

The Extended, Asymmetric Hot Gaseous Halos of Early-Type Galaxies

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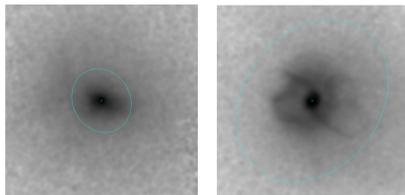
Hot Gas in Early-Type Galaxies (ETGs)

- Dominant emission of ETGs is the hot interstellar medium (ISM) gas in the X-ray regime with $kT \sim 0.5\text{-}2$ keV.
- Observations of ETG ISM critical for understanding galaxy evolution:
 - **AGN and stellar feedback**- star formation history and its quenching, regulation of gas cooling.
 - **Stellar mass loss and supernovae ejecta**- chemical enrichment history, constrain supernovae and star formation rates.
 - **Environmental interactions and mergers**- ram pressure stripping, sloshing, nuclear outbursts.

Harnessing Chandra & XMM-Newton

Chandra X-Ray Observatory

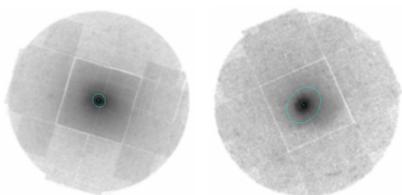
- Fine subarcsecond spatial resolution
- Hot gas morphology on the small scale, in central regions
- Can identify jets, cavities, cold fronts, filaments



Chandra X-ray diffuse gas 0.5-2 keV smoothed image, with NGC 1550 on the left and NGC 4636 on the right.

XMM-Newton

- Wider field of view (30 arcminutes diameter)
- Larger collecting area (10 times more sensitive than Chandra at 1 keV)
- Extract iron abundance maps and image galaxy outskirts



XMM-Newton X-ray diffuse 0.5-5 keV smoothed image, with NGC 1550 on the left and NGC 4636 on the right.

The X-Ray Galaxy Atlas

- Catalog of **70+** nearby early-type galaxies (elliptical and lenticular).
- Maps and radial profiles include **temperature, density, metallicity, projected pressure, entropy, and mass.**

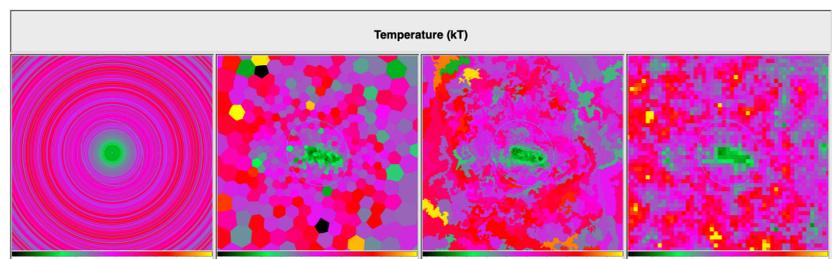
Chandra Galaxy Atlas (CGA) [1] + XMM-Newton Galaxy Atlas (NGA) [2]
= **X-Ray Galaxy Atlas (XGA)**

Key Pipeline Steps



Four Spatial Binning Methods

Circular annuli, weighted Voronoi tessellation (WVT), contour, and hybrid



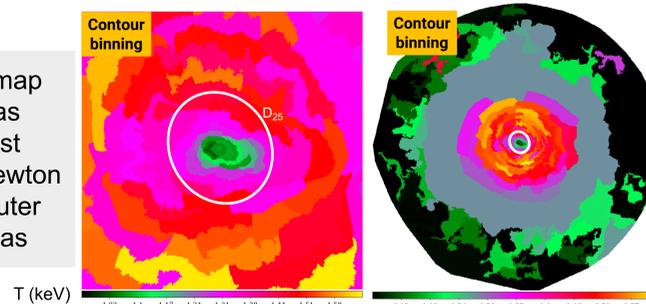
2D Spectral Maps

Case Study: NGC 1550

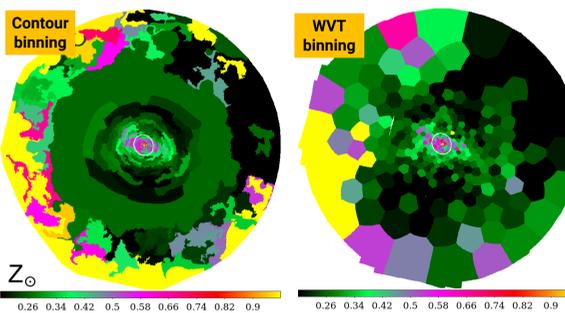
- Fossil group undisturbed S0 galaxy at 51.1 Mpc.
- Metal distribution extends into outer regions.

NGC 1550: Temperature

Left: Chandra map showing cool gas extension in west
Right: XMM-Newton map showing outer regions of hot gas



NGC 1550: Fe Abundance



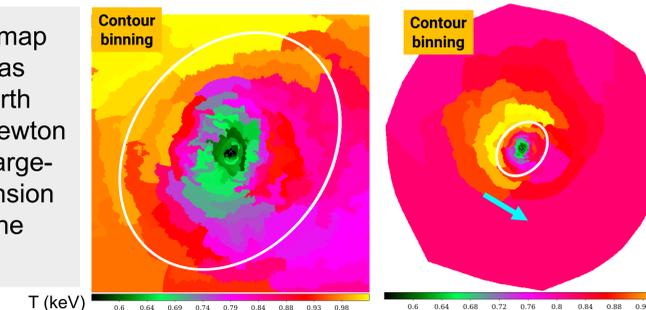
- Elongation in metal distribution in E-W direction
- Core $0.2Z_{\odot}$ higher than surroundings

Case Study: NGC 4636

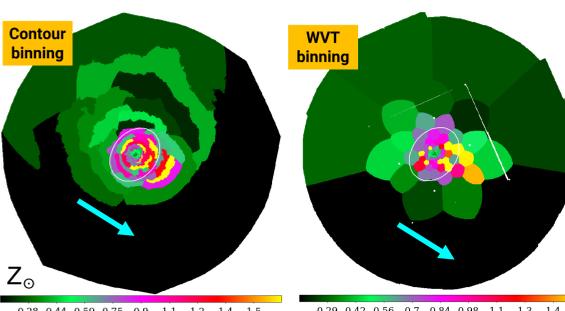
- X-ray bright E0 type located at 14.7 Mpc.
- Arm-like "S" structures extend 8 kpc outwards.

NGC 4636: Temperature

Left: Chandra map showing cool gas extension in north
Right: XMM-Newton map showing large-scale gas extension in direction of the arrow

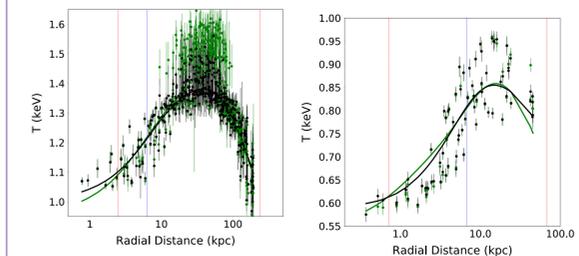


NGC 4636: Fe Abundance



- Extension in direction of arrow
- Possibly supersolar at optical D_{25} radius

3D Radial Profiles



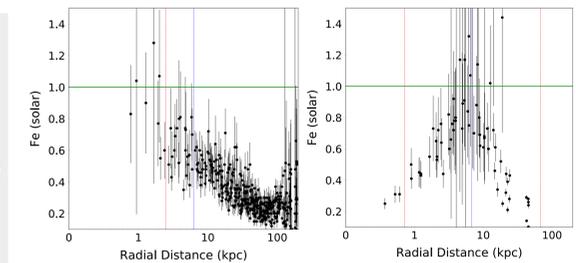
Temperature Profiles

Left: NGC 1550
Right: NGC 4636
Typical hybrid-bump shape for both

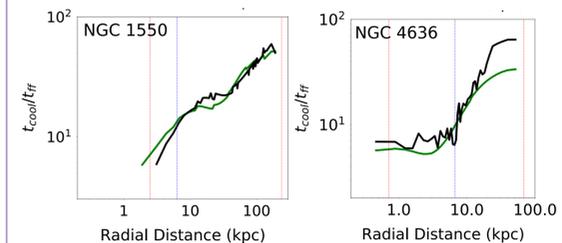
Green denotes fixed abundance model
Black denotes variable abundance model

Fe Profiles

Contrasting metal distributions
Left: NGC 1550 monotonically decreasing abundance
Right: NGC 4636 central abundance drop



Cooling Time



Left: Ratio under 10 within first kpc of center
Right: Ratio under 10 within 10 kpc. Cool gas reservoirs, consistent with [CII] observations

Conclusions & Next Steps

1. Understanding hot gas distribution with 2D maps essential for identifying astrophysical mechanisms in ETGs responsible for disturbed structure.
2. NGC 1550: Small scale asymmetries from AGN feedback.
3. NGC 4636: Significant cooling in suggests bulk motion such as sloshing from tidal interactions.

Upcoming

1. Characterizing the varieties of abundance radial profiles.
2. Synthesizing CGA and NGA products into the XGA.
3. Comparing radial profiles with hydrodynamical simulations.

References

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