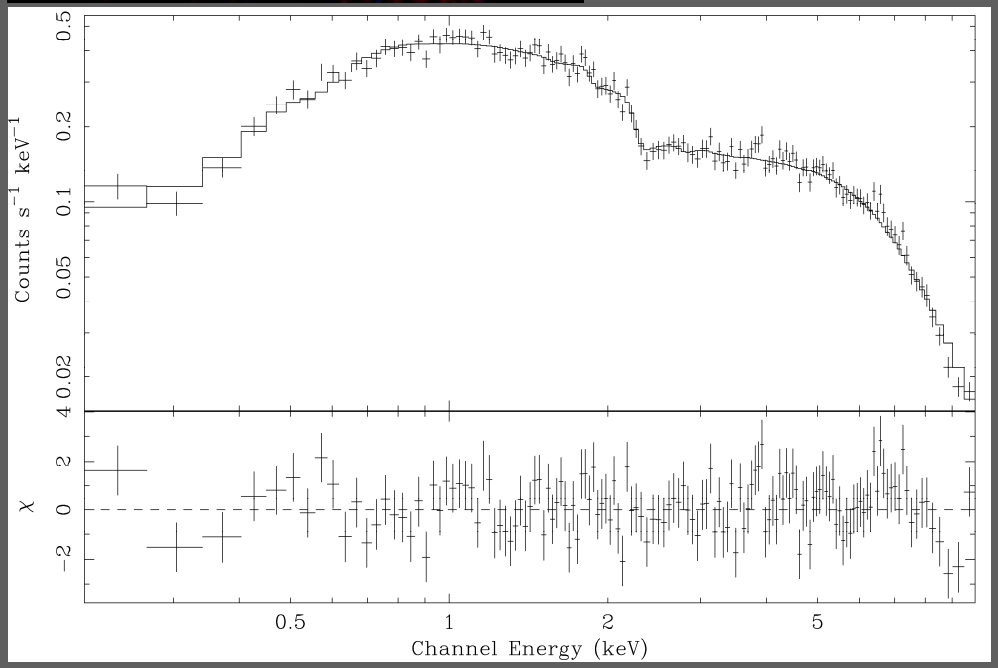


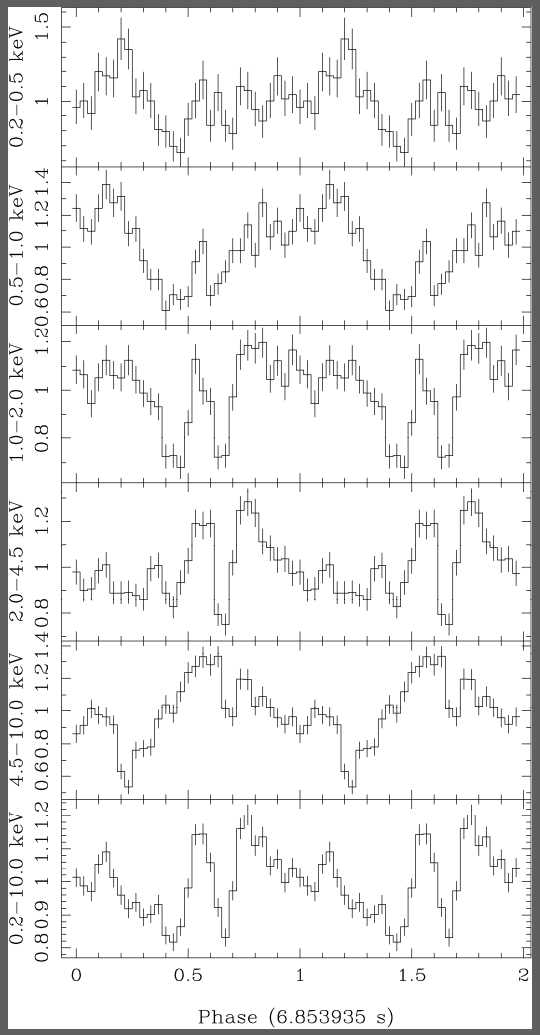
Many discoveries of X-ray transients with RXTE, ASCA, ROSAT, BeppoSAX
Chandra and XMM-Newton can do spectral and timing analysis down to 10^{34} erg/s

The Be/X-ray binary pulsar XMMU J010253.1-724433



EPIC-pn:
17.7 ks
1.4 cts/s
$L_x = 1.7 \cdot 10^{37}$ erg/s
(0.2-10 keV)





Haberl & Pietsch 2008, A&A 484, 451

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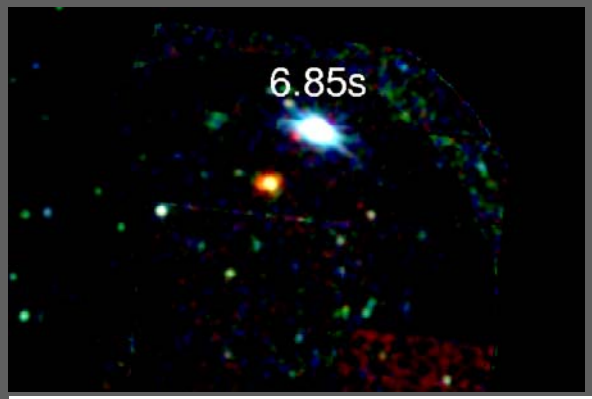
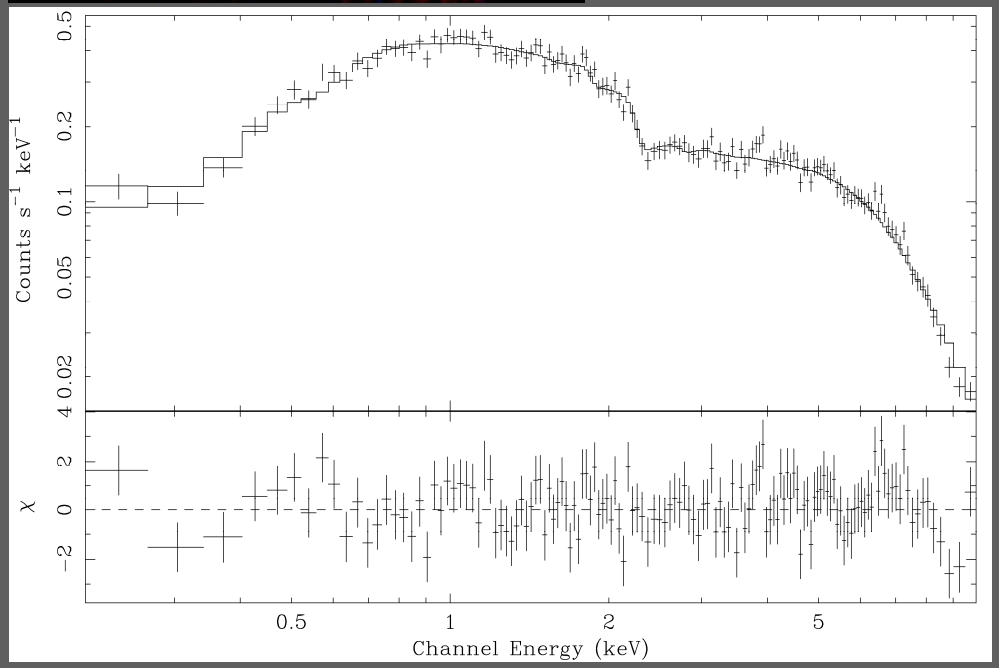
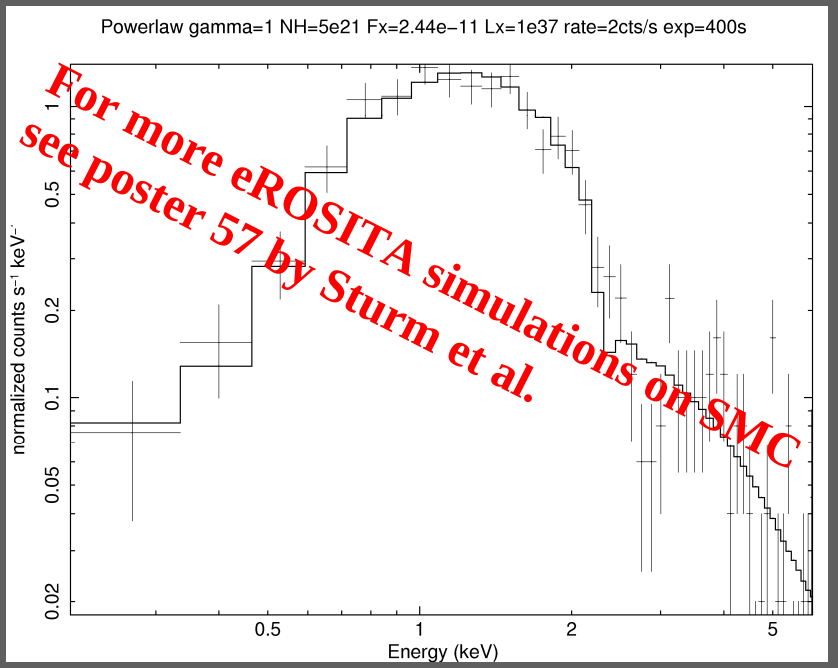


EPIC-pn:
17.7 ks
1.4 cts/s
$L_x = 1.7 \cdot 10^{37}$ erg/s
(0.2-10 keV)

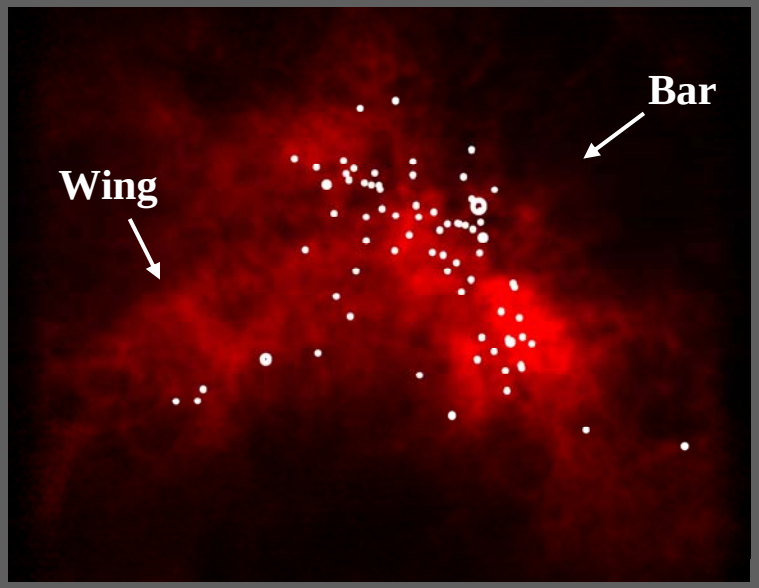
eROSITA half-year survey:
400 s: spectrum with 800 cts
photon index can be determined to ±0.2



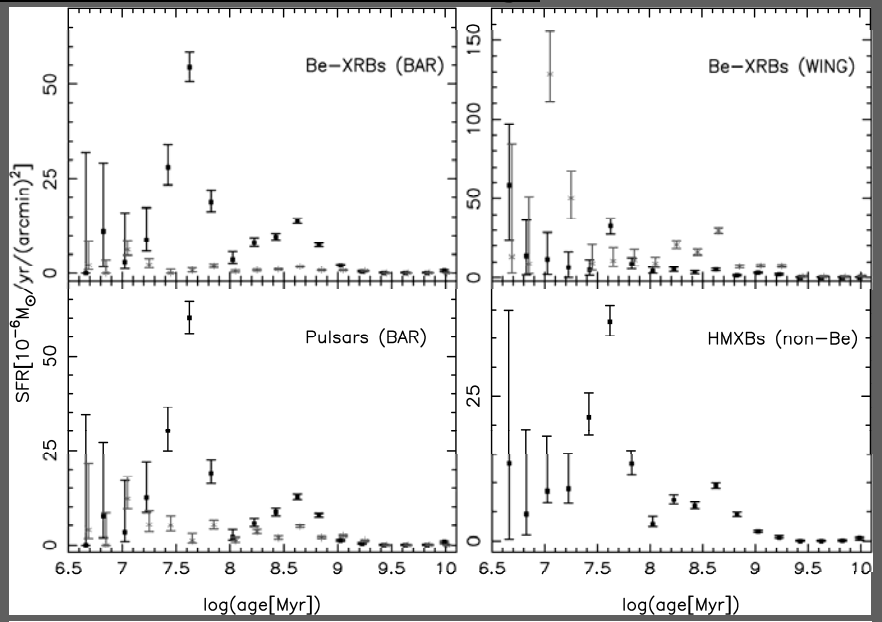


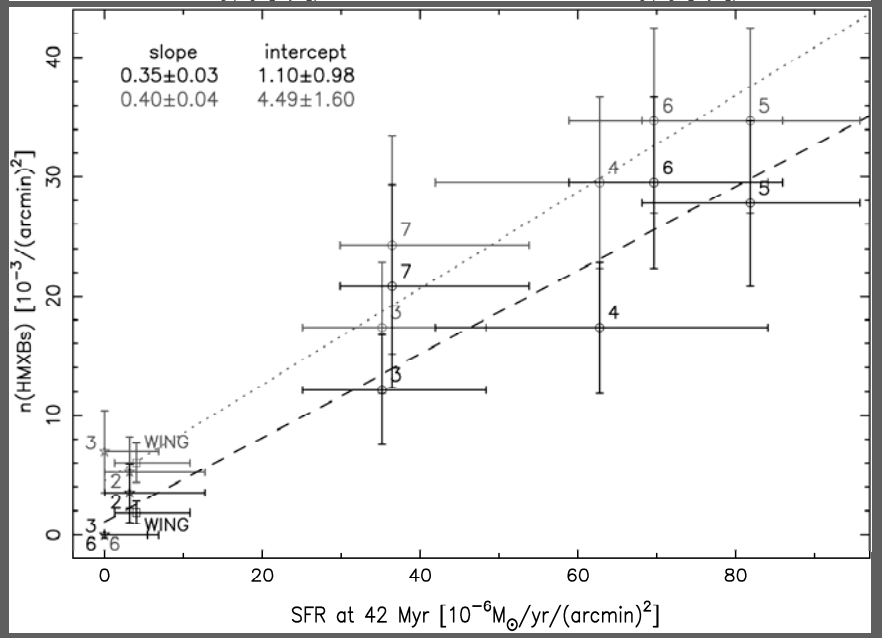
Haberl & Pietsch 2008, A&A 484, 451

HMXBs and Star Formation History



HI map Stanimirovic et al. (1999)

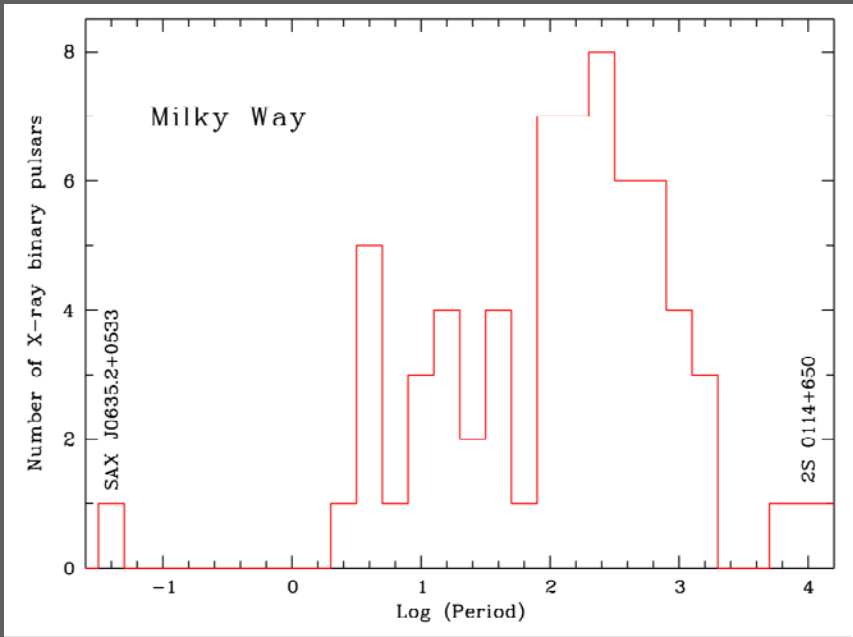


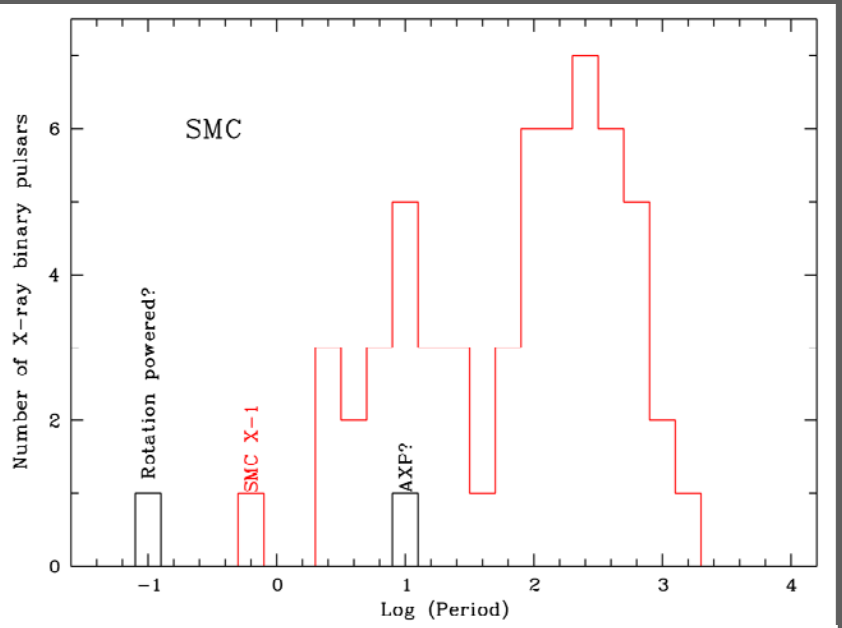


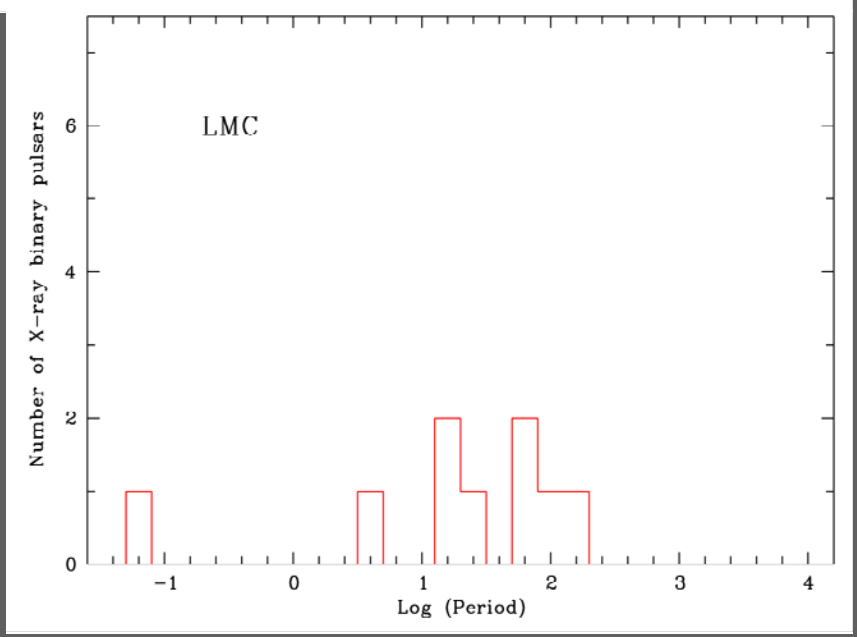
- HMXBs in regions with star formation bursts 25-60 Myrs ago
- number of HMXBs correlates with SFR at 42 Myr

Antoniou et al. 2010

Neutron star spin periods



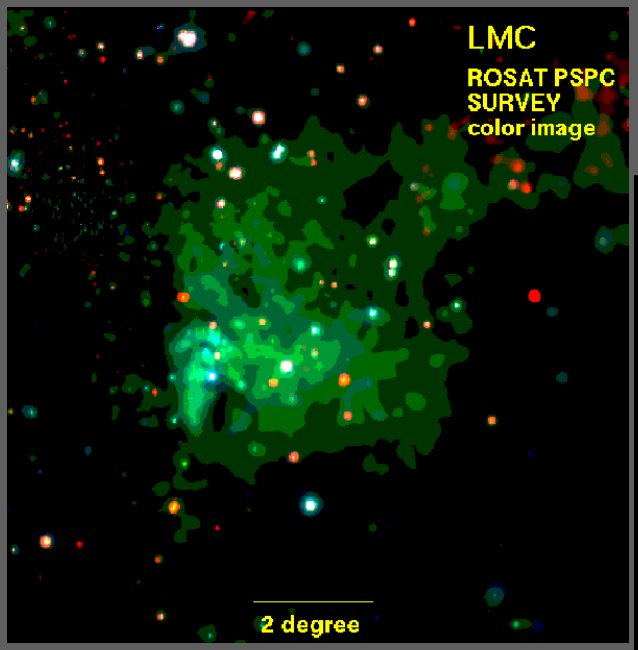




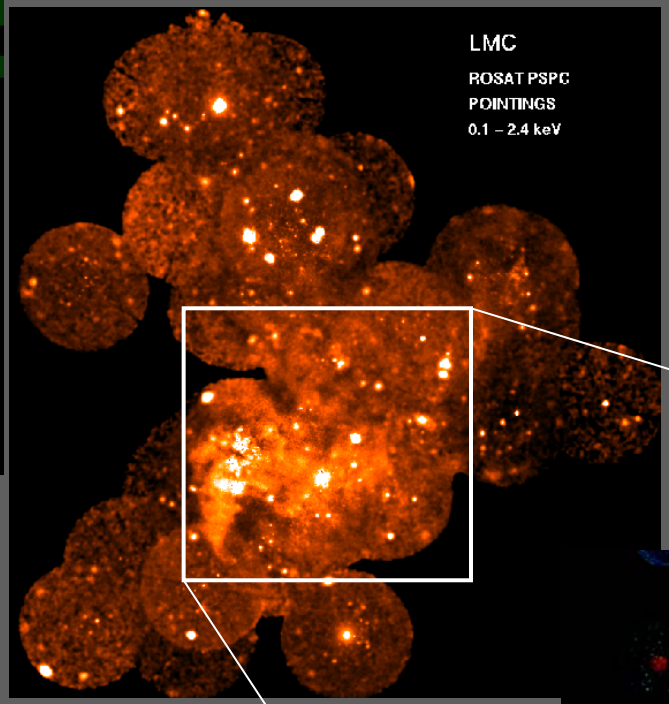
MW: 113 HMXBs + candidates
66 pulsars
SMC: 89 HMXBs + candidates
55 pulsars
LMC: 25 HMXBs + candidates
9 pulsars

- **Peak between 100 s and 1000 s**
- **Bimodal structure in the spin distribution**

The Large Magellanic Cloud

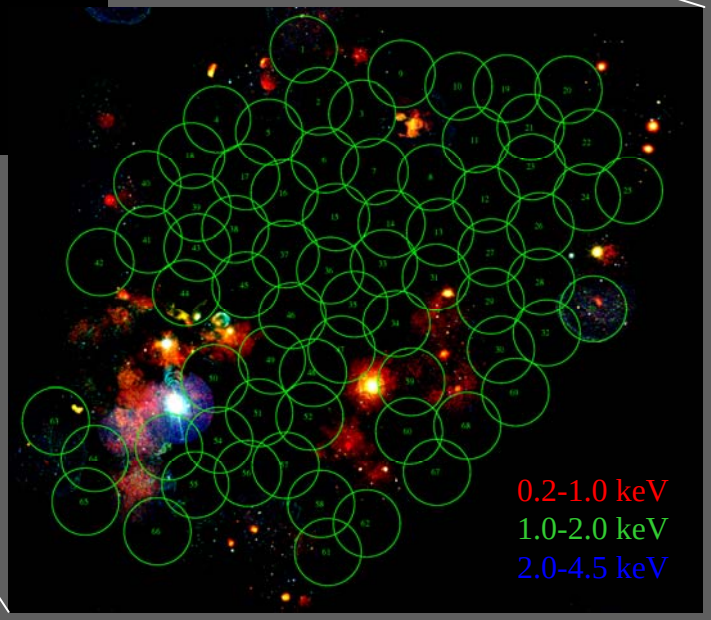


ROSAT



ROSAT

XMM-Newton



eROSITA will obtain the first full survey of the LMC in the 0.1-10 keV band

eROSITA Survey Parameters

- Field of view 1^o diameter
- Scan speed longitude 180^o in 180 days / 1^o per day
- Scan speed latitude 4-6 hour per scan / 6-4 scans per day
  i.e. 40-60s for central scan, in total 250s
- 4 year scan mode
  => 8 x 250 s = 2000 s typical total exposure
- 1000 s sensitivity (from Cappeluti et al. 2010)
  5 σ upper limit 3×10^{-14} erg cm^{-2} s^{-1} (0.5-2 keV)
  7×10^{-13} erg cm^{-2} s^{-1} (2-10 keV)

=> in one day 2×10^{-13} erg cm^{-2} s^{-1} (0.5-2 keV)

Sensitivity for Local Group Galaxies (0.5-2 keV)

LMC	50 kpc	6×10^{34} erg s^{-1}
SMC	60 kpc	9×10^{34} erg s^{-1}
M 31	780 kpc	1.5×10^{37} erg s^{-1}
M 33	795 kpc	1.5×10^{37} erg s^{-1}

Expected Source Numbers

Extrapolating from XMM surveys

Limiting flux 10^{-13} erg cm^{-2} s^{-1}	number of sources M 31		M 33	
		Σ		Σ
>25	3	3	1	1
16-25	-	3	1	2
10-16	8	11	2	4
6.3-10	8	19	1	5
4-6.3	12	31	2	7
2.5-4	17	48	-	7
1.6-2.5	15	63	2	9

Summary

Large samples of X-ray sources are available in Local Group galaxies

- **Observations of many systems simultaneously at similar distance / low foreground absorption**
- **Statistical studies**
  - **Global properties**
  - **Population studies**
- **example: HMXBs in SMC as tracer for recent SF**
  - **In regions with star formation bursts 25-60 Myrs ago**
  - **Number of HMXBs correlates with SFR at 42 Myr**

MCs: **Sensitivity ~10^{35} erg/s**

- **New HMXBs in LMC, SMC and Magellanic Bridge**
  - **SSSs (outskirts in the older stellar population)**
  - **SNRs**

M 31/33: **Sensitivity ~10^{37} erg/s**

- **hard X-ray transients**
- **Classical novae**