X-ray observations of M31 and other nearby galaxies

Ákos Bogdán

Harvard-Smithsonian Center for Astrophysics

Einstein fellow

M. Gilfanov, L. David, W. Forman, C. Jones, R. Kraft

Chandra X-ray Observatory

Origin of X-ray emission from galaxies

- AGN

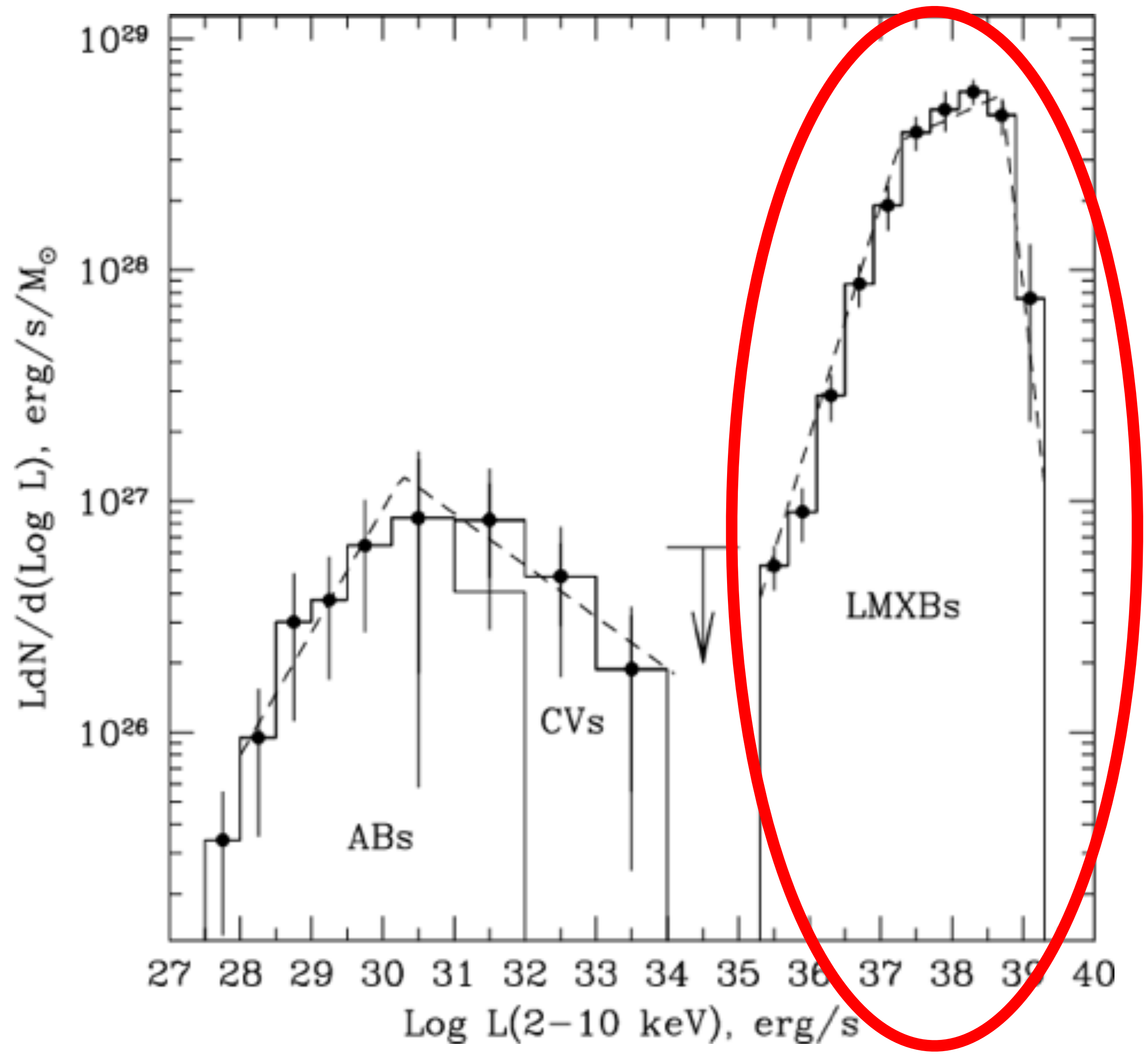
- X-ray binaries
- Faint compact sources
- Hot ionized gas

- Cosmic X-ray background

Low mass X-ray binaries

- Accreting BHs and NSs
- $L_X \sim 10^{35} - 10^{39}$ erg/s
- Resolved at the distance of M31

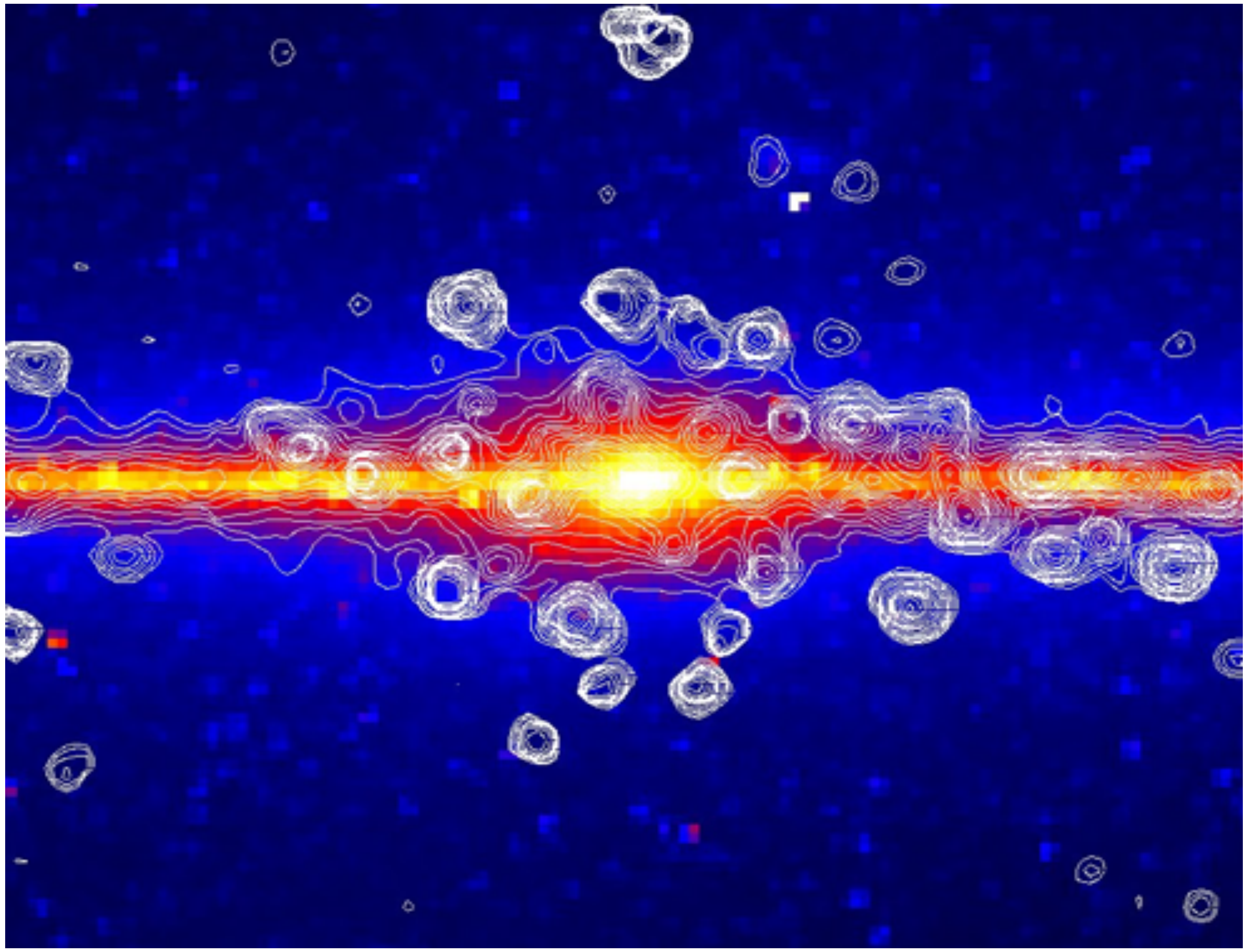
luminosity function plot

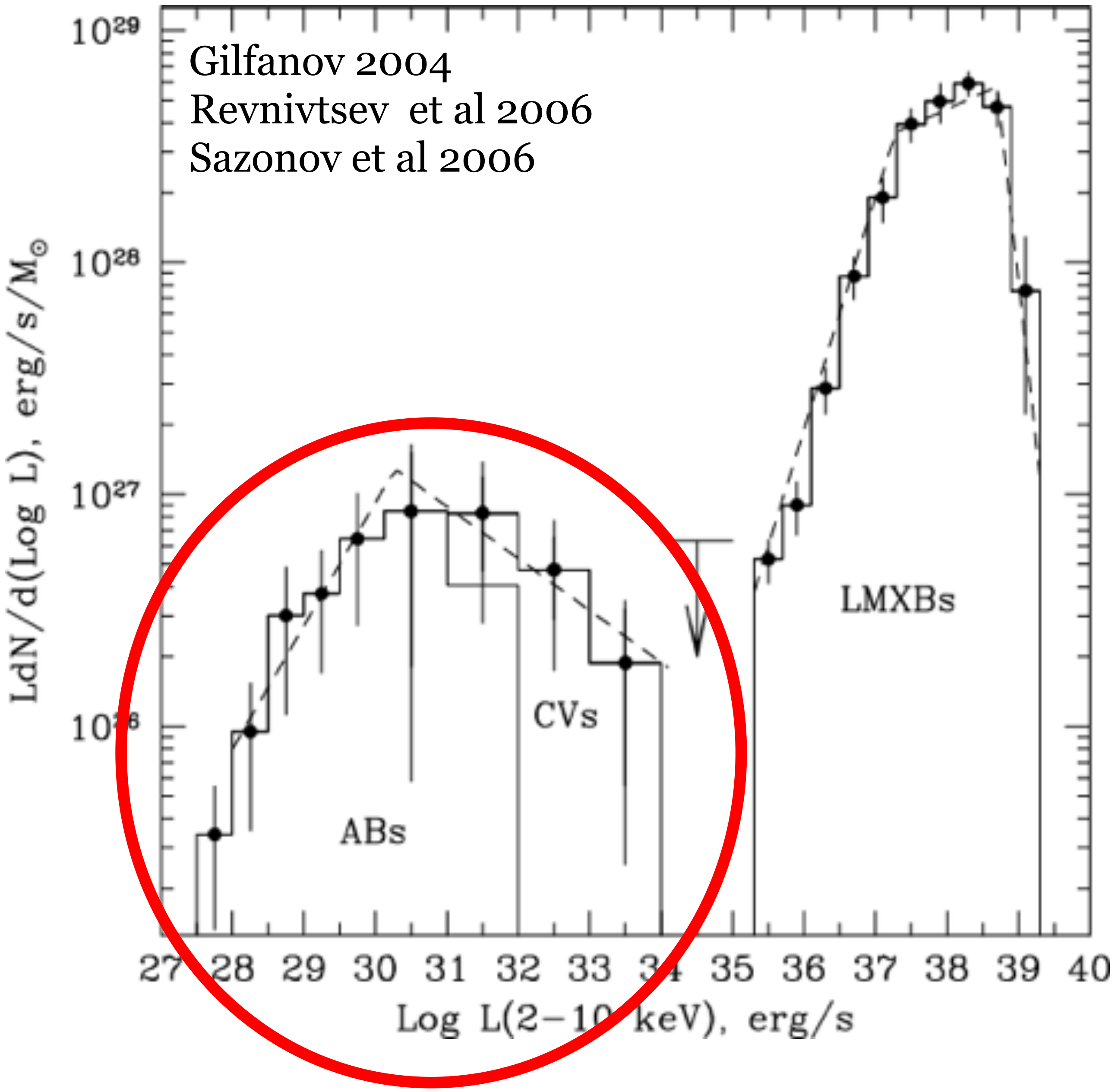


Gilfanov 2004
Revnivtsev et al 2006
Sazonov et al 2006

Faint compact objects

- Cataclysmic variables and active binaries
- $L_X \sim 10^{27} - 10^{34}$ erg/s
- Remain undetected at the distance of M31
- Distribution follows the stellar light





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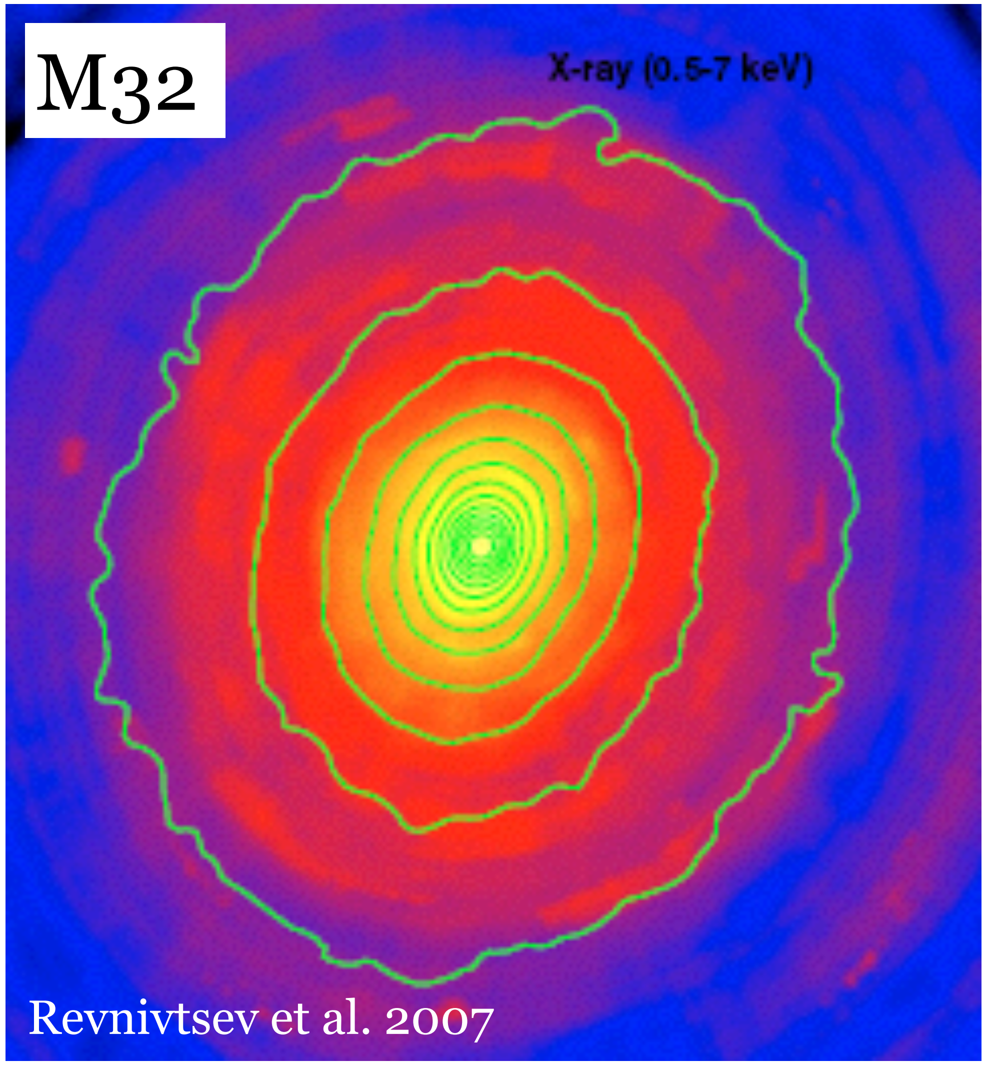
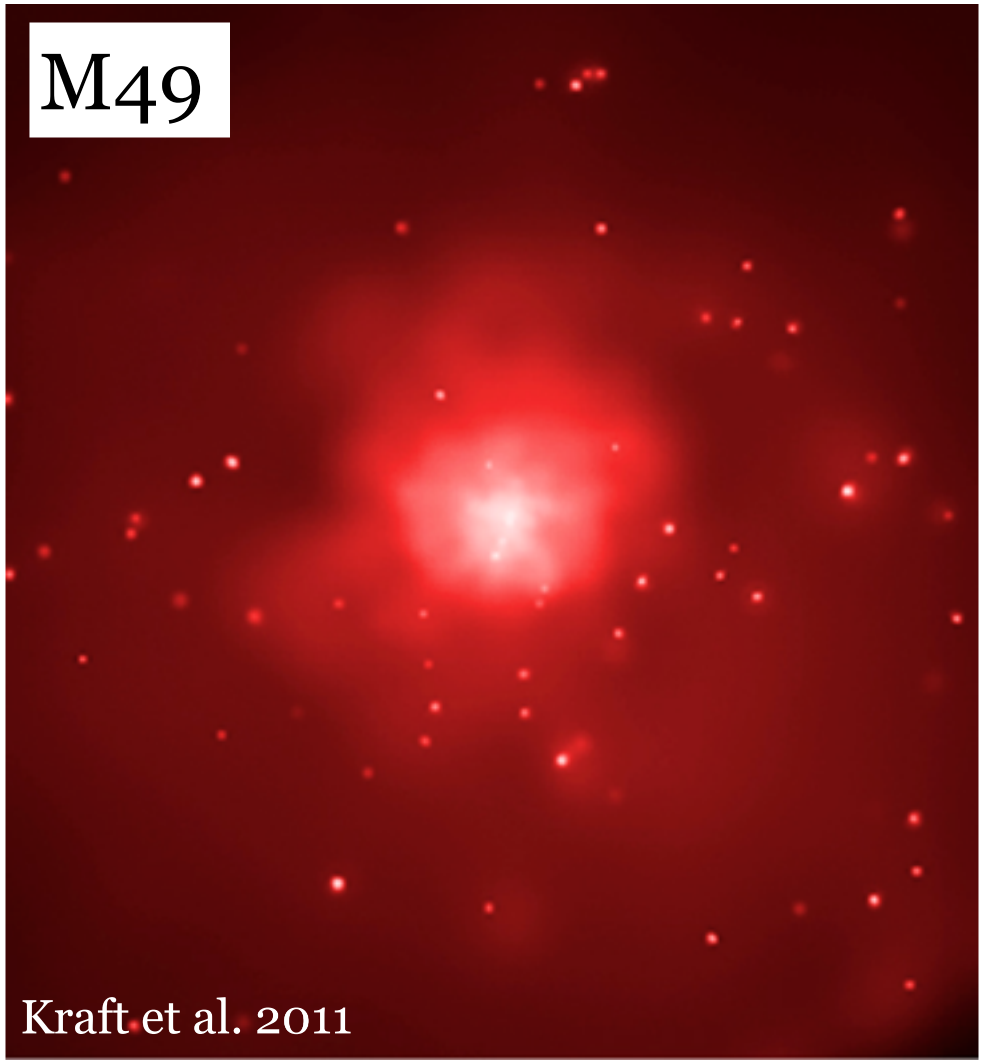
Heidelberg, 7/17/2014

Hot ionized gas

- Sub-kev temperatures in galaxies
- Amount of hot gas shows large variations

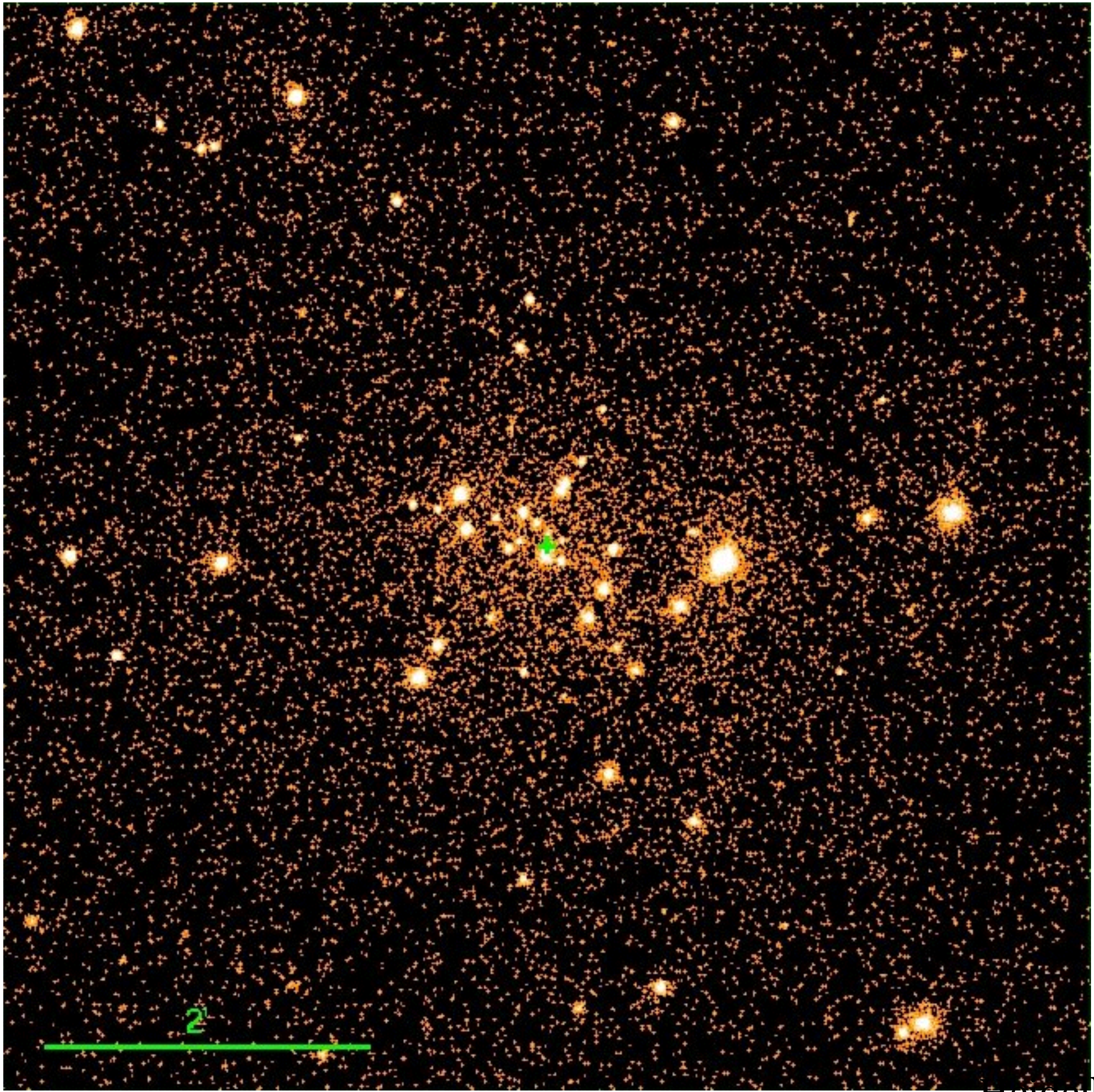




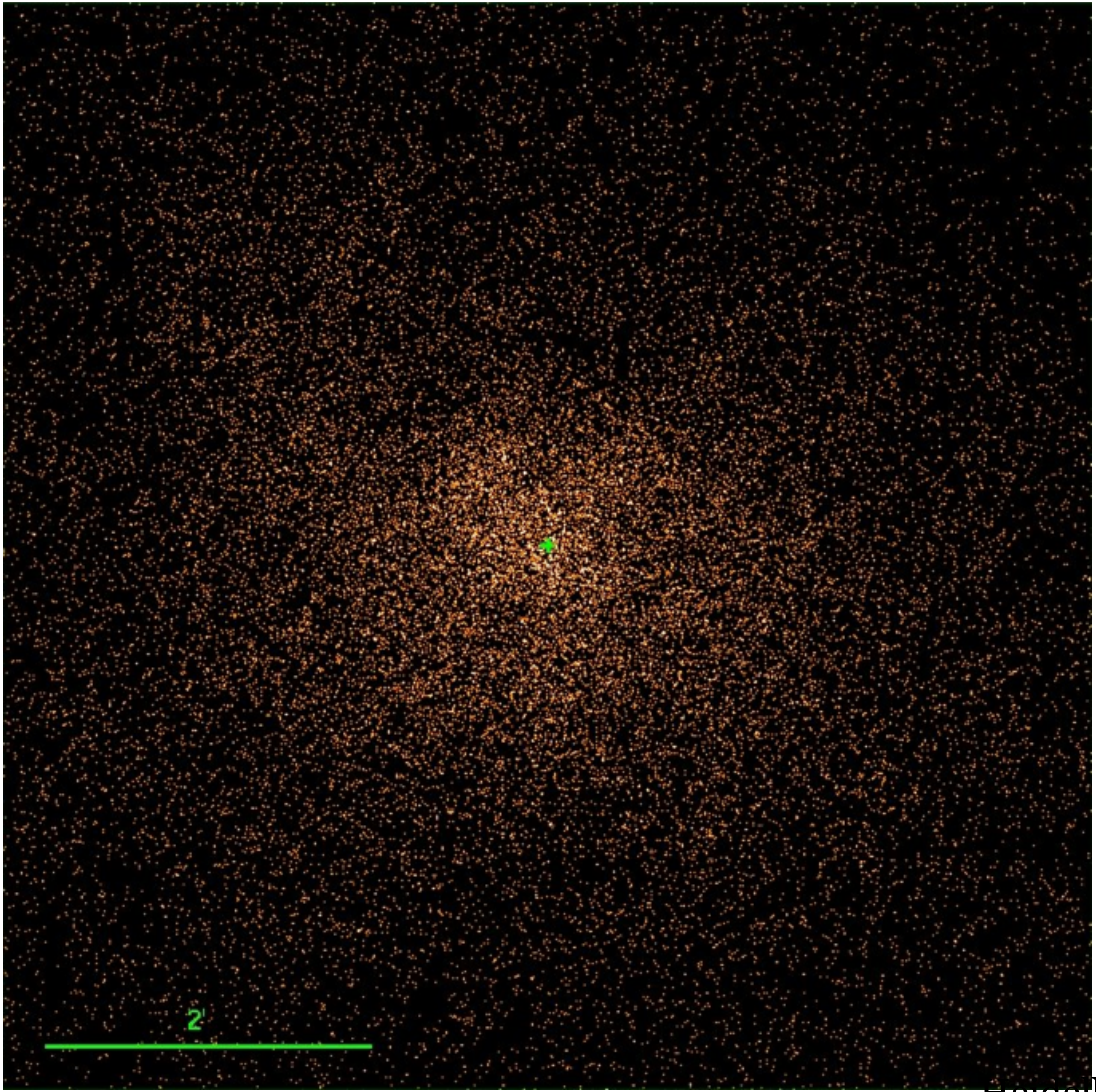
- No hot gas detected
- Unresolved X-ray emission from faint compact objects

- Large amount of hot gas
- Gas dominates the X-ray appearance

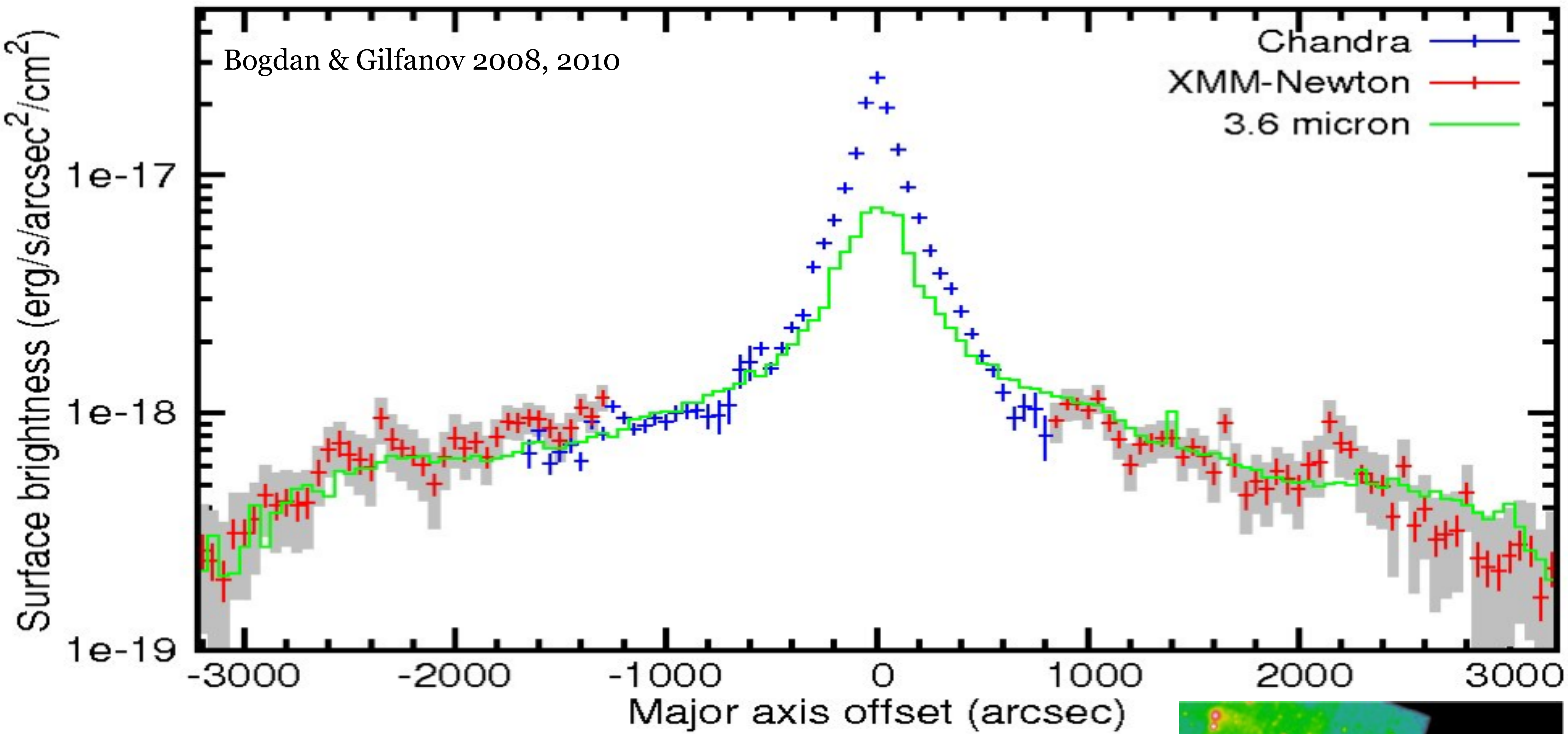
The bulge of M31 in X-rays

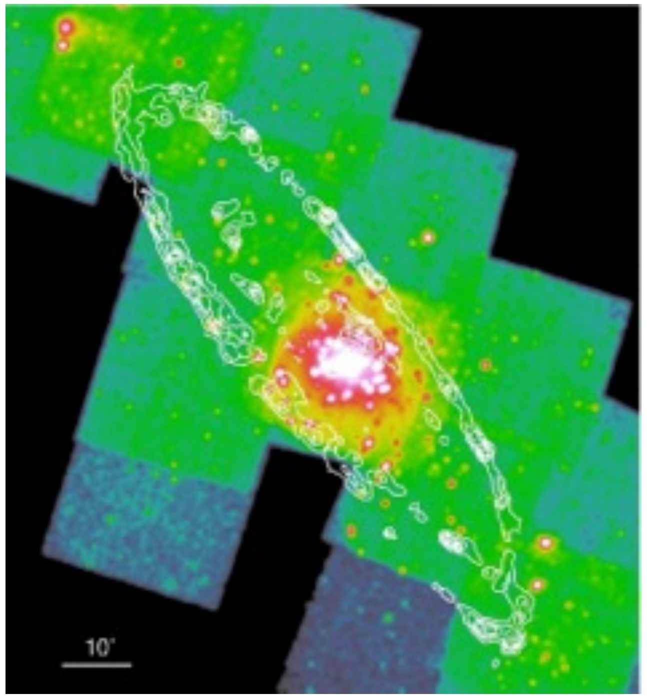


The bulge of M31 in X-rays w/o X-ray binaries



Surface brightness distribution





- Near-infrared traces the stellar light
- Peak in the X-ray light distribution

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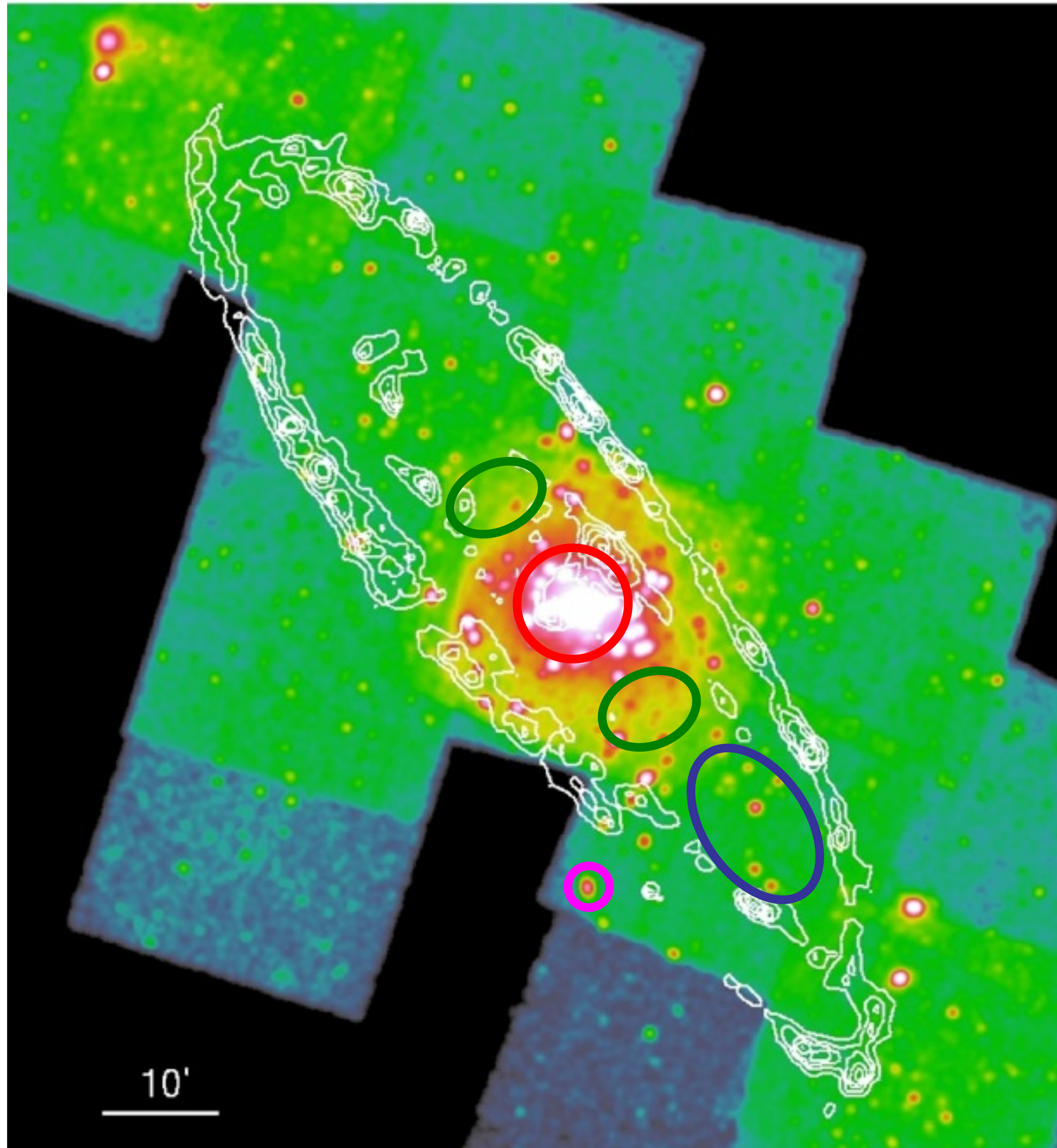
X-ray energy spectra

Central region

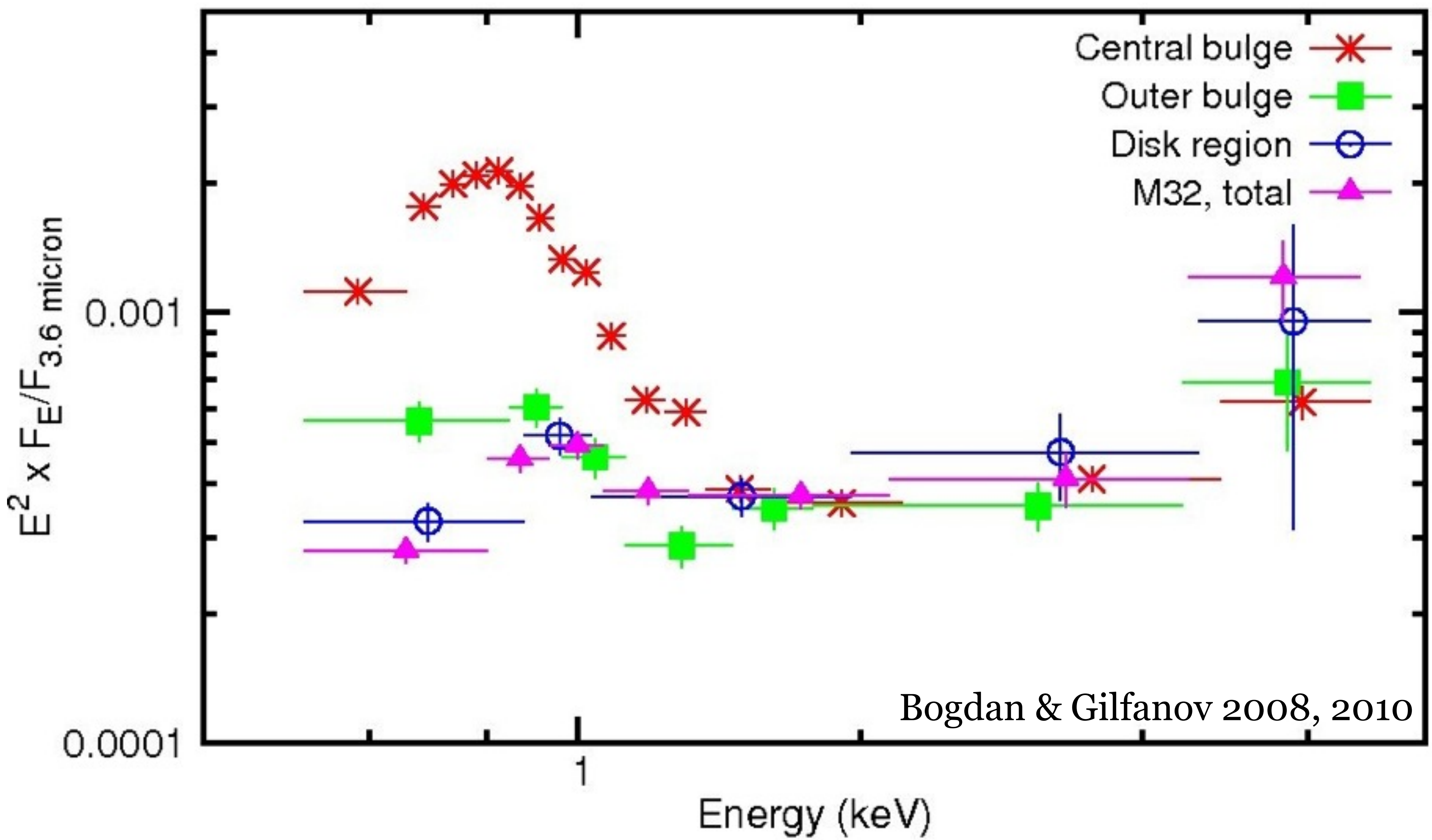
Outer bulge region

Disk region

M32

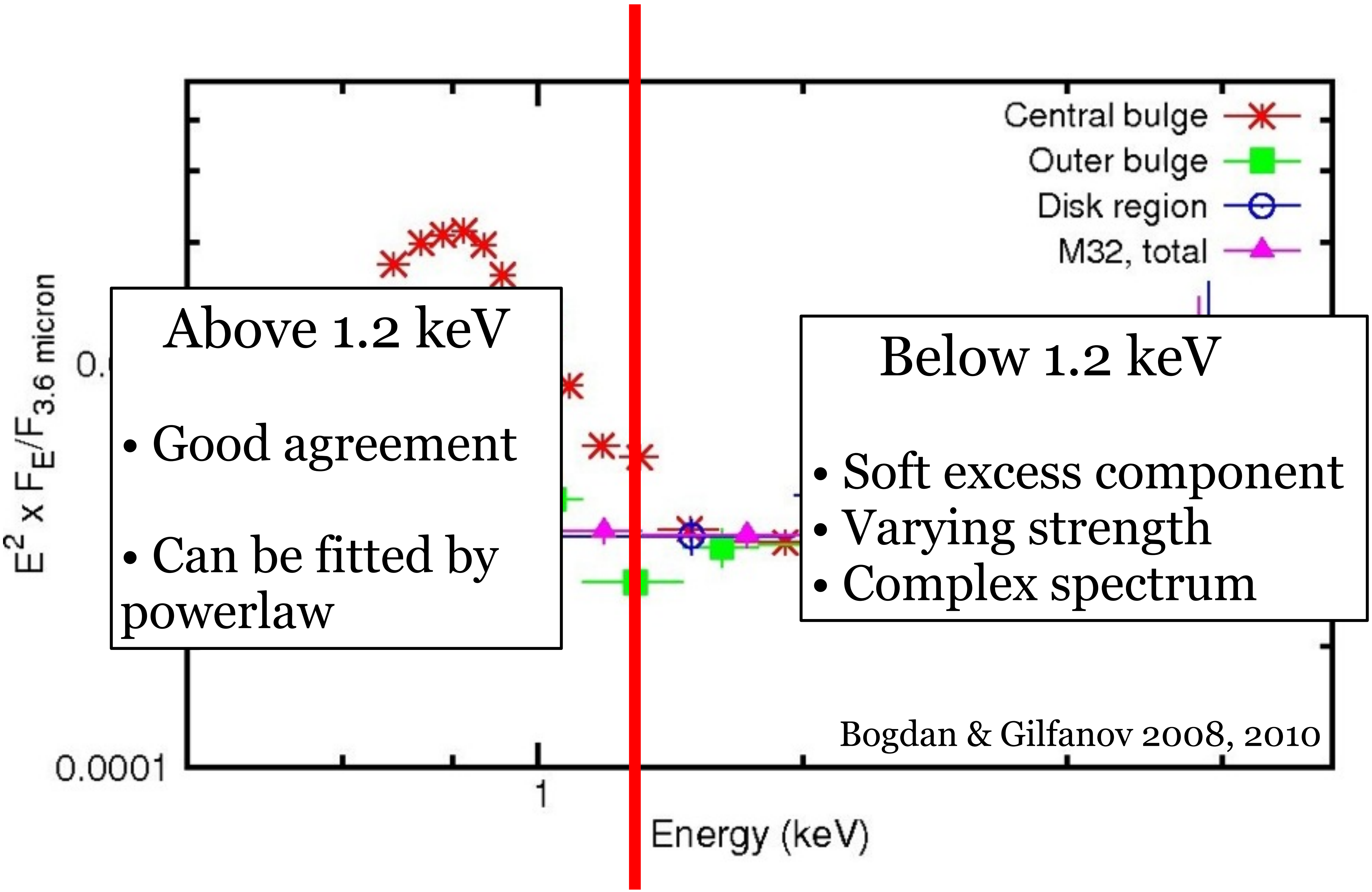


X-ray energy spectra



Bogdan & Gilfanov 2008, 2010

X-ray energy spectra



Above 1.2 keV

- Good agreement
- Can be fitted by powerlaw

Below 1.2 keV

- Soft excess component
- Varying strength
- Complex spectrum

X-ray emitting components

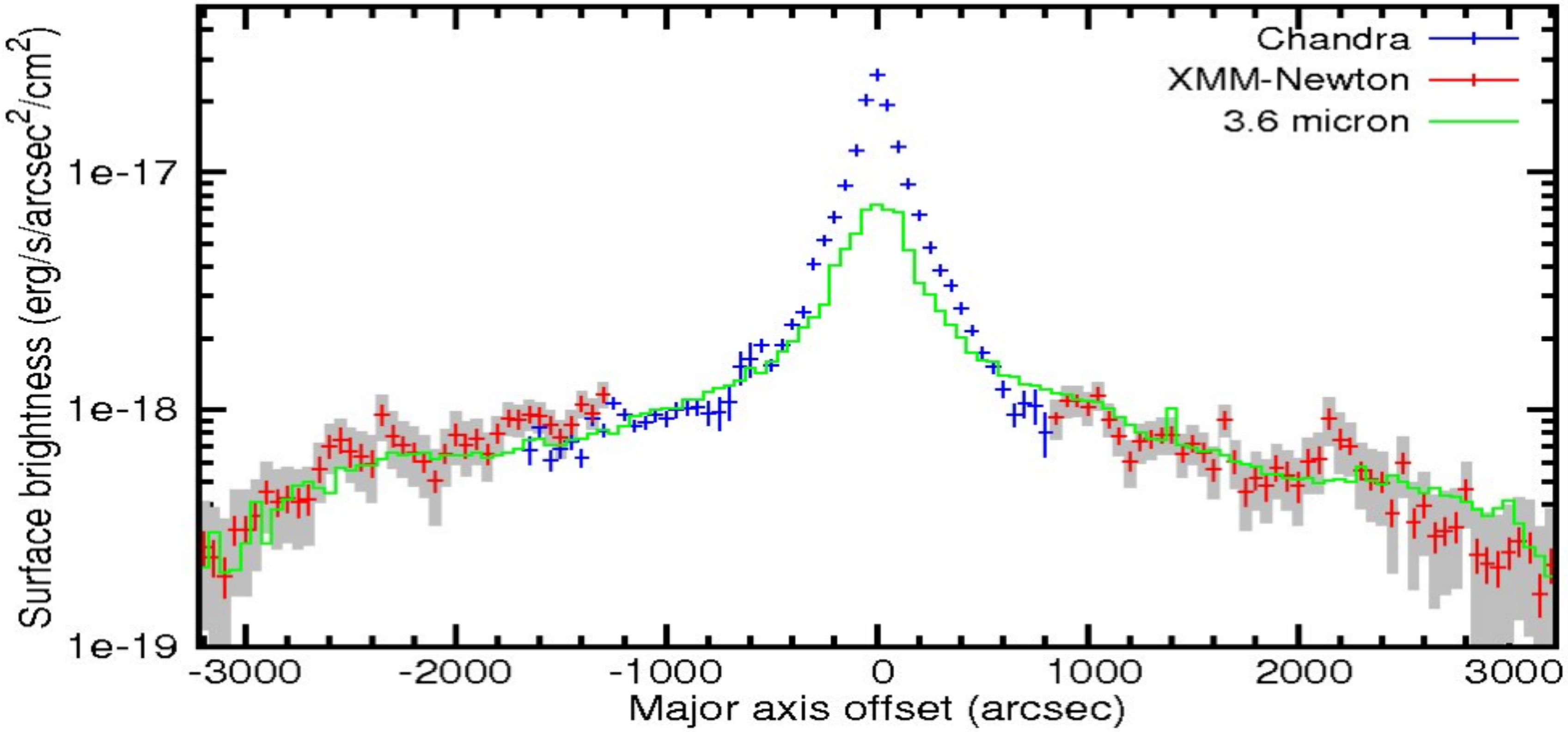
1. Broad band component
   - Large number of faint compact X-ray sources
   - Agreement between X-ray and NIR profiles
   - Normalized spectra are consistent with each other

2. Soft emission in the central regions
   - Concentrated towards the center
   - Hot ionized gas

3. Emission from star forming regions

Distribution of the hot gas

Goal: remove X-ray emission from faint compact sources



Gas distribution = X – N · NIR

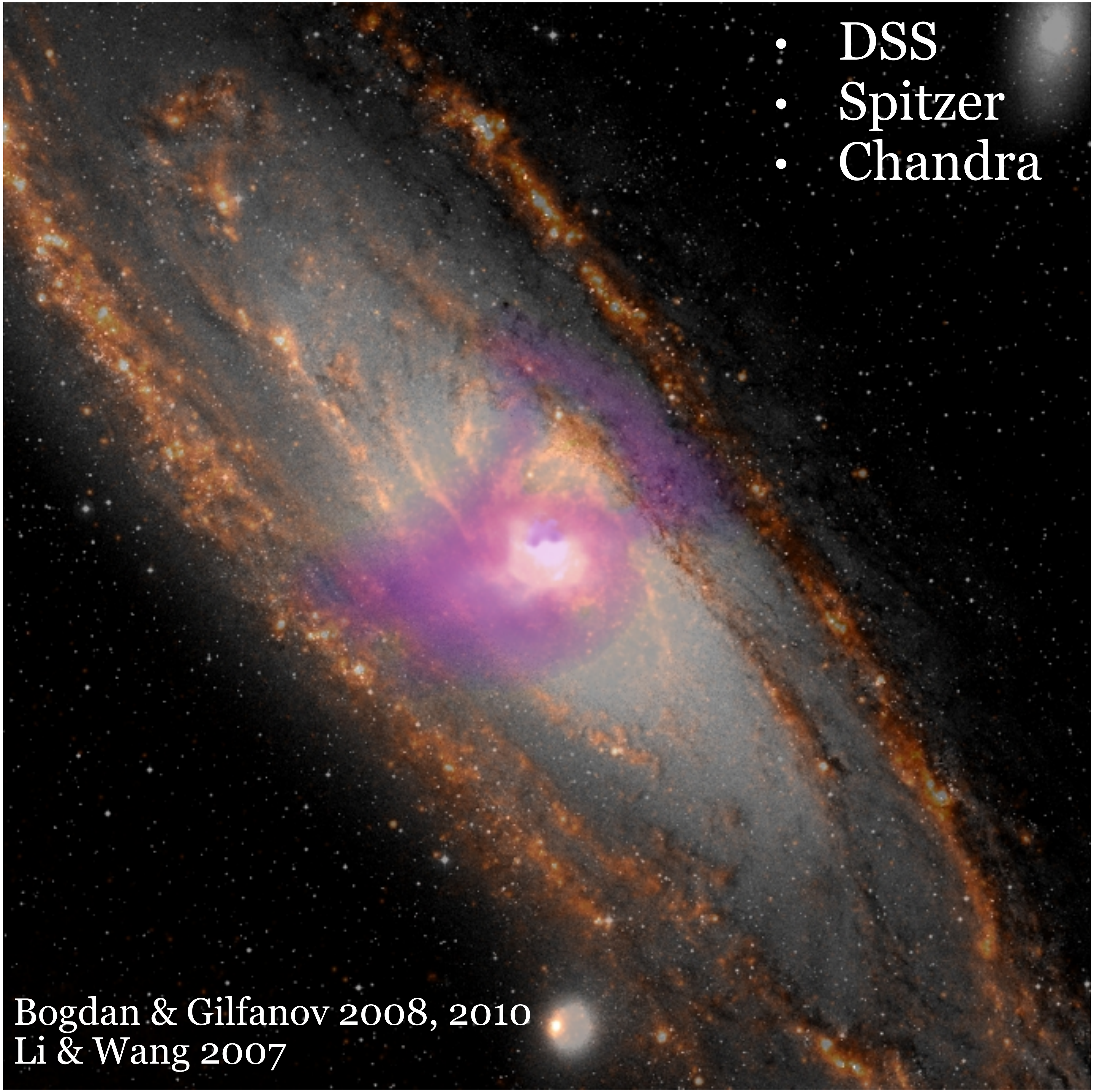
X-ray image in the 0.5-1.2 keV band

Normalization obtained from profile

Near-infrared image

Distribution of the hot gas

- kT ~ 0.3 keV
- L_X ~2 x 10^{38} erg/s
- M ~ 2 x 10^6 M_{sun}
- t_{cool} ~ 250 Myears



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Mass and energy budget of the outflow

Stellar winds from evolved stars

- Mass loss rate ~0.06 M_{sun}/yr
- Mass of the gas: ~2 x 10^6 M_{sun}
- Replenished in ~35 million years (<cooling time)

Type Ia SNe add energy to lift the gas

- $E_{SNIa} = 10^{51}$ erg
- Energy from SN Ia: ~3 x 10^{40} erg/s
- Lift and heat the gas: ~8 x 10^{39} erg/s

Other examples?

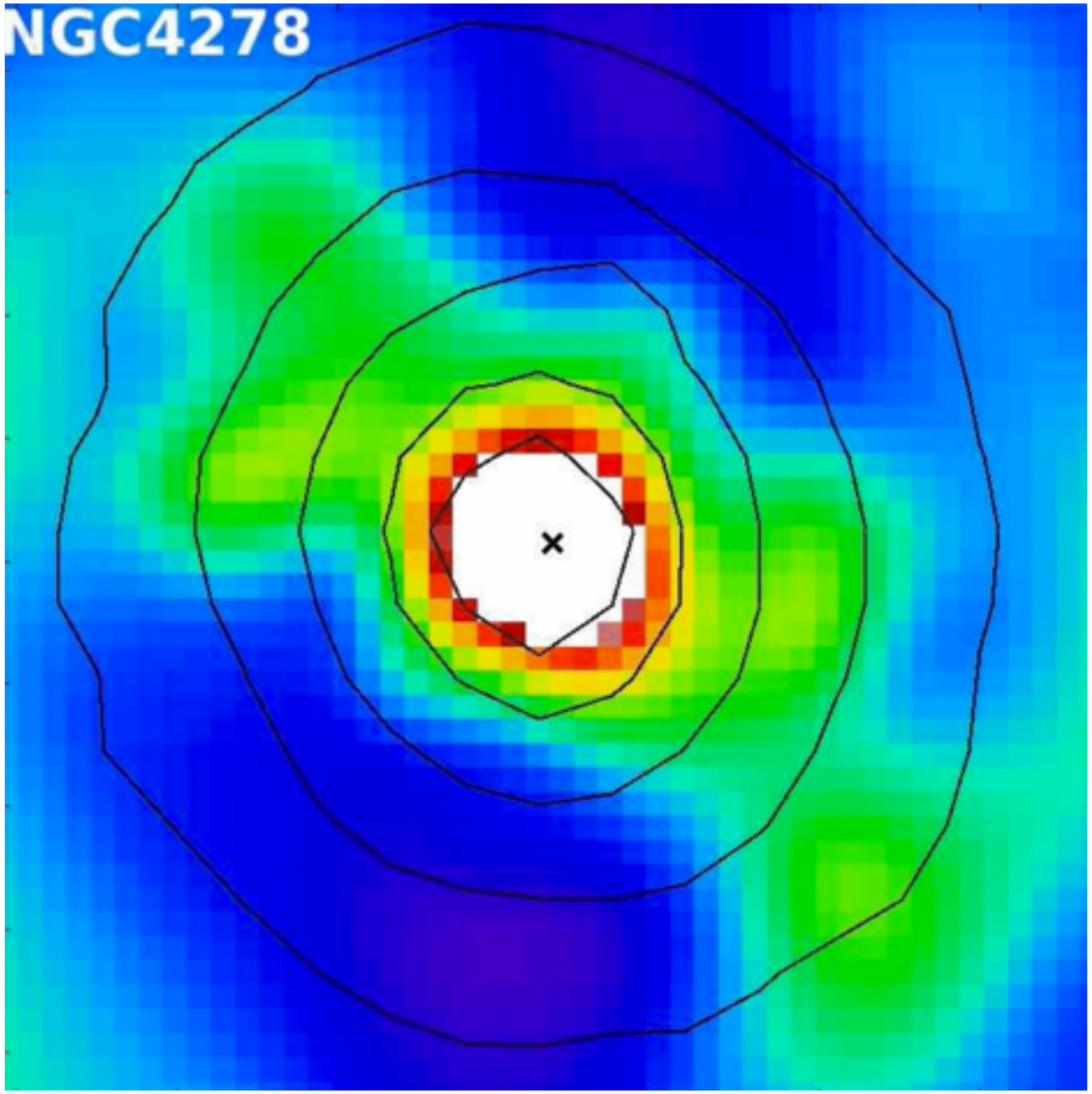
NGC4278

- elliptical galaxy
- X-ray gas poor

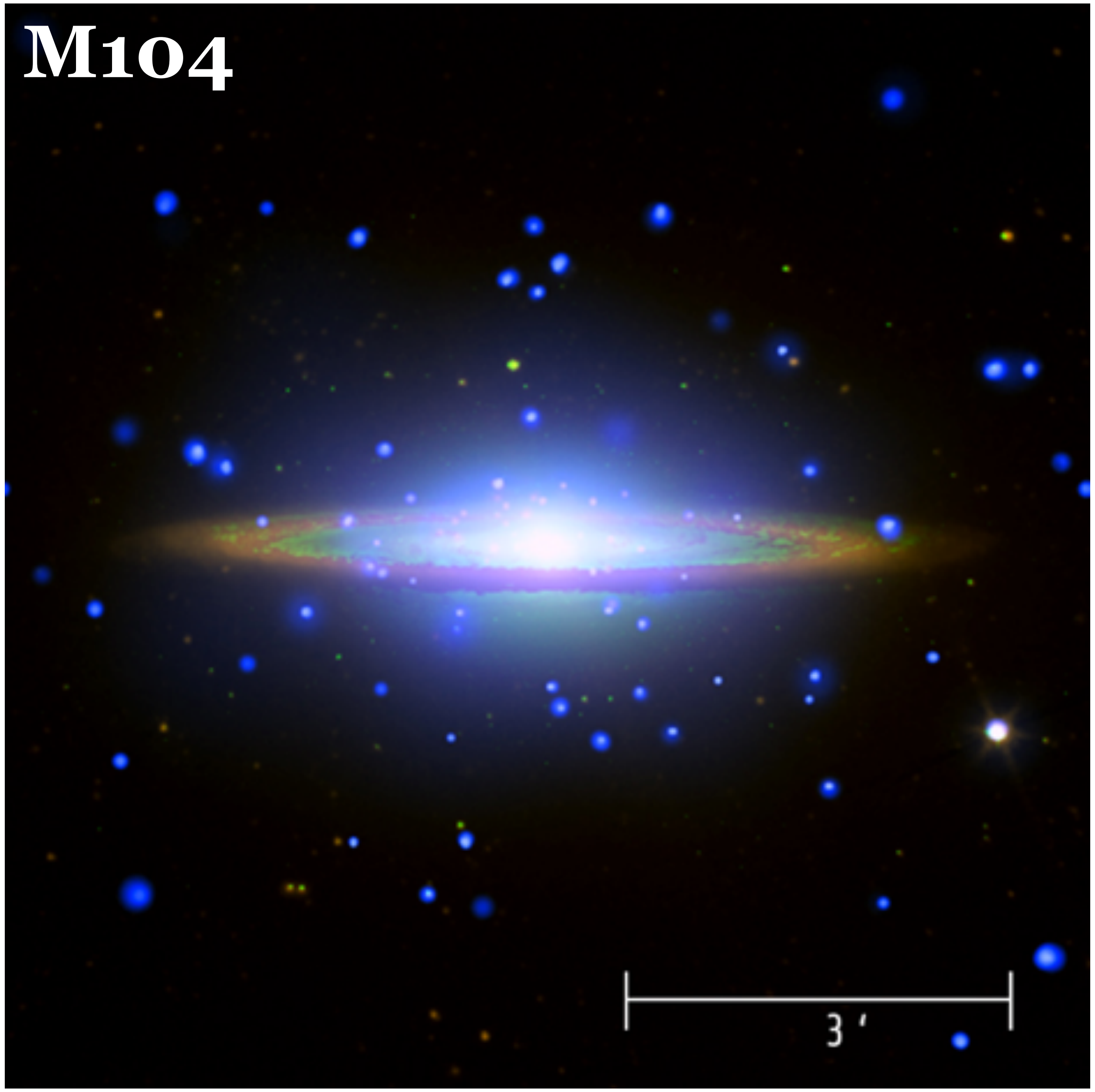
M104

- S0 galaxy
- hosts X-ray gas

NGC4278, another nearby example



Bogdan et al. 2012
Pellegrini et al. 2012



Wang et al. 2007,
Li et al. 2011

- Bipolar outflows detected
- Outflowing gas mass can be replenished by evolved stars
- SN Ia can lift the gas from the potential

Are we detecting outflows routinely?

NO!

- Very demanding observations
- EM $\propto$ n^2
- But such outflows should be common

- In ~1 Gyr evolved stars eject 10^9 M_{sun} gas
- This hot gas is not observed in low-mass ellipticals

Importance of SN Ia driven outflows

- Each SN Ia contributes ~0.7 M_{sun} iron
- Assuming perfect mixing z_{Fe} ~ 6 is expected

- **BUT!**
- Strictly sub-solar (z_{Fe} ~ 0.1-0.2) abundances observed
- What happens to the iron?
- Does not mix effectively (Tang et al 2009)?

Thank you!