



# WHAT HAVE WE LEARNED FROM THE XMM-NEWTON SURVEYS OF LOCAL GROUP GALAXIES?

Frank Haberl

Max-Planck-Institut für extraterrestrische Physik

- Accretion onto compact objects
- Supernova remnants
- The hot interstellar medium

- **The Small Magellanic Cloud**

A unique population of high-mass X-ray binaries

- **The Large Magellanic Cloud**

Supernova remnants

- **The Andromeda galaxy (M31)**

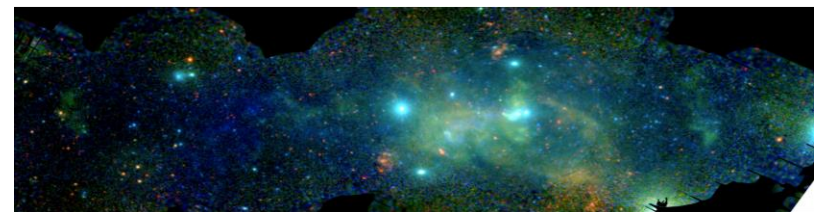
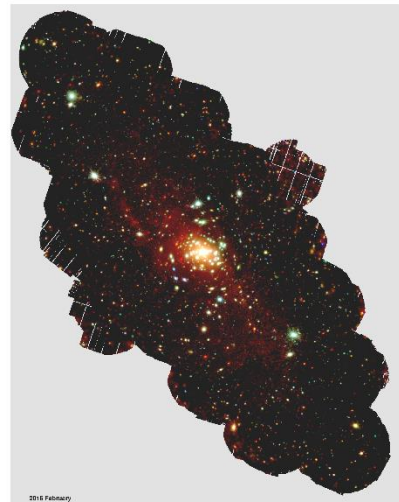
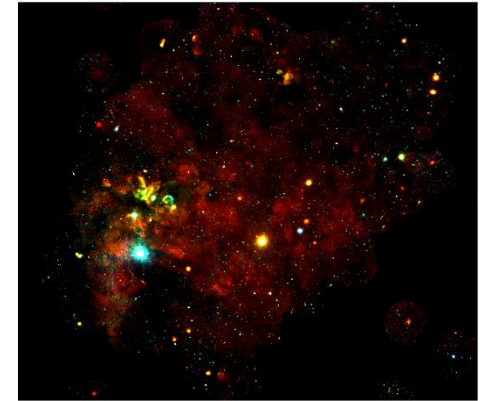
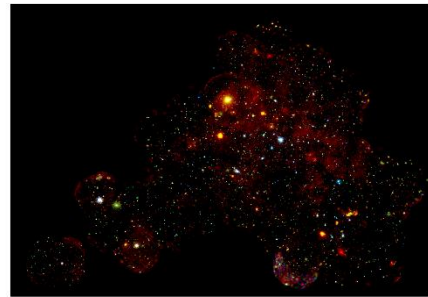
Classical Novae as supersoft X-ray sources

- **The Triangulum galaxy (M33)**

Supernova remnants

- **The Milky Way**

Galactic centre scan



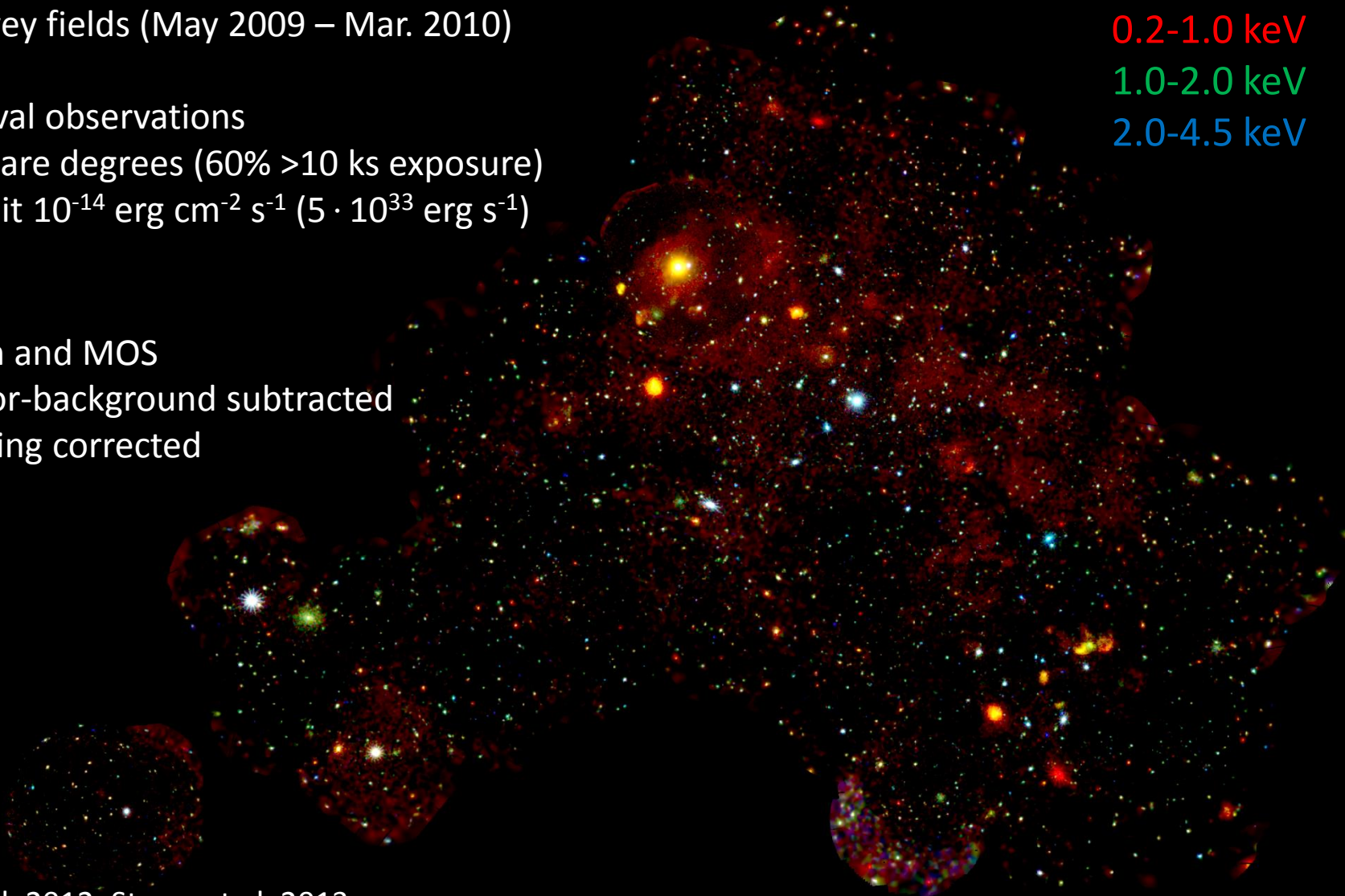


# The XMM-Newton survey of the SMC

30 survey fields (May 2009 – Mar. 2010)  
1 Ms  
+ archival observations  
5.5 square degrees (60%  $>10$  ks exposure)  
flux limit  $10^{-14}$  erg cm $^{-2}$  s $^{-1}$  ( $5 \cdot 10^{33}$  erg s $^{-1}$ )

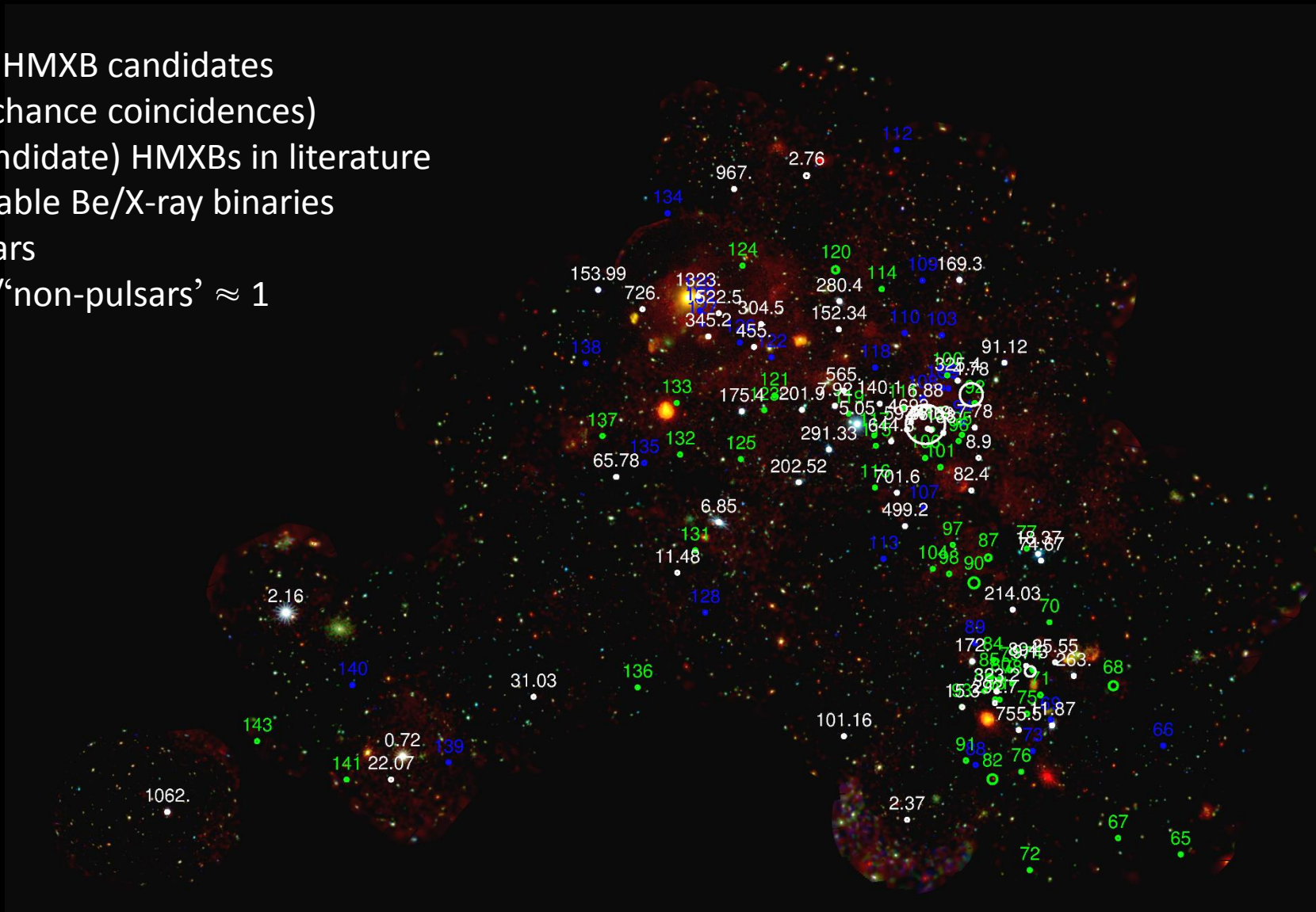
EPIC pn and MOS  
detector-background subtracted  
vignetting corrected

0.2-1.0 keV  
1.0-2.0 keV  
2.0-4.5 keV



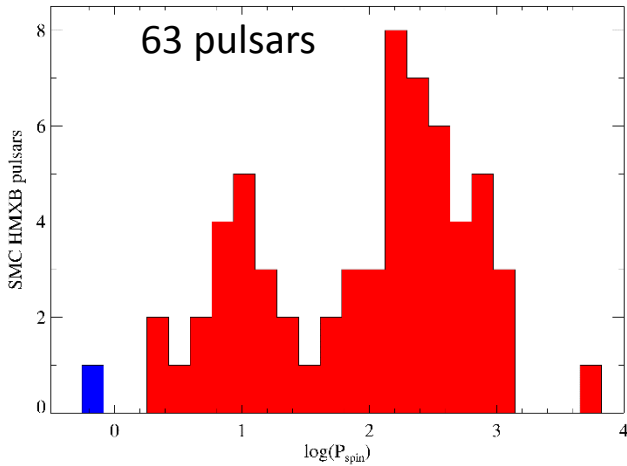
# High mass X-ray binaries in the SMC

- 40 new HMXB candidates
- (15-20 chance coincidences)
- 147 (candidate) HMXBs in literature
- 120 reliable Be/X-ray binaries
- 63 pulsars
- pulsars/‘non-pulsars’  $\approx 1$

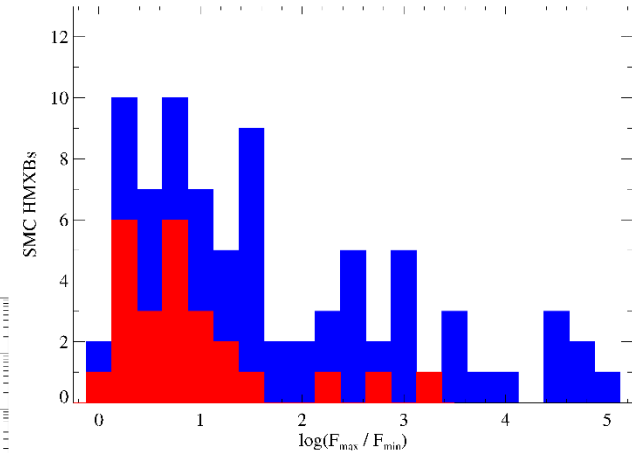
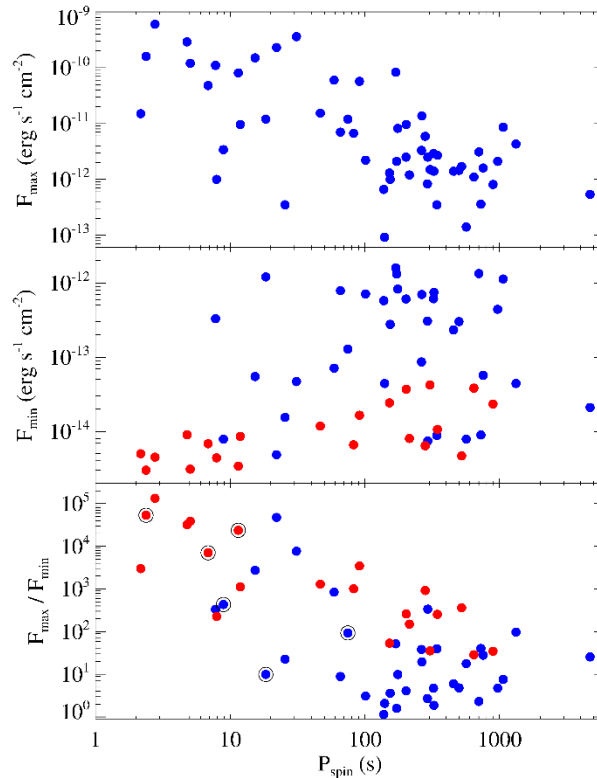




# High mass X-ray binaries in the SMC



- Knigge et al. 2011: Two different types of SNe
  - 1) Capture of electrons by a 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



- Variability distribution for pulsars and non-pulsars are consistent
- Long periods expected for non-pulsars
- Alignment of rotation / magnetic axes?

70 survey fields

2 Ms

(Dec. 2011 – Mar. 2014)

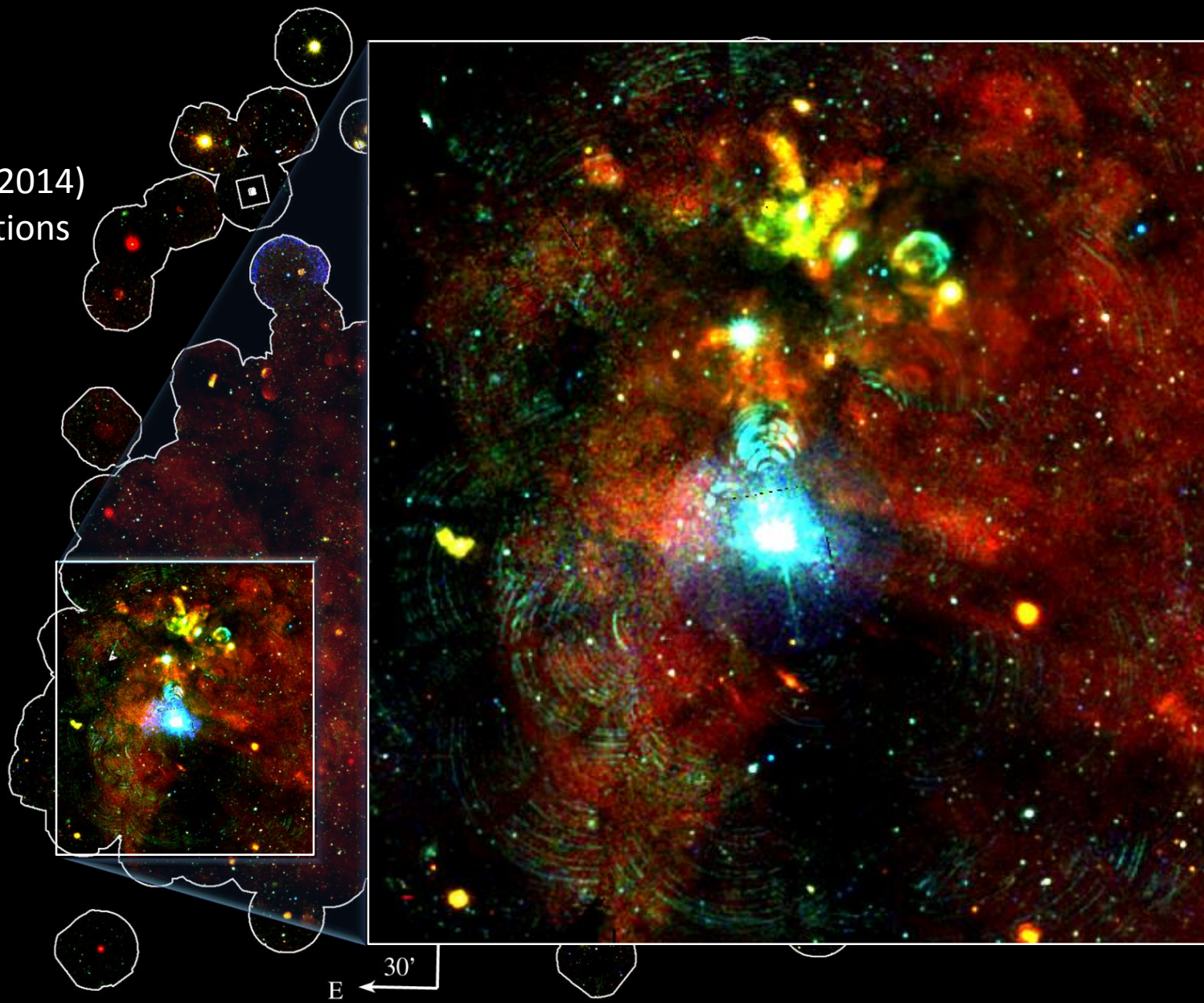
+ archival observations

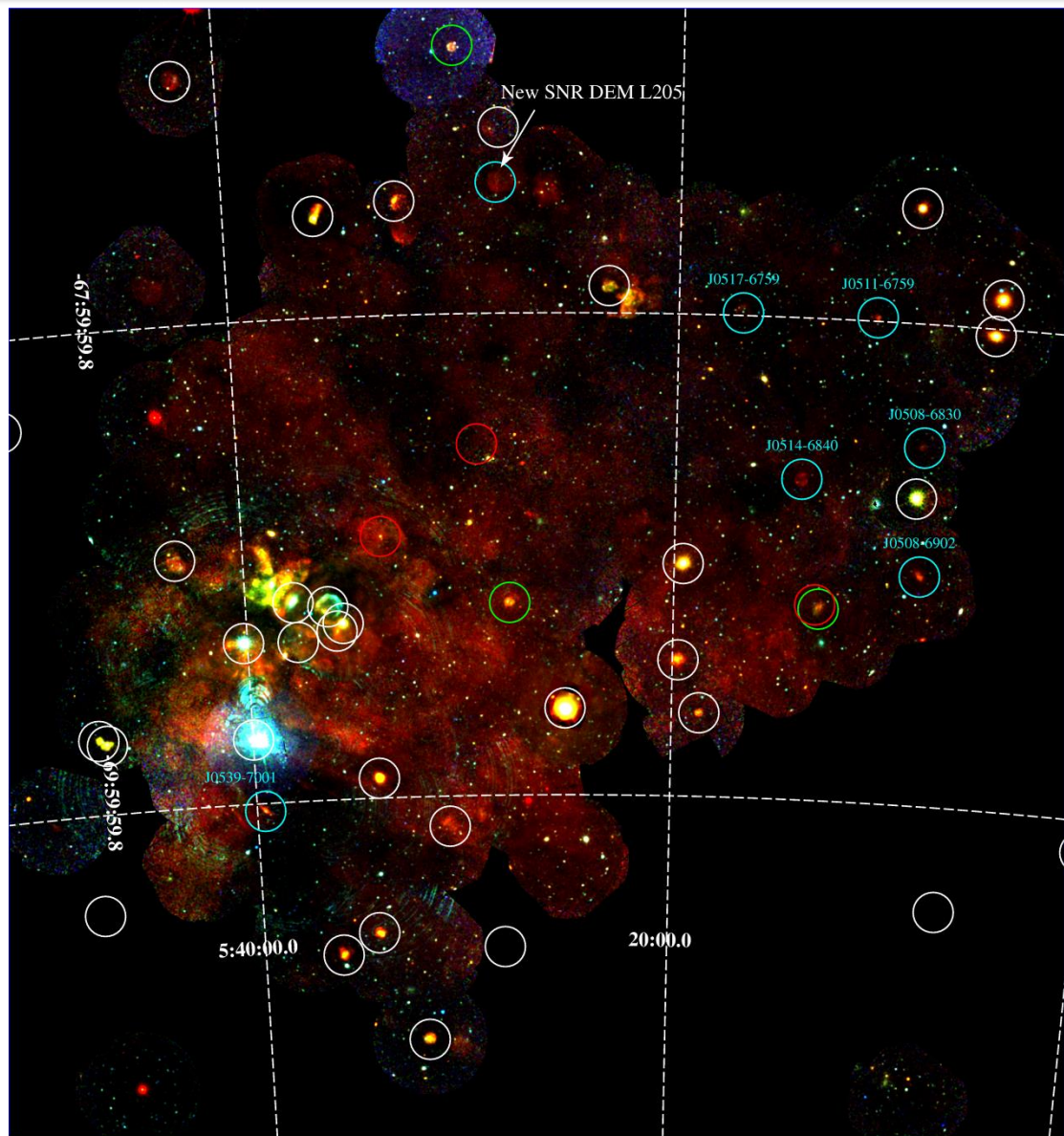
10 square degrees

0.2-1.0 keV

1.0-2.0 keV

2.0-4.5 keV





## SNRs in the LMC survey

J0508-6902 (Fe)  
Bozzetto et al. 2014

J0508-6830 (Fe)

J0511-6759 (Fe)

J0514-6840

J0517-6759

Maggi et al. 2014

J0528-6727 (DEM L205)

Maggi et al. 2012

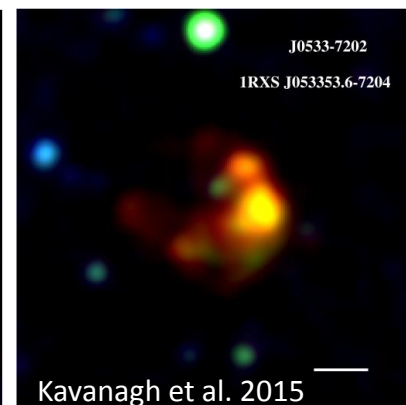
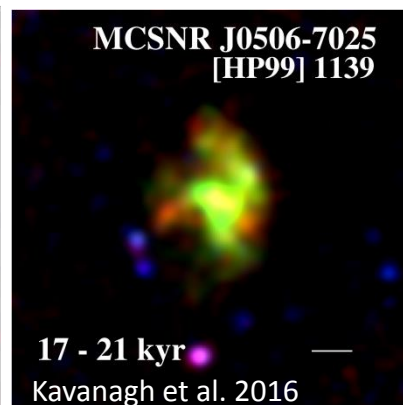
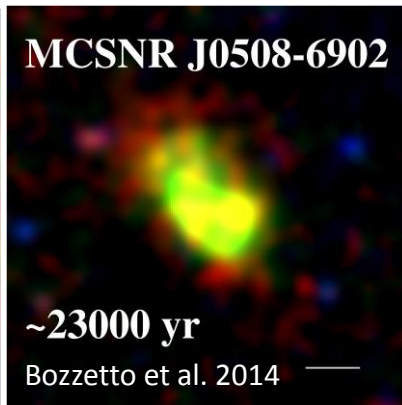
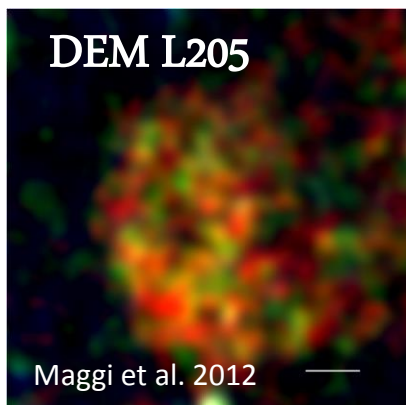
(Fe):

X-ray spectra dominated by  
Fe L-shell lines

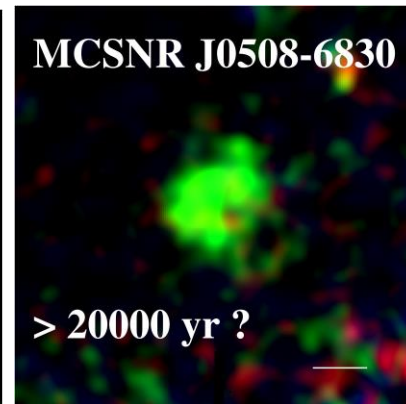
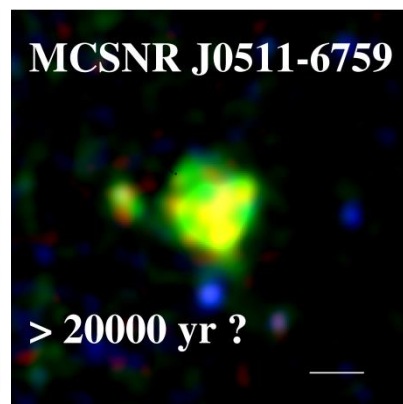
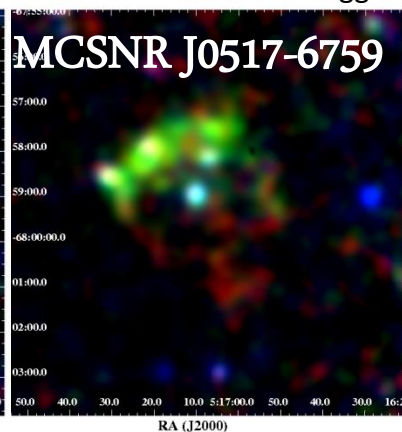
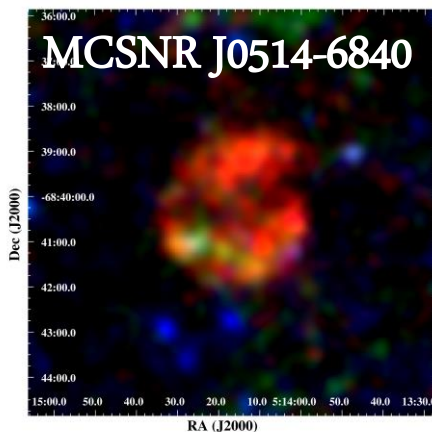
Thermonuclear origin (Ia)

Faint/X-ray soft SNRs  
cannot be observed in the  
Galaxy

# New LMC supernova remnants



Maggi et al. 2014:



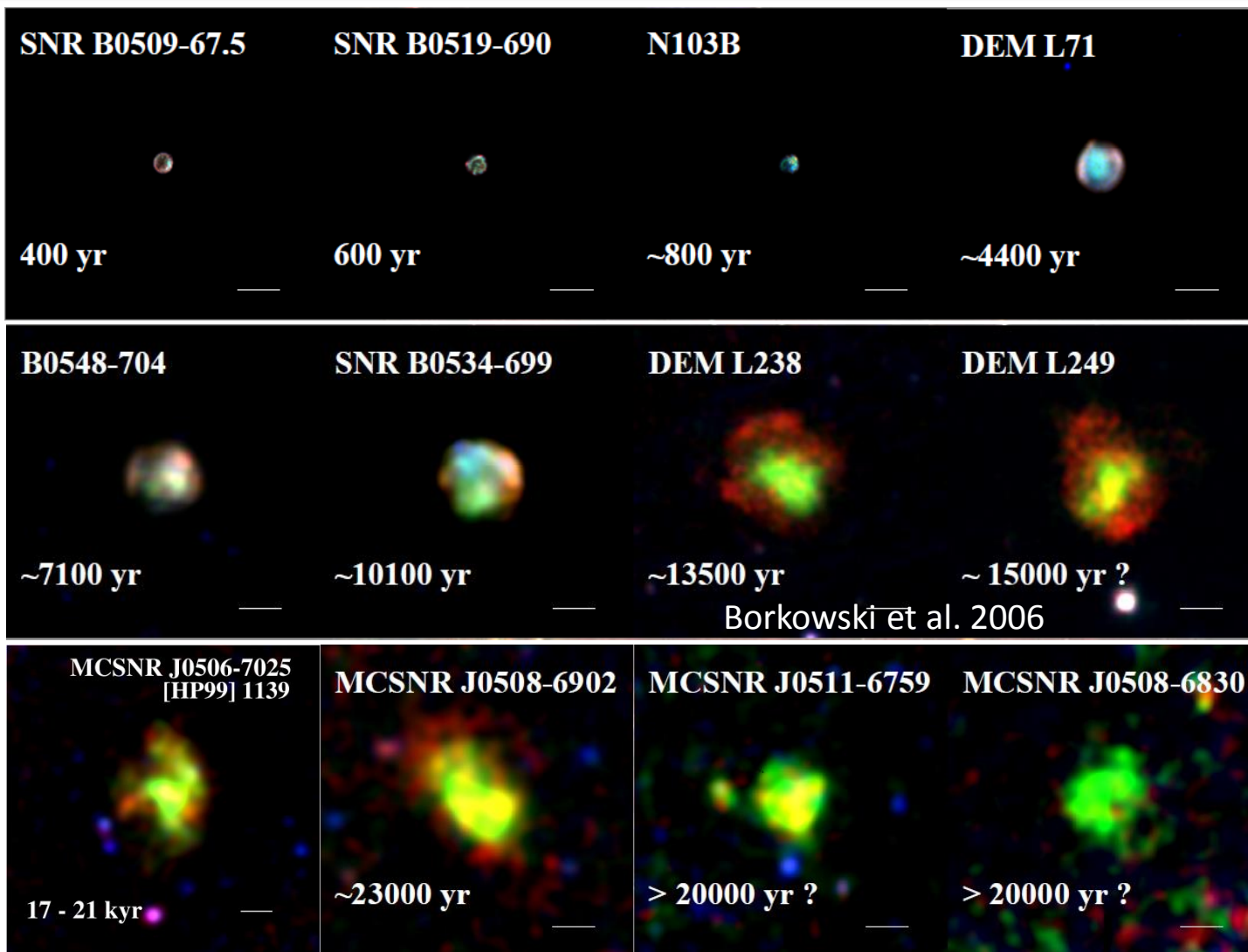
- Now 59 confirmed SNRs, 51 covered by XMM-Newton
- Multi- $\lambda$  studies  $\rightarrow$  density, temperature, abundance, age...
- XMM-Newton sensitive to the faint end of the population
- LMC provides a variety of different ISM environments
- $N_{CC}/N_{Ia} = 1.35 (+0.11/-0.24)$ , lower than derived from local SNe and galaxy cluster abundances  
missing CC SNe in superbubbles? More likely consequence of SFH of the LMC

0.3-0.7 keV  
0.7-1.1 keV  
1.1-4.2 keV



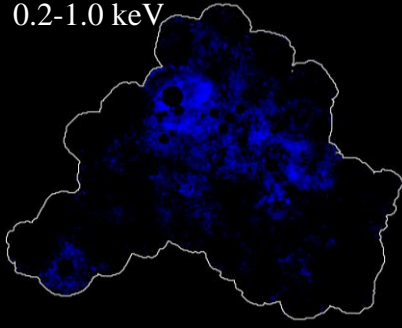


# The evolution of type Ia SNRs in the LMC

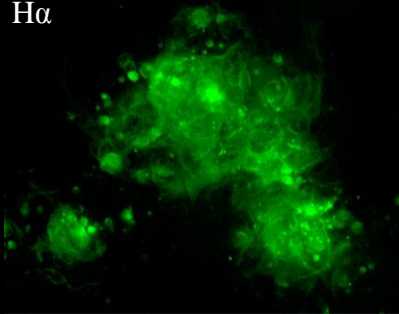


# Diffuse emission from the hot ISM in the SMC

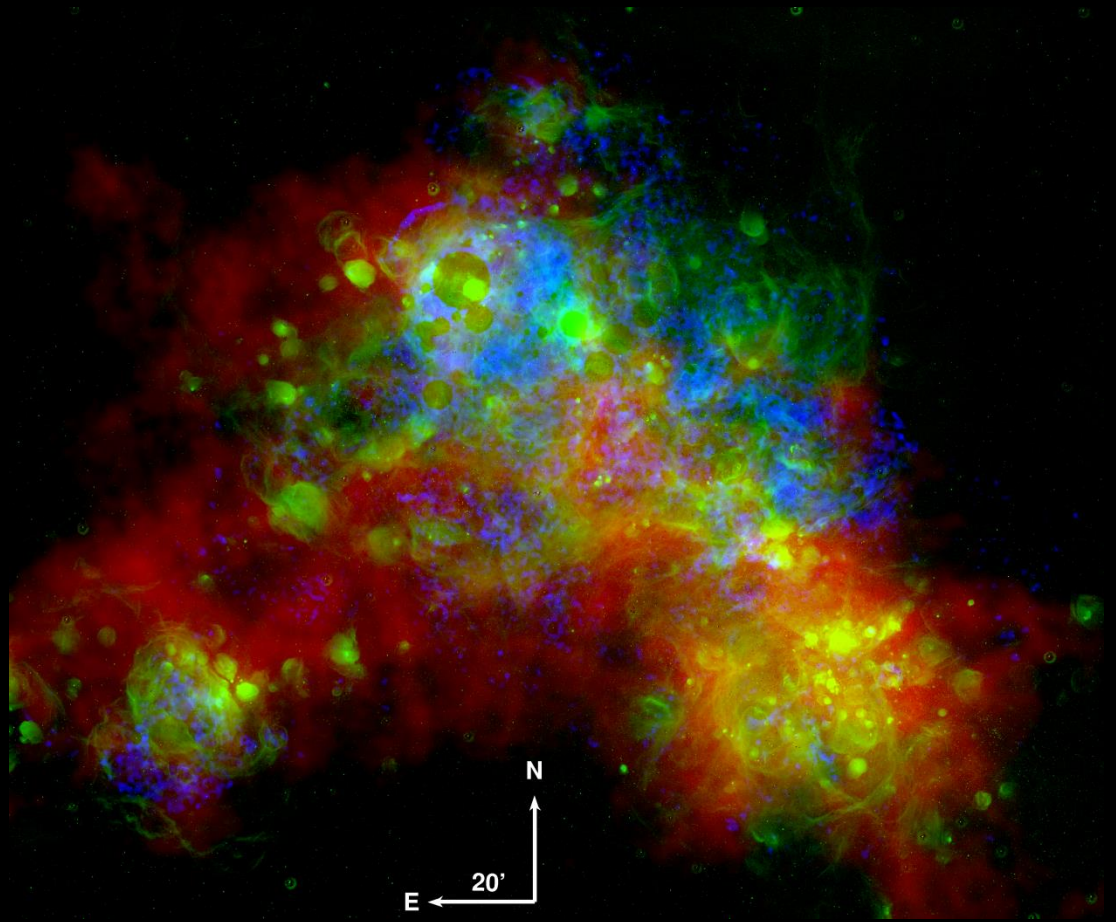
0.2-1.0 keV



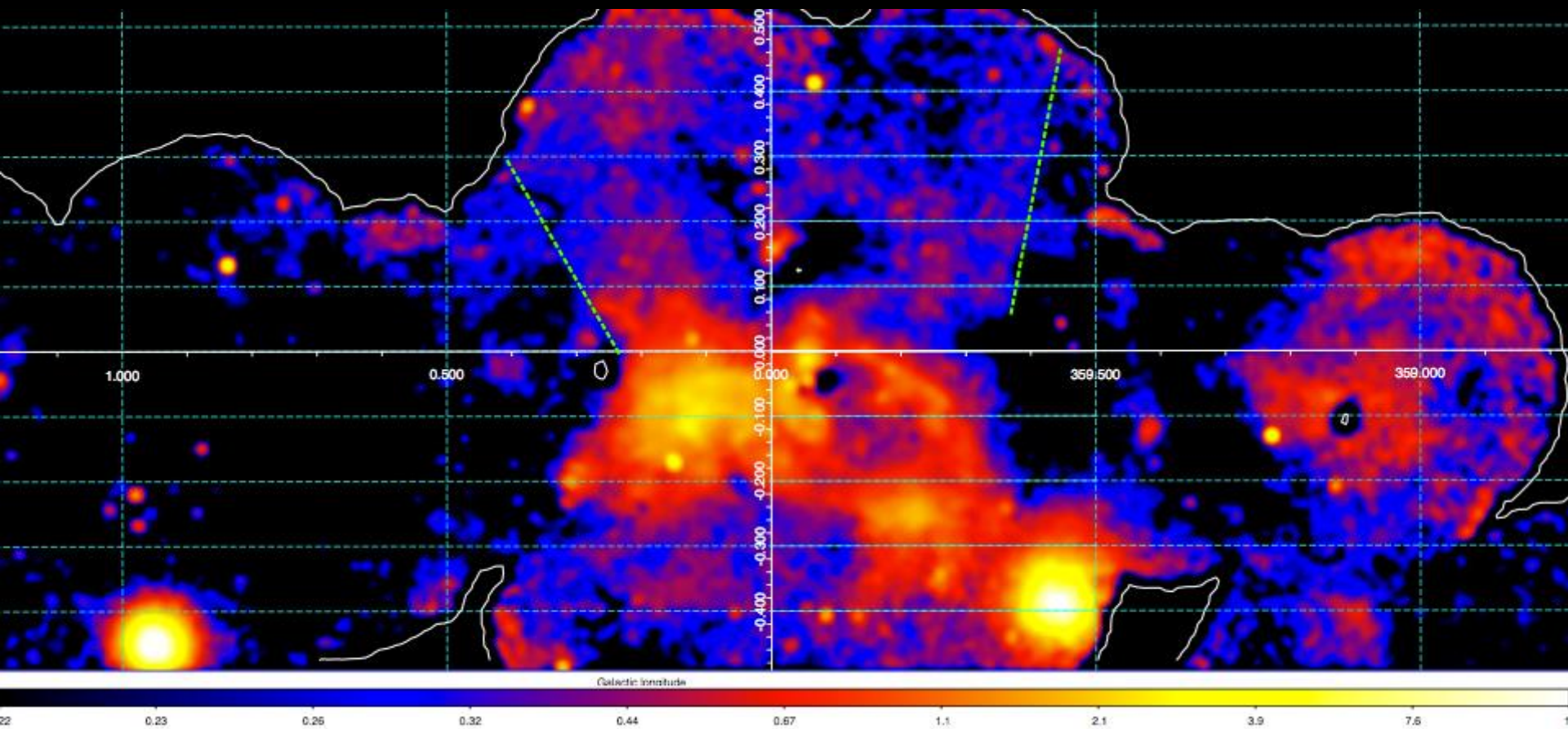
H $\alpha$



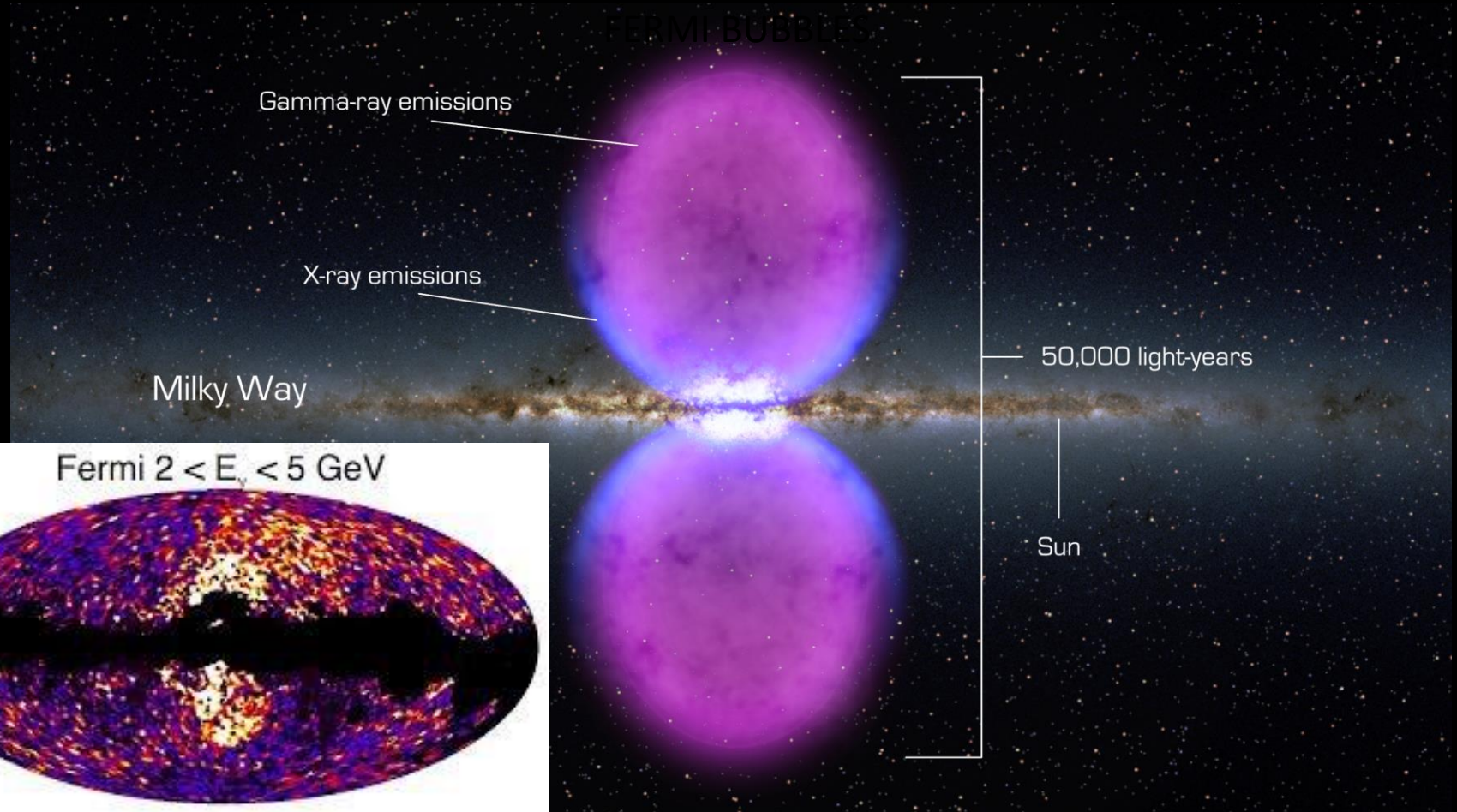
HI



# Hot plasma filling the GC Radio Lobe?



# A connection to the Fermi bubbles?



## XMM-Newton Observations of the Local Group

Extended our knowledge on the X-ray source populations

Different source classes dominate depending of SFH

Help to understand the unresolved X-ray emission from more distant galaxies

Prepare for future missions like Athena

Questions for the next decade:

### HMXBs in SMC

- Intrinsic ratio of pulsars / non-pulsars ( $\propto$  rotation and magnetic axis)?
  - Bimodal spin period distribution, maximum spin period ?
- Extended monitoring, long observations (+EPIC FoV)

### SNRs in the LMC

- Evolutionary sequence of type Ia SNRs
  - More SNRs in supergiant shells ?
- Larger coverage, deep observations of faint SNRs (+EPIC FoV, soft sensitivity)

### Hot gas and outflows

- SMC, Galactic Centre – other?
- Larger, deeper coverage (+EPIC FoV, soft sensitivity)

## THANKS TO

### SMC-survey:

R. Sturm, J. Ballet, D. Bomans, D.A.H. Buckley, M.J. Coe, R. Corbet, M. Ehle, M.D. Filipovic, M. Gilfanov, D. Hatzidimitriou, N. La Palombara, S. Mereghetti, W. Pietsch, S. Snowden, A. Tiengo

### LMC-survey:

P. Maggi, G. Vasilopoulos, A. Becker, D. Bomans, L. Bozzetto, Y.-H. Chu, J. Dickel, M. Ehle, M. Filipovic, D. Hatzidimitriou, P. Kavanagh, J. Ott, W. Pietsch, S. Points, M. Sasaki, S. Snowden, R. Sturm, R. Williams

### Galactic Centre:

G. Ponti, M.R. Morris, R. Terrier, R. Sturm, M. Clavel, S. Soldi, A. Goldwurm, P. Predehl, K. Nandra, G. Belanger, R.S. Warwick, V. Tatischeff