Barred Galaxies
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A K-Band Search for Induced Bars in Interacting Systems

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1. Introduction

Both active and starburst galactic nuclei are best understood if they are fuelled by gas inflow to the nucleus (e.g. Simkin, Su & Schwarz 1980; Hutchings & Campbell 1983).

There is observational evidence that the occurrence of Seyfert and QSO activity is enhanced in the presence of nearby companions (Dahari 1984; Keel et al 1985; Hummel et al. 1987). At least some samples of Seyfert host galaxies show more close companions than would be expected for a random sample of similar galaxies, though the situation for tidal disturbances themselves is more complex. The selection effects modelled by Byrd et al. (1987) suggest that virtually all the Seyfert galaxies in Dahari's sample have a companion which is (in principle) physically sufficient to provoke gas inflow in the disk.

Long-lived perturbing bars are theoretically attractive as mechanisms for transferring angular momentum and driving gas inflow (Simkin et al. 1980). A bar is in fact seen to form in strongly perturbed disk-galaxy models (Byrd et al. 1986; Noguchi 1988). Elmegreen et al. (1990) found that binary galaxies preferentially tend to be barred and early in type. There may be a connection between nuclear activity, tidal perturbation and bar triggering for some galaxies.

The near-infrared regime offers several striking advantages for tracing a disk galaxy's response to perturbation, advantages which can be fully exploited with the advent of panoramic detectors sensitive in the JHK passbands. These bands are much less sensitive to dust extinction than shorter wavelengths, and the old disk population (tracing the response to tidal perturbation most clearly) is less likely to be masked by regions of recent star formation in which small amounts of mass contribute a disproportionate share of the light. We have accordingly used the IR Imager at the (late) KPNO 1.3-meter telescope to observe about 110 pair members, describing here results for the 66 galaxies which were well-resolved and symmetric enough for a photometric analysis to find evidence of bars. We were particularly interested in the occurrence of masked bars, as seen in NGC 1068 - bars which are not detected in the optical, either due to dust obscuration or the strong blue light from recent star formation.

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The configuration of the optics gave a field of 81 arcseconds at about 1.35 arcseconds/pixel, a compromise between spatial resolution and field. Exposures were about equally divided between object and adjacent sky fields, with typically 700-900 seconds on the object itself. All the data we report were obtained in the K band (2.2 μ).

Table 1. K-band bars versus RC3 morphological class.

Galaxy	RC3 type	IR bar?	Galaxy	RC3 type	IR bar?
Arp 191A	LB	?	NGC 935	S 6	no?
Arp 191B	LB?	?	NGC 1241	SBT3	bar
K016A	S?	bar	NGC 1614	SBS5	bar/twist
K016B	S?	bar	NGC 2146	SBS2P	no
K019A,NGC 317A	S?	E	NGC 2623	1P	elongated ctr
K019B,NGC 317B	SB?	twist/bar	NGC 2881	S?	2881B yes
K064A,Arp 273A	SAS3	twist	NGC 3395	SXT6	weak
K064B,Arp 273A	SBS1	twist	NGC 3396	IB9P	no
K065A	SXS4	bar	NGC 3504	SXS2	bar
K065B	I 9	indeterminate	NGC 3786	SXT1	bar
K107A,VV225	S?	weak bar	NGC 3995	SA 9	yes, type unclear
K107B,VV225	S?	no	NGC 4258	SXS4	no
K119A	–	no	NGC 4647	SXT5	yes
K119B	–	weak oval?	NGC 4676N	L	no
K134A	–	no	NGC 4676S	SBS0	yes
K134B	–	no	NGC 5257	SXS3	bar
K167N	–	bar	NGC 5258	SAS3	bar/twist
K167S	–	E	NGC 5278	SAS3	small bar
K194A,NGC 2802	S?	fat bar	NGC 5279	SBS1	bar
K194B,NGC 2803	S?	no	NGC 5421	SB?	A: bar/twist
K203E,Arp 300	SXS5	bar	NGC 5427	SAS5	nuclear bar
K209B,Arp 129	S:6	small bar	NGC 5430	SBS3	bar
K221A	S 6	bar	NGC 5929	S 2	?
K221B	–	bar	NGC 5930	SXT3	small bar
K265,NGC 3509A	SAS4	twist or bar	NGC 5953	SA 1	lumps
K363A,NGC 4922A	I0	?	NGC 5954	SXT6	yes
K363B,NGC 4922B	–	?	NGC 7319	SBS4	yes
K369A,Arp 238	S?	bar/twist	NGC 7435	SBS1	edge-on
K369B,Arp 238	S?	?	NGC 7436	E	no
NGC 275	SBT6	bar	NGC 7674	SAR4	yes
NGC 833	S 1	no	NGC 7714	SBS3	yes
NGC 835	SXR2	bar			

2. Results

The "barredness" of each galaxy from the K imagery was judged not only from inspection, but via ellipse-fitting surface photometry. Coupled changes in ellipticity and position angle (twists) can show the presence of bars and strong oval distortions in systems of a wide range of inclination, except for those seen almost perfectly edge-on. Some tidally disturbed galaxies have intrinsic isophotal twists, so the photometric diagnosis of a bar is ambiguous. The results are summarized in Table 1, and compared to the morphological types from the RC3 (de Vaucouleurs et al. 1991) as an indicator of the strength of any optically prominent bar. The sample spanned the properties of paired galaxies, including strongly disturbed as well as relatively undisturbed galaxies, and with significant representation of Seyfert and starburst galaxies. The K numbers are from the Karachentsev (1972) pair catalog.

Our main results are as follows:

- We detect bars on K-band images in essentially all galaxies classified as barred or transition (SB or SAB) in the RC3 system. These constitute 2/3 of our sample.

- We also find bars in 15% of the "nonbarred" galaxies (those classified SA in the RC3).These bars are either hidden by obscuration, masked by recent star formation, or identifiable optically but not conspicuous enough to affect the classification.

The most interesting galaxies in our study are the three showing K-band bars but without prominent optical bars. Of the three galaxies with IR bars which are classified in the SA family (nonbarred) in the RC3, two (NGC 5427 and 7674) have small-scale bars that can be seen on V images. NGC 5278 has a clear K bar without an R-band counterpart, and is the best masked bar in our sample. The small number of galaxies with IR-detected bars that do not appear as such in the RC3 system is important beyond the small numbers involved, since only about 1/3 of disk galaxies are classified as SA in this system. In our selection, the three systems amount to 15% of all nonbarred galaxies having hidden stellar bars.

Even though our sample was targeted specifically toward pairs and recent merger remnants, it is still too small to tell whether bars are being induced by tidal perturbations. It does suggest that induced bars are not quite ubiquitous, since some galaxies (20%) show no significant bar or oval distortion to our resolution limits.

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