Morphology of the galaxies around the X-ray source 2MASXJ14391186+1415215 through GIM2D

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ABSTRACT

We considered a group of galaxies in the constellation of Bootes and we studied the r-band photometry of these objects, in order to obtain their morphological classification. We developed a model using GIM2D and, by means of the information provided by this program, we determined the morphological type of each galaxy, the brightness values of their bulge and disk, if any.

I. INTRODUCTION

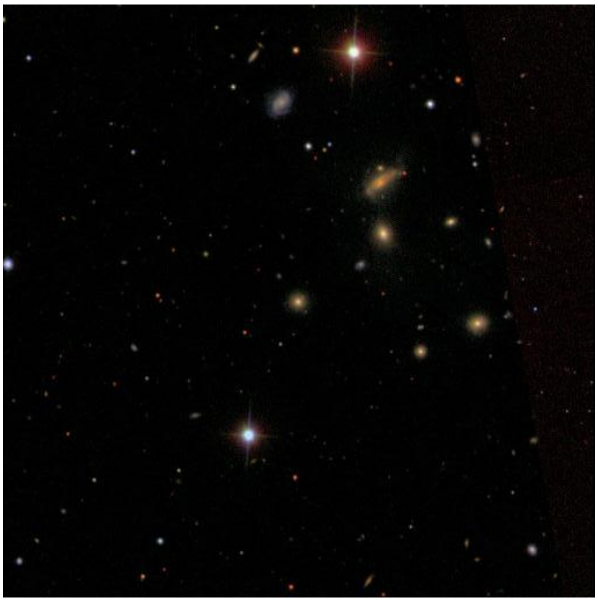

Fig 1: The Sloan Digital Sky Survey image of the studied galaxies.

Studying the morphology of a group of galaxies means to classify these objects according to their shape. The morphological classification is the first step to understand the physics of galaxies. In order to do this, we considered the Hubble sequence, the classification scheme which divides the galaxies in four different families: elliptical, lenticular, spiral and irregular. The spiral galaxies are composed of a bulge and a disk with at least two spiral arms or structures extending from the bulge. They are indicated with the letter S followed by the letters a, b, c, that depend on the prominence of the bulge with respect to the disk, the wrapping of spiral arms, and the resolution of the disk. The elliptical galaxies are classified with letter E and with a number that can have values from 0 to 7 depending on the eccentricity. These galaxies have a diffused structure and do not have any disk. The lenticular galaxies S0 are intermediate between elliptical and spiral, and different from the latter because their disk contains few interstellar matter, and do not show any spiral structure. Finally there are also peculiar galaxies, known as irregular galaxies, that just have an irregular shape, sometimes due to interaction with other galaxies.

The programs we used to do this work were: IRAF: used to view and analyze the images; GIM2D: used to perform the decomposition of a galaxy into bulge and disk by using mathematic models.

II. OBSERVATIONAL DATA

We used r-band images of a group of galaxies around the X-ray source 2MASX J14391186+1415215 extracted from the archive of the Sloan Digital Sky Survey. The group under examination had never been studied before, for this reason these galaxies have no name. We only knew that they all are in the constellation of Bootes. Here we report the celestial coordinates of each object studied:

	RA	DEC
A	14 39 17.5	+14 16 18.3
B	14 39 21.3	+14 15 10.7
C	14 39 15.1	+14 16 29.0
D	14 39 11.9	+14 15 22.1
E	14 39 10.9	+14 17 24.9

Tab 1: Coordinates of the galaxies belonging to the group we studied.

III. WORK DESCRIPTION

To analyze our galaxies we used GIM2D (Galaxy Image Two Dimensional), a program that uses the images of galaxies and builds detailed models of these celestial objects by using information such as the brightness of the bulge and of the galactic disk.
First, the atmospheric turbulence (seeing effect) on the images must be taken into account, because it causes a deterioration on the quality of the images of the observed astronomical objects. In particular, we have to create a model of the point spread function (PSF), that is a model of the stellar shape: in fact, stars should be point-like sources, but they appear as extended circular spots because of the seeing effect. Since seeing affects also galaxy images, modeling mathematically some stars, we have the information to apply in order to obtain the right models of the galaxies.
Each pixel is represented by a number that indicates the quantity of photons received by the detector. The instrumental magnitude let us know the exact number of photons emitted by the galaxy collected by the CCD. Its value m_s is given by the formula:

$$m_s = -2.5 \cdot \log\left(\frac{I - N_{px} \cdot I_{sky}}{T_{\exp}}\right)$$

where I = intensity of the galaxy, N_{px} = number of pixels occupied by the galaxy, I_{sky} = intensity of the sky and T_{exp} = exposure time.
The so obtained magnitude must be further corrected with the following relationship: $m = m_s + m_0 - k \cdot X$, where m_0 = photometric zero point. It is a constant depending on the used filter. In our case, for the r filter m_0 = 24.037 mag; k is the atmospheric extinction coefficient and it is inversely proportional to the wavelength: k = 0.136. X = 1/cosec z is the airmass, where z is the distance of the target from zenith: X = 1.112. Subtracting $k \cdot X$ from the magnitude, we obtain a value corrected for atmospheric extinction.
We worked mainly with two functions: the Sersic's Law and the Freeman’s Law. Both of them represent the brightness of galaxies, namely the surface brightness measured along the major axis of the galaxy: the first one is used for the bulge, the central component of the galaxy, and the other one for the galactic disk.

Sersic’s Law: $S = S_e \exp \{-b[(R/R_e)^{1/n} -1]\}$

R is the distance from the center of the galaxy, and it is a variable. R_e is the effective radius, the radius within which half of the light of the bulge is contained. n is called Sersic index. b_n is a constant which depends on the value of n. Finally, S_e is the surface intensity at the distance $R = R_e$
For n = 4 we obtain the De Vaucouleurs’ law, which reproduce the surface brightness profile of elliptical galaxies:

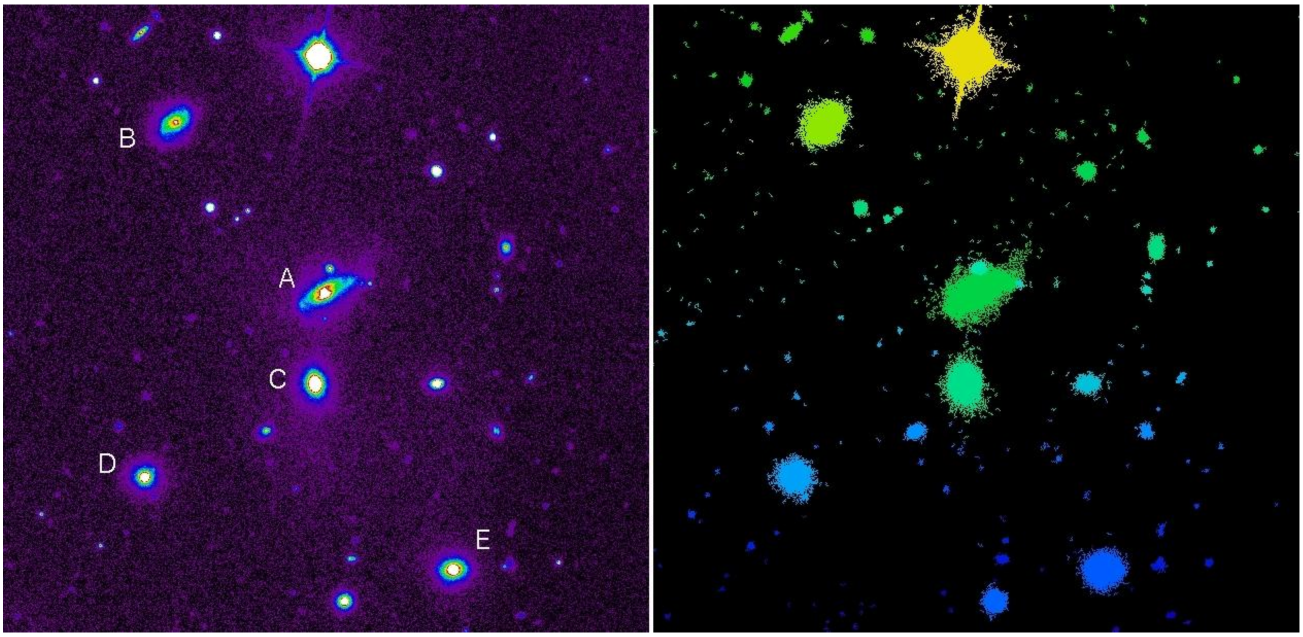

Fig 2: Legenda and Mask of our galaxies.

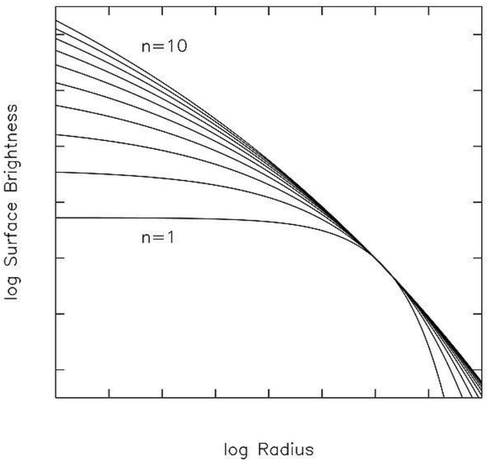

Fig 3: Sérsic models with different indices *n*.

De Vaucouleurs' Law: $I = I_e \exp\{-7.67[(R/R_e)^{1/4} - 1]\}$

where I_e = surface brightness at R_e.
For n=1 we obtain the exponential profile often used for the bulge of spiral galaxies:

$$I = 5.36\, I_e \exp\{-1.68\,(R/R_e)\}$$

Freeman's Law:

$$S = S_0 \exp(-R/h)$$

where R is the distance from the centre, and it is a variable. h is the scale length of the disk ($R = h \Rightarrow S = S_0/e$)
The model developed by GIM2D gave us information about the total brightness (L_{tot}) and the relationship between the bulge brightness and the total brightness of the galaxy (B / T).
Then we calculated $\Delta m = -2.5 \log (B/T)$ and thanks to the following graph, we could determine the morphological type of each galaxy.

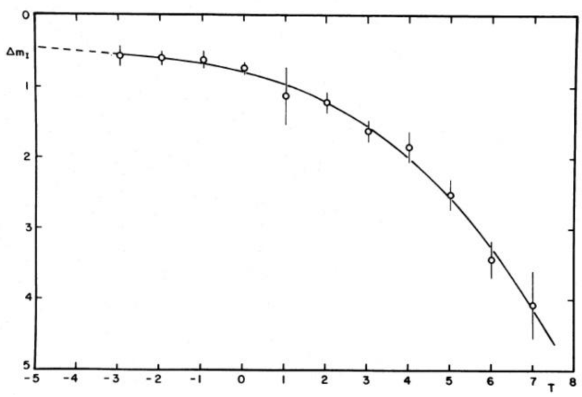

Fig. 4: Plot taken from Simien & De Vaucouleurs (1986).

T	-5	-3	-2	0
Type	E	E-S0	S0	S0/Sa

T	1	2	3	4	5
Type	Sa	Sab	Sb	Sbc	Sc

Tab. 2: T-type and morphological classification.

Gal.	Ltot	B/T	Morph. type	L bulge	L disk
A	149329	0.49	S0/Sa	74266	75063
B	66950	0.12	Sc	8283	58667
C	130512	0.92	E	119985	10527
D	63303	0.44	S0/Sa	28177	32126
E	89512	0.32	Sa	28724	60788

Tab. 3: Results of the fitting.

We determined the value of the brightness for bulge and disk of individual galaxies using the following formulae:

$L_{bulge} = L_{TOT} \cdot (B/T)$
$L_{disk} = L_{TOT} - I_{bulge}$

Finally, we used GIM2D again, changing a bit the input parameters in order to check for possible influence on the results. We confirmed the results previously obtained for all galaxies except A, that was found to be an Sc rather than an Sa.

Gal.	Ltot	B/T	Comparison with fit	Morphological type
A	126666	0.09	Different	Sc
B	663645	0.01	Ok	Sc
C	131026	0.93	Ok	E
D	63315	0.46	Ok	S0/Sa
E	89457	0.32	Ok	Sa

Tab. 4: Additional test obtained changing input parameters.

IV. RESULTS

Galaxies A and B resulted to be two spirals of type c, galaxy C is an elliptical, D is an intermediate between a S0 and a Sa and finally E is a Sa.
Fig 5 shows the results provided by GIM2D: in the first line are drawn the images of our five galaxies. The second line reports the model of the galaxies, elaborated by the program. Finally, the last line contains the residuals, the differences between image and model.

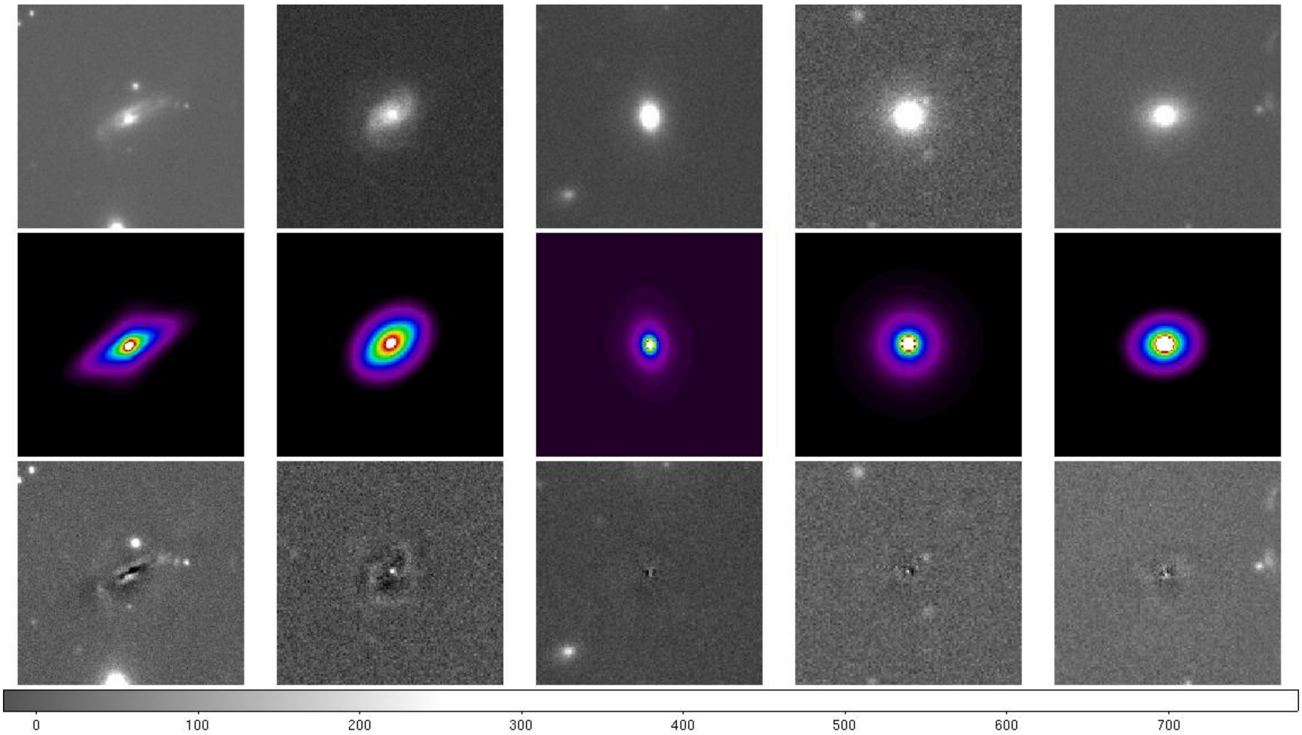

Fig. 5: on the three lines are placed the images of galaxies, the models developed by GIM2D, and the residuals.

V. BIBLIOGRAPHY

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