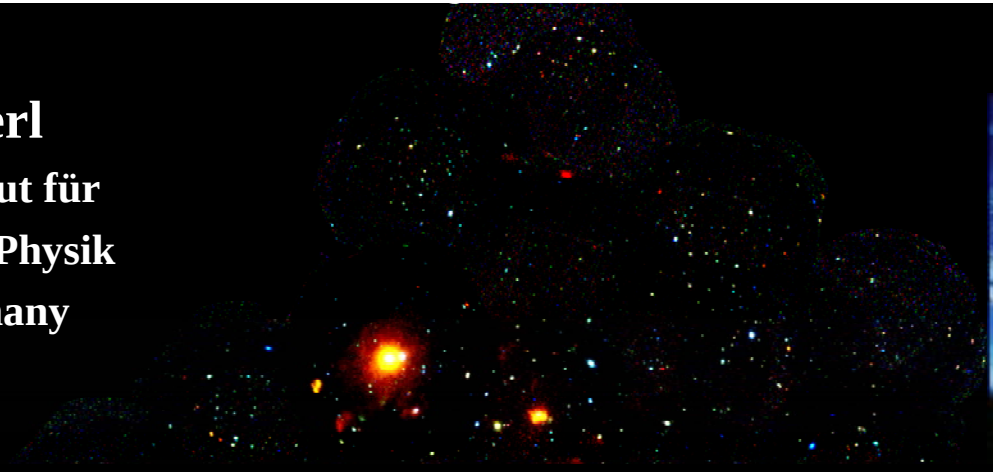
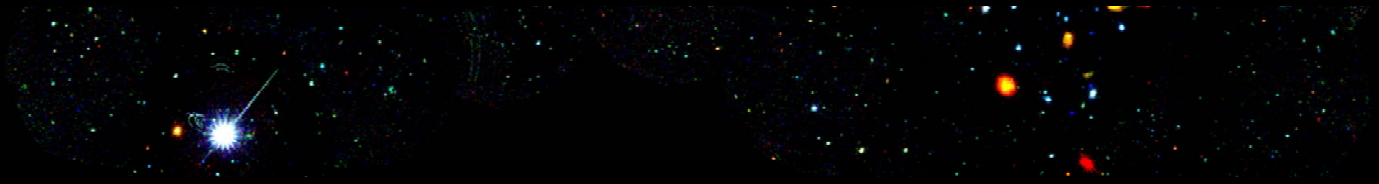
The XMM-Newton survey of the Small Magellanic Cloud

Frank Haberl
Max-Planck-Institut für extraterrestrische Physik
Garching, Germany



- **History of X-ray observations of the SMC**
- **Archival XMM-Newton observations**
- **The XMM-Newton survey**
  - **Source catalogue**
  - **Population studies**
    SSS, HMXBs, SNRs

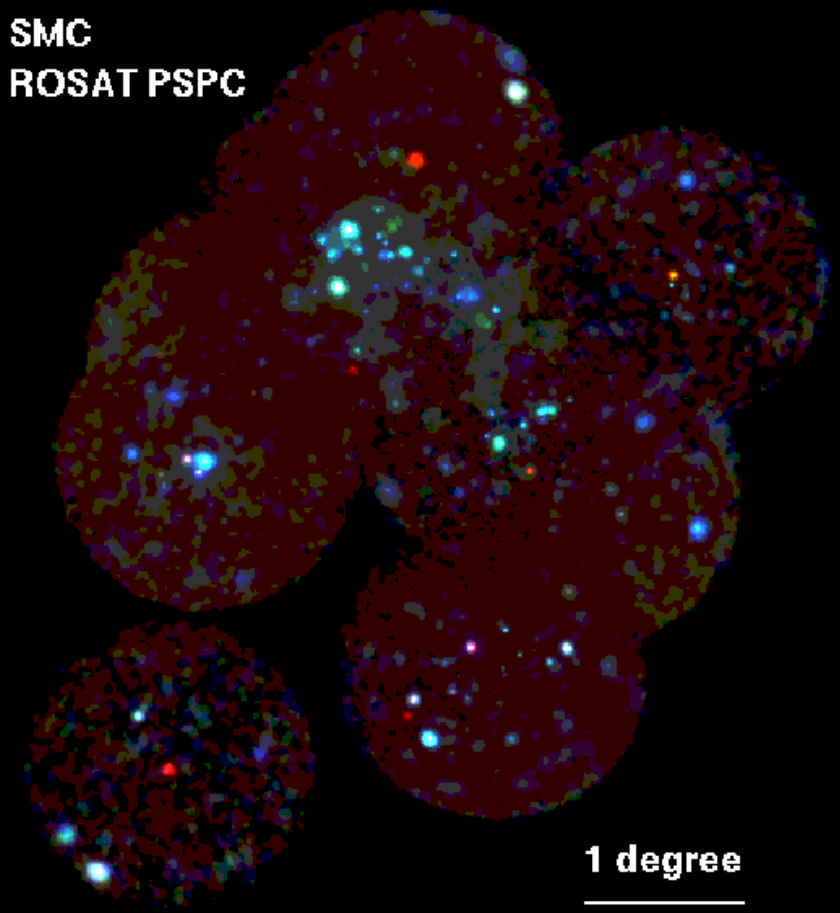


An XMM-Newton large project in collaboration with
J. Ballet, D. Bomans, D.A.H. Buckley, M.J. Coe, R. Corbet, M. Ehle, M.D. Filipovic, M. Gilfanov, D. Hatzidimitriou, S. Mereghetti, R. Owen, N. La Palombara, W. Pietsch, R. Sturm, S. Snowden, A. Tiengo

The X-ray Universe 2011, Berlin, Germany, 27-30 June 2011

Historical X-ray studies

- 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)*
- ASCA: 106 discrete sources, 17 (8 new) pulsars *(Yokogawa et al. 2003)*
- RXTE: monitoring of pulsars (over more than 10 years) *(Galache et al. 2008)*

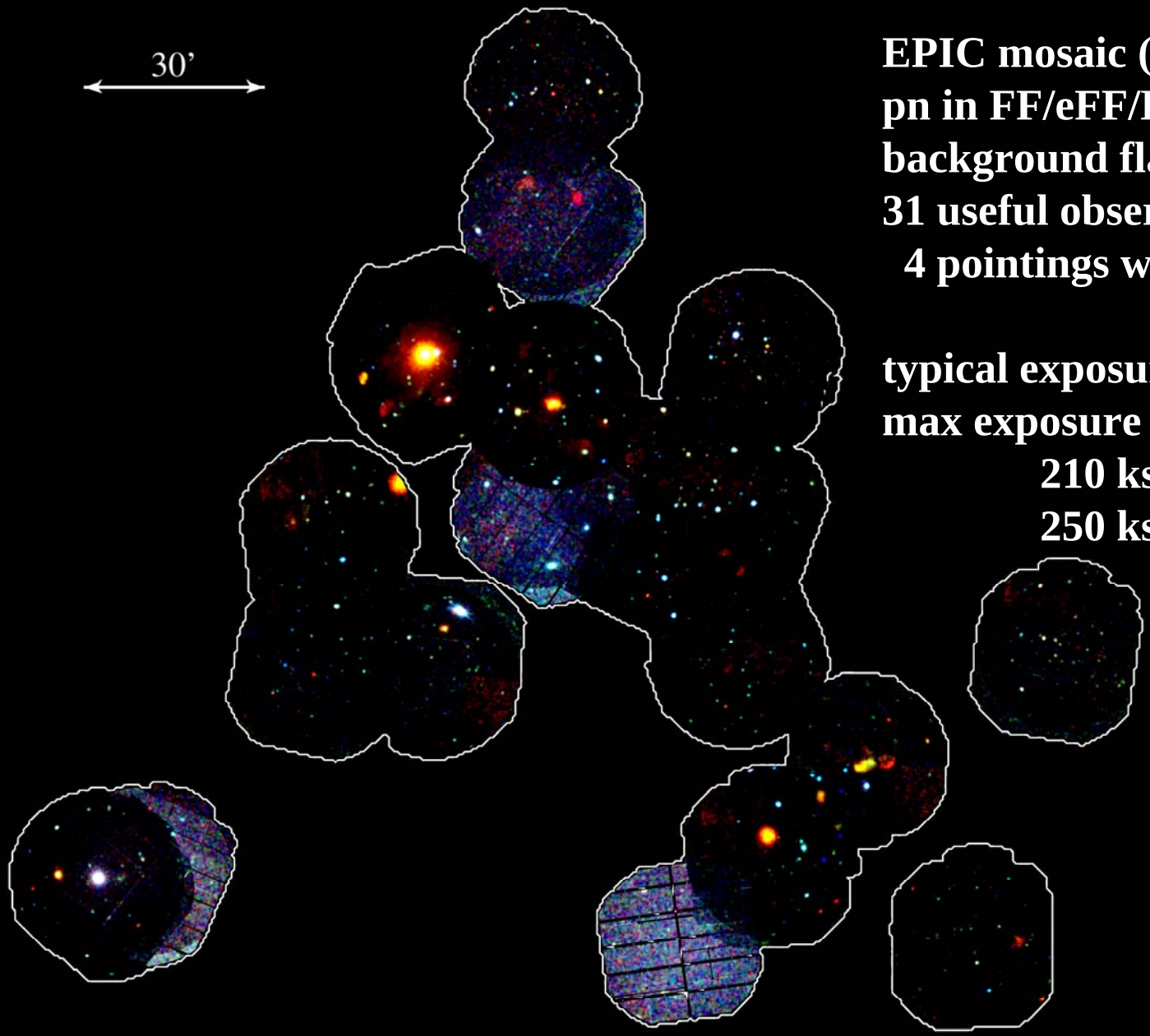


Mosaic of ROSAT pointed observations
6x6 degree field (~18 square degrees)

HMXBs (blue)
SNRs (greenish)
SSSs (red)

background AGN
foreground stars

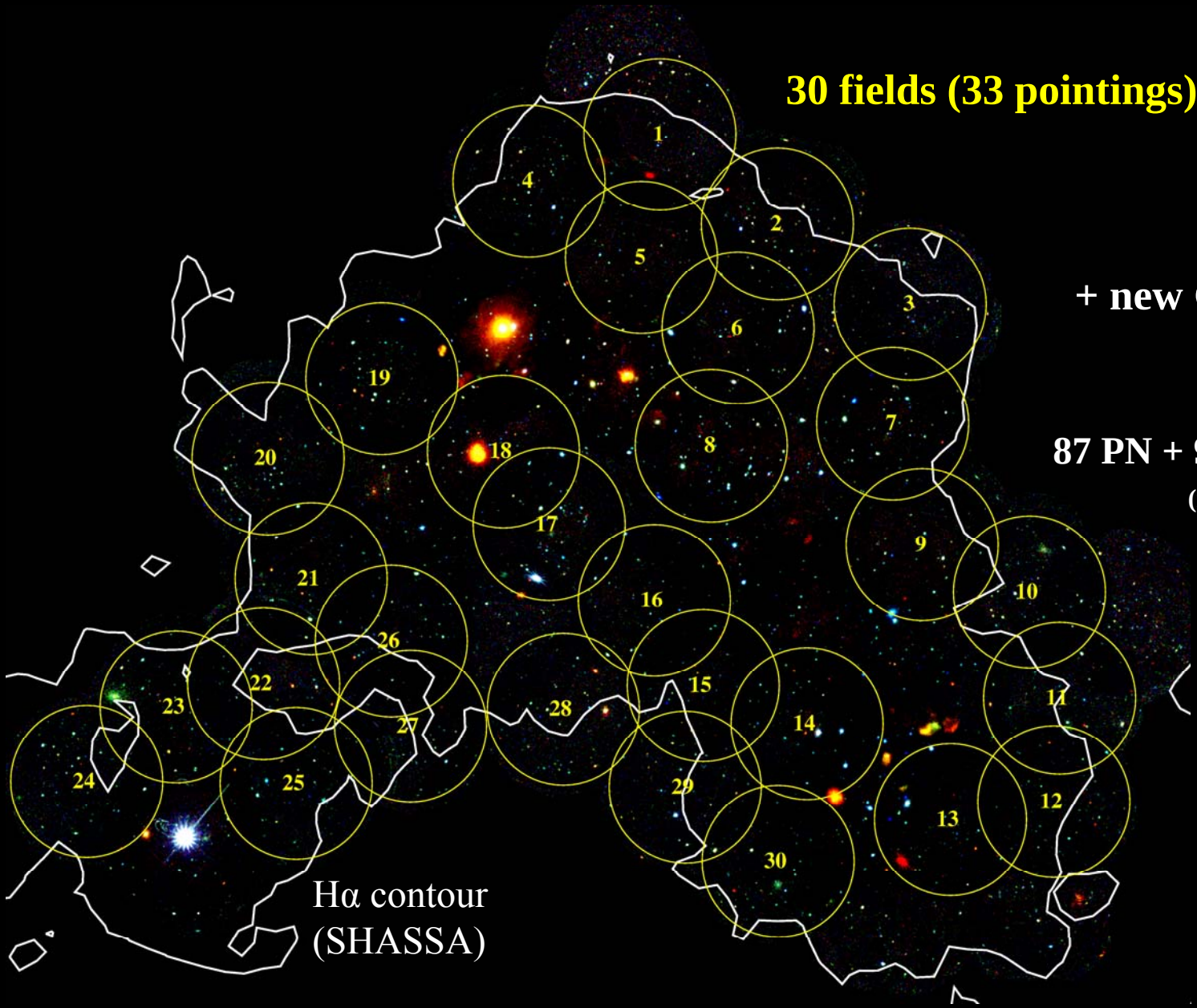
Archival XMM-Newton observations of the SMC



EPIC mosaic (2007)
pn in FF/eFF/LW mode
background flare screening
31 useful observations
4 pointings with enhanced bg

typical exposure: 10 – 20 ksec
max exposure @ 1E0102-72.3:
210 ksec (pn)
250 ksec (MOS)

The XMM-Newton survey of the SMC



30 fields (33 pointings) LP in AO8

+ new GO pointings

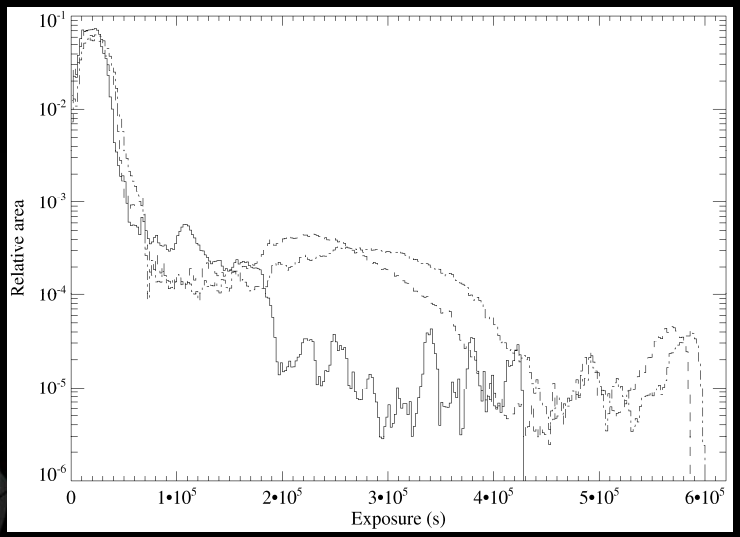
87 PN + 90 MOS exposures

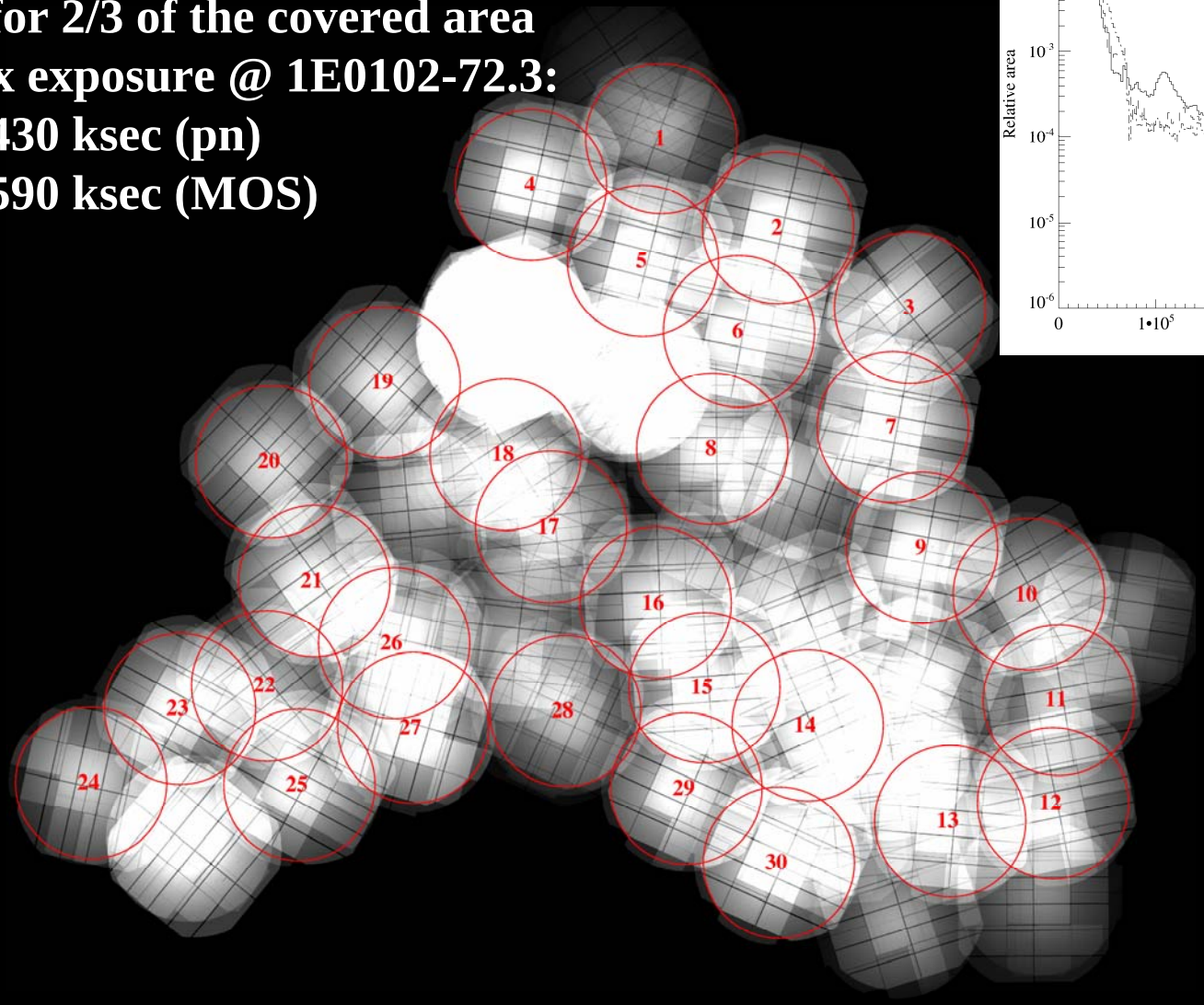
(noisy MOS CCDs removed, bg flare screening)

0.2 – 1.0 keV
1.0 – 2.0 keV
2.0 – 4.5 keV

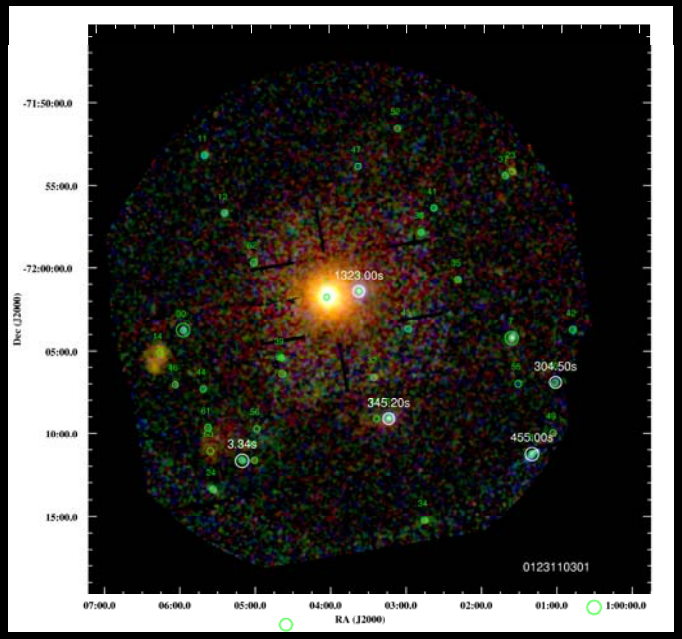
The XMM-Newton survey of the SMC

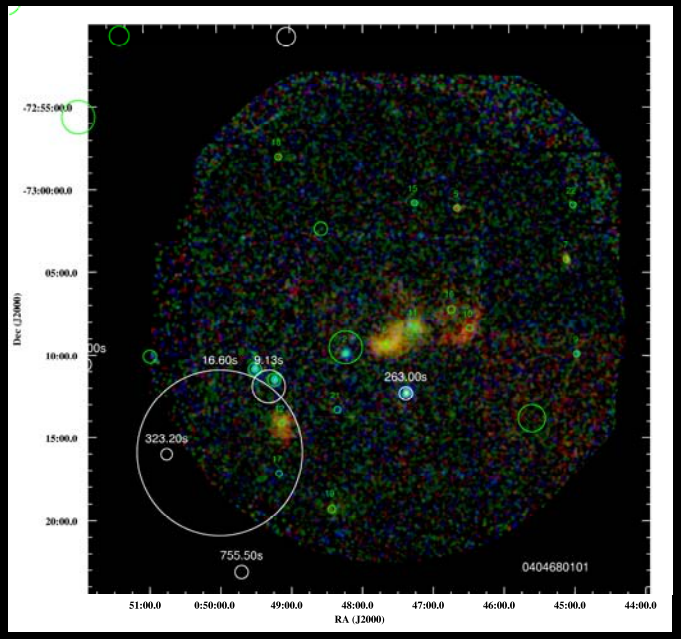
covered area of 5.5 square degrees
typical exposure: 10 – 30 ksec
for 2/3 of the covered area
max exposure @ 1E0102-72.3:
430 ksec (pn)
590 ksec (MOS)

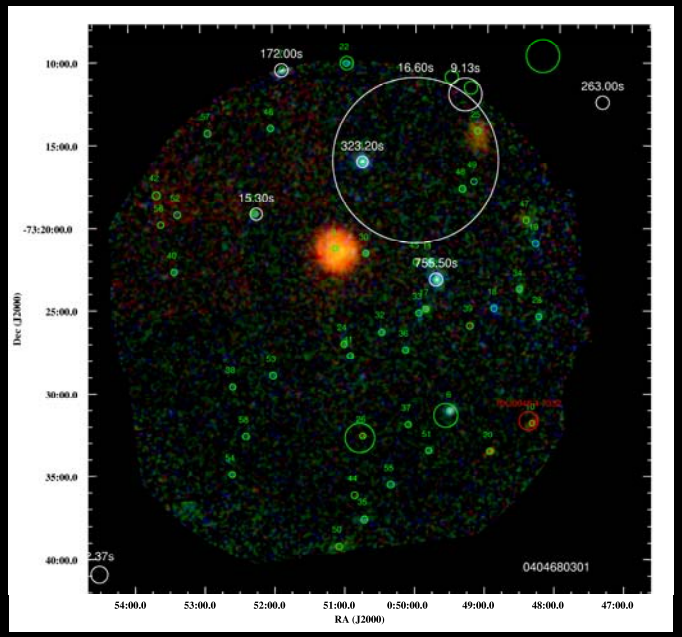




Catalogue of discrete sources







- 95 (-3) observations
- 28 of them on 1E0102-72.3
- astrometric boresight correction
- source detection simultaneously on 15 images
  5 energy bands, 3 EPIC instruments
  0.2-0.5 / 0.5-1.0 / 1.0-2.0 / 2.0-4.5 / 4.5-12 keV

- 5236 detections after manual screening
  (multiple detections in extended regions, oot events)
- 3053 individual sources
  2126 are detected once
  927 with multiple detections (maximum 34)

Catalogue of 3053 discrete sources

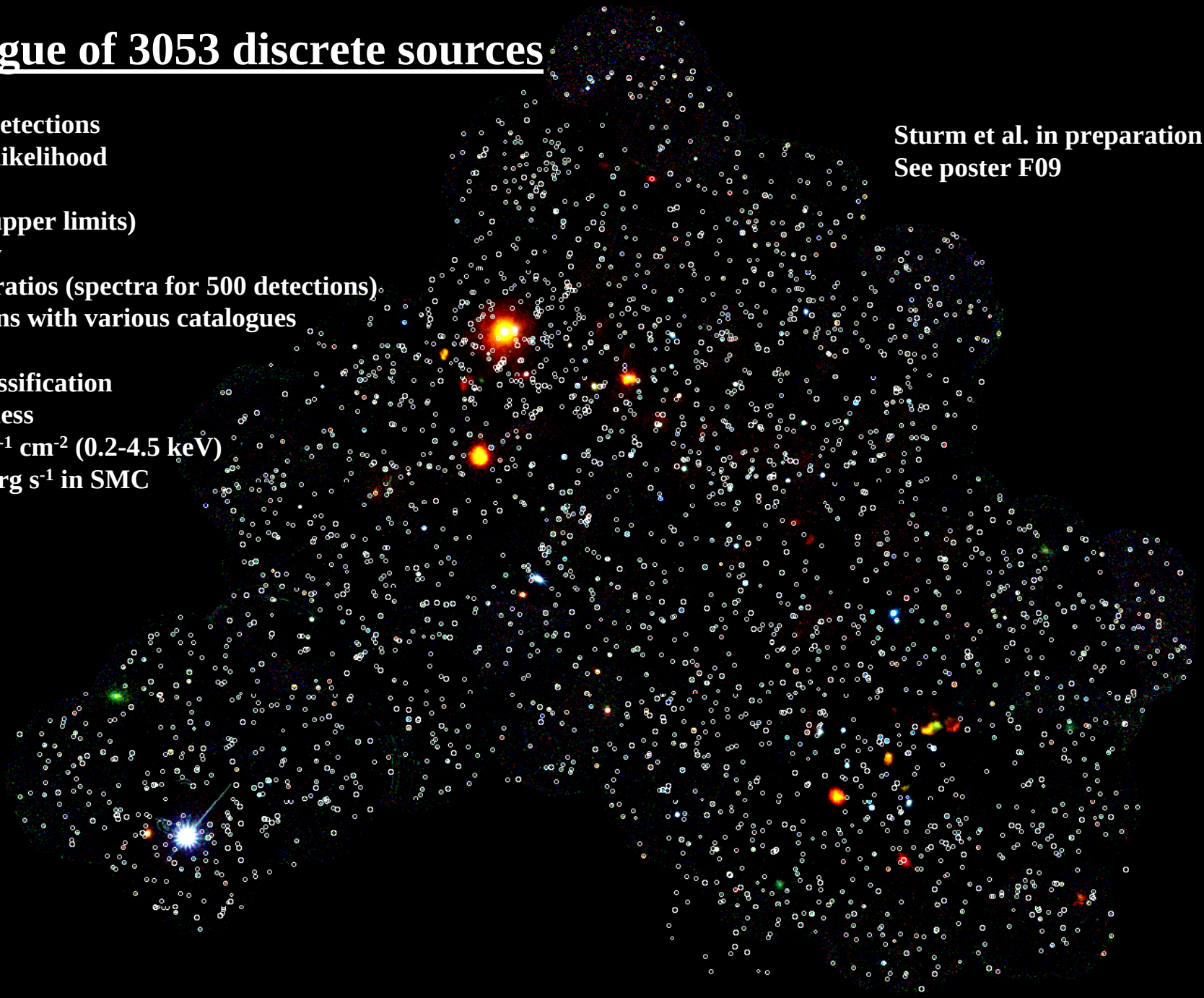
- multiple detections
- detection likelihood
- position
- fluxes (+ upper limits)
- variability
- hardness ratios (spectra for 500 detections)
- correlations with various catalogues
- f_x/f_{opt}
- source classification
- completeness

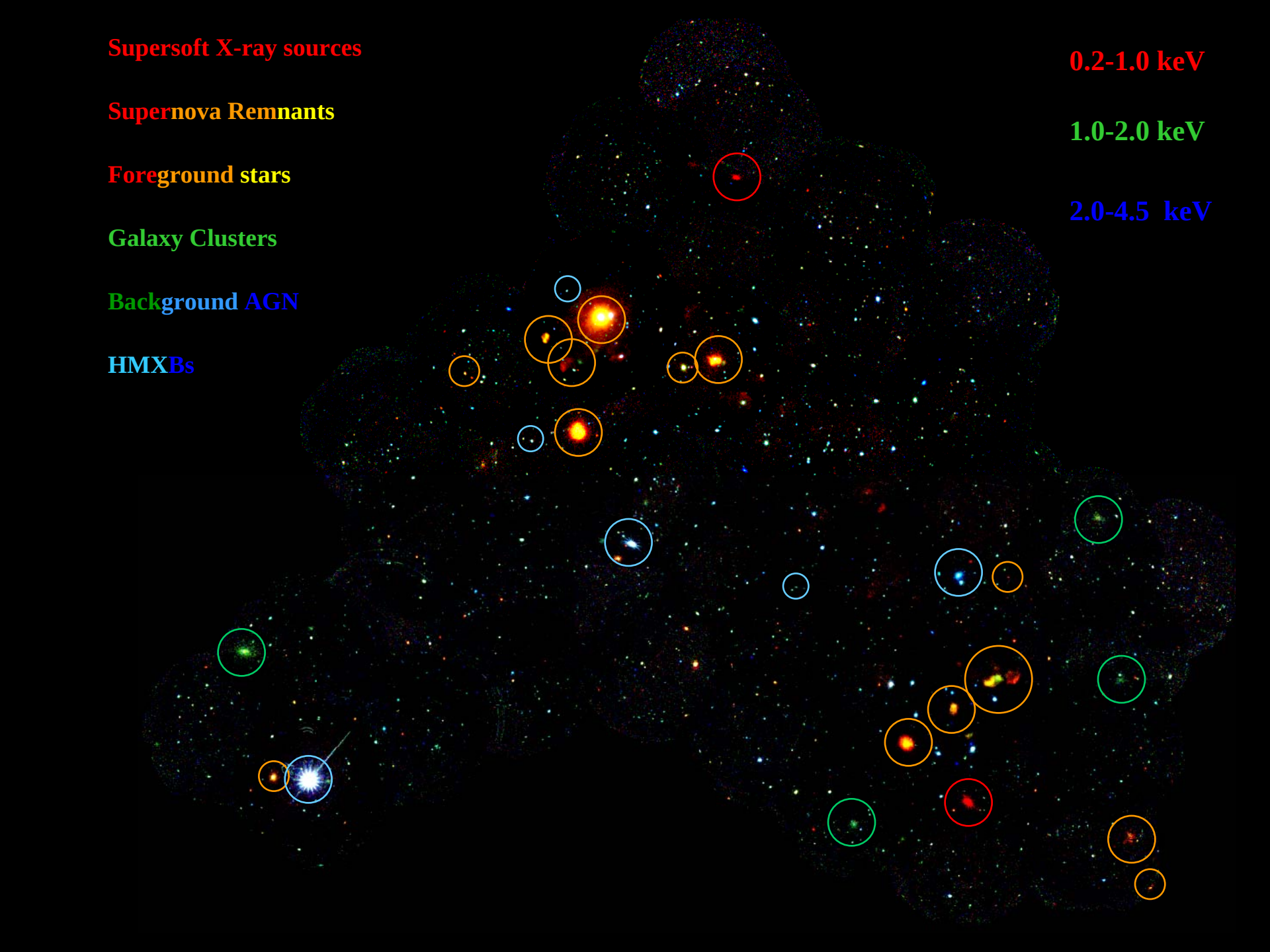
  10^{-14} erg s^{-1} cm^{-2} (0.2-4.5 keV)

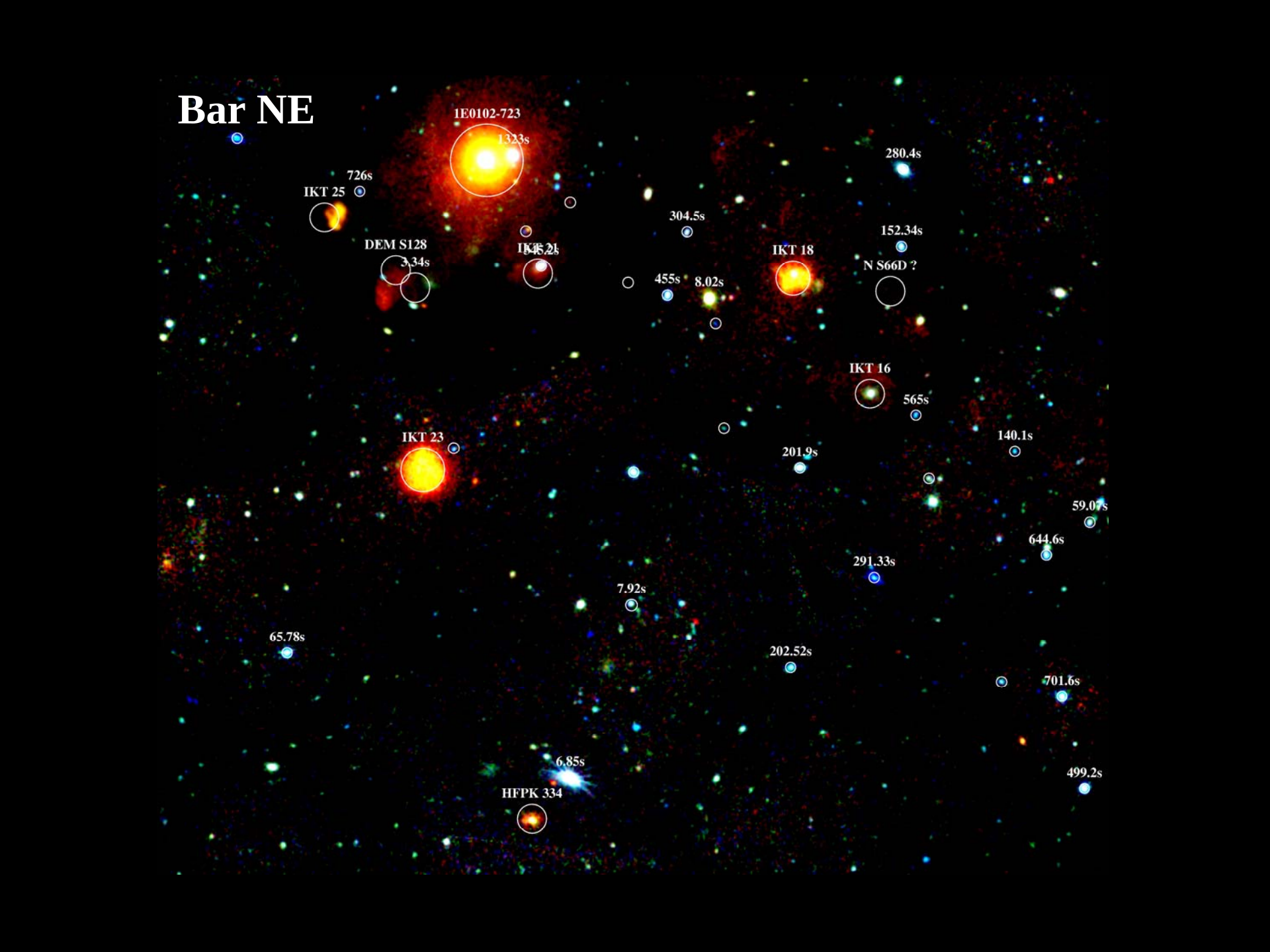
  4.3×10^{33} erg s^{-1} in SMC

Sturm et al. in preparation

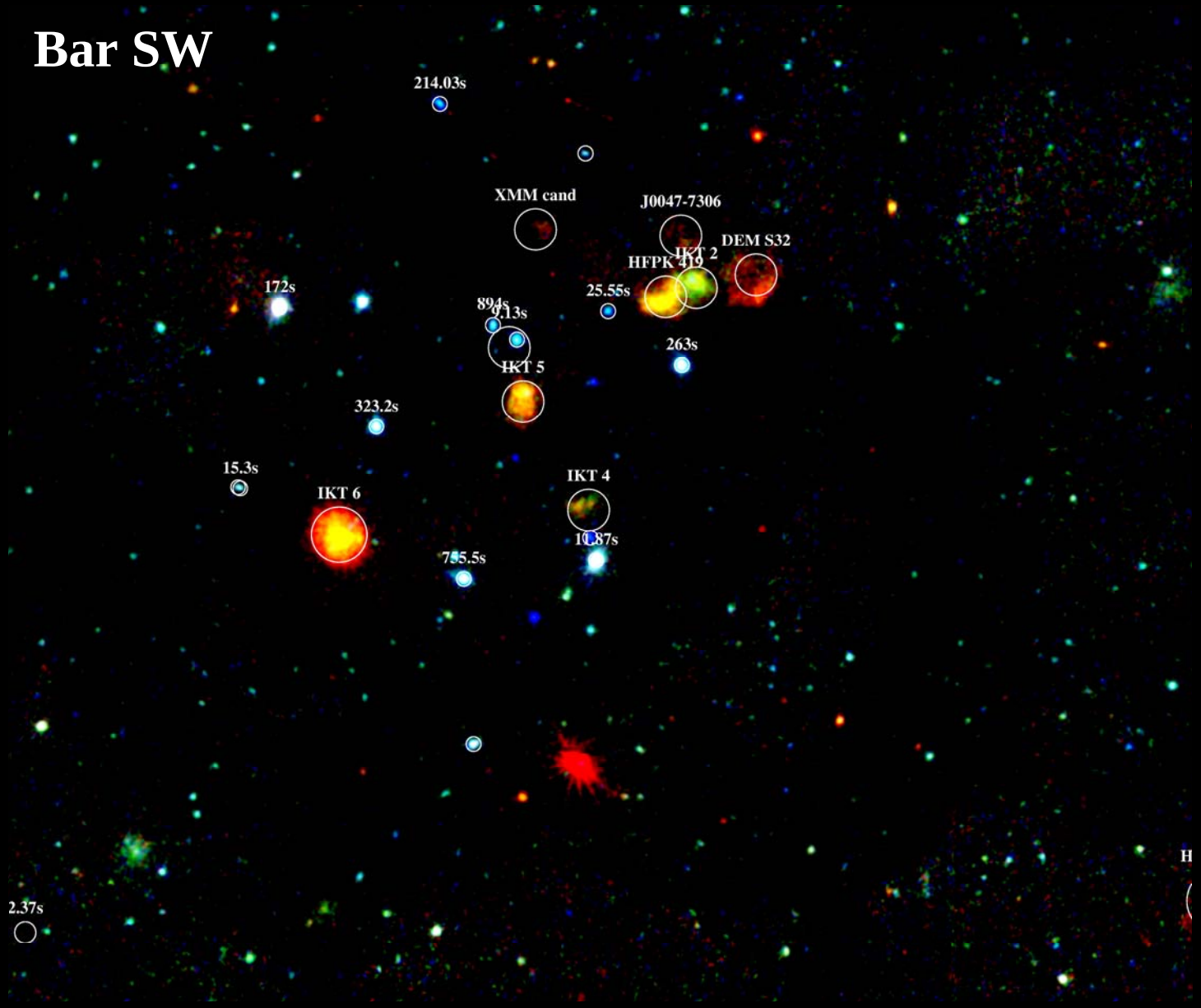
See poster F09



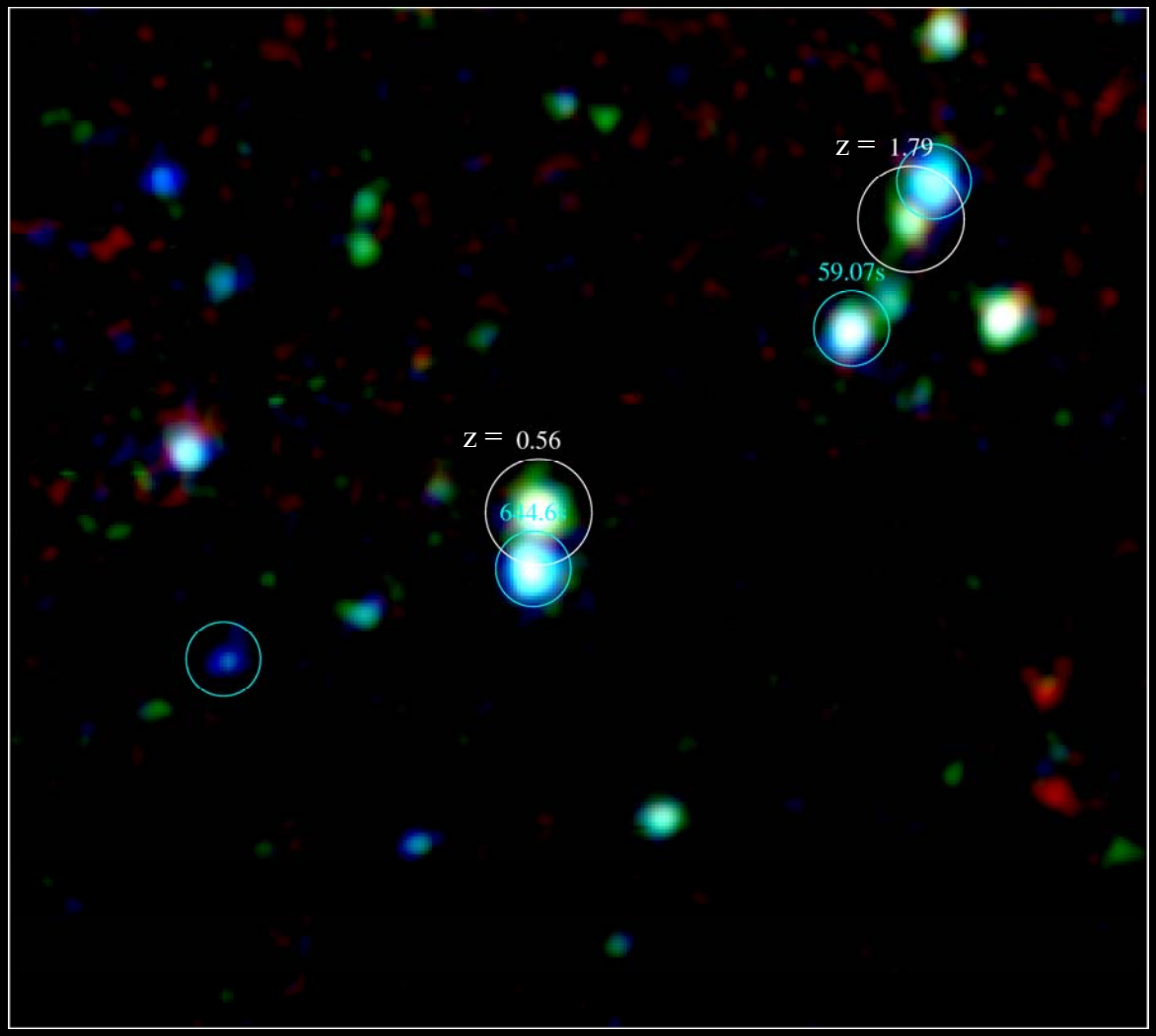

Supersoft X-ray sources
Supernova Remnants
Foreground stars
Galaxy Clusters
Background AGN
HMXBs
0.2-1.0 keV
1.0-2.0 keV
2.0-4.5 keV


Bar NE
1E0102-723
1323s
726s
IKT 25
280.4s
304.5s
152.34s
DEM S128
IKT 18
N S66D ?
455s
8.02s
IKT 16
565s
IKT 23
140.1s
201.9s
59.07s
644.6s
291.33s
7.92s
65.78s
202.52s
701.6s
6.85s
499.2s
HFPK 334

Bar SW


214.03s
XMM cand
J0047-7306
DEM S32
IKT 2
HFPK 419
172s
25.55s
894s
913s
263s
IKT 5
323.2s
15.3s
IKT 6
IKT 4
10.87s
755.5s
2.37s

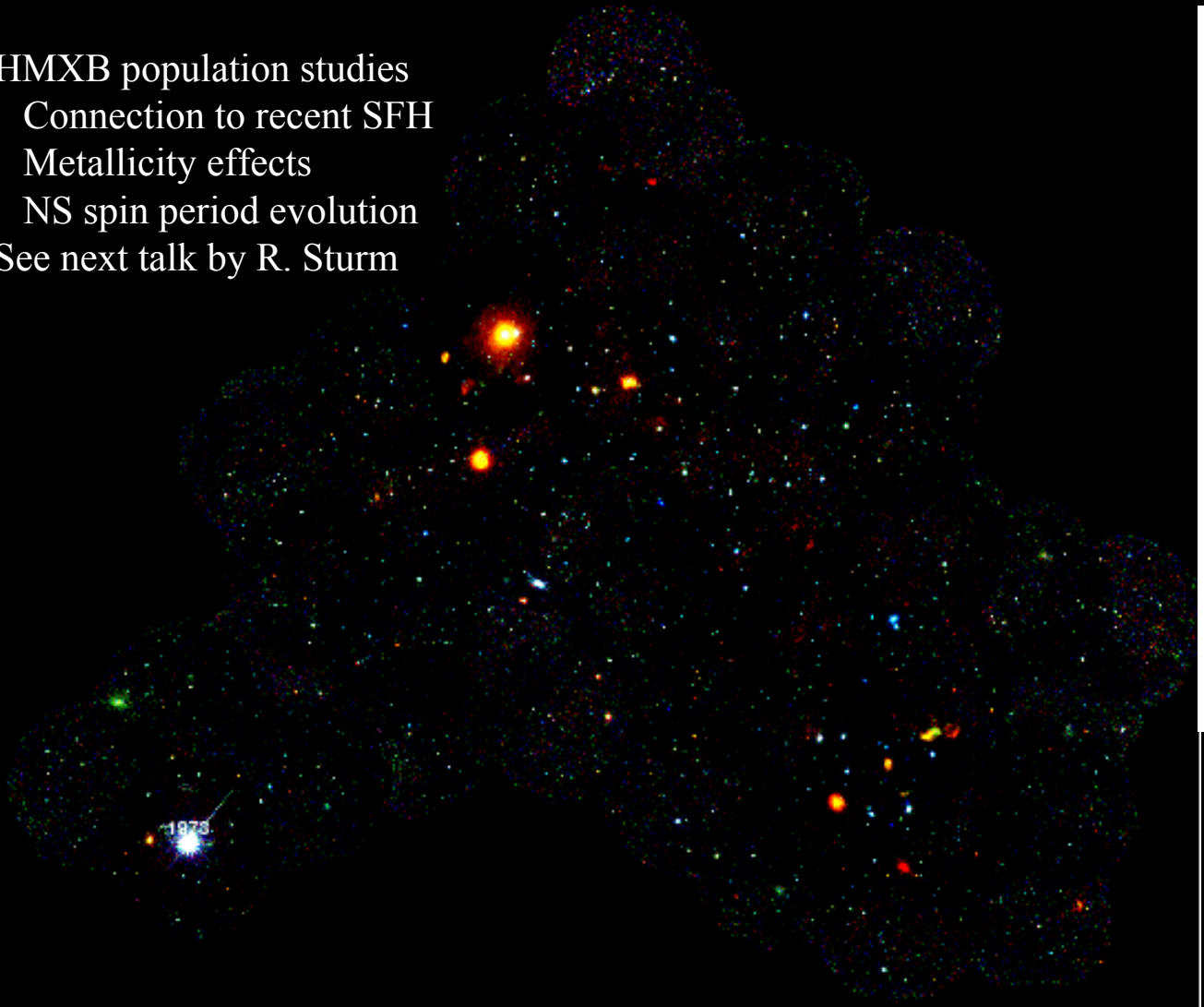
HMXBs and AGN

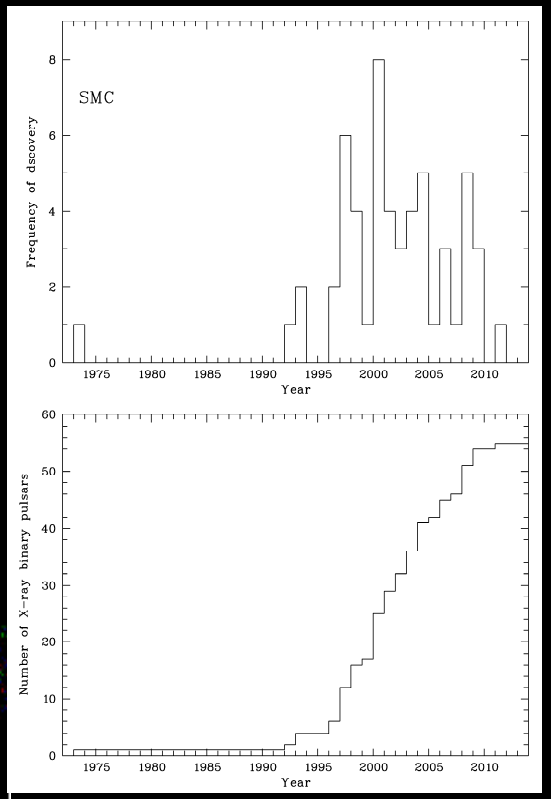


An exceptionally large number of HMXBs in the SMC

HMXB population studies
- Connection to recent SFH
- Metallicity effects
- NS spin period evolution

See next talk by R. Sturm





55 HMXB pulsars
51 with known positions

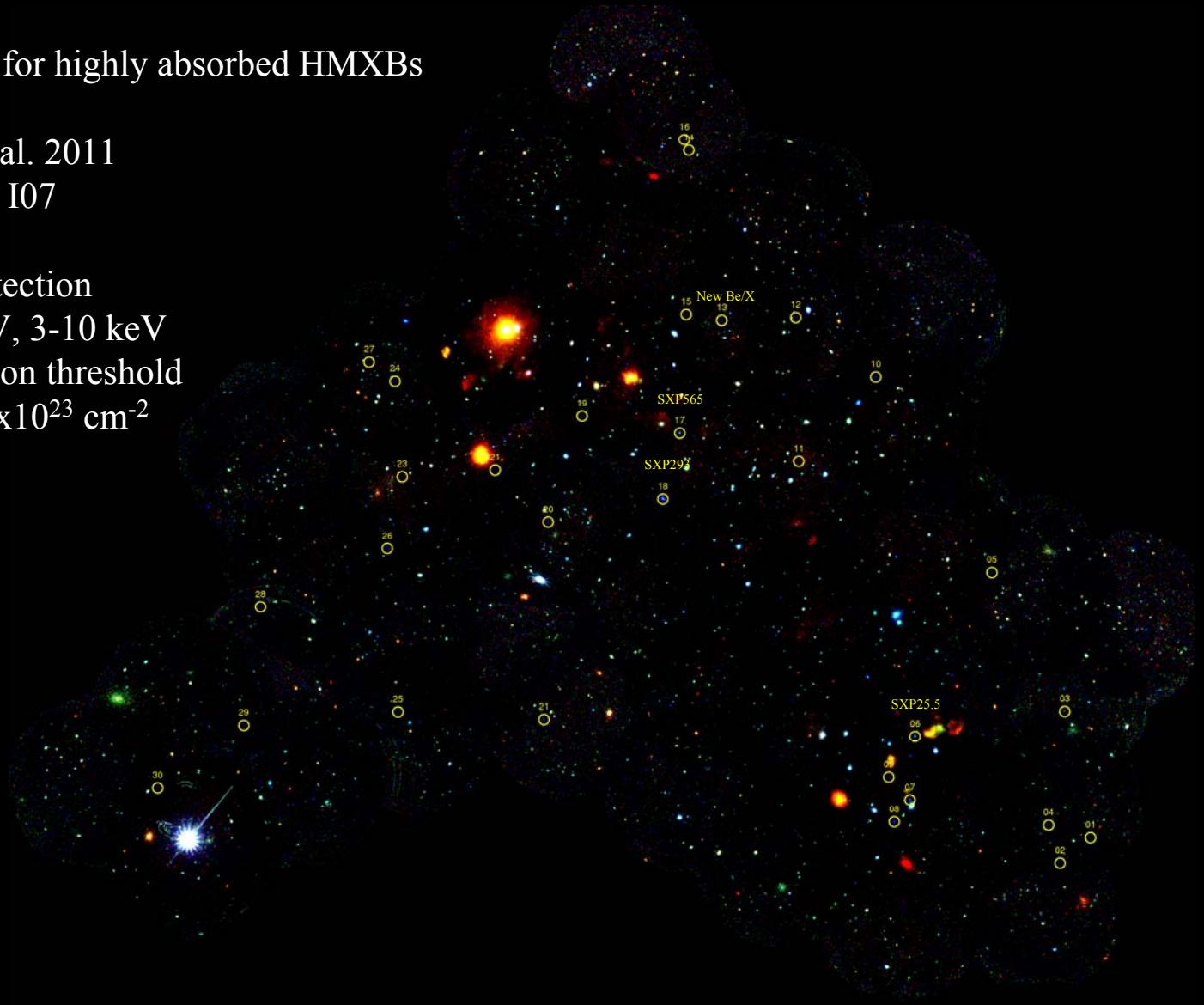
Many discoveries of X-ray transients with RXTE, ASCA, ROSAT, BeppoSAX
Chandra and XMM-Newton can do spectral and timing analysis down to 10^{34} erg/s

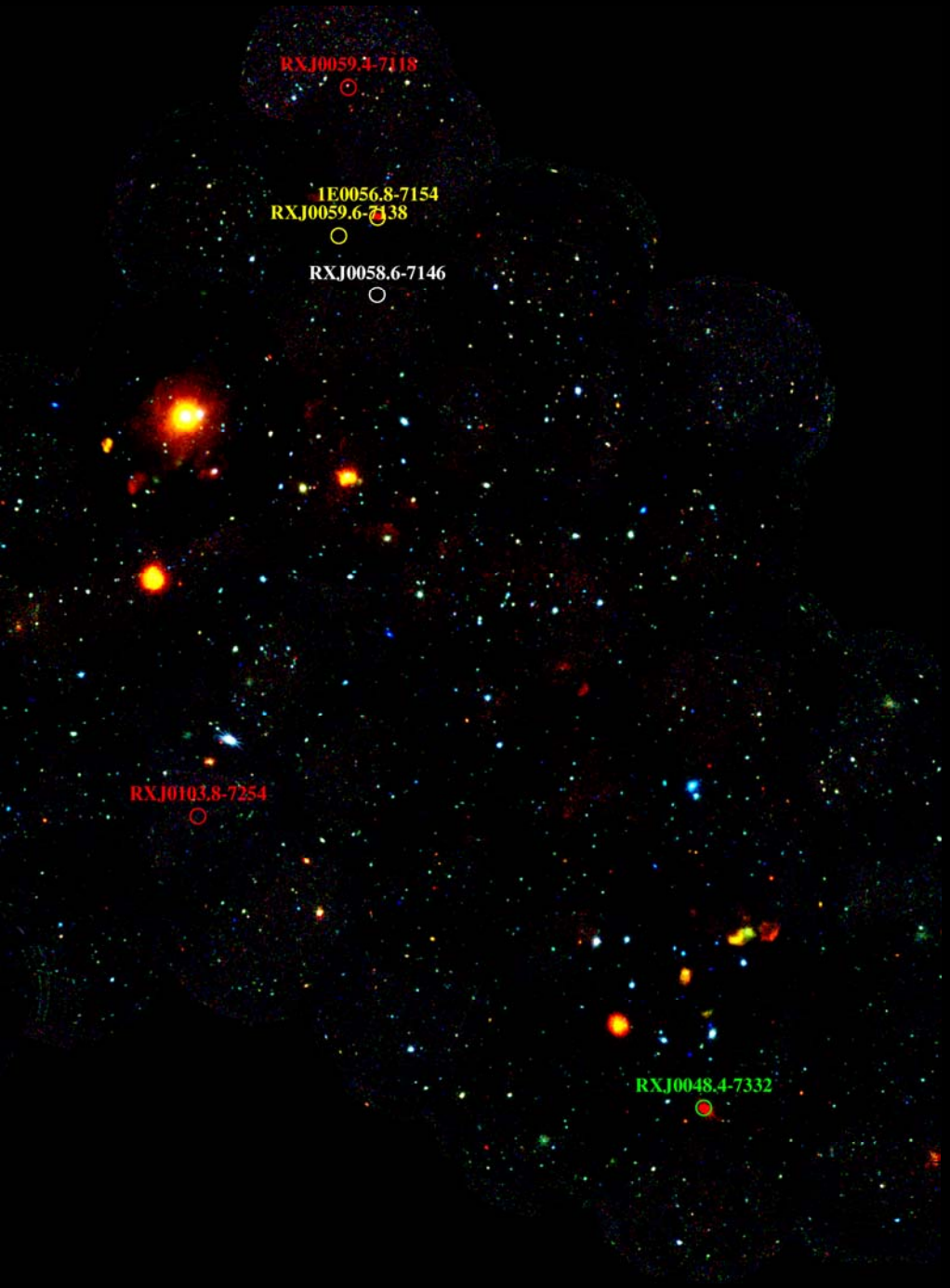
Highly absorbed sources

Searching for highly absorbed HMXBs

Novara et al. 2011
See poster I07

Source detection
1-3 keV, 3-10 keV
HR selection threshold
$N_H > 3x10^{23}$ cm^{-2}





Supersoft X-ray sources

Old population involving white dwarfs
Best observable in the Magellanic Clouds
Located in outer (older) parts

Classical SSS (stable H burning)
RXJ0058.6-7146 not detected
1E0035.4-7230 not covered (west)

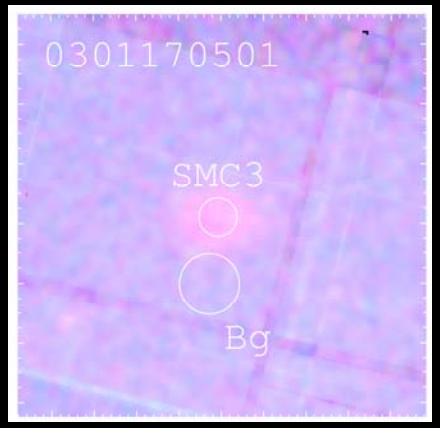
Planetary Nebulae (cooling central star)
1E0056.8-7154 LIN 333, SMP SMC 22
RXJ0059.6-7138 LIN 357, SMP SMC 25
(Mereghetti et al. 2010 – see poster E09)

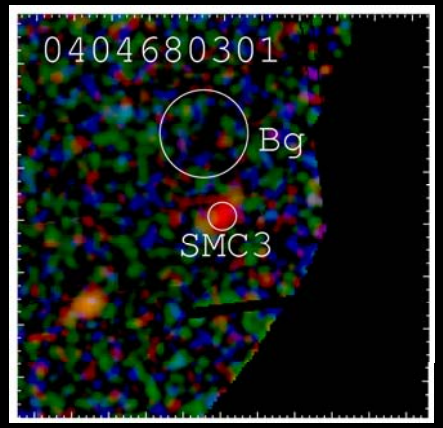
Symbiotic Systems (cool red giant):
RXJ0059.1-7505 LIN 358 (Kahabka & Haberl 2006)
in pointing to the south
RXJ0048.4-7332 SMC 3 (Sturm et al. 2011)

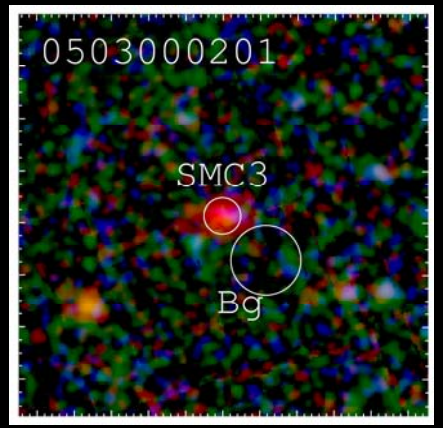
Faint SSS
RXJ0059.4-7118 foreground object?
RXJ0103.8-7254 not detected
RXJ0050.5-7455 (in pointing to the south)

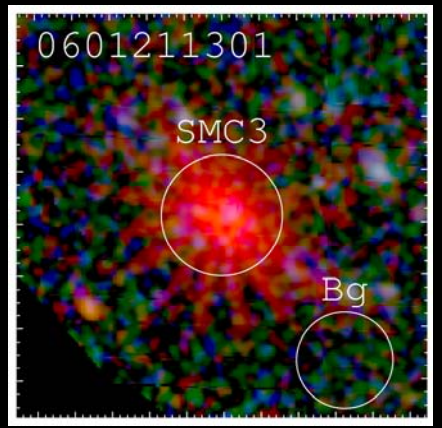
SSS+Be star (Be/WD X-ray binary)
see following talk by R. Sturm

Supersoft X-ray sources: RXJ0048.4-7332 = SMC 3

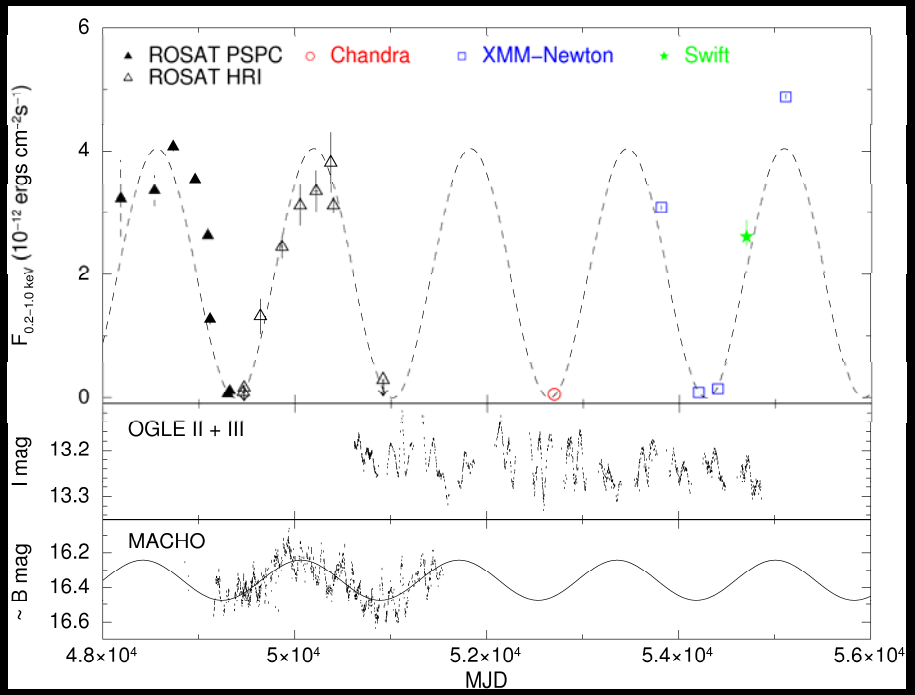


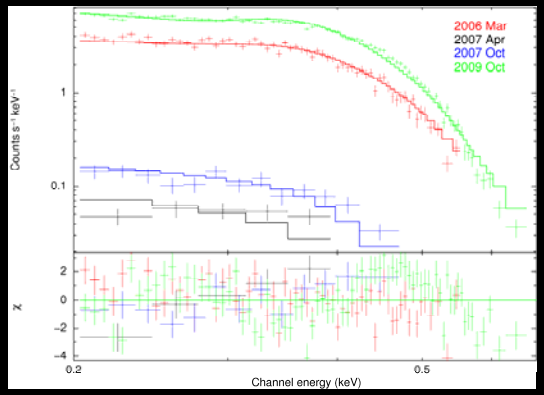






20 year light curve: highly variable - factor 50
4.5 year period





EPIC-pn spectra:

1) exclude variations caused by changing absorption by neutral gas

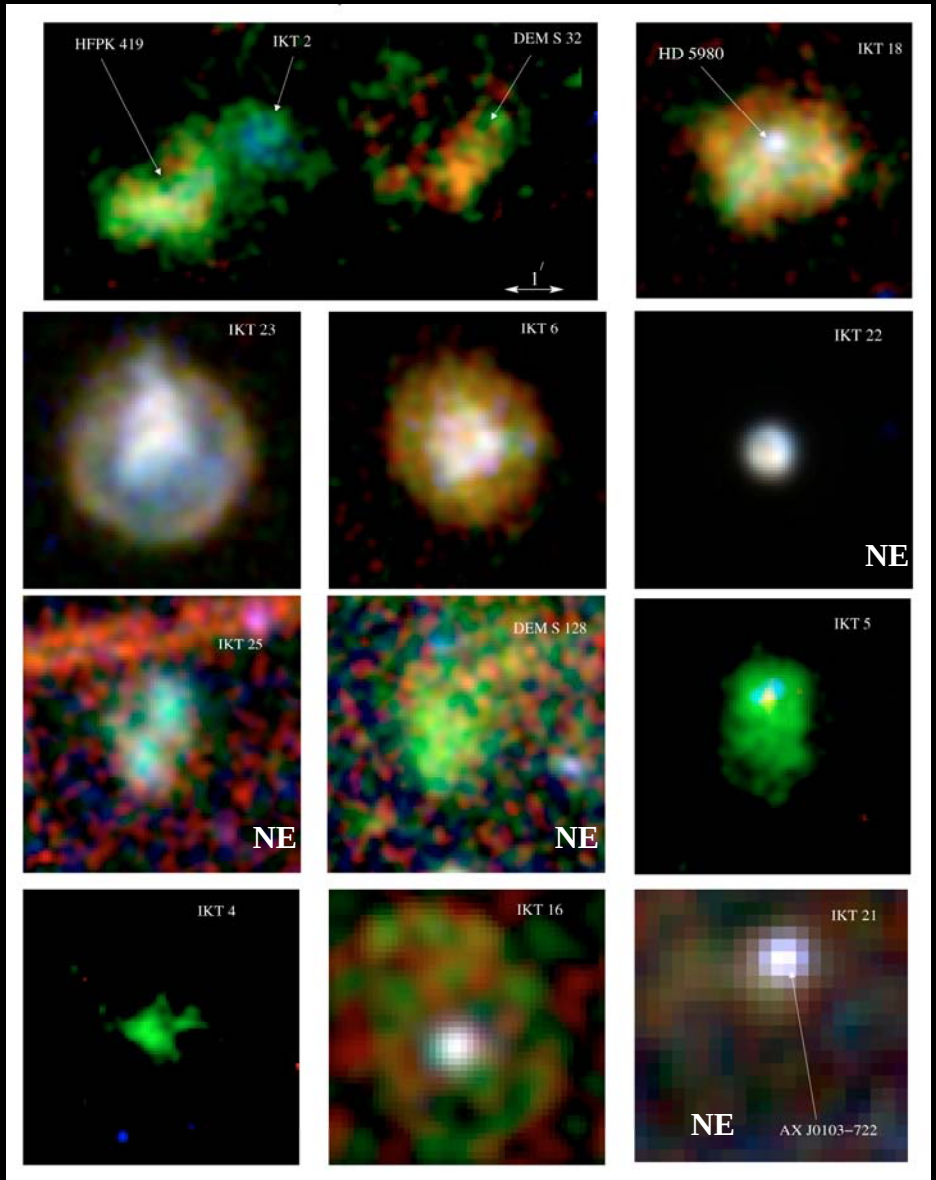
2) N_H and T constant, L varies 10^{37} – $6x10^{38}$ erg/s
Compton scattering in highly ionised gas?
Eclipse by star and stellar wind

3) N_H constant, T varies ($L \sim T^4$) 24-34 eV
Lbol changes by factor 4.3
variable accretions leads to changes in T?

Sturm et al. 2011, A&A 529, A152

Supernova Remnants

Concentration in regions of recent star forming activity in SMC bar



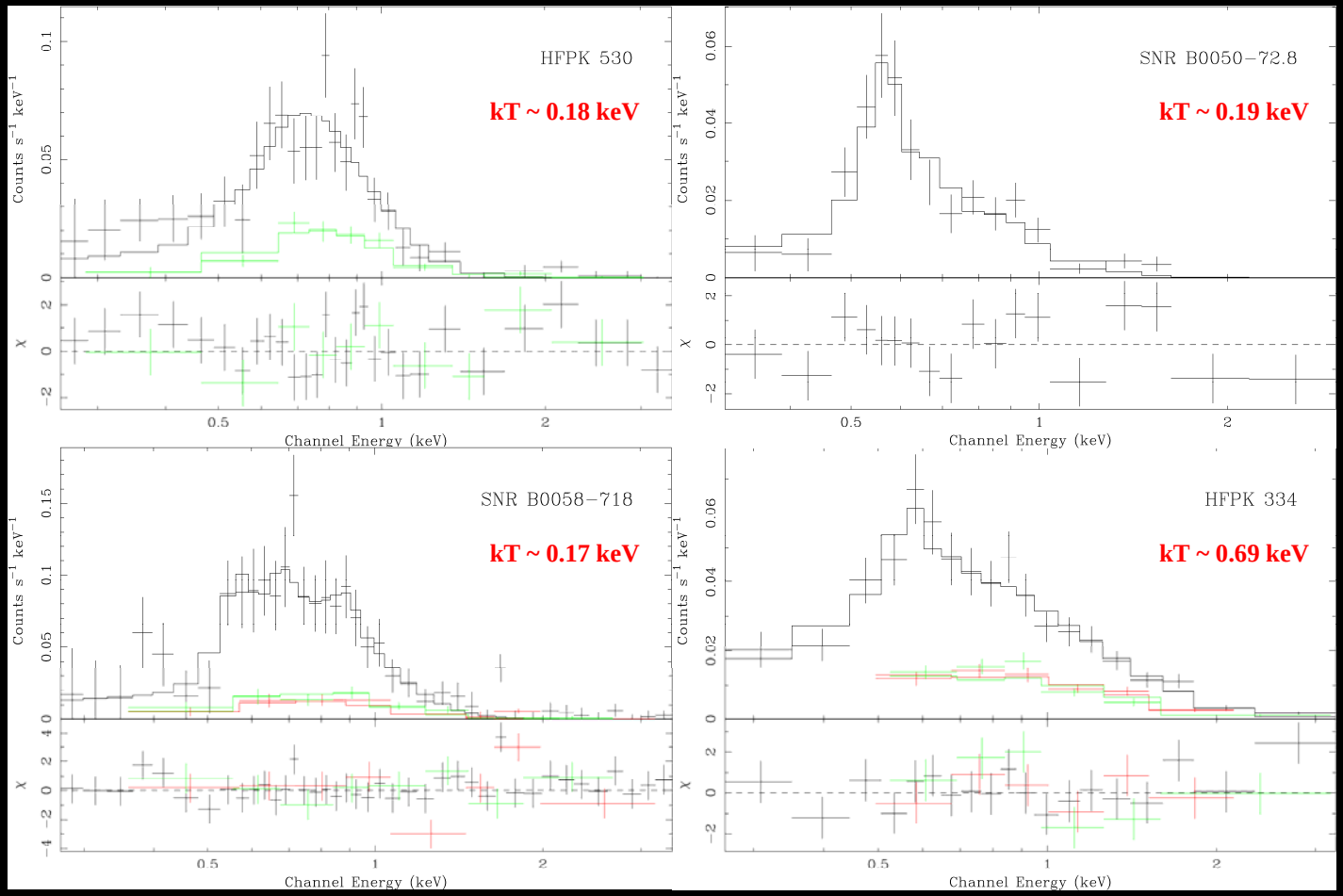
van der Heyden et al. 2004
- synoptic study of 13 known SNRs
  - EPIC images
  - Spectra

Filipovic et al. 2008
- three X-ray faint SNRs
- one new candidate

Owen et al. 2011
- IKT 16
- hard point source inside
- (see talk session E1)

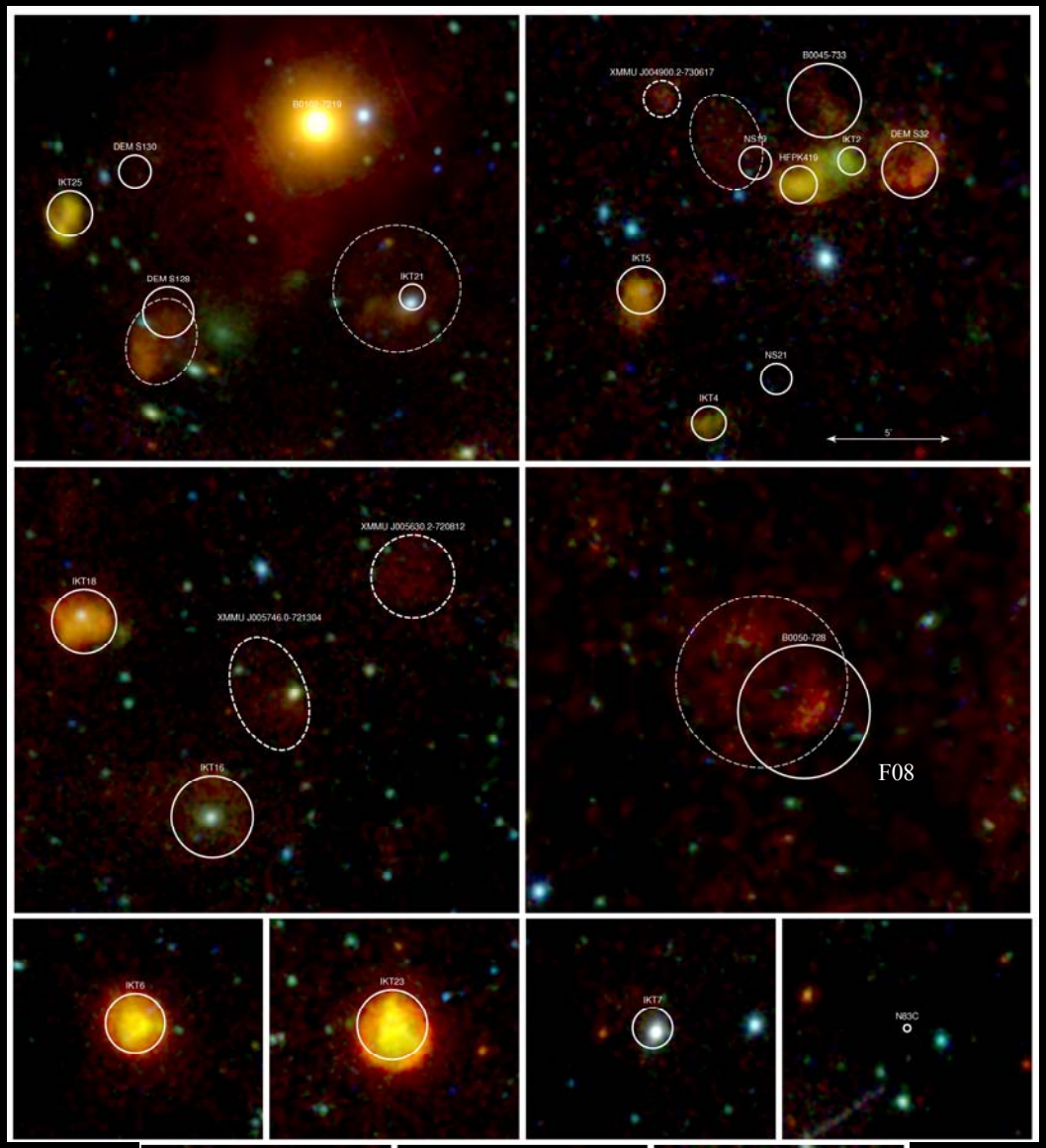
Supernova Remnants

Faint SNRs not covered by van der Heyden at al. (2004)
EPIC X-ray spectra (NEI model)



Filipovic et al. (2008)

Supernova Remnants



enhanced statistics
imroved images
- **out-of-time events subtracted**
- **detector background subtracted**
- **vignetting corrected**

a number of SNRs show larger extent
- **compare Badenes et al. 2010**

new candidates with low surface brightness and large extent

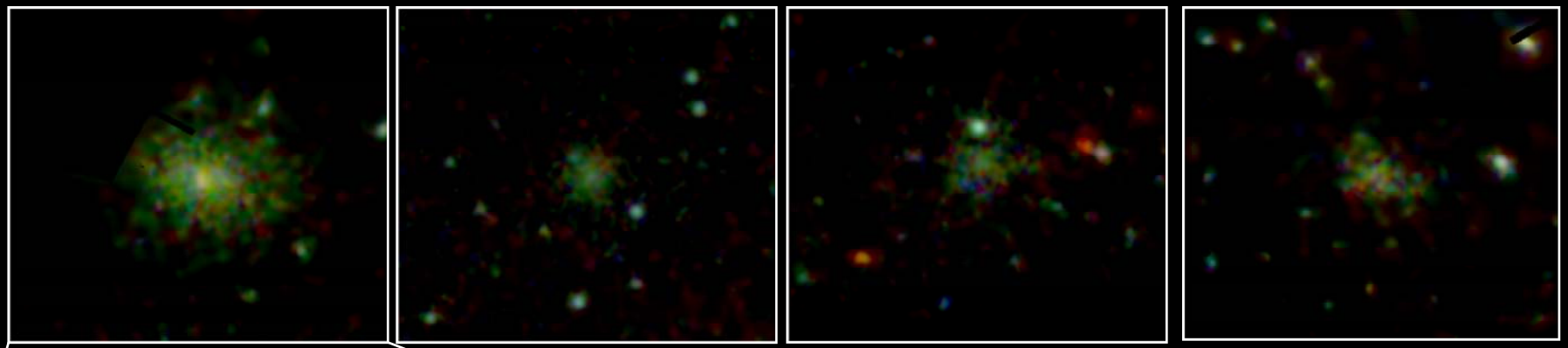
no SNR at position of IKT 7 (172s Be XRB)

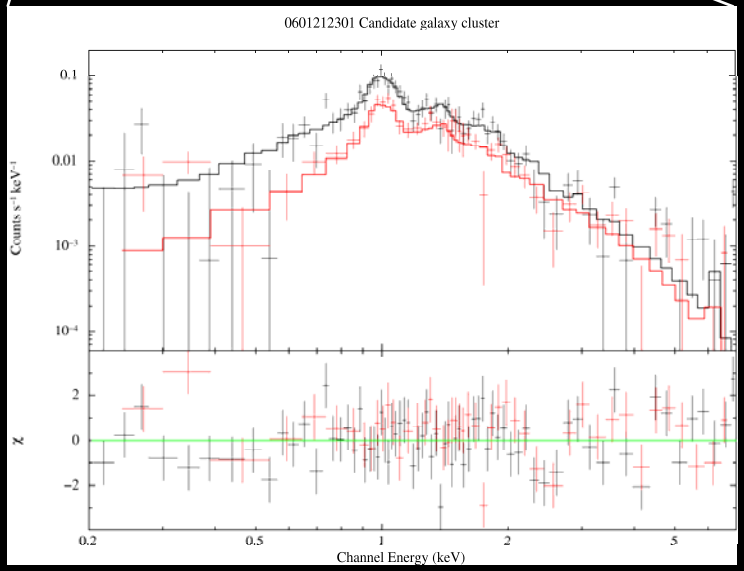
no detection of DEM S130, NS21 and N83C

Haberl et al. in preparation

F08 = Filipovic et al. (2008)

Other extended sources – Clusters of galaxies





Mekal model:

$N_H = 4x10^{21}$ cm^{-2}
kT = 1.7 keV
z = 0.07±0.01

Summary

The XMM-Newton survey of the SMC provides a unique data set
for X-ray source population studies.
It complements surveys at other wavelengths.

- Supernova remnants
  - Interaction with their environment
- High Mass X-ray binaries
  - A large population of Be/X-ray binaries in the SMC
  - Allows statistical studies (SFH, spin periods)
- Supersoft X-ray sources
  - Discovered as a heterogeneous class of X-ray sources in the MCs
  - The nature of faint supersoft sources

Classification of new sources by

- X-ray properties (energy spectrum, temporal behaviour)
- Information from other wavelength (radio, optical)
- Remove foreground (stars) and background (AGN) objects