N93-26821

TIDAL INTERACTIONS AND THE FORMATION OF MAGELLANIC SPIRAL GALAXIES

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The closest, brightest and best resolved galaxy in the sky, the Large Magellanic Cloud, is a prototype of the late-type disk systems referred to collectively as barred Magellanic spiral galaxies (SBm). These systems occupy a pivotal stage in the Hubble sequence since they represent the transition from spiral disk galaxies to chaotic, irregular galaxies and are characterized by an asymmetric spiral arm which emanates from one end of a high surface brightness bar. We present evidence that the formation of the one-armed spiral morphology involves the tidal interaction with a companion galaxy. In summary the major points of our observational investigation presented here are:

1. The vast majority of one-armed spiral galaxies possess bright nearby neighbors which appear to be physically associated.

2. The HI gas distribution and kinematics of one pair of SBm galaxies clearly reveal this system to be tidally interacting.

3. The infrared properties of the bars in two SBm galaxies support optical studies of bar luminosity profiles in late-type systems, and also suggest that the formation of compact star forming regions in these bars may not be uncommon.

Many of the classic cases of SBm morphology occur when a nearby neighbor galaxy is present. In some spectacular cases the neighbor galaxy also displays a one-armed spiral morphology. Could such a close match in galaxy types occur by accident, or could the formation of one-armed spirals be related to the mutual gravitational interaction of the two disks?

A search for neighbor galaxies in the vicinity of the largest ($\log D_{25} > 1.3$) Sm galaxies in the RC3 catalog was performed using the Palomar and UK Schmidt Sky Surveys. Statistical analysis of the data gathered in this survey revealed that among 75 galaxies with well classified asymmetric arms, only 4 were found to have no nearby neighbor within a separation of $5 \log D_{25}$. In fact, the classification of these 4 systems as Magellanic type galaxies is highly questionable (Corwin, private communication). In no case was a bright, dominant arm classified in a galaxy in which a clear neighbor galaxy was absent. The frequency distribution of apparent separations, which is strongly peaked at small separations, suggests that the observed galaxy pairs are not due to chance optical alignments, but are in fact the result of physical associations. Hence, scenarios invoking the formation of offset bars and/or dominant spiral arms through some tidal interaction mechanism might be attractive, since a common trait among the Sm galaxies appears to be the presence of a physical neighbor.

There is a high abundance of neighbor galaxies around SBm systems, and N body simulations of perturbed disks often produce one-armed spiral structures (Odewahn 1989). These facts support the idea that one-armed spiral features are produced through gravitational interaction. To identify signs of physical interaction in a paired SBm system, a HI kinematic study was undertaken using the VLA C and D array configurations. In Fig. 1, we present maps of the HI distribution, velocity field and velocity dispersion for the NGC4618-4625 system. Evidence that this is an interacting system can be seen in the bridge of HI extending from NGC 4625, and in the strong twisting of the kinematic line of nodes in the disk of NGC 4618. As explained by Bosma (1978), such nodal twisting in the outer regions of a disk is indicative of a strong warp which can be induced through tidal perturbations. A feature of additional interest is the degree of structure in the HI velocity dispersion map in NGC 4618. This is probably due to gas heating as a result of OB star formation in the arm region.

In conjunction with the kinematic observations, a systematic infrared study of the JHK properties of SBm systems has commenced using the new Simultaneous Quad Infrared Imaging Device (SQIID) at KPNO. In part, the objective of this imagery is to assess the role of dust absorption in determining the optical morphology and to deduce the stellar populations present in the bars. As discussed by Bothun (1990), combining high quality optical and infrared surface photometry will permit probing of the distribution of metallicity, age and rate of star formation throughout these systems.

In Fig. 2, we present an H-band image of NGC 4618. The IR morphology is very similar to the optical morphology derived from previous BVRI and Hα studies (Odewahn 1989). However, the bar light clearly dominates the total luminosity of the galaxy in the case of the IR, whereas the bar contributes only 10% to 15% of the total light in B. Elliptically averaged profiles in BVRHK (Fig. 3) have roughly the same form indicating very little change in exponential disk scale length from B to K. Of particular interest in the case of NGC 4618 was the structure of the bar. As predicted in Odewahn (1991) on the basis of optical photometry, the bar has a two lobed appearance in the IR. Linear profiles along the bar major axis (Fig. 4) reveal two peaks in the bar light from B to K. The northeastern peak appears to be due to a compact star forming region. The exponential decay in luminosity along the bar axis commonly observed in late-type barred galaxies (Elmegreen & Elmegreen 1985) is confirmed in the IR imaging of NGC 4618.

ACKNOWLEDGMENTS: This research was supported in part by the U. Wyoming Research Office and the Wyoming Faculty Grant-in-Aid Program. J.M.B. was supported by the NSF Research Experience for Undergraduates Grant AST91-00602.

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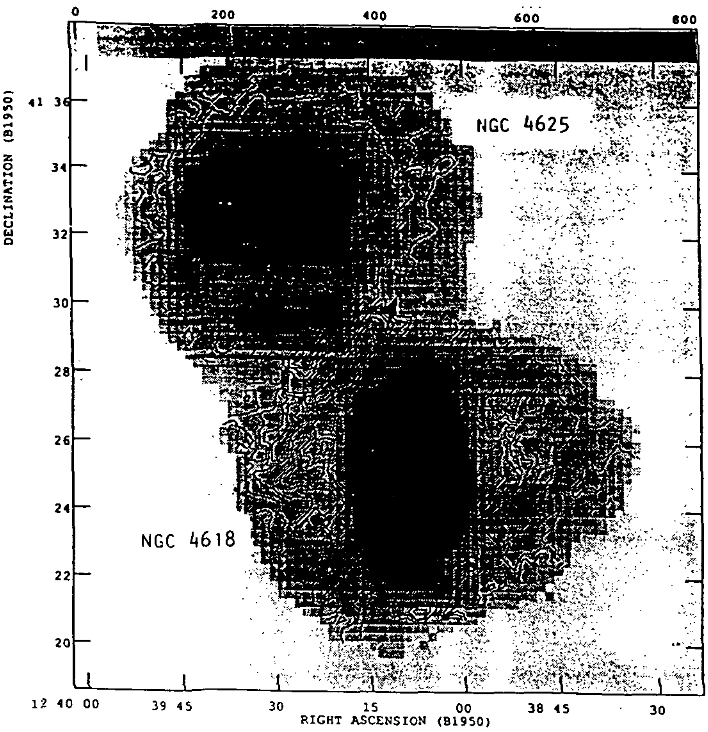


0
200
400
600
800
DECLINATION (B1950)
41 36
34
32
30
28
26
24
22
20
NGC 4625
NGC 4618
12 40 00
39 45
30
15
00
38 45
30
RIGHT ASCENSION (B1950)

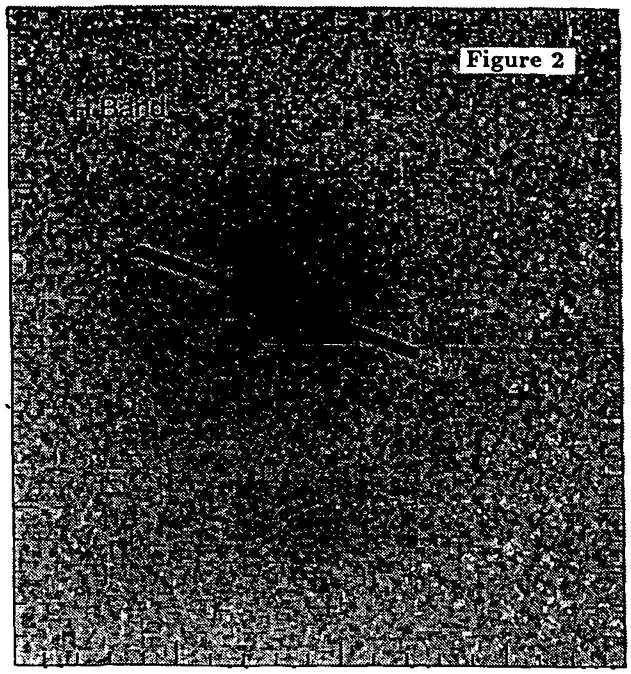
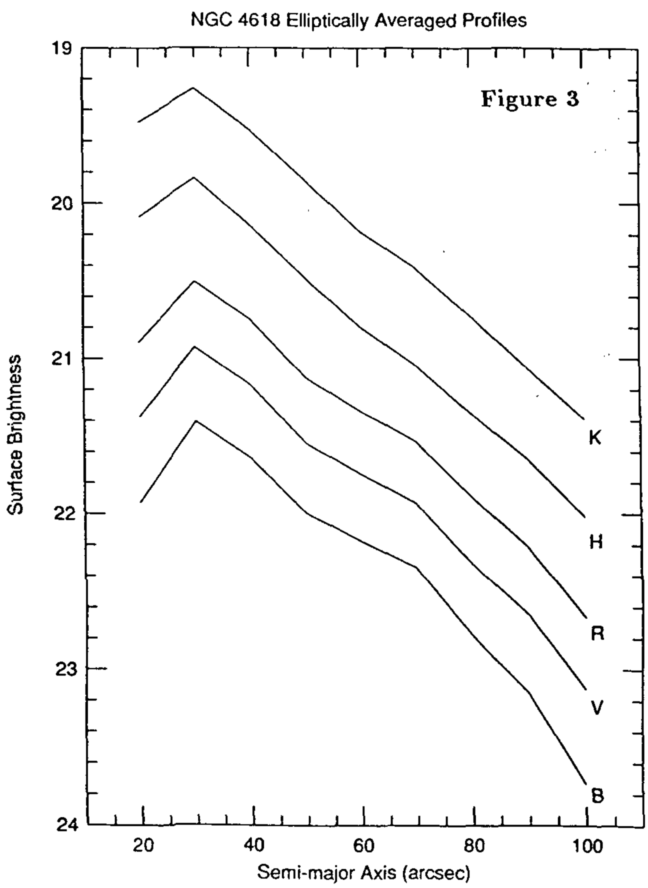
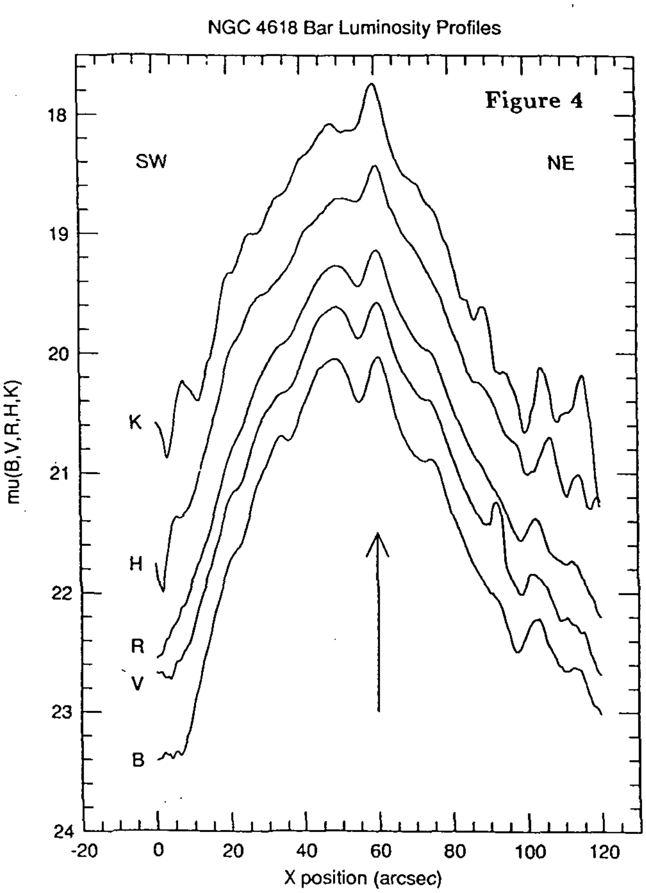


Figure 2



NGC 4618 Elliptically Averaged Profiles
Figure 3
Surface Brightness
Semi-major Axis (arcsec)
19
20
21
22
23
24
20
40
60
80
100
K
H
R
V
B



NGC 4618 Bar Luminosity Profiles
Figure 4
SW
NE
mu(B,V,R,H,K)
X position (arcsec)
18
19
20
21
22
23
24
-20
0
20
40
60
80
100
120
K
H
R
V
B