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M33: THE EXISTENCE OF A BAR

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RESUMEN

Una fracción significativa de galaxias en el Universo Local que han sido clasificadas sin barra en el RC3, resultan barradas en las bandas óptica y NIR. En el Grupo Local la Vía Láctea y M31 son también barradas y éste podría ser también el caso de M33. En este trabajo presentamos los resultados del ajuste de elipses y del análisis bidimensional de Fourier de la galaxia M33, en las bandas R e I, de imágenes proyectadas y no deproyectadas en el cielo, obtenidas del DSS2 y de *Spitzer*-IRAC

ABSTRACT

A significant fraction of galaxies in the Local Universe classified as unbarred in the RC3 turn out to be barred in optical and NIR wavelengths. In the Local Group the Milky Way and M31 have shown to be barred as well, this also could be the case of M33. In this paper we present the results of the Ellipse fitting and bidimensional Fourier Analysis, on the R and I bands, deprojected and non-deprojected, images of M33 obtained from DSS2 and *Spitzer*-IRAC.

Key Words: galaxies: individual (M33) — galaxies: structure

1. GENERAL

Messier 33 (M33) or NGC 598, also known as the Triangulum galaxy is a spiral galaxy in the Local Group classified as SA(s)cd in the RC3 (Third Reference Catalogue of Bright Galaxies), type T=6 (de Vaucouleurs et al. 1976) and Arm Class = 5 (Elmegreen & Elmegreen 1987). M33 is a nearby (840 Kpc) and almost face-on galaxy (see Table 1), and hence ideal for a study of galactic structure.

The aim of this paper is to report the analysis of deprojected and nondeprojected M33 images in two bands. In order to detect the presence of a bar, we use two techniques: ellipse fitting using a program under IRAF and a bidimensional Fourier Analysis. The data is presented in § 2, in § 3 we present the results, and in § 4 the discussion.

TABLE 1

POSITION (PA) AND INCLINATION ANGLE (IA) COMPARISON

Author	PA	IA
DH	23°	56°
IK	22°	57°
RWL	21° ± 0.5°	55° ± 2°
DSS2 I*	24° ± 0.35	58° ± 4°
DSS2 R*	24° ± 0.21	57° ± 5°
IRAC*	24° ± 0.24	55° ± 4°

DH: Deul & van der Hulst (1978); IK: Ivanov & Kunchev (1986); RWL: Rogstad, Wright, & Lockhart (1976).
*This work.

2. DATA

The M33 R (6300 Å) and I (8200 Å) images (Figure 1) were obtained from the Second Digital Sky Survey (DSS2) produced by the Space Telescope Science Institute, the scale of the images is $0'.0167$/pix. We also analyzed the resulting image from the combination of four *Spitzer* images from the InfraRed Array Camera (IRAC) at 3.6 microns ($1''.2$/pix). The combined image allowed us to have a better signal to noise ratio. For M33, $1''$ corresponds to 4.07 pc (Freedman et al. 2001). All image processing was performed using IRAF packages.

Deprojection of images were made following García-Gómez et al. (2004) programs. We derived deprojection parameters using the ellipse fitting routine under IRAF, we used our own values for DSS2 images since they are in well agreement with other authors (see Table 1). *Spitzer* image has a rotation of $-16.81°$ with respect to the North (*y-axis* in our images). In this case, first we deprojected the image with the value obtained from ellipse fitting, then we aligned the images with the North.

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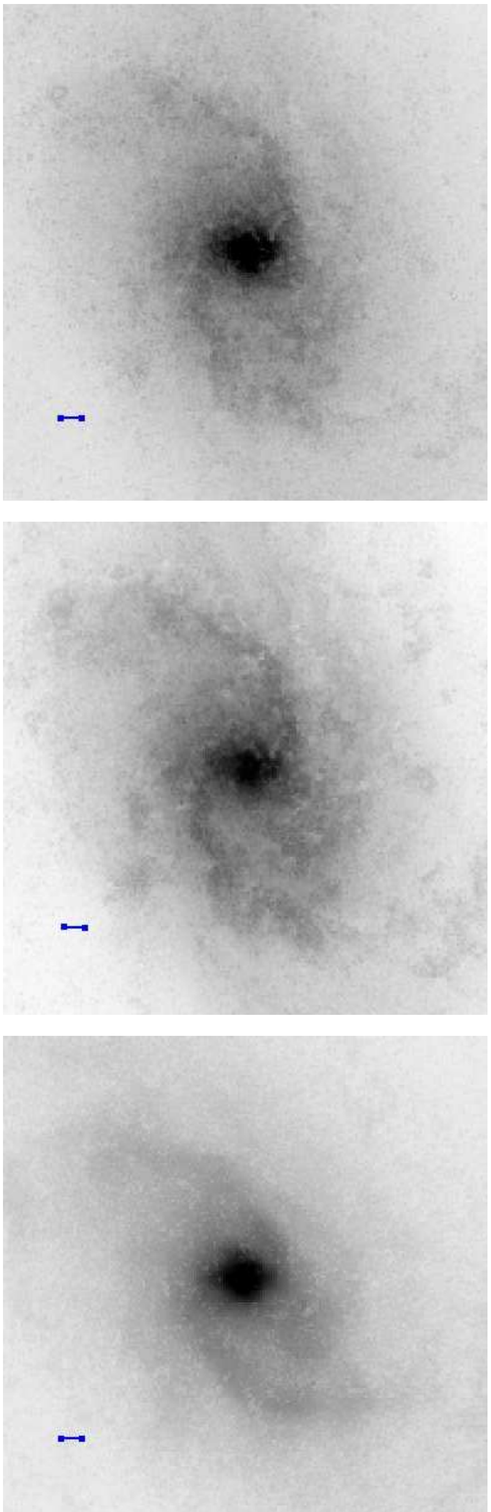

Fig. 1. Non-deprojected images of M33. Top: DSS2 I band image. Middle: DSS2 R-band. Bottom:*Spitzer* image. The mark represents $1'$. North is up and east is left.

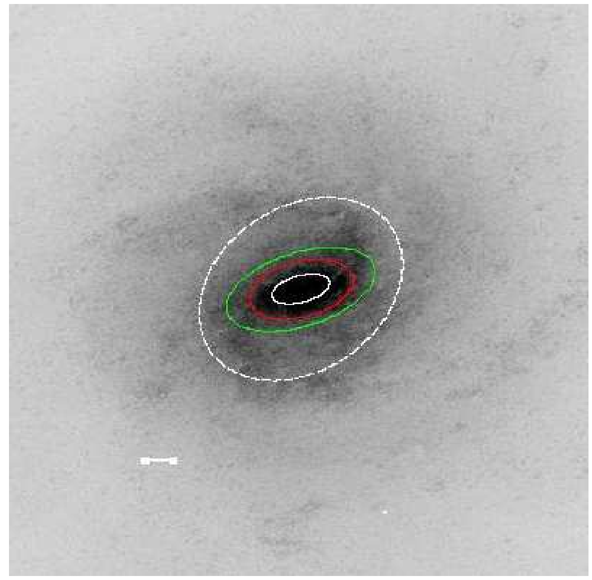

Fig. 2. Deprojected I-band image of M33. Inner ellipses show the bar according to our discussion, the second ellipse from inside is the best lenght we found in this work.

3. RESULTS

We show the results of the deprojected bar length according with different authors (Table 2), and the possible values of bar lenght according to our analysis. Notice the large difference in Elmegreen et al., where they claim a deprojected bar longer than the others. The deprojected bar radial extent estimated is ~ 1.5 Kpc for both I and R bands of DSS2 and for *Spitzer* images, this radius enclose the begining of the spiral arms. In Table 2 superindex (a) shows the bar extent, this can be estimated about ~ 0.8 Kpc and the result are similar to the analitically deprojected bar showed by the superindex (b).

4. DISCUSSION

In this work we analized I and R bands images of M33 from DSS2 and one combined image of 4 (3.6 microns) images from *Spitzer*-IRAC. From visual inspection of deprojected images we can clearly note an elongated shape in the central part of the galaxy, that can be interpreted as a signature of the bar shape. In order to check the existence of the bar, we made the analysis by ellipse fitting and bidimensional Fourier analysis.

The results of the lenght of the bar are shown in Table 2. If we constraint the lenght of the bar with the spiral arms, for the deprojected bar radial values we found a length of ~ 0.8 Kpc for both I and R bands and for *Spitzer* image. In this radius the

TABLE 2

DEPROJECTED BAR LENGTH COMPARISON

	Deprojected				Non Deprojected			
Author	$R_{\rm bar}$ ($'$)	$R_{\rm bar}$ (Kpc)	$PA_{\rm bar}$ (deg)	$e_{\rm bar}$ (deg)	$R_{\rm bar}$ ($'$)	$R_{\rm bar}$ (Kpc)	$PA_{\rm bar}$ (deg)	$e_{\rm bar}$ (deg)
Corbelli & Walterbos (2007)	3.01	0.7	K-band image. Deprojection was made with PA=−22deg and i=52deg					
Regan & Vogel (1994)	1.5	0.4	NIR images. Deprojection was made with PA=23deg and i=56deg					
Elmegreen et al. (1992)	6.72	1.5	B-band images. Deprojection was made with i=55deg. $R_{CR} = 0.19R_{25}$					
DSS2 I	5.7	1.4	69.8	0.4870	2.76	0.67	83.57	0.2125
DSS2 R	6.3	1.5	64.22	0.4052	2.5	0.61	89.3	0.013
IRAC	5.1	1.5	66.26	0.3992	2.35	0.57	87.45	0.1872
DSS2 I[a]	3.8	0.93	73	0.4304	3.25	0.79		
DSS2 R[a]	3.8	0.93	74.2	0.4879	2.94	0.72		
IRAC[a]	2.8	0.82	72.23	0.4844	2.66	0.65		
DSS2 I[b]	3.25	0.79						
DSS2 R[b]	2.94	0.72						
IRAC[b]	2.66	0.65						

[a]The bar values from ellipse fitting.

[b]The analyticaly values.

isophotes show an elongated figure in the central region and the well defined ellipses in the overlays (see the I band image in Figure 2), clear signature of the presence of a bar. This result is in well agreement with Regan & Vogel (1994) and Corbelli & Walterbos (2007), both studies are based on NIR observations, as they are less affected by extinction and star formation, the bar should be most prominent in this bands. Furthermore, we could note in the deprojected radial profiles the constant behavior of ellipticity and position angle. With this result we found a radial value of ~ 0.8 Kpc. However, for this radius the isophotes and the ellipses enclose the spiral arms. Moreover, this result is in agreement with Elmegreen et. al (1992). They use a B-band images in which spiral arms are more prominent and, as they are tightly wound, is easy to confuse them with the third ellipse showed in Figure 2.

For the three images, Fourier spectra show the classical m=2 spiral structure and a pick at P=−0.56 for the I band image, P=−0.64 for R, and P=−0.71 for *Spitzer*.

We calculated the strenght of the bar (r$\sim$ 0.8 Kpc) with the ellipticity method and for both, R-band and I-band, images we found a value of ~ 0.5 and for *Spitzer* image we found a lower value of $f_{\rm bar} = 0.4$, all these values show the presence of a weak bar.

We have discussed different methods to show the presence a bar-like shape, however, there are still uncertainties in the size, nevertheless our analysis is in good agreement with results from other authors, proving those methods are very efficient to detect bars in galaxies.

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