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Structural Properties of early type Galaxies with Ionised Gas

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Abstract

Morphology is a fundamental property of galaxies. We discuss the morphological analysis of early type galaxies in the near infra-red K band observations from Two Micron All Sky Survey (2MASS). The sample covers nearby (z < ~ 5500 km/s) ellipticals and lenticulars from low density environments. For each image, structural parameters were extracted assuming Sérsic bulge and an exponential disk for the surface brightness profile of every galaxy, using the 2D galaxy fitting algorithm, GALFIT. The sample shows very significant and tight correlation between the bulge and disk scale radii (linear correlation coefficient = 0.934, Significance > 99.99%), suggesting a strong interplay between the bulge and disk components in early type galaxies with ionised gas.

Keywords: Morphology, elliptical and lenticular galaxies, fundamental properties, infra red galaxies, ionised gas.

Introduction

Studies on various correlations among structural parameters of galaxies can provide vital information regarding their formation and evolution. Early type galaxies, consisting of ellipticals and lenticulars, are widely believed to populate a planar distribution called the Fundamental Plane (FP)[1]. Their formation and evolution was primarily attributed to the local environmental processes external to the galaxy [2]. Recent observations suggest that it also directly depends on the interstellar medium (ISM)[3]. Interestingly, multi-wavelength observations hint at the co-existence of multi-phase ISM, even though ellipticals show signatures of warm and cool phase ISM in low amounts. The star formation occurs within the dense molecular clouds of ISM. The imaging and spectroscopy is helpful for studying physical condition in galactic nuclei, the excitation mechanism, and chemical abundances through the components of the ISM, mainly gas and dust. The presence of ISM is detected by the observation of dust lanes, central disk structures and the existence of ionised gas[4,5]. Even though most of the early-type galaxies were considered gas and dust free, recent surveys detect the presence of external gaseous disk and filaments of dust[6]. The nature, origin and features of gas and dust in elliptical galaxies are challenging because they do not show any evidence of a cool interstellar matter[7,8]. In addition, the relationships between the interstellar components of spiral galaxies are not always followed by early-type galaxies[9,10]. Optical emission lines are useful tracers of activities in the galaxies and the emission features mainly come from the warm (T~ 10^4 K) ISM, referred to as ionised gas and excited component present in the circumnuclear (r < 1 kpc) ISM[11]. The non homogeneity in the appearance of early type galaxies shows various emission types. The emission lines are different for hot component emitting X-rays[12], cold component atomic gas[13] and molecular gas[14,15] and cold dust components[16].

Studies on light distribution and quantitative analysis of structural parameters are important keys for deeper understanding of galaxies. Different scenarios exist now for discussing the formation of bulge and disk of galaxies[17,18]. Total luminosity of galaxies is distributed to the components of galaxies. Usual method for extraction of parameters of galaxy components is by profile fitting. 1D image profile can be uniquely extracted from galaxy images. This is not possible if a strong but highly inclined disk is present. Light distribution in galaxies is measured by using 1D parametric method, which never considered the galaxy components correctly and accordingly produced systematic errors in the result. Various other methods of decomposition techniques are available for fitting each component of galaxies individually. Most of the decomposition techniques consider de Vaucouleurs law for surface brightness profile of bulge and exponential for the disk.

This paper describes the sample and the decomposition procedure used to extract the bulge and disk parameters and also discuss the different correlations present in our analysis.

Material and Method

Sample: Our sample is based on the near infra-red, K band images of Two Micron All Sky Survey (2MASS). It contains 55 early type galaxies with ionised gas component having the redshift less than ~5500 km/s. These galaxies belongs to Revised Shapely Ames Catalogue of Bright Galaxies (RSA)[19] mainly in a low density environment. The emission lines features in their optical spectra shows ISM traces in at least one of the following bands: IRAS 100μm, X-Ray, radio, HI and CO[20]. Further details of the sample can be had from literature[21].

Data Reduction: For quantitative analysis of light distribution we used the method of 2D decomposition, proposed by Byun and Freeman[22]. In this 2D decomposition technique the bulge and disk models are fitted to the surface brightness profile of the galaxy. This will use the entire galaxy image rather than the major axis profile. Comparing to 1D fitting, the non-axisymmetric components can be fitted well, which will improve the fitting result. This technique, performs a χ^2 measurement by fitting of the light profile model to the galaxy image.

We have used the GALFIT package[23] for extracting the bulge and disk components of the galaxy. The GALFIT uses a non-linear least square fitting Levenberg algorithm. It determines the goodness of fit by analysing the reduced χ^2 and computing how to adjust the parameter for next step. In our analysis we used the K band images for better extraction of structural parameters as light in K band is less disturbed by the dust component and hence provides smoother surface brightness profiles when compared with other bands like B. Also K band light reflects the mass distribution inside galaxies as a major share of it is produced by evolved stars. We decomposed all the galaxies in our sample by fitting a Sérsic profile to the surface brightness profile of the bulge and an exponential function to the disk respectively. The bulge intensity distribution described by Sérsic bulge is given by

$$I_b(x,y) = I_b(0)\exp[-2.303 b_n (r_{bulge}/r_e)^{1/n}];$$
$$r_{bulge} = [(x^2+y^2)/(1-e_b)^2]^{1/n}; \qquad (1)$$

Where b_n is evaluated as the root of an equation involving the incomplete gamma function and can be approximated to a linear function of the Sérsic index n. The x and y are the distances from the galaxy along the major and minor axes , r_e is the half light radius of the bulge and e_b is the ellipticityof the bulge . The disk intensity is represented by exponential distribution, and is given by

$$I_d(x,y) = I_d(0)\exp(-r_{disc}/r_d);$$
$$r_{disc} = [(x^2+y^2)/(1-e_d)^2]^{1/2} \qquad (2)$$

Where r_d is the disk scale length , I_d (0) is the disk central intensity and e_d is the disc ellipticity.

In our 2D decomposition method, the position angle, ellipticity, shape parameter n and sky are considered free variables. Initial approximations for these parameters are obtained by fitting the elliptical isophotes along with the measurement of the surface brightness profile of each galaxy. This was done by using the ELLIPSE task within STSDAS package provided by IRAF[24]. The sky brightness determined outside the galaxy are one of the main source of error found in the fitting processes, which mainly comes from the preliminary reduction, and hence we have conducted a trial run of GALFIT just to find out extracted sky values, and made them fixed in subsequent runs.

Results and Discussion

Correlation: Different morphological types show galaxy components like bulge, disk and bar with varying strengths. Each of these components has different structural parameters. Determination of correlations among such structural parameters is helpful in distinguishing models of galaxy formation. In certain cases, like the FP, existence of a tight correlation between distance dependant and independent parameters can be effectively used to determine distances to the galaxies. Several such correlations between the structural parameters are reported in the literature[25-27].

Kormendy Relation: Kormendy first reported a strong correlation between in $\mu_b(0)$ and r_e for elliptical galaxies assuming de Vaucouleur's law($r^{1/4}$) for their surface brightness profile. When Sérsic law is taken, however, no such tight correlation is observed[28]. Our work reports the correlation between the r_e and the mean surface brightness within the effective radius $<\mu_b(<r_e)>$. The variation of $<\mu_b(<r_e)>$ with r_e is given in figure.1. Relation between these two parameters are expressed as

$$<\mu_b(<r_e)> = 1.71\log r_e + 15.05 \qquad (3)$$

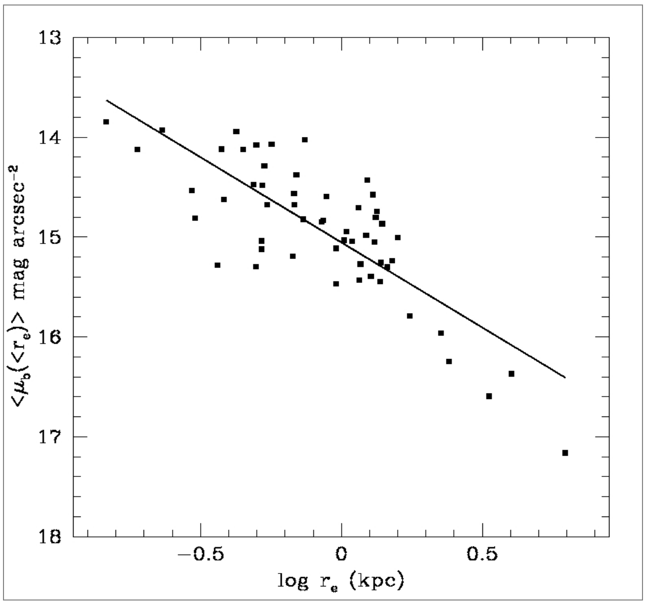

Figure-1
Kormendy relation: correlation between effective radius and mean surface brightness within the effective radius

The linear correlation coefficient for this relation is 0.79 at a significance level greater than 99.99 %. The fact that the scatter in the diagram is larger than that can be accounted by the observational errors in the observables, resulted in the determination of more tight correlation called the FP.

r_e - r_d Correlation: Another important correlation present in our work is relationship between the bulge and disk scale lengths and is shown in figure. 2. The disk scale length linearly increases with the bulge effective radius. The tight correlation between these two parameters is more pronounced in K band. The correlation coefficient is 0. 93 at a significance greater than 99.99 %. A tight correlation like this supports the formation of the bulges from already existing disks[29]. This type of correlation has already been reported in late type spirals[30].

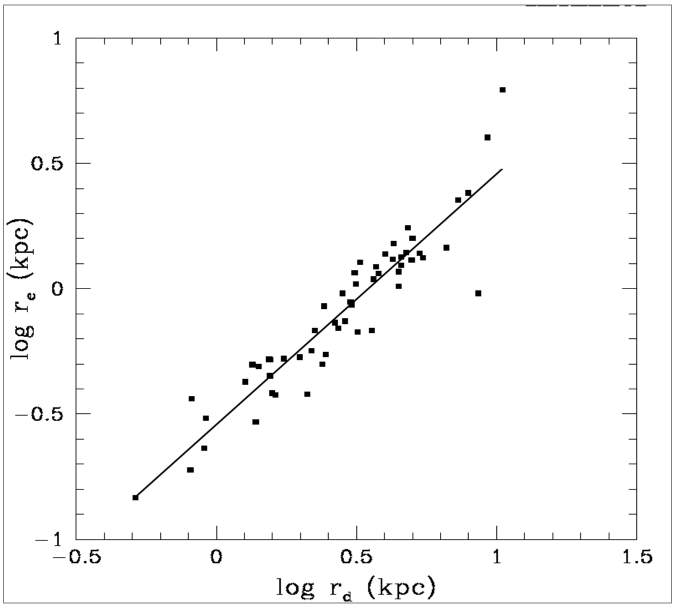

Figure-2
Linear relation between bulge disk and scale lengths

Conclusion

In this paper we discussed the 2D bulge disk decomposition of 55 early-type galaxies in the near infrared K band using the code GALFIT. We have assumed a Sérsic bulge and an exponential disk. We report tight correlations for the Kormendy relation and r_e – r_d correlation. The latter correlation strongly support the idea that bulges form from existing disks in the case of early type galaxies with ionised gas. We will be undergoing more detailed analysis of the population of bulges and disks in the sample galaxies for further light on their formation scenarios.

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