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Bars and Seyferts

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Abstract. We describe the results of two studies recently undertaken, aimed at quantifying the properties of single and nested *stellar* bars in well-matched samples of Seyfert and non-Seyfert galaxies. We find that Seyfert host galaxies are more often barred than non-Seyferts. Sub-kpc bars in nested systems are probably confined to within the inner Lindblad resonance(s), and have a different formation and evolution history from large-scale bars. We do not find a substantial prevalence of stellar sub-kpc bars in Seyferts.

1. Introduction

Galactic disks contain a plentiful reservoir of gas which can serve as a potential fuel for the central activity, both stellar (in the form of nuclear or circumnuclear starbursts) and non-stellar (AGN-type). But in order for this gas to reach the innermost regions of the galaxy it must lose most of its angular momentum. Various mechanisms producing gravitational torques, of which large-sale non-axisymmetries, such as bars, are perhaps the most important ones, can strip gas of its angular momentum. Since the net inflow rates required for the fueling of the activity are of the order of a few $M_\odot$ yr^{-1}, weak perturbations, such as spiral arms, stellar and gaseous, are insufficient to drive a radial gas inflow of such magnitude toward or within the central kpc.

Although there is a string of observational evidence, starting with the work of Heckman (1980), that bars are directly related to starburst activity within

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the central kiloparsec, there was until recently no credible evidence for such a relation in AGN hosts. In this short paper, we review our recent work addressing this issue.

2. Bars and AGN

Strong bars are found from optical studies in about 1/3 of disk galaxies in optical studies. This bar fraction goes up to at least 2/3 when using near-IR imaging (e.g., Laine et al. 2002 and refs. therein; Grosbøl 2002). Large-scale stellar bars have been invoked in observational works to explain the fueling of AGN (Simkin, Su & Schwarz 1980). However, this and a number of other studies suffer from the absence of properly matched control samples, and/or from the use of low-resolution optical imaging which underestimates the bar fraction. Theoretically, it is also difficult to understand how large-scale bars extract the angular momentum from the gas within the central kpc, as their potential is nearly axisymmetric in this region (Shlosman, Begelman & Frank 1990).

We have recently performed two independent studies of matched samples of Seyfert and non-Seyfert galaxies, with $29+29$ and $56+56$ galaxies, respectively (Knapen, Shlosman & Peletier 2000; Laine et al. 2002). The first of these studies was based upon our own subarcsec resolution, ground-based, near-IR K-band imaging of the CfA sample of Seyfert galaxies and a carefully selected control sample of non-active galaxies (Peletier et al. 1999), and using objective and reproducible criteria for the bar classification. From this study, we found that Seyfert hosts are more often barred than non-Seyferts, but only at a significance level of just over 2σ (79%±8% vs. 59%±9%). We also found that the stellar bars in the control galaxies are "thinner" (thus presumable stronger) than those in the Seyfert galaxies (Shlosman, Peletier & Knapen 2000), which can be understood as a plausible evolutionary effect of larger central mass concentration in the Seyferts.

In our second study, we aimed first to increase the sample size, and next to image smaller (sub-kpc) stellar bars. We consequently based this study on *HST* NICMOS imaging as obtained from the *HST* archive, thus reaching scales of $< 1''$, or < 100pc. By considering all available NICMOS imaging we were able to produce matched samples of Seyferts and non-Seyferts, each containing 56 galaxies (Laine et al. 2002). Prompted by the small field of view of the NICMOS images, we collected a large set of ground-based images to cover the complete disks of the galaxies. We then produced radial profiles of ellipticity and position angle from the innermost to the outermost radii in the galaxy disks, which were used to derive the presence of a bar or bars, as well as the basic properties of these bars: intrinsic length and ellipticity. Considering bars of all scales, we confirmed the result of our previous study that the Seyferts are more often barred than the non-Seyferts, now at a formal significance level of 2.5σ (73%±6% vs. 50%±7%).

3. Nuclear bars and AGN

One of the main aims of our study was to analyze the role played by nuclear, or secondary, stellar bars in the process of bringing gaseous fuel into the central

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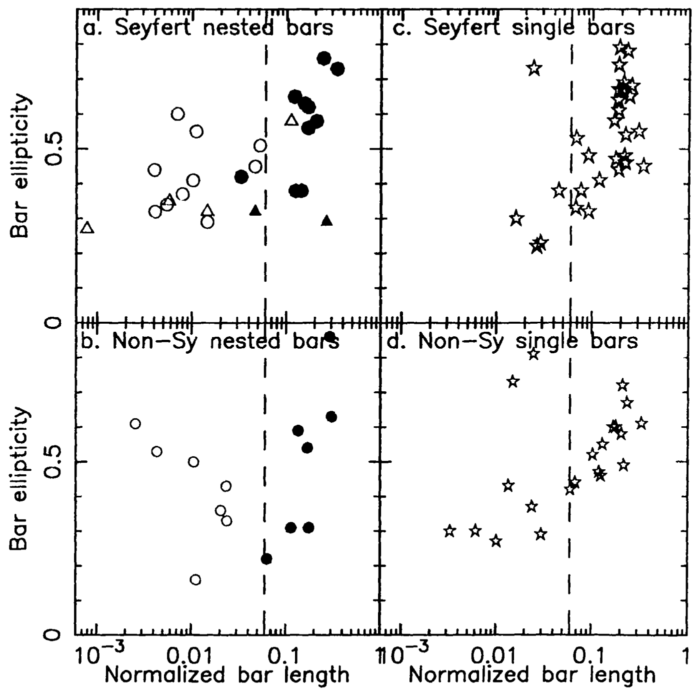

Figure 1. Normalized sizes of the stellar bars in our Seyfert (top) and non-Seyfert control (bottom) galaxies, plotted against the intrinsic ellipticity of the bars. Primary (large-scale) bars are shown with filled circles, secondary (sub-kpc) bars with open circles, and single bars with asterisks (plotted in the right panels). Triangles denote bars in triple-barred galaxies. The vertical dashed line is at 0.06 (see text). From Laine et al. (2002).

regions of barred galaxies. Since large-scale bars are not efficient within a few hundred parsec from the center, nested bars (stellar and gaseous) were suggested more than a decade ago as, at least theoretically, viable means to transport the gas further in ("bars within bars", Shlosman, Frank & Begelman 1989). As we confirmed in our study, the most detailed and complete one to date, a significant fraction of galaxies have more than one stellar bar (17%±4% of all sample galaxies) and almost 1/3 of barred galaxies host a second bar (Laine et al. 2002). We did not find, however, a significant excess of *stellar* nested bars among the Seyfert host galaxies.

Figure 1 shows the distribution of normalized (to the size of the complete disk of the host galaxy, D_{25}) sizes and intrinsic ellipticities of the bars in our active and non-active samples. Primary and secondary bars are plotted separately, and are cleanly separated in size, where secondary bars are no larger than $0.06\,D_{25}$, and primary bars are no smaller than this value. In galaxies where only one bar exists, however, this single bar can have any size, as shown in the right panels of Fig. 1. There is also a tendency for larger bars to be more elliptical, stronger among the single rather than the nested bars. From our overall data set, we confirm the results of Shlosman et al. (2000), showing that the bars in Seyfert galaxies have smaller ellipticities, and are thus presumably weaker, than the bars in non-Seyferts.

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The clean separation in normalized size between primary and secondary bars is in itself interesting, but becomes even more so if we consider the size distribution of nuclear rings, which peaks at a value very similar to the separation between the bars, namely 0.06 D_{25} (see Fig. 8 of Laine et al. 2002). This supports our claim that the formation and evolution histories of primary and secondary bars are different, and that the sizes of secondary bars are in fact limited by the size of the inner Lindblad resonance(s), since nuclear rings are known to be directly associated with such resonances (e.g., Schwarz 1984; Combes & Gerin 1985; Knapen et al. 1995a,b).

4. Concluding remarks

In this paper, we have briefly summarized the main findings of two related studies we performed over the past few years, which reveal the properties of single and nested stellar bars in Seyfert galaxies and in well-matched control samples of non-Seyfert galaxies. We find that the dynamical properties of sub-kpc bars differ substantially from those of the large-scale bars. Specifically, we find that stellar sub-kpc bars appear to be confined to the inner Lindblad resonances. We do not find that sub-kpc stellar bars are prevalent in Seyferts, but note that the overall strategy used so far, to search for bars using photometric methods, appears not to be the optimal one due to the dust and star forming regions frequently found in the central kpc. Future studies should focus on the dynamical properties of gas within the central kpc.

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