Detailed morphological characterization of selected Seyfert galaxies

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(Submitted on 21.06.2012; Accepted on 24.07.2012)

Abstract. We present a detailed morphological characterization of seven Seyfert galaxies. Based on analysis of various images, residuals, maps and profiles, we revealed a bar in Ark 479, an oval/lens in Mrk 595, inner rings in Ark 120 and Mrk 376, features of possible tidal origin in 3C 382 and NGC 7603, and a nuclear bar and ring in Mrk 352.
Key words: galaxies Seyfert

Introduction

Disk galaxies are dominated by two components, bulges and disks. Supermassive black holes are thought to reside in the centres of most galaxies with bulges (Kormendy & Gebhardt 2001). A great deal of correlations among disk and bulge parameters have been established, e.g., bulge vs. disk scale lengths (Möllenhoff 2004, Aguerri et al. 2005), bulge effective colour index vs. disk central colour index (de Jong 1996b). Some structural parameters, like bulge effective surface brightness, are found to correlate with the Hubble type (de Jong 1996a, Möllenhoff 2004). Furthermore, the bulge-to-disk ratio is the most objective criterion for the Hubble type classification of disk galaxies. Empirical relations uniquely associate the mass of the supermassive black hole with some bulge parameters (Ferrarese & Ford 2005). Generally, the way to have a precise differentiation of the flux of the individual components is photometric decomposition, which, on its part, is supposed to consider all significant components in the galaxy. The omission of components, e.g. bars, can result in modifying bulge and disk parameters and furthermore in compromising the correlations they are involved in.

The model of active galaxies involves an accretion flow onto a supermassive black hole. The importance of fueling mechanisms depends on the accretion rates and spatial scales. Bars, tidal interactions, and minor mergers are efficient large-scale mechanisms for Seyfert galaxies (Jogee 2006). Bars can cause gas inflow down to about 1 kpc (Piner et al. 1995); among the possibilities for further driving the gas within the gravitational influence of the central source are nested bars (Shlosman et al. 1989) and central spiral dust lanes (Regan & Mulchaey 1999). Rings may trace the dynamical resonances related to bars. Numerical simulations show that tidal interactions and (minor) mergers could induce tails, shells, bars, various types of asymmetries and finally cause gas inflow to the nuclear regions (Toomre & Toomre 1972, Hernquist & Mihos 1995). Finding clear evidence of minor mergers is generally hard and they have often been associated with asymmetries (De Propris et al. 2007). Thus, detailed morphological characterization, i.e., disclosure of the features present, is important for studies on the fueling mechanisms of active nuclei and correlations among structural parameters, as well as for the precise morphological classification of galaxies.

We present a detailed morphological characterization of seven galaxies, selected from a sample of Seyfert galaxies, observed at the Rozhen National Astronomical Observatory (NAO), Bulgaria, with the 2-m Ritchey-Chrétien telescope. The sample selection, observational details, and data reduction are described in Slavcheva-Mihova & Mihov (2011a).

1 Comments on the individual galaxies

We scrutinized the morphology of the selected galaxies on the basis of various types of data. We inspected contour maps, $BVR_{\rm C}I_{\rm C}$ profiles of the surface brightness, ellipticity, and position angle, as well as colour index profiles. To facilitate revealing the individual galaxy features, we further constructed some subsidiary images: colour index images, residual images, and structure maps. We used model-subtracted and unsharp masked (unsharp mask-subtracted and unsharp mask-divided) residual images[1] (Slavcheva-Mihova & Mihov 2011a).

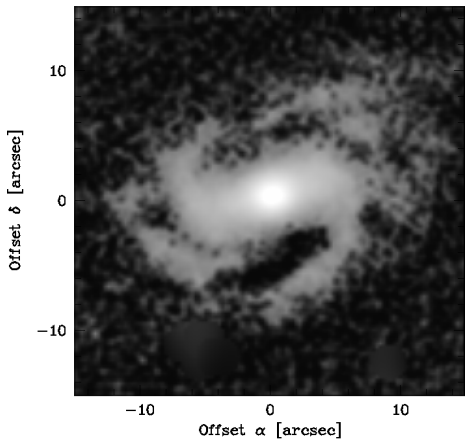

Fig. 1. Ark 479 V unsharp mask-subtracted residual image. The bar and spiral structure can be traced.

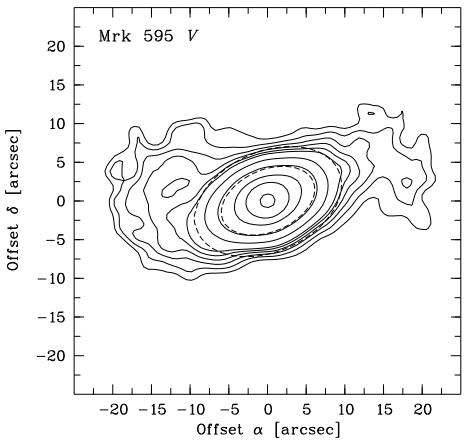

Fig. 2. Mrk 595 V unsharp mask-divided residual map. Overplotted are the V model contours corresponding to the two ellipticity peaks. The oval/lens and the spiral arm stubs can be traced.

Ark 479. The ellipticity profile shows a maximum around $a = 6''$, accompanied by a weak surface brightness bump and an almost constant position angle, which corresponds to a bar. The bar and spiral structure can be traced in the unsharp masked residual image (Fig. 1).

Mrk 595. The profiles and contour map suggest a bar-like structure, which is most probably an oval/lens, given its small deprojected ellipticity (Slavcheva-

[1] In all figures north is up, east to the left.

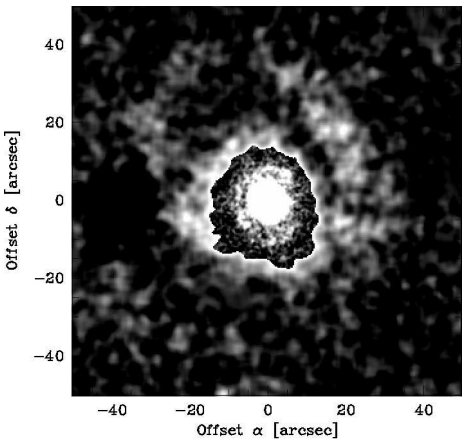

Fig. 3. Ark 120 B residual image, composite of two unsharp mask-subtracted residual images, so that the inner knotty ring and the two faint arcs running to the north could be traced.

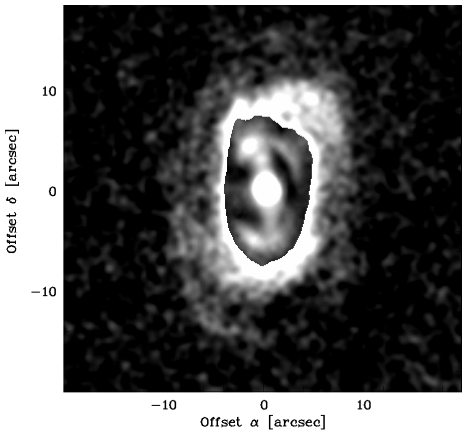

Fig. 4. Mrk 376 $R_{\rm C}$ residual image, composite of an unsharp mask-divided/-subtracted one. The bar, the ring around it, and the spiral arms, forming a weak outer pseudo-ring, are clearly outlined.

Mihova & Mihov 2011b). Weak spiral arm stubs can be seen in the unsharp masked residual map (Fig. 2).

Ark 120. The unsharp masked residual image (Fig. 3) reveals a blue knotty ring and a couple of arcs extending to the north on either side of the nucleus, the western one being more pronounced.

Mrk 376. The unsharp masked residual image (Fig. 4) reveals a bent bar. It is encircled by a ring with knots of star formation that are outstanding in the colour images. The two spiral arms get noticeably not so bright and form a weak outer pseudo-ring.

3C 382. Three filaments can be discerned in the model-subtracted residual map (Fig. 5). The north-eastern and eastern filaments are oriented toward a barred spiral galaxy about $1\farcm4$ to the north-east. The south-western filament could also be of tidal origin.

NGC 7603. NGC 7603 and the galaxy about $1'$ to the south-east are an example of an anomalous redshift association (Arp 1971). NGC 7603 is disturbed and shows evidence of tidal interaction (López-Corredoira & Gutiérrez 2004). There are a number of loop-like features (Fig. 6), which appear blue in the colour images.

Mrk 352. There is evidence of a nuclear bar around $a = 2''$: the ellipticity profile shows a peak, accompanied by a plateau on the position angle profile; however, there is no obvious surface brightness bump. Moreover, the unsharp masked residual reveals a nuclear ring (Fig. 7). We processed archival Hubble Space Telescope (HST) $F606W$ data, which verified our findings (Fig. 8).

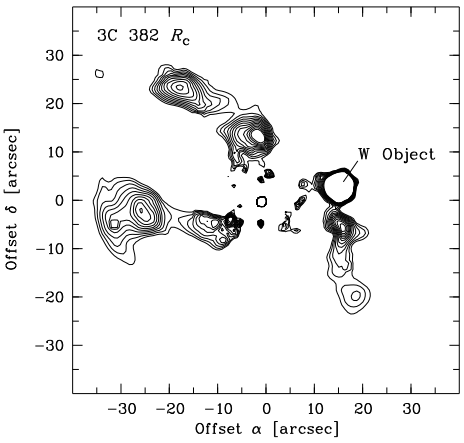

Fig. 5. 3C 382 R_C model-subtracted residual map. Three filaments are outstanding.

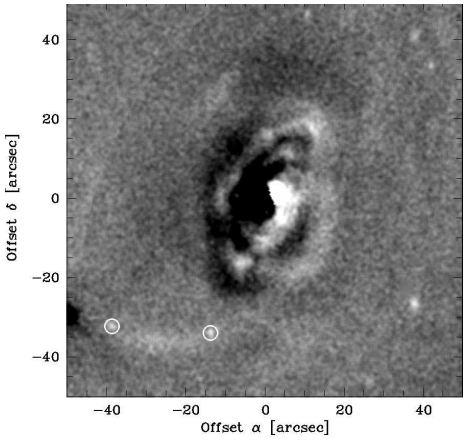

Fig. 6. NGC 7603 V model-subtracted residual image. A complex of loop-like features and a filament with two emission-line galaxies overposed (encircled) are outlined.

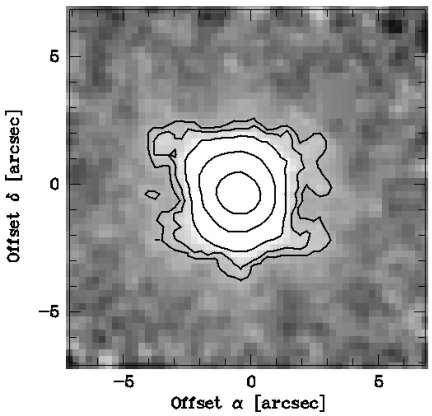

Fig. 7. Mrk 352 R_C unsharp mask-divided residual image. The nuclear ring can be discerned.

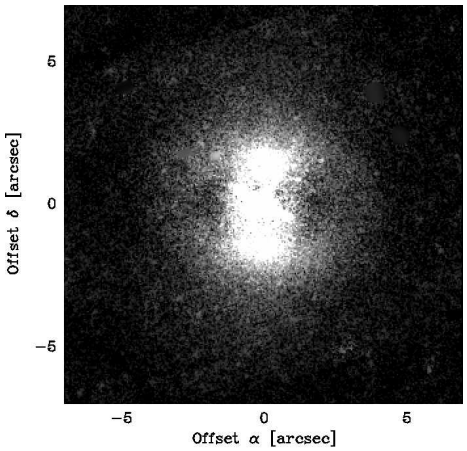

Fig. 8. Mrk 352 HST $F606W$ 2D model-subtracted residual image. The bar encircled by a ring can be traced.

2 Results

We carried out a detailed morphological characterization of seven Seyfert galaxies on the basis of various images, residuals, maps, and profiles in a case-by-case approach. As a result we revealed a bar in Ark 479, an oval/lens in Mrk 595, inner rings in Ark 120 and Mrk 376, and features of possible tidal origin in 3C 382 and NGC 7603; the nuclear bar and ring of Mrk 352, unveiled on the basis of data from the 2-m telescope of Rozhen NAO, were confirmed

by HST data. The galaxy structures found could be important for the fueling of Seyfert nuclei as well as for the precise estimate of structural parameters based on surface brightness decomposition. Thus, the correlations among particular galaxy parameters can be improved. Furthermore, the morphological classification of the given galaxies could be specified.

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