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A SUPERMASSIVE DOUBLE GALAXY IN THE CLUSTER ABELL 1775*

GUIDO CHINCARINI,†‡ HERBERT J. ROOD,‡ GUMMULURU N. SASTRY,‡
AND GARY A. WELCH‡
Van Vleck Observatory, Wesleyan University, Middletown, Connecticut 06457
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ABSTRACT

Spectrographic and photometric data are presented for the giant double galaxy in the cluster Abell 1775. Several independent pieces of evidence are offered to support our belief that the system is a stable physical entity. The two nuclei show a radial-velocity difference of approximately 1700 km s^{-1}, which when combined with a Hubble constant of 75 km s^{-1} Mpc^{-1} and the assumption of circular orbits leads to a lower mass limit of $2 \times 10^{13}\, M_{\odot}$. This does not suffer from the large uncertainties that affect mass estimates for single giant galaxies. The absolute visual magnitude to a surface brightness of 25.5 mag per square arc second is found to be -23.7, which yields a minimum mass-to-light ratio of 83 in solar units.

I. INTRODUCTION

It is recognized that the first-brightest galaxies in great clusters are likely to contribute significantly to our understanding of fundamental cosmological processes (Humason, Mayall, and Sandage 1956; Sandage 1966, 1968*a*, *b*, 1969; Morgan and Lesh 1965; Sastry 1968). Important recent contributions of basic data for these systems include a large number of magnitudes by Sandage (see Peach 1969), and radial velocities by Jenner (1970). Using relative radial velocities (ΔV) for ten systems having double nuclei, Jenner applied the statistical method of Holmberg (1954) and Page (1961) to derive a mean mass per component of $8 \pm 5 \times 10^{12}\, M_{\odot}$. The largest ΔV value (1871 km s^{-1}) measured by Jenner was for the double system in the cluster Abell 1775.

In 1970 as part of a larger program concerned with radial velocities and photometry of galaxies in groups and clusters we obtained photographic, photoelectric, and spectrographic observations of the Abell 1775 system. The large ΔV found originally by Jenner has been confirmed, and analysis of the photometric material supports the assumption that the two galaxies comprise a gravitationally bound system. On this basis we have determined for the mass the extremely large lower limit $M \geq 2 \times 10^{13}\, M_{\odot}$.

II. OBSERVATIONS AND RESULTS

A spectrogram of the Abell 1775 system was obtained in April 1970 at Kitt Peak National Observatory by Chincarini and Rood. The Carnegie image-tube spectrograph attached to the 84-inch telescope was employed. A wavelength range of from 3500 to 6000 Å was obtained at a dispersion of 250 Å mm^{-1}. The focus was set at $\lambda = 4000$ Å and the slit oriented across both nuclei. Figure 1 (Plate 1) shows a reproduction of the spectrogram. Radial velocities were derived by using a digitized two-screw Grant comparator and a program developed for the Univac 1108 computer at the NASA Manned Spacecraft Center. Details of the reduction procedure are given elsewhere (Chincarini and Rood 1971). The mean error of a given velocity determination is about 100 km s^{-1}.

* Based in part on material gathered by two of us (G.N.S. and G.A.W.) as guest investigators at the Hale Observatories.

† Visiting Scientist, NASA Manned Spacecraft Center, Houston, Texas. Present address: McDonald Observatory, Fort Davis, Texas.

‡ Visiting Astronomer, Kitt Peak National Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc. under contract with the National Science Foundation.

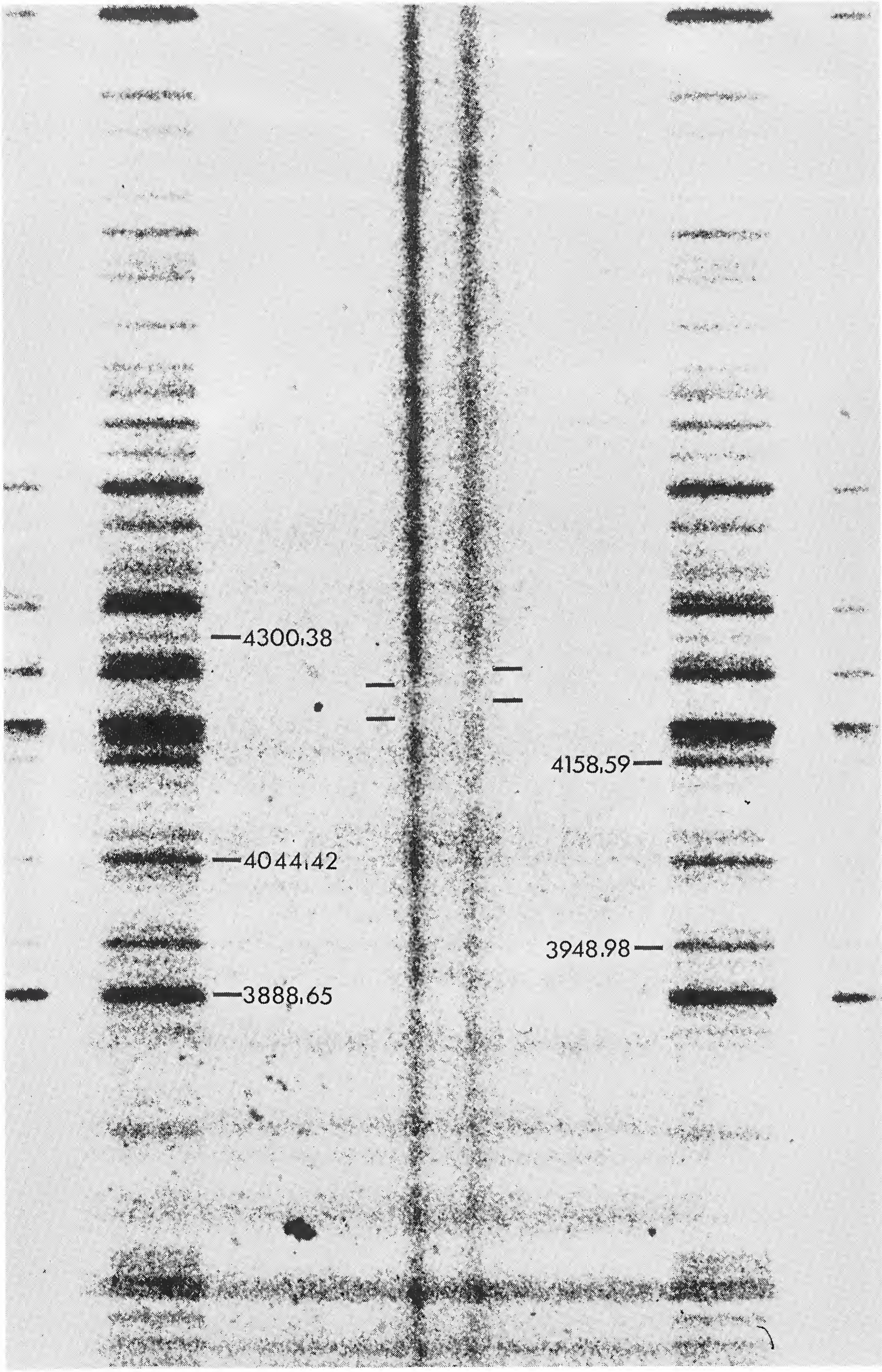

FIG. 1.—Reproduction of a spectrogram of the giant double galaxy in Abell 1775, with He-Ne-Ar comparison spectra. The H- and K-lines in each nucleus are indicated by short bars.

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The spectrum is late-type, with the K- and H-lines of Ca II and the G-band visible. Radial velocities are based on the K- and H-lines alone, because the G-band is located away from optimum focus. Our radial velocities and those by Jenner (1970), obtained with comparable equipment parameters, are given in Table 1.

In February 1970, Sastry and Welch obtained U, B, V, photoelectric measurements with the 36-inch telescope at Kitt Peak National Observatory. More photoelectric data were obtained in March with the 84-inch telescope. Resulting visual magnitude values are presented in Table 2.

Direct plates in U, B, V, and R of Abell 1775 were obtained with the 48-inch Schmidt telescope of the Hale Observatories by Sastry and Welch. Several exposure times were used. Tube-sensitometer spots provide calibration. A photographic reproduction and Joyce-Loebl isodensitracing of the 20-minute-exposure V plate PS 5724 appear in Figure 2 (Plates 2 and 3). The nuclei are separated by $21\farcs4 \pm 1''$. From planimeter measurements of areas bounded by successive isodents it is found that within an isodent corresponding to a surface brightness of 25.5 mag sec^{-2}, the total apparent magnitude is $V = 13.8$ mag. Microphotometer tracings were made of the image on two plates, PS 5724 and the more lightly exposed PS 5749, for purposes discussed in § III. The tracings were along the systemic major axis (defined here as the line passing through the two nuclei) and at 90° to it through both nuclei.

III. DISCUSSION

Mass determinations for isolated gas-deficient galaxies suffer from basic theoretical and observational defects. No realistic dynamical model exists at present. Because the mass of a galaxy depends strongly on the very uncertain radial dependences of velocity dispersion and mass, it is not surprising that recent determinations of the mass of M87 differ by an order of magnitude (Brandt and Roosen 1969; Bertola and Capaccioli 1970).

Estimates for the lower limit of the mass of a *double system* from the observed relative radial velocity and separation are generally more reliable. The system is simply approximated by two gravitationally bound point masses moving in circular orbits. The

TABLE 1

MEAN AND RELATIVE RADIAL VELOCITIES FOR THE NUCLEI OF THE FIRST-BRIGHTEST GALAXY IN ABELL 1775

Observer(s)	$\langle V \rangle$ (km s^{-1})	ΔV (km s^{-1})
Chincarini and Rood...........	21524	1569
Jenner........................	21753	1871
Adopted.......................	21639	1720

TABLE 2

PHOTOELECTRIC DATA FOR THE FIRST-BRIGHTEST GALAXY IN ABELL 1775

V	$B-V$	Diaphragm	Centering	Telescope
14.1 ±0.04........	1.34±0.05	$46\farcs6$	both components	36-inch
14.33±0.03........	1.20±0.05	$36\farcs8$	both components	84-inch
15.48±0.05........	...	$18\farcs3$	NW component	84-inch
15.24±0.05........	...	$18\farcs3$	SE component	84-inch

NOTE.—Errors are standard deviations based on several galaxy–standard star comparisons.

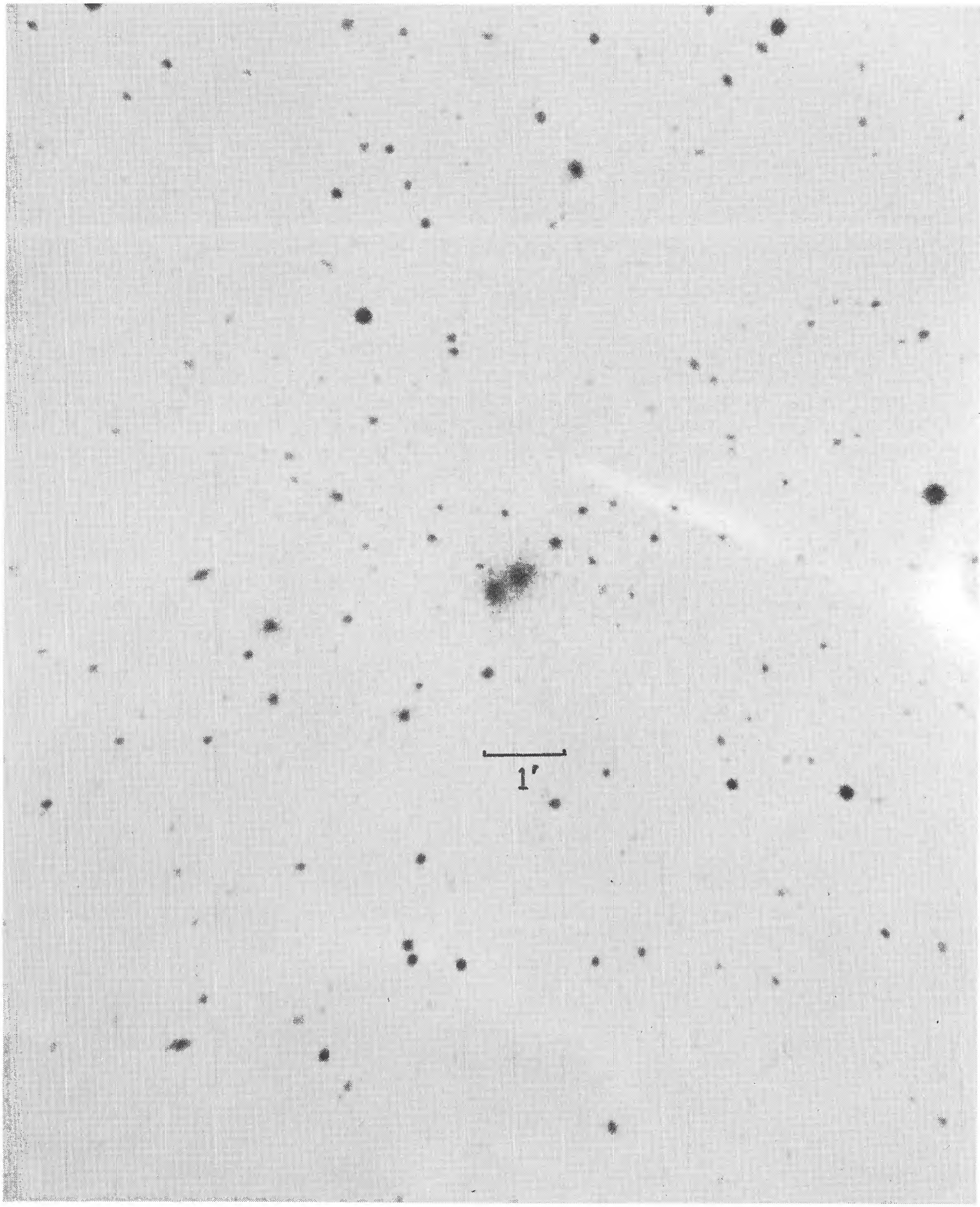

FIG. 2.—Reproduction of a 48-inch Schmidt photograph and an isodensitracing of the Abell 1775 double system. The plate PS 5724 was a 20-minute exposure on 103a-D emulsion behind a Wratten-12 filter. Each successive change in symbol (*space-dot-dash*) corresponds to a density increment of 0.05. Projected dimensions of the scanning aperture were large ($4''.7 \times 4''.7$) to reduce noise in the outer regions. Photometric measurements were made from an isodensitracing obtained with an aperture of $3''.0 \times 3''.0$. Orientation in both reproductions is with north at top and east on the left.

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failure to correct for projection factors and the point-mass approximation act toward making the lower limit an underestimate, as does the circular-orbit approximation "on the average," although this assumption could make the lower limit too large by at most a factor of 2 if the system has highly eccentric orbits and we happen to be observing near a perigalacticon passage. Hence, the major cause of uncertainty is the assumption that such a system is bound.

One gains considerably more confidence that an observed double galaxy is bound if a physical connection is observed. Figure 2 shows that the system indeed appears to be immersed in a common envelope. Further, the microphotometry indicates a deficiency of surface brightness at the minimum between the two nuclei compared with the sum at equal distance on either side. This empirical result is expected for two reasons if a physical connection exists: (1) An optical *dust-free* double must give *no* deficiency. (2) Consider two identical point masses. The gravitational potential midway between them is weaker than the sum at identical distances on either side. If it is assumed that the mass within a bound double system tends to be located at positions with stronger potential, and that the surface brightness is a mass-density indicator, then the empirical result for Abell 1775 is plausibly explained.[1]

In addition to the photometric reasons given above, we believe the Abell 1775 system to be stable because (i) the color and late-type absorption-line spectrum give no indication of the presence of violent activity, and (ii) on the Palomar 48-inch Schmidt plates the system appears to lie near the center of a cluster, and the two components seem to be the brightest galaxies within a circular area whose radius is at least 25 times their individual diameters. Considering Abell clusters of distance class 4 or less, we estimate under these circumstances that the probability of finding one such alignment arising from a chance superposition is less than about one part in 10^3.

The physical properties of the Abell 1775 system, represented by a model of two gravitationally bound point masses moving in circular orbits, are given in Table 4. These properties were derived from the data given in § II.

The mass of the Abell 1775 double galaxy $M \geq 2 \times 10^{13}\ M_{\odot}$ is larger than the mean lower limit for first-brightest double galaxies in clusters ($\langle M \rangle = 4 \pm 2 \times 10^{12}\ M_{\odot}$, Jenner 1970). Its mass-to-light ratio $M/L_v \geq 83$ solar units, compares with $M/L_p \approx 50 \pm 30$ for the centers of giant elliptical galaxies (King, Byrnes, and Minkowski 1967)

TABLE 3

SURFACE-BRIGHTNESS DEFICIENCY AT THE MINIMUM BETWEEN THE TWO ABELL 1775 NUCLEI

Plate (1)	Major Axis (2)	Major Axis+90° (3)
PS 5724.....	23	28
PS 5749.....	11	14

NOTE.—Column (2) gives the percent by which this surface brightness falls below the sum of the two surface brightnesses measured along the systemic major axis (defined in text) at equal distances from the nuclei but at *exterior points*. Column (3) lists the deficiency compared instead with the sum of mean surface brightnesses for each nucleus. The mean value for each nucleus was obtained from two points at the same distance as the minimum but lying along the *perpendicular* to the major axis.

[1] If the two supergiant galaxies near the center of the Coma cluster were a physically bound pair with circular orbits, then the mass of the two-galaxy system would be $\geq 2 \times 10^{13}\ M_{\odot}$ (Rood *et al.* 1971). However, a preliminary examination of the luminosity profile presented by G. and A. de Vaucouleurs (1970, Fig. 7) suggests that the system could be an optical pair.

TABLE 4

PHYSICAL PROPERTIES OF THE ABELL 1775 DOUBLE GALAXY REPRESENTED BY A MODEL OF TWO GRAVITATIONALLY BOUND POINT MASSES MOVING IN CIRCULAR ORBITS

($H=75$ km s^{-1} Mpc^{-1})

Relative radial velocity	$\Delta V=1720$ km s^{-1}
Projected separation of nuclei	$R=30$ kpc
Mass of the system	$M\geq 2\times 10^{13}\ M_{\odot}$
Absolute photovisual magnitude	$M_v=-23.7$*
Apparent color index	$B-V=1.34$†
Ratio of mass to luminosity	$M/L_v\geq 83$ solar units

* To surface brightness level of 25.5 mag per square arc second, and corrected for K-dimming by 0.2 mag according to results of Oke and Sandage (1968) and for galactic absorption.

† Within a diaphragm of 47 arc seconds diameter, uncorrected for galactic absorption.

and $M/L_p = 68 \pm 28$ (data of "high weight") for E and S0 double systems (Page 1962). Since the components of Abell 1775 have the largest radial-velocity difference in Jenner's sample of ten double galaxies, it is possible that the derived mass and mass-to-light ratio are not just lower limits, but instead may be good approximations to the actual values for the system. Sandage[2] finds from Table 2 that the absolute visual magnitude M_v of the brighter component of Abell 1775 is -22.5 (at standard aperture V_{25}, with galactic absorption $A_v = 0.0$, and K-correction $K_v = 0.12$), which compares well with the mean $\langle M_v\rangle = -22.5$ for the first-ranked single galaxies in clusters (Peach 1969). We conclude that the Abell 1775 system is among the most massive, most luminous galaxies presently known.

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[2] Private communication.