

H α IMAGING OF THE HICKSON COMPACT GROUP 62¹

M. VALLURI

Columbia University, Department of Astronomy, New York, New York, 10027
Electronic mail: mvalluri@astro.columbia.edu

G. C. ANUPAMA

Indian Institute of Astrophysics, Bangalore 560034, India
Electronic mail: gca@iiap.ernet.in

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ABSTRACT

We report results of a search for optical emission line gas in the Hickson compact group 62. From narrow band (H α) imaging observations we estimate $10^4 M_{\odot}$ of ionized hydrogen gas within the central regions of three of the galaxies in the group. There has been considerable interest in this group since *ROSAT* detected an extended halo of diffuse x-ray emission, possibly with a cooling flow at the center. The optical emission line luminosities from the three galaxies are comparable to each other ($\sim 10^{39}$ erg s⁻¹) and resemble those seen in normal x-ray luminous early type galaxies. There is no evidence for any excess emission in the galaxy which lies at the center of the x-ray cooling flow. We find that the most likely source of excitation for the emission line nebulosities is photoionization by young stars. © 1996 American Astronomical Society.

1. INTRODUCTION

Compact groups are dense concentrations of galaxies with densities comparable to those in the centers of rich clusters. They have always been of interest since their high galaxy densities and small crossing times make them ideal sites for studying galaxy interactions and mergers and the products of these processes. In the last few years *ROSAT* observations of several groups of galaxies have shown that compact groups are frequently associated with extended diffuse x-ray halos. The first *ROSAT* images of extended diffuse x-ray halos of hot (1 keV) gas in the compact group HCG62 (Ponman & Bertram 1993) and the group NGC 2300 (Mulchaey *et al.* 1993) imply that in both systems the group galaxies are embedded in a giant dark matter halo. Since these first observations at least eight other groups with diffuse x-ray emission arising from the extended hot gas have been observed (Ebeling *et al.* 1994 and Pildis *et al.* 1995a). An interesting feature of all the groups with extended x-ray emission is that they are dominated by early type galaxies.

In the group HCG62 (Ponman & Bertram 1993, PB hereafter) the x-ray surface brightness peaks on the dominant galaxy HCG62a and decreases outwards. PB found that the spectral hardness varied significantly with radius and fitted multiple Raymond-Smith hot plasma models to the x-ray spectrum in annular rings to show that the gas temperature is low at the very center rises sharply outwards to peak at about 3' from the center and then decreases again towards larger radii. Pildis *et al.* (1995a) estimate a similar radial temperature profile beyond 3'. Both sets of authors estimate a central temperature of ~ 0.8 keV for the gas. For this temperature,

PB estimate a cooling time for the gas in the central region of $9 \times 10^8 h_{50}^{-1/2}$ yr. The drop in central temperature and the presence of a high surface brightness central component suggests the presence of a cooling flow in this system.

From the earliest x-ray observations of clusters (Lea *et al.* 1973) and subsequent theoretical considerations (Cowie & Binney 1977; Fabian & Nulsen 1977) it has been known that since the cooling time for the hot gas in many clusters is shorter than a Hubble time, under hydrostatic equilibrium conditions, the cooler gas will sink to the center of the potential under the weight of the overlying hot gas. Fabian & Nulsen (1977) predicted that the cooler components of the resulting "cooling flow" would be detectable in optical emission lines as the gas cooled through 10^4 K. Extensive observations of the x-ray emission in clusters have shown that the gas in cooling flows is inhomogenous and consists of gas of varying temperatures and densities throughout the cooling radius (100–200 kpc). Optical line-emitting nebulae have been observed at centers of about 40% of central cluster galaxies (Cowie *et al.* 1983; Hu *et al.* 1985; Johnstone *et al.* 1987; Edge *et al.* 1992) and in 50%–60% of normal early type galaxies (Demoulin-Ulrich *et al.* 1984; Phillips *et al.* 1986). In central cluster galaxies the optical emission lines arise from asymmetrically distributed bright filamentary structures generally within the central 10–20 kpc regions of the galaxy. These regions have LINER spectra (Heckman *et al.* 1989, hereafter HBvBM), with line widths of ~ 100 km s⁻¹ due to turbulent velocities, suggesting that a possible source of excitation could be low velocity shocks or a dilute power-law continuum. The ratios of the [S II] $\lambda\lambda$ 6717, 6731 lines imply that the electron densities are of the order 10^3 cm⁻³ (HBvBM). The presence of the [O I] λ 6300 line indicates that the emission lines arise from semi-ionized regions,

¹Based on observations using Vainu Bappu Telescope, VBO, Kavalur, India.

possibly the ionized-outer skins of cooler clouds (Baum 1992). The strongest piece of evidence connecting the hot gas to the emission line regions is the fact that emission-line nebulae are only detected in those clusters with cooling times shorter than 10^{10} yr (Hu *et al.* 1985). While this is evidence that emission-line nebulae and cooling flows are associated, short cooling times and large x-ray derived mass accretion rates do not appear to be a sufficient condition for the existence of emission-line regions (e.g., A2029, Edge *et al.* 1992). X-ray cooling flows with optical emission line nebulae generally also have an excess of UV/blue continuum emission (Johnstone *et al.* 1987; McNamara & O'Connell 1989; Allen *et al.* 1992) frequently correlated with the emission-line luminosities, distinguishing them from giant elliptical galaxies where such blue continuum emission is rarely observed.

Over the last decade extensive optical spectroscopy (e.g., Phillips *et al.* 1986 [PJDSB hereafter], Kim 1989) and narrow band imaging of early type galaxies (e.g., Demoulin-Ulrich *et al.* 1984; Shields 1991) have established that these galaxies have a significant mass (10^2 – $10^4 M_{\odot}$) of warm (10^4 K) ionized gas and dust. This warm ionized component is detected in emission lines with luminosities of 10^{38} – 10^{40} erg s^{-1} in the $H\alpha$ + $[N II]$ lines alone. Both the narrow band imaging surveys and spectroscopic studies indicate that the ionized emission line component is generally in a disk about 1–1.5 kpc in radius probably rotating about the nucleus. The gas kinematics indicates that gas disk has a rapidly rising inner rotation curve with peak rotation velocities frequently as high as 100 km s^{-1} (Kim 1989). In addition the gas is generally more centrally peaked than the background continuum and is not aligned with the continuum image of the host triaxial elliptical galaxy. This lack of correlation between the continuum image and the orientation of the gas disk could imply that the gas and stars are kinematically and dynamically decoupled. In some cases the kinematics of the gas clearly suggests that cold gas was acquired through an accretion or merger event with a gas rich late-type companion galaxy was subsequently ionized by the hot gas (Macchetto & Sparks 1992). The existence of dust lanes supports this hypothesis in several galaxies (e.g., Goudfrooij *et al.* 1994). As in the case of cluster nebulae these nebulae generally have LINER spectra (although $H II$ region like spectra are observed in a few cases [e.g., PJDSB]). Gas densities are similar to those in cluster nebulae (100 – 1000 cm^{-3}). Emission line luminosities are found to correlate with the absolute B magnitudes of the galaxies (PJDSB, Macchetto *et al.* 1996) and systems with radio sources are found to have more luminous emission line nebulae (Buson *et al.* 1993, hereafter B93). Whether a connection exists between the x-ray fluxes and the emission-line fluxes is even less certain than in the case of cluster cooling flow nebulae.

The observation of a possible x-ray cooling flow in the compact group HCG62 provides a situation that is intermediate between x-ray cooling flows in clusters and those in individual x-ray luminous galaxies. The central cooling time for the x-ray gas in this system is $\sim 10^9$ yr and the x-ray images suggest that the cooling flow is centered on the galaxy HCG62a. We imaged the compact group HCG62 to

TABLE 1. Journal of observations.

Date (UT) 1994 March	Filter	Exposure sec
24.892	V	600
24.906	V	1200
24.810	R	600
24.818	R	300
24.842	$H\alpha$	1800
24.866	$H\alpha$	1800
25.849	$H\alpha$	1800

search for warm ionized gas associated either with a global cooling flow or with the individual galaxies. In this paper we present images of the $H\alpha$ + $[N II]$ emission-line regions in three of the galaxies in this group.

In Sec. 2 we describe the observations and the data reduction. In Sec. 3 we present the main results of the observations. In Sec. 4 we discuss possible models to account for the observed emission line fluxes. In Sec. 5 we summarize the main conclusions from this paper.

2. OBSERVATIONS AND DATA REDUCTION

The compact group HCG62 was observed using the 2.3 m Vainu Bappu Telescope at Kavalur, India, on 1994 March 24 and 25. The CCD camera system was used at the prime focus. This system consists of a GEC back illuminated chip, with 385×578 pixels of $23 \times 23 \mu\text{m}$ size. The image scale is 0.56×0.56 arcsec. The characteristics of the CCD system are described in Prabhu *et al.* (1992) and Anupama *et al.* (1993). The seeing was ~ 2.5 arcsec on both nights.

Seven images were obtained, three narrow band ($\Delta\lambda = 80 \text{ \AA}$), centered at $\lambda 6680 \text{ \AA}$ corresponding to the $H\alpha$ emission redshifted to $z = 0.0137$, the mean redshift of the group (Hickson 1993), and two images each in the broad-band V and R filters. The details of the observations are given in Table 1.

All frames were reduced following standard procedures. Each frame was bias-subtracted using bias values from the overscan region, and flat-field corrected with averaged twilight flats taken through the corresponding filter. The bias subtracted and flat-field corrected images were then partly cleaned for cosmic ray hits. Sky subtraction was effected using a sky value measured in those parts clearly unaffected by the light from the galaxies and stars in the field. The frames were then aligned using positions of the stars in the field and a shift in both the X and Y directions. Individual frames in each of the filters were then co-added. To obtain a continuum-free narrow-band image a rescaled R frame was subtracted from the narrow band $H\alpha$ + $[N II]$ image. The re-scaling of the continuum image is generally the most tricky procedure and in this case it was estimated using the stars in the field. In addition to the stars being completely subtracted from the resultant images, the outer regions of the galaxies were also fully subtracted out, giving us greater confidence in the scale factor. The IRAF software package was used for reductions.

The spectrophotometric standard G60–54 (Oke 1990) was observed through V, R and the narrow band filter and

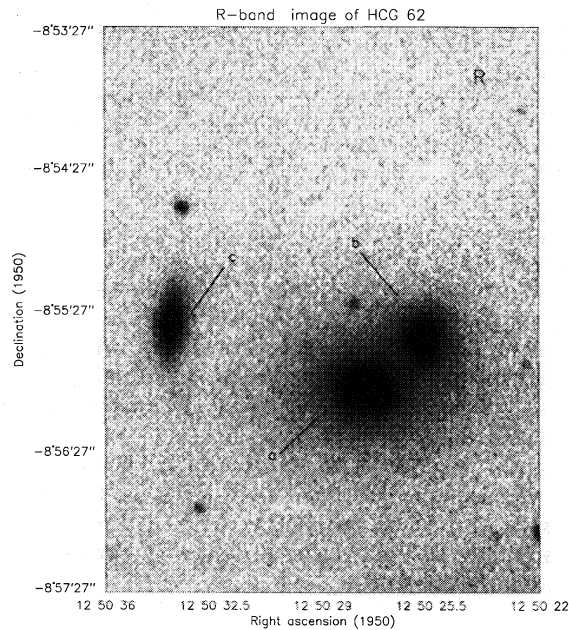


FIG. 1. Coadded R band image with galaxies a , b , c as marked.

used for flux calibration. The observed magnitude of the standard star in the $H\alpha + [N II]$ filter was compared with the standard magnitude (Oke 1990), and the zero point correction estimated. This zero point correction was applied to the $H\alpha + [N II]$ fluxes estimated for the individual galaxies. The fluxes were corrected for atmospheric extinction determined as $10^{-2.5XB/\lambda^4}$, where λ is in μm , X is the airmass, and $B = 0.014 \text{ mag } \mu\text{m}^4$ is the mean differential extinction coefficient for the site. Thin clouds were present during both nights resulting in errors in the magnitudes of 0.1 mag in $H\alpha$ and 0.07 mag in R . These translate to an error of 15% in

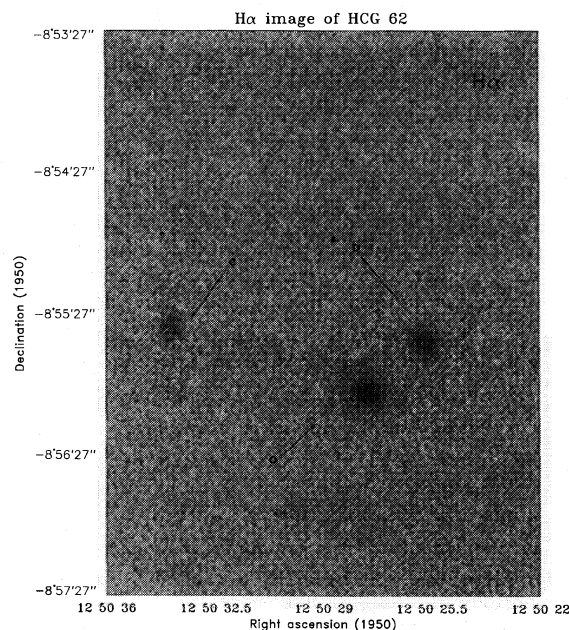


FIG. 2. Continuum subtracted $H\alpha + [N II]$ image.

TABLE 2. $H\alpha + [N II]$ fluxes.

Galaxy	flux/ 10^{-15} ergs cm^{-2} s^{-1}		luminosity/ 10^{39} ergs s^{-1}		$\log(F_{H\alpha+[N II]}/F_B)$
	$H\alpha + [N II]$	$H\alpha^a$	$H\alpha + [N II]$	$H\alpha^a$	
HCG62a	1.91	0.803	1.57	0.66	-4.10
HCG62b	1.25	0.525	1.03	0.43	-4.06
HCG62c	0.93	0.391	0.77	0.32	-3.86

^a $H\alpha$ fluxes corrected for $[N II]$ using $[N II]/H\alpha = 1.38$ (PJDSB).

the $H\alpha$ flux estimates from the images, including all other systematic errors.

3. RESULTS

The coadded R band image of the group is shown in Fig. 1 with the galaxies marked a , b , c as in the Hickson catalogue (Hickson 1982). HCG62d was not observed. The observed galaxies are classified as E3 (HCG62a), and S0 (HCG62b and HCG62c) (Hickson 1982). In deep images the galaxies a and b overlap significantly and are embedded in a diffuse common stellar envelope. Pildis *et al.* (1995b) find this diffuse envelope to be roughly symmetric about galaxy a , with some enhancements in the direction of galaxies b and c . This diffuse envelope could imply that the central galaxy is the product of a previous merger. No other signs of interaction or merger, such as tidal tails, are visible even in deep images (Pildis *et al.* 1995b).

3.1 $H\alpha$ Fluxes

Figure 2 shows the continuum subtracted $H\alpha + [N II]$ line-emission from the compact group HCG62. Emission is detected from the central regions of the three group galaxies observed. The total extent of the emission-line region is 17 arcsec in HCG62a, 13 arcsec in HCG62b, and 11 arcsec in HCG62c, assuming a mean distance to the group of 83 Mpc² (PB) the corresponding diameters are 6.8 kpc, 5.2 kpc, and 4.4 kpc, respectively. In the galaxy HCG62b the emission appears to arise in a partial annular ring. This feature is detected within the point-spread-function (PSF) of the frame, and could be a result of slight differences in the PSF in the $H\alpha + [N II]$ and R frames. A similar feature is however not detected in either HCG62a or HCG62c indicating that the annular distribution in HCG62b could be real. Annular emission regions have occasionally been detected in the past in x-ray bright elliptical galaxies (e.g., NGC 4636 [B93] and NGC 3607 [Singh *et al.* 1994]). Imaging under better observing conditions are required before this feature can be established.

The total emission-line flux from each galaxy was obtained using apertures of radius 8.5 arcsec, 6.6 arcsec, and 5.5 arcsec, respectively, for the galaxies HCG62a, HCG62b, and HCG62c. In Table 2 we list the observed $H\alpha + [N II]$ fluxes and luminosities and the $H\alpha$ fluxes and luminosities which are estimated by assuming that the ratio of $[N II]/H\alpha = 1.38$ (PJDSB). The observed luminosities of

²In this paper all distance dependent quantities assume $H_0 = 50 \text{ km s}^{-1} \text{ Mpc}^{-1}$ and $q_0 = 0$.

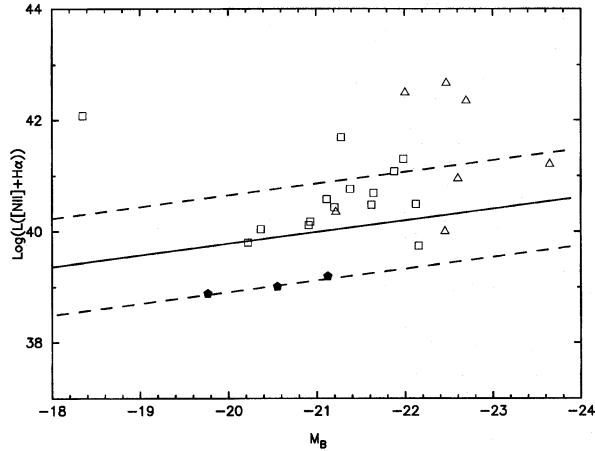


FIG. 3. Best fit line (solid) with 1σ errors (dashed) for the emission-line luminosity versus absolute B magnitudes for magnitude-limited sample of early type galaxies from PJDSB. HCG62 galaxies (filled pentagons), luminous emission-line nebulae in elliptical galaxies (open squares) (B93) and cooling flow galaxies (open triangles) (Heckman *et al.* 1989).

$\sim 10^{39}$ ergs s^{-1} are comparable to those observed in the emission line regions of luminous elliptical galaxies (e.g., PJDSB, Kim 1989).

It has been known for some time that the emission line luminosities of normal early type galaxies are correlated with their absolute magnitudes, and that luminous ellipticals are more likely to have emission lines than smaller galaxies (PJDSB). In cooling flow clusters the emission line luminosity of the central galaxy is found to correlate with the x-ray inferred mass accretion rate (Johnstone *et al.* 1987). Furthermore, HBvBM showed that cooling flow nebulae have emission line luminosities well in excess of the emission-line luminosity of a typical giant elliptical galaxy. Figure 3 shows the total $H\alpha + [N II]$ emission-line luminosity for the HCG 62 galaxies (filled pentagons) plotted against absolute magnitude. The solid line is a linear fit (with one sigma errors) to the emission-line luminosity versus absolute B -magnitude (not including upper limits) for a complete magnitude limited survey of early type galaxies (PJDSB). (The fit obtained by B93 includes upper-limits and has a larger slope and a smaller intercept but comparable 1σ errors). Elliptical galaxies with luminous emission-line nebulae (generally associated with nuclear radio sources) (open squares) from B93 and cluster cooling flow galaxies (open triangles) from HBvBM are also plotted in the figure. This figure clearly shows that the emission-line nebulae in the three HCG62 galaxies are not as luminous in emission lines for their optical magnitudes as are the luminous elliptical galaxies or the cooling flow galaxies. We estimate the quantity $\log(F_{([N II]+H\alpha)}/F_B)$, the ratio of fluxes in emission-lines and B -band for each of the galaxies a, b , and c (column 6 Table 2) taking the B magnitudes of these galaxies as [13.47, 14.04, and 14.83, respectively (from NED)].³ This quantity was also computed for the emission line and cooling flow

³The NASA/IPAC Extragalactic Database (NED) is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

TABLE 3. Electron density and hydrogen mass.

Galaxy	$n_e = 100 \text{ cm}^{-3}$	$n_e = 400 \text{ cm}^{-3}$	$n_e = 10^3 \text{ cm}^{-3}$
	$M_H (10^4 M_\odot)$	$M_H (10^4 M_\odot)$	$M_H (10^4 M_\odot)$
HCG62a	1.52	0.39	0.15
HCG62b	1.01	0.25	0.10
HCG62c	0.83	0.19	0.08

galaxies: for the B93 sample the mean was -2.67 ± 0.86 and for the sample of HBvBM the mean was -1.55 ± 2 . Thus the estimated flux ratios for the HCG62 group galaxies (Table 2) are between 1–2 standard deviations *below* the mean value of the B93 sample and the HBvBM sample. While this deviation is not statistically significant enough to claim that these galaxies do not belong to the sample of highly luminous emission-line/cooling flow objects it seems unlikely that they are cooling flow nebular systems. Furthermore the variation between the individual objects is significantly smaller than the standard deviation of the galaxies in either the B93 sample or the HBvBM sample, indicating that the group dominant galaxy which is at the focus of the x-ray cooling flow is no more luminous in emission lines (relative to B band continuum) than its companions. We therefore conclude that the observed emission line nebulae resemble those in normal elliptical galaxies and are not necessarily the result of accretion from the cooling flow associated with the group. It may be noted here that a similar ratio of emission line to B -band flux is also observed in NGC 2300 (Goudfrooij *et al.* 1994).

An absence of excess emission from the dominant galaxy is rather surprising since the x-ray image suggests that the cooling flow is centered on this galaxy. It is also surprising since the galaxy HCG62a hosts a moderate nuclear radio source [$\log(P/\text{MHz}^{-1}) = 20.22$ at 1635 MHz] (Menon & Hickson 1985) and a correlation exists between the existence of highly luminous emission line nebulae and nuclear radio sources (HBvBM, Shields 1991, B93). It must be emphasised however that while nearly 60% of early type galaxies in the field have emission line regions (B93) only about 39% of x-ray selected cooling flow cluster galaxies have detectable optical emission line regions (Edge *et al.* 1992; Donahue *et al.* 1992). This suggests that rather special conditions are required to power the emission line regions in cluster cooling flows.

3.2 Mass of Ionized Gas

The mass of the warm ionized gas component can be estimated from the $H\alpha$ luminosity ($L_{H\alpha}$). Under case B recombination conditions, we have

$$L_{H\alpha} = V\epsilon[\alpha_{H\alpha}^{\text{eff}} h\nu_{H\alpha}]n_e n_H, \quad (1)$$

where V is the volume of the emitting region, ϵ is the filling factor and $\alpha_{H\alpha}^{\text{eff}}$ is the effective recombination coefficient for $H\alpha$ emissivity (Osterbrock 1989), n_e is the electron density, and n_H is the hydrogen density. Assuming that the gas is

fully ionized and $n_p = n_H = n_e$ we estimate the mass of ionized hydrogen in each of the three galaxies (Table 3) by the expression,

$$\frac{M_{\text{gas}}}{M_{\odot}} = 2.8 \times 10^2 \left(\frac{D}{10 \text{ Mpc}} \right)^2 \left(\frac{F(\text{H}\alpha)}{10^{-14} \text{ ergs s}^{-1} \text{ cm}^{-2}} \right) \times \left(\frac{10^3 \text{ cm}^{-3}}{n_e} \right) \quad (2)$$

(Kim 1989), where D is the distance to the source and $F(\text{H}\alpha)$ is the $\text{H}\alpha$ flux corrected for contribution from the $[\text{N II}]$ line using the mean $[\text{N II}]/\text{H}\alpha$ ratio of 1.38 (HBvBM, PJDSB). The estimated mass depends on an accurate estimate of the electron density in the nebula. Densities measured directly from spectroscopic data using the $[\text{S II}]$ line ratios (approximately unity) for a sample of early type galaxies (PJDSB) imply typical values for the electron density of $n_e \sim 10^3 \text{ cm}^{-3}$. For cluster cooling flow galaxies HBvBM estimate densities in the range $150\text{--}400 \text{ cm}^{-3}$ and derive filling factors of $10^{-6}\text{--}10^{-7}$. Alternatively if we assume that the hot and warm components are in pressure equilibrium then $n_X T_X = n_e T_H$ (where T_H is the temperature of the emission line nebula). With $n_X = 0.1$ (typical x-ray estimated density for the hot gas in the central region), $T_H = 10^4 \text{ K}$ we estimate an electron density of $n_e = 100 \text{ cm}^{-3}$ for $T_X = 10^7 \text{ K}$, the estimated temperature for the gas in the central region (PB). In Table 3 we list the estimated masses of ionized hydrogen for three possible values of n_e using $\text{H}\alpha$ fluxes in the equation above.

To estimate the volume filling factor of the gas we assume that it occupies a spherical volume of radius determined by the extent of the emission. The filling factor are given by $\epsilon = V_{\text{gas}}/V_{\text{tot}}$, where $V_{\text{gas}} = M_{\text{gas}}/n_e m_H$, and $V_{\text{tot}} = \frac{4}{3} \pi r^3$ (HBvBM). This gives mean filling factors of $\log(\epsilon) = -7.7 \pm 0.1$ for $n_e = 100 \text{ cm}^{-3}$, and $\log(\epsilon) = -9.6 \pm 0.1$ for $n_e = 10^3 \text{ cm}^{-3}$. Comparing these filling factors with those in other systems (HBvBM) we conclude that the most reasonable values for the filling factors are $\epsilon \sim 10^{-7}$ for $n_e \sim 100$. We thus estimate that there is between $0.8\text{--}1.5 \times 10^4 M_{\odot}$ of ionized emission-line gas in each of the three elliptical galaxies in this compact group.

4. $\text{H}\alpha$ EMISSION MECHANISM

In this section we discuss some possible mechanisms that may account for the $\text{H}\alpha$ emission seen in this group. Despite the fact that emission line nebulae have been observed in galaxies and cluster cooling flows for over two decades there is still no general consensus on the source of excitation that provides both the required energy flux as well as accounts for the observed spectral-line features (Baum 1992, for a review).

Early observations of isolated early type galaxies indicated that the $\text{H}\alpha$ luminosity of the emission-line nebulae was correlated with the x-ray luminosity of the host galaxy (e.g., PJDSB) suggesting that recombinations in the hot gas could produce the required flux of emission line gas. The $\text{H}\alpha$ luminosity can be estimated under the assumption that as the gas cools from above 10^6 K to below 10^3 K it recom-

bins and emits (Balmer) photons. The resultant $\text{H}\alpha$ luminosity in HCG62a for a cooling rate $\dot{M} = 0.5\text{--}1 M_{\odot} \text{ yr}^{-1}$ within the emission line region (estimated from a value of $\dot{M} = 10 M_{\odot} \text{ yr}^{-1}$ within the cooling radius of 75 kpc and $\dot{M} \propto r$ [PB]) is $L_{\text{H}\alpha} \approx 10^{37} H_{\text{rec}} \text{ ergs s}^{-1}$. As in other cooling flow systems (HBvBM, Fabian 1994) each hydrogen atom would have to recombine between 100–500 times to produce the observed flux in HCG62a at the center of the flow. If the emission line flux was a result of recombination in the hot gas one might naively expect that at larger distances from the center, the local cooling and mass accretion rate of the hot gas would be smaller (since the gas densities are lower) and the galaxies HCG62b and c would have proportionately smaller fluxes. Since the observed fluxes are similar the required value of H_{rec} would be even higher for galaxies further out. Ionization due to recombination in cooling flow thus fails to account for the observed $\text{H}\alpha$ luminosities, and photoionization offers a possible mechanism.

A linear correlation exists between the emission-line luminosity and the absolute B magnitudes of normal early type galaxies (e.g., PJDSB; Fig. 3). A recent study by Macchetto *et al.* (1996) also shows that the emission line flux is even more tightly correlated with the B -band flux within the line-emitting region. These correlations suggest that photoionization by stars is a possible mechanism (Johnstone *et al.* 1987; HBvBM, McNamara & O'Connell 1989; Trinchieri & Di Serego Alighieri 1991; Allen 1995). If the gas is photoionized by Lyman continuum photons from stars, the minimum number of Lyman continuum photons necessary to produce the observed $\text{H}\alpha$ luminosity is $N_{\text{Ly}\alpha} \text{ ph s}^{-1} = 7.34 \times 10^{11} L_{\text{H}\alpha} \text{ ergs s}^{-1}$, for case B recombination (Osterbrock 1989). This implies that about $(2\text{--}5) \times 10^{50}$ photons s^{-1} are required to explain the current observations.

Trinchieri & di Serego Alighieri (1991) suggest photoionization by post-asymptotic-giant-branch (PAGB) stars could produce enough ionizing photons to explain the observed luminosity and satisfactorily account for the observed spectrum. Assuming that each PAGB star emits 5×10^{46} photons s^{-1} we would require about 10^4 stars. This value is a lower limit since the covering factor for Lyman continuum radiation is likely to be less than 1. For a total galactic luminosity $\sim 10^5 L_{\odot}$ within the line emitting region (3 kpc), one expects ~ 0.2 PAGB stars at any given epoch (Renzini & Buzzoni 1986), i.e. the chance of finding one PAGB star in the emitting region is only 20%. It thus appears that PAGB stars alone cannot account for the ionization of the line emitting medium in the HCG62 group galaxies.

We now investigate the possibility of photoionization by young stars. Spectroscopy of the underlying population in ellipticals by Johnstone *et al.* (1987) provide evidence for the presence of hot young stars. If the ionization is due to O stars or OB associations, then 5–10 stars are sufficient to explain the observed $\text{H}\alpha$ luminosities, and the line emitting medium would be in the form of large clumps. However, narrow band imaging of the line-emitting regions of ellipticals show a fairly smooth distribution of matter. On the other hand, intermediate-mass stars could be formed in cool gas providing the ionizing radiation. The ionizing radiation for an instantaneous burst of star formation with an IMF of slope 2.5,

and a stellar mass range of $1\text{--}30 M_{\odot}$ is 6×10^{45} photons $s^{-1} M_{\odot}^{-1}$ (Mayya 1993, 1995). The total mass in the young stars needed to explain the observations is thus $(4\text{--}8) \times 10^4 M_{\odot}$. The e -folding time for the ionizing radiation due to evolution of the burst is about 5.5×10^6 yrs. We are hence looking at either a young burst at the present epoch or a continuous star formation at a rate of $(0.007\text{--}0.015) M_{\odot} \text{ yr}^{-1}$. The total mass in the young stars estimated here would require $\geq 10^6 M_{\odot}$ of cold gas assuming star formation efficiency in normal spirals (0.2–0.5). Cold gas (H_2 and $H\text{ I}$) with masses of the order $10^5\text{--}10^6$ have been detected in several early type galaxies (see Knapp 1990). Star formation with an upper cutoff $\sim 30 M_{\odot}$ appears to be a viable mechanism to explain the observed $H\alpha$ luminosities.

Emission-line nebulae associated with radio galaxies are typically more luminous than nebulae in normal early-type galaxies. This has led several authors to suggest that active galactic nuclei could provide a source of ionizing radiation (HBvBM; Shields 1991, B93). Although there is a correlation between the emission line luminosities in clusters cooling flow nebulae and radio-power, the variation of the line ratios as a function of radius are not consistent with a point source of radiation (HBvBM). As mentioned earlier the dominant elliptical galaxy (HCG62a) is known to be a weak nuclear radio source (Menon & Hickson 1985) which could be an additional source of ionizing radiation for this galaxy. It does not, however, account for the ionized gas in the other two galaxies.

Finally, we investigated the importance of turbulent mixing (Begelman & Fabian 1990 and Crawford & Fabian 1992) and the energy input from buoyancy waves (g -waves) generated by galaxy motions through the intracluster medium (Balbus & Soker 1990 and Lufkin *et al.* 1995). It was found that neither of these mechanisms satisfactorily accounts for the energetics of the emission-line regions, therefore we do not discuss them in any detail.

Since we find no evidence to suggest that the emission line nebula in HCG62a is more luminous in a statistical sense than either its companions or nebulae in typical field elliptical galaxies we are inclined to believe that the emission-line nebulae in all three galaxies are sustained by the same mechanism—namely photoionization, possibly by young intermediate mass stars. Spectral-line observations are being planned to determine whether the line ratios support this mechanism.

5. DISCUSSION AND SUMMARY

The primary issue arising out of the results presented here is that despite the fact that the estimated cooling time for the x-ray gas is much shorter than a Hubble time ($\sim 10^9$ yr), the central dominant galaxy HCG62a is not more luminous per unit B-band luminosity than its companions. We emphasise again that while about 60% of early type field galaxies have emission line nebulae (B93, Macchetto *et al.* 1996), only about 40% of central cluster galaxies have emission lines (Edge *et al.* 1992; Donahue *et al.* 1992), so the presence of a cooling flow in x-rays is by no means a sufficient condition for optical emission lines to be detected.

It is well known (e.g., Forman 1988) that the presence of a dominant central galaxy is crucial to the existence of a cooling flow. Rich, x-ray luminous clusters without a dominant galaxy generally have very irregular x-ray emission and no cooling flow (e.g., Coma cluster) suggesting that cooling flows are fragile structures that are easily disrupted by the tidal effect of a large secondary galaxy. It is therefore surprising that a cool central component (apparently a cooling flow) exists in this group where two large galaxies (probably in an early stage of merger) dominate the central region. Recent simulations (for instance by Diaferio *et al.* 1995; Pildis *et al.* 1996) show that substructure within collapsing loose groups have x-ray and optical properties resembling many compact groups. These simulations however indicate that mergers are continuously occurring within the denser regions. This suggests that the time scale over which the central region is quiescent allowing gas accretion to occur is very short. The x-ray images of other compact groups observed to have diffuse x-ray emission are rarely as regular and centrally concentrated as that associated with the group HCG62. An indication that the group may have experienced a recent merger comes from the fact that the outer isophotes of the x-ray halo are not concentric with the central isophotes (PB), similar to clusters which have experienced recent mergers. Recent *ROSAT* observations of NGC 2300 (Davis *et al.* 1996) indicate that two of the large individual galaxies in the group are themselves strong x-ray sources. The smooth image of the group generated by subtracting the point sources indicates that the diffuse gas emission does not peak on either galaxy. It seems likely that higher resolution observations will show greater structure in the hot gas in the HCG62 group as well, possibly altering some of the current estimates of the gas accretion rate (Edge *et al.* 1992). Alternatively HCG62b could be merely projected on the center rather than close to it or may have only recently arrived at the center, explaining the absence of signs of strong tidal interaction in the optical images. It is possible that once the merger begins the flow would once again be disrupted as is apparently the case in HCG94 (Pildis 1995).

It has been proposed that hierarchical mergers of clusters might actually help to ‘inject kinetic energy into the cluster core’ and power the emission line gas (Edge *et al.* 1992, Fabian 1994). It seems unlikely that the impending merger in the HCG62 group has enhanced the optical emission fluxes. It seems likely that in order to be effective in powering emission-line nebulae the merger must include a galaxy or group of galaxies that are of late type and which bring with them some cold gas which is then ionized either by low mass star formation, or thermal conduction from the hot gas (Macchetto & Sparks 1992), or by turbulent mixing and shocks (Crawford & Fabian 1992). *This then suggests that a possible explanation for why the optical emission-line nebulae in this group are less luminous than those in cooling flows is that it does not have a gas rich member and has not recently accreted one.* This argument is supported by the findings of B93 that the emission line regions in luminous ellipticals are more closely associated with the cold ISM component than with the hot x-ray component.

To summarize the main findings of this paper:

We have detected extended emission line regions at the centers of three of the galaxies in the compact group HCG62. The luminosities in the $H\alpha + [N II]$ emission line are of the order $\sim 10^{39}$ erg s^{-1} and arise in 3 kpc size regions in the galaxies HCG62*a*, HCG62*b*, and HCG62*c*. The luminosities are comparable to the lower limit of the $H\alpha + [N II]$ line luminosities observed in elliptical galaxies. The observed fluxes imply a total mass of ionized gas of $5 \times 10^3 - 10^4 M_{\odot}$ in each of the galaxies.

Although the x-ray cooling flow is centered on the dominant galaxy HCG62*a* we find no evidence to suggest that the emission line luminosity of the central galaxy HCG62*a* is significantly greater than that of the other two galaxies in the group leading us to conclude that these emission line regions resemble those in isolated ellipticals.

We have investigated various possible mechanisms for accounting for the energetics of the ionized gas regions in the galaxies. We find that photoionization by starlight, most

probably from a population of young intermediate mass stars can account for the observed emission line luminosities.

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