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
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
- $L_X \sim 10^{35} - 10^{39} \text{ erg/s}$
- Resolved at the distance of M31 luminosity function plot

Akos Bogdan

Heidelberg, 7/17/2014
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

Gilfanov 2004
Revnivtsev et al 2006
Sazonov et al 2006
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

Akos Bogdan

Heidelberg, 7/17/2014
The bulge of M31 in X-rays w/o X-ray binaries

Akos Bogdan

Heidelberg, 7/17/2014
• Near-infrared traces the stellar light
• Peak in the X-ray light distribution
X-ray energy spectra

Central region

Outer bulge region

Disk region

M32
X-ray energy spectra

Below 1.2 keV

• Soft excess component
• Varying strength
• Complex spectrum

Bogdan & Gilfanov 2008, 2010

Above 1.2 keV

• Good agreement
• Can be fitted by powerlaw

Bogdan & Gilfanov 2008, 2010

Akos Bogdan

Heidelberg, 7/17/2014
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 = \( X - N \cdot \text{NIR} \)

X-ray image in the 0.5-1.2 keV band

Near-infrared image

Normalization obtained from profile
Distribution of the hot gas

- $kT \sim 0.3$ keV
- $L_X \sim 2 \times 10^{38}$ erg/s
- $M \sim 2 \times 10^6 M_{\text{sun}}$
- $t_{\text{cool}} \sim 250$ Myears

Bogdan & Gilfanov 2008, 2010
Li & Wang 2007
Mass and energy budget of the outflow

**Stellar winds** from evolved stars
- Mass loss rate \( \sim 0.06 \, M_{\text{sun}}/\text{yr} \)
- Mass of the gas: \( \sim 2 \times 10^6 \, M_{\text{sun}} \)
- Replenished in \( \sim 35 \) million years (<cooling time)

**Type Ia SNe** add energy to lift the gas
- \( E_{\text{SNIa}} = 10^{51} \, \text{erg} \)
- Energy from SN Ia: \( \sim 3 \times 10^{40} \, \text{erg/s} \)
- Lift and heat the gas: \( \sim 8 \times 10^{39} \, \text{erg/s} \)
Other examples?

NGC4278

- elliptical galaxy
- X-ray gas poor

M104

- So galaxy
- hosts X-ray gas

Akos Bogdan

Heidelberg, 7/17/2014
NGC4278, another nearby example

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

Bogdan et al. 2012
Pellegrini et al. 2012
Wang et al. 2007,
Li et al. 2011

Akos Bogdan

Heidelberg, 7/17/2014
Are we detecting outflows routinely?

**NO!**

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

- In $\sim 1$ Gyr evolved stars eject $10^9 M_{\text{sun}}$ gas
- This hot gas is not observed in low-mass ellipticals
• Each SN Ia contributes \( \sim 0.7 \text{ M}_{\odot} \) iron
• Assuming perfect mixing \( z_{\text{Fe}} \sim 6 \) is expected

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