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Multiwavelength Study of Radio Loud Early-Type Galaxies from the B2 Sample

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Abstract. We present multiwavelength study of a sample of radio loud early-type galaxies chosen from the B2 sample. We performed surface photometry in BVR broad band filters and Hα narrow band filter on CCD images of sample galaxies using IGO 2m telescope, Pune (INDIA), to get radial profiles of various photometric and geometrical parameters that describe elliptical isophotes fitted to the 2D light distribution of the galaxies. The analysis of radial profiles of quantities such as the (local) surface brightness, the ellipticity, and the deviations from elliptical isophotes parametrized by the Fourier coefficients are main focus of our study. We generated color maps, residual maps, and dust extinction maps, Hα emission maps of the galaxies to study the morphology of the dust and ionized gas content present in the galaxies. We carried out detailed analysis of the properties of the dust present in our sample galaxies. Additionaly, we investigated properties of the dust in the central $\sim$10 arcsec region of our sample galaxies using optical images available from the HST (WFPC2) data archive. We estimated mass and temperature of the dust, molecular gas mass, in the sample galaxies using FIR fluxes of the galaxies obtained from IRAS.

We used spectroscopic data available from the SDSS (DR7) to get an estimate of the mass of the central super massive black-hole for B2 1257+28 (NGC 4874). We plotted rotation curve for coma cluster (Abell 1656), which indicates the presence of dark matter halo around the galaxy B2 1257+28.

Keywords: *Early-type galaxies, Super massive black hole, Radio loud galaxies, ISM.*

1. Introduction

We selected 44 galaxies from the B2 sample based on the following criteria (i) the presence of prominent dust feature reported in Capetti *et al.* (2000) and/or in Gonzalez-Serrano, J. I. *et al.* (2000), and (ii) the availability of X-ray, IR, Radio data for the galaxy from various data archives. The quantitative surface photometric analysis has revealed morphological peculiarities in radio loud galaxies (Colina & Prez-Fournon 1990; Gonzalez-Serrano *et al.* 1993), and it has been reported that many radio-loud elliptical galaxies possess distributions of dust and molecular gas at $\sim$100 pc scale, often in the form of settled disk-like structures surrounding the AGN (Ferrarese *et al.* 1996; Jaffe *et al.* 1996; Ferrarese & Ford 1999). The multiwavelength study of our galaxies will enable us to address wide variety of issues related to the origin, nature and the fate of dust component present in the radio-loud early-type galaxies and coexistence of multiphase ISM in the extra-galactic environment.

2. Observation, Data Reduction and Analysis

We observed our sample galaxies in broad-band (BVR) and narrow band (Hα) filters using IGO 2m telescope, Pune. We obtained images and spectra of the sample galaxies in optical and IR bands available through various data archives such as HST (WFPC2), SDSS (DR7) and IRAS. The imaging data were reduced and processed using standard tasks available within IRAF software package. Multiple frames taken in each band were

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Table 1. Basic Information, IR results, Extinction Coeficients and Relative dust grain sizes($< a > /a_{Gal}$) for B2 1217+29(NGC 4278).

Object name	**B2 1217+29**	**B2 1257+28**	**Ext. Coef.**	$R_B \pm \Delta R_B$	$R_V \pm \Delta R_V$	$R_R \pm \Delta R_R$
RA (hh:mm:ss)	12 : 20 : 06.8	12 : 59 : 35.7	Milky Way	4.1	3.1	2.3
DEC (dd:mm:ss)	+29 : 16 : 51	+27 : 57 : 33	B2 1217+29	4.77 ± 0.63	3.66± 0.35	2.37± 0.41
Dust Temp (T_dK)	32.38	34.35	Relattive Grain size	1.21 (B)	1.16 (V)	1.0 (R)
Dust Mass ($M_{d(IRAS)})M_\odot$	$3.9X10^4$	$4.6X10^5$	Molecular gas mass(M_g)$M_\odot$	$4.1X10^7$ (NGC 4278)		$6.4X10^8$ (NGC 4874)

geometrically aligned and then co-added to improve the signal-to-noise ratio of the images. The sky background in the images were estimated by box method as described in Sahu *et al.* (1998) and subtracted from respective images. Surface photometry were performed on the images of Johnsons BVR broad-band, HST (WFPC2) F-439W, F-555W and F-814W filters. The radial profiles of surface brightness (μ_B), position angle (PA), ellipticity (e) and B_4 (boxyness/diskyness) parameters were generated using ellipse task available within IRAF. After carefully matching the differences of PSFs in different filters, color maps were generated for each galaxy. Dust free model images were generated for the galaxies using the average surface brightness profiles obtained by surface photometry which were used to create extinction maps and residual maps for further investigation of morphological and dust extinction properties of the galaxies. The X-ray data were obtained from Chandra Data Archive (CDA), and the data (observed on Feb. 20, 2007 for an effective exposure time of 110.82ks[OBSID7071] were reprocessed using the standard tasks available within the Chandra Interactive Analysis of Observations1 (CIAO version 4.2.0) and CALDB (version 4.3.0) provided by the Chandra X-ray Centre (CXC). And, 3? Smoothed X-ray emission maps were derived for the sample galaxies.

3. Conclusions

(1) Most of our sample galaxies show boxy isophotes with $B_4 < 0$. (2) The derived extinction curve for B2 1217+29 (NGC 4278) runs parallel to the extinction curve of the Milky Way which implies that the properties of the dust in the NGC 4278 are similar to those of the Milky Way. The value of $R_V = 3.8 \pm 0.4$, estimated by us for NGC 4278 is higher than the canonical value of $R_V = 3.1$ for the Milky Way. Our estimate of the RV value for the NGC 4278 is in good agreement with the results obtained by Patil *et al.* (2007), and Finkelman *et al.* (2008). (3) The multiband imaging analysis of NGC 4278 reveals a qualitative spatial correspondence between the morphologies of the dust, Hα emission as well as diffuse x-ray emission. This in turn implies the coexistence of multiphase ISM and their physical association in sample galaxies (see e.g. Patil *et al.* 2007, Finkelman *et al.* 2008, 2010). (4) Rotation curve obtained for coma cluster (Abell 1656) indicates the presence of dark matter halo around the galaxy B2 1257+28 (NGC 4874). The estimated mass of the central super massive black hole using the SDSS spectroscopic observation is found to be $\sim 10X10^9\ M_\odot$.

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