Morphological characterization of selected Seyfert galaxies and comparative analysis with a sample of inactive galaxies

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The generally accepted active galactic nucleus model requires gas accretion onto a supermassive black hole. There are a number of fueling mechanisms of different relative importance depending on mass accretion rates and spatial scales. At Seyfert luminosities, bars, tidal interactions, and minor mergers become important (Jogee 2006). Bars have long been considered an efficient mechanism for inward gas transport down to about 1 kpc (Piner et al. 1995); nested bars and central spiral dust lanes are among the possibilities for further driving the gas within the gravitational influence of the central source (Shlosman et al. 1989) (Regan & Mulchaey 1999).

The relation between galaxy interactions and the onset of nuclear activity is founded upon the key study of (Toomre & Toomre 1972). Minor mergers could induce gas inflow to the nuclear regions (Hernquist & Mihos 1995). Numerical simulations show that (minor) mergers, together with tidal interactions, could induce tails, bridges, shells, bars, and various types of disturbed spiral structure and asymmetries; thus, asymmetries have often been associated with mergers (De Propris et al. 2007). The question of statistical differences between Seyfert and inactive galaxies considering non-axisymmetric perturbations of the potential, is somewhat controversial. It is a prevalent view that neither bars, companions, minor mergers, nested bars, nor nuclear dust spiral arms are specific signatures of Seyfert galaxies; some studies, however, prompt an excess of features in Seyfert galaxy samples (Jogee 2006).

We analyzed the evidence of non-axisymmetric perturbation of the potential in a sample of 35 Seyfert galaxies and in a matched sample of inactive galaxies on the basis of a detailed morphological characterization with the following main results:

1. We presented a detailed morphological characterization of a sample of Seyfert galaxies. We scrutinized various images, residuals, maps, and profiles in order to reveal galaxy structures that could be important for the fueling of Seyfert nuclei, as well as for the proper photometric decomposition, which is ongoing. The careful analysis of these data on an individual, case-by-case basis, has led to a more explicit morphological status of a part of the galaxies, resulting in improved morphological type accuracy, and uveiling of new structural components and features:

- 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 for the first time to our knowledge;

- we discussed some structures of controversial/unclear morphology in the galaxies Mrk 573, Mrk 376, NGC 3227, NGC 3516, Mrk 279, Mrk 506, 3C 382, and NGC 7469.

2. We compared the large-scale morphology and local environment of the Seyfert sample and a control one, matched in morphological type, radial velocity, absolute B magnitute, and ellipticity (Slavcheva-Mihova & Mihov 2011a), with the following results:

- we found similar fractions of bars in Seyfert, $(49 \pm 8)\%$, and control, $(46 \pm 8)\%$, sample;
- the Seyfert bars are weaker than the bars in the control sample with median deprojected bar ellipticity values of 0.39 vs. 0.49, respectively, at the 95% confidence level; it had been shown that deprojected bar ellipticity is a first order approximation of the bar strength (Combes & Sanders 1981, Athanassoula 1992);
- this is the first comparative study on rings in Seyfert galaxies based on a control sample to our knowledge;
- the incidence of rings in the Seyfert and control sample is similar – $(49 \pm 8)\%$ and $(54 \pm 8)\%$, respectively;
- practically equal parts of the Seyfert, $(44 \pm 9)\%$, and control, $(43 \pm 8)\%$, sample have at least one close physical companion within a projected linear separation of five galaxy diameters and an absolute radial velocity difference of $600\,\mathrm{km\,s^{-1}}$;
- there is no correlation between the presence of asymmetries and companions for both samples; minor mergers, at least without companions, do not occur in the Seyfert sample more often than in the control one;
- the vast majority of both samples, $(91 \pm 5)\%$ of the Seyfert and $(94 \pm 4)\%$ of the control one, have bars, rings, asymmetries, or close companions;
- similar fractions of the Seyfert, $(86 \pm 6)\%$, and control, $(83 \pm 6)\%$, sample show morphological evidence of non-axisymmetric perturbations of the potential.

Thus, we came up with the conclusion that the fueling of Seyfert nuclei does not appear directly related to the large-scale morphology and local environment of their host galaxies. The weaker Seyfert bars may be related to the generally larger cold gas amounts reported in their disks in the context of angular momentum transfer. A possible explanation of this lack of correlations is in the low accretion rates of Seyfert nuclei that can be provided by local or weak largescale mechanisms. In the framework of these results, we have started a study of the circumnuclear regions of a sample of Seyfert galaxies using HST archival images. As first results of this research, we revealed a nuclear bar and ring in Mrk 352 and nuclear dust lanes in Mrk 590.

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