Publ. Astron. Obs. Belgrade No. 100 (2021), 371 - 374 *Poster*

DEEP PHOTOMETRY OF SPIRAL GALAXY NGC 941

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Abstract. We have modelled surface brightness profile of the spiral galaxy NGC 941 using SDSS Stripe82 deep images in the r-band. The depth of Stripe82 images reaches the stellar halo brightness level (28.5 mag arcsec^{-2} in the r-band), which was our basic motivation to start the study. We have simultaneously modelled NGC 941 galaxy with multiple components to find that its surface brightness profile could be missclassified as Type II. The "feature" responsible for the apparent downbending of the light profile is the spiral arms structure.

1. INTRODUCTION

The radial surface brightness profiles of spiral galaxies are exponential. However, only minority of spirals show simple exponential decline, while the majority (∼90%) show either up- or down-bending profiles. They are being classified according to the outer shape of their profiles as: Type I galaxies that follow a simple exponential law, Type II galaxies that show a downbending break with a steeper outer exponential (Pohlen et al. 2002; Erwin, Pohlen & Beckman 2008) and Type III galaxies that show an upbending break with a shallower outer exponential (Erwin, Beckman & Pohlen 2005).

Different shapes of surface brightness profiles may indicate different evolutionary paths. This was our motivation to explore in great depth the shape of NGC 941 galaxy surface brightness profile.

2. DATA

We have used SDSS Stripe 82 data[1] for our study, because they are very deep. The SDSS Stripe82 Survey is a wide region (2.5 degree) along the celestial equator. It has been imaged repeatedly 80 times. The images were co-added taking special care of background subtraction. These final co-added images reached 3-sigma surface brightness limit of 28.5 mag/arcsec^2 in the r-band.

[1]SDSS Data Archive Server: http://research.iac.es/proyecto/stripe82/pages/data.php

3. METHODS

Modelling of the surface brightness profile of the galaxy NGC 941 was done following the standard procedure. First, we have used Sextractor (Bertin & Arnouts 1996) to build a catalog of objects in the image to obtain a good mask. Then we modelled light profile of NGC 941 using Galfit code (Peng, Ho & Impey 2010), that creates 3D models. We were working with SDSS Stripe82 data with the exposure map instead of the sigma-image. To create a sigma-image we have masked all the objects except for the target galaxy, and then run Galfit code without sigma-image to get estimate of the RMS (root-mean-square). Then we created the sigma image, using the formula

$$\sigma_{i,j} = I_{i,j} * \mathrm{GAIN}_{\mathrm{eff}} + \mathrm{RMS}^2 * \mathrm{GAIN}^2_{\mathrm{eff}}, \quad (1)$$ [2]

where $I_{i,j}$ is the intensity in each i, j pixel of the image, and $\sigma_{i,j}$ the corresponding uncertainty.

Additionally, we have extracted the surface brightness profile applying isophotal analysis that resulted in a set of concentric ellipses inside which flux intensity was averaged, using Photutils package from the Astropy library.[3] To model properly outer parts of the light distribution, we kept ellipticity and position angle fixed.

4. RESULTS

Galfit results are shown in Figure 1: galaxy image, model and the residuals, respectively.

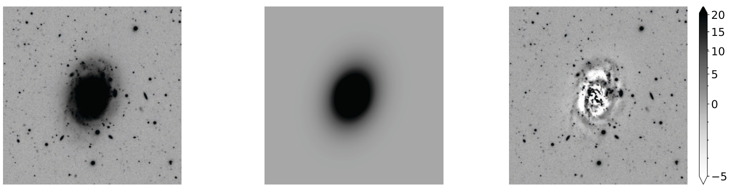

Figure 1: 3D decomposition: galaxy (left) was modelled with multiple components: a point spread function (PSF), inner and outer bar, an exponential disk, and a bar-like structure that successfully modelled spiral arms (center). The residual structure is also shown (right).

To better visualize the results, we have plotted our modelling results obtained with Galfit over the surface brightness points from the isophotal analysis (Figure 3). The most successful fit is the five-component fit with galaxy disk modelled as a pure exponential disk, inner and outer bars modelled as Sersic components with index n = 0.2, and another "bar-like" structure that accounts for the spiral arms contribution (Figure 3). Broken disk model (green dashed line in Figure 2) is not

[2] $\mathrm{GAIN}_{\mathrm{eff}} = 2./3. * \mathrm{GAIN} * \mathrm{weightmap.data}$. Factor of 2/3 comes from the fact that images are median combined.

[3] https://photutils.readthedocs.io/en/stable/

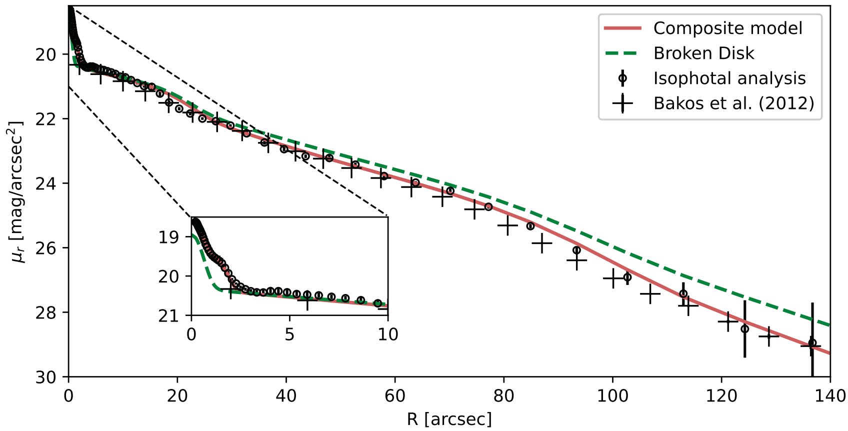

Figure 2: Results of the isophotal analysis (open circles) agree well with Bakos et al. (2012) which are presented with crosses. Three dimensional models from Galfit are shown : Composite model (solid red line; see Fig. 4 for details) with χ^2=1.47, and Broken Disk model (green dashed line) consisting of a PSF, an inner bar, an exponential broken disk, and a bar with χ^2=1.50. Inner most part is shown enlarged as inset figure.

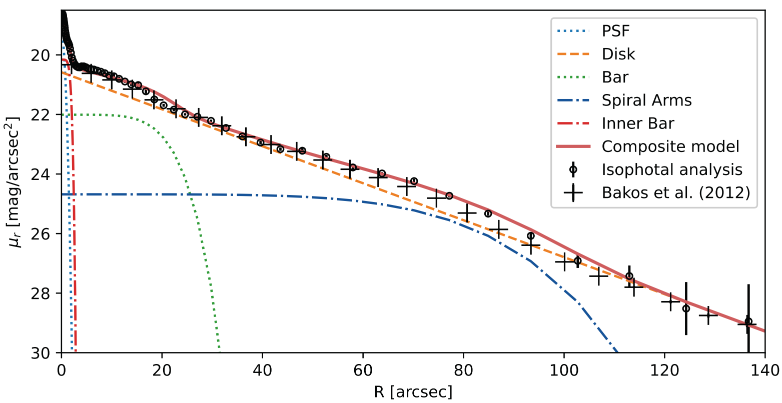

Figure 3: Components of the 3D modelling of the surface brightness profile of NGC 941 galaxy: five-component profile (red line) is decomposed into constituent components – a point spread function (PSF; blue dashed line), a disk (orange dashed line), a bar (green dotted line), inner bar (red dash-dotted line), and spiral arms modelled as a bar structure (blue dash dotted line).

particularly successful in modelling both the inner most part and the outer part of the surface brightness galaxy profile. Bakos et al. (2012) concluded that this galaxy has a downbending disk, but we believe that the presence of the spiral arms resembles the break in their 1D analysis. Residuals from the best fitting model can be seen in the Figure 4: the left image contains the spiral structure, successfully modeled by the "bar-like" component resulting in the residuals given in the middle image. Residuals in the right image come from modeling the structure on the left with the broken disk. The residuals in the middle and in the right image are indistinguishable, but there is a slight difference in the χ^2 value seen more clearly in the Figure 2. "Bar-like" component has a χ^2=1.47 and the broken disk gives χ^2=1.50.

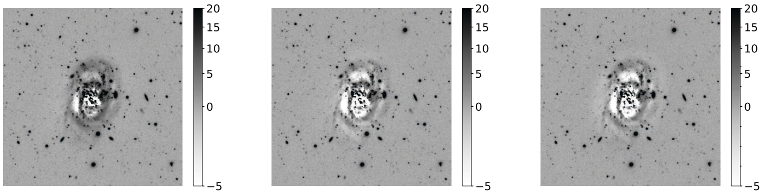

Figure 4: Residuals from the modelling the NGC 941 galaxy surface brightness profile: (left) residual image with spiral arms left (χ^2=1.65); (center) residual image without spiral arms that were modeled as a "bar-like" structure (χ^2=1.47); (right) residual image without spiral arms modelled as a broken disk (χ^2=1.50).

5. DISCUSSION

Using SDSS Stripe82 data we have modelled surface brightness profile of the galaxy NGC 941. We have found that downbending of the light profile of NGC 941 galaxy might be caused by the presence of the spiral arms structure. The analysis was done for a single galaxy, so it is a question if the conclusion holds in general.

Acknowledgements

This work was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia (MESTDRS) through the contract No 451-03-9/2021-14/200002.

References

Bakos, J., Trujillo, I.: 2012, arXiv:1204.3082.
Bertin, E., Arnouts, S.: 1996, *Astronomy and Astrophysics Supplement Series*, **117**, 393-404.
Erwin, P., Beckman, J. E., Pohlen, M.: 2005, *Astrophy. J.*, **626**, L81.
Erwin, P., Pohlen, M., Beckman, J. E.: 2008, *Astron. J*, **135**, 20.
Peng, C. Y., Ho, L. C., Impey, C. D.: 2010, *Astron. J*, **139**, 2097.
Pohlen, M., Dettmar, R. J., Lütticke, R. et al.: 2002, *Astron. & Astroph.*, **392**, 807.