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NEAR-INFRARED PHOTOMETRY OF THE NEARBY SPIRAL GALAXY NGC 2841

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Abstract. We present near-infrared photometry (Johnson-Cousins I passband) of the nearby spiral galaxy NGC 2841 obtained with the Apogee U42 CCD camera mounted on the 1.4m Milanković telescope at Astronomical Station Vidojevica (ASV) of Astronomical Observatory Belgrade (AOB). The methodology of observation given the sensitivity of the near-infrared I band to the sky background variations and fringing is presented in more details. The background model is created from a set of dithered exposures of a non-crowded field, avoiding the galaxy itself as an extended object by pointing the telescope 1 degree away from the galaxy to create the correct fringing pattern. The galaxy frames are corrected for this effect by subtracting the fringing pattern from each of them. The galaxy images are also taken with dithering to enable the creation of large mosaic, thus enlarging the field of view (FoV). This may be particularly useful in searching for dwarf candidates around nearby galaxies. The astrometric calibration was done using publicly available Astrometry code. Also, the photometric calibration was done using The Whole-Sky USNO-B1.0 catalog of stars. Finally, the surface brightness of NGC 2841 galaxy was decomposed into the bulge and the disk. The results are compared to the previous work in the infrared 3.6μm band.

1. INTRODUCTION

We have obtained deep near-infrared photometry (I band) with the use of the Apogee U42 CCD camera mounted on the 1.4m Milanković telescope. We selected the nearby giant, spiral galaxy NGC 2841, with the existing photometry, for the comparison. For this galaxy, the mid-infrared photometry is available from the Spitzer Infrared Nearby Galaxies Survey (SINGS; Kennicutt et al. 2003), but also the optical photometry from the Sloan Digital Sky Survey (SDSS-DR6; Adelman- McCarthy et al. 2008) and near-infrared photometry from the Two Micron All Sky Survey (2MASS) Large Galaxy Atlas (LGA; Jarrett et al. 2003). We compare derived surface brightness profile with the available optical, trough the near-infrared to the mid-infrared surface brightness profiles, from the literature.

2. DATA REDUCTION

We acquired 20 images of NGC 2841 galaxy in the I passband, dithered by one and a half of its semi major axis (1365 pixels or 220″) in many directions. The optimal exposure time was 60 seconds. The reduction was done following the standard procedure in IRAF.

Astrometric calibration was done using `astrometry` software[1] (Hogg et al. 2010) and applied to all the images. Then, the IRAF's `imcombine` task was used to create a large mosaic of input images using WCS information in each of the image's header to determine the shift between the images. Afterwards, they were combined using median filter creating in addition the sigma image as the standard deviation of the input pixel values. Finally, we obtained FoV $= 18' \times 18'$ out of the individual image FoV $= 8' \times 8'$ (native). The point spread function image was created following the standard procedure in IRAF (`psf`) and will be used for the final surface brightness decomposition.

3. PHOTOMETRIC CALIBRATION

Relative photometry requires calibration using the set of standard stars. However, since we were not keen to achieve accuracy better than few percents, we used the simplified method. We relied on the existing stellar photometry in the I band from The Whole-Sky USNO-B1.0 catalog of stars (USNO-B.1; Monet et al. 2003) matching our field of view. First, we have created a catalog of stars with IRAF's `daofind` procedure, then measured aperture magnitudes of all the stars inside 20 pixels aperture (found using the curve-of-growth analysis). Then, we used `xy2sky` programme (Mink 1997) distributed as a part of a World Coordinate System Tools package (WCSTools) to produce a list of RA(2000) and Dec.(J2000) from the pixel coordinates using the WCS information in the image header for all the stars in the image.

Finally, the `Topcat` tool (Taylor 2005) was used to load a part of the USNO-B.1 catalog in the circle of $20'$ in radius around our image centre (NGC 2841), since our FoV was $\sim 18'$. Then we preformed the so-called "pair-match" between two catalogs and found 55 stars in common. However, after closer examination and exclusion of a few very faint stars and those lying close to the edge of the image and also a few faint galaxies, only 37 stars were left. We applied a weighted least-square fit in R 3.1.2 software, weighting these 37 stars by the number of their observations. We also required the slope to be equal to one exactly, since the offset (i.e. the intercept) is the zero-point magnitude. We found this offset to be 22.83 ± 0.03, including extinction correction, since the difference in magnitudes includes both zero-point and extinction correction.

4. IMAGE DECOMPOSITION

Surface brightness profile of the galaxy NGC 2841 was decomposed into bulge and disk component using publicly available `GALFIT` code (Peng 2010), that fits 2-D analytic functions to image objects (galaxies and point sources) based on the Levenberg-Marquardt algorithm. Initial fitting parameters (center coordinates, major-to-minor axes ratio and position angle) were estimated from the `Sextractor` (Bertin & Arnouts 1996) run on the mosaic image, providing also the mask image (with all the objects masked but the galaxy itself).

We kept the image center fixed, along with position angle to minimize the number of free parameters. Our best fit model has a bulge: $\mu_{\rm eff}[{\rm mag}/''^2] = 19.2, n = 3.7, R_{\rm eff}[''] = 28.0$ and a disk: $\mu_{\rm h}[{\rm mag}/''^2] = 20.6, R_{\rm h}[''] = 74.25$. In Samurović et

[1] `http://nova.astrometry.net`

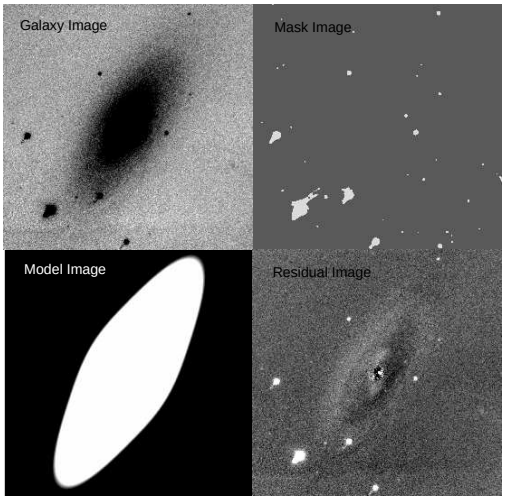

Figure 1: Image decomposition into a bulge and a disk. Upper-left: input galaxy image; upper-right: image of all the objects masked; lower-left: best-fitting model; lower-right: image residuals.

al. (2015) we derived structural parameters of the same galaxy in the mid- infrared (3.6 μm) using `Galfit` code and obtained disk scale length $R_h[''] = 56.69 \pm 1.1$ and the Sersic index $n = 3.22$ and the effective radius of the bulge $R_{\rm eff}[''] = 17.95 \pm 0.02$. The difference with the results obtained using the same procedure only in the near-infrared may be due to the different passband and/or different exposure time. In Fig. 1 decomposition is shown trough the steps included in the fitting procedure: the galaxy image (upper left) is modelled using a bulge and a disk component (lower left) starting from the initial parameters, masking all the objects in the mask image (upper right) and then convolved with the PSF to get the realistic model that is subtracted from the galaxy image to produce the fitting residuals (lower right). The fitting is done iteratively. In each step fine tuning initial galaxy parameters reduces the χ^2 until, at some point, this change becomes negligible.

Furthermore, the surface brightness was azimuthally averaged and modelled with the IRAF's `ellipse` procedure for the comparison with the previous work (Fig. 2).

5. RESULTS

This work was done to test the capabilities of the newly installed 1.4m Milankovic telescope, in particular enlarging the existing field of view ($\sim 8'$) trough mosaic creation to $18' \times 18'$ and, a part from that, inspecting large-scale variations of the sky in the near- infrared (I band). Two-dimensional decomposition is done. The radial surface brightness profile is in the good agreement with the previous work (Fig. 2).

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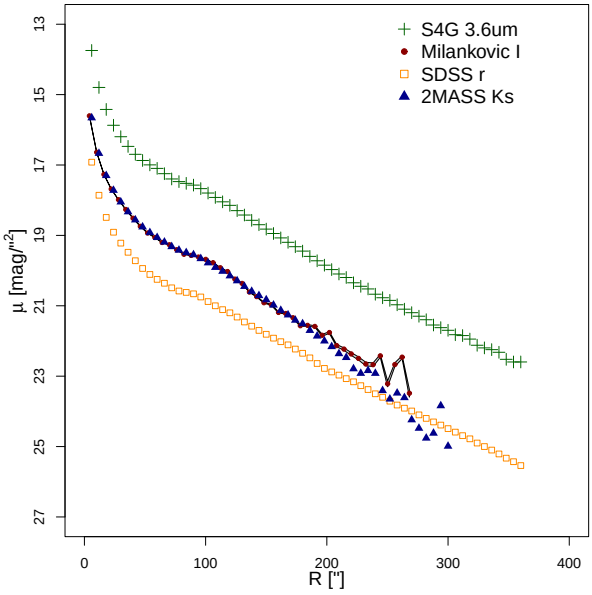

Figure 2: Radial surface brightness profile of galaxy NGC 2841: Milankovic I - this work (full circles); S4G 3.6μm - Spitzer's mid-infrared profile (crosses); SDSS r - optical SDSS profile in the r-band (empty boxes) and 2MASS Ks - near-infrared 2MASS data in the Ks-band (full triangles).

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References

Adelman-McCarthy, J. K., Agueros, Marcel A., Allam, Sahar S., Allende Prieto, C. et al.: 2008, *Astrophysical J. Supp. Series*, **175**, 297.

Bertin, E. & Arnouts, S.: 1996, *Astronomy & Astrophysics Supp.*, **117**, 393.

Hogg, L. D., Mierle, D. W., Blanton, K. & Roweis, M. S.: 2010, *Astronomical J.*, **139**, 1782.

Jarrett, T. H., Chester, T., Cutri, R., Schneider, S. E. et al.: 2003, *Astronomical J.*, **125**, 525.

Kennicutt, R. C. Jr., Armus, L., Bendo, G., Calzetti, D. et al.: 2003, *Publ. of the Astronomical Soc. of the Pacific*, **115**, 928.

Mink, D. J.: 1997, *ASP Conf Ser. 125*, ed. G. Hunt and H. E. Payne, **249**.

Monet, D. G., Levine, S. E., Canzian, B., Ables, H. D. et al.: 2003, *Astronomical J.*, **125**, 2, 984.

Peng, C. Y., Ho, L. C., Impey, C. D. & Rix, H.-W.: 2010, *Astronomical J.*, **139**, 6, 2097.

Samurović, S., Vudragović, A. and Jovanović, M.: 2015, *Mon. Not. R. Astron. Soc.*, **451**, 4073.

Taylor, M. B.: 2005, *Astronomical Soc. of the Pacific*, **347**, 29.