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Surface photometry of ellipticals : radio and cluster galaxies

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Abstract. Broad-band surface photometry in *V*, *R* and *I* colours is presented for three elliptical galaxies immersed in hot intracluster gas emitting X-rays due to thermal bremsstrahlung. The galaxies are (i) a cD galaxy, and (ii) a radio bright galaxy with a narrow angle tail in the cluster of galaxies, 2A0335+096, and (iii) NGC 3607 in a small nearby group of galaxies. Strong H_α emission from NGC 3607 has also been imaged. Detection of a dust ring in NGC 3607 is being reported here for the first time.

Key words : photometry—elliptical galaxies

1. Introduction

Surface photometry of elliptical galaxies is important for understanding the structural, evolutionary and physical properties of the galaxies. We are carrying out broad-band and narrow-band CCD surface photometry of elliptical galaxies, with the 2.3m Vainu Bappu Telescope (VBT) at Kavalur near Bangalore. Our sample consists of radio bright ellipticals, dominant galaxies in clusters and groups and some standard ellipticals.

Here, we present the details of the observations, results of the isophotal analysis, a search for dust lanes and excess absorption, and $H\alpha$ emission in three elliptical galaxies.

2. Galaxies in a cooling flow cluster, 2A0335+096

2A0335+096 is an X-ray source in the second catalogue based on observations with the Ariel-V X-ray astronomy satellite. Although, identified with a compact group or a poor cluster of galaxies at a redshift of 0.035, its X-ray luminosity of 4×10^{44} ergs s^{-1} (Hubble constant = 50 km s^{-1} Mpc^{-1} used everywhere) is comparable to that of the rich clusters. The X-ray emission is extended, size $\simeq 12$ arcmin (700 kpc), and due to thermal emission from hot intra-cluster gas at a temperature (kT) of $\simeq 3.0$ keV (Singh, Westergaard & Schnopper 1986, 1988). A cD galaxy lies at the centre of the cluster and is associated with a cooling flow with a flow rate of ≤ 200 $M_\odot$ y^{-1} (Singh, Westergaard & Schnopper 1988). The cD galaxy is a weak steep spectrum radio source with flux density of 0.140 ± 0.029 Jy at 327 MHz (Patnaik & Singh 1988).

Another galaxy 0335 + 099 ($z = 0.03816 \pm .00016$), comparable in brightness to the cD galaxy, and a very strong radio source, resides near the outer periphery of the cluster. The radio galaxy has an unusually long and narrow angle radio tail (NAT) (Patnaik & Singh 1988). Its flux density is 1.49 ± 0.06 Jy at 327 MHz.

These two galaxies were observed on 1990 January 26-30 with a GEC P8603/B front illuminated CCD at the prime focus of the Vainu Bappu telescope using *V, R* and *I* filters. The details of the CCD and its standardization based on calibration with the stars in the "dipper asterism" of an open cluster, M67 are given in Bhat *et al.* (1990) and Bhat *et al.* (1992). The point spread function during the observations was ~ 2.7″ (FWHM).

2.1. *Results from ellipse fitting*

The images were bias subtracted and flat fielded. The cosmetic defects and impact of cosmic rays were removed by application of median filter. Multiple images with the same filter were co-added. The isophotes of the galaxies were analyzed using the ellipse fitting program (Jedrzejewski 1987), and surface brightness, ellipticity, and position angle profiles were derived. The surface brightness profiles of the cD galaxy and the NAT galaxy are shown together in figure 1, and the $V - I$ colour profiles are shown in figures 2(a) and 2(b) respectively

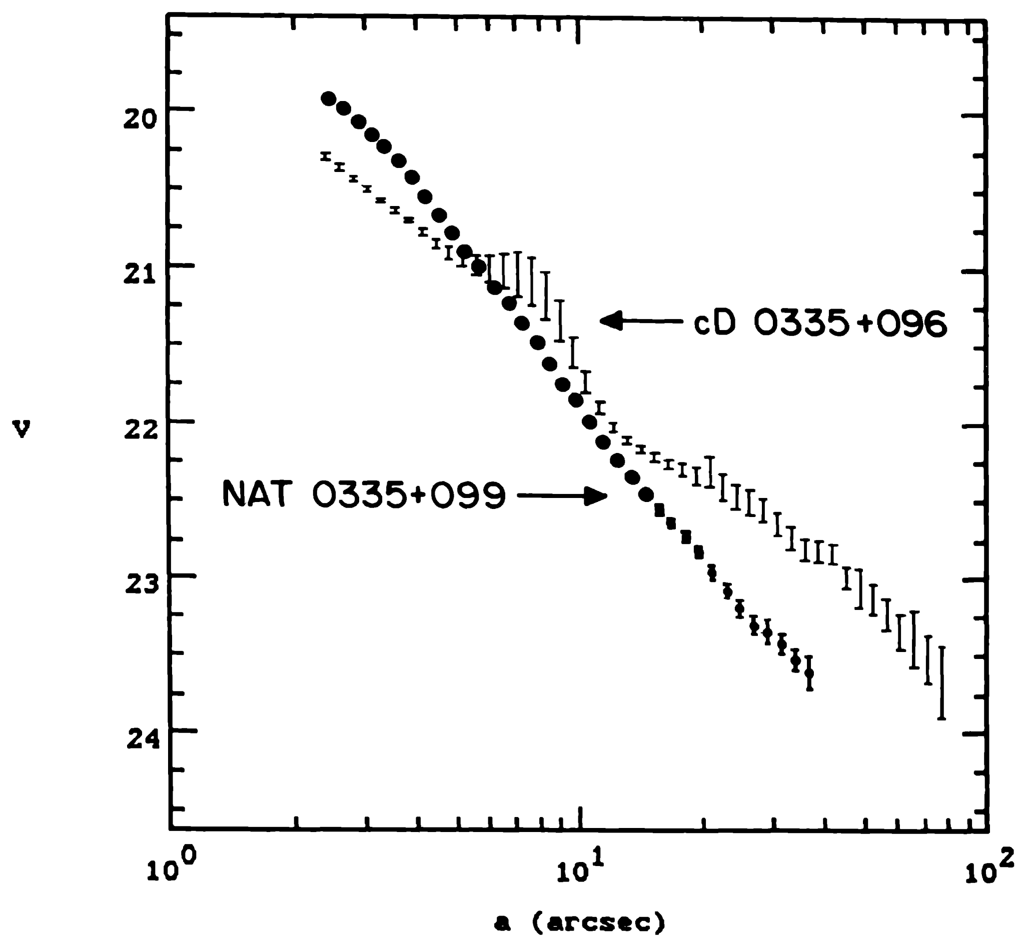

Figure 1. Surface brightness profile in *V* magnitude per arcsec^2 for the cD galaxy and the NAT galaxy in 2A0335 + 096 cluster.

for the cD and the NAT. A hump in the profile of the cD galaxy (figure 1) is due to the dwarf galaxy near (distance = 7″) the nucleus of the cD galaxy. The NAT 0335 + 099 galaxy with overall smaller total luminosity shows higher central surface brightness (figure 1). The $V - I$ colour profiles (figure 2) indicate more reddening towards the centre of the galaxies, indicating the presence of more low mass stars or distributed dust in those regions. This is

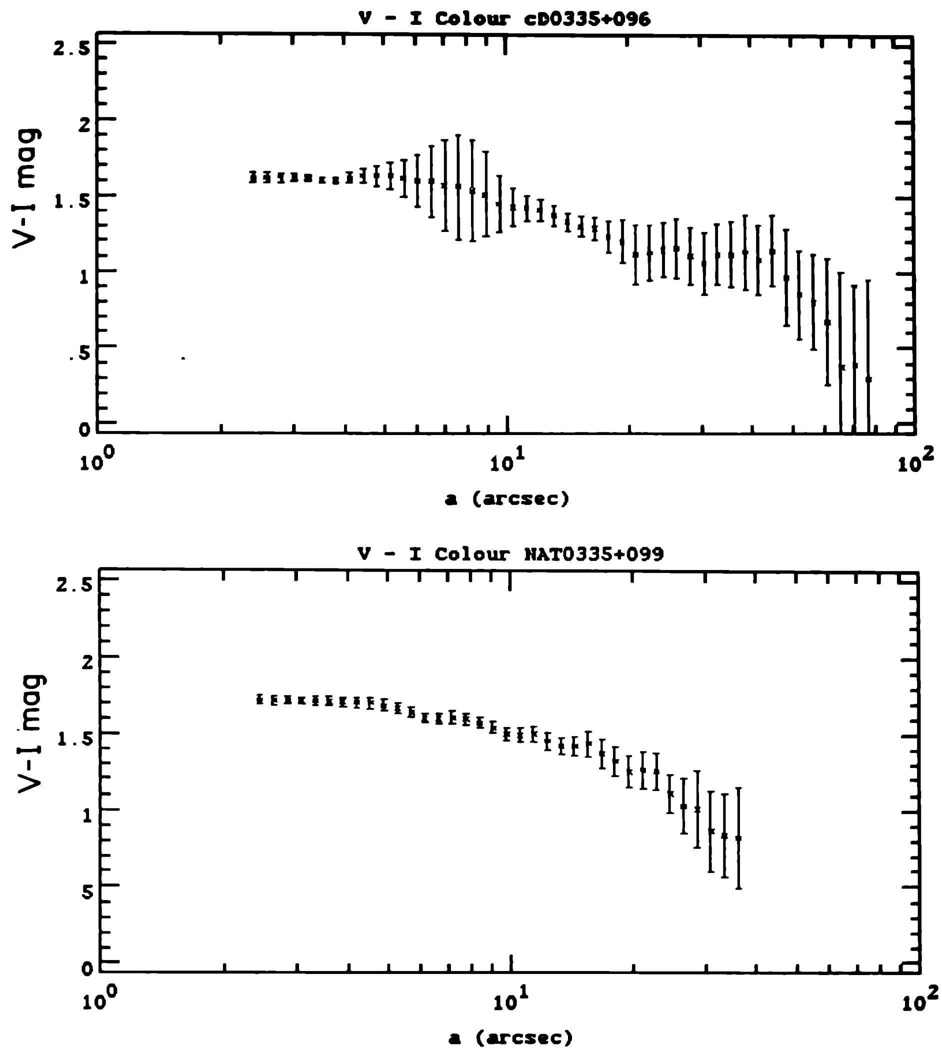

Figure 2. $V - I$ colour profiles of (a) cD galaxy, (b) NAT galaxy in 2A0335 + 096 cluster.

typical of most elliptical galaxies. The excess red colour reported (Romanshin & Hintzen 1988) towards the nucleus (< 6 kpc) was not resolvable with our measurements. Both the galaxies show larger ellipticity beyond a distance of 10″, except in the outermost regions where the reduced surface brightness complicates the determination of the structural parameters. The wide spread inhomogeneities and filamentary structure in the central region of the cD galaxy observed in X-rays with the ROSAT High Resolution Imager (Sarazin, O'Connell & McNamara 1992) seem to have no counterpart in the visible band.

3. NGC 3607

NGC 3607 is the dominant elliptical galaxy in a small nearby group (N3607 group) of galaxies (Vennik 1986) with two close neighbours viz., NGC 3605 and NGC 3608 at a projected separation of about 2 arcmin and 5 arcmin respectively. The heliocentric radial velocity of NGC 3607 is 934 km $s^{-1} \simeq$ the unweighted mean of the group (944 km s^{-1}). The velocity dispersion for the group is 245 km s^{-1}. Its distance (corrected for Virgo-centric flow) is 32 Mpc (Fabbiano, Kim & Trinchieri 1992). At this distance $10'' \simeq 1.55$ kpc and the total size of the galaxy is 46 kpc × 23 kpc.

The central galaxies of the group are immersed in a hot thermal gas ($kT \simeq 1.2$ keV) seen at X-ray wavelengths by the Einstein Observatory (Fabbiano, Kim & Trinchieri 1992; Kim, Fabbiano & Trinchieri 1992).

The galaxy was observed on 1993 January 19 with a GEC P8603 CCD, coated for better performance in blue, at the prime focus of the Vainu Bappu Telescope using *V*, *R* and a narrow band filter ($\lambda = 6584$ Å; $\Delta\lambda = 100$ Å) centred near the redshifted $H\alpha$ emission. The details of the CCD are given in Anupama *et al.* (1993). Further details of these observations are given in Singh *et al.* (1993). The point spread function during the observations was ~ 2.0 arcsec (FWHM).

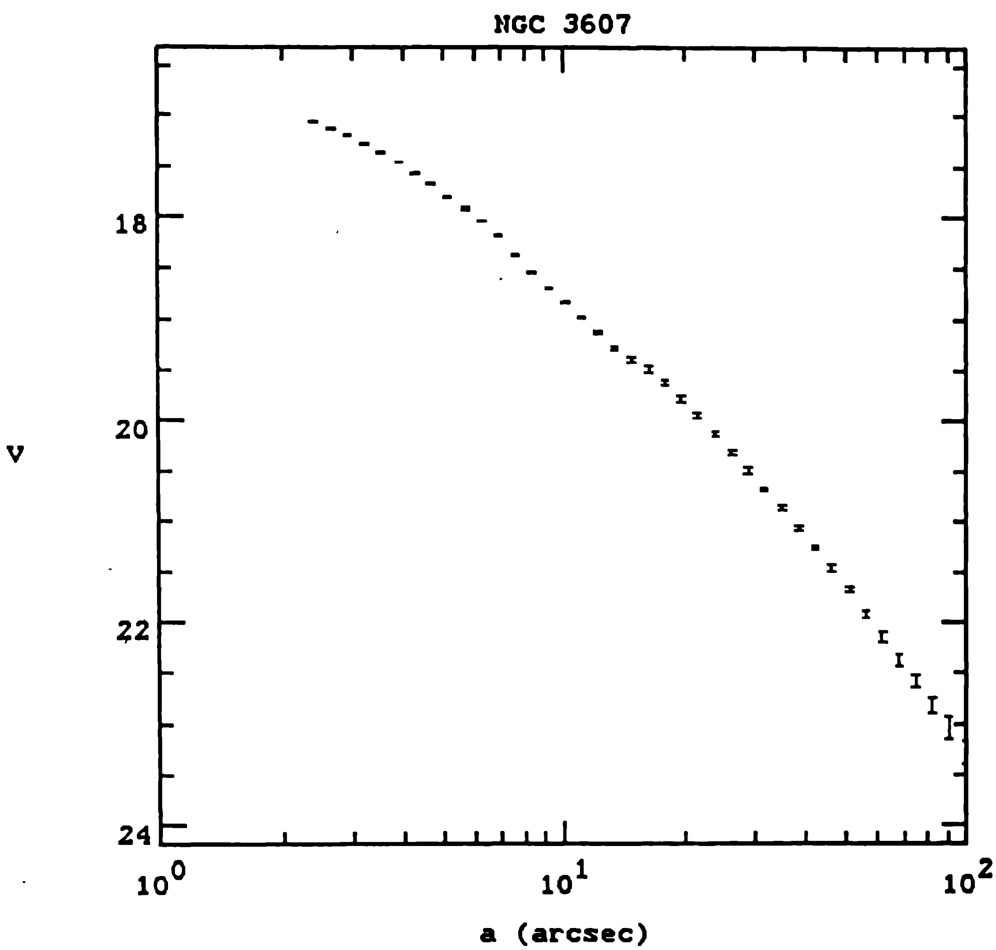

Figure 3. Surface brightness profile in *V* magnitude per arcsec^2 for NGC 3607.

3.1. *Results of V, R and Hα photometry*

A broad dust ring with an inner radius of ~ 1.3 kpc and a width of ~ 0.75 kpc has been detected on the basis of increased reddening in the *v*/*r* colour map of NGC 3607. The ring is seen partially in the direct image. The isophotal analysis shows a broad dip in the surface brightness profile shown in figure 3, and in the kinks in the ellipticity and position angle profiles at the positions corresponding to that of the dust ring. The extinction, $E(V - R)$, is measured to be 0.094 ± 0.018 in the dust ring. A total mass of $4 \times 10^7 M_\odot$ for N(HI) is implied in the ring.

Extended Hα + N [II] emission is observed from the interior of the dust ring with a total luminosity of 4.3×10^{39} ergs s^{-1}, confirming the earlier reported nebulosity by Shields (1991). A full discussion and implications of these results on cooling flow recombination, heat transfer, ionization by stars and the existence of the neutral gas and dust are presented in Singh *et al.* (1993).

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