Sloshing, Stripping, Bubbles, & Shocks In the NGC 5846 Group

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Introduction

The NGC5846 galaxy group shares many properties with highly evolved fossil groups, yet its intra-cluster medium is far from relaxed. We use a combined 120 ks Chandra exposure to study the `sloshing' gas motions, established by galaxy interactions in the group, and AGN activity, driven by AGN activity in the dominant group galaxy NGC5846.

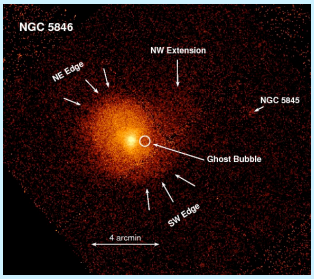
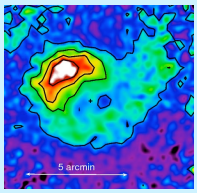


Fig. 1: 0.5-2 keV X-ray image of NGC 5846. Note the multiple edges , 38.5 kpc spiral tail to the NW , and bubbles from AGN activity.

Sloshing

Cold fronts, multiple edges, & spiral features indicate `sloshing'. Lack of the analogous spiral feature in the temperature map implies the perturbing interaction is not in the plane of the sky, consistent with an interaction < 200 Myr ago with disturbed spiral galaxy NGC5850 located 71.5 kpc to the east.



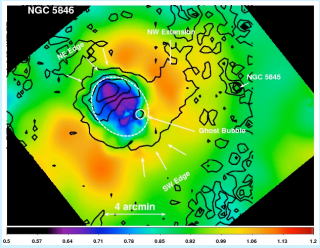
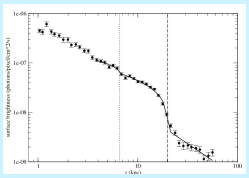
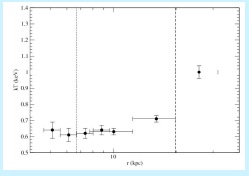


Fig. 2: (left) Ratio image (Img – Mod)/Mod to highlight the spiral tail. Img is the image from Fig. 1 and Mod is the mean β model . (right) Temperature map of NGC 5846 with contours from the ratio map overlaid.

Constraining gas velocities



Surface brightness (upper) & temperature (lower) profiles across the NE edges



Edge Analysis Results

Table 5. Cold Front Analyses

Edge	r_{edge} (kpc)	n_i/n_o	T_i/T_o	p_i/p_o	Mach	v (km s^{-1})
NE$_{outer}$	19.8	$2.9^{+0.5}_{-0.4}$	$0.71^{+0.5}_{-0.5}$	$2.1^{+0.5}_{-0.4}$	$1.0^{+0.2}_{-0.2}$	520^{+90}_{-100}
SW$_{outer}$	19.1	$2.1^{+0.7}_{-0.4}$	$0.88^{+0.71}_{-0.10}$	$1.8^{+1.7}_{-0.6}$	$0.9^{+0.4}_{-0.3}$	510^{+270}_{-240}
NE$_{inner}$	6.7	$1.4^{+0.2}_{-0.2}$	$0.98^{+0.12}_{-0.10}$	$1.3^{+0.4}_{-0.3}$	$0.6^{+0.3}_{-0.5}$	250^{+100}_{-190}
SW$_{inner}$	11.0	$1.6^{+0.2}_{-0.2}$	$0.79^{+0.10}_{-0.07}$	$1.3^{+0.4}_{-0.3}$	$0.6^{+0.2}_{-0.4}$	260^{+190}_{-190}

Note. — Cold front ratio analyses following Vikhlinin et al. (2001). The edge positions are measured from the center of NGC 5846. Mach numbers are relative to the speed of sound outside each edge.

Bubbles and AGN Activity in the Central Region of Galaxy NGC5846

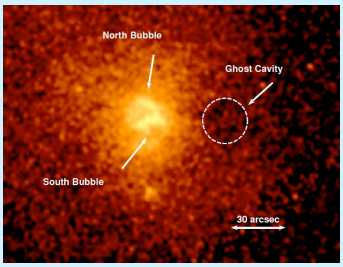


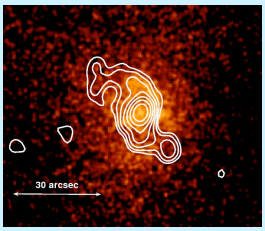
Table 7. Bubble Properties

Label	d (kpc)	r (kpc)	$4pV$ (10^{55} ergs)	t_s (Myr)	t_b (Myr)	L_{mech} (10^{41} erg s^{-1})
ghost	5.23	1.68	5.3	11.8	12.1	1.38
north	0.75	0.58	1.3	1.8	1.1	3.76
south	0.93	0.58	1.2	2.2	1.6	2.45

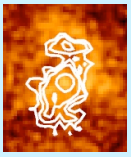
Note. — Columns (1) bubble label, (2) distance d from the nucleus of NGC 5846, (3) bubble radius, (4) the work needed to evacuate the cavity for a relativistic plasma ($\gamma = 4/3$), (5) bubble age for bubble rising at the speed of sound in the ambient gas (6) bubble age for bubble rising buoyantly at its terminal velocity, (7) the instantaneous mechanical power of the outburst estimated using the buoyancy timescale t_b

Multi-Wavelength View of the Inner Bubbles

VLA 1.5 GHz Contours

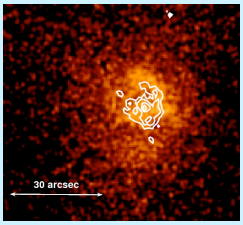


Low resolution 1.5 GHz contours show radio plasma inflates the inner bubbles.

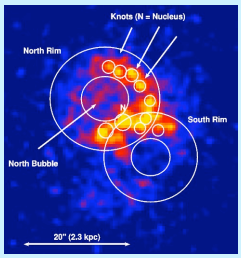


Close up of north bubble. High resolution 1.5 GHz radio contours trace the bubble rim

Hα contours



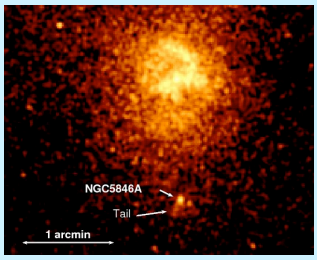
Weak Hα is also strongly correlated with bubble rims ➔ star formation rate of 0.037 $M_\odot$/yr.

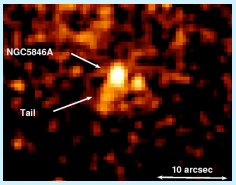


Knotty Structure in Bubble Rims

Unsharp-masked image (left) reveals 9 knots threading the inner bubble rims. If knots are spherical, $n_e = 0.33 \pm 0.03$ cm^{-3} & kT= 0.72 keV suggests knots are over-pressured by ~ factor 3 compared to surroundings with cooling time ~30 Myr. **Interpretation: `Knots' are gas clouds compressed by recent passage of a mach > 1.3 shock**

Stripping of cE Galaxy NGC5846A





First observation of ram-pressure stripping of a compact elliptical galaxy NGC5846A as it plummets supersonically (v_r=486km/s) into the core of NGC5846. The 0.54 kpc tail contains 10^5 $M_\odot$ of gas. The residual gas corona in NGC5846A is small (r<150 pc) ➔ stripping is efficient. Time needed for AGB stars to replenish the gas mass seen in the tail is ~ 5.5 Myr.