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# GLOBULAR CLUSTERS IN THE INTERACTING GALAXIES NGC 1549 AND NGC 1553

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## ABSTRACT

We have identified globular cluster populations in the interacting early-type galaxies NGC 1549 and NGC 1553. Starcounts on a deep Anglo–Australian Telescope prime-focus plate reveal that the globular clusters are spatially distributed in a way that seems to mimic the extrapolation of the underlying distribution of halo light. In NGC 1553 alone, there is evidence of a central deficit of clusters analogous to that seen in NGC 4486 (M87), although that finding may be an artifact of the photographic study. The azimuthal distribution of clusters around each galaxy seems random, despite the manifest interaction. Finally, the specific frequencies of the globular cluster populations are low: $S_{1549} = 1.0 \pm 0.5$, $S_{1553} = 2.5 \pm 1.0$. Given that NGC 1549 and NGC 1553 are in a sparse group, this finding provides yet more evidence for a picture within which the specific frequency of globular cluster populations depends to first order upon parent galaxy environment.

## I. INTRODUCTION

To date, extragalactic globular cluster systems (GCSs) have been studied predominantly in supergiant elliptical galaxies located in rich clusters. The familiar examples include M87 and several other Virgo Cluster ellipticals (Hanes 1977; Harris 1988a; Grillmair *et al.* 1986), NGC 3311 in Hydra (Harris, Smith, and Myra 1983), NGC 1399 in Fornax (Hanes and Harris 1986a), the central ellipticals in the Coma cluster (Harris 1987; Thompson and Valdes 1987), and NGC 6166, the central cD galaxy in Abell 2199, a cluster of richness class II (Harris 1989). Studies have also been made in the fields of several relatively cluster-poor spiral and lenticular galaxies (van den Bergh and Harris 1982; Harris *et al.* 1985; Hanes and Harris 1986b) and in the peculiar galaxy NGC 5128 (Harris *et al.* 1984).

Among other things, these studies have revealed a puzzling disparity of GCS property from galaxy to galaxy. For example:

(1) The radial surface density profile of the GCS is significantly shallower than that of the halo luminosity in some galaxies, including M87, but is similar to the halo light in other galaxies in apparently similar environments (including NGC 3311 and NGC 1399).

(2) In some galaxies, but not all, there is a central deficit of globular clusters (as inferred from turndowns in the projected density profiles). The reasons for such central deficits are unknown; for instance, the disruption of globular clusters by processes such as dynamical friction and tidal shocking (which are only effective within 1–2 kpc of the galactic center) cannot explain the globular cluster distribution near the center of M87 (Lauer and Kormendy 1986; Grillmair *et al.* 1986). In other words, such central deficits, or cores, may be relics of galaxy formation and not reflect any subsequent dynamical evolution (Harris 1988a).

(3) The specific frequency $S$ of GCSs [the number of globular clusters per unit ($M_V = -15$) galaxian luminosity, as originally defined by Harris and van den Bergh (1981)] varies from galaxy to galaxy in a way that appears to depend to first order upon the galactic surroundings: galaxies in richer environments have more abundant cluster systems. Superabundant systems are also seen, with specific frequencies three to five times the average for galaxies in rich clusters; generally these are giant ellipticals located in the dynamical centers of rich clusters (such as M87 in Virgo), but central location alone is no guarantee of such a superfluity (NGC 6166 provides a counterexample; Harris 1989). Moreover, a couple of dwarf galaxies [the Fornax dwarf spheroidal in the Local Group; Anon 2 in the field of NGC 3115 (Hanes and Harris 1986b)] also have GCSs of large specific frequency but are otherwise undistinguished.

A complete understanding of these disparate properties will require the identification and study of GCSs in many more galaxies, so that we may investigate the relative importance of galaxy type and luminosity, environment, the dynamical effects of interactions between galaxies, the dynamical effects internal to single galaxies leading to the disruption of individual globular clusters, cooling flows and the implications for star and cluster formation, and so forth.

Both in single and in interacting galaxies, globular clusters may serve as luminous dynamical test particles that permit studies of galactic mass distributions in regions not otherwise accessible [see, for example, the analyses of the M87 cluster system dynamics by Huchra and Brodie (1987) and Mould *et al.* (1987)]. Moreover, the very existence of superabundant GCSs has on occasion been attributed—without much success—to the results of galaxy mergers or globular cluster "swapping" in galaxy interactions [see Muzzio (1987) for a comprehensive review]. It would be especially useful to identify interacting pairs of galaxies with rich GCSs amenable to subsequent dynamical study. In this paper we report the detection and preliminary assessment of the globular cluster populations associated with an interacting pair of southern elliptical/lenticular galaxies, NGCs 1549/1553. While the original motivation for the study was the extension of a more general program to galaxies in sparse environments, it is apparent that this system is of special interest for the reasons noted just above.

The paper will take the following form: In Sec. II, we describe the program galaxies and summarize the evidence for interactions. In Sec. III, we describe the plate material used in the GCS detections and explain our starcount procedures. In Sec. IV, we present an analysis of the counts, deriving radial projected surface density profiles (which we compare to the underlying luminosity distributions), total cluster populations, and specific frequencies. Finally, in Sec. V, we summarize our principal conclusions.

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## II. THE PROGRAM GALAXIES

The program galaxies, NGC 1549 and NGC1553, were among a set chosen by Hanes for photographic investigation at the Anglo–Australian Telescope (AAT) in a study of GCSs in sparse environments. The salient properties of the galaxies are given in Table I. Figure 1 [Plate 41] is a reproduction of a limiting AAT prime-focus plate (103a-J + GG385) that will be further described in Sec. III. A contrast-enhanced version of that plate, prepared at our request by Dr. David Malin of the AAT, is shown in Fig. 2 [Plate 42]. It is apparent that these two early-type galaxies are interacting: streamers and shell-like features are seen to extend beyond 5 arcmin radius, and were reported by Malin and Carter (1988).

The existence of an interaction was earlier suggested by Freeman's (1975) surface photometry of NGC 1553, which revealed a warp in the disk, and by Jedrzejewski's (1987) finding of twisted outer isophotes in NGC 1549. In confirming Jedrzejewski's analysis, Franx *et al.* (1989) report that NGC 1549 is one of the most extreme cases (in their sample of 17 galaxies studied) in this respect.

NGC 1549 and NGC 1553 appear in the Southern Catalogue of Peculiar Galaxies (Arp and Madore 1987), where they are described without elaboration as a "close pair." As such, they are fairly well isolated on the sky, but are in fact members of the moderate-sized Dorado group (G16), according to de Vaucouleurs (1975). More recently, Tully (1988) has assigned NGC 1549 and NGC 1553 to the NGC 1566 cluster (his group G53-1), which is essentially identical to that defined by de Vaucouleurs; it contains 13 galaxies.

## III. STARCOUNT DATA

### *a) Starcount Procedures*

In Table II, we describe the single AAT prime-focus plate used for this study. Following the procedures outlined by Hanes and Harris (1986b), we carried out double-blind starcounts for each galaxy in turn. A superposed reseau, centered on the galaxy of interest, was used to subdivide the field into 12 radial annuli of width $3.16 \pm 0.02$ mm (corresponding to $0.806 \pm 0.005$ arcmin) and 18 equal sectors. For a central plate scale of 15."3/mm, our counts reach to 9.7 arcmin radius. The corrections for field distortion (as tabulated in the AAT User's Manual) were negligible over these scales and were ignored.

The galaxy-to-galaxy separation is 11.8 arcmin, so that each galaxy in turn lay well outside the outermost annulus while the other was being counted. Nonetheless, it is important to consider the effect of any intrusion into the reseau by the globular cluster "cloud" of the second galaxy, especially insofar as it may lead to biases in determinations of the asymptotic background level. We have subdivided our data according to various restrictions in azimuth and radius to assess the importance of the effect, and find it to be negligible—not surprisingly, given that such excesses as are seen (Sec. IV*a*) are significant only in the innermost few annuli around each galaxy. (For a distance scale corresponding to $H_0 = 75$ km s$^{-1}$ Mpc$^{-1}$, the projected separation of the galaxies amounts to some 40 kpc.)

We counted all visible images, making no attempt to distinguish between those of stellar and nonstellar appearance. Counts were made for every cell in the reseau, except for those in the innermost circle (annulus 1, extending to a radius of 0.806 arcmin), which is centered on the galaxy and is heavily overexposed.

TABLE I. Program galaxies.

| Parameter | NGC 1549 | NGC 1553 | Source |
|---|---|---|---|
| $\alpha$ (1950) | $4^h 14^m.7$ | $4^h 15^m.1$ | RSA[a] |
| $\delta$ (1950) | $-55°42'.9$ | $-55°54'.2$ | RSA |
| $l^{II}$ | 265°.4 | 265°.6 | RSA |
| $b^{II}$ | $-43°.8$ | $-43°.7$ | RSA |
| Classification | E2 | $S0_{1/2}(5)$ pec | RSA |
| $B_{T,0}$ | 10.57 | 10.09 | RC2[b] |
| $(B-V)_{T,0}$ | 0.86 | 0.85 | RC2 |
| $A_B$ | 0.29 | 0.29 | RC2 |
| $V_0$ (km/s) | 938 | 1064 | RC2 |

[a] RSA = Sandage and Tammann (1981).
[b] RC2 = de Vaucouleurs, de Vaucouleurs, and Corwin (1976).

TABLE II. Plate material employed.

| Parameter | Value |
|---|---|
| Plate | AAT 2089 |
| Date | 21/22 March 1982 |
| Telescope | 3.9 m AAT |
| Focus/corrector | *f* 3.3 prime/triplet |
| Emulsion + filter | IIIa-J + GG385 |
| Exposure (min) | 90 |
| Seeing (arcsec) | ~1.5 |

### *b) Comparison of the Counts*

In Fig. 3 we plot the ratios of our counts (in the sense TJB/DAH), summed around each annulus, as a function of annulus number (equivalent to radius) for each field. The broken horizontal lines in Fig. 3 represent the average ratios calculated from the counts summed over the whole reseau. It is evident that the count ratios display no radial trends larger than the uncertainties imposed by size-of-sample effects. Two features, however, warrant special mention:

(1) The overall count ratios are significantly larger than unity (1.33 and 2.00 for NGC 1549 and NGC 1553, respectively); that is, one of us (T.J.B.) counted more objects per field, at all radii, than did the other (D.A.H.).

(2) The overall count ratios are not the same for the two galaxies separately. The raw data reveal that one of us (D.A.H.) had counts that asymptotically fell to very nearly the same level at large radii around each galaxy separately; the other (T.J.B.) saw different asymptotic backgrounds in the two counting sessions. Some differences between "personal equations" are not unusual in work of this nature [see, for example, the description in Harris *et al.* (1984) of their counts in the field of NGC 5128], but they may have been exacerbated here by the fact that T.J.B.'s counts were made in two sessions separated by several months, with no guarantee of identical illumination and so forth.

Given the absence of radial trends and the lack of compelling reasons to question any particular dataset, we have chosen to adopt simple averages of the counts (with the corresponding Poisson size-of-sample uncertainty). Our final conclusions are scarcely sensitive to this treatment. If, for example, we restrict the analysis to the D.A.H. counts only (those with the better internal consistency), the deduced

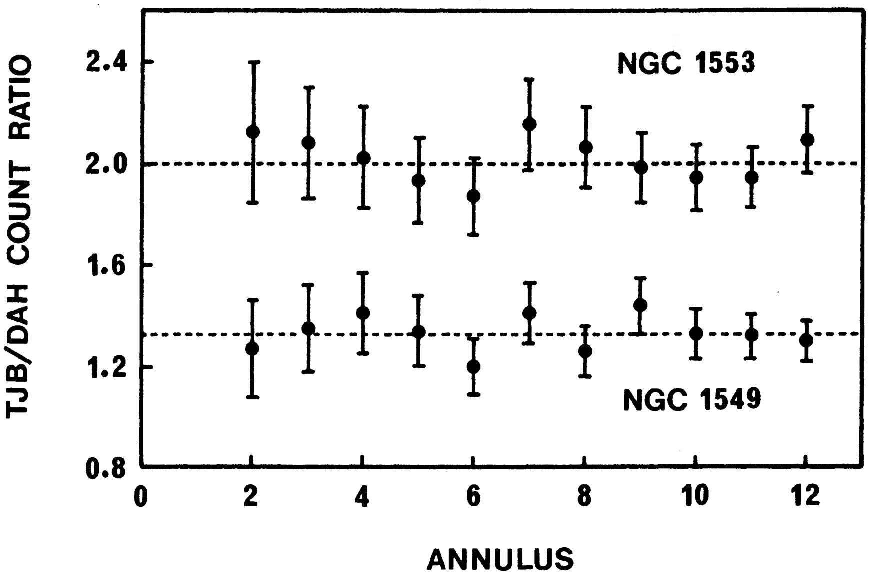



FIG. 3. Ratio of our separate sets of counts (in the sense T.J.B./D.A.H.) summed around annuli and plotted as a function of annulus number (equivalent to radius). The error bars are those implied by the size-of-sample (Poisson) noise in the counts. For each galaxy, the broken line represents the mean ratio implied by the grand sum of all counts by each author. No significant radial trends are seen.

specific frequencies and total populations are reduced by only about 30%, and the rest of our conclusions (such as the apparent agreement between the cluster distribution and the underlying galaxian light) go through unmodified. In the spirit of the double-blind experiment, however, we make no discrimination between the datasets in our averaging, and trust that this procedure serves to minimize any subjective biases.

### *c) Final Starcount Data*

Our final counts are presented in Tables III(a) and III(b), where successive columns give (1) the annulus (or ring) number, with annulus 1, the central circle, containing the galaxy itself; (2) the harmonic mean radius $\bar{r} = (r_i r_{i+1})^{1/2}$, in arcminutes; (3) the area of each annulus, in square arcminutes; (4) the number of objects counted in

TABLE III(a). Starcounts in NGC 1549.

| Ring | $\bar{r}$ (arcmin) | Area (arcmin$^2$) | $n$ | $\sigma$ (arcmin$^{-2}$) | $\sigma_{cl}$ (arcmin$^{-2}$) | $n_{cl}$ |
|---|---|---|---|---|---|---|
| 2 | 1.14 | 6.12 | 94.0 ± 9.7 | 15.36 ± 1.58 | 5.18 ± 1.59 | 31.7 ± 9.7 |
| 3 | 1.97 | 10.21 | 130.5 ± 11.4 | 12.78 ± 1.12 | 2.60 ± 1.14 | 26.6 ± 11.6 |
| 4 | 2.79 | 14.29 | 161.5 ± 12.7 | 11.30 ± 0.89 | 1.12 ± 0.91 | 16.0 ± 13.0 |
| 5 | 3.61 | 18.37 | 190.5 ± 13.8 | 10.37 ± 0.75 | 0.19 ± 0.76 | 3.5 ± 14.0 |
| 6 | 4.42 | 22.45 | 236.0 ± 15.4 | 10.51 ± 0.69 | 0.33 ± 0.70 | 7.4 ± 15.7 |
| 7 | 5.22 | 26.53 | 270.0 ± 16.4 | 10.18 ± 0.62 | 0.00 ± 0.64 | 0.0 ± 17.0 |
| 8 | 6.03 | 30.62 | 327.5 ± 18.1 | 10.70 ± 0.59 | 0.52 ± 0.61 | 15.9 ± 18.7 |
| 9 | 6.84 | 34.70 | 328.0 ± 18.1 | 9.45 ± 0.52 | − 0.73 ± 0.54 | − 25.3 ± 18.7 |
| 10 | 7.65 | 38.78 | 394.5 ± 19.9 | 10.17 ± 0.51 | − 0.01 ± 0.53 | − 0.4 ± 20.6 |
| 11 | 8.45 | 42.86 | 414.5 ± 20.4 | 9.67 ± 0.48 | − 0.51 ± 0.50 | − 21.9 ± 21.4 |
| 12 | 9.26 | 46.94 | 499.5 ± 22.3 | 10.64 ± 0.48 | 0.46 ± 0.50 | 21.6 ± 23.5 |

TABLE III(b). Starcounts in NCG 1553.

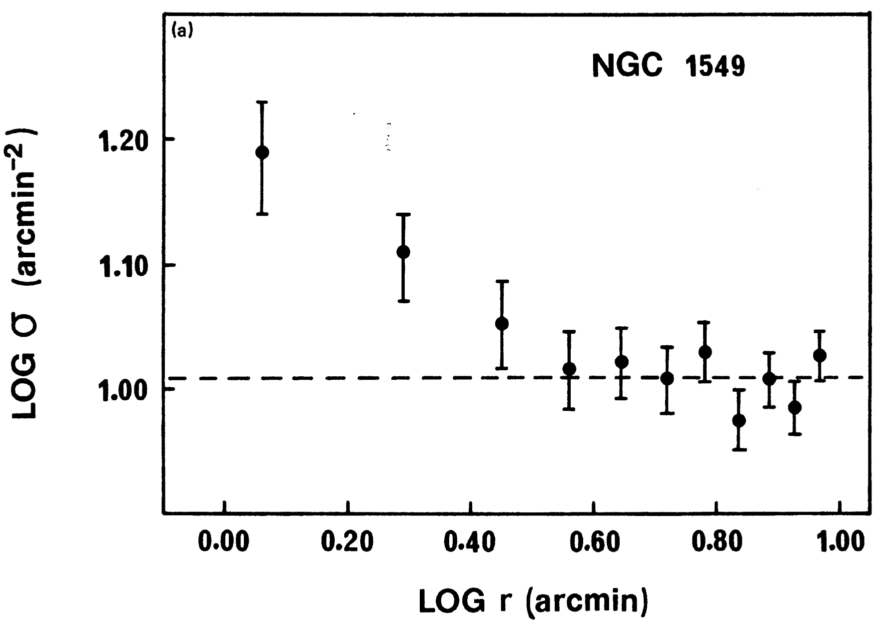
| Ring | $\bar{r}$ (arcmin) | Area (arcmin$^2$) | $n$ | $\sigma$ (arcmin$^{-2}$) | $\sigma_{cl}$ (arcmin$^{-2}$) | $n_{cl}$ |
|---|---|---|---|---|---|---|
| 2 | 1.14 | 6.12 | 132.5 ± 11.5 | 21.65 ± 1.83 | 8.42 ± 1.85 | 51.5 ± 11.3 |
| 3 | 1.97 | 10.21 | 195.5 ± 14.0 | 19.15 ± 1.37 | 5.92 ± 1.39 | 60.4 ± 14.2 |
| 4 | 2.79 | 14.29 | 238.5 ± 15.4 | 16.69 ± 1.08 | 3.46 ± 1.11 | 49.4 ± 15.9 |
| 5 | 3.61 | 18.37 | 276.5 ± 16.6 | 15.05 ± 0.90 | 1.82 ± 0.93 | 33.4 ± 17.1 |
| 6 | 4.42 | 22.45 | 332.5 ± 18.2 | 14.81 ± 0.81 | 1.58 ± 0.84 | 35.5 ± 18.9 |
| 7 | 5.22 | 26.53 | 344.5 ± 18.6 | 12.99 ± 0.70 | − 0.24 ± 0.74 | − 6.4 ± 19.6 |
| 8 | 6.03 | 30.62 | 377.5 ± 19.4 | 12.33 ± 0.63 | − 0.90 ± 0.67 | − 27.6 ± 20.5 |
| 9 | 6.84 | 34.70 | 473.0 ± 21.7 | 13.63 ± 0.63 | 0.40 ± 0.67 | 13.9 ± 23.3 |
| 10 | 7.65 | 38.78 | 533.5 ± 23.1 | 13.76 ± 0.60 | 0.53 ± 0.65 | 20.6 ± 25.2 |
| 11 | 8.45 | 42.86 | 571.0 ± 23.9 | 13.32 ± 0.56 | 0.09 ± 0.61 | 3.9 ± 26.1 |
| 12 | 9.26 | 46.94 | 617.0 ± 24.8 | 13.14 ± 0.53 | − 0.09 ± 0.58 | − 4.2 ± 27.2 |

the annulus, with associated Poisson-statistical uncertainties; (5) the surface density of counts; (6) the surface density of globular clusters after the subtraction of a uniform field surface density, as described in Sec. IV*a*; and (7) the total number of globular clusters in each ring (column 3 multiplied by column 6). We now turn to the analysis of these data.

## IV. ANALYSIS

### *a) Background Density and Limiting Magnitude*

In Figs. 4(a) and 4(b), we present the radial dependence of the surface densities of our starcounts for NGC 1549 and NGC 1553, respectively, in log–log representations. There is obviously a strong and statistically significant central concentration of objects in both galaxies, as well as an asymptotic leveling off to a uniform surface density of field objects at radii larger than about 5 arcmin. From the total counts in the outermost eight annuli for NGC 1549, where no central concentration is evident, we derive a field object ("background") surface density of $\sigma_b = 10.2 \pm 0.2$ arcmin$^{-2}$; the horizontal broken line shows that asymptotic level. Similarly, the six outer annuli for NGC 1553 imply a field object density of $\sigma_b = 13.2 \pm 0.2$ arcmin$^{-2}$, also shown as a broken line. These background surface densities permit a crude determination of the limiting magnitude of the counts,



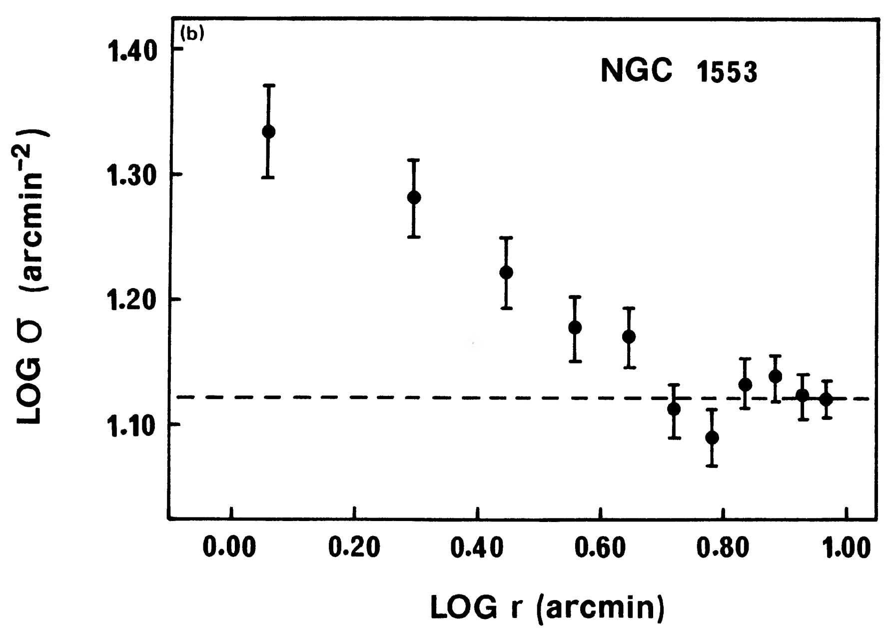




FIG. 4. (a) Radial dependence of the surface density of counts, in a log–log representation, around NGC 1549. The error bars are those implied by size-of-sample effects. The broken line represents the adopted "field" or "background" surface density, and was calculated from a sum of counts in the outermost eight annuli, where no appreciable radial gradient is seen. The adopted background surface density corresponds to $\sigma_b = 10.2 \pm 0.2$ arcmin$^{-2}$. (b) Same as (a), except that the data are for NGC 1553. Here the background surface density (which has a value of $\sigma_b = 13.2 \pm 0.2$ arcmin$^{-2}$ was derived using the outermost six annuli.

as explained in Hanes and Harris (1986a). The estimates are $B_{lim} = 24.9$ mag and $B_{lim} = 25.2$ mag for NGC 1549 and NGC 1553, respectively; these values are likely to be precise to no better than $\pm$ 0.3 mag, an uncertainty consistent with the level of agreement between the separate datasets.

It is worth noting that the inferred globular cluster specific frequencies (Sec. IV*d*) are only slightly sensitive to these limits: if the limits are made *brighter* by, say, 0.5 mag, the specific frequencies change by less than the formal errors imposed by the size-of-sample statistics. The robustness of our determination is a reflection of a fact noted by Hanes and Harris (1986b): for galaxies in the distance range studied here, the globular cluster populations are fairly deeply sampled in a limiting photograph (that is, a fair fraction of the globulars are detected directly), and only relatively small changes in $S$ result from changing assumptions about limiting magnitude and adopted distance.

### *b) Radial Distribution of the Globular Clusters and Comparison with the Halo Light*

In Figs. 5(a) and 5(b) we show the radial dependence of the background-subtracted surface density of objects in the fields of NGC 1549 and NGC 1553, respectively. Multicolor surface photometry for NGC 1549 is available from Franx *et al.* (1989) and Jedrzejewski (1987), but their data are restricted to radii no larger than about 1 arcmin. From Franx *et al.*, we find that the luminosity profile in $R$ has a slope of

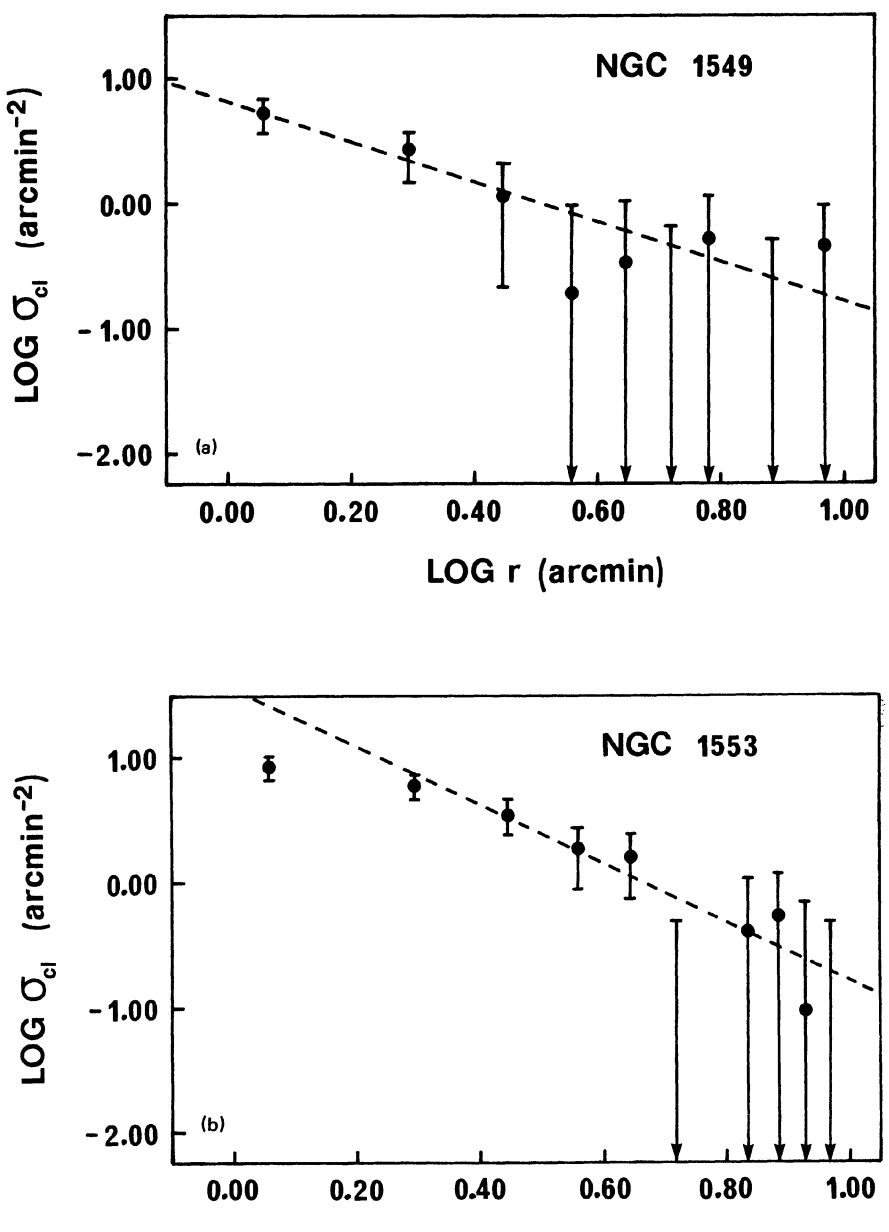



FIG. 5. (a) Radial dependence of the surface density of "excess" objects around NGC 1549, after subtraction of the background level shown in Fig. 4(a), in a log–log representation. The broken line shows the power law dependence of the luminosity profile in $R$ provided by Franx *et al.* (1989), extrapolated beyond the region in which they derived it ($r \leqslant 60$ arcsec) and fitted by eye to the data points. (b) The same as (a), except that the data are for NGC 1553. The broken line shows the power law dependence of the luminosity profile in $V$ derived from Freeman's (1975) Fig. 1(b); his profile extended to $r \sim 150$ arcsec and has been extrapolated here. The fitting was done by eye to all but the innermost data point.

about $-1.6$ (in a log–log representation) between $r \sim 20$ and $r \sim 60$ arcsec. There is no significant color gradient over this range. In Fig. 5(a), we have superimposed a power law of this slope (the broken line) with a vertical scaling determined by eye. The good match to the globular cluster data suggests that the GCS mimics the underlying light. This conclusion depends, of course, on the assumption that the luminosity profile may simply be extrapolated beyond the limits of the studies so far available.

Similar statements may be made for NGC 1553 [Fig. 5(b)] with reference to surface photometry by Freeman (1975). While Freeman's paper gives no tabular results, inspection of his Fig. 1(b) yields a power law of slope $-2.33$ for the major-axis luminosity profile in $V$ over the range 50–150 arcsec. We have again shown that profile as a broken line in Fig. 5(b), after a fitting by eye to all but the innermost data point. It is not clear whether the relatively low value for the globular cluster surface density in the innermost ring plotted (#2) is significant; it may represent a real deficit in the cluster population, or it could simply be due to some incompleteness in the counts owing to obscuration of the innermost annuli by the galaxy itself. It is now well established that genuine central deficits are seen in some GCSs, perhaps the outstanding example of which is M87 (Lauer and Kormendy 1986; Grillmair *et al.* 1986); the reasons are not yet fully understood. NGC 1553 may represent yet another example, of extra interest because it is a galaxy very different in type from M87. It must, moreover, be remembered that Freeman's luminosity profile pertains to the major axis of NGC 1553, while our cluster counts are summed azimuthally around annuli. An *azimuthally averaged* luminosity profile would be somewhat steeper than that presented by Freeman, so that in fact the central deficit of globular clusters would appear yet more significant. Given the uncertain effect of variable photographic backgrounds on the detection threshold in the study reported here, however, the finding must be considered tentative. High-quality CCD data will be needed if the effect is to be confirmed and quantified.

At the suggestion of a referee, we have also compared the distribution of globular clusters with an extrapolation of the underlying light for each galaxy under the assumption of a de Vaucouleurs $r^{1/4}$ law normalized at the outermost radii for which surface photometry exists. In the log–log plane, such representations display a slight downward curvature, and are in fact also satisfactory fits to the data of Figs. 5(a) and 5(b), given the uncertainties. The apparent deficit in NGC 1553 persists. In either case, the agreement may be purely fortuitous: either galaxy, or both, may diverge from these simple extrapolations. (The usual sense of such divergences, in nondisturbed galaxies at least, is such that the luminosity profiles become steeper at large radii.)

### *c) Azimuthal Dependence of the Counts*

In Fig. 6, we show the azimuthal dependence of the number density of objects counted around NGC 1549 and NGC 1553. (We have summed the data over pairs of sectors and over annuli 2–6 to improve the contrast of the globular clusters against the background.) For each dataset, the superimposed horizontal broken line represents the expectation for the same total population uniformly distributed in azimuth. Simple inspection suggests, and a straightforward chi-squared test confirms, that there is no significant dependence of cluster count upon position angle for either dataset.

We have, however, carried out the same statistical test upon our individual datasets, and find just a suggestion (at the $2.5\sigma$ level) in the data of DAH alone that the distribution is nonrandom in the field of NGC 1549, in the sense that there is an excess of counts both toward and away from its companion, NGC 1553. (The marginal excesses show no correlation with the major axis of NGC 1549 itself.) It is tempting, but certainly premature, to speculate that this excess is a result of the interaction between the two galaxies: perhaps we are marginally detecting tidal tails, as modeled by Toomre and Toomre (1972), for example. Deep photometry will improve the statistics and permit a sharper discrimination of this interesting question.

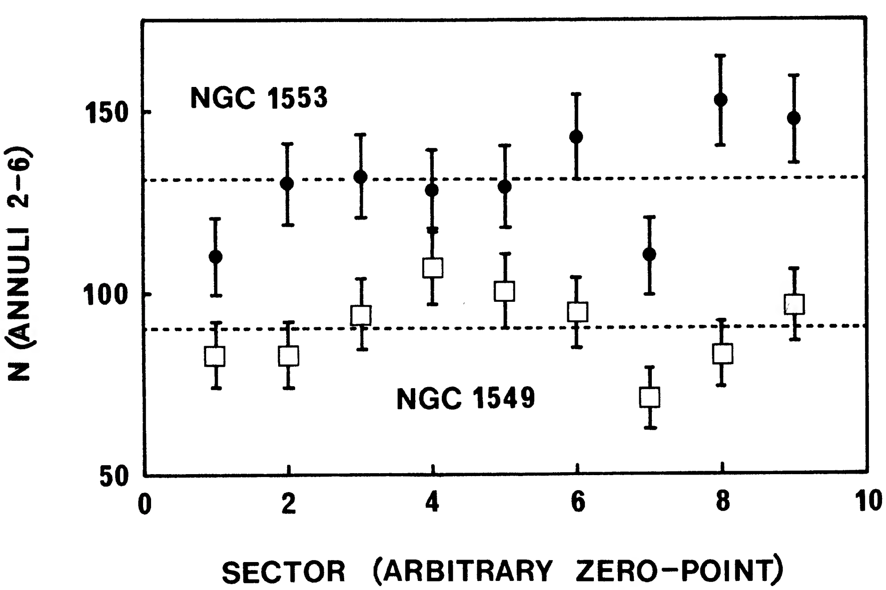



FIG. 6. Azimuthal dependence of the number of objects counted in nine 40° sectors around each galaxy, summed over annuli 2–6 (to increase the contrast against the field). The data for NGC 1549 are shown as open squares, with size-of-sample error bars; those for NGC 1553 are filled circles. The zero point is arbitrary and not necessarily the same for the separate datasets. The broken lines show the expectation in each case for the same total population uniformly distributed in azimuth.

### d) Total Populations and Specific Frequencies

The specific frequency $S$ of a GCS is defined as the number of clusters per unit ($M_V = -15$) luminosity of the parent galaxy (Harris and van den Bergh 1981). Its derivation in the present context requires that we estimate the total globular cluster population and the absolute magnitude of the parent galaxy in each case. The second of these follows directly from an assumption of distance, but the first requires extra assumptions about the form of the globular cluster luminosity function. In brief, our treatment is as follows [see Hanes and Harris (1986b) for more details of these calculations].

We first correct the *observed* globular cluster population for the unseen central portion to derive a *total* population down to the limiting magnitude of the study. Ignoring the possibility of a central deficit in either field, we assume that the globular cluster distribution mimics that of the underlying light and predict the requisite correction from the behavior of the halo luminosity profile (assigning a generous margin of error). In this way, we correct the observed total in NGC 1549 from $74.3 \pm 20.5$ to $110 \pm 40$; for NGC 1553, the total changes from $230.3 \pm 37.2$ to $450 \pm 100$. The large change for NGC 1553 stems, of course, from our perhaps unwarranted assumption that the cluster distribution exactly follows the rather steep luminosity distribution ($\alpha = -2.33$). Given the suggestive evidence for a central deficit, it is perhaps more reasonable to consider the totals settled upon as upper limits.

We make the now conventional assumption that the globular cluster luminosity function (LF) may be adequately described by a standard normal curve in a number–magnitude relationship. [See Harris (1988a) for the most recent discussion of this question.] We adopt a mean (turnover) absolute magnitude of $M_B = -7.0 \pm 0.15$ and permit the characteristic dispersion $\sigma$ of the LF to vary over the likely range $1.00 \leqslant \sigma \leqslant 1.50$ mag.

Failing direct distance estimates for NGC 1549 and NGC 1553, we use instead their mean recession velocity, coupled with an assumed Hubble constant $H_0$ chosen over the range $50 \leqslant H_0 \leqslant 100$ km s$^{-1}$ Mpc$^{-1}$, to infer cosmological distances. We have also corrected the Revised Shapley–Ames Catalog (Sandage and Tammann 1981) velocities (subtracting 150 km/s) to compensate for an assumed Virgocentric pattern infall (Huchra and Geller 1982).

The actual calculations are straightforward. The adoption of a Hubble constant implies a distance modulus (d.m.), whence the absolute magnitude of the galaxy of interest. Likewise, the limiting apparent magnitude of the cluster counts may be translated to a known absolute magnitude in the intrinsic LF, which may be integrated to yield an inferred total population. Finally, the specific frequency is calculated.

In Table IV, we present the final results of the numerical exercise. This table was generated assuming that the absolute magnitude of the turnover in the globular cluster LF lies at $M_B = -7.00$, but the adoption of values differing by $\pm 0.15$ mag from this changes the inferred values of $S$ by typically $\pm 0.06$—considerably less than the uncertainties imposed by other factors (dominantly the sparse sample sizes). For this reason, we have not presented separate tabulations for other adopted mean absolute magnitudes.

It is apparent that the derived specific frequencies $S$ and total populations $T$ are quite insensitive to the assumed dispersion ($\sigma$) characterizing the intrinsic LF for a given assumed distance, but are moderately sensitive to the adopted value of the Hubble constant (i.e., the distance scale) for a given $\sigma$. Even considering the fully allowed range of these parameters, however, we conclude that the globular cluster populations in these galaxies are of rather low specific frequency, a conclusion adequately summarized in the statement

$$S_{1549} = 1.0 \pm 0.5, \quad S_{1553} = 2.5 \pm 1.0.$$

These specific frequencies are lower than those seen for the well-studied early-type galaxies in the Virgo Cluster, for example, for which $S_{\rm av} = 6$, and very much lower than those for the anomalous supergiant systems such as M87, for which $S \sim 20$ (Harris 1988a). The values are, however, consistent with a picture in which the globular cluster specific frequency is dependent to first order upon environment in the sense that those galaxies in sparse surroundings are relatively cluster poor [Harris and van den Bergh (1981); see Harris (1988b) for a thorough discussion of this point]. NGC 1549 and NGC 1553 thus confirm and extend this important dependence of GCS property upon parent galaxy environment.

TABLE IV. Specific frequencies and total populations.

| | NGC 1549 | | NGC 1553 | |
|---|---|---|---|---|
| $H_0 = 100$ (d.m. = 29.65) | $M_V = -19.94$ | | $M_V = -20.41$ | |
| $\sigma$ | $S$ | $T$ | $S$ | $T$ |
| 1.00 | $1.19 \pm 0.48$ | 113 | $3.12 \pm 0.69$ | 455 |
| 1.25 | $1.30 \pm 0.52$ | 123 | $3.33 \pm 0.74$ | 486 |
| 1.50 | $1.44 \pm 0.58$ | 136 | $3.66 \pm 0.81$ | 534 |
| $H_0 = 75$ (d.m. = 30.27) | $M_V = -20.56$ | | $M_V = -21.03$ | |
| $\sigma$ | $S$ | $T$ | $S$ | $T$ |
| 1.00 | $0.72 \pm 0.29$ | 121 | $1.83 \pm 0.41$ | 474 |
| 1.25 | $0.81 \pm 0.33$ | 137 | $2.04 \pm 0.45$ | 528 |
| 1.50 | $0.90 \pm 0.36$ | 152 | $2.26 \pm 0.50$ | 587 |
| $H_0 = 50$ (d.m. = 31.15) | $M_V = -21.44$ | | $M_V = -21.91$ | |
| $\sigma$ | $S$ | $T$ | $S$ | $T$ |
| 1.00 | $0.43 \pm 0.17$ | 163 | $1.00 \pm 0.22$ | 581 |
| 1.25 | $0.47 \pm 0.19$ | 178 | $1.13 \pm 0.25$ | 656 |
| 1.50 | $0.50 \pm 0.20$ | 189 | $1.22 \pm 0.27$ | 713 |

## V. CONCLUSIONS

Our principal conclusions are:

(1) We have identified globular cluster populations in the pair of interacting early-type galaxies NGC 1549 and NGC 1553; the total populations are estimated at 150 and 600 clusters, respectively (with uncertainties of a factor of order 1.5).

(2) The globular clusters seem to be distributed spatially in a way that broadly mimics the underlying luminosity of the galaxies, a conclusion contingent upon the correctness of our extrapolation of the available luminosity profiles outward over the relevant range.

(3) NGC 1553 alone shows a suggestive central deficit of globular clusters relative to the underlying luminosity, a feature already noted in other galaxies [ranging from M87, a supergiant elliptical (Lauer and Kormendy 1986; Grillmair *et al.* 1986) to an anonymous dwarf galaxy associated with

NGC 3115 (Hanes and Harris 1986b)]. The deficit is seen at radii less than about 1.5 arcmin (corresponding to 5 kpc, for $H_0 = 75$ km s$^{-1}$ Mpc$^{-1}$). This finding must be considered as tentative, however, because of the uncertain effect of the dark photographic background upon the detection process.

(4) There is no significant azimuthal dependence of the globular cluster surface density around either galaxy, despite the manifest evidence for an interaction, but deeper imaging (to improve the count statistics) will certainly be required if this point is to be explored further.

(5) The specific frequencies for NGC 1549 and NGC 1553 are $S_{1549} = 1.0 \pm 0.5$ and $S_{1553} = 2.5 \pm 1.0$, relatively low values that might have been predicted on the basis of the now well-developed picture of the richness of globular cluster systems being, to first order, dependent upon parent galaxy environment.

These galaxies are of special interest for further study because of the potential for the use of globular cluster "test particles" in exploring the dynamics of the interaction on scales not otherwise amenable to observation. We note that the proximity of the galaxies and their populous globular cluster systems should provide attractive targets for a program of multiobject spectroscopy similar to that carried out in the fields of M87 (Huchra and Brodie 1987; Mould *et al.* 1987) and Centaurus A (NGC 5128) (Harris *et al.* 1984; Sharples 1988). Such studies could also shed light upon the importance of globular cluster swapping or loss in galaxy interactions (Muzzio 1987).

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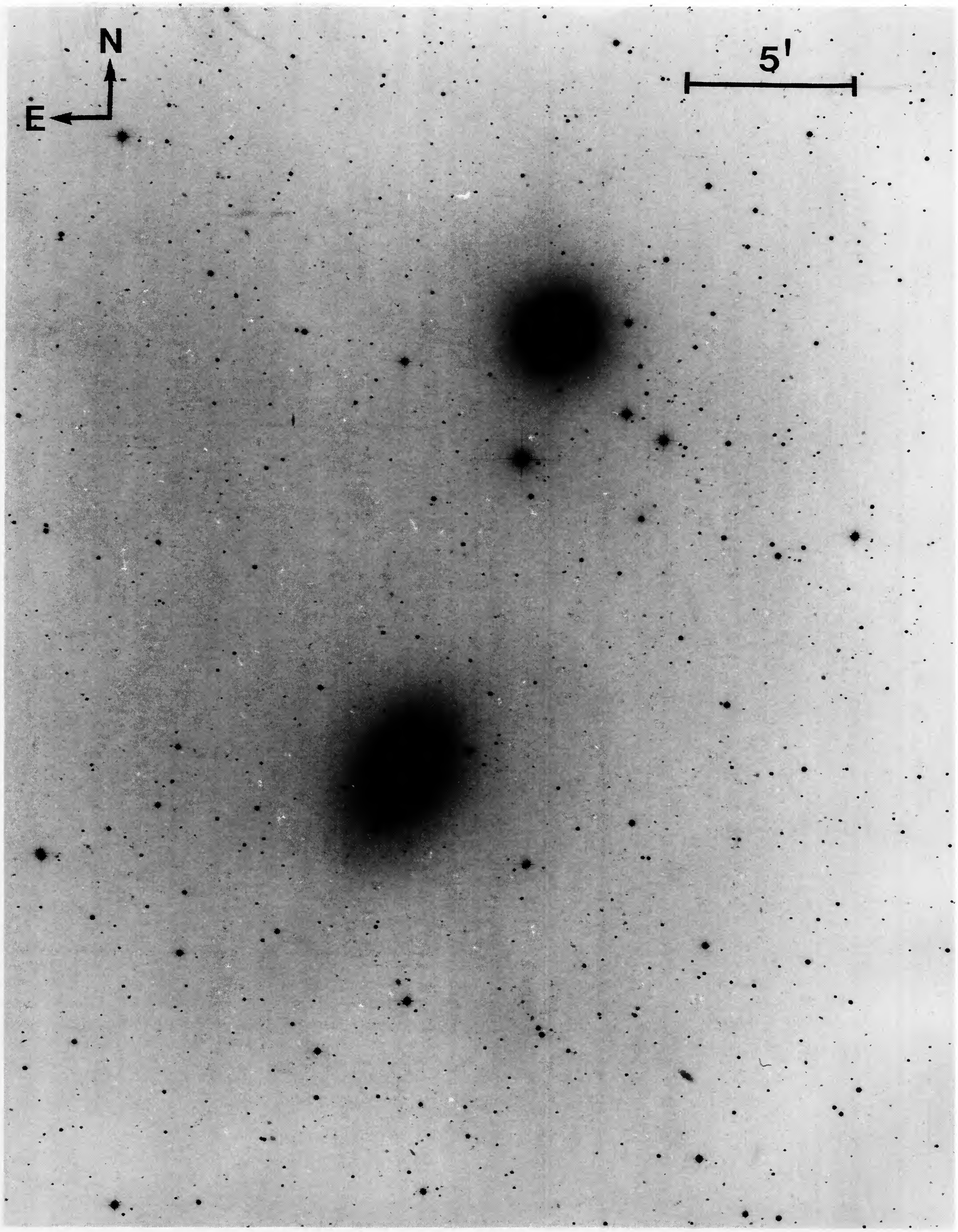


FIG. 1. Reproduction of the central regions of AAT plate #2089, a 90 min exposure (IIIa-J + GG385) taken at the $f/3.3$ prime focus. The scale and orientation are shown.

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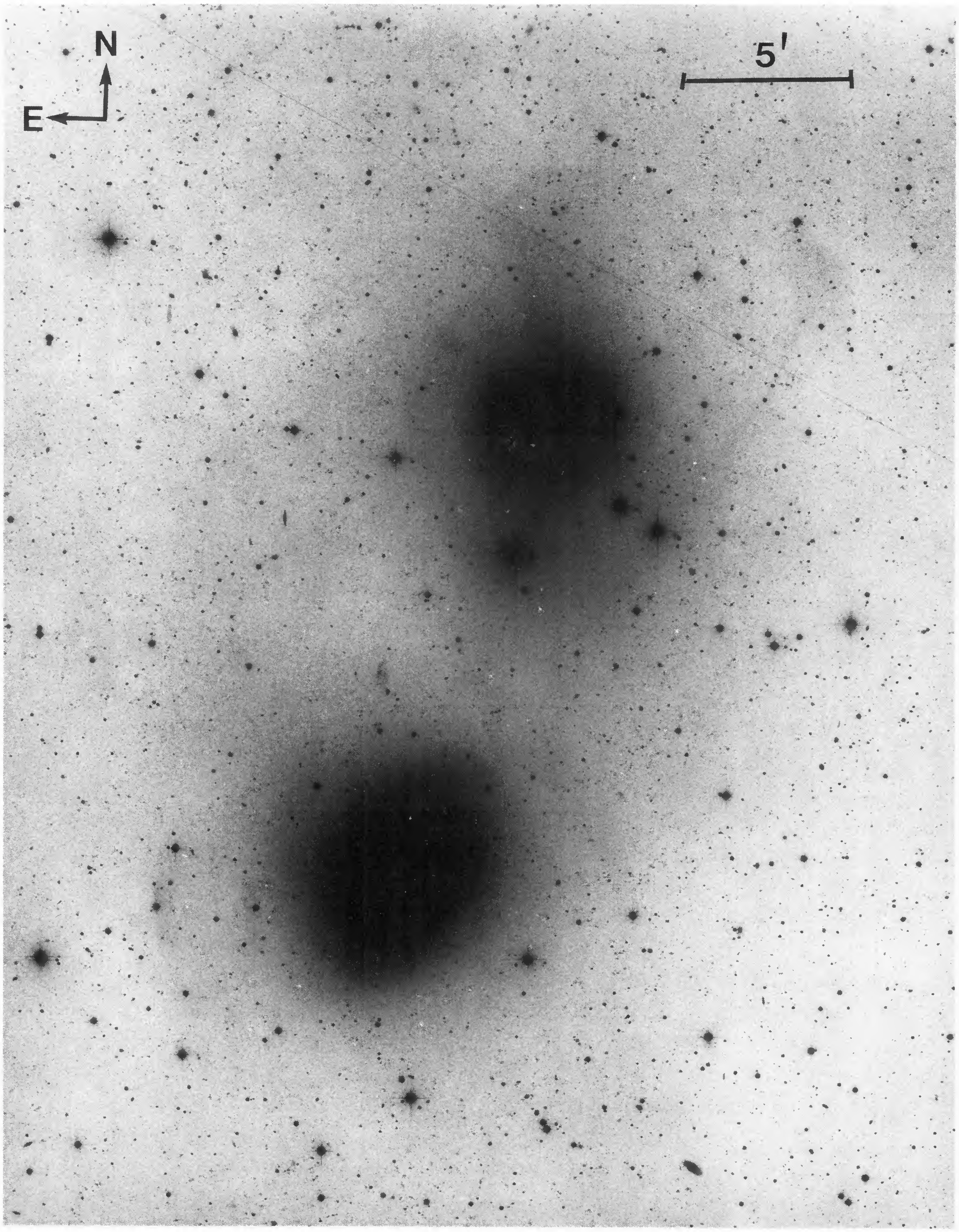


FIG. 2. Contrast-enhanced version of the field shown in Fig. 1, prepared from AAT plate #2089 by Dr. David Malin. Streamers and shell-like arcs are clearly seen.

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