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STRUCTURE IN HCG 62: CHANDRA IMAGING AND SPECTROSCOPY OF AN X-RAY LUMINOUS COMPACT GROUP

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We present recent data on the compact group HCG 62 taken with ACIS-S on Chandra. The sparseness of groups and their relatively simple dynamical history allow the properties of the IGM to be more directly related to galaxy evolution than may be possible in clusters, and their lower gas temperatures produce strong lines from a broader range of elements than is the case in hotter clusters. Our goals with this observation were to exploit the high X-ray brightness of HCG 62 to determine accurately the abundances of heavy elements as a function of position in the group, to test whether abundance variations are associated with individual galaxies, and to trace the origin of the enrichment. The *Chandra* image reveals an unanticipated, complex spatial structure, in particular two "cavities" of approximately 20 kpc extent placed almost symmetrically on opposite sides of the X-ray peak.

1 Introduction

Groups of galaxies are the fundamental building blocks of large scale structure in the Universe. Within the context of hierarchical clustering (Blumenthal et al. 1984), groups are the first systems to collapse and virialize after galaxy formation. Every rich cluster then formed through the coalescense of a number of groups. Most galaxies in the present-day Universe are still in groups or poor clusters. A detailed understanding of groups is accordingly a prerequisite for understanding the formation and evolution of structure.

How do groups fit into the general continuum between individual galaxies and clusters? Given the difficulties of optically deducing the dynamics of groups from the line-of-sight velocities of a small number of galaxies, X-ray study of the intragroup medium offers a powerful approach to addressing some of the major questions that still remain about almost all aspects of groups: their ages, origins, importance of composition of various galaxy types, relations to clusters, as well as origin and enrichment of the intragroup gas.

We selected HCG 62 principally for its X-ray brightness, for the availability of extensive prior optical and X-ray data, and for its angular scale (if H_0=50, the distance is 83 Mpc, giving 400 pc per arcsec) that allows all the galaxies and almost all of the X-ray emission to fall on a single ACIS chip.

2 Observation

HCG 62 was observed on 2000 Jan 25 for 50,000 s (about 70,000 counts) with ACIS-S. The S3 (BI) chip was selected because of its high quantum efficiency at low energies, which is well matched to this soft source. We specified the pointing position so that the X-ray center of HCG 62 falls at the geometric center of the ACIS-S BI chip S3. This ensures that the $8' \times 8'$ chip covers almost all the X-ray emission from the group (see Figure 1) as well as member galaxies without regard for the roll angle. The observation was fortunate with respect to backgound flaring events: counting rates are stable throughout and no integration time was lost to this problem.

Table 1: Properties of HCG 62.

Redshift	$z = 0.014$
n_H	3×10^{20}cm^{-2}
Count rate (ACIS S3/BI)	1.4 cts s^{-1}
Central galaxy content	1 E3 (HCG 62a)
	2 S0 (HCG 62b,c)
Temperature	$\sim$1 keV
Metallicity	$Z_{solar} \simeq 0.4$
log L_x	43.0 (0.1 – 2.4 keV)

3 Discussion

The original principal purpose of this observation was the tracing of variations in heavy element abundances throughout the group to assist in interpreting their origins. The data make it clear, however, that this group is substantially more complex than might have been anticipated, with striking departures from a smoothly-varying structure. Perhaps the most remarkable features are the two cavities nearly symmetrically positioned on opposite sides of the X-ray peak (most clearly visible in Figure 2, but also quite apparent in the raw data in Figure 1).

It is interesting to speculate on the cause of these cavities.

• An attractive possibility is that we are observing the consequences of activity in the nucleus of HCG 62a. This activity could be current or else the cavities could be the remnants of earlier activity. The weak (5 mJy) pointlike radio source coincident with the optical center of HCG 62a (see Figure 2 and its caption) and the absence of apparent radio lobes would argue for the latter possibility. If so, the nuclear activity must have been recent, as the sound crossing time of the cavities can be estimated at only $\sim 2 \times 10^7$ years. A deeper radio image than what is now available would constrain the current radio activity still further. Cavity creation through radio lobes raises issues about heating sources for the X-ray-emitting gas. The lobes in HCG 62 are in any case reminiscent of those recently found in Chandra observations of Hydra A (McNamara et al. 2000).

• Another possibility is the presence of X-ray absorbing material, perhaps associated with a cooling flow. There is some evidence for this in PSPC data, but it would not clearly account for the apparent symmetry of the cavities.

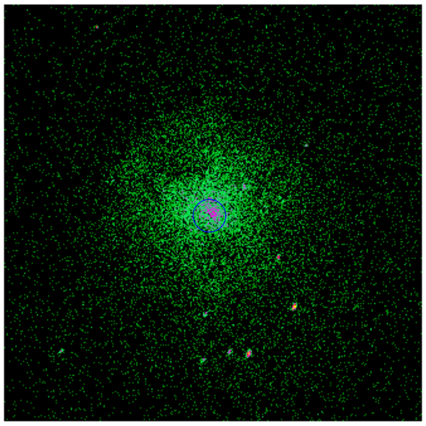

Figure 1: Raw Chandra image of HCG 62. The segment of the ACIS S-3 chip shown here is 4 arcmin on a side, with north to the top and east to the left. Only photon events in the energy range from 0.4 to 3 keV have been selected; the lower cutoff is determined by calibration uncertainties and the upper is due to the softness of the source.

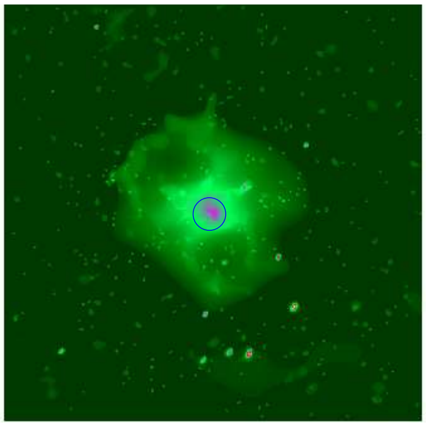

Figure 2: The same image as above, after background subtraction and wavelet-based smoothing. The circles in this and the above image are centered on the position of a 5 mJy point source detected by the VLA at 1.4 GHz (H. Quintana and H. Liszt, unpublished), which coincides to arcsecond accuracy with the optical position of HCG 62a (NGC 4761), the elliptical galaxy at the group center.

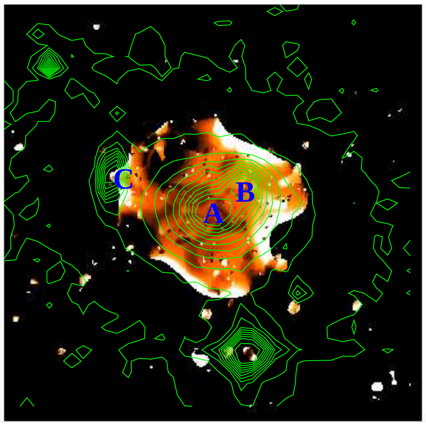

Figure 3: Hardness ratio map of HCG 62. The ratio is computed as hard (above 1keV)/soft (below 1keV); in the Figure brighter color indicates harder emission. The soft and hard maps were independently wavelet-smoothed before their quotient was computed. Contours are from the DSS and show the three central galaxies in HCG 62; they are labeled A (HCG 62a = NGC 4761), B (HCG 62b = NGC 4759), and C (HCG 62c = NGC 4764). The X-ray and optical point source at the lower center is a bright foreground star.

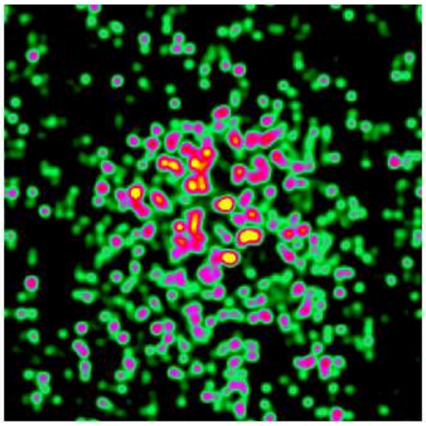

Figure 4: Image of HCG 62 in the silicon feature (1.7 to 1.9 keV), with continuum from the adjacent spectrum subtracted, and then normalized by that continuum. Gaussian smoothing of about 5 arcsec was applied.

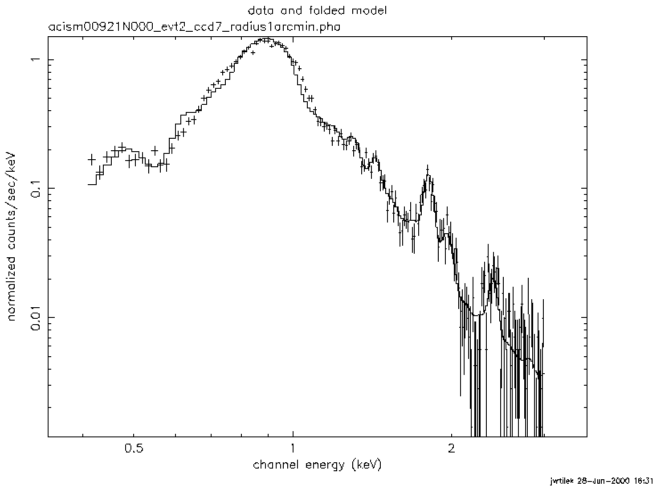

Figure 5: 0.4 to 3.0 keV spectrum of HCG 62 in a 1 arcmin radius around the X-ray peak. A local background has been removed. A MEKAL model fited to the data is shown; the quality of the fit deteriorates shortward of about 1 keV owing to currently unresolved calibration issues. Strong features from Mg (1.3 keV), Si (1.8 keV), and S (2.4 keV) are apparent and will allow abundances to be traced in several spatial regions.

The Chandra spectrum of the central (2 arcmin across) region of HCG 62 is consistent with a spatially-averaged abundance of 0.4 solar, the same as found from ROSAT data by Helsdon and Ponman (2000). The ACIS spectrum (Figure 5) shows very strong magnesium, silicon, and sulfur features, which allow us to prepare maps of the "equivalent width" of a single spectral feature across the group (Figure 4). It should prove possible to examine variations in the distribution of heavy elements and correlate these variations with other spatially-varying group properties.