

PROJECT

The XMM-Newton surveys of the Magellanic Clouds

Georgios Vasilopoulos

Max-Planck-Institut für extraterrestrische Physik

On behalf of the XMM-Newton SMC-survey collaboration:

F. Haberl, 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, Richard Sturm, A. Tiengo,
and the XMM-Newton LMC-survey collaboration:

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

ESA's X-ray observatory XMM-Newton

XMM Surveys
of the MCs

G. Vasilopoulos

Project
XMM-Newton
MCs fields
MCs exp. map
SMC in X-rays
LMC in X-rays

Point Sources
SMC catalogue

Class. X-ray

Class. opt

Results

HMXBs
Individual

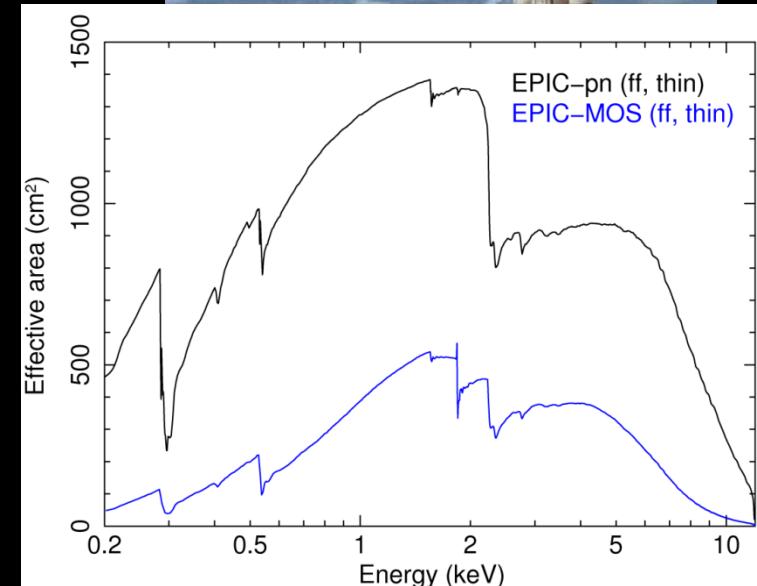
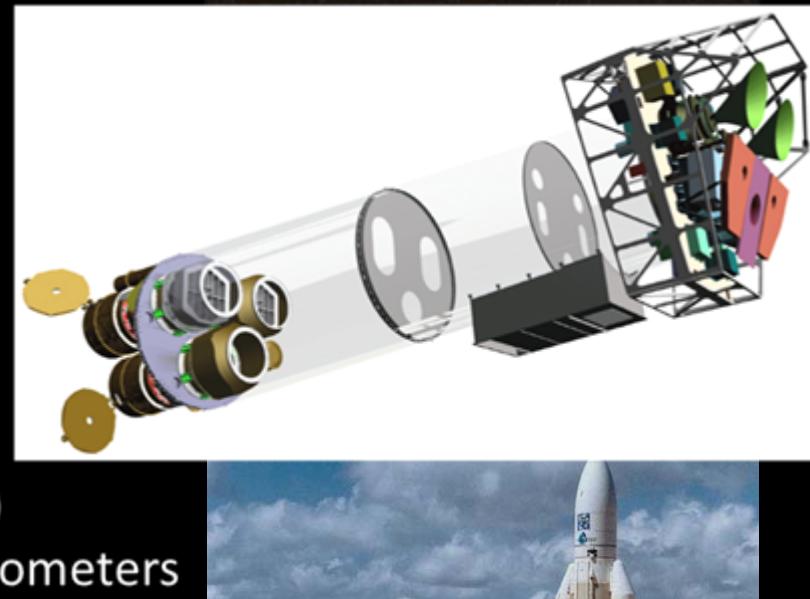
SNRs
SMC sample

Diffuse emission
Analysis
Morphology

Summary

11th Hel.A.S Conf.
Athens
10-9-13

- Cornerstone mission:
 - Weight: 4t
 - Length: 10 m
 - Launched on 10 Dec. 1999
 - Elliptical 48 h orbit
- Payload
 - 3 X-ray telescopes
 - 3 X-ray CCD cameras (EPIC)
 - 2 Reflection Grating Spectrometers
 - 1 Optical monitor
- EPIC Capability
 - Spatial resolution:
 $5'' \Rightarrow 1.5 \text{ pc}$ (for SMC)
 - Spectral resolution:
 $\Delta E/E = 20 - 50$
 - Time resolution:
73.3 ms (Epic-pn, ff)



The Magellanic Clouds

XMM Surveys of the MCs

G. Vasilopoulos

Project
XMM-Newton
MCs fields
MCs exp. map
SMC in X-rays
LMC in X-rays

- Point Sources
- SMC catalogue
- Class. X-ray
- Class. opt

Results

HMXBs

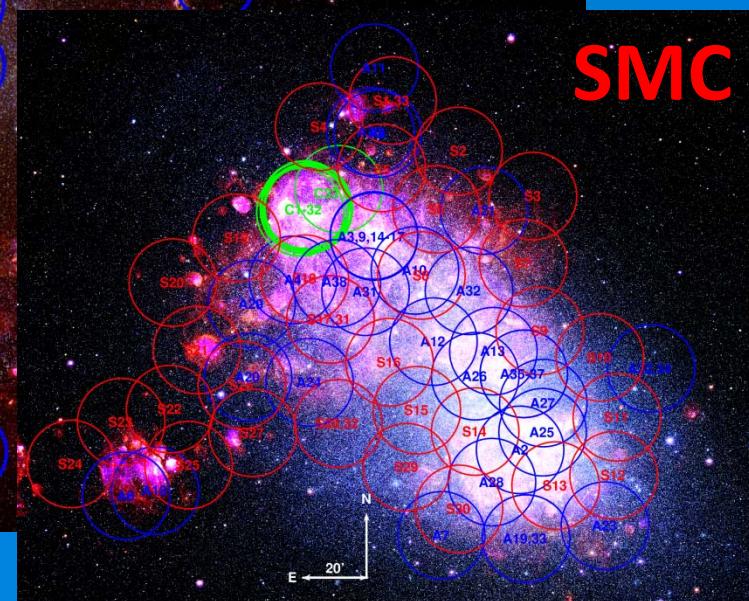
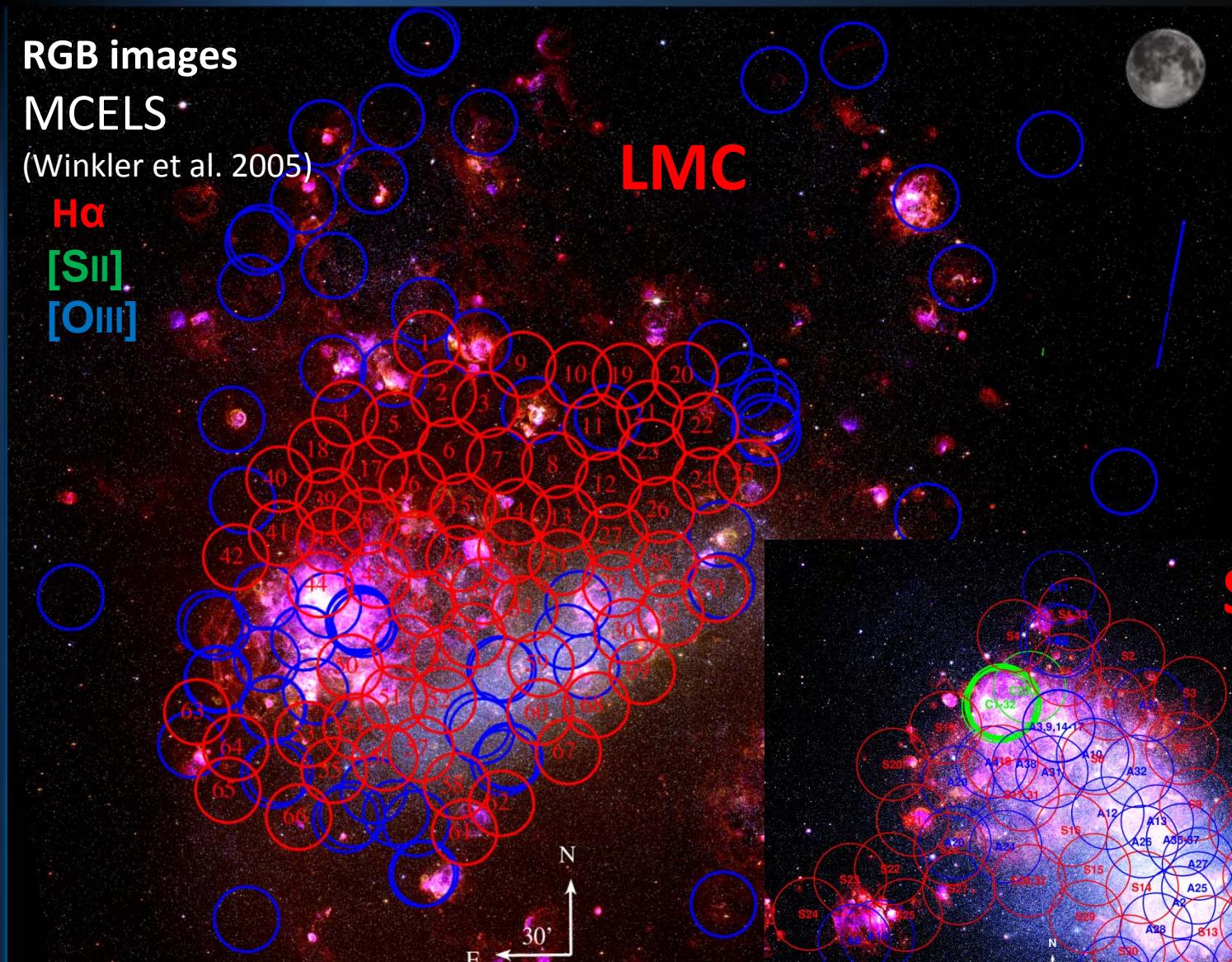
Individual

SNRs
SMC sample

Diffuse emission Analysis Morphology

Summary

11th Hel.A.S Conf.
Athens
10-9-13



The Magellanic Clouds

XMM Surveys
of the MCs
G. Vasilopoulos

Project
XMM-Newton
MCs fields
MCs exp. map
SMC in X-rays
LMC in X-rays

Point Sources
SMC catalogue

Class. X-ray
Class. opt

Results

HMXBs
Individual

SNRs
SMC sample

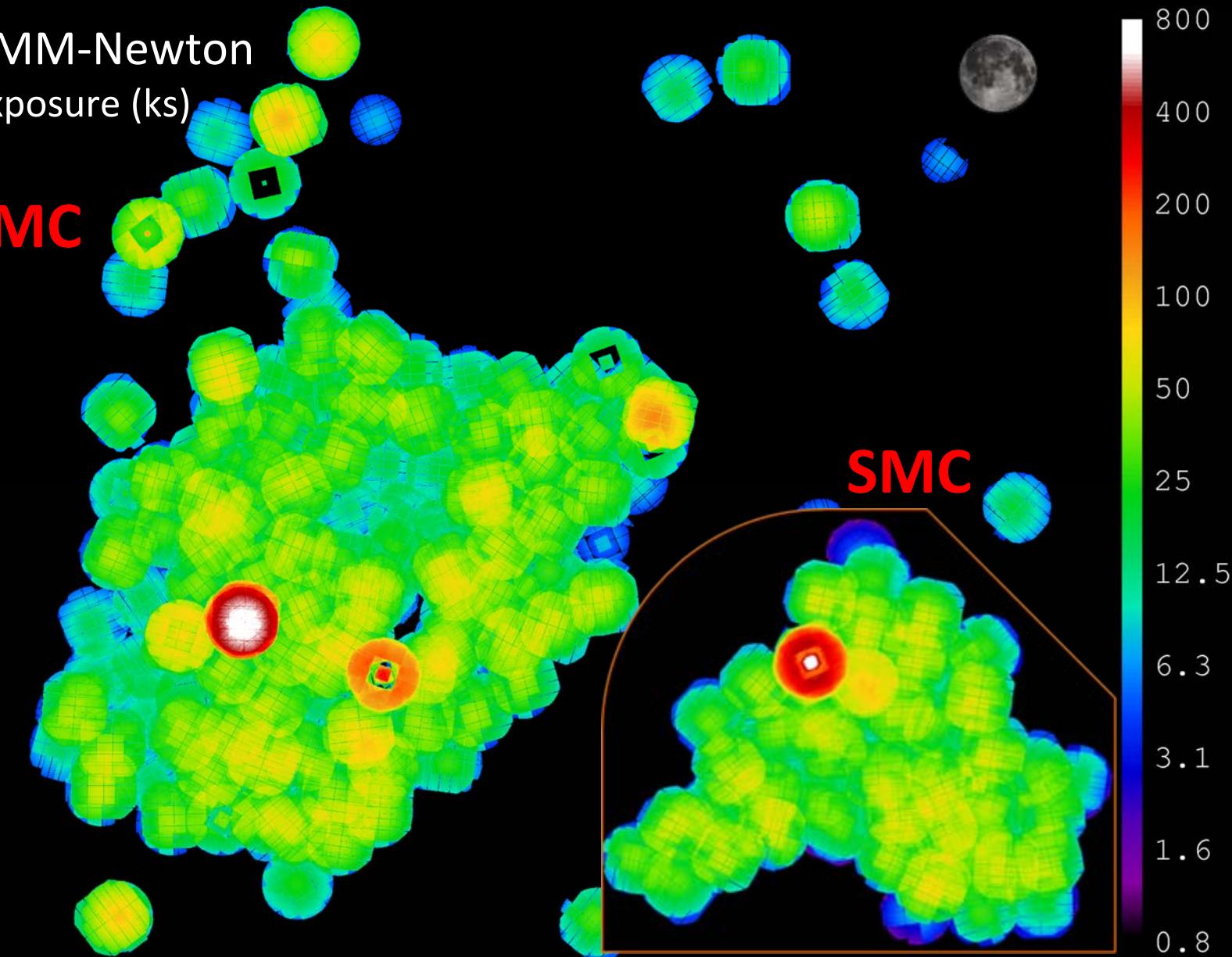
Diffuse emission
Analysis
Morphology

Summary

11th Hel.A.S Conf.
Athens
10-9-13

XMM-Newton
Exposure (ks)

LMC



SMC

The SMC in X-rays

XMM Surveys
of the MCs

G. Vasilopoulos

Project
XMM-Newton
MCs fields
MCs exp. map
SMC in X-rays
LMC in X-rays

Point Sources
SMC catalogue

Class. X-ray

Class. opt

Results

HMXBs

Individual

SNRs

SMC sample

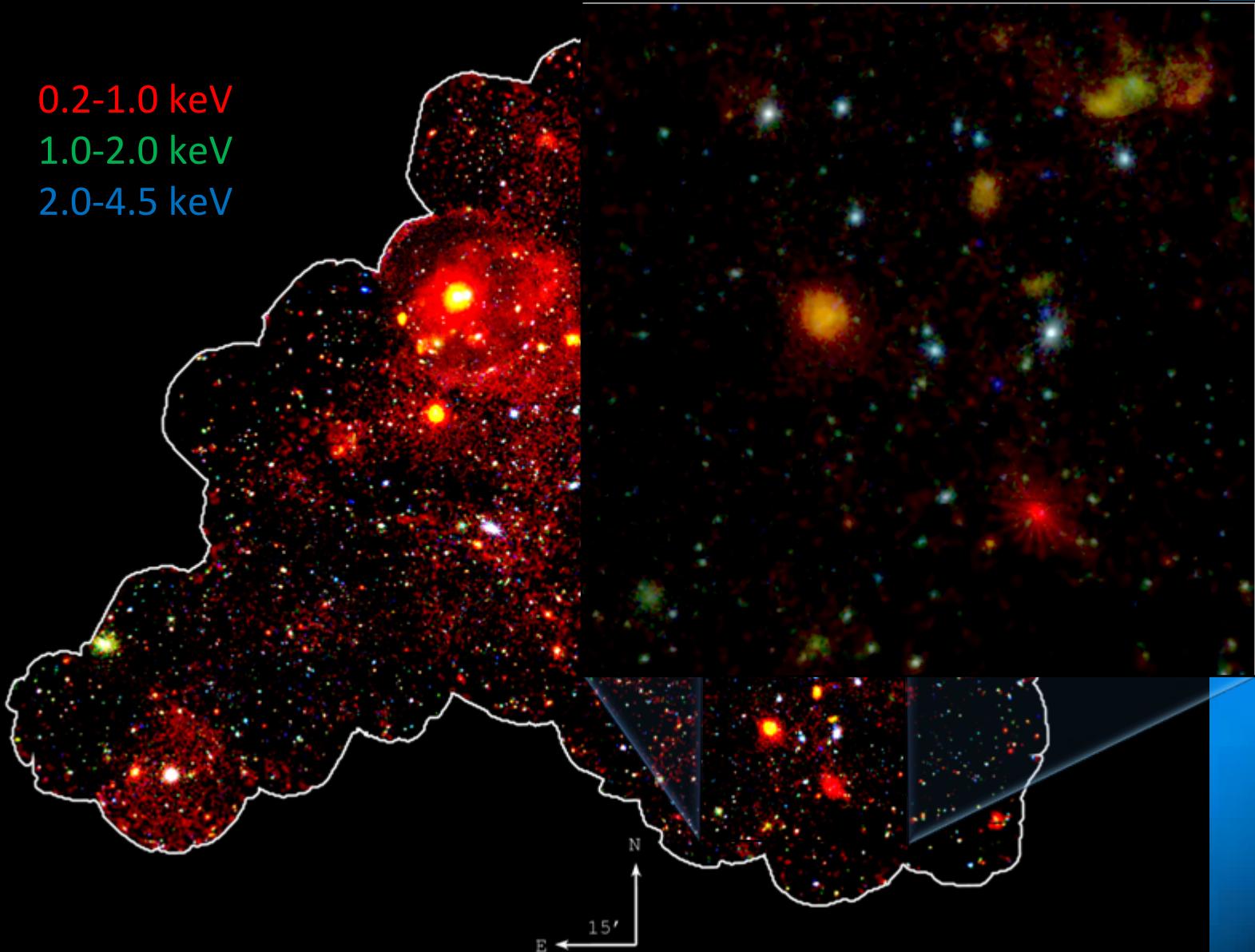
Diffuse emission

Analysis

Morphology

Summary

11th Hel.A.S Conf.
Athens
10-9-13



The LMC in X-rays (Preliminary)

XMM Surveys
of the MCs

G. Vasilopoulos

Project
XMM-Newton
MCs fields
MCs exp. map
SMC in X-rays
LMC in X-rays

Point Sources
SMC catalogue
Class. X-ray

Class. opt

Results

HMXBs
Individual

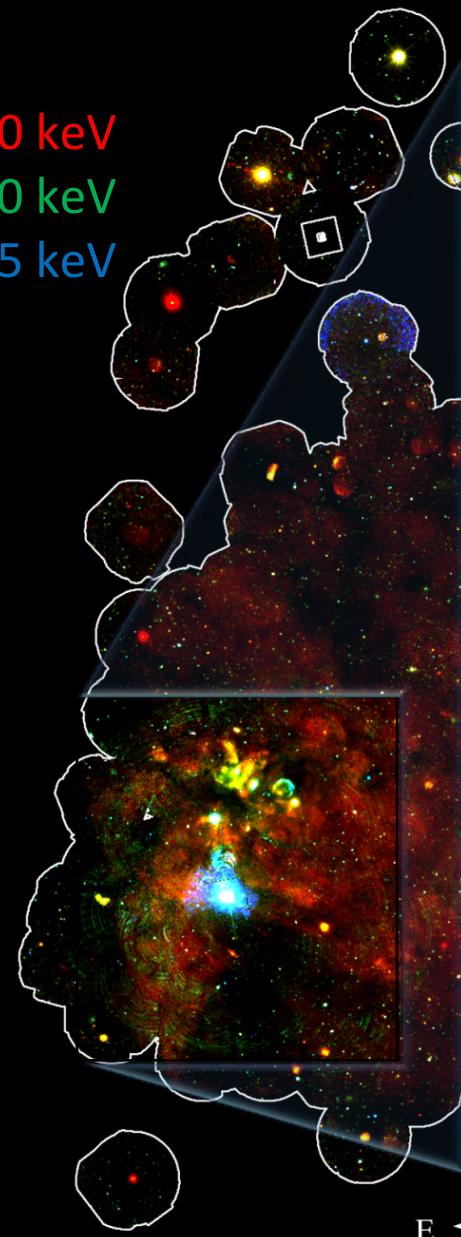
SNRs
SMC sample

Diffuse emission
Analysis
Morphology

Summary

11th Hel.A.S Conf.
Athens
10-9-13

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



E ← 30'



POINT SOURCES

The X-ray point-source population in the MCs

The SMC X-ray point-source catalogue

XMM Surveys
of the MCs

G. Vasilopoulos

Project
XMM-Newton
MCs fields
MCs exp. map
SMC in X-rays
LMC in X-rays

Point Sources
SMC catalogue
Class. X-ray
Class. opt
Results

HMXBs
Individual

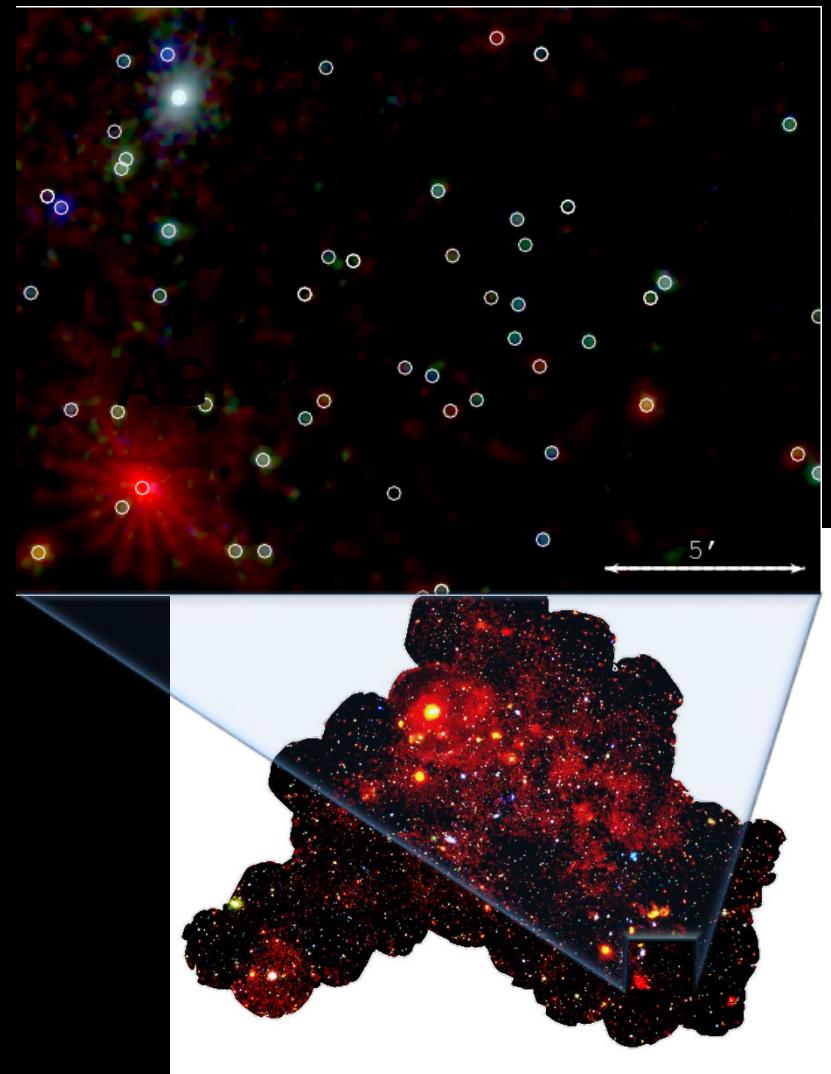
SNRs
SMC sample

Diffuse emission
Analysis
Morphology

Summary

11th Hel.A.S Conf.
Athens
10-9-13

- 3053 sources from
- 5236 detections
(after manual screening)
- 6433 upper limits
for non-detections
- Position accuracy:
1.42" (median)
with astrometric corrections
(using identified sources)
- Containing:
 - Fluxes
 - Hardness ratios
 - Variability
 - Source classification
- Complete to
 $F = 10^{-14} \text{ erg cm}^{-2} \text{s}^{-1}$
 $L_{SMC} = 4.3 \times 10^{33} \text{ erg s}^{-1}$



Spectral classification

XMM Surveys
of the MCs
G. Vasilopoulos

Project
XMM-Newton
MCs fields
MCs exp. map
SMC in X-rays
LMC in X-rays

Point Sources
SMC catalogue
Class. X-ray
Class. opt
Results
HMXBs
Individual
SNRs
SMC sample
Diffuse emission
Analysis
Morphology
Summary

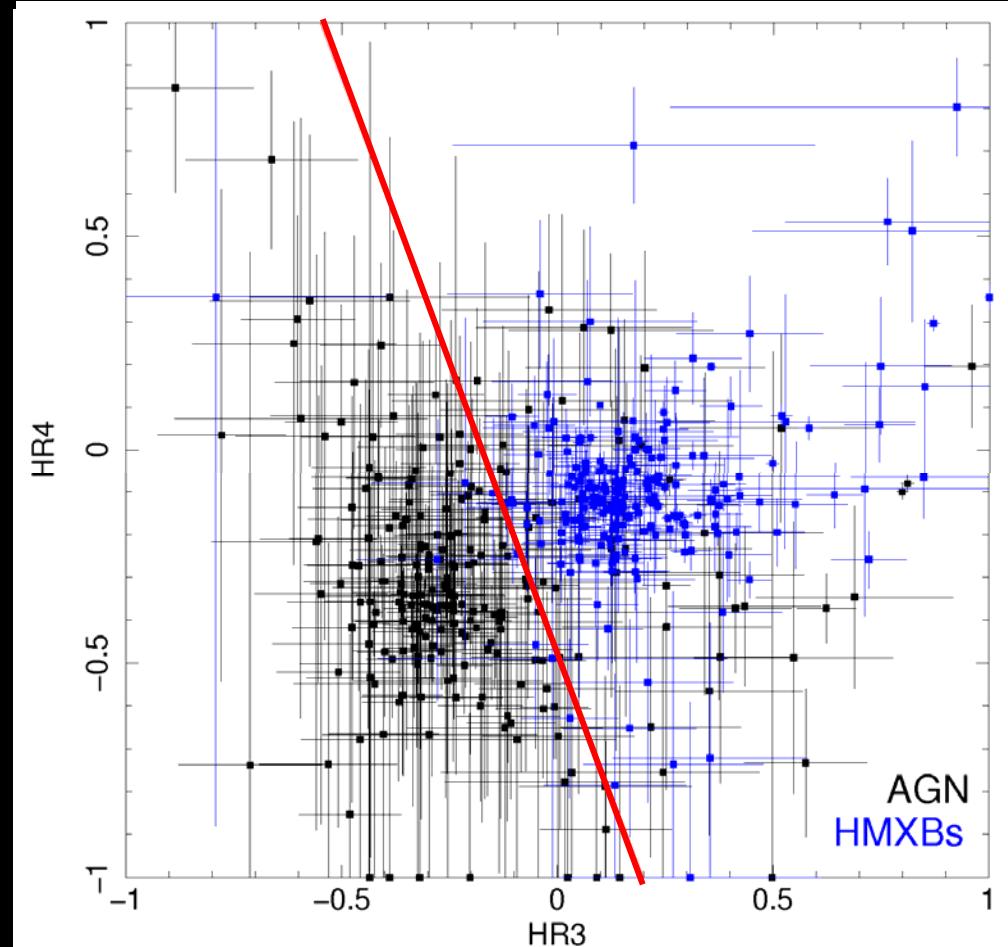
Hardness ratios:

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

⇒ 2711 hard sources

⇒ 945 very hard sources

<i>i</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



Optical counterpart

XMM Surveys
of the MCs
G. Vasilopoulos

Project
XMM-Newton
MCs fields
MCs exp. map
SMC in X-rays
LMC in X-rays

Point Sources
SMC catalogue
Class. X-ray
Class. opt

Results

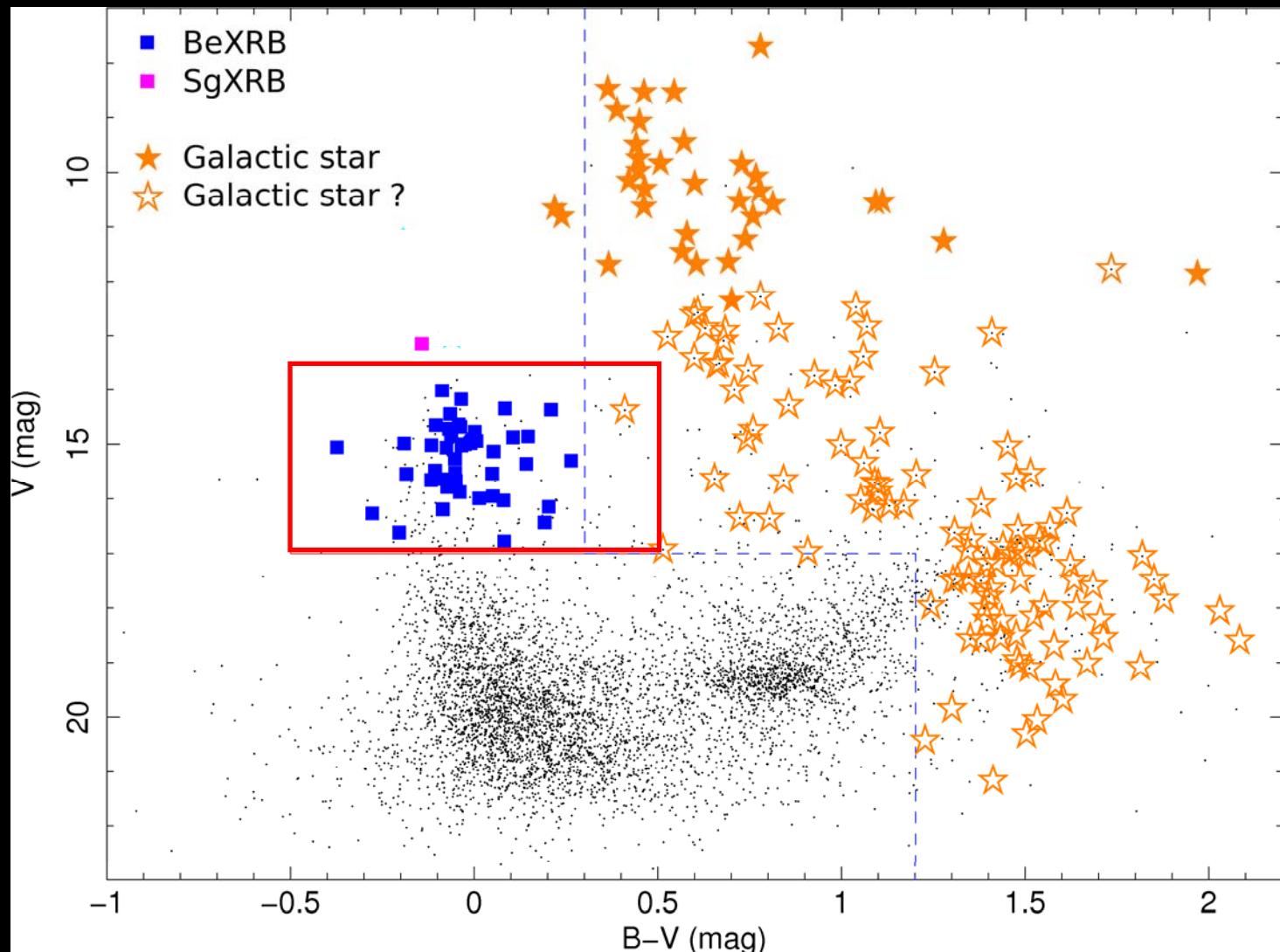
HMXBs
Individual

SNRs
SMC sample

Diffuse emission
Analysis
Morphology

Summary

11th Hel.A.S Conf.
Athens
10-9-13



⇒ 16 605 Be-star candidates in the XMM field

Optical counterpart (fx vs fo)

XMM Surveys
of the MCs

G. Vasilopoulos

Project
XMM-Newton
MCs fields
MCs exp. map
SMC in X-rays
LMC in X-rays

Point Sources
SMC catalogue
Class. X-ray
Class. opt

Results

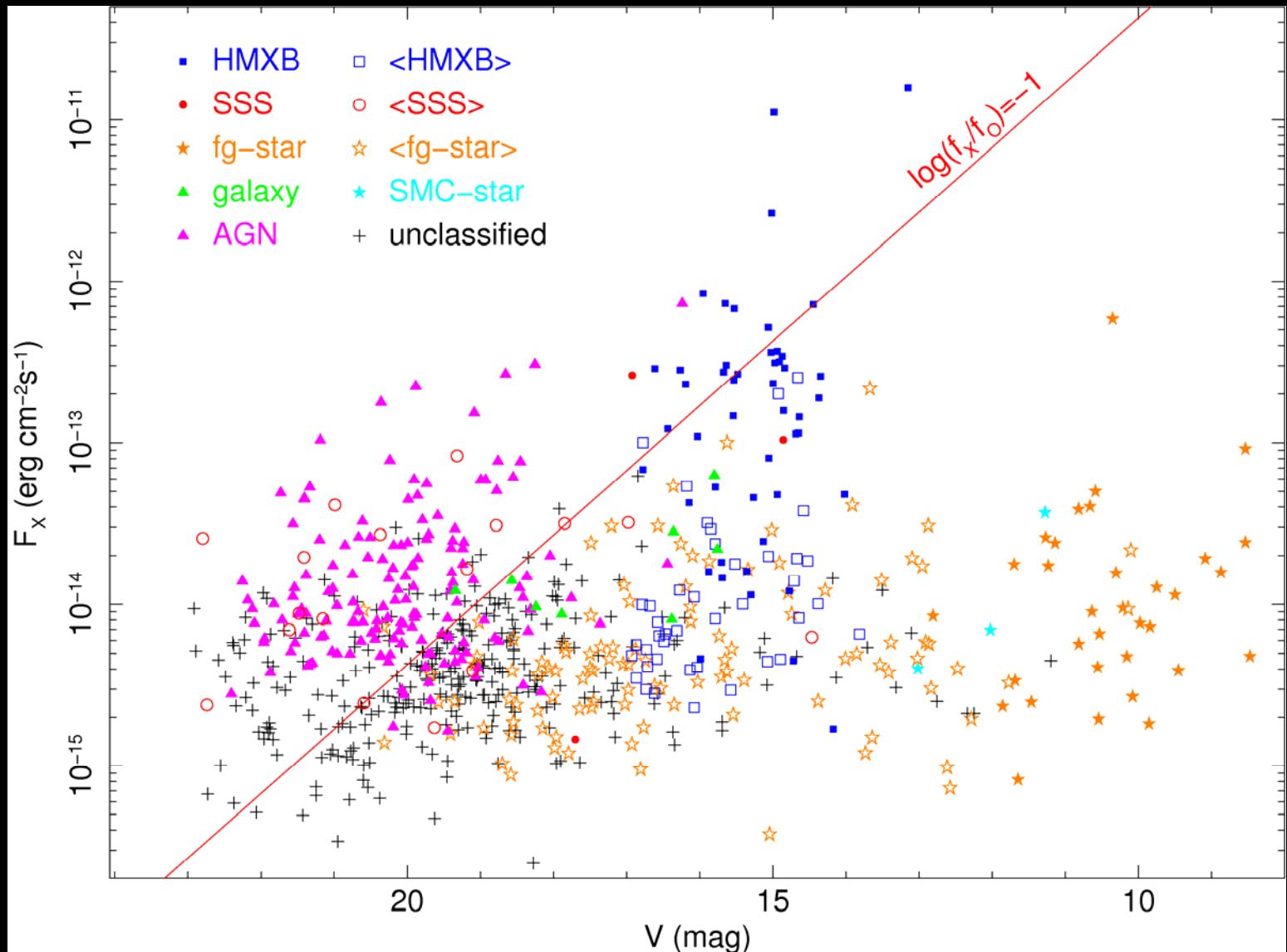
HMXBs
Individual

SNRs
SMC sample

Diffuse emission
Analysis
Morphology

Summary

11th Hel.A.S Conf.
Athens
10-9-13



Source classification - Results

XMM Surveys
of the MCs

G. Vasilopoulos

Project
XMM-Newton
MCs fields
MCs exp. map
SMC in X-rays
LMC in X-rays

Point Sources
SMC catalogue

Class. X-ray
Class. opt
Results

HMXBs
Individual

SNRs
SMC sample

Diffuse emission
Analysis
Morphology

Summary

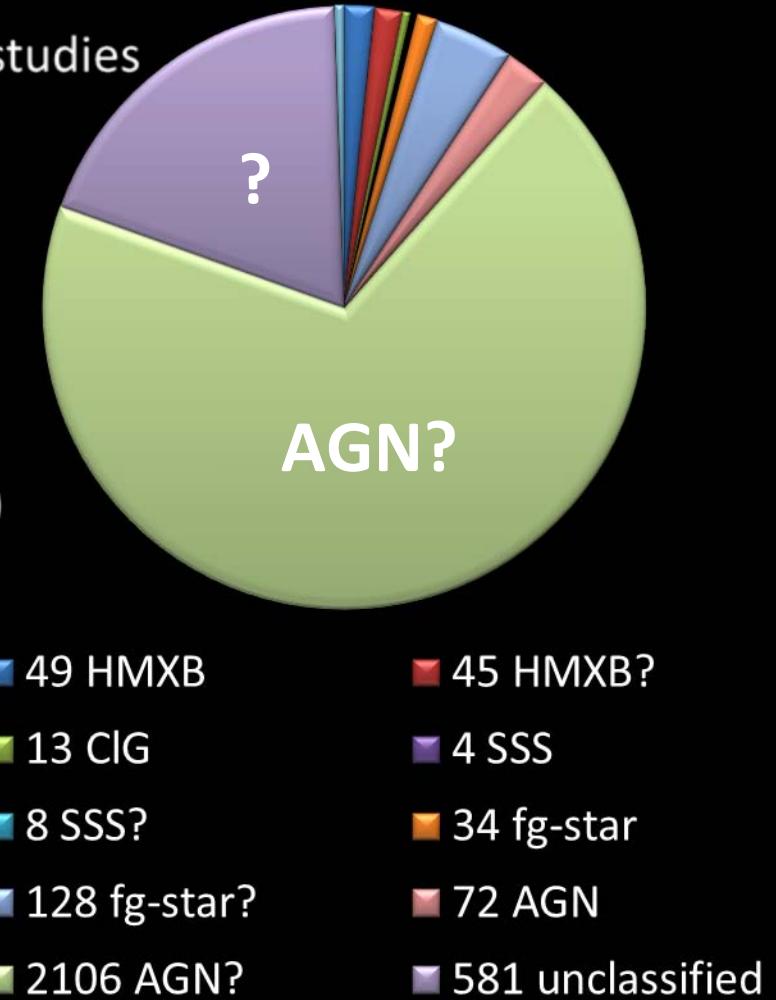
11th Hel.A.S Conf.
Athens
10-9-13

- HMXBs
 - 49 identified
 - 13 candidates from previous studies
 - 32 new candidates

⇒ Chance correlations ($51 \pm 10\%$)

⇒ Further investigations necessary

- AGN:
 - 72 identified (known redshift)
 - 244 good candidates
(Radio, Spitzer, or Chandra counterpart)
 - 1861 weak candidates
 - 581 unclassified sources



Individual Point Sources

XMM Surveys
of the MCs
G. Vasilopoulos

Project
XMM-Newton
MCs fields
MCs exp. map
SMC in X-rays
LMC in X-rays

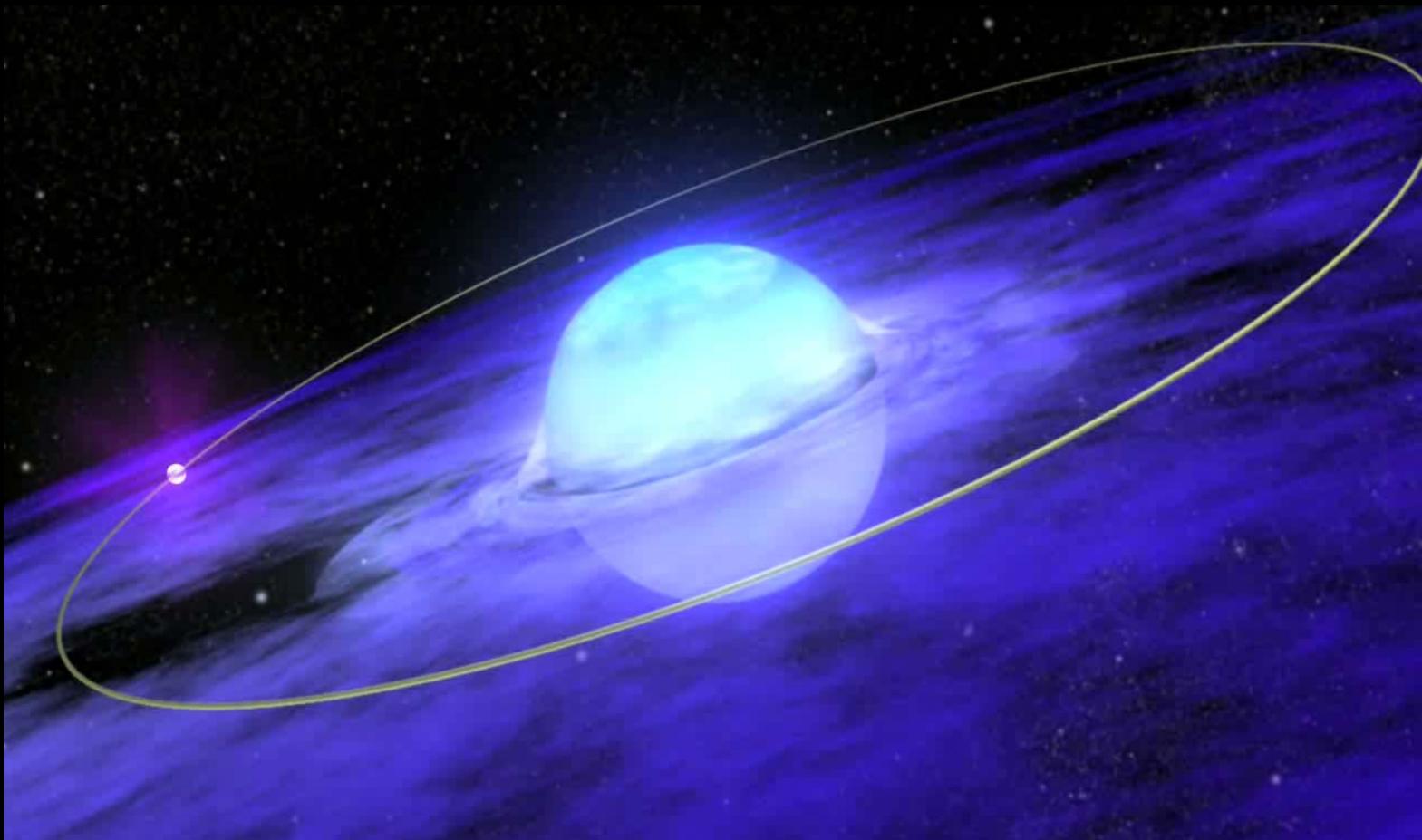
Point Sources
SMC catalogue
Class. X-ray
Class. opt
Results
HMXBs
Individual
SNRs
SMC sample

Diffuse emission
Analysis
Morphology

Summary

11th Hel.A.S Conf.
Athens
10-9-13

HMXB



Individual Point Sources

XMM Surveys
of the MCs
G. Vasilopoulos

Project
XMM-Newton
MCs fields
MCs exp. map
SMC in X-rays
LMC in X-rays

Point Sources
SMC catalogue
Class. X-ray
Class. opt

Results

HMXBs
Individual

SNRs
SMC sample

Diffuse emission
Analysis
Morphology

Summary

11th Hel.A.S Conf.
Athens
10-9-13

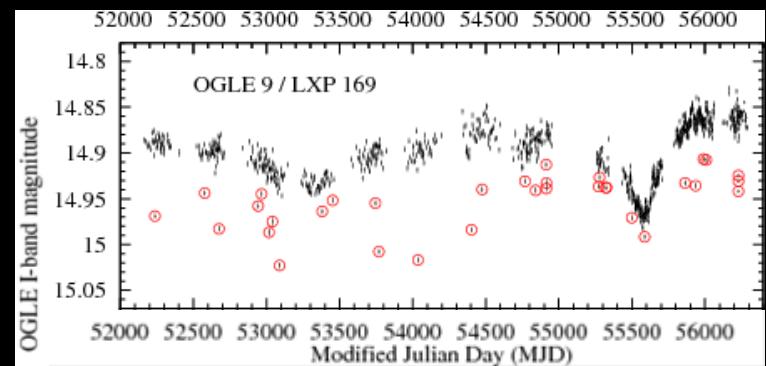
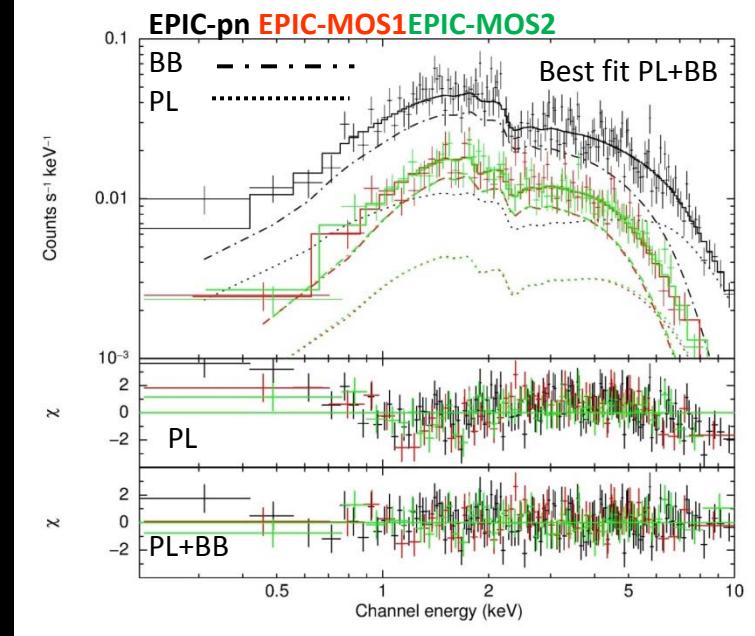
Two newly confirmed Be/XRBs in the LMC ,
raising the number 16.

Swift J053041.9-665426

A new Be/XRB 28.775 pulsar exhibiting
evidence of hot black body emission
Vasilopoulos et al. 2013 A&A (in press)

LXP 168

A transiting neutron star
Maggi et al. 2013 (arXiv1302.4665)



For more details see
POSTER S4-19 by Vasilopoulos et al.



XMM Surveys
of the MCs
G. Vasilopoulos

Project
XMM-Newton
MCs fields
MCs exp. map
SMC in X-rays
LMC in X-rays

Point Sources
SMC catalogue
Class. X-ray
Class. opt
Results
HMXBs
Individual
SNRs
SMC sample

Diffuse emission
Analysis
Morphology

Summary

11th Hel.A.S Conf.
Athens
10-9-13

SUPERNOVA REMNANTS

The flux-limited sample in the Magellanic Clouds

The SNR population of the SMC/LMC

XMM Surveys
of the MCs
G. Vasilopoulos

Project
XMM-Newton
MCs fields
MCs exp. map
SMC in X-rays
LMC in X-rays

Point Sources
SMC catalogue

Class. X-ray
Class. opt

Results

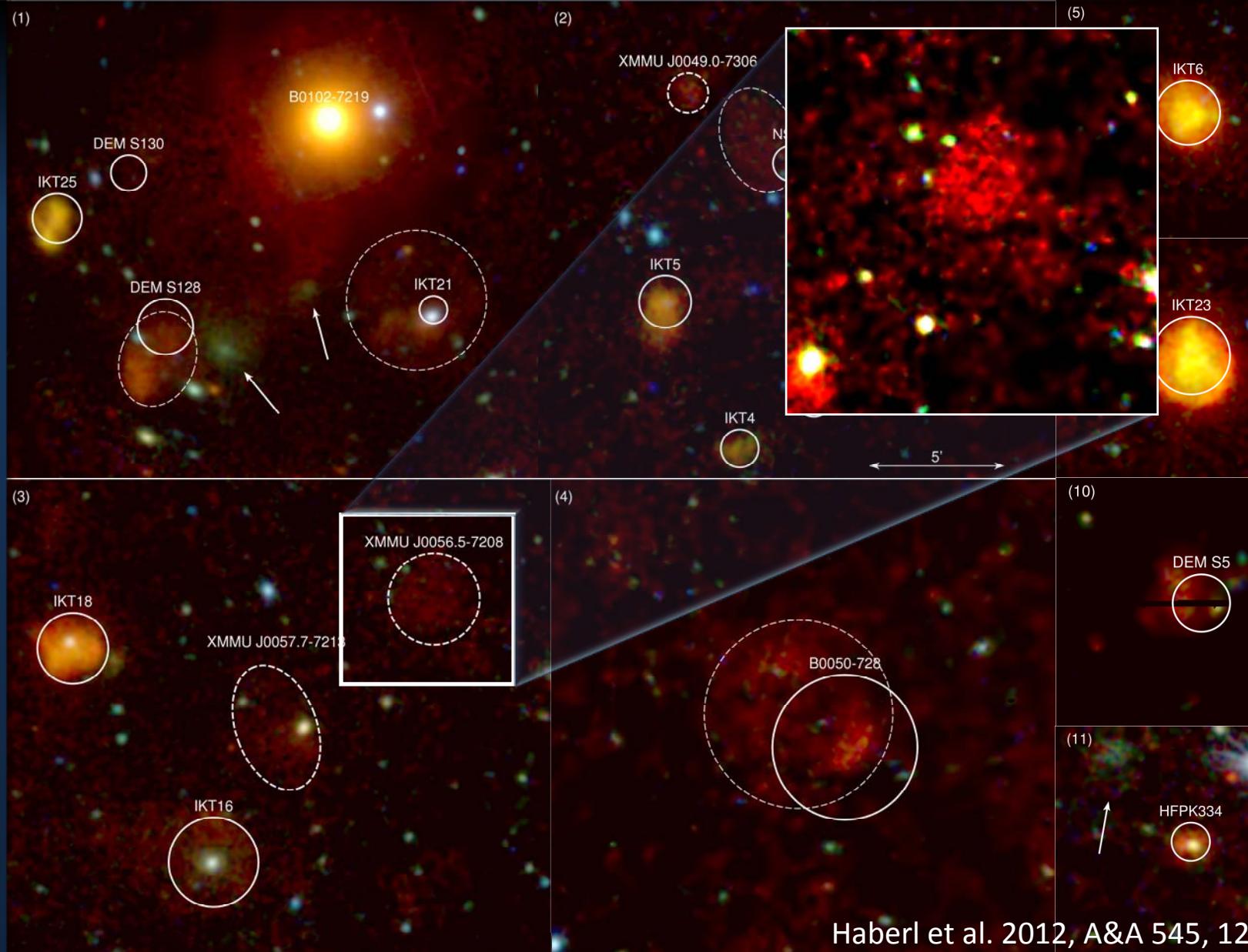
HMXBs
Individual

SNRs
SMC sample

Diffuse emission
Analysis
Morphology

Summary

11th Hel.A.S Conf.
Athens
10-9-13





XMM Surveys
of the MCs

G. Vasilopoulos

Project

XMM-Newton
MCs fields
MCs exp. map
SMC in X-rays
LMC in X-rays

Point Sources

SMC catalogue
Class. X-ray
Class. opt

Results

HMXBs
Individual

SNRs
SMC sample

Diffuse emission
Analysis
Morphology

Summary

11th Hel.A.S Conf.
Athens
10-9-13

DIFFUSE

The interstellar medium of the SMC

Analysis of the diffuse emission

XMM Surveys
of the MCs
G. Vasilopoulos

Project
XMM-Newton
MCs fields
MCs exp. map
SMC in X-rays
LMC in X-rays

Point Sources
SMC catalogue

Class. X-ray

Class. opt

Results

HMXBs

Individual

SNRs

SMC sample

Diffuse emission

Analysis

Morphology

Summary

11th Hel.A.S Conf.
Athens
10-9-13

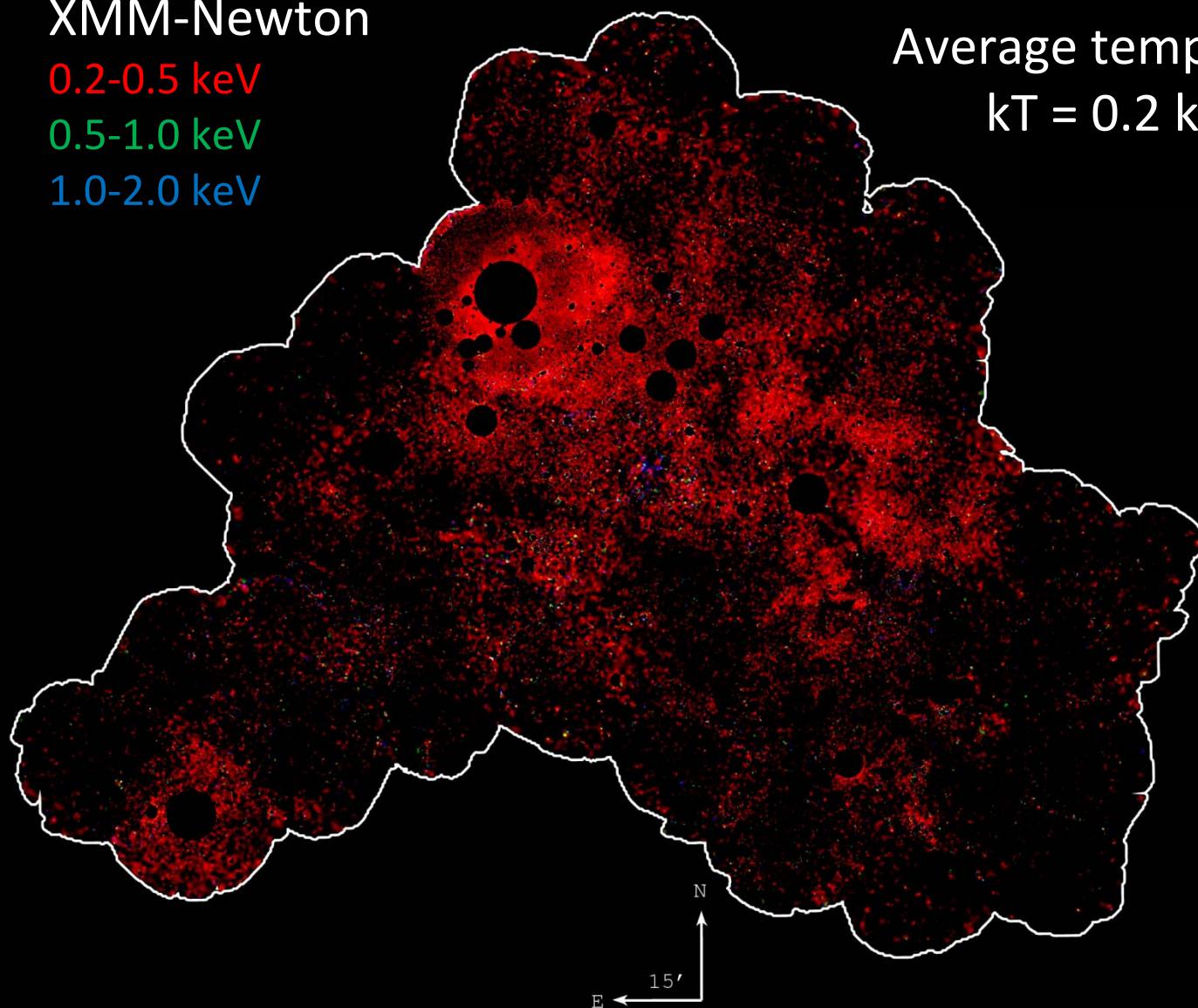
XMM-Newton

0.2-0.5 keV

0.5-1.0 keV

1.0-2.0 keV

Average temprature
 $kT = 0.2 \text{ keV}$



Morphology of the ISM

XMM Surveys
of the MCs
G. Vasilopoulos

Project
XMM-Newton
MCs fields
MCs exp. map
SMC in X-rays
LMC in X-rays

Point Sources
SMC catalogue
Class. X-ray
Class. opt
Results
HMXBs
Individual
SNRs
SMC sample

Diffuse emission
Analysis
Morphology

Summary

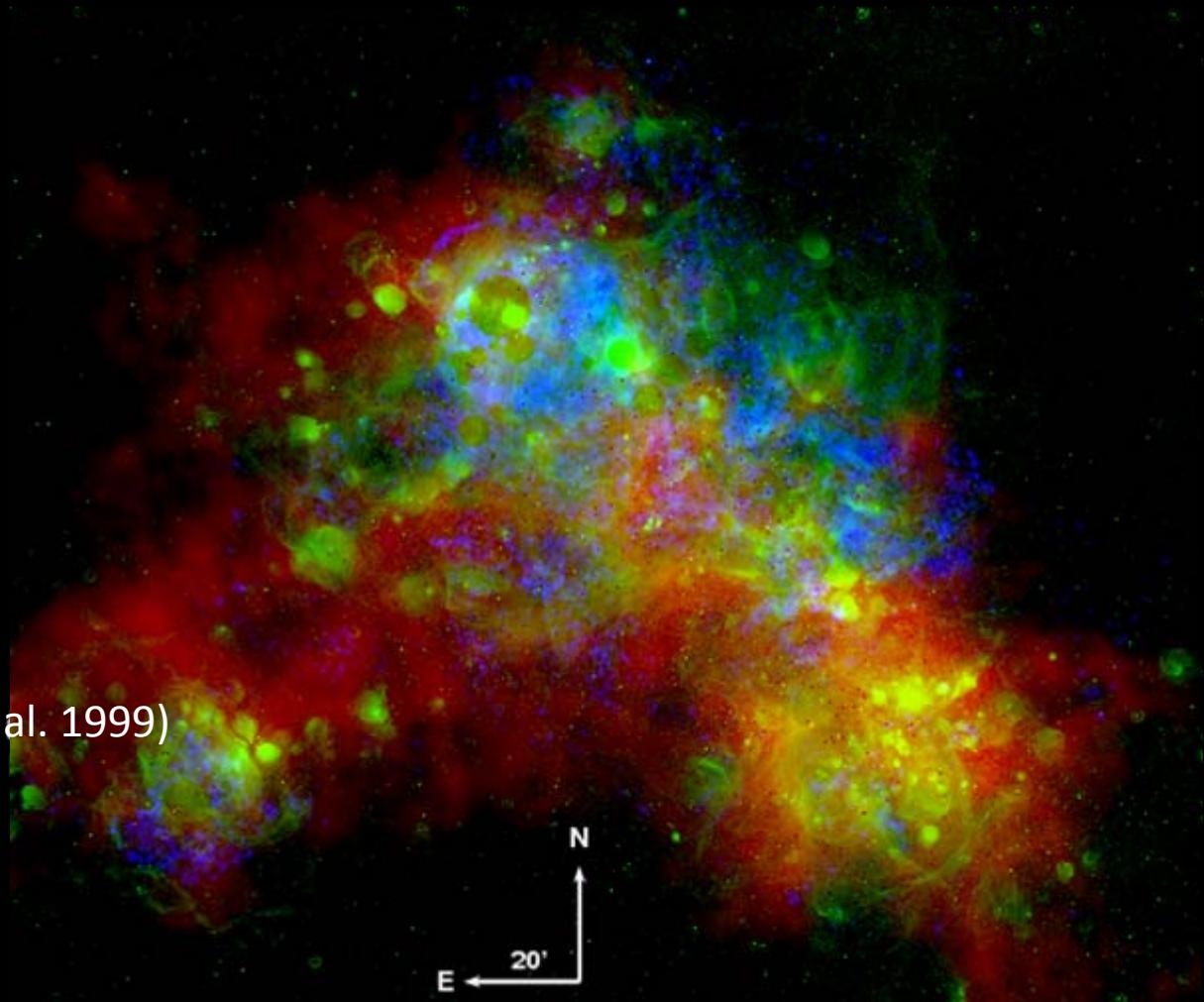
11th Hel.A.S Conf.
Athens
10-9-13

(0.2-1.0) keV

the individual phases (hot, **warm**, **cold**) of the ISM

H α (MCELS)

HI (Stanimirovic et al. 1999)



R. Sturm, PhD Thesis 2012, TU Munich

Summary

XMM Surveys
of the MCs

G. Vasilopoulos

Project
XMM-Newton
MCs fields
MCs exp. map
SMC in X-rays
LMC in X-rays

Point Sources
SMC catalogue

Class. X-ray

Class. opt

Results

HMXBs

Individual

SNRs

SMC sample

Diffuse emission

Analysis

Morphology

Summary

- The XMM-Newton survey of the MC
 - A unique dataset
 - Complementing surveys at other wavelengths
- X-ray point-source catalogue (so far only SMC)
 - 3053 X-ray sources
 - 94 identified/classified HMXBs
 - ~ 2200 AGN behind the SMC
- High-mass X-ray binaries
 - New Be/X-ray binaries in the MCs
 - Large population of Be/X-ray binaries allows statistical studies
 - Discovery of the interesting individual sources
- Supernova remnants
 - Complete (surface-brightness limited) sample
 - XMM can detect low kT (old) remnants
- Diffuse X-ray emission
 - Spectral parameterization (T, EM, N_H)
 - correlating with star formation

THANK YOU

XMM Surveys
of the MCs
G. Vasilopoulos

Project
XMM-Newton
MCs fields
MCs exp. map
SMC in X-rays
LMC in X-rays

Point Sources
SMC catalogue
Class. X-ray
Class. opt

Results

HMXBs
Individual

SNRs
SMC sample

Diffuse emission
Analysis
Morphology

Summary

11th Hel.A.S Conf.
Athens
10-9-13



The LMC and the SMC as seen from La Silla Chile

Comparison with ROSAT

XMM Surveys
of the MCs
G. Vasilopoulos

Project
XMM-Newton
MCs fields
MCs exp. map
SMC in X-rays
LMC in X-rays

Point Sources
SMC catalogue

Class. opt
Results

HMXBs
Individual

SNRs
SMC sample

Diffuse emission
Analysis
Morphology

Summary

11th Hel.A.S Conf.
Athens
10-9-13

XMM-Newton

0.2-0.5 keV

0.5-1.0 keV

1.0-2.0 keV

