Dynamical Evolution Diagnostics of Compact Galaxy Groups & Isolated Systems

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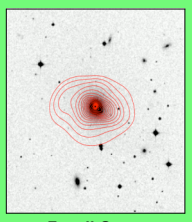
ABSTRACT

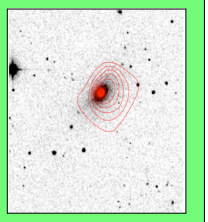
Compact groups contain galaxies within dense galactic environments, typically with separations less than a few diameters. Due to their short dynamical timescales, these systems are excellent probes of merging and interaction phenomena. Compact groups are the likely precursors to fossil groups and highly isolated elliptical galaxies. The morphology of hot gas is uniquely suited for distinguishing isolated ellipticals with a merged group origin from systems, which evolved along alternative paths. As part of a larger study to understand the origin and evolution of isolated early-type galaxies identified in the Sloan Digital Sky Survey, we have analyzed the diffuse x-ray emission of 11 Hickson Compact Groups (HCG) and several isolated early-type systems, using archival data from NASA's Chandra X-ray Observatory. We use the morphology and physical extent of the soft (0.3-2.5 keV) emission, x-ray luminosity, and gas temperature as diagnostics of the dynamical state of these systems. Correlations of x-ray measurements with other group properties provide a tool for assessing dynamical evolution, which can be used to infer the properties of the precursors of isolated ellipticals. A hot intergroup medium is not detected in 5 groups. Most of the members of these spiral-dominated groups exhibit axisymmetric x-ray emission, suggesting that this gas has experienced few external perturbations. The remaining 6 contain an intergroup medium, which extends beyond the optical extent of individual galaxies and shows significant structure. The x-ray luminosity of these groups ranges from $6.8 \times\times 10^{39}$ to 8×10^{41} ergs/sec, with gas temperatures ranging from $0.62\ \mathrm{keV} \leq kT \leq 1.1\ \mathrm{keV}$. The HCGs are observed to have sub-solar abundance values. Support for this project comes from NASA's Astrophysical Data Program; grant NNG05C53G, and a Texas Space Grant Consortium fellowship.

Fossil Groups and Isolated Elliptical Galaxies



Digital Sky Survey images with x-ray contours overlaid.

Contours are displayed on a log scale from 1 to 84 σ above background.

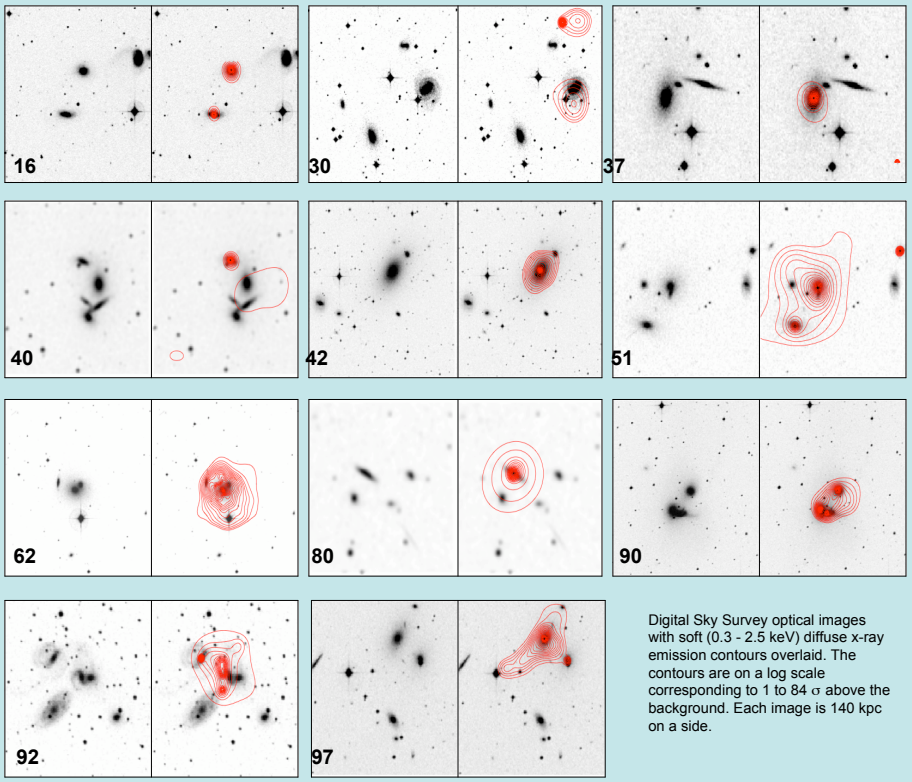


Fossil Group NGC 1550

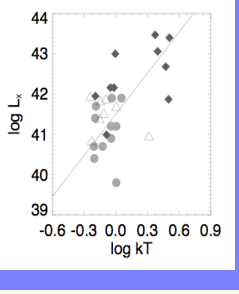
Isolated Elliptical NGC 1132

Fossil groups and isolated early-type galaxies are theorized to be the end points of evolution of a compact group. X-ray observations of fossil groups and isolated ellipticals have detected halos of hot gas with similar extension to the x-ray gas around the Hickson compact groups. The distortions of the contours may be the result of satellite galaxy accretion or nuclear activity.

Hickson Compact Groups: Diffuse Emission in 0.3 - 2.5 keV Energy Band



Digital Sky Survey optical images with soft (0.3 - 2.5 keV) diffuse x-ray emission contours overlaid. The contours are on a log scale corresponding to 1 to 84 σ above the background. Each image is 140 kpc on a side.



HCGs are displayed as filled circles, fossil groups by solid diamonds, and Isolated ellipticals by open triangles.

Table 1 lists the derived x-ray properties. Values of M_{HI} are taken from Verdes-Montenegro et al 2007. Velocity dispersion values come from Ponman et al 1996.

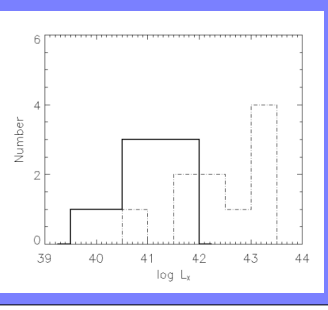
Histogram of L_X for the HCGs (solid line) and fossil groups (dashed line) is at lower left.

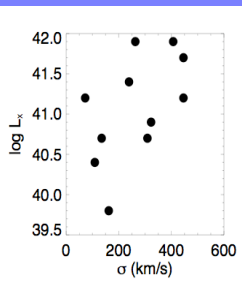
At upper left is plotted L_X:kT relation for isolated ellipticals, compact and fossil groups.

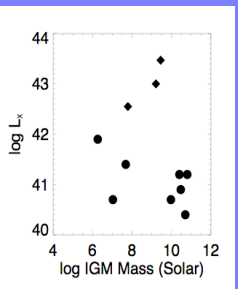
The lower plot displays L_X: σ relation.

At lower right is plotted L_X and hot gas mass for the HCG sample and three fossil groups.

Group	log L_x (ergs/sec)	kT (keV)	log M_{gas} (M⊙)	log M_{HI} (M⊙)	σ (km/sec)
16	40.7	0.75	7.03	10.42	135
30	41.2	1.01	10.8	8.62	72.4
37	41.2	0.90	10.4	9.19	446
40	39.8	1.01	11.4	9.14	162
42	41.4	0.64	—	9.4	239
51	41.9	1.13	7.68	9.66	263
62	40.9	0.90	6.26	9.06	323
80	40.7	0.62	—	10.4	309
90	40.4	0.63	10.47	—	109
92	41.7	0.65	9.97	10.02	446
97	41.9	0.92	10.7	9.10	407







Conclusions

- HCG 16, 37, 40, 42 and 80 appear to have not experienced many crossing times and the groups members may not have extensively interacted. It is these may be young groups that have not yet redistributed gas into the group potential.
- HCG 51, 62, 90, 92 and 97 have gas distributed throughout the group which could indicate a system that has undergone many crossing times and the group members may be deficient in hot gas.
- Sharma & Statler (2007) found that the inter-group light of HCG 40 suggests that the group is a dynamically young system.
- Verdes-Montenegro et al (2007) found that HI depletion for member galaxies may be a sign of an evolutionary sequence. Removal of the ISM from individual galaxies and deposition of gas into the group potential would explain the x-ray nature we have highlighted.
- There is observed lack of high velocity dispersion HCGs that also exhibit low x-ray luminosity. This trend is expected as higher velocity dispersions will result in an increase in interactions which will heat the gas.
- While the fossil groups have much larger L_x values, the compact groups and isolated ellipticals follow the same general trend.