

X-ray Source Population Studies in Nearby Galaxies



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Outline

- Introduction to source population
- NGC 253
 - transients, XRB, diffuse emission
- The Local Group
 - LMC, SMC
 - M33
 - The Andromeda galaxy M31
- Summary

Introduction

X-ray sources in nearby galaxy fields:

- Within Galaxy
 - X-ray binaries
 - Low mass X-ray binaries (SSS, neutron star, black hole)
 - High mass X-ray binaries
 - Bright transients
 - Supernova remnants
 - Young supernovae (thermal, compact remnant? radioactive lines of debris?)
 - Thermal remnants
 - Plerions
 - Nuclear source
 - Diffuse emission in disk and halo
- Foreground Stars
- Galaxies, galaxy clusters and AGN in Background

XMM-Newton EPIC view of the starburst galaxy NGC 253

A multi-color X-ray image of the starburst galaxy NGC 253, showing a bright central region and a dense field of stars. The image is overlaid with a grid of black lines, likely representing the EPIC detector's field of view or a specific region of interest. The colors represent different energy bands, with blue and green being the most prominent.

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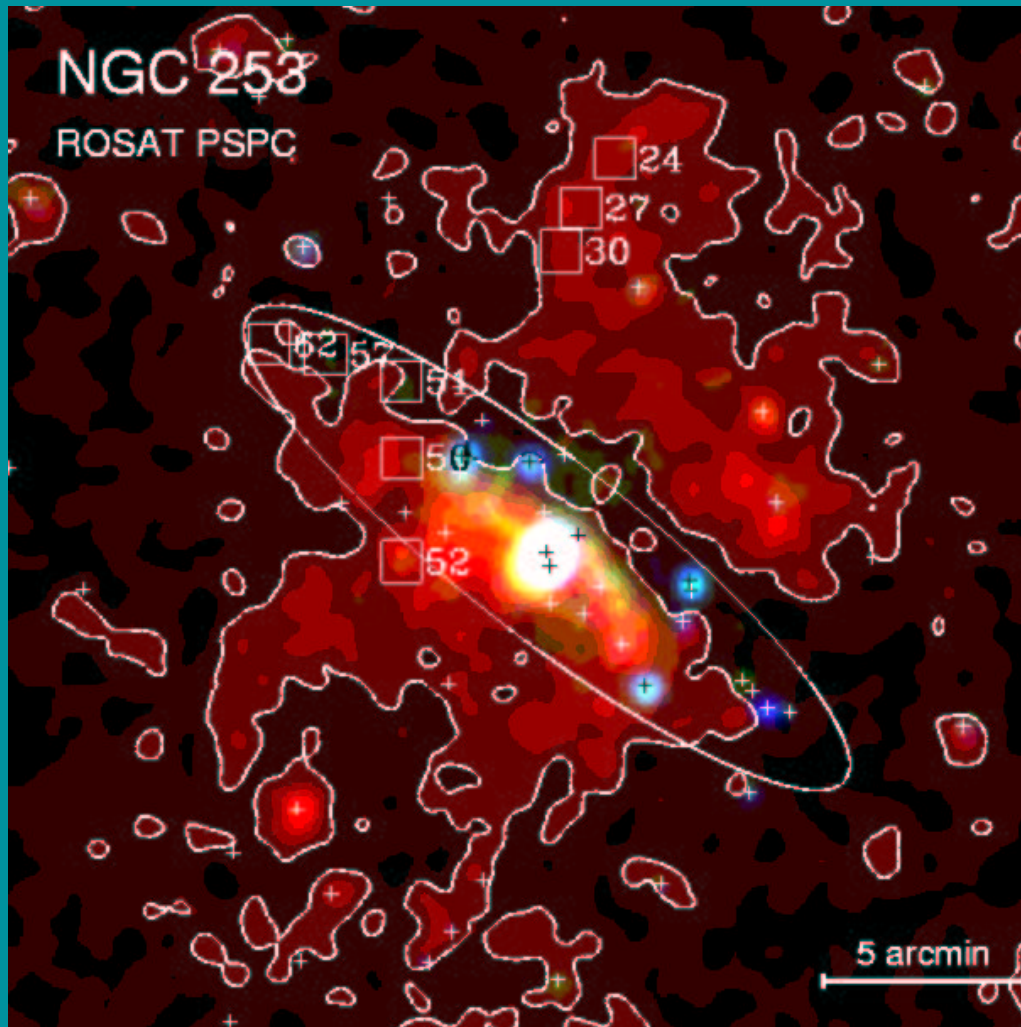
ROSAT observations of NGC 253

PSPC colour image:

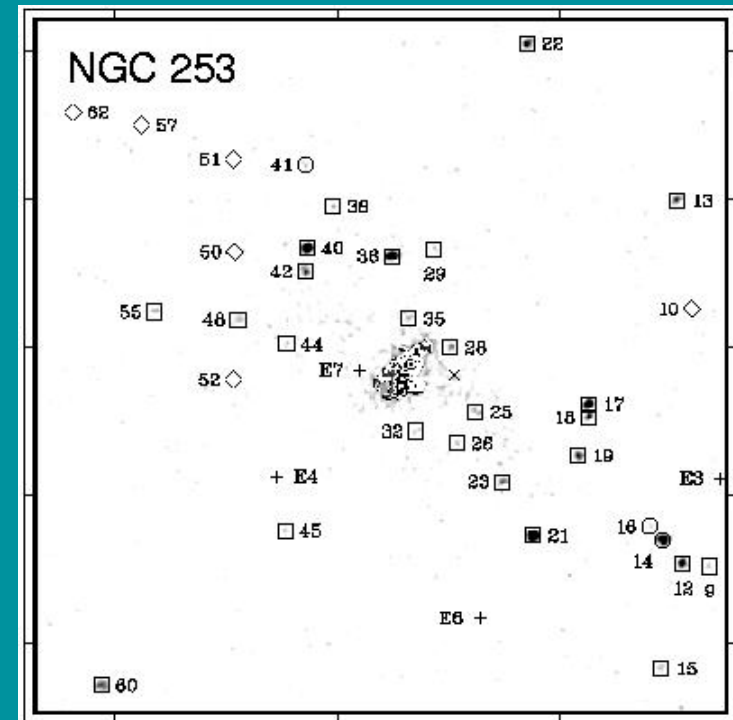
0.1-0.4 keV 0.5-0.9 keV 0.9-2.0 keV

Vogler & Pietsch 1999, A&A 342, 101

Pietsch et al. 2000, A&A 360, 24

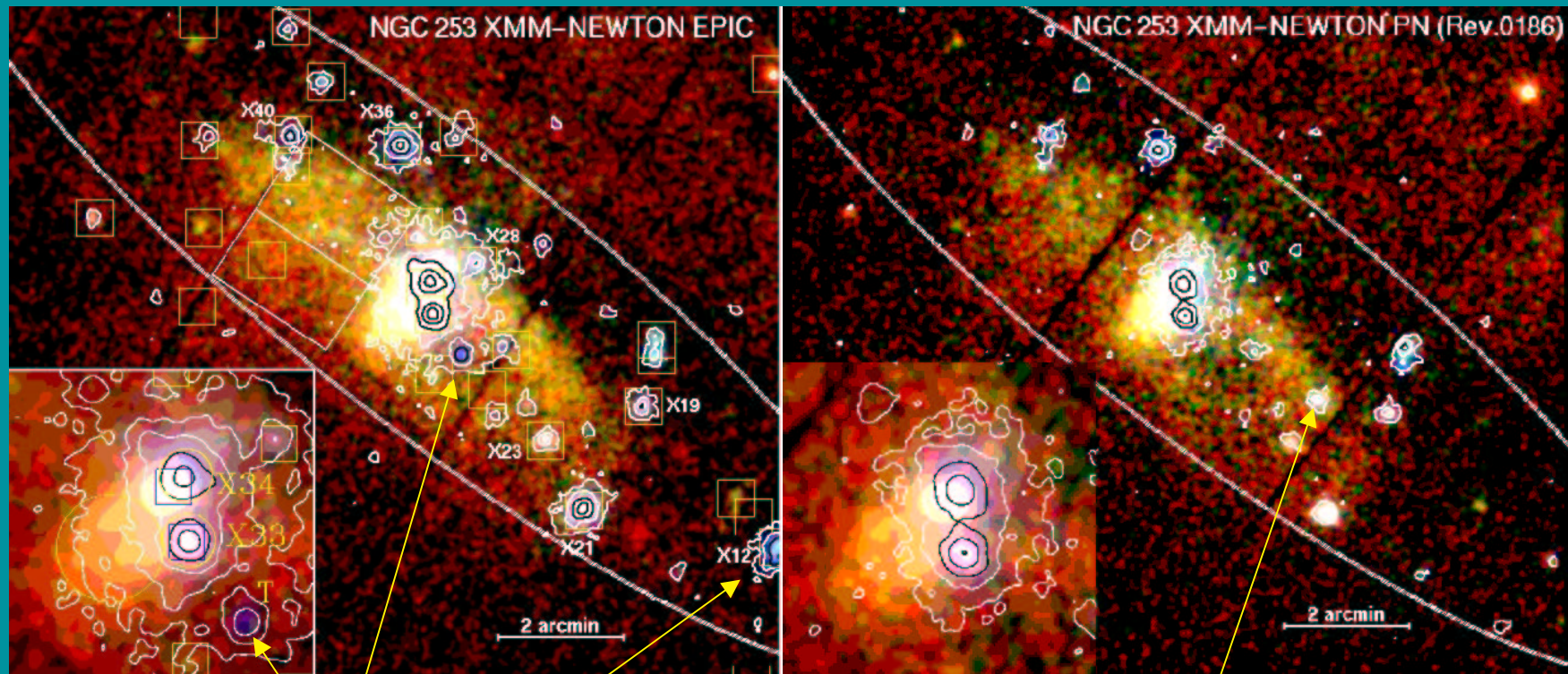


HRI image



XMM-Newton observations of NGC 253 transients in outburst I

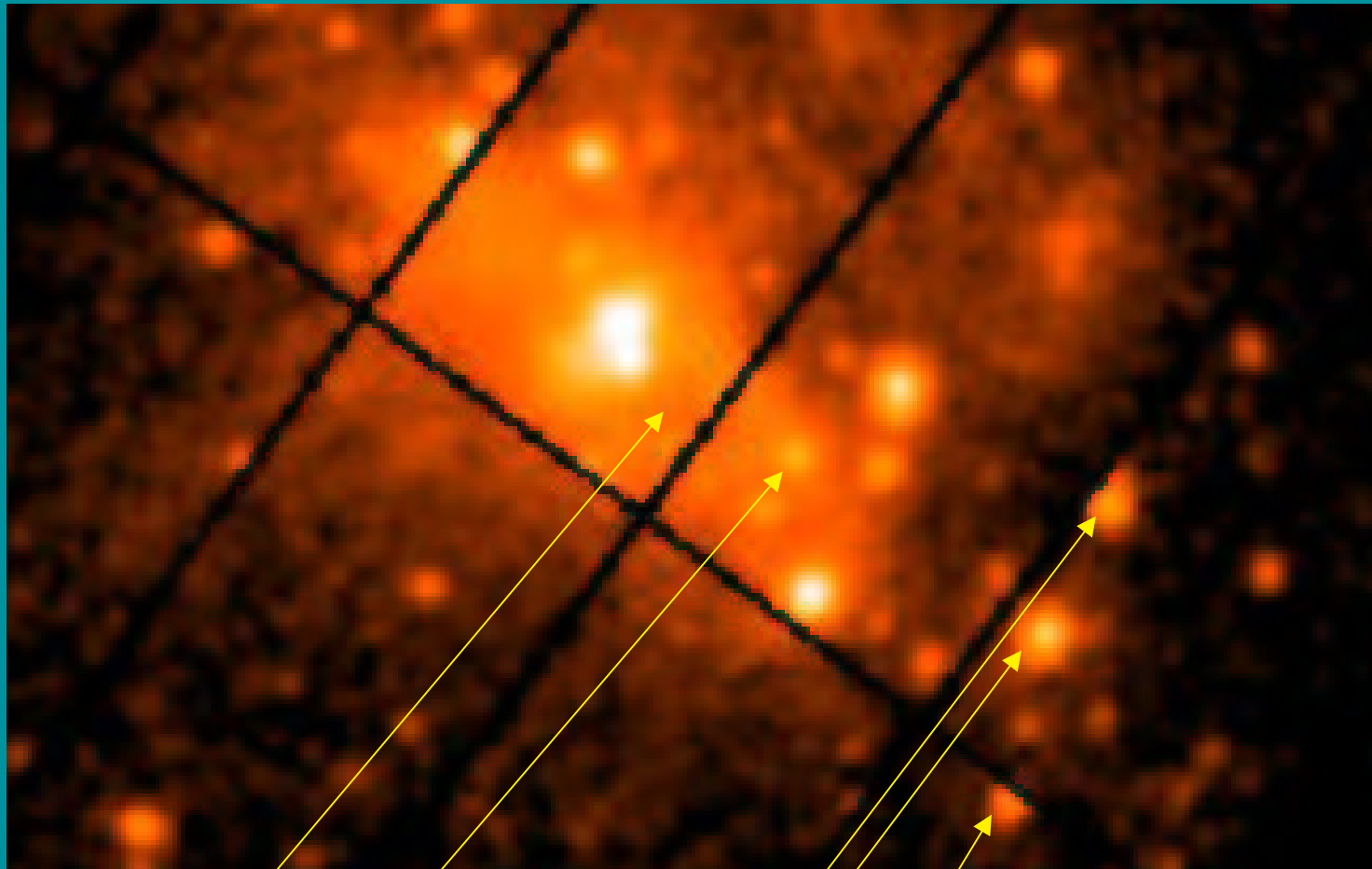
Colour images: 0.2-0.5 keV 0.5-0.9 keV 0.9-2.0 keV contours 2-10 keV



PV Jul 2000

SSC GT Dec 2000

XMM-Newton observations of NGC 253 transients in outburst II



AO2 June 19/20, 2003

EPIC PN colour image:

0.2-0.5 keV 0.5-1.0 keV 1.0-2.0 keV

RX J004717.4-251811: The first eclipsing XRB outside the Local Group

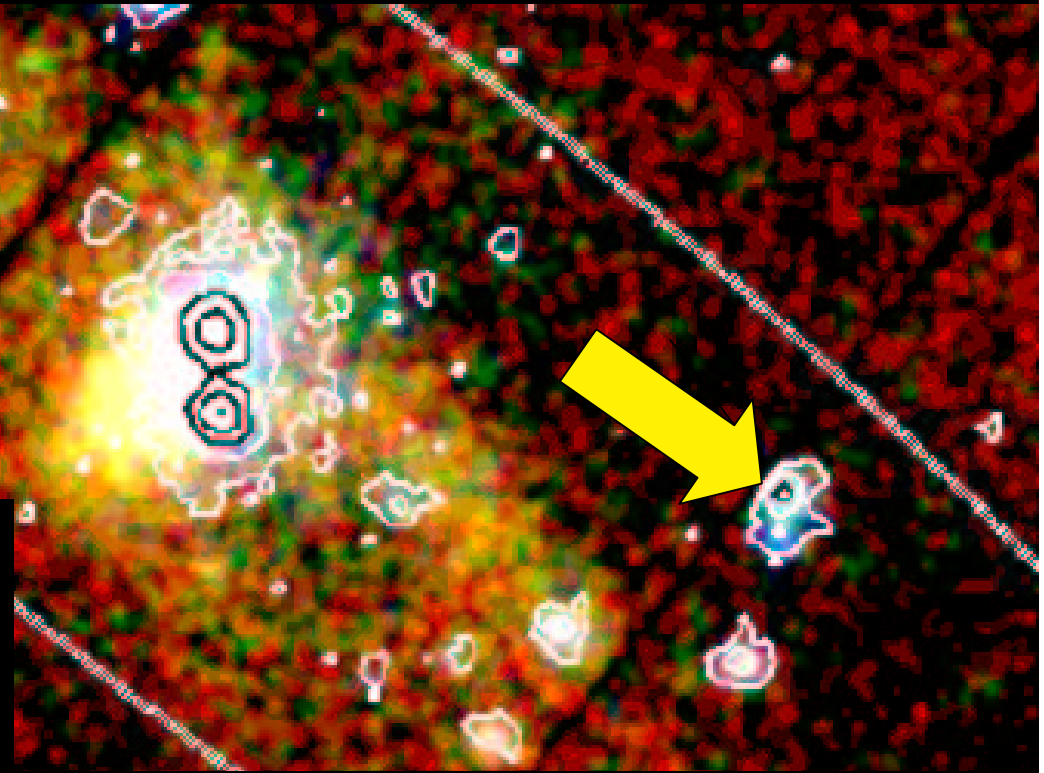
NGC 253

XMM-Newton EPIC PN

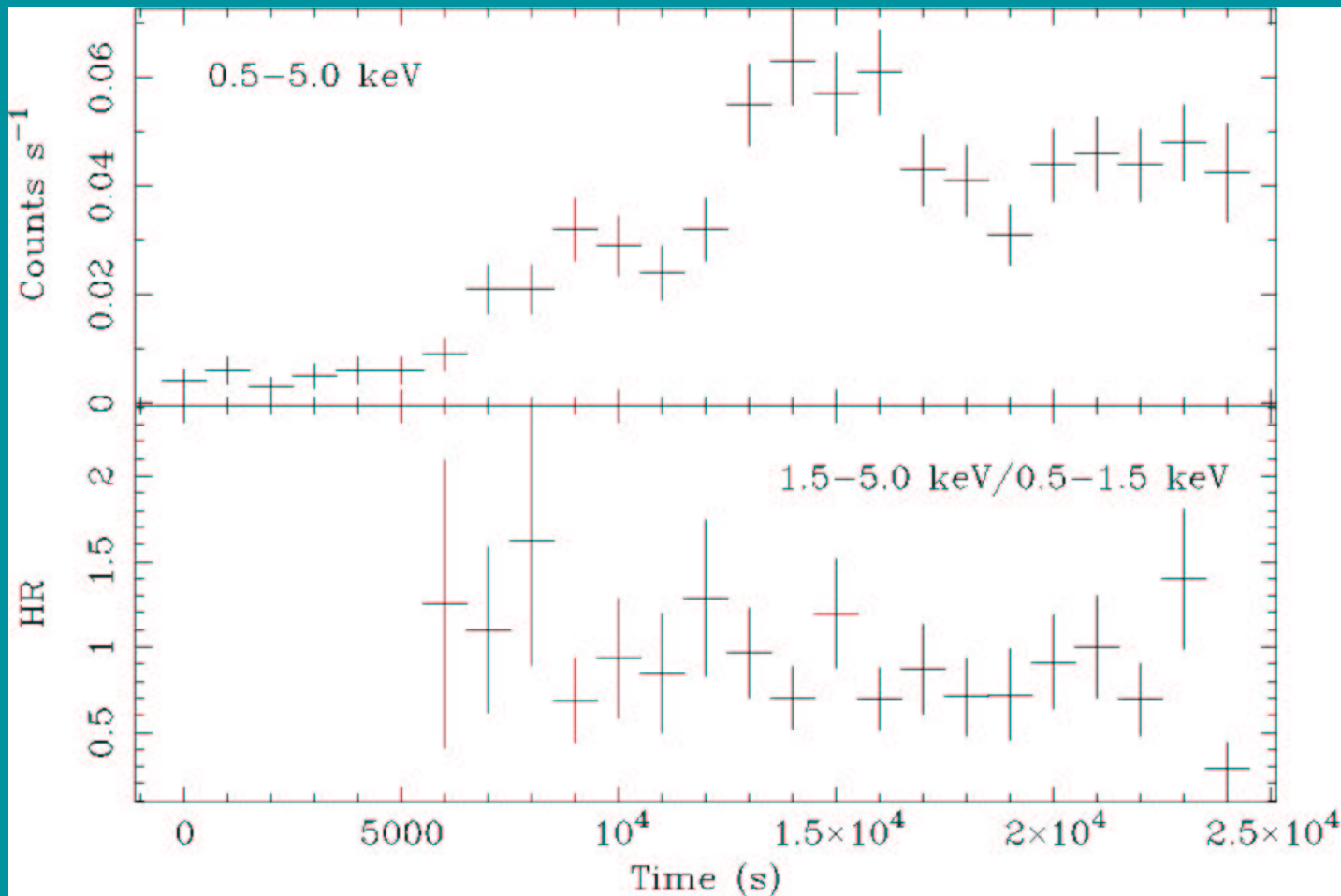
Wolfgang Pietsch, Frank Haberl, Andreas Vogler

Max Planck Institut für extraterrestrische Physik

A&A 402, 457 (2003)

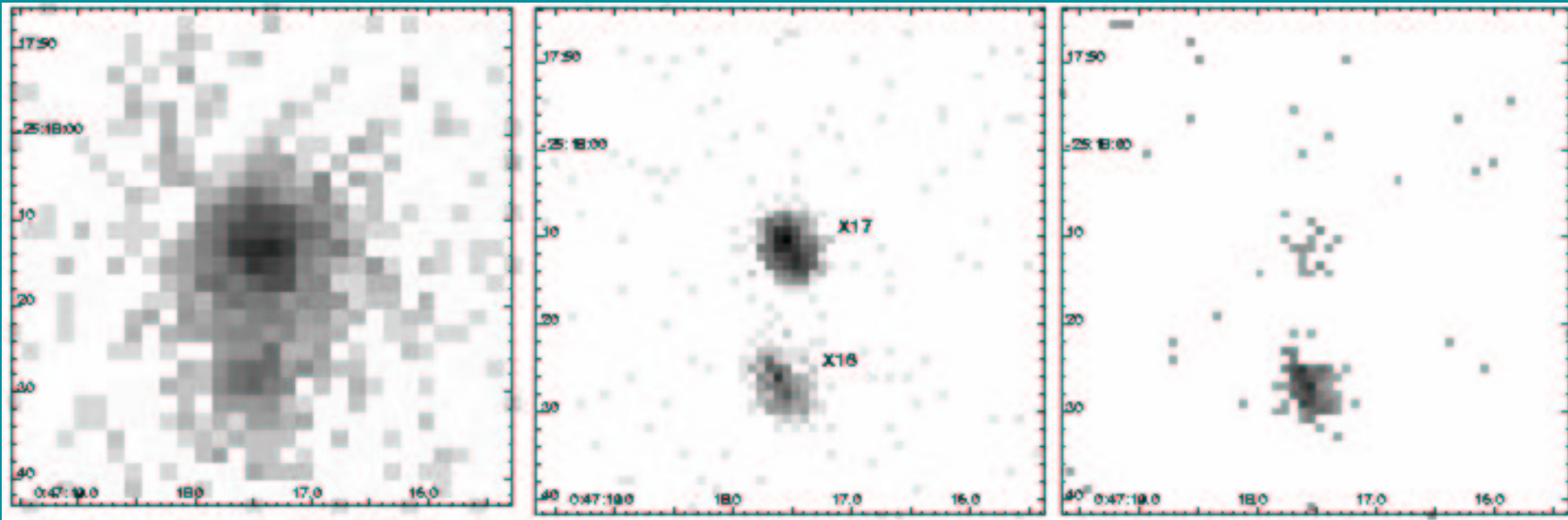


XMM-Newton EPIC PN light curve and hardness ratio: December 13/14, 2000



Egress from low to high state at MJD 51892.146 (6)

Images of RX J004717.4-251811 region logarithmically scaled



XMM-Newton

EPIC PN

Dec 13/14, 2000

high state

Chandra

ACIS S

Dec 27, 1999

high state

Chandra

ACIS S

Dec 27, 1999

low state

Allowed orbital periods of RX J004717.4-251811 (NGC 253 X17)

Period (d)	Error* (10^{-6} d)	Ecl. dur. (**)	Obs. 383 (***)	Comment (****)
1.470243	10	0.15		B
2.484902	10	0.13		B
2.778391	10	0.13	E	B
3.207928	10	0.14		
4.969849	20	0.13	E	B
6.190937	20	0.14		B, E-
7.671308	20	0.15		E-

Notes:

* : determined to achieve longest possible eclipse duration

** : maximum allowed eclipse duration (Δ phase)

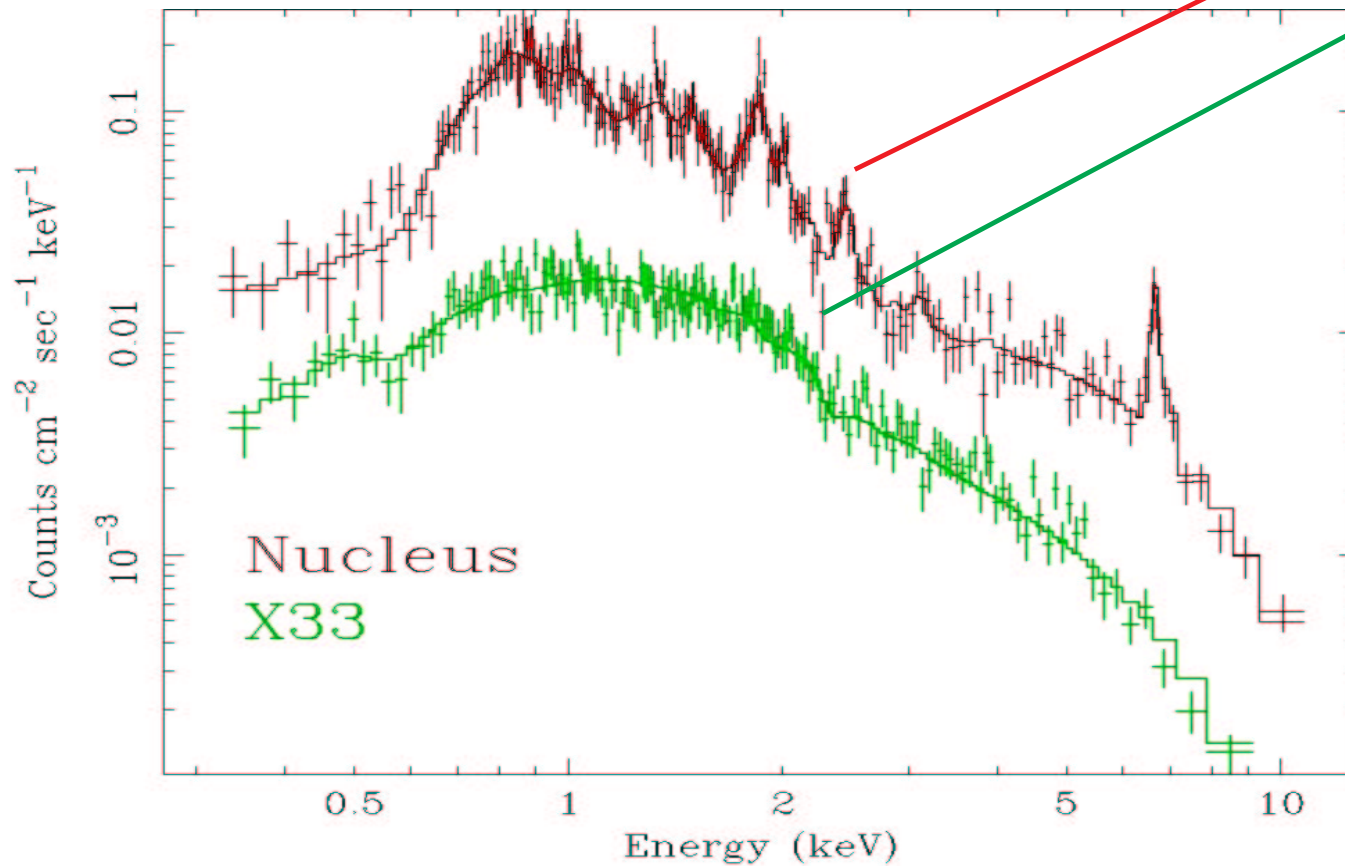
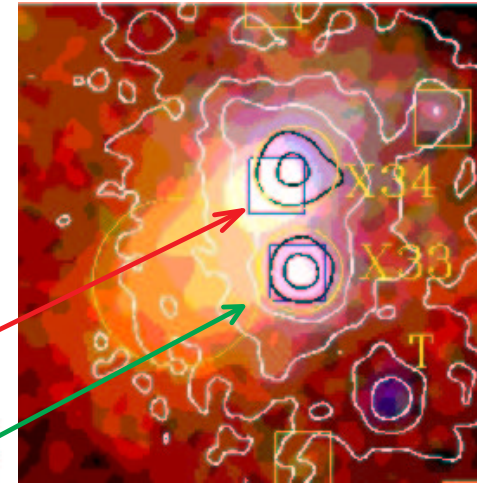
*** : E if RX J004717.4-251811 in eclipse during *Chandra* 383

****: B period at boundary of allowed window, E- no *Einstein* exposure during eclipse

Best period candidates: 1.470243 d, 3.207928 d

EPIC PN spectra

- nuclear area
- X33 (BH XRB)



3 MEKAL spectra

$$N_{\text{H}} = (0.3, 1.8, 13) \times 10^{22} \text{ cm}^{-2}$$

$$kT = (0.6, 0.9, 6.3) \text{ keV}$$

DiskBB

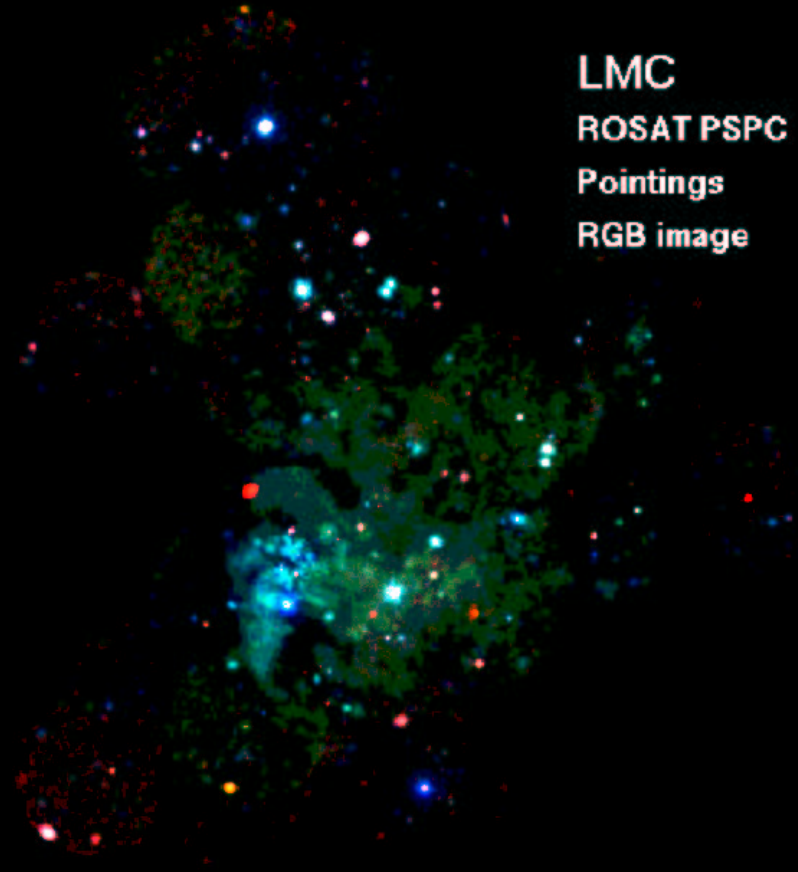
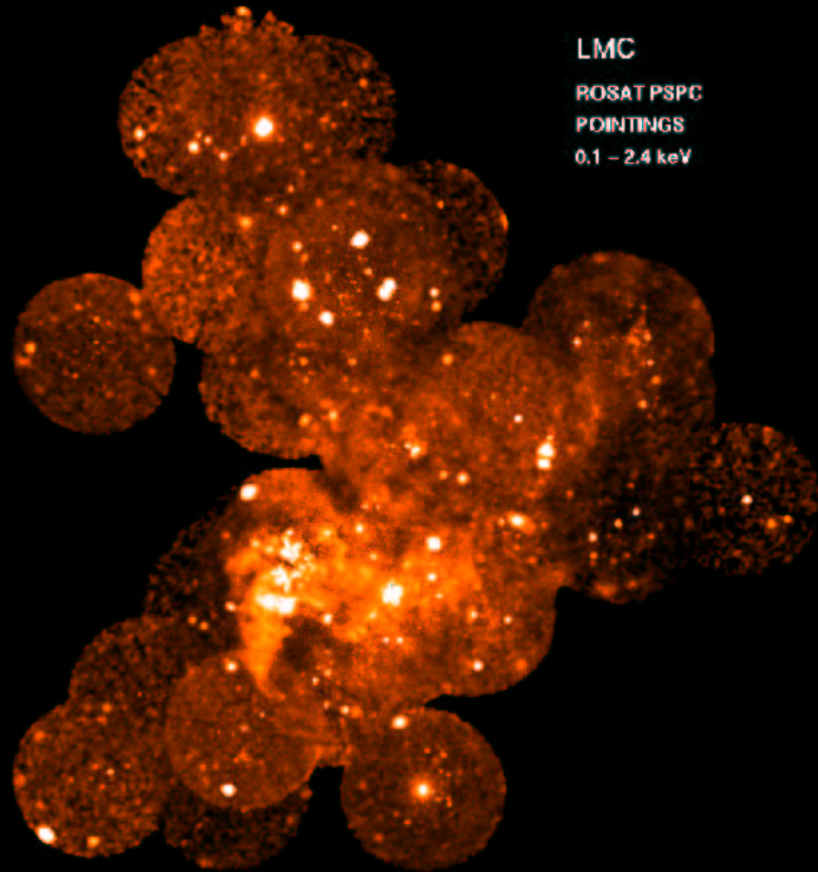
$$N_{\text{H}} = 5 \times 10^{21} \text{ cm}^{-2}$$

$$kT = 1.6 \text{ keV}$$

$$r_{\text{in}}(\cos i)^{0.5} = 10 \text{ km}$$

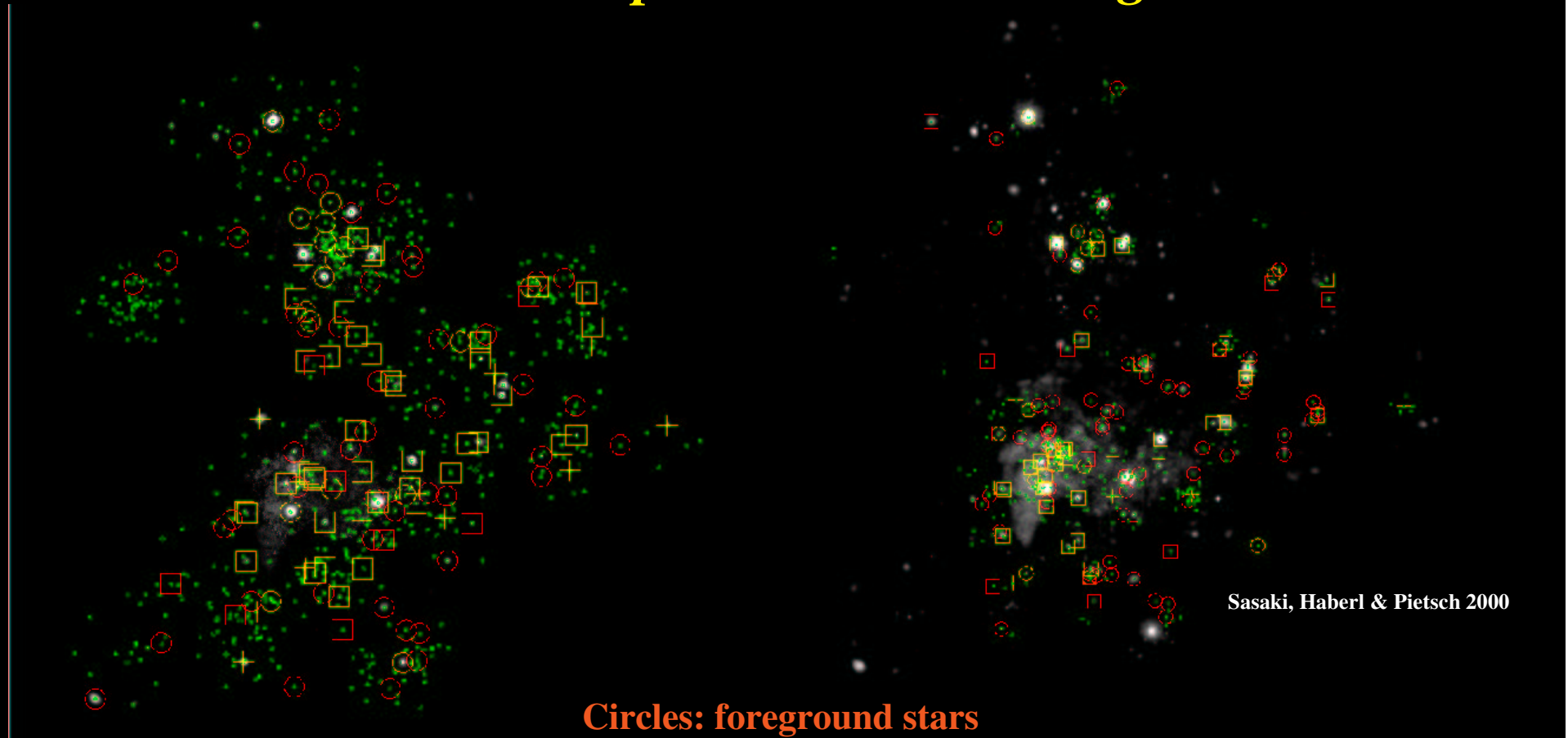
$$\text{photon index } 4.3$$

The ROSAT PSPC pointings



Haberl & Pietsch 1999

The ROSAT point-source catalogues



Sasaki, Haberl & Pietsch 2000

PSPC

59 sq. degrees

758 Sources

Circles: foreground stars

Squares: background AGN

Circles: X-ray binaries

Squares: SNRs

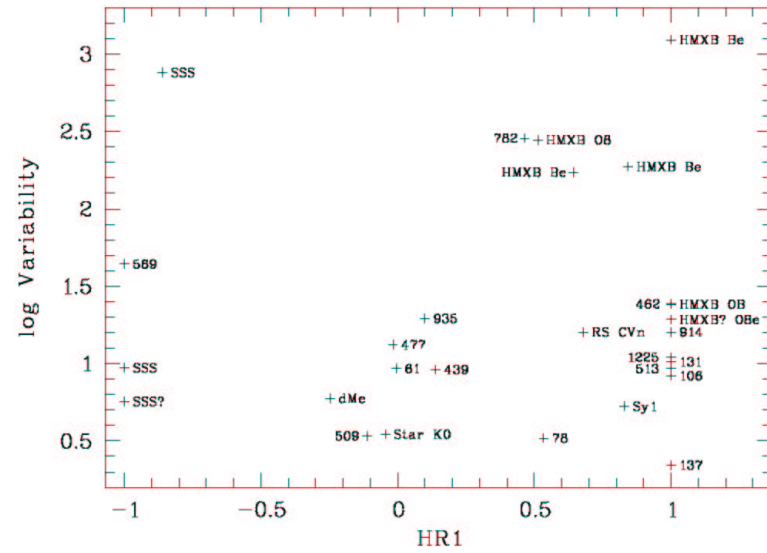
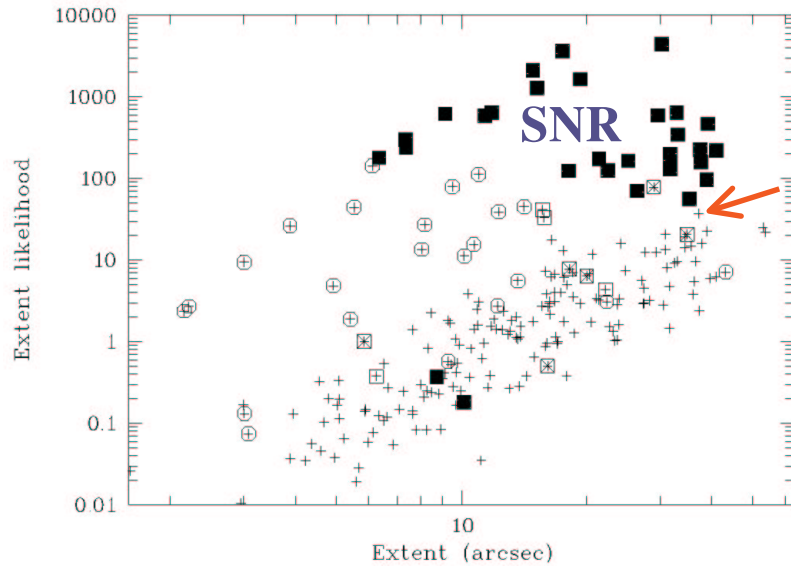
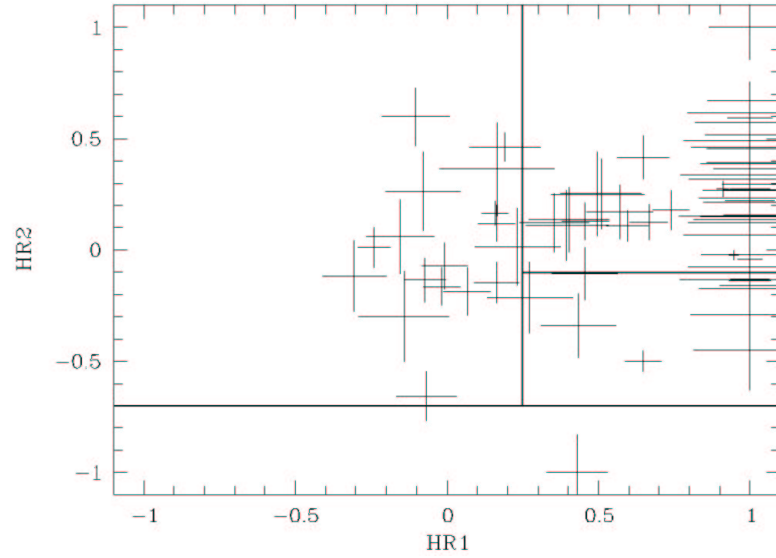
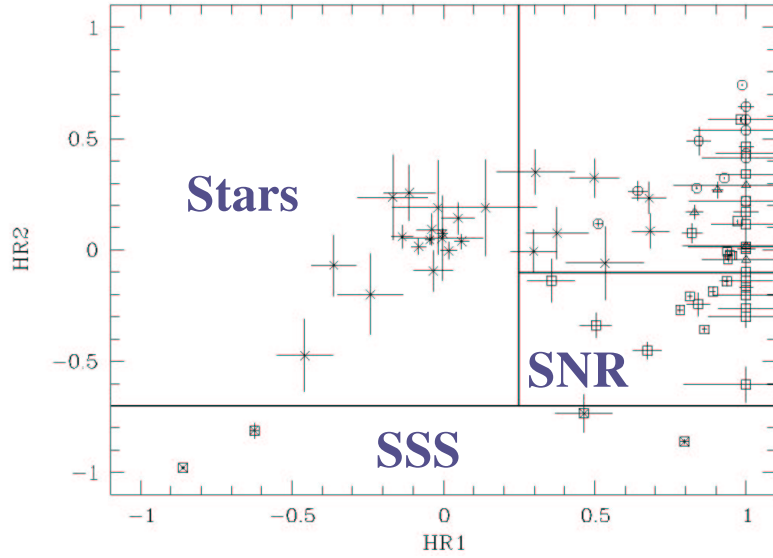
Crosses: Supersoft sources

HRI

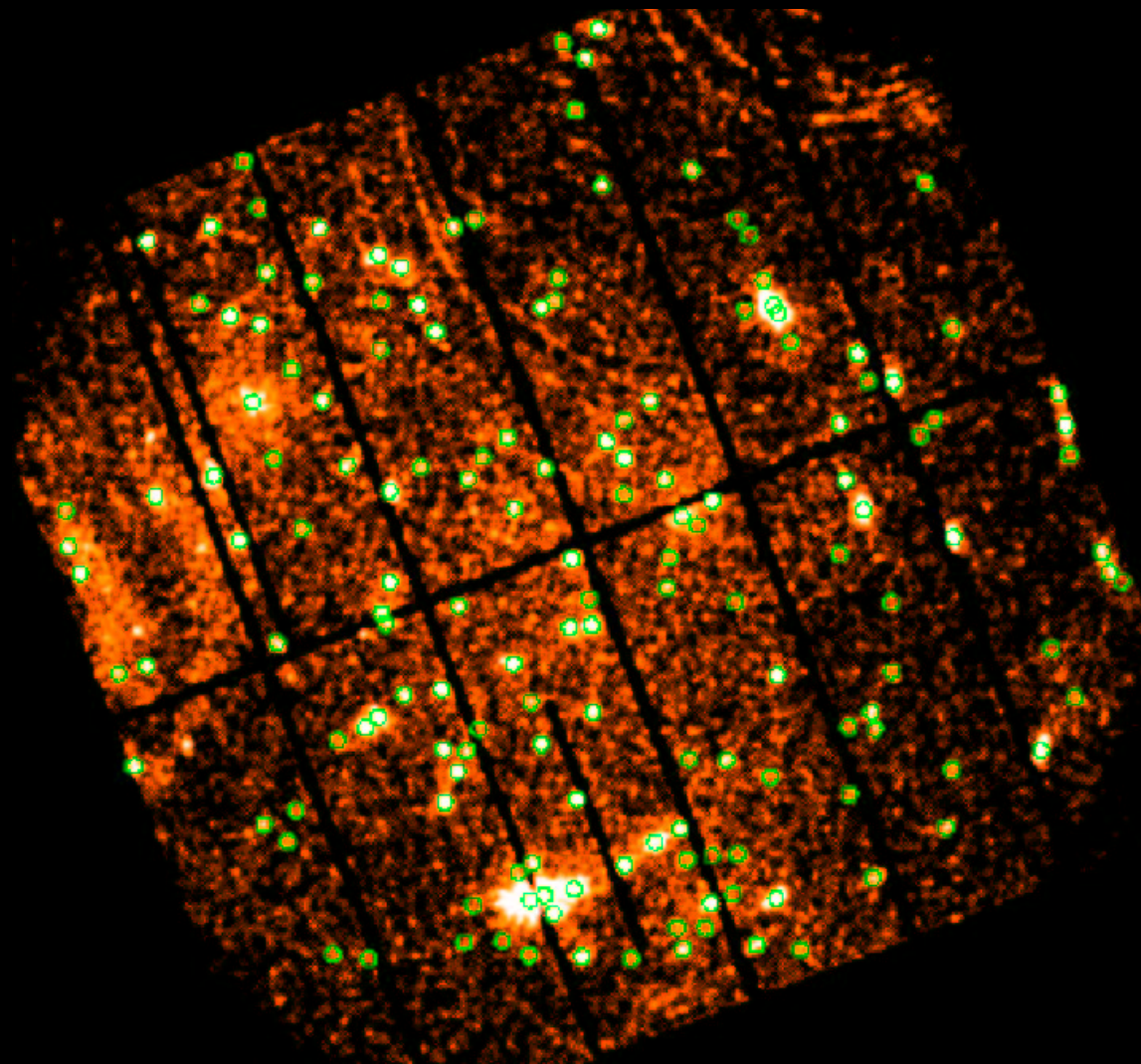
397 Sources

259 new

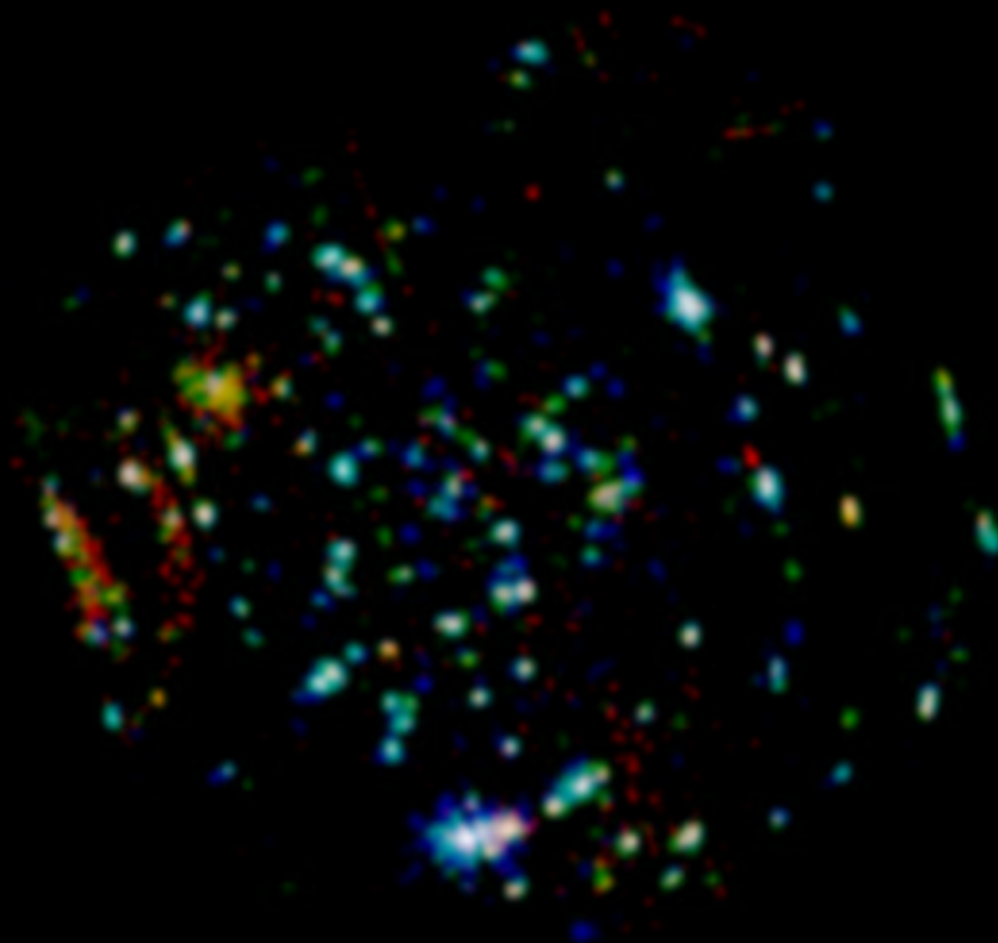
Source classifications



A deep XMM-Newton pointing

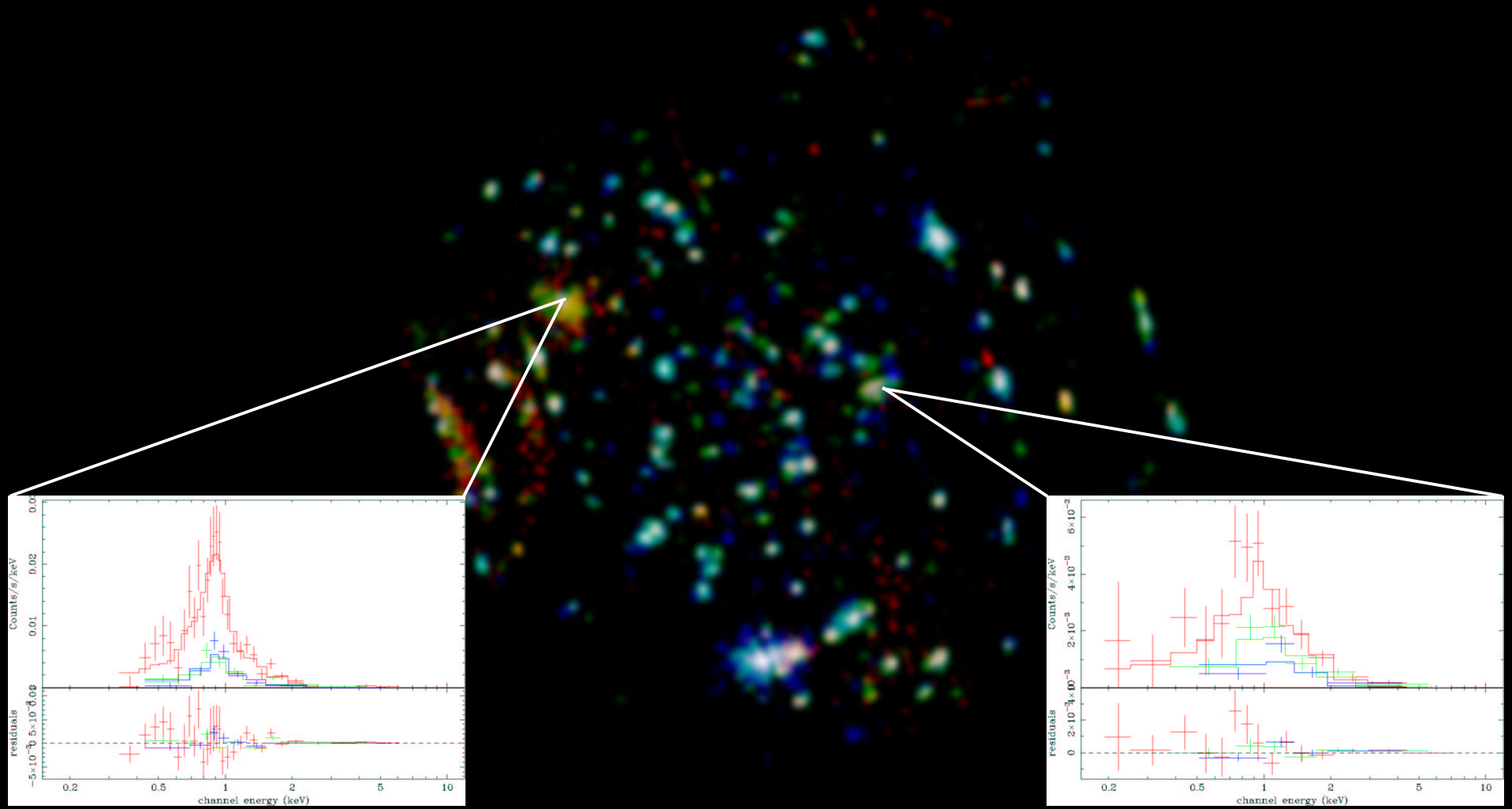


A deep XMM-Newton pointing

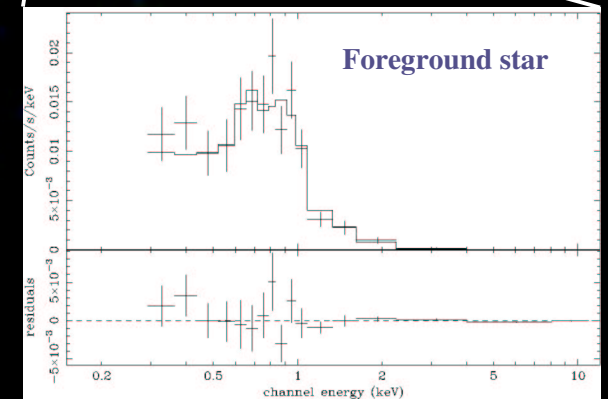
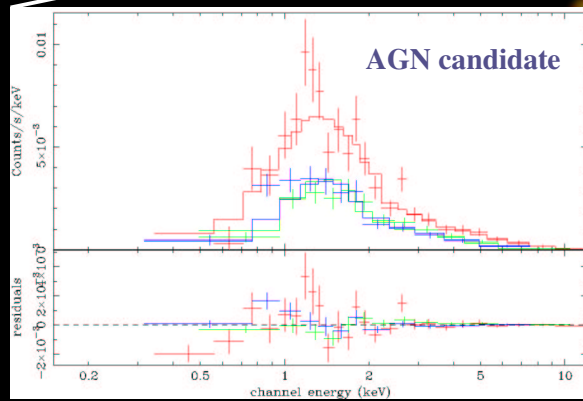


New Supernova Remnants

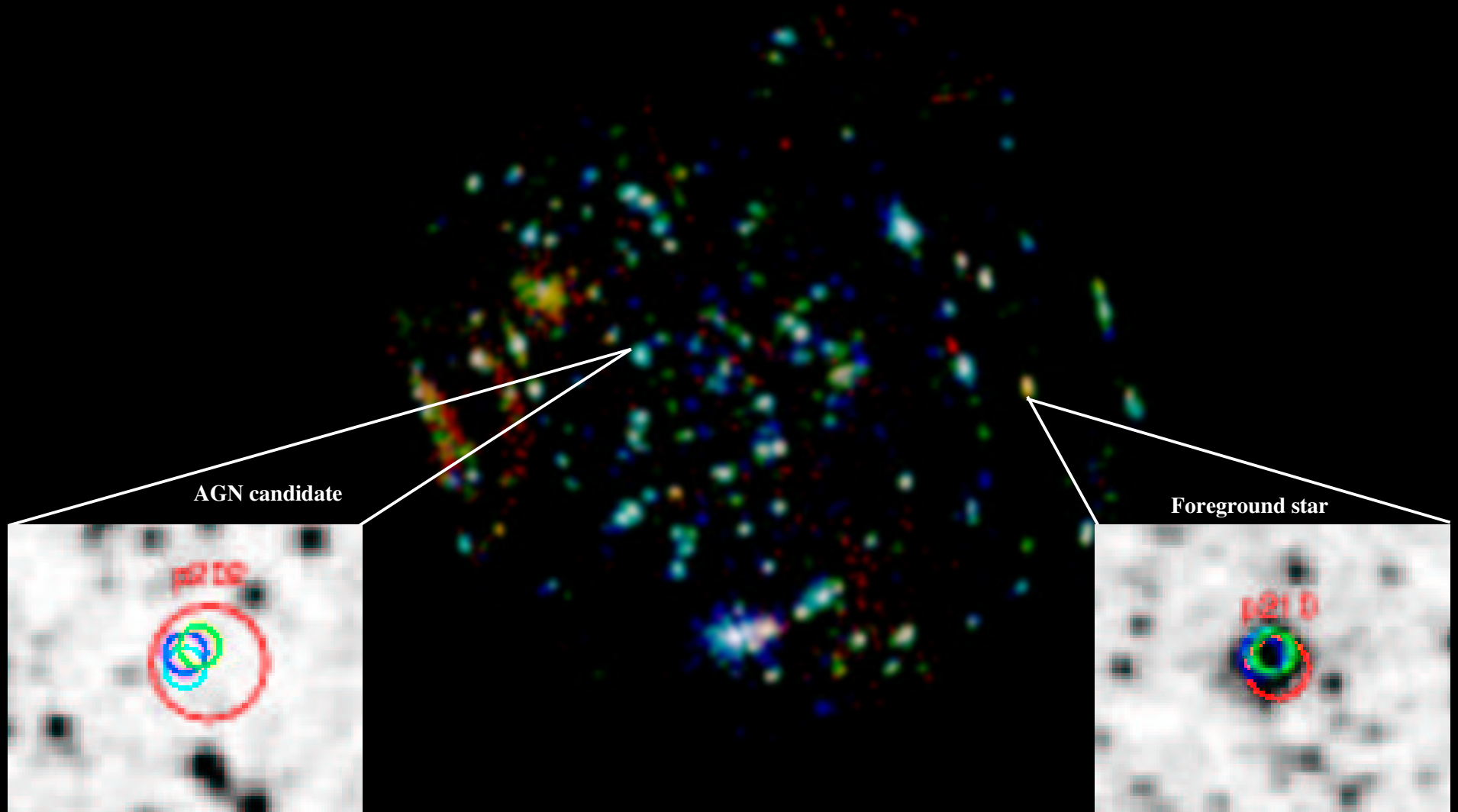
EPIC spectra



Foreground stars and background AGN EPIC spectra



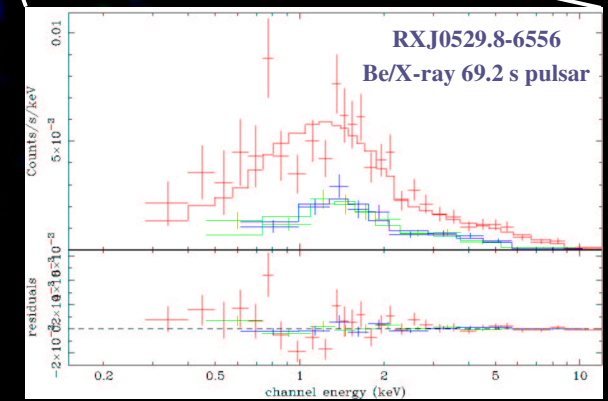
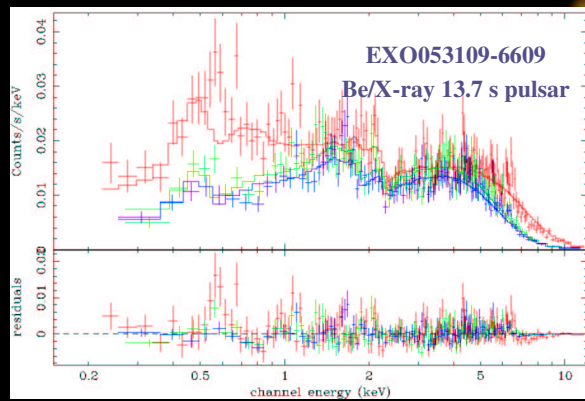
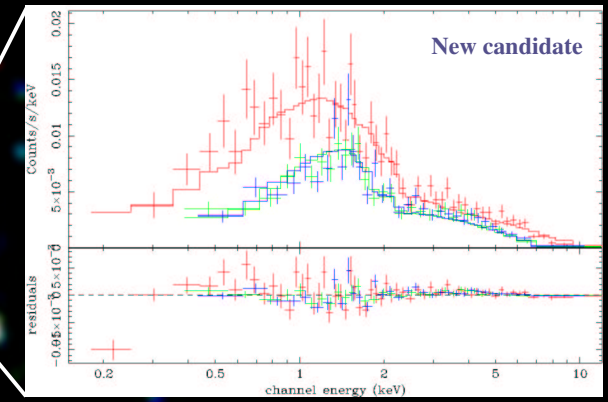
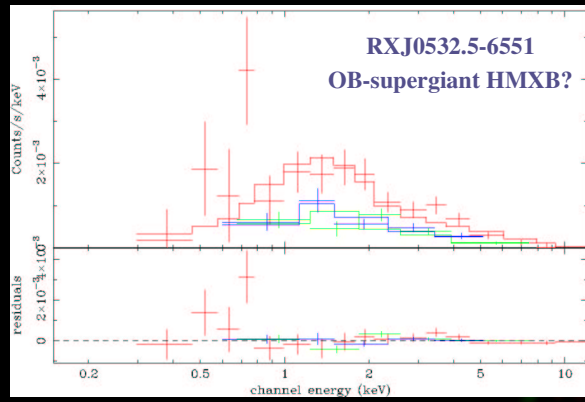
*Foreground stars and background AGN
Optical counterparts*



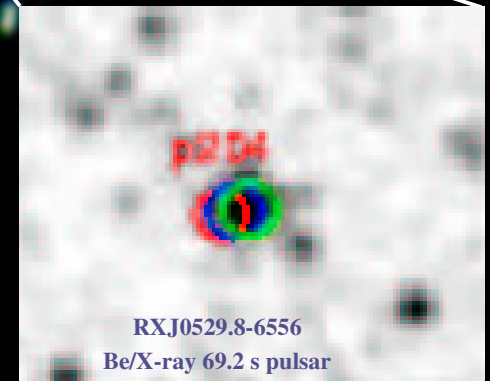
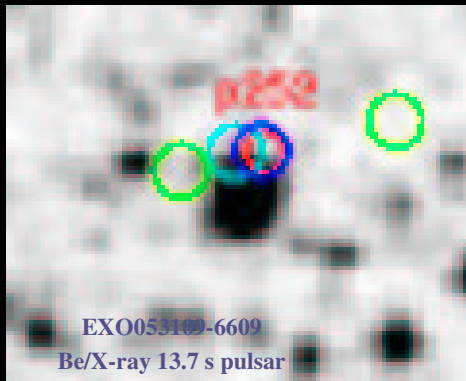
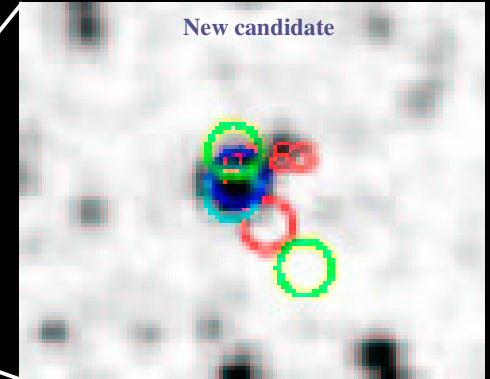
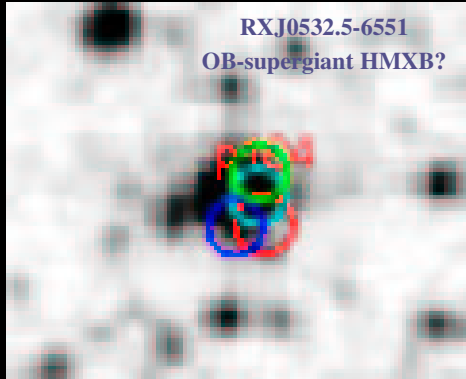
AGN candidate

Foreground star

High mass X-ray binaries EPIC spectra



High mass X-ray binaries Optical counterparts



A deep XMM-Newton pointing

Summary

150 sources detected (88 within 10')

limit $7.2 \cdot 10^{-4}$ cts s⁻¹, flux $3.7 \cdot 10^{-15}$ erg s cm⁻², LMC luminosity $1.1 \cdot 10^{33}$ erg s⁻¹

New SNRs (2)

thermal spectra

HMXBs (3 + 1 new candidate)

powerlaw spectra (index~1.1), luminosities $1.1 \cdot 10^{34}$ – $5.7 \cdot 10^{35}$ erg s⁻¹

14-15 mag counterpart

Foreground stars

soft spectra, little absorption

bright optical counterpart

AGN

powerlaw spectra

expected index~1.9, but wide distribution

faint counterpart

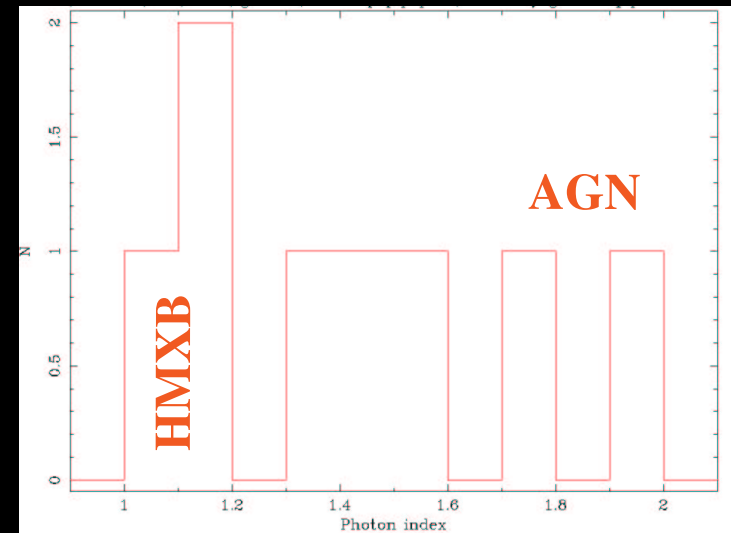
log N – log S:

<50 expected (nH~ 10^{21} cm⁻²) within 10'

Unknown

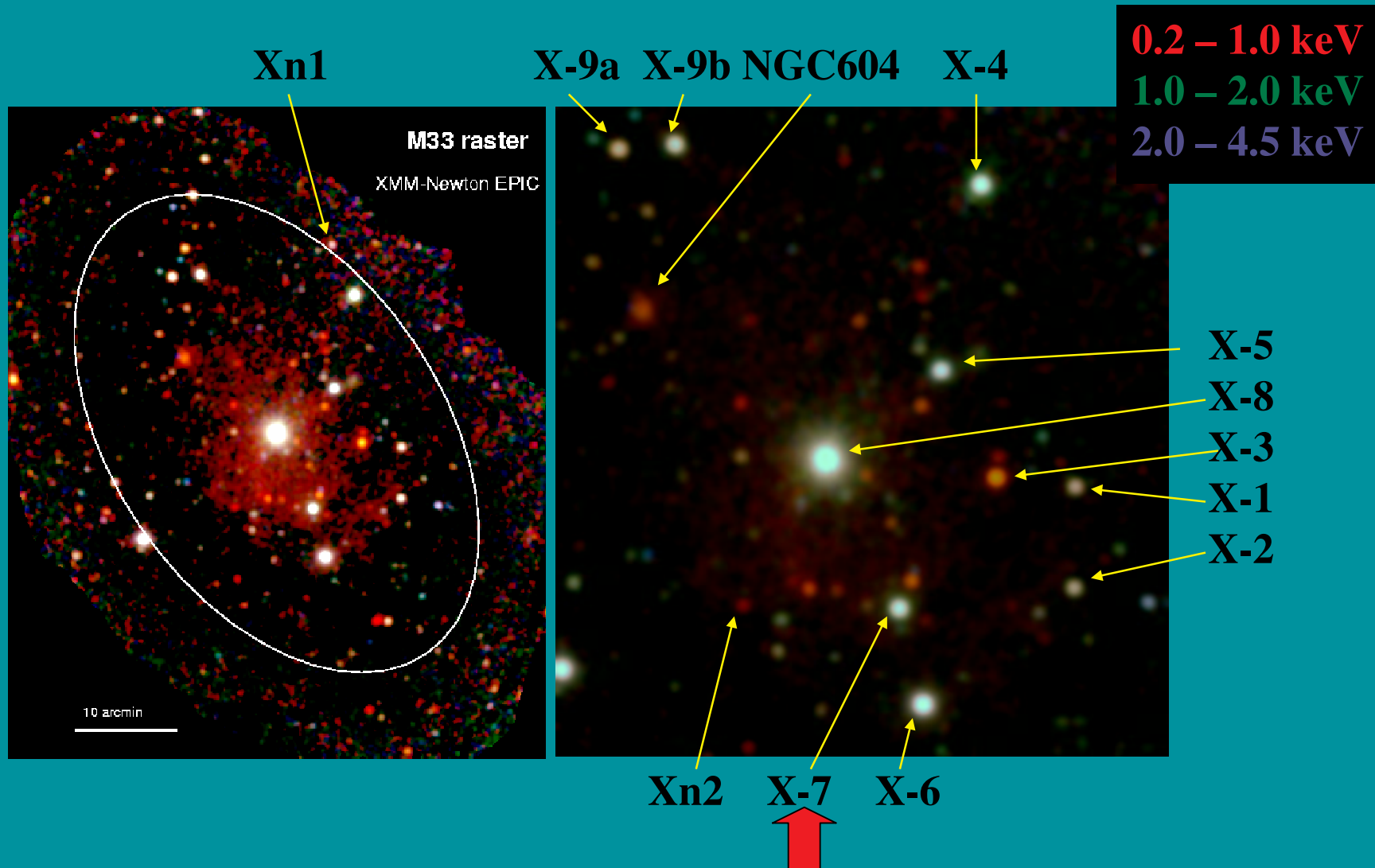
Cataclysmic Variables?

Low mass X-ray binaries?



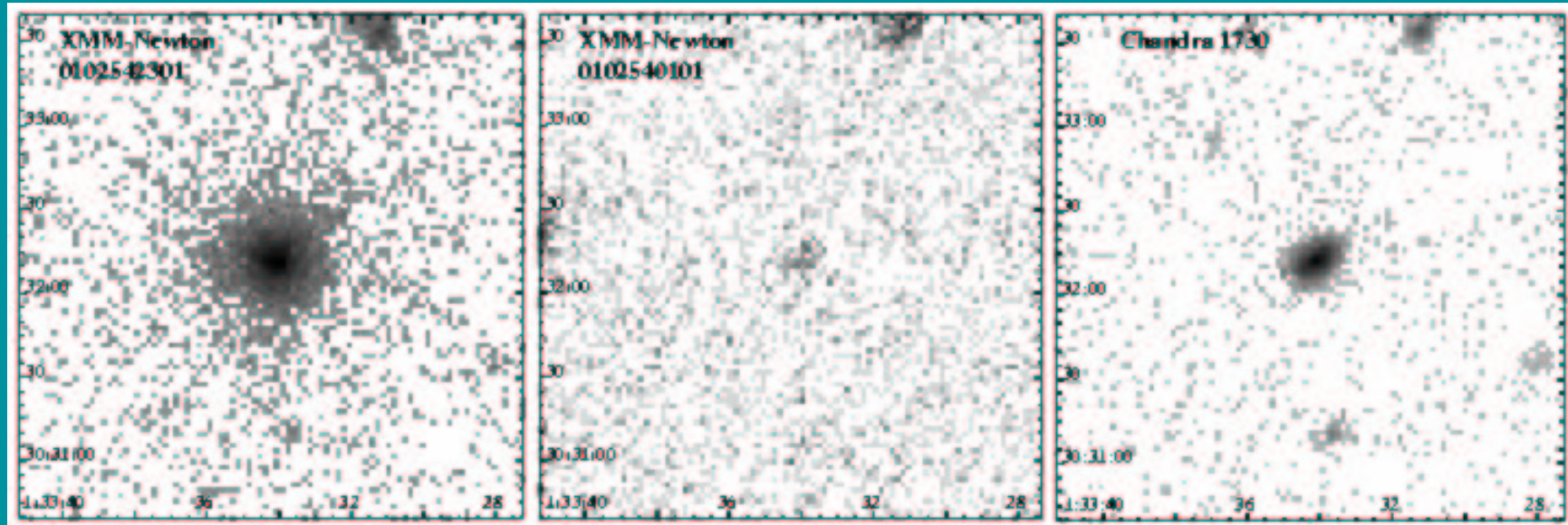
XMM-Newton view of M33

EPIC colour images



Eclipsing X-ray binary M33 X-7

W. Pietsch, B.J.Mochejska, Z.Misanovic, F.Haberl, M.Ehle,
G.Trinchieri 2004, A&A 413, 879



On state

Eclipse

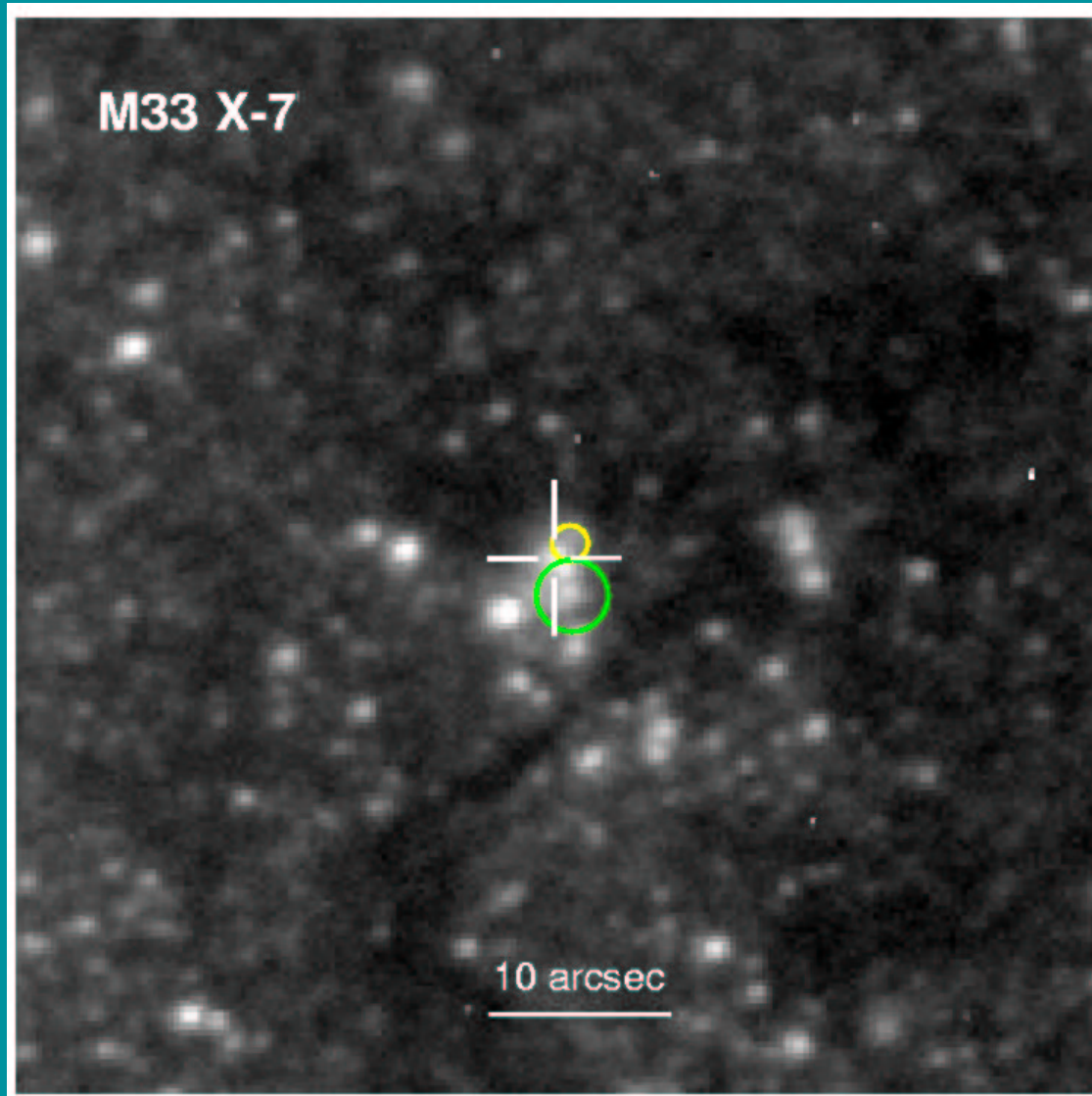
On state

XMM-Newton EPIC

Chandra ACIS I

0.5-4.5 keV images

Eclipsing X-ray binary M33 X-7



Optical identification

Star with V 18.9 mag
with 3.45 d variability
in unresolved
emission

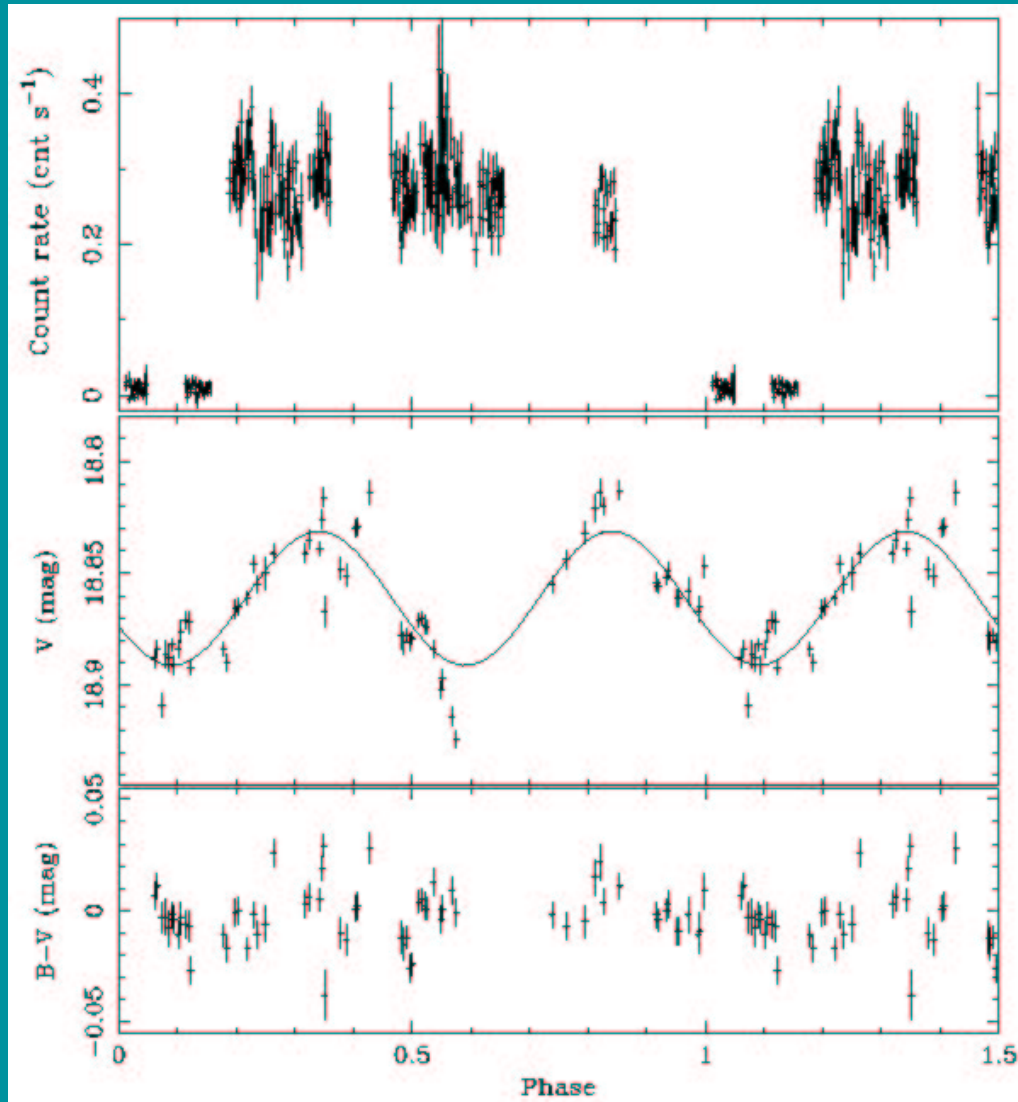
DIRECT image by
B. Mochejska

Green circle: ROSAT
error box

Haberl & Pietsch 2001

Yellow circle:
Chandra error box

Eclipsing X-ray binary M33 X-7



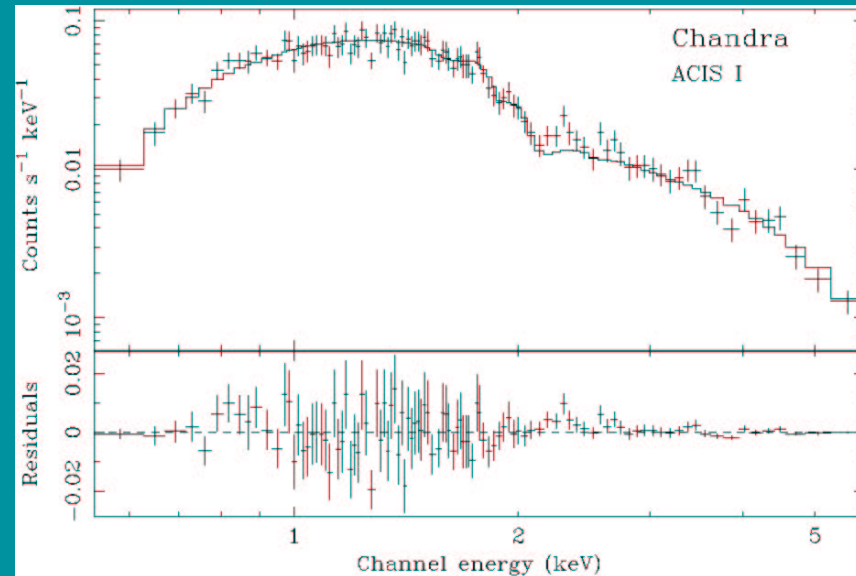
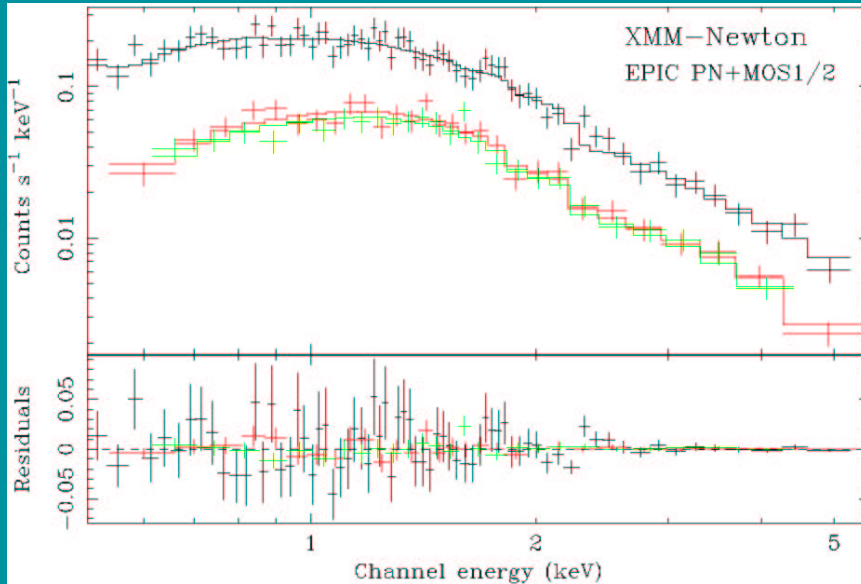
**XMM-Newton EPIC
TS GT and AO2
Chandra archive**

**Optical V and B-V
light curve
re-analysis of
DIRECT data by
B. Mochejska**



**Improved binary
ephemeris**

Eclipsing X-ray binary M33 X-7



Best fitting spectral models:

Absorbed bremsstrahlung or disk blackbody

First eclipsing black hole (high mass)

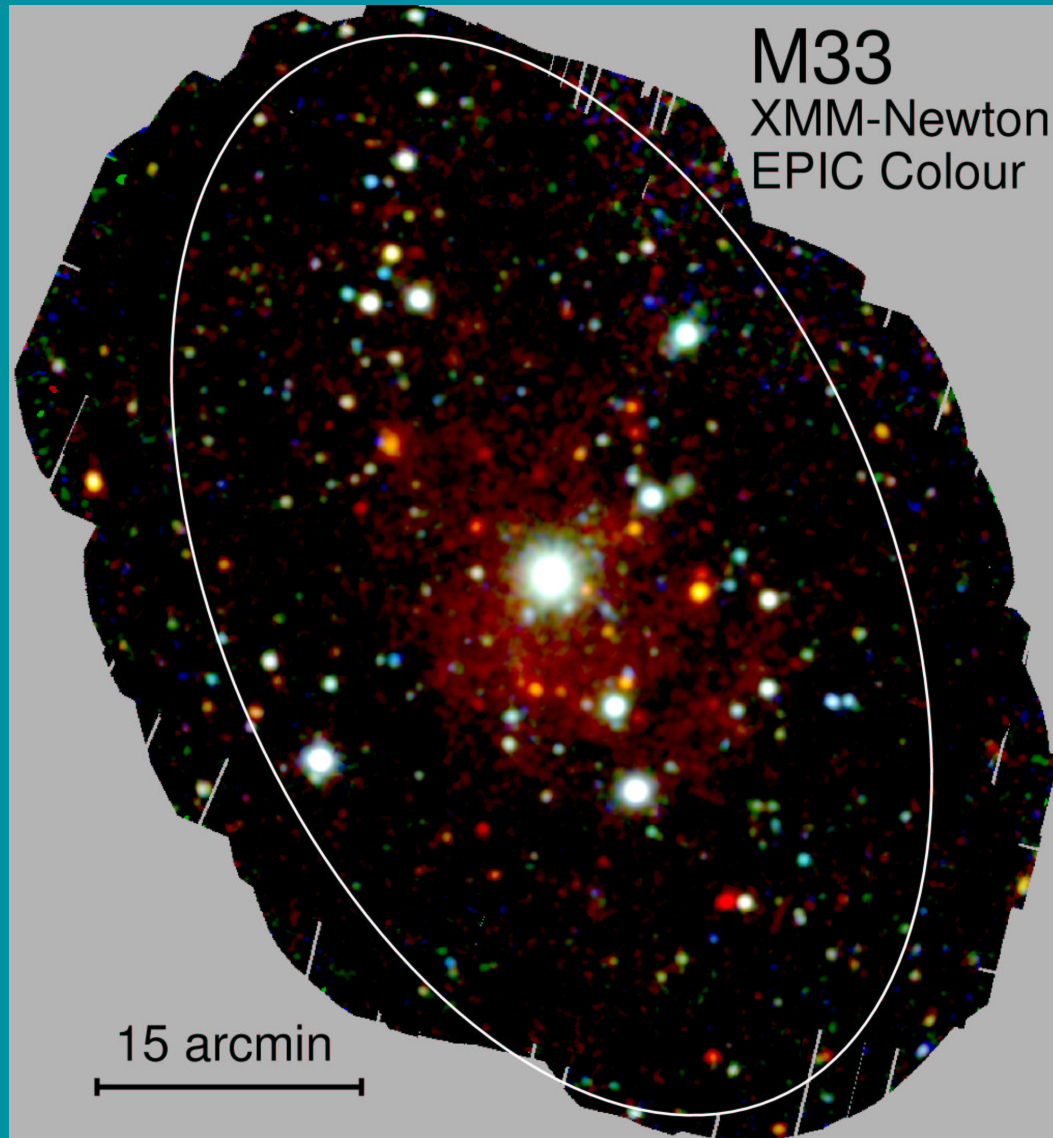
X-ray binary ?

**Dedicated XMM-Newton AO3 proposal
for pulsations and spectra, not accepted**



XMM-Newton survey of the Local Group galaxy M33

W.Pietsch, Z.Misanovic, F.Haberl,
D.Hatzidimitriou, M.Ehle, G.Trinchieri
2004, A&A submitted



408 X-ray sources

X-ray properties

Correlation with catalogues
from other wavelength

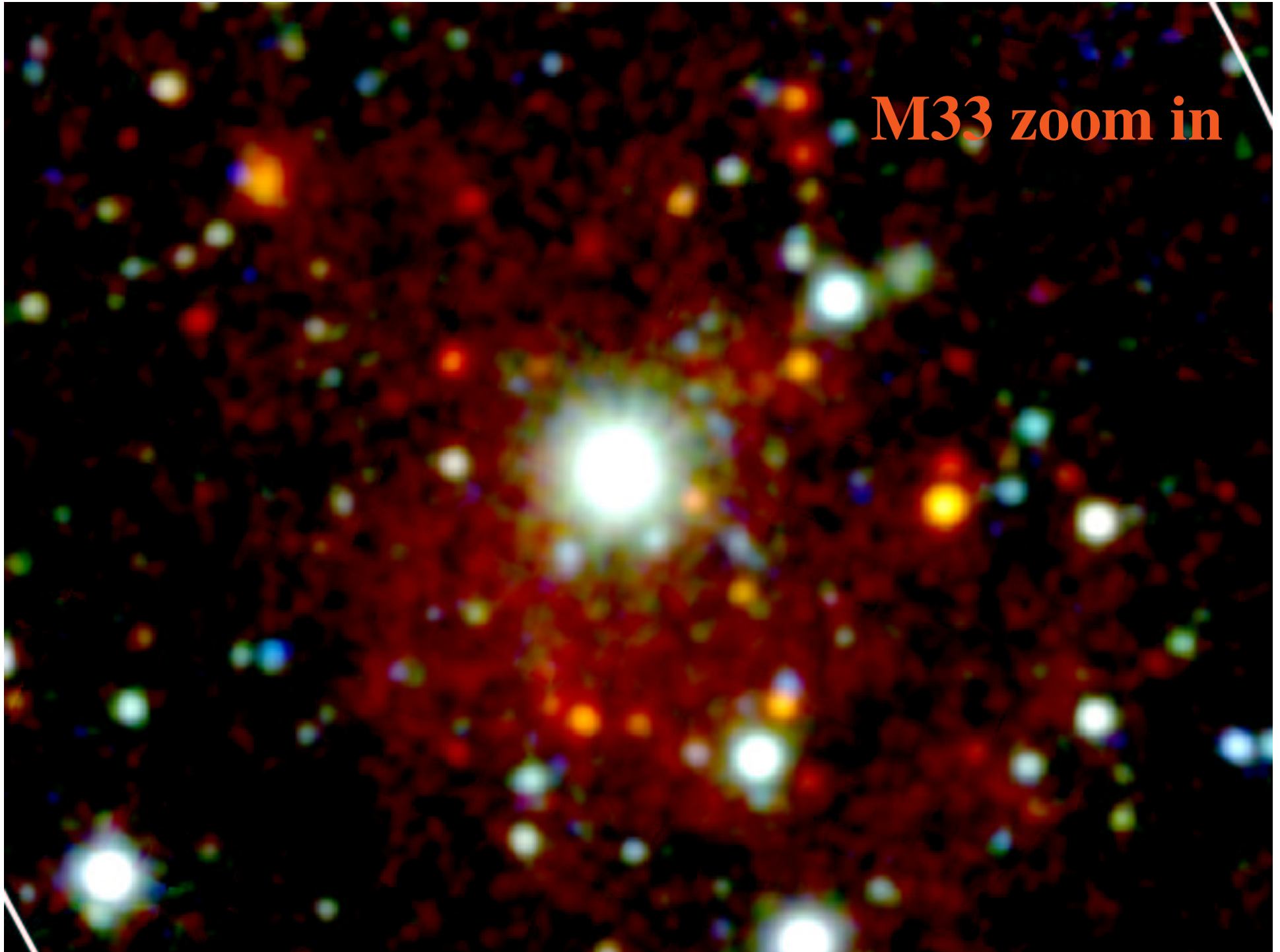
Optical identification

Identify foreground and
background sources



Characterisation of X-ray
source population of M33

M33 zoom in



Hardness ratio plots of M33 sources

$$\text{HR}_i = (\text{B}_{i+1} - \text{B}_i) / (\text{B}_{i+1} + \text{B}_i)$$

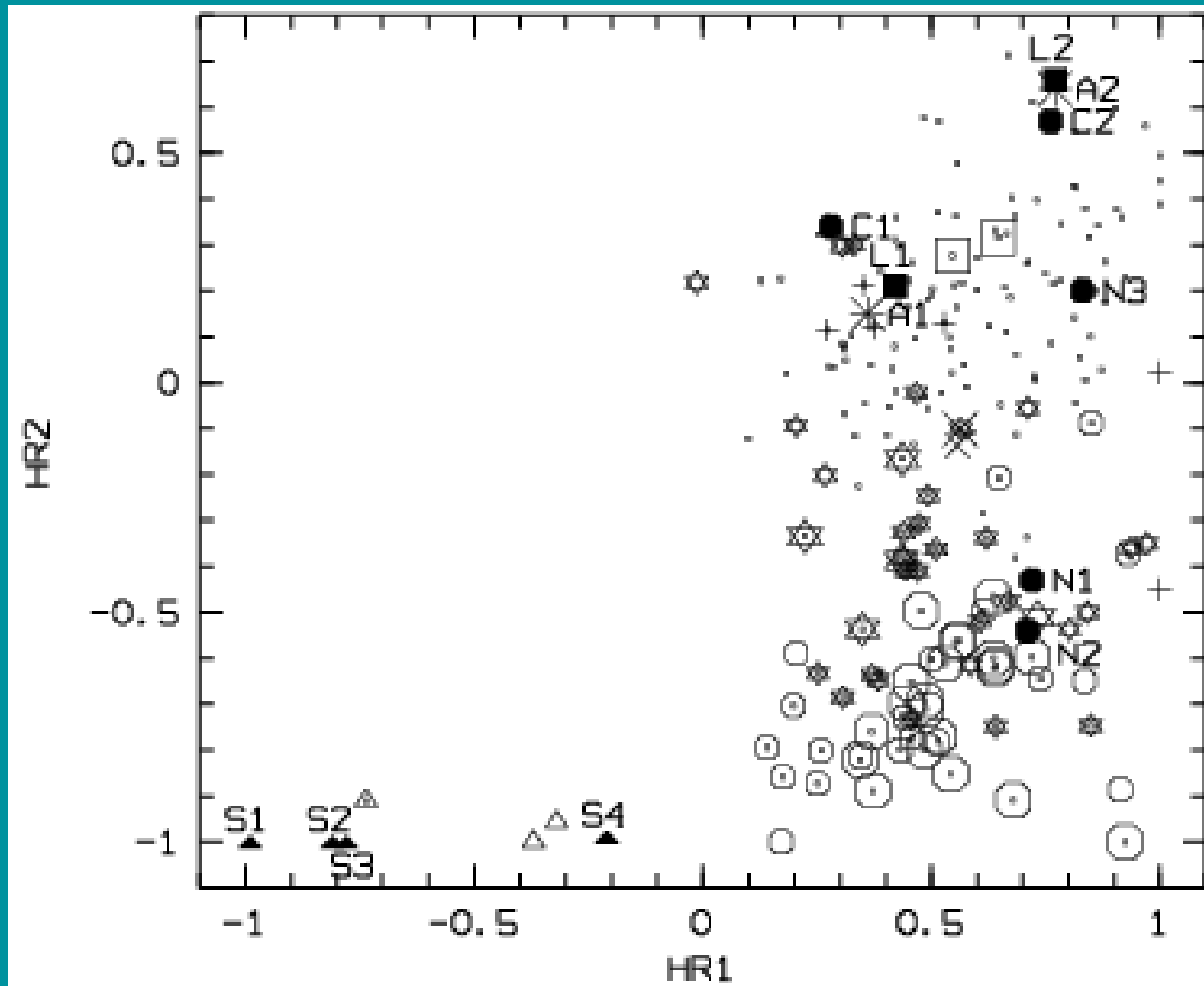
B1: 0.2-0.5 keV

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

Hardness ratio plots of M33 sources

$$\text{HR}_i = (\text{B}_{i+1} - \text{B}_i) / (\text{B}_{i+1} + \text{B}_i)$$

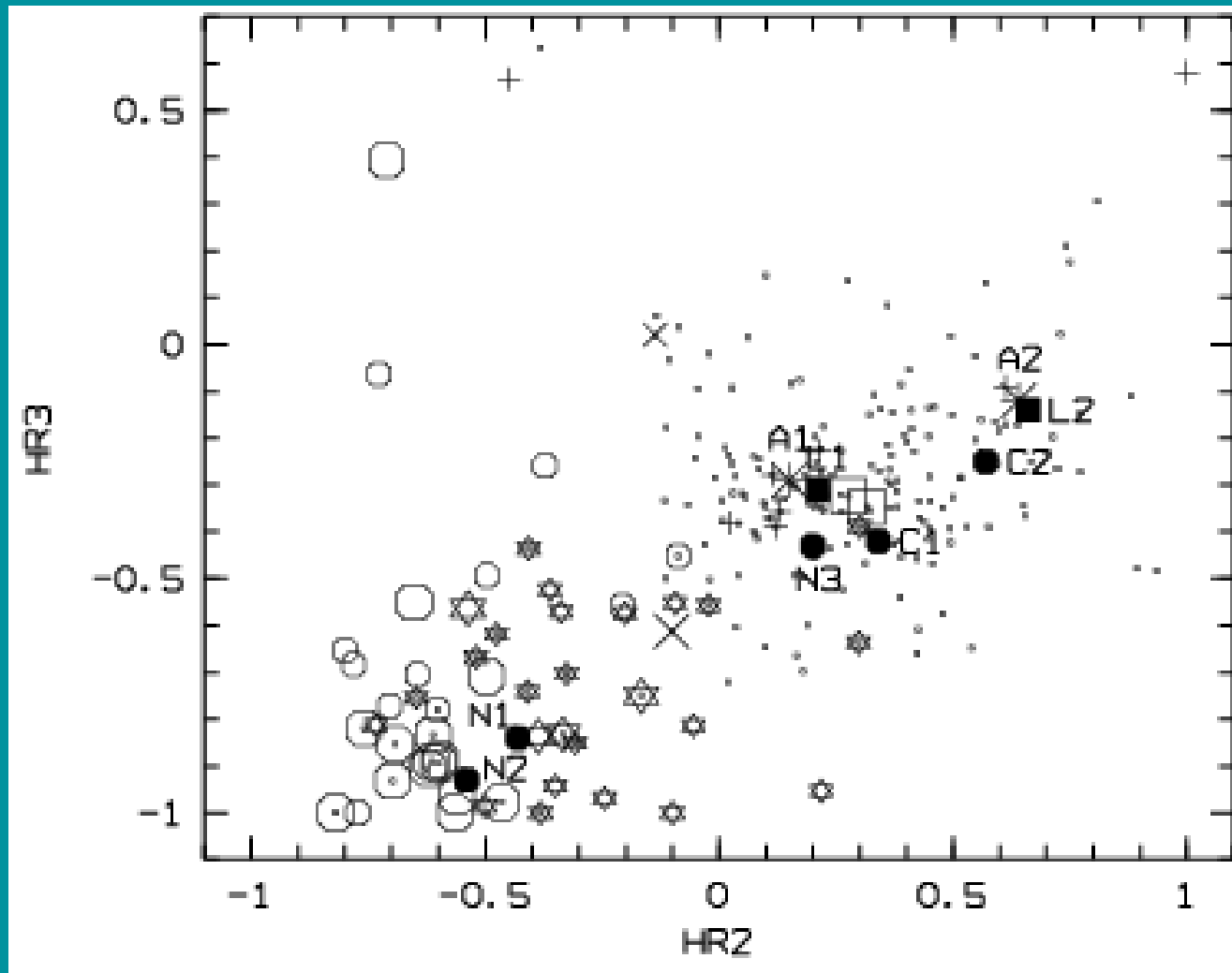
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Hardness ratio plots of M33 sources

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

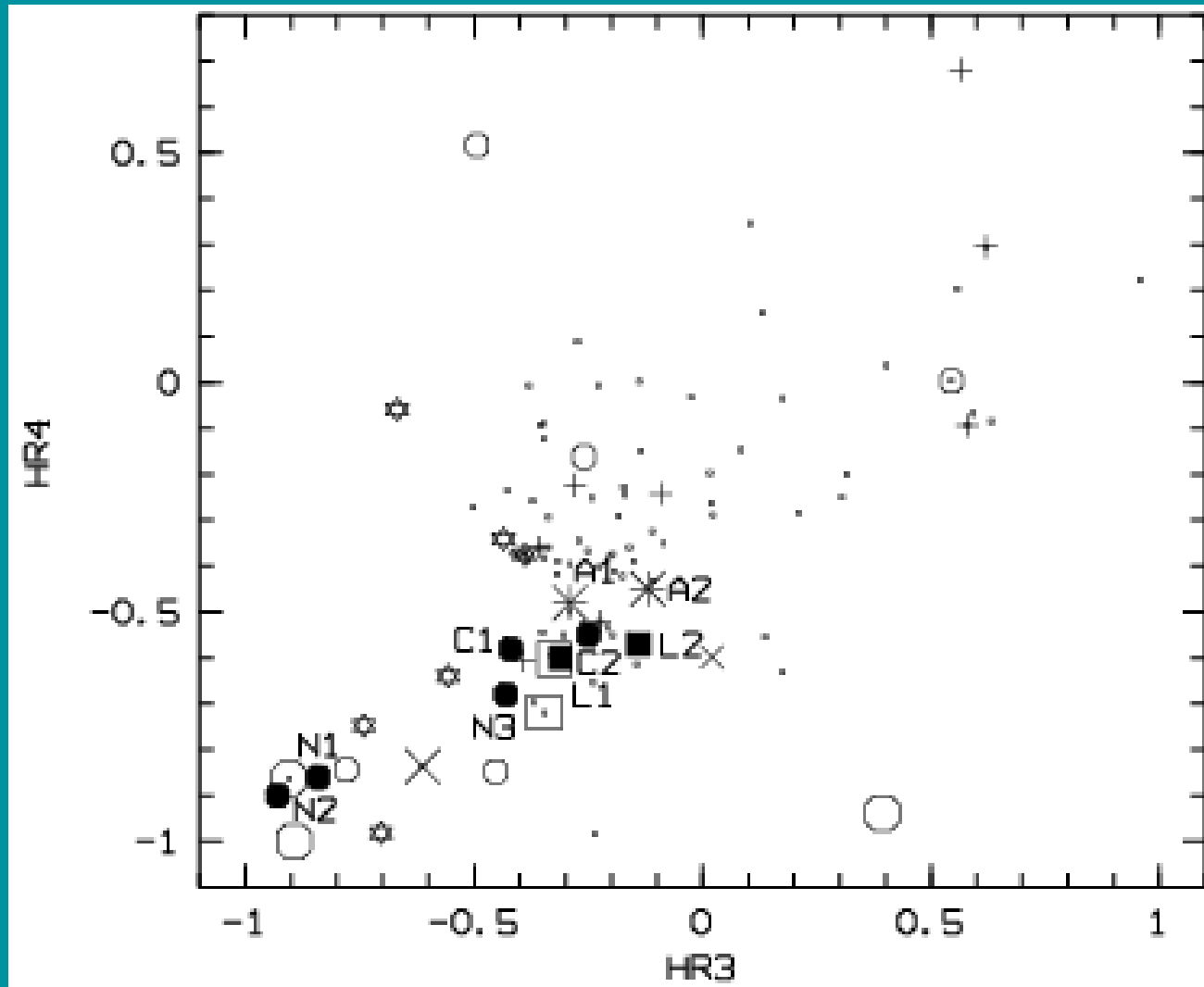
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+ AGN

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⬡ SNR

□ XRB

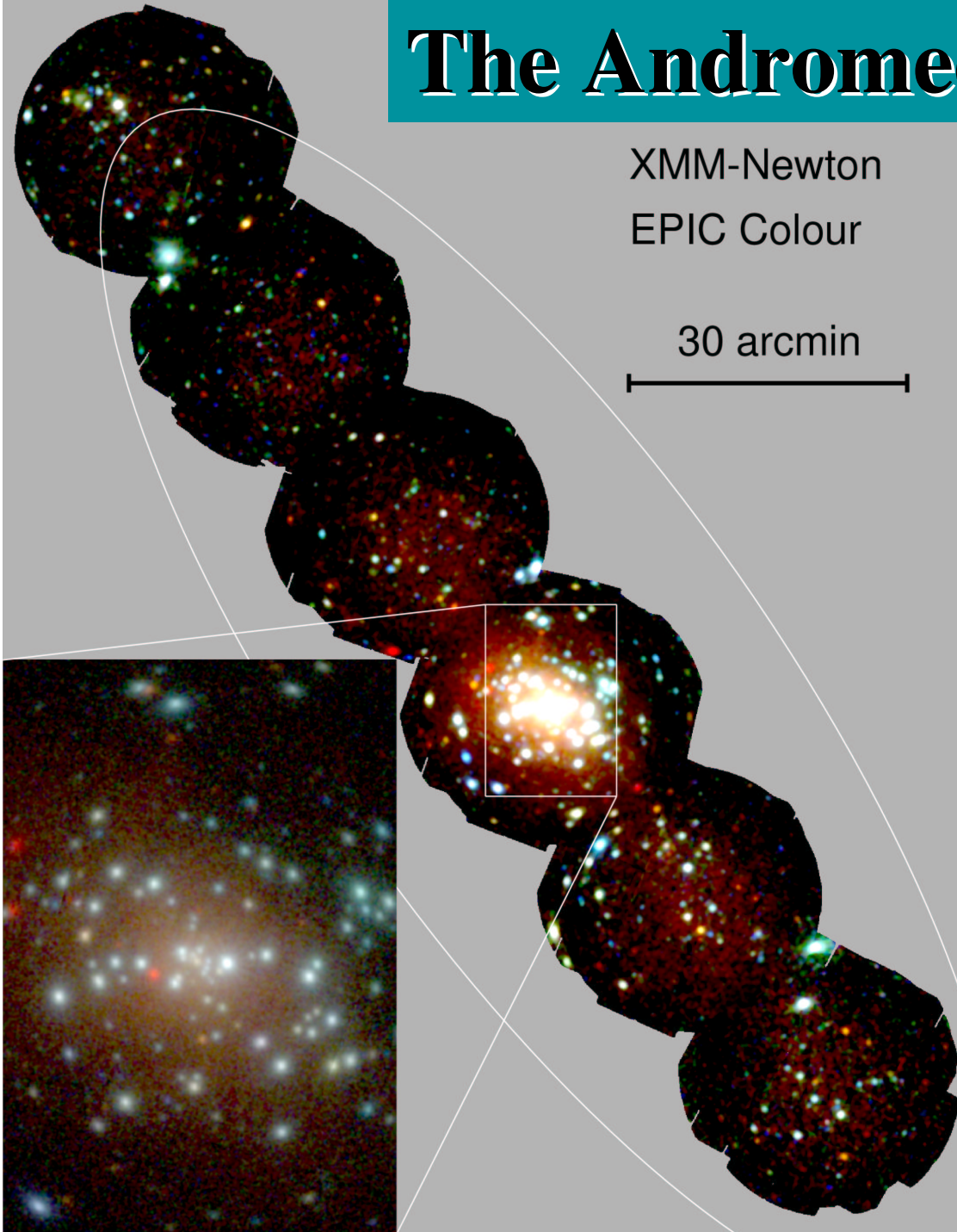
X-ray sources in M33 field: identification and classification

	identified	classified
• foreground stars	5	30
• AGN		12
• Galaxies	1	1
• SSS		5
• SNR	21	23
• XRB	2	
• Hard		267

The Andromeda Galaxy M31

XMM-Newton
EPIC Colour

30 arcmin



**W.Pietsch, M.Freyberg,
F.Haberl et.al. 2004, in
preparation**

- Similar analysis to M33 on archival data
- more than 800 sources in fields
- Hardness ratio and time variability
- classification and identification in progress



M 31 centre

All EPIC mosaic (~100 ks)

- Many LMXBs
- Galactic center sources not fully resolved
- SNRs
- foreground stars
- diffuse emission



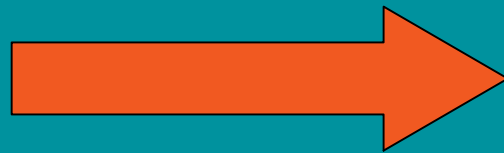
Movie of centre area by
blinking four observations
with separation of half a year



Variable X-ray sources in the M31 centre

Summary

- Hard X-ray spectra very important for classification:
separates
 - XRBs
 - Active nuclei
 - Plerions
- Time variability studies of XRBs
- emission from young supernovae
- High energy sensitivity of SIMBOL-X better than XMM-Newton, therefore better selectivity



SIMBOL-X

Nearby galaxy
observations need:

- Low energy response and low background
- Spatial resolution as good as possible
- Field of view as big as possible