IV

BARRED GALAXIES

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MORPHOLOGY, STELLAR KINEMATICS AND DYNAMICS OF BARRED GALAXIES

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ABSTRACT

A brief review is given of the morphology of barred galaxies, following Kormendy (1981, 1982). The features illustrated include bulges, bars, disks, lenses, and inner and outer rings.

Most of the paper is devoted to a detailed discussion of the absorption-line velocity field of the prototypical SB0 galaxy NGC 936. The stars in the bar region show systematic non-circular streaming motions, with average orbits which are elongated parallel to the bar. Beyond the end of the bar, the data are consistent with circular orbits. The bar region also shows large random motions: the velocity dispersion at one-half of the radius of the bar is 1/2-2/3 as large as the maximum circular velocity. The observed kinematics are qualitatively and quantitatively similar to the behavior of n-body models by Miller and Smith (1979) and by Hohl and Zang (1979). The galaxy and the models show similar radial dependences of simple dimensionless parameters that characterize the dynamics. These include the local ratio of rotation velocity to velocity dispersion, which measures the relative importance of the ordered and random motions discussed above. Also similar are the residual streaming motions (relative to the circular velocity) in a frame of reference rotating with the bar. Circulation is in the same direction as rotation in all galaxies studied to date. Thus, except for the fact that NGC 936 has a slightly larger velocity dispersion, both n-body models are good first-order approximations to bars. Thus bars are different from elliptical galaxies, which in general are also triaxial, but which rotate slowly. This study of NGC 936 will be published in Kormendy (1983).

A brief discussion is given of the kinematics of lens components. In both barred and unbarred galaxies, the velocity dispersions in the inner parts of lenses are large. The ratio of rotational to random kinetic energy is $\sim$ 1/2 at 1/3-1/2 of the radius of the lens. This ratio then decreases to small values at the rim of the lens. Thus at least some kinds of disk components have large stellar velocity dispersions, even in unbarred galaxies.

E. Athanassoula (ed.), Internal Kinematics and Dynamics of Galaxies, 193–196.

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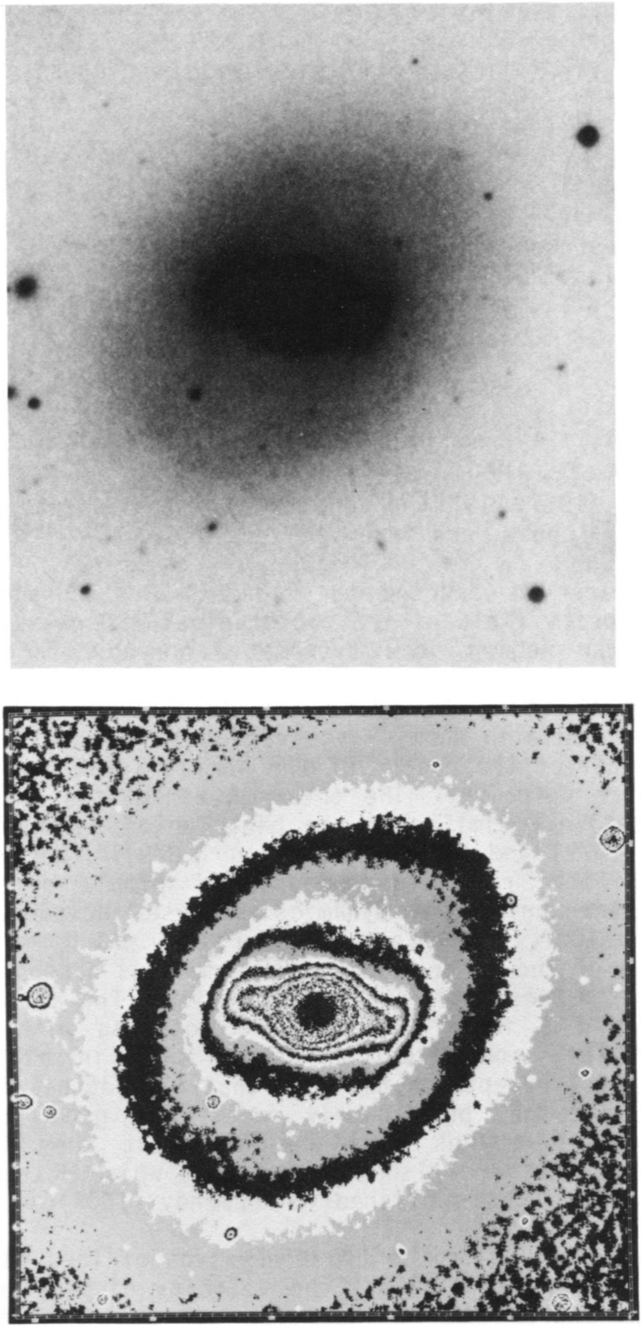

Fig. 1 Photograph and isodensity tracing of NGC 936.

REFERENCES

Hohl, F. and Zang, T.A. : 1979, Astron. J. 84, 585.
Kormendy, J. : 1981, in The Structure and Evolution of Normal Galaxies, ed. S.M. Fall and D. Lynden-Bell, p. 85, Cambridge : Cambridge University Press.
Kormendy, J. : 1982, in Morphology and Dynamics of Galaxies, Twelfth Advanced Course of the Swiss Society of Astronomy and Astrophysics ed. L. Martinet and M. Mayor, in press Sauverny : Geneva Obs.
Kormendy, J. : 1983, Astrophys.J., in preparation.
Miller, R.H. and Smith, B.F. : 1979, Astrophys.J. 227, 785.

DISCUSSION

RICHSTONE : You compare your observed dependence of V/σ along the bar to that in N-body models. You could also compare V and σ separately with a free scale factor. Have you tried that ?

KORMENDY : Not yet in detail. However, the rotation velocity V(r) and dispersion σ(r) behave similarly in NGC936 and in the models beyond the central region dominated by the bulge. V(r) rises gradually to a V = constant rotation curve which is reached slightly interior to the end of the bar. The dispersion drops by a factor $\sim$ 2-3 from near the center to the end of the bar. At a more detailed level there are differences, some of which are physically significant and some not. The galaxy has a bulge, so its rotation curve is higher at small radii than in the models. The models do not have dark halos, so V(r) is not constant but is falling at large radii. In addition the models are anisotropic in the equatorial plane, with a larger dispersion parallel to the length of the bar than across it. This is not seen in the data. More quantitative comparisons will be given in a paper on NGC936, which will be published soon in Astrophys. J.

SELLWOOD : The Miller and Smith and Zang and Hohl models do not have anything like the central concentration of NGC 936. Is it remarkable that the velocity fields agree so well ?

KORMENDY : The central concentration of NGC 936 is contained in the bulge. This produces a peak in V(r) at small radii. In this region the galaxy and models behave very differently. At larger radii the bulge is apparently felt only as a fuzzy central mass, which is no longer very important compared to the rest of the mass distribution. So it is perhaps not too surprising that the galaxy and models are similar over the outer two-thirds of the length of the bar. The agreement actually surprises one more because the models are so much thicker than we assume the galaxy to be.

SANDERS : If lenses are hot and flat, then the velocity distribution must be highly anisotropic. Do you have any evidence for this ? Have you observed any face-on lenses and detected a small velocity dispersion ?

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KORMENDY : There is no direct evidence for the large velocity anisotropy. The small axial dispersion is inferred from photometric studies of edge-on galaxies with lenses. For example, Tsikoudi (1977, Ph. D. Thesis, University of Texas at Austin ; 1980, Astrophys. J. Suppl., 43, 365) and Burstein (1979, Astrophys. J., 234, 829) conclude that the lens is part of the thin disk in the edge-on, probably SB0 galaxy NGC 4762. In general, half of all edge-on galaxies are barred, but edge-on galaxies do not obviously divide themselves into two groups with thin and thick disks. All this suggests that lenses are flat, despite their large planar dispersion. Direct measurements of the axial dispersion are needed to test this conclusion, but will be difficult to obtain.

CHRISTIAN : You indicated that you chose galaxies which are likely to have integrated spectra similar to the spectrum of a single template star. Does the integrated spectrum of such a galaxy change at all with position angle, that is, from along the bar to perpendicular to the bar ?

KORMENDY : I have seen no sign of a change in spectral properties with position angle. In SB0 galaxies the bulge, bar and disk have similar populations. Interestingly, at intermediate Hubble types ($\sim$ SBb ; e.g., NGC 2523), the bar has the same population as the bulge and not the disk (which is blue and full of HII regions). This is true despite the fact that the bar is part of the disk. The above preliminary remarks are based on the morphology, on broad-band color measurements, and on a qualitative examination of the present spectra. No detailed study has been made of stellar populations in barred galaxies.