THE ASTROPHYSICAL JOURNAL, **193**:19–25, 1974 October 1

# TIDAL EFFECTS AS CRITERIA FOR MEMBERSHIP IN SMALL GROUPS OF GALAXIES: APPLICATION TO VV 166

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*Received 1974 April 12; revised 1974 May 20*

## ABSTRACT

Brightness distributions of galaxies in clusters are distorted by gravitational tidal forces due to their neighbors. In particular, the brightness profiles are truncated at radii determined by the minimum separation from perturbing objects. The presence or absence of these effects is evidence for or against cluster membership of galaxies with discrepant redshifts.

The galaxy group VV 166 (the NGC 70 group) is a compact group of 8 galaxies, one of which, NGC 68, has a velocity 1000 km s$^{-1}$ smaller than the average. New velocities are presented for seven objects; the best mean values yield a velocity dispersion of 404 km s$^{-1}$ if NGC 68 is included, or 240 km s$^{-1}$ if it is omitted. These imply mass-to-light ratios $M/L$ of 144 and 70 in solar units ($H_0 = 75$ km s$^{-1}$ Mpc$^{-1}$). When the galaxies are weighted in the averaging according to their assumed relative masses, the values become 186 and 51, respectively. A brightness profile has been measured for NGC 68. This reveals no departure from a de Vaucouleurs relation to 70″, or ~30 kpc, radius, which equals the galaxy's separation from its neighbors. The absence of tidal distortion, and the dynamical implausibility of a group whose most massive member has the most loosely bound orbit, makes it unlikely that NGC 68 is a member of VV 166. Then the implied $M/L \simeq 51$ is reasonable for a group of spirals and ellipticals.

*Subject headings:* galaxies, clusters of — redshifts

## I. MOTIVATION

Whenever a galaxy's motion takes it too close to another massive object, gravitational tidal forces will distort its surface brightness profile, and can remove its outer envelope. This effect has been noted and measured previously, for example by King (1962), Hodge (1963), Rood (1965), and King and Kiser (1973). The process has also been advanced as the explanation of the abnormally high surface brightnesses of certain compact elliptical galaxies (Faber 1973).

In this paper we will explore the use of tidal distortions for another purpose, namely as indicators of galaxy membership in small groups or clusters. In ordinary loose clusters of galaxies, the tidal limiting radius (King 1962) can be measured and could be used as a firm criterion for membership. However, in very compact groups the galaxies are so close together that their light distributions overlap. Tidal truncation is then not evident, but is replaced by a general sharing of stars in a common gravitational well. Accordingly we can only use the presence or absence of tidal distortion in a galaxy's luminosity profile at radii comparable to its projected separation from nearby objects. These methods have potential application to the problem of apparent redshift discrepancies in clusters of galaxies (e.g., Burbidge and Sargent 1971). We will study here the NGC 70 group (VV 166). Although it does not contain a wildly discrepant object, as does, for example VV 172 (Sargent 1968), it does contain an elliptical galaxy, NGC 68, whose velocity makes its membership suspect, and which is reasonably well located for our purposes.

VV 166 is described in § II, and new redshift measurements are listed for seven of the objects. Section III is devoted to an application of the virial theorem; we show that the presence or absence of NGC 68 makes a difference of a factor of 2–4 in the mass-to-light ratio $M/L$ deduced for the system. In § IV we determine isophotes for the cluster region, and a radial light distribution westward from NGC 68. Based on these data, arguments against the membership of NGC 68 are then presented in § V.

## II. THE NGC 70 GROUP (VV 166)

The compact group of galaxies around NGC 70 has been described by Holmberg (1937) and by van den Bergh (1961), who pointed out its resemblance to Stephan's Quintet. The group is illustrated by Vorontsov-Vel'yaminov (1958), where it is VV 166. There is an excellent photograph of the system in Arp's (1966) *Atlas of Peculiar Galaxies*, where it is object no. 113. The group comprises four relatively bright galaxies NGC nos. 70, 68, 71, and 72, together with four fainter galaxies NGC nos. 67 and 69, the object designated NGC 72A in the *Reference Catalogue* (de Vaucouleurs and de Vaucouleurs 1964), and an anonymous galaxy 0ʹ.8 Spr NGC 67. Keys to the identification of the galaxies are given in table 1 and in figure 1. We have classified the galaxies from the reproduction in Arp's atlas; the resulting types are listed in table 1. We note that two of the four bright galaxies are spirals and two are ellipticals. In table 1, the photographic magnitudes $m_p$ are taken from Zwicky and Kowal (1968), or, if in parentheses, are our own estimates. VV 166 is ~ 1° northeast of the center of a loose cluster Zw Cl 0013.6+2927 (Zwicky and Kowal 1968), which contains 145 galaxies over an irregular area 1°.8 in diameter. The surface concentration of

TABLE 1

DATA FOR NGC 70 GROUP (VV 166)

| GALAXY | NGC | REDSHIFT (km s$^{-1}$) This Paper | Ref. Cat. | Mean | $m_p$ | TYPE |
|---|---|---|---|---|---|---|
| F........ | 67 | 6832 | ... | 6832 | 15.7 | E5 |
| B........ | 68 | 5877 | 6011 | 5944 | 14.5 | E1 |
| E........ | 69 | 6937 | 6861 | 6899 | 15.7 | S0 |
| A........ | 70 | 7356 | ... | 7356 | 14.5 | Sc |
| C........ | 71 | 6913 | 6815 | 6864 | 14.8 | E1 |
| D........ | 72 | 7161 | 7200 | 7181 | 15.0 | SBa |
| H........ | 72A | ... | 7031 | 7031 | (16.0) | E |
| G........ | Anon. | 6554 | ... | 6554 | (16.0) | E5 |

galaxies around NGC 70 is about 25 times that in the cluster as a whole. It is, therefore, reasonable to treat VV 166 as a separate dynamical entity.

Both van den Bergh (1961) and Karachentsev (1966) studied the virial mass of VV 166. Based on only five redshifts they deduced high mass-to-light ratios, namely $M/L = 350$ (van den Bergh, $H_0 = 100$ km s$^{-1}$ Mpc$^{-1}$) and $M/L = 190$ (Karachentsev, $H_0 = 75$ km s$^{-1}$ Mpc$^{-1}$). Since VV 166 is one of the best examples of a compact cluster of galaxies, it was decided to measure more redshifts—particularly that of NGC 70. We also remeasured the redshift of NGC 68, which is about 1000 km s$^{-1}$ lower than the mean defined by the other members of the group. These new measurements were made with the Cassegrain image tube spectrograph on the Hale telescope. The spectrograms have a dispersion of 90 Å mm$^{-1}$. The redshifts of seven galaxies in VV 166 were measured; four of these, including NGC 68, have redshifts listed in the *Reference Catalogue*. A comparison of the measurements for these four objects indicate that the new observations are systematically lower than those in the *Reference Catalogue* by 37 km s$^{-1}$. Accordingly all the new measurements have been corrected by this amount. The resulting values are listed in column (3) of table 1; all velocities have been corrected for solar motion. The new measurement confirms that NGC 68 has a redshift about 1000 km s$^{-1}$ lower than the mean for VV 166.

## III. APPLICATION OF THE VIRIAL THEOREM

The virial theorem as applied to clusters of galaxies has been derived by Limber and Mathews (1960). Let $M$ be the mass of the cluster, $v_i$ the radial velocity of the $i$th galaxy, and $r_{ij}$ the separation in the plane of the sky of any pair of galaxies $i$ and $j$. With $V = \sum_{\text{galaxies}} \mu_i v_i$, we then have

$$\text{Kinetic Energy} \simeq \frac{3}{2} M \sum_{\text{galaxies}} \mu_i (v_i - V)^2 \, ;$$

$$\text{Potential Energy} \simeq -\frac{2}{\pi} G M^2 \sum_{\text{pairs}} \mu_i \mu_j / r_{ij} \, ,$$

$$M = \frac{3\pi}{2G} \frac{\sum_i \mu_i (v_i - V)^2}{\sum_{i,j,i<j} \mu_i \mu_j / r_{ij}} \, . \qquad (1)$$

In the above, $\mu_i$ is the fractional mass of the $i$th galaxy. To avoid the necessity of making more complicated assumptions about $\mu_i$, it is common to treat all galaxies as being equal in mass. Equation (1) then reduces to

$$M = \frac{3\pi}{2G} \frac{n^2 \sigma_r^2}{\sum_{i,j,i<j} 1/r_{ij}} \, , \qquad (2)$$

where $n$ is the number of galaxies and $\sigma_r$ is the radial velocity dispersion. This is a poor approximation in the present case, because NGC 68, which has the largest velocity with respect to the group, probably also has the largest mass. Equation (2) would greatly underestimate its influence in the group. We will therefore adopt equation (1), weighting galaxies according to their masses by using the luminosity and assuming $(M/L)_{\text{ellipticals}} = 6\,(M/L)_{\text{spirals}}$. For completeness, and to indicate the sensitivity of the results to weighting, we will also give the results of assuming all galaxies equal in mass.

Table 2 lists the dynamical parameters derived for the group. A Hubble constant of 75 km s$^{-1}$ Mpc$^{-1}$ and a galactic absorption of 0.24 mag cosec ($b$) = 0.45 mag have been assumed. Note that the radial velocity dispersion in row (2) must be corrected for measurement errors. We estimate from a comparison of our new redshifts with those in the *Reference Catalogue* that the standard deviation of a single measurement is $\pm 60$ km s$^{-1}$. This reduces the velocity dispersions as shown in row (3).

If NGC 68 is included, its large mass and velocity require that the group be very massive if it is to be in equilibrium. The resulting $M/L \simeq 186$ is large compared with commonly accepted values of $M/L \simeq 5$ for

TABLE 2

DYNAMICAL PARAMETERS OF THE NGC 70 GROUP

| QUANTITY | ALL EIGHT GALAXIES Weighted | ALL EIGHT GALAXIES Unweighted | OMITTING NGC 68 Weighted | OMITTING NGC 68 Unweighted |
|---|---|---|---|---|
| Systematic velocity.............. | 6573 km s$^{-1}$ | 6833 km s$^{-1}$ | 6901 km s$^{-1}$ | 6960 km s$^{-1}$ |
| $\sigma_v$ (uncorrected)................. | 483 km s$^{-1}$ | 404 km s$^{-1}$ | 204 km s$^{-1}$ | 240 km s$^{-1}$ |
| $\sigma_v$ (corrected).................. | 480 km s$^{-1}$ | 400 km s$^{-1}$ | 195 km s$^{-1}$ | 233 km s$^{-1}$ |
| $\langle 1/r_{ij} \rangle^{-1}$...................... | 40 kpc | 49 kpc | 50 kpc | 54 kpc |
| Mass........................ | $2.56 \times 10^{13} M_\odot$ | $1.98 \times 10^{13} M_\odot$ | $5.45 \times 10^{12} M_\odot$ | $7.47 \times 10^{12} M_\odot$ |
| Luminosity..................... | $1.376 \times 10^{11} L_\odot$ | $1.376 \times 10^{11} L_\odot$ | $1.074 \times 10^{11} L_\odot$ | $1.074 \times 10^{11} L_\odot$ |
| $M/L$.......................... | 186 | 144 | 51 | 70 |

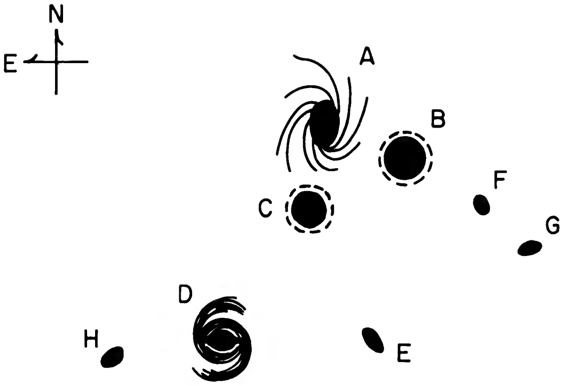

FIG. 1.—Identification chart of the NGC 70 group

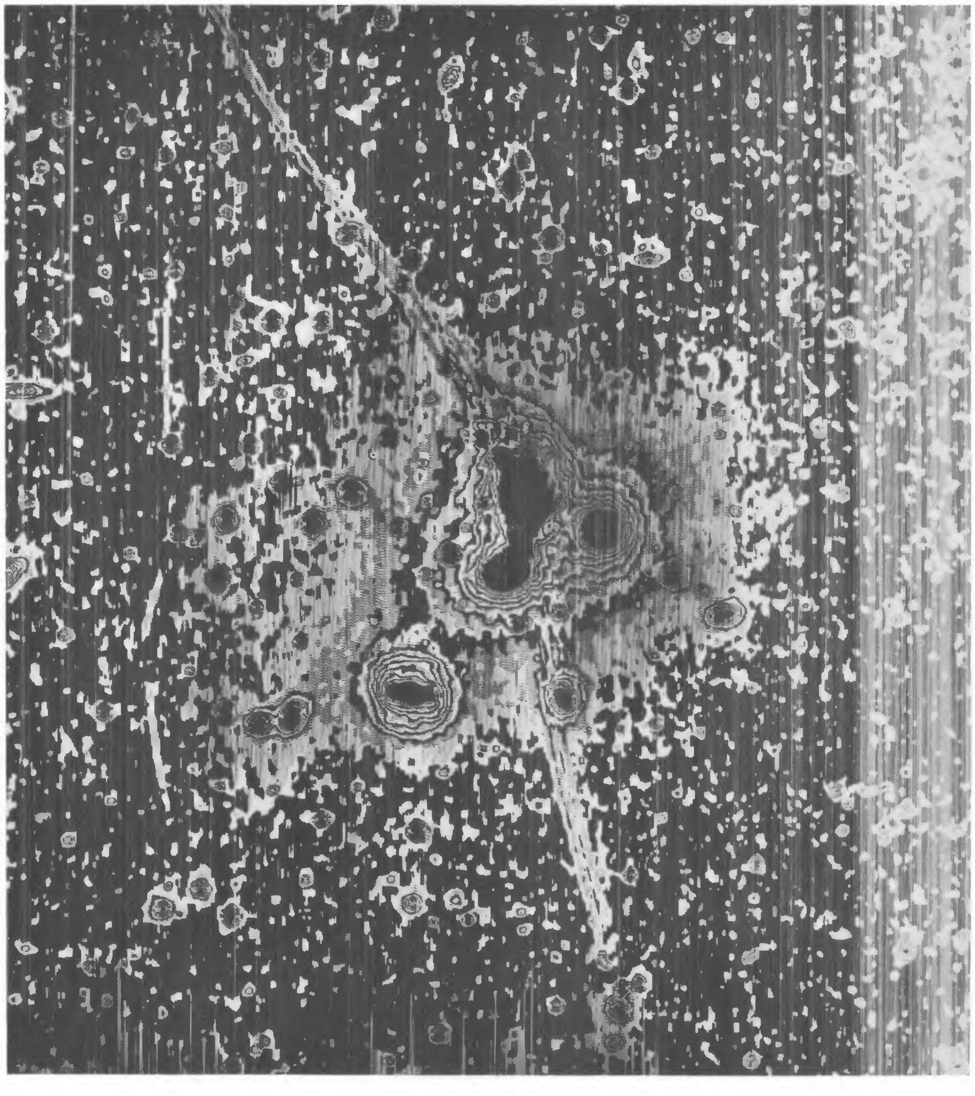

FIG. 3.—Isodensity tracing of the 2-hour Schmidt plate of the NGC 70 group. The density step size is 0.031, and the analyzing spot is 75 μm or 5″.1 × 5″.1. Fig. 1 has the same scale as fig. 3, and can be used as an identification chart. Note that a very prominent scratch crosses the group from NNE to SSW, and a smaller scratch runs NS to the east of the group. Fortunately, neither flaw affects the usefulness of the tracing.

spirals and $M/L \simeq 30$ for ellipticals. This result is not sensitive to errors in the weighting factors; even the unweighted $M/L \simeq 144$ is large.

On the other hand, if NGC 68 is omitted, the mass-to-light ratio drops to $M/L \simeq 51$. NGC 71 (E1) then dominates the system, and the four most massive members, with the above assumptions, are the elliptical galaxies. Considering the kinds of errors inherent in a virial theorem analysis of such a small group, the derived value of 51 is entirely reasonable. This result is again not sensitive to errors in the weighting.

Is there an independent test of whether NGC 68 is a member of VV 166? Fortunately, the galaxy lies near one edge of the group. Thus its light distribution should be little enough contaminated by its neighbors to allow us to use these data to make deductions about membership. Accordingly, we investigate in §§ IV and V what limits can be placed on the three-dimensional proximity of NGC 68 to the rest of the cluster by looking for tidal distortion in the galaxy's light distribution.

## IV. THE SURFACE BRIGHTNESS DISTRIBUTION OF NGC 68

The brightness profile of NGC 68 has been measured in the $G$ photometric system discussed by Kormendy and Bachall (1974). To study the central parts of the galaxy, two 40-minute exposures were obtained at the Newtonian focus of the Mount Wilson 100-inch (2.5-m) telescope. Kodak special plate, Type 124-01, which is equivalent to the former 103a-J, was used with a Wr 4 filter. Both plates were calibrated with 1-hour exposures through a density-step mask in contact with the emulsion. The diffuse density of any strip in the mask was assumed to define its transmission. The outer parts of NGC 68 were recorded on IIIa-J plates baked $4\frac{1}{2}$ hours in a dry nitrogen atmosphere at 68° C. One 2-hour and one 3-hour exposure were obtained with a Wr 4 filter and the Palomar 48-inch (1.2-m) Schmidt telescope. The plates were calibrated in a region masked off from the sky exposure with 1.5-hour and 2-hour spot sensitometer exposures. At this time, the sky was exceptionally dark, with an estimated $B$ surface brightness near 22.7 mag per square arcsecond; this enabled us to extend the measurements to fainter than normal brightness levels. All plates were developed for 9 minutes in MWP-2 developer. Finally, we note that the plates were taken on four different nights.

All measurements were made with the Caltech microphotometer, using the technique described by Kormendy (1973). The composite luminosity distribution is based on six partial profiles made with slit sizes ranging from 0″.5 × 1″.8 to 3″.6 × 7″.5. Near the nucleus, four full scans across the galaxy were averaged. However, at fainter light levels, due to light contamination by nearby galaxies A and C, the measurements were restricted to a 100° sector around the westward direction. The immediate vicinity of galaxies F and G was also avoided. Then three half-scans outward from the nucleus were averaged to give each partial profile at large radii. The partial profiles were fitted together by minimizing the scatter in the measurements.

TABLE 3

Photoelectric Photometry of NGC 68

| Magnitude or Color | 14″.5 Aperture | 15″.2 Aperture |
|---|---|---|
| $V$ . . . . . . . . . . . | 14.81 ± 0.06 | 14.59 |
| $U - B$ . . . . . . . . | 0.47 ± 0.03 | . . . |
| $B - V$ . . . . . . . . | 1.06 ± 0.02 | 1.08 |
| $V - R$ . . . . . . . . | 0.96 ± 0.02 | 0.90 |

To obtain the zero point of the magnitude scale, we have made photoelectric $UBVR$ measurements of NGC 68 through a 14″.5 aperture using the Palomar 60-inch (1.5-m) telescope and pulse counting electronics. Table 3 lists our results, together with Sandage's (1973) photometry through a 15″.2 aperture. The error estimates are based on the mean deviation of the four measurements made, and on the degree of reproducibility of the photometric system, which varies slightly with the particular standard stars chosen from Sandage's (1973) list. The colors are in reasonable agreement, but when corrected for the different aperture size, our $V$-magnitude is 0.15 mag fainter than Sandage's. Since some of this could be due to the relatively greater difficulty of centering the galaxy in the 60-inch telescope as compared with the 100-inch, the $V$-magnitude used has been weighted 2:1 in favor of Sandage's value. $V$ is then converted to $G$ using the relation $B - G = 0.65\,(B - V)$ found by Kormendy and Bahcall (1974). Identifying with this $G$-magnitude the relative brightness profile integrated to the radius of the photometer apertures then gives the zero point.

The composite luminosity distribution westward of NGC 68 is given in table 4 and illustrated in figure 2. We estimate the photometric errors as follows. The mean deviation of the measurements from the adopted profile shown is smaller than 0.05 mag at all radii greater than 0″.7. This suggests that cumulative scale errors introduced by fitting together the profile segments are small. Experimenting with the fitting procedure shows that such errors could be ~0.05 mag between 22 and 25 mag per square arcsecond and ~0.10 mag at levels fainter than this. To the limiting surface brightness adopted in figure 2 there are two profile segments; they agree to better than 0.1 mag and have similar slopes. We will adopt 0.1 mag as our

TABLE 4

Luminosity Distribution Westward of NGC 68

| $r^{1/4}$ (arc sec) | $\mu_G$ | $r^{1/4}$ (arc sec) | $\mu_G$ | $r^{1/4}$ (arc sec) | $\mu_G$ |
|---|---|---|---|---|---|
| 0.0 . . . . . . | 18.56: | 1.6 . . . . . . | 21.35 | 2.5 . . . . . . | 24.88 |
| 1.0 . . . . . . | 18.99 | 1.8 . . . . . . . | 22.20 | 2.6 . . . . . . | 25.20 |
| 1.1 . . . . . . | 19.35 | 2.0 . . . . . . | 22.99 | 2.8 . . . . . . | 25.86 |
| 1.2 . . . . . . | 19.81 | 2.2 . . . . . . | 23.75 | 3.0 . . . . . . | 26.51 |
| 1.4 . . . . . . | 20.57 | 2.4 . . . . . . | 24.54 | 3.2 . . . . . . | 27.17 |

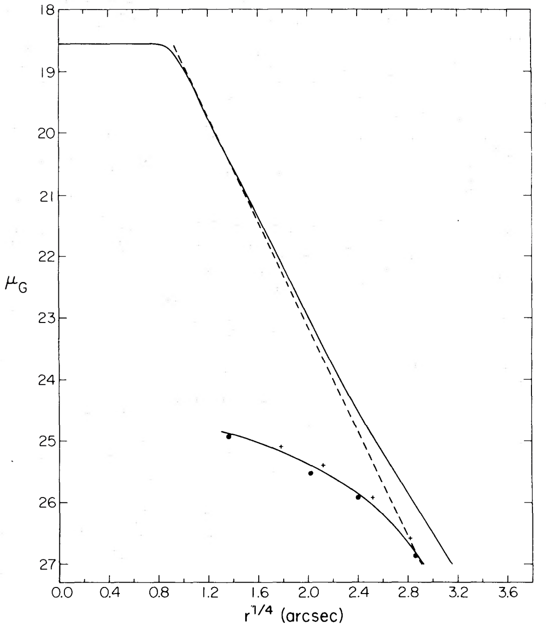

FIG. 2.—Luminosity distribution in NGC 68. Surface brightness in *G*-magnitudes per square arcsecond is plotted against the one-fourth power of the radius in arcsec. The upper curve is the mean composite profile westward of NGC 68. The lower curve is the adopted contamination, as defined by the dots (from a tracing of the 2-hour Schmidt plate) and crosses (from the 3-hour plate; see the text for details). The dashed line is then the approximate profile of NGC 68, corrected for contamination.

estimated relative brightness error, and 0.1 mag as the possible error in the zero point. However, there are a number of sources of error whose effects are difficult to estimate. These include errors in calibration; i.e., in the relation between density and intensity. Since we have a photoelectric zero point at only one radius, we have no direct check on the calibration. However, we note that the profile slopes on plates obtained with the 100-inch and 48-inch telescopes are in agreement, despite the different densities and calibration methods involved. Also, a previous photoelectric check on the spot sensitometer used for the Schmidt plates revealed no noticeable scale errors (Kormendy 1973). The second problem involves possible contamination by light from the nearby galaxies. To investigate this, we have obtained several isodensity tracings of the Schmidt plates with a Joyce-Loebl microdensitometer. As shown in fig. 3, all the galaxies are embedded in a bright common envelope (cf. Kormendy and Bahcall 1974). The *G* surface brightness detected by the outermost four contours are, from the composite profile, 27.0, 25.9, 25.5, and 24.9 mag per square arcsecond, to ~0.15 mag. We can estimate the contamination due to galaxies A and C by assuming that their brightness distribution is symmetric about a north-south line midway between them. This will tend to overestimate the required correction since the line A–C–D is concave away from B = NGC 68, and since the concave side of the line will have the higher surface brightness. Calibrating the isodensity contours as above gives the contamination contribution shown as the lowest curve in figure 2. Subtracting this from the composite profile gives an estimate of the surface brightness distribution in NGC 68 (*dashed line* in fig. 2). These observations are satisfied between 1″ and 70″ by a de Vaucouleurs (1948) relation $\log(I/I_0) = -3.33\,[(r/r_0)^{1/4} - 1]$, with $r_0 = 15''$ (6.3 kpc) and $\mu_{I_0} \equiv \mu(r_0) = 22.8$ *G* mag per square arcsecond. Similarly, the uncorrected data satisfy a de Vaucouleurs relation between 1″ and 35″, with $r_0 = 20''$ (8.8 kpc) and $\mu(r_0) = 23.4$ *G* mag per square arcsecond. The deviation at larger radii is presumably due to contamination. The correct profile is between the above two, and is probably undistorted by any tidal effects out to at least 70″ (~30 kpc).

## V. DISCUSSION

Let us consider the implications of the above results on the possible membership of NGC 68 in VV 166. The radius $R_{\text{obs}} = 30$ kpc out to which the galaxy's brightness profile is undistorted is almost as large as the harmonic mean separation $R_0 = 50$ kpc of the other galaxies. We will show that this, coupled with the high mass of NGC 68 makes it unlikely that the galaxy is a member of the group.

Suppose first that the galaxy is closely bound, so that its typical separation from its neighbors is near $R_0$, or alternatively, near the projected distance ~$0.6\,R_0$ to the other two bright members of the group, galaxies A and C. Then the characteristic orbital time scale in the group is at least as small as the free-fall time scale, ~$5 \times 10^8$ years, in the outer envelope of NGC 68. Thus the galaxy cannot have retained an undistorted envelope of radius $R_{\text{obs}} \simeq 0.6\,R_0$; indeed, there has been time for several even closer encounters. Even if the galaxy presently finds itself far out and at one side of the group, there is insufficient time to repopulate its envelope in the way observed. The result will be a common halo around the group, composed of stars dynamically shared by its members. The halo stars either were stripped tidally from the outer envelopes of the galaxies if they formed before the group became as compact as it is today, or were presumably formed in situ. Therefore NGC 68 cannot be as closely bound in the group as its present projected separation from its neighbors.

We can estimate how close NGC 68 can have come to any massive perturbing galaxies. King (1962) has shown that a galaxy's tidal radius $r_t$ is approximately related to the minimum separation $R_{\min}$ of the two objects concerned by the equation

$$r_t \simeq R_{\min}\,[m/4M]^{1/3}\,.$$

Here $m$ and $M$ are, respectively, the mass of the perturbed and perturbing galaxy, and an eccentricity of ~1 has been assumed for the orbit. For reasons discussed in the above paper, we will make no correction for any dynamical readjustment in the radius of the galaxy after an encounter. The fact that $R_{\text{obs}} \simeq R_0$ implies, as discussed above, that NGC 68 cannot come very close to its neighbors. Then we assume temporarily that the rest of the group is a dynamical entity interacting with NGC 68. We will discuss this assumption further below. Adopting, from § III, a mass ratio of $m/M \simeq \frac{1}{4}$ and using $R_{\rm obs}$ for $r_t$, gives

$$R_{\min} > 2.5\, R_{\rm obs} \simeq 75 \text{ kpc}\,.$$

In fact, $r_t$ must be considerably larger than $R_{\rm obs}$, so that $R_{\min} \gtrsim 10^2$ kpc. Comparing this with the harmonic mean separation 50 kpc of the other galaxies in VV 166 suggests that NGC 68 is not a member of the group.

Additional evidence is provided by the isodensity tracing in figure 3. As we have already mentioned, galaxies A, B, and C are roughly equidistant from each other. However, the contours around B = NGC 68 are relatively little influenced by the presence of A and C. Especially in the north, where there is no outlying galaxy to affect the observations, the contours are relatively circular around NGC 68 until they come quite near NGC 70, and then they *abruptly* change direction. There is no sign of any tidal distortion; the observed contours are consistent with light contamination being the only effect present. On the other hand, galaxies A and C are more prominently connected, and the contours east of the pair are more distorted.

Finally, a purely dynamical argument can be used against the membership of NGC 68 in VV 166. If it were a member, it would have the largest energy and therefore the most eccentric orbit in the group. But then we would have a very massive particle in a loosely bound orbit around several less massive particles and some essentially massless test particles. The latter form a compact unit, with the test particles having a much smaller velocity dispersion than the velocity discrepancy of the most massive galaxy. This is a violently unstable situation. Within one or two orbital periods of NGC 68 (i.e., several times $10^9$ yr), the swarm of test particles will no longer be more compact than the group of massive particles. In fact, there will be a tendency for the test particles to acquire some of the excess energy of NGC 68, and therefore to have relatively high velocities (cf. Szebehely and Peters 1967). Thus the type of orbit we have assumed is very improbable.

For all of these reasons, it seems very likely that NGC 68 should be excluded from the virial theorem analysis of VV 166. Then the weighted velocity dispersion of 204 km s$^{-1}$ implies a mass of $5.5 \times 10^{12}\, M_\odot$ for the group, and a mass-to-light ratio of 51 $M_\odot/L_\odot$. NGC 68 may still be a member of Zw Cl 0013.6+2927, but is only accidentally seen in projection to be very close to the group.

In the present case there remains some small doubt about the effects of contamination of the light distribution of NGC 68 by nearby galaxies. The situation could be improved somewhat by making a two-dimensional intensity map of the region, but the corrections required would probably remain too large to allow an estimate of the galaxy's limiting radius. Similarly, we cannot search for tidal distortions in the profiles of the other elliptical galaxies except insofar as they appear in figure 3. For instance, NGC 71, the other bright elliptical, is surrounded on three sides by bright neighbors. Thus VV 166 is at the compact end of the range of groups that can be studied by the present technique. The effects of tidal distortion, and especially the use of tidal limiting radii as criteria for group membership, should therefore be useful for investigating velocity anomalies in more ordinary clusters of galaxies.

We thank Dr. I. King for helpful comments on the manuscript. One of us (J. K.) is partly supported by the National Research Council of Canada. W. S. wishes to thank Professor D. E. Blackwell and Dr. J. V. Peach for their hospitality at the Department of Astrophysics, Oxford University where part of this work was done.

## REFERENCES

Arp, H. C. 1966, *Ap. J. Suppl.*, **14** (No. 123).
Burbidge, E. M., and Sargent, W. L. W. 1971, in *Study Week on Nuclei of Galaxies*, ed. D. J. K. O'Connell (Vatican City: Pontificia Academia Scientiarum).
de Vaucouleurs, G. 1948, *Ann. d'Ap.*, **11**, 247.
de Vaucouleurs, G., and de Vaucouleurs, A. 1964, *Reference Catalogue of Bright Galaxies* (Austin: University of Texas Press).
Faber, S. M. 1973, *Ap. J.*, **179**, 423.
Hodge, P. W. 1963, *A.J.*, **68**, 691.
Holmberg, E. 1937, *Lund Obs. Ann.*, No. 6.
Karachentsev, J. D. 1966, *Astrofizica*, **2**, 81.
King, I. 1962, *A.J.*, **67**, 471.
King, I. R., and Kiser, J. 1973, *Ap. J.*, **181**, 27.
Kormendy, J. 1973, *A.J.*, **78**, 255.
Kormendy, J., and Bahcall, J. N. 1974, *A.J.*, **79**, 671.
Limber, D. N., and Mathews, W. G. 1960, *Ap. J.*, **132**, 286.
Rood, H. J. 1965, *A.J.*, **70**, 689 (Abstract).
Sandage, A. 1973. *Ap. J.*, **183**, 711.
Sargent, W. L. W. 1968, *Ap. J. (Letters)*, **153**, L135.
Szebehely, V., and Peters, C. F. 1967, *A.J.*, **72**, 876.
van den Bergh, S. 1961, *A.J.*, **66**, 566.
Vorontsov-Vel'yaminov, B. A. 1958, *Atlas and Catalog of Interacting Galaxies* (Moscow: Moscow State University).
Zwicky, F., and Kowal, C. T. 1968, *Catalogue of Galaxies and of Clusters of Galaxies*, Vol. **6** (Pasadena; California Institute of Technology).

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