MEASURING SPIRAL ARM TORQUES: M100 IN K

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Spiral arms exert gravitational torques on stars that lead to redistribution of angular momentum within galactic disks: in the inner part stars lose angular momentum and fall towards the center of galaxy and in the outer part stars gain angular momentum and move farther away from the center. These torques depend only on the non-axisymmetric mass distribution and can be measured directly from photometry, if light traces mass. The method to calculate the gravitational torques is described in Gnedin, Goodman, and Frei 1995 (hereafter GGF).

We used the GRIM II camera on the Apache Point Observatory 3.5 meter telescope to obtain a K' band (2.1μ) image of M100 (NGC 4321) for comparison with GGF's optical I,R, & V band CCD images. Due to the small field of view of the camera ($123''$) we used a mosaic of 187 15-second exposures to cover the inner $4' - 5'$. Each exposure was sky-subtracted, flat-fielded, and corrected for a fluctuating bias level in the camera electronics (see also Rhoads 1995). Foreground stars were removed using Z. Frei's semi-automatic procedure (Frei 1995). The resulting image is shown in Fig. 1.

The image was deprojected according to $i \sim 27°$, $PA \sim 158°$ (GGF). We decompose the surface light distribution into polar Fourier harmonics. Corresponding Fourier harmonics are in good agreement among the three optical bands. Generally, the harmonics in K follow the main optical features but have more noise. However, the $m = 1$ component is unusually bright in K. Computation of a rotation curve from the axisymmetric light and comparison with kinematic observations yields $M/L_K \approx 1.16$ in solar units.

To use photometry in the study of dynamical evolution of the stellar disks of galaxies we need a good tracer of the underlying mass (presumably in old stars). Studies by Rix (1993) and Rix & Zaritsky (1995) suggested K band light is the best indicator of the mass. However, Rhoads (1995) showed for

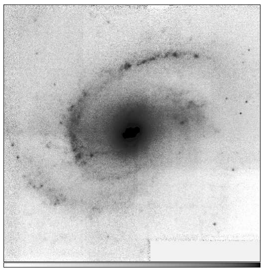

Fig.1: M100 in K.

NGC 1309 that young red supergiants may contribute a significant fraction of the galactic emission in K.

We have compared azimuthal brightness variations for five selected radii. We found that the variations of **even** Fourier harmonics have same amplitude and shape for all colors, from 0.5μ to 2.1μ. The maximum brightness contrast between arm and interarm regions is about 1.2 mag, or a factor of 3, at intermediate radii in M100. However, examine carefully fig. 1. In K band, the upper spiral arm appears much stronger than its lower counterpart. Bright knots along the arm are presumably young red supergiants in OB associations. They correlate with similar knots seen in optical V in GGF. Thus we observe that young stars are prominent in K. Since the Fourier harmonics represent global (azimuthally integrated) non-axisymmetric features, the observed $m = 1$ enhancement should have a serious impact on photometrically derived properties of spirals (such as lopsidedness of stellar disks).

Thus our first result is: we report that **young red supergiants in M100 contribute a significant fraction of the K light**, as proposed recently by Rhoads (1995). Therefore, K light may not be the best tracer of the old stellar population. We suggest that any conclusions concerning *dynamics* of spiral galaxies should rest on multi-band photometry, and not on K alone.

Second, we confirm our measurement of the torque reported in GGF, since it is dominated by the $m = 2$ component. Consistency among all bands in the $m = 2$ component indicates the robustness of the procedure. If the present epoch is representative, the timescale for angular momentum transport in M100 is about 6 Gyr (GGF). It may thus seriously affect the axisymmetric disk structure over a Hubble time. This work was supported in part by NASA grant NAGW-2491.

References

Frei, Z. 1995, PASP, in press
Gnedin, O. Y., Goodman, J., & Frei, Z. 1995, AJ, 110, 1105 [GGF]
Rhoads, J. E. 1995, this volume
Rix, H.-W. 1993, PASP, 105, 999
Rix, H.-W. & Zaritsky, D. 1995, this volume