A Fossil Group in Formation

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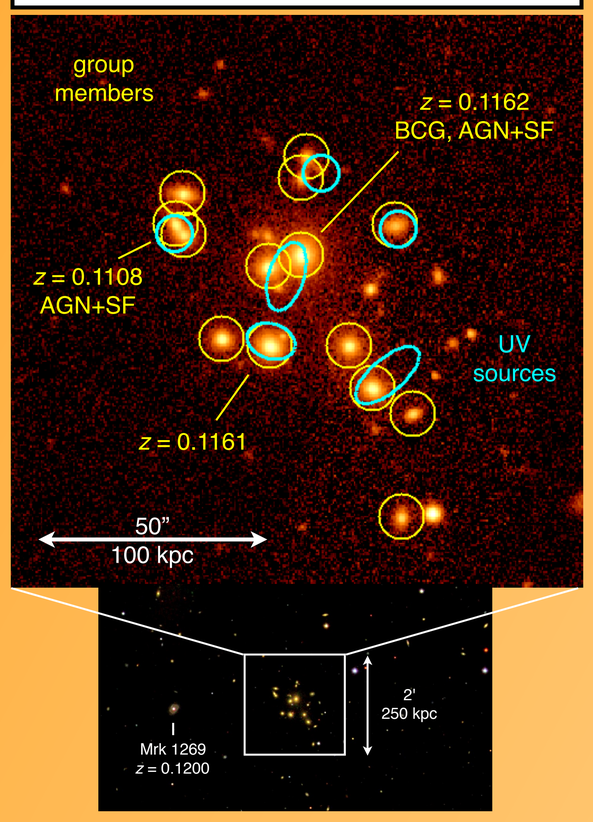
Background

In the current picture of hierarchical structure formation, galaxy groups form the seeds from which large assemblies of matter form. Groups also present important environments in which to watch the fueling of star formation and AGN activity, as the conditions here are ideal for galaxy-galaxy interactions: high space density; low relative velocities among galaxies; and little ISM lost to ram-pressure stripping.

Fossil groups in particular remain puzzling. These systems are lacking bright galaxies, yet their X-ray emission indicates a cluster-scale potential. They are thought to be isolated groups in which large galaxies have coalesced, and may represent an end-point to isolated group evolution (e.g., Jones et al. 2003, Miller et al. 2012) or a transitional phase experienced by many galaxy groups

We have identified a system that defies easy classification and may represent an intermediate or transition stage in group evolution, and here present optical and X-ray observations.

SDSS (*i* band)
star-forming galaxies, AGN



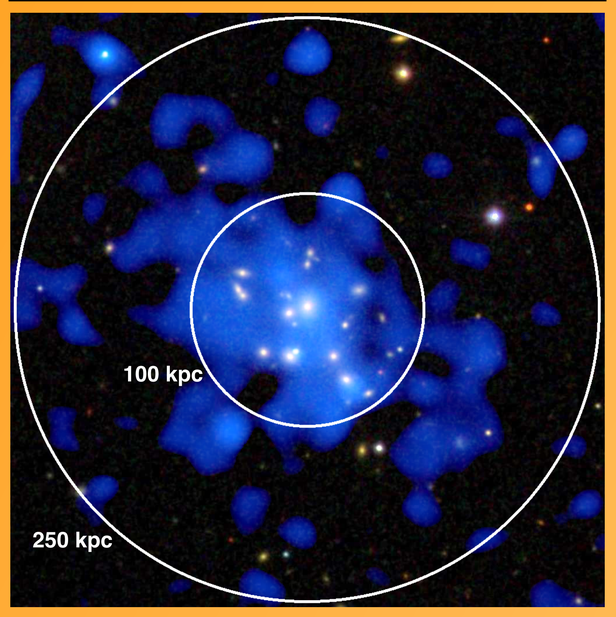
An Unusually Compact Group

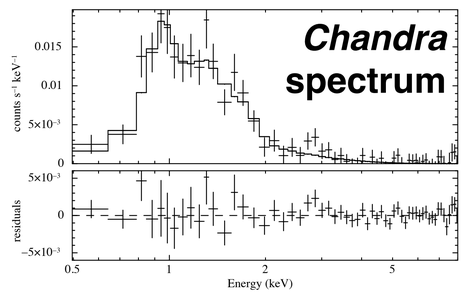
This remarkably compact system is the richest group in the Shakhbazyan (SHK) group sample, which consists of 376 compact, isolated groups with 5–15 red galaxies observed in POSS plates (Shakhbazyan 1973, Shakhbazyan & Petrosyan 1974). SHK 1 is unusual because:

- the galaxy density is like a rich cluster core, not a group:
  inner 500 kpc: 15 galaxies brighter than 0.4 L^*
  inner 100 kpc: 9 galaxies brighter than 0.4 L^*
  3 galaxies brighter than L^*
- there is a bright, extended envelope of intra-group starlight;
- the fraction of UV-emitting, star-forming galaxies and AGN in the group core is very high.

The *Chandra* data reveals a hot, diffuse intra-group medium, as well as several AGN. Discovery Channel Telescope optical imaging reveals the extent of the stellar envelope. Gemini spectroscopy reveals the unrelaxed dynamic state.

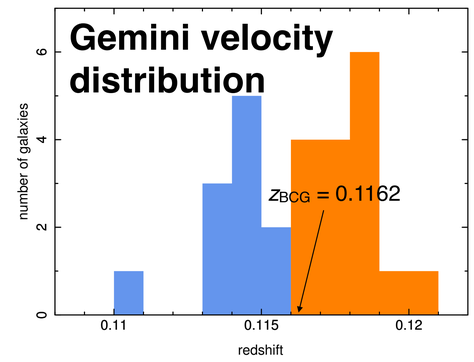
***Chandra* (50 ksec, 0.5–5 keV)**
diffuse X-rays, AGN





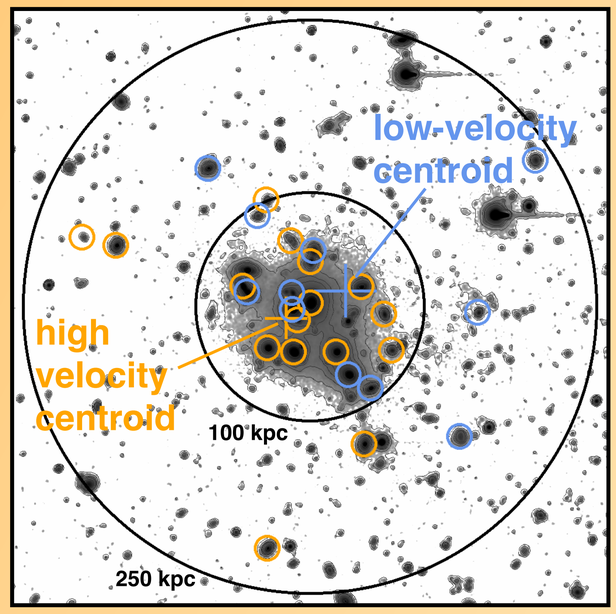
Spectral analysis of the *Chandra* data reveals a 1.5 keV extended halo with several AGN.

***kT* (keV)**	1.5 ± 0.2
abund (solar)	0.14 ± 0.07
flux (0.5-8 keV)	17±1x10^{-14}
L_X (0.5-8 keV)	7x10^{42}
net counts	835



Gemini MOS reveals a possible bimodal velocity distribution. Centroids of each population are similar and consistent with the BCG location. The velocity dispersion is 690 km/s, much larger than expected for a 1.5 keV group (~500 km/s).

DCT (LMI *r*-band)
intra-group starlight



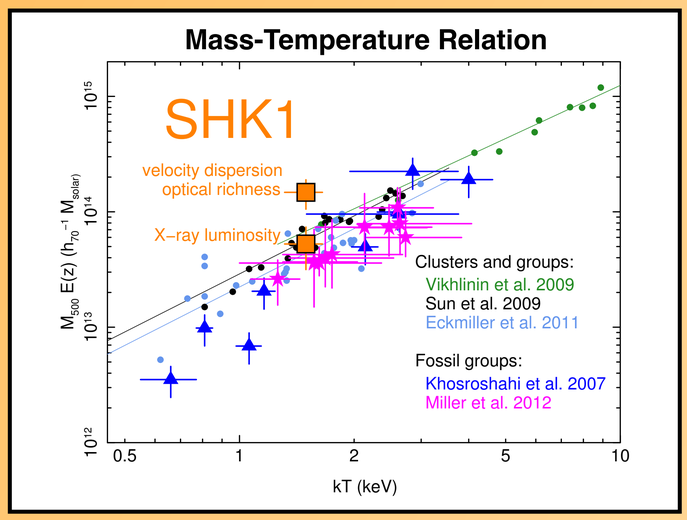
What is SHK 1?

Projection of Multiple Groups?

This scenario is supported by the large line-of-sight velocity dispersion and possible bimodal velocity distribution. The mass derived from the SDSS optical richness is twice the X-ray mass, which could arise from projection effects of two similar groups. Yet it is clear from the intra-group light that there is galaxy-galaxy interaction, which is difficult to explain by a pure superposition unless it is late in the stages of a line-of-sight merger.

Fossil Group in Late Stages of Galaxy Coalescence?

This scenario is supported by the very extended intra-group starlight in the DCT image, and by the large fraction of both UV star-forming galaxies and X-ray AGN in the core. The X-ray mass, temperature, and luminosity are all consistent with what is found for fossil groups, as shown in the M–T_X relation to the right. The fact that this is an unusual system suggests that, if this scenario is correct, it is a short-lived stage in FG evolution.



Future Work

With the optical data in hand, we will compute a complete census of the stellar mass and light to compare to the X-ray luminosity and the expected relations for fossil groups and other systems. Further follow-up ground-based observations are planned, including narrow-band imaging to measure star formation in member galaxies and to search for extended diffuse ionized gas. Perhaps a large portion of the intra-group gas is in a cooler, lower-ionization state than the typical ICM.

References

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We gratefully acknowledge support from NASA through *Chandra* grant GO6-17109X.