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NARROW BAND IMAGES OF SUSPECTED COOLING FLOW GALAXIES

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ABSTRACT: We present narrow-band (Hα and [NII]) CCD images of elliptical galaxies suspected of having cooling flows.

I. INTRODUCTION: Cooling flows analogous to those in clusters of galaxies are also present on smaller scales in isolated (i.e. not in the center of a cluster) early-type galaxies as evidenced by observed soft x-ray halo emission around these galaxies (Forman, Jones and Tucker (1985); Canizares, Fabbiano and Trinchieri (1987); Fabbiano et al (1987)). The typical luminosity in these halos is $L_X = 10^{39} - 10^{41}$ ergs s^{-1}. This gas most probably originates as mass loss from stellar evolution which has been driven out of the galaxy by supernovae induced winds and subsequently flows inward in a cooling flow (Mathews and Loewenstein 1986). These smaller flows should exhibit temperature and density gradients, optically emitting filaments and star formation (at the rate of up to a few M_o yr^{-1}). Therefore one expects to find cool gas ($T = 10^4$ K) in the inner few kpc of elliptical galaxies.

II. OBSERVATIONS: Narrow-band (20 Å bandpass) interference filter images in Hα and [NII] of a subsample of 12 of approximately 40 cooling flow galaxies were taken at the MDM observatory with the 1.3m McGraw-Hill Telescope. Previous narrow-band imaging has been at a resolution insufficient to separate Hα from [NII]. Typical exposure times are 900 seconds.

III. RESULTS and DISCUSSION: We find evidence of optical emission from cool gas which is most likely associated with a cooling flow. At least 4 galaxies (NGC3998, NGC4203, NGC4550 and NGC4697) show emission of [NII] and/or Hα within the central 20", a fraction consistent with results from Phillips et al (1987) and Caldwell (1984). In these four, [NII]λ6584Å emission is stronger than Hα (which is often in absorption e.g. as seen in long slit spectra of NGC4697). From long slit spectra of these galaxies, Deustua and Teske (1989) infer electron densities, N_e, of order 1.2×10^3 cm^{-3} assuming $T = 10^4$ K for the optically emitting gas. NGC 2685, NGC 3489 appear to have emission in [NII]; NGC 4636 may also, but, is difficult to see in our data (Demoulin-Ulrich, Butcher and Boksenberg (1984) did not see emission from this galaxy). NGC 4472, NGC 4473, NGC 4365, NGC 4638 and NGC 4649 show no emission.

Table 1

Parameters of the Sample Galaxies

OBJECT	type	$\log L_X$ erg/s	a_X kpc	$N_e(0)$ cm^{-3}	$t_{cl}(0)$ 10^7 yr	M_{gas} $10^{10} M_\odot$
NGC 2685	S0	39.91	0.25	0.14	4.7	0.017
NGC 3489	S0/Sa	<39.80	0.24	0.13	5.2	0.015
NGC 3998	S0	41.74	0.44	0.50	1.4	0.338
NGC 4203	S0	41.34	0.40	0.36	1.9	0.186
NGC 4365	E3	40.29	0.65	0.05	13.2	0.117
NGC 4472	E1/S0	41.71	1.80	0.06	11.8	2.741
NGC 4473	E5	39.95	0.46	0.06	11.5	0.047
NGC 4550	E7/S0	<39.85	0.18	0.21	3.2	0.010
NGC 4636	E0/S0	41.64	0.70	0.22	3.1	0.618
NGC 4638	S0	39.59	0.22	0.11	5.9	0.011
NGC 4649	E0	41.40	1.16	0.08	8.7	0.988
NGC 4697	E6	40.27	0.95	0.03	23.4	0.199

Galaxy type is from the Revised Shapley-Ames Catalog. $\log L_X$ is given in Canizares, Fabbiano and Trinchieri (1987): the values of the core radius, a_X, central density, $N_e(0)$, central cooling time, $t_{cl}(0)$, and gas mass, M_{gas}, for the hot gas are calculated using their equations.

The best candidates for active cooling flows are NGC 3998 and NGC 4203. Both have Hα and [NII] emission as well as large central densities and short central cooling times as calculated from their x-ray properties (Table 1), furthermore, van Driel et al (1988) observed an HI disk in NGC 4203. Whereas the galaxies with weaker [NII] emission and no Hα have lower central densities and longer cooling times.

It has been suggested in the literature that distorted isophotes i.e. pointy or boxy, indicate the presence of accretion processes. Jedrzejweski (1987) found pointy isophotes for NGC 4473 and NGC 4697, and Mollenhoff and Bender (1986) found boxy isophotes in NGC 4365 and NGC 4472. However, while NGC 4697 has optical emission, its central Ne_{Xray} is small and $tcool_{Xray}$ is large. We find that broad-band U, B, and I images of 7 southern cooling-flow galaxies show that 3 have boxy isophotes at intermeditate radii and pointy isophotes at the inner and outermost radii (i.e. mixed), two are essentially boxy, one has ellitpical isophotes and one, PKS0745-191, is too small to fit. Three of the control galaxies

have isophotes which are essentially elliptical. However, IC 3370, while not a cooling flow candidate, also has very obvious boxy isophotes (Jarvis 1987).

Distorted isophotes probably confirm the presence of a cooling flow via its dynamical effect but do not alone provide sufficient evidence. Whether the presence of Hα and [NII] emission alone are related to cooling flows is unclear (see also Donahue, Stocke and Voit this conference), though Hu, Cowie and Wang (1985) observed such emission filaments in several cluster cooling flows.

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