Hot Gas Halos in Early-Type Galaxies

Tesla Jeltema
University of California, Santa Cruz

Collaborators: John Mulchaey, Breanna Binder, Jesper Rasmussen, Xue-Ning Bai, Jacqueline van Gorkom, Ann Zabludoff
What is the contribution of hot gas to galaxy halos?

• In clusters, interaction with the ICM may remove galactic hot gas through e.g. ram-pressure stripping.

• With Chandra and XMM we can survey hot gas in galaxies in different environments.

Caveat: samples smallish and limited to bright galaxies.
Hot Gas Stripping?

- Examples of X-ray tails are observed

However,

- ROSAT: no trend in $L_X/L_K$ with environment (Ellis & O’Sullivan 2006)
- Chandra: X-ray halos found in bright group and cluster galaxies (Jeltema et al. 2008, Sun et al. 2007)
Hot Halos in Different Environments

Early-Type Galaxies in Groups:
- 13 groups from the Chandra archive with $z < 0.035$
- Selected satellite galaxies (no BCGs)
(Jeltema, Binder, & Mulchaey 2008)

Early-Type Field Galaxies:
- 23 isolated early-type galaxies observed with Chandra and XMM with $z < 0.03$ and similar range of $L_K$
(Mulchaey & Jeltema 2010)

Cluster galaxies from Sun et al. 2007
Data Analysis

- Search for extended X-ray emission

- Search for thermal emission
  - spectrum modeled as a combination of thermal gas and a power law for X-ray binaries/AGN contribution

- Derive upper limits on thermal emission for undetected galaxies and those consistent with having no thermal component
Example X-ray Halos

Extended, thermal X-ray emission detected around bright early-type galaxies in all environments.

**NGC383 Group**

**Isolated Galaxies**

even at small radius
• We detect a few examples of active stripping, but only for \(~2\%\) of $L^*$ galaxies.

⇒ rare or short-lived events
Galaxy-galaxy mergers in two compact groups show diffuse X-ray emission tracing tidal features in the optical.
Cluster and Group Galaxies

- $L_X - L_K$ relation a bit steeper for groups than clusters but consistent within the errors

Early-type galaxies with extended X-ray emission
- * group gals
- ◇ cluster gals
(Sun et al. 2007)

Jeltema, Binder, & Mulchaey 2008
• Detect 80% of $L^*$ galaxies in groups vs. 43% in clusters

• Even considering the errors there are more non-detections in clusters.

Jeltema, Binder, & Mulchaey 2008
Early-Type Field Galaxies

- At high $L_K$, field galaxies have similar or brighter X-ray halos to cluster and group galaxies.
- At $L_K < L^*$, field galaxies are less luminous and mostly undetected.

Mulchaey & Jeltema 2010
Early-Type Galaxies and Environment

• Some hot gas stripping in dense environments, but not much for bright galaxies
  - Higher detection rate in groups than clusters
  - Somewhat higher $L_X$ for brightest field galaxies
  - A few examples of active stripping (small percentage)

• What is happening for sub-$L^*$ galaxies?
  - Winds expel gas from field galaxies while ICM confines gas in group/cluster galaxies? - not supported by simulations (Bahé et al. 2012)
  - Accretion from the ICM?
Early-Type Galaxies and Environment

- What is happening for sub-$L^*$ galaxies?
  ➡ Samples are small!!

adding field S0’s from Li et al. 2011
The X-ray halos of group galaxies are somewhat cooler than those in clusters, no strong trend with $L_K$.

Jeltema, Binder, & Mulchaey 2008
Halo Temperature - $L_x-T_x$

- Steeper relation than for group and cluster size halos

Crain et al. 2010
Late-Type Galaxies
(Group and Cluster)

- Not many of these!
- Brighter galaxies follow \( L_X - L_K \) of early-types. Stronger correlation with \( L_B \) and consistent with field.

Jeltema, Binder, & Mulchaey 2008
Virial Radius Survey of NGC2563 Group

Chandra Mosaic

- No thermal gas detected from galaxies at $R<300$ kpc, compared to 5 at larger $R$
- Small numbers, but brightest non-central at $R=90$ kpc under luminous by a factor of 10

Rasmussen et al. 2012
Virial Radius Survey of NGC2563 Group

- HI detected in 20 late-type group members, including all 15 $L_K > 0.1 L^*$
- Late-type group galaxies are mildly HI deficient
- HI tails and galaxy-galaxy interactions are seen for 6 galaxies

(Note interesting asymmetry with most of the HI detections on western side)
Summary

• Field galaxies appear to have a steeper $L_X - L_K$ relation than group and cluster galaxies.

• A higher detection rate of halos in groups and the field than in clusters, but many galaxies maintain extended hot gas halos even in group/cluster cores.

• Evidence for gas stripping (tails, tidal features) is seen in some galaxies.

⇒ Complex interplay between galactic hot gas and ICM, which may act to both remove and maintain hot halos

⇒ Hot gas stripping occurs with moderate/mild efficiency

⇒ Larger samples, particularly at low $L_K$, are needed