

Cluster–Galaxy Interactions in Coma

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Abstract.

The galaxies NGC 4911 and 4921 in the Coma cluster provide spectacular examples of luminous, grand design spirals passing through the hot intracluster medium of a rich cluster of galaxies. Chandra ACIS-I imaging of their environment, coupled with CFHT, HST/WFPC2, and VLA radio imaging, reveal the interactions between the hot X-ray gas and the ISM of the spirals, highlighting the linkage between galaxy and cluster evolution generated by such interactions.

Keywords: Galaxies, interactions, clusters, ICM

1. Introduction

Coma, like most large clusters of galaxies, is still being built through infall of subclusters and smaller groups. Evolution of the infalling galaxies is altered by the cluster environment where hot intracluster gas can ablate or strip the interstellar medium of galaxies, radically altering their star formation histories. Systems can be “harassed” (Moore et al. 1996) or, in the extreme, even completely disrupted by tidal forces, spilling their contents throughout intracluster space (Gregg & West 1998). Infalling gas stripped from galaxies augments and heats the intracluster medium (ICM), thereby accelerating galaxy evolution through ram-pressure stripping. Over time, the material removed from galaxies is recycled into an ever-growing intracluster population of stars, gas, and dwarf galaxies (e.g., West et al. 1995; Côté, Marzke & West 1998; Côté et al. 2000; Thompson & Gregory 1993; Lopez-Cruz et al. 1997).

There are two giant spiral galaxies in the core of Coma, NGC4911 and NGC4921, which are undergoing intense and stressful interactions with their environment. Gregg & West (1998) documented several extended low surface brightness (LSB) objects in the Coma cluster, one of which is trailing NGC4911 into the core of Coma (Figure 1). Such LSB features are most likely transient, produced by galaxy-galaxy interactions or by stripping of galaxies by the global cluster tidal field and ICM.



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2. Optical Observations

We have obtained HST/WFPC2 V (F606W) and I (F814W) images of NGC 4911 and also of its LSB tidal debris wake. The left panel in Figure 1 shows the original discovery image of the LSB material following in the wake of NGC 4911; at this contrast, the galaxy and its companion S0 are burned into one. The center panel shows the WFPC2 V image of NGC 4911 at intermediate contrast to reveal the companion; the WF chips are filled with extended low surface brightness material from NGC4911. The right panel shows just the PC chip to reveal the nuclear region; there appears to be a disembodied spiral arc of enhanced surface brightness on the leading side of the disk toward the cluster core, which is 0.29° away. This arc may be an example of ram-pressure-induced star formation, perhaps a bow shock, as NGC 4911 plows through the hot X-ray emitting ICM in Coma.

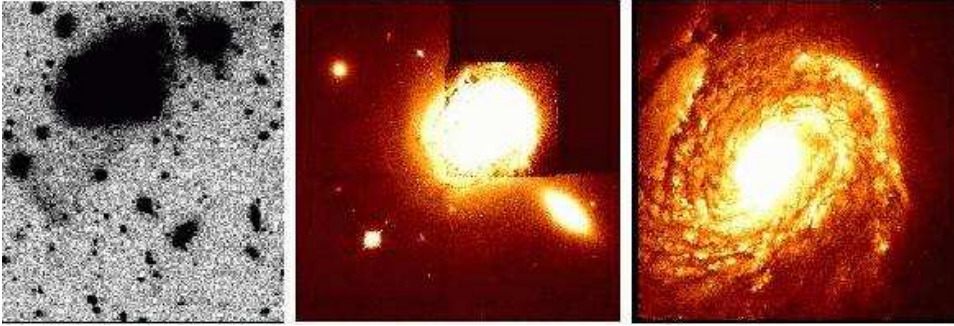


Figure 1. Left: A portion of the KPNO Schmidt discovery image of the LSB tidal debris following NGC 4911. *Center:* WFPC2 F606W (V-band) image of NGC4911. The S0 galaxy (NGC4911A) to the lower right is perhaps responsible for generating the tidal debris, but itself shows no morphological disturbances. *Right:* F606W (V-band) PC field shown at different stretch to reveal more detail. The core of Coma is to the upper right; on this side of the galaxy is a bright, disjoint spiral arm, perhaps the result of ram pressure-induced star formation.

The second WFPC2 field was obtained with most of the trailing LSB material on WF3, clearly seen in Figure 2. Using SEXTRACTOR, we have cataloged all objects in the LSB image; a 3σ excess of objects is found in the WF3 chip relative to the other two WFPC2 fields. These objects have roughly globular cluster luminosities; if these are really in Coma, we are witnessing the present-epoch creation of intergalactic star clusters. We will be obtaining redshifts with Keck for the brightest objects in this field; a spectrum obtained last year shows that one of the brightest has emission lines and a velocity placing it in the cluster.

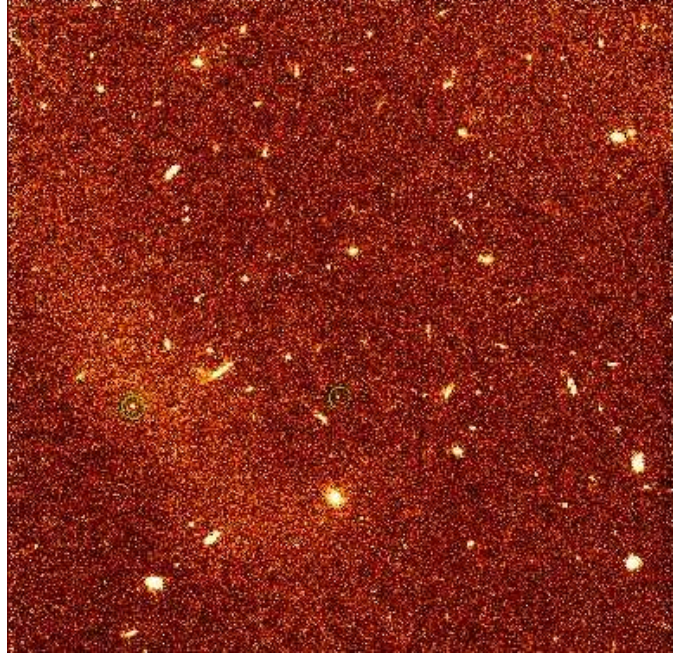


Figure 2. WFPC2/WF3 image of LSB material near NGC4911. Circles indicate Chandra X-ray point sources.

3. X-ray Observations

We obtained a 65ks Chandra image, centered near NGC4911, a known X-ray source. Our Chandra X-ray spectrum of NGC4911 shows that it houses an active galactic nucleus, perhaps spawned by the same interactions which have produced the LSB material.

Of the many point sources in our Chandra field, two have optical counterparts in the WF3 field of the LSB material (circles in Figure 2). The brighter of these has a soft X-ray spectrum, consistent with being an X-ray binary in Coma with a luminosity of $\sim 7 \times 10^{38}$ ergs/s. The other two WFPC2 chips have no X-ray point sources with optical counterparts.

4. Radio Observations

VLA 21cm observations also show evidence for interactions between NGC 4911 and the intracluster medium (Figure 3). The VLA observations also captured the continuum of NGC4921, a giant spiral to the east of NGC4911. Both galaxies appear to be losing their ISM, as indicated by the distorted, asymmetric, and flowing contours seen in the

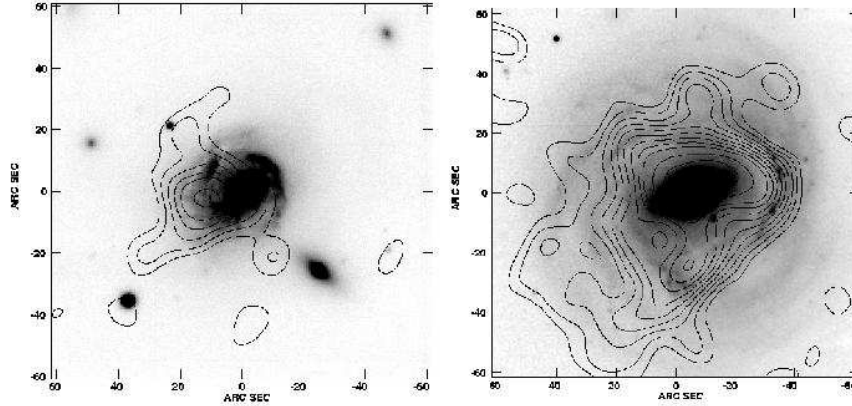


Figure 3. LEFT: VLA C-array map of HI in NGC 4911 for a representative velocity channel, superimposed on a CFHT R-band image. The gas is off-center and exhibits a confused velocity structure, evidence of being stripped from the galaxy by the hot ICM. *RIGHT:* A VLA C-array 20cm continuum map of NGC 4921, superimposed on a CFHT image. The gas is being compressed on the side towards the cluster core and extends much farther out into the disk on the opposite side, evidence of being stripped from the galaxy. Cluster core is to the upper right in both panels.

radio (Figure 3). More extensive studies by Bravo-Alfaro et al. (2000) show similar behavior for these galaxies and other, smaller spirals in Coma.

5. Summary

- Coma, dominated by early type galaxies, is still accreting spiral galaxies at the present epoch.
- The spirals are being drastically transformed by their interaction with the cluster. Vigorous star formation is induced, using up the gas, and the ICM also removes gas by heating and stripping the galaxies' ISM.
- The outer stellar portions of NGC4911 are being removed by the global cluster tidal field or its S0 companion, further altering its evolution.
- The stripped material will eventually disburse throughout the core of Coma, augmenting the general intergalactic populations of stars, star clusters, gas, and perhaps even X-ray binaries. Through this process, the infalling galaxies in turn help drive the evolution of the whole cluster.

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