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DYNAMICS OF EARLY-TYPE GALAXIES. III. THE ROTATION CURVE OF THE S0 GALAXY NGC 4762

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ABSTRACT

We present the rotation curve of the flat S0 galaxy NGC 4762, derived from measurements of the absorption lines of Ca II H and K out to a distance of 1'.1 (5 kpc) from the nucleus. This curve shows a moderate central gradient and a steady increase up to a value of 165 km s^{-1}, with no definite indication that the turnover velocity has been reached. Using a simple model, we estimate that the mass up to the last observed point is $3.5 \times 10^{10} M_{\odot}$. The corresponding mean mass-to-light ratio has the small value $M/L_B = 4$. It is pointed out that S0's and spiral galaxies appear to possess similar amounts of angular momentum.

Subject headings: galaxies: individual — galaxies: internal motions — galaxies: structure

I. INTRODUCTION

NGC 4762 is an early-type edge-on galaxy which has been classified $S0_1$ by Sandage (1961) and S(r)B0^0 by de Vaucouleurs and de Vaucouleurs (1964). In his recent classification scheme, van den Bergh (1976) designates it as S0b, i.e., an S0 with a disk-to-bulge diameter ratio in the range from 3 to 10. The photograph published in the Hubble Atlas (Sandage 1961) clearly shows that this galaxy possesses a bright nucleus surrounded by a faint spheroidal component and an extremely thin, sharply bounded disk structure. The faint outer regions at the ends of the disk look warped on the deep exposure.

Its location in the sky together with its corrected systemic velocity of 907 km s^{-1} (this paper) suggests that NGC 4762 is a member of the Virgo cluster. Therefore, using the same distance modulus as in Bertola and Capaccioli (1975, hereafter Paper I) for NGC 4697, we will assume for NGC 4762 the distance of 14.8 Mpc ($H = 75$ km s^{-1} Mpc^{-1}).

In his photographic photometry of this galaxy, van Houten (1961) tried to separate quantitatively the bulge from the disk component. Information on color variations is also available from low-resolution photoelectric photometry published by Strom *et al.* (1976). According to de Vaucouleurs, de Vaucouleurs, and Corwin (1976, RC2), the total apparent magnitude of NGC 4762 is $m_B = 11.125$ mag. The corresponding absolute magnitude, with a correction of 0.25 mag to account for galactic absorption, is $M_B = -19.98$ mag.

Minkowski (1962) has measured a mean velocity dispersion of 195 km s^{-1} in the central region (from 4'' to 18'' along the major axis), while Faber and Jackson (1976) give a value less than 150 km s^{-1}. NGC 4762 has been also detected at 21 cm in emission (Krumm and Salpeter 1976). With a 3'.2 beam, the source appears unresolved and exhibits a full line width of 300 km s^{-1} at 20% of the peak level.

In the comment to the photograph published in the Hubble Atlas, Sandage (1961) describes NGC 4762 as the galaxy possessing the flattest form of any galaxy known. This property induced us to include it in our program of observations of rotation curves of early-type galaxies.

II. THE ROTATION CURVE: OBSERVATIONS

In order to derive the rotation curve of NGC 4762, four spectra of the galaxy were recorded with the image-tube spectrograph attached to the Cassegrain focus of the 5 m Palomar reflector. The slit was set across the nucleus along the major axis at P.A. 30°. All the spectra, listed in Table 1, cover the same wavelength range, from about 3300 to 5000 Å, with a dispersion of 80 Å mm^{-1}. The scale normal to the dispersion is 42'' mm^{-1}. No emission from the galaxy is detected. The only measurable features are the absorption lines H and K of Ca II which extend over the full length of the slit (~80''). For both measurements and reductions, we adopted the same procedure described in Paper I. The radial velocities were derived up to a distance of about 70'' on both sides from the nucleus of the galaxy, where the surface brightness is

TABLE 1

NGC 4762: SPECTROSCOPIC MATERIAL

Spectrum No.	Date	Exposure (minutes)	Remarks
Q1916	1970 April 6	30	Nucleus SW end of the slit
Q1917	1970 April 6	30	Nucleus NE end of the slit
Q1918	1970 April 6	10	Nucleus centered
Q1944	1970 April 9	20	Nucleus SW end of the slit

NOTE.—All spectra have been taken at P.A. 30°.

TABLE 2

HELIOCENTRIC RADIAL VELOCITIES ALONG P.A. 30°*

DISTANCE FROM CENTER (arcsec)	VELOCITY (km s^{-1})			
	Q1916	Q1917	Q1918	Q1944
SW 67.2......	...	811	...	...
63.0......	...	793	...	...
58.8......	...	830	...	...
54.6......	...	872	...	...
50.4......	...	850	...	...
46.2......	...	830	...	...
42.0......	...	815	...	...
37.8......	...	840	...	...
33.6......	...	872	...	...
29.4......	...	859	...	...
25.2......	...	830	...	...
21.0......	...	851	880	...
16.8......	...	862	901	841
12.6......	938	882	913	904
8.4......	923	898	918	917
4.2......	914	898	931	921
0.0......	970	968	959	954
4.2......	1004	1046	1002	1001
8.4......	1039	1039	1038	1057
12.6......	1060	...	1076	1065
16.8......	1073	...	1085	1083
21.0......	1099	...	1068	1080
25.2......	1118	...	1076	1088
29.4......	1142	...	...	1105
33.6......	1161	...	...	1113
37.8......	1114	...	...	1096
42.0......	1092	...	...	1088
46.2......	1113	...	...	1175
50.4......	1105	...	...	1122
54.6......	1136	...	...	1196
58.8......	1160	...	...	1194
NE 63.0......	1149	...	...	...

* See Table 1 for reference.

$\mu_{pg} = 20.9$ mag arcsec^{-2} (van Houten 1961). Mean velocities from the two lines are given in Table 2 and plotted in Figure 1 for individual spectra. A mean difference of 8 km s^{-1} was found in the radial velocities from H and K lines, with an internal agreement of ± 14 km s^{-1} on each single measurement. The systemic heliocentric velocity, obtained by taking the mean of all the velocities for points less than 8″.4 from the nucleus, is 970 ± 20 km s^{-1} (907 km s^{-1} when galactic rotation is taken into account). This value is in good agreement with the previous measures of 933 km s^{-1} (mean Mount Wilson and Lick from Humason, Mayall, and Sandage 1956) and 935 km s^{-1} from 21 cm line (Krumm and Salpeter 1976).

The mean points plotted in Figure 2 are obtained from the radial velocities of Table 2 after reflection with respect to the nucleus and to the systemic velocity of the galaxy. The full line is a smooth polynomial interpolation through them and represents the observed rotation curve along the major axis of NGC 4762 out to 70″ from the center. The central slope within 10″ from the nucleus is 7.5 km s^{-1} arcsec^{-1}. This rather small value may reflect the averaging effect introduced by the rather large radial distance subtended by the scanning slit of the measuring machine (8″). It is apparent from Figure 2 that the observed rotation curve tends to increase slightly from about 30″ outward up to a value of 165 km s^{-1}. This figure is consistent with the half-width of the hydrogen profile (Krumm and Salpeter 1976), which gives an estimate of the maximum radial velocity of the gaseous component within 100″ from the center. However, we are unable to conclude that we have reached the turnover velocity. It is possible that the radial-velocity curve may still be increasing beyond 70″ from the center, as observed in NGC 128 (Bertola and Capaccioli 1977, hereafter Paper II).

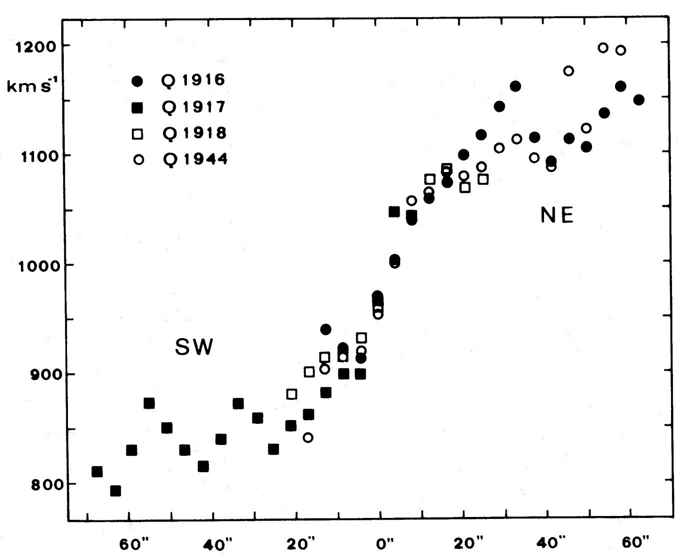

FIG. 1.—Observed heliocentric radial velocities as a function of the distance from the center along the major axis (P.A. 30°) of NGC 4762 from four Palomar spectra.

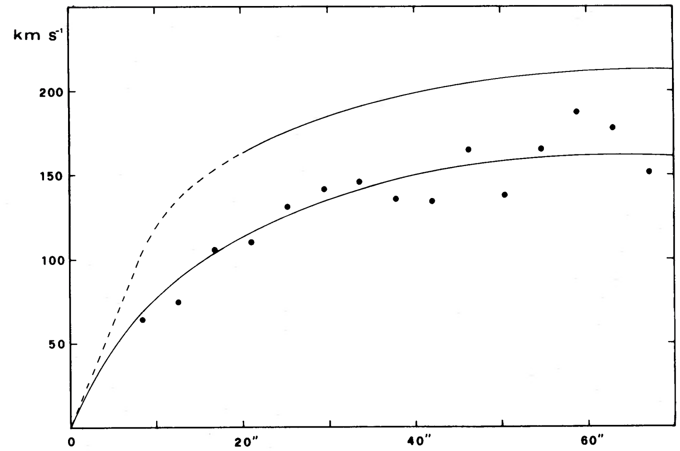

FIG. 2.—Dots are mean values of the radial velocities from four 5 m Palomar spectra as function of the distance from the center along the major axis of NGC 4762, scaled with respect to the heliocentric systemic velocity of 970 km s^{-1}. The solid line through them is a smooth representation of the observed rotation curve up to the last observed point at about 70″. The upper solid line is the deprojected rotational velocity curve, corresponding to the circular velocity of the disk component (see Text). The dashed line is an arbitrary connection to the center.

III. THE ROTATION CURVE: ANALYSIS

In his study, van Houten (1961) gives separate photometry for the bulge and the disk component of NGC 4762. At a distance of 10″ from the nucleus along the major axis, the contribution of the two components is equal; then the disk dominates over the bulge. For this reason the observed rotation curve outside 10″ is predominantly related to the flat component. If one assumes that random motions are negligible in the flat disk, then the observed velocity of rotation is simply the projection of the circular velocity along the line of sight. It is clear, however, that in the inner region, where the bulge is dominant, any dynamical discussion must also include the velocity dispersion. Following the procedure of Paper II, we confine our analysis to only that part of the rotation curve which is due to the flat component.

The upper solid line of Figure 2 represents the trend of the circular velocity in the disk of NGC 4762 outside 20″. It has been computed from the observed rotation curve by using formula (1) of Paper I, which holds under the assumptions listed there. No correction for inclination is needed, since NGC 4762 is seen edge-on. The weighting function is the luminosity profile given by van Houten (1961). Since this profile falls rapidly at 100″, the technique of extrapolating the observed rotation curve outside the last observed point, as required by formula (1), does not significantly affect the final result.

The partial circular velocity curve obtained in this way enables us to derive the mass of NGC 4762 up to the last observed point, i.e., 5 kpc from the nucleus along the major axis. We apply to our data the spheroidal model (Burbidge, Burbidge, and Prendergast 1959) with a constant axial ratio of 0.15, as indicated by van Houten's (1961) photometry. To perform the calculations, the velocity curve has been arbitrarily extended to the center, as shown by the dashed line of Figure 2. However, it is easy to prove that the uncertainty due to different reasonable extrapolations of the circular velocity curve toward the center will affect the mass determination by less than 10%. No allowance has been made to account for the increase of the axial ratio in the first few seconds of arc from the center. With the assumed distance of 14.8 Mpc, we find that the mass of NGC 4762 within 70″ from the center is $3.5 \times 10^{10}\, M_{\odot}$. In order to derive the mass-to-light ratio, we have integrated the luminosity profile given by van Houten (1961) within the same area. After correction for galactic absorption, we obtain $L_B = 9 \times 10^9\, L_{\odot}$. With this we obtain a mean mass-to-blue-light ratio, $M/L_B = 4$.

IV. CONCLUSIONS

As shown in Figure 2, NGC 4762 exhibits a rotation curve which, in the range of our observations, has a maximum value of 165 km s^{-1}. This becomes 200 km s^{-1} when corrected for projection. There are only five more bona fide S0's for which an extended rotation curve is now available, namely, NGC 128 (Paper II), NGC 3115 (Williams 1975), NGC 4111 (reported by van Houten 1961), NGC 5866 (Simkin 1972), and NGC 7332 (Morton and Chevalier 1973). All of them have the maximum of their observed radial-velocity curve in the range from 160 to 260 km s^{-1}, with no evident correlation with galaxy luminosity. When these are compared with the distribution of the maxima of the rotational velocity curves of spirals (Brosche 1971) it is apparent that S0 galaxies possess rotational velocities comparable to those of early-type spirals. This is not the case for true ellipticals of similar luminosity, such as NGC 4473 (Morton and Chevalier 1972), NGC 4621 (C. J. Peterson, unpublished), and NGC 4697 (Paper I). These rotate at least a factor of 2 more slowly than the S0's discussed above.

The mass-to-blue-light ratio obtained for NGC 4762 is low. It is almost a factor of 2 smaller than that found in Paper II for the much brighter S0 NGC 128. This fact suggests the possible existence of a relation between M/L_B and the absolute luminosity L_B for S0's which is similar to that found for elliptical galaxies (Faber and Jackson 1976). It is also clear that the mean M/L_B value of S0 galaxies is very similar to that of spirals (see, for instance, de Vaucouleurs 1974). This is particularly interesting in itself, since similar values have been also found for the cores of ellipticals (Faber and Jackson 1976). Moreover, if we combine this with the similarity between the kinematical properties of S0's and (early-type) spirals, it seems possible to generalize the conclusion drawn in Paper II for the case of NGC 128, i.e., that these two classes of galaxies share a similar amount of angular momentum.

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REFERENCES

Bertola, F., and Capaccioli, M. 1975, *Ap. J.*, **200**, 439 (Paper I).
———. 1977, *Ap. J.*, **211**, 697 (Paper II).
Brosche, P. 1971, *Astr. Ap.*, **13**, 293.
Burbidge, E. M., Burbidge, G. R., and Prendergast, K. H. 1959, *Ap. J.*, **130**, 26.
de Vaucouleurs, G. 1974, in *IAU Symposium No. 58, Formation and Dynamics of Galaxies*, ed. J. R. Shakeshaft (Dordrecht: Reidel), p. 1.
de Vaucouleurs, G., and de Vaucouleurs, A. 1964, *Reference Catalogue of Bright Galaxies* (Austin: University of Texas Press).
de Vaucouleurs, G., de Vaucouleurs, A., and Corwin, H. G. 1975, *Second Reference Catalogue of Bright Galaxies* (Austin: University of Texas Press) (RC2).
Faber, S. M., and Jackson, R. E. 1976, *Ap. J.*, **204**, 668.
Humason, M. L., Mayall, N. U., and Sandage, A. R. 1956, *A.J.*, **61**, 97.
Krumm, N., and Salpeter, E. E. 1976, *Ap. J.* (*Letters*), **208**, L7.
Minkowski, R. 1962, in *IAU Symposium No. 15, Problems of Extragalactic Research*, ed. G. McVittie (New York: Macmillan), p. 112.
Morton, D. C., and Chevalier, R. A. 1972, *Ap. J.*, **174**, 489.
———. 1973, *Ap. J.*, **179**, 55.
Sandage, A. R. 1961, *The Hubble Atlas of Galaxies* (Washington: Carnegie Institution).
Simkin, S. M. 1972, *Nature*, **239**, 43.
Strom, S. E., Strom, K. M., Goad, J. W., Vrba, F. J., and Rice, W. 1976, *Ap. J.*, **204**, 684.
van den Bergh, S. 1976, *Ap. J.*, **206**, 883.
van Houten, C. J. 1961, *Bull. Astr. Inst. Netherlands*, **16**, 1.
Williams, T. B. 1975, *Ap. J.*, **199**, 586.

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