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THE PECULIAR DISK GALAXY UGC 7576

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ABSTRACT

Optical photometry of UGC 7576 supports the view that this system consists of an edge-on disk galaxy with a prominent bulge aligned almost orthogonally to a low surface brightness disk. A mass of $2 \times 10^9\ M_\odot$ of H I is detected in the system, which has the unusually high mass-to-light ratio of 30.

Subject headings: galaxies: individual — galaxies: structure — radio sources — 21 cm radiation

I. INTRODUCTION

In their *Morphological Catalogue of Galaxies*, Vorontsov-Velyaminov *et al.* (1962–1968) note that the galaxy MCG 5-29-86 has two narrow, elongated rays nearly perpendicular to the major axis of the principal body. A nondetection of this object (= UGC 7576) in the radio continuum led Sofue *et al.* (1982) to suggest that these "jets" might actually be an edge-on view of a thin disk or ring of old population stars around the brighter central portion of the galaxy. In this *Letter* we present 21 cm observations and optical photometry of UGC 7576 which tend to confirm the disk hypothesis and help to constrain the dynamics of this interesting system.

II. H I OBSERVATIONS

We observed UGC 7576 at 21 cm in 1982 February with the 306 m telescope of the Arecibo Observatory. We used the dual-channel, cooled GaAs field effect transistor receivers (see Bothun 1981 for a description of this configuration, its calibration, and data reduction procedures). A hydrogen detection was obtained after 45 minutes of ON integration time at a heliocentric velocity of 7036 ± 5 km s^{-1}, which is in good agreement with the optical absorption-line redshift of 7040 km s^{-1} (Wakamatsu and Arp 1982). The 21 cm profile (Fig. 1) is a classical double-horned rotation profile, characteristic of luminous disk galaxies observed edge-on. The observed H I flux corresponds to a hydrogen mass of $2 \times 10^9\ M_\odot$. The 20% velocity width of 485 km s^{-1} (after correction for redshift) yields an indicative total mass (Fisher and Tully 1975) of $1.1 \times 10^{11}\ M_\odot$ with the dimensions and inclination obtained in the following section. The distance adopted in these estimates was 80 Mpc, using a Hubble constant appropriate to the location of this galaxy from equations (9) and (10) of Aaronson *et al.* (1980).

A second possible H I detection was obtained at the same telescope coordinates (with a different local oscillator and feed position) at a velocity of 11,590 km s^{-1}. In this case, the profile is a very narrow single peak with $\Delta V = 45$ km s^{-1}.

III. OPTICAL PHOTOMETRY

Deep optical images of UGC 7576 were obtained in clear conditions on 1982 March 18 and 19 with a CCD Camera at the f/7.5 focus of the number 1 0.9 m telescope on Kitt Peak. The pictures were debiased and flattened with dome-flats. Figure 2 (Plate L3) is a reproduction of the sum of three 30 minute exposures in the *R* bandpass and shows a galaxy which, but for the almost orthogonal orientation of the major axes of its two components, resembles an early-type system seen edge-on. Thirty-minute *U* and *B* frames were also obtained (through $CuSO_4$ blocked filters).

Standards observed on these nights and one following one, in M92 and in the equatorial selected areas, allow

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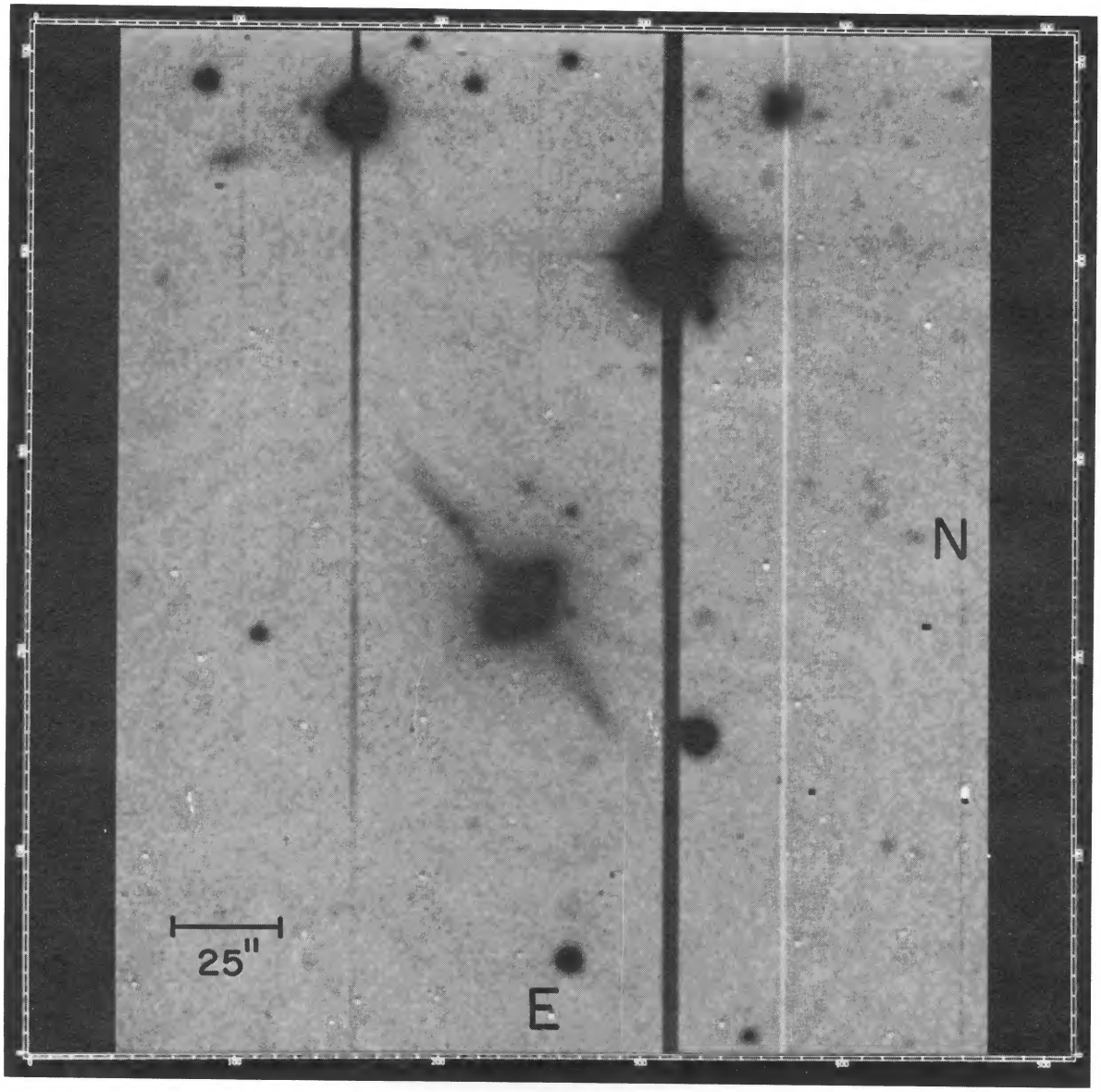

FIG. 2.—A deep optical image of UGC 7576 obtained in the *R* bandpass in a 1.5 hr exposure with the no. 1 0.9 m CCD direct camera at KPNO. The strong vertical tails on the two bright stars are a conventional CCD artifact due to charge transfer inefficiency. A (white vertical) threshold column is also visible.

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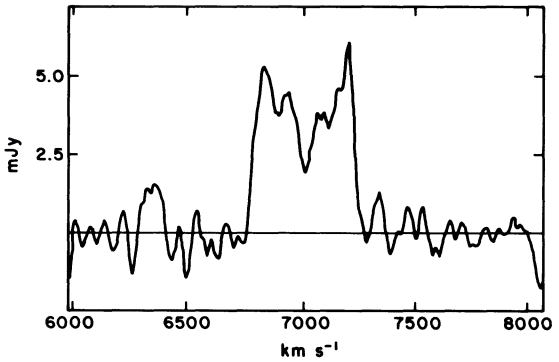

FIG. 1.—The 21 cm profile of UGC 7576

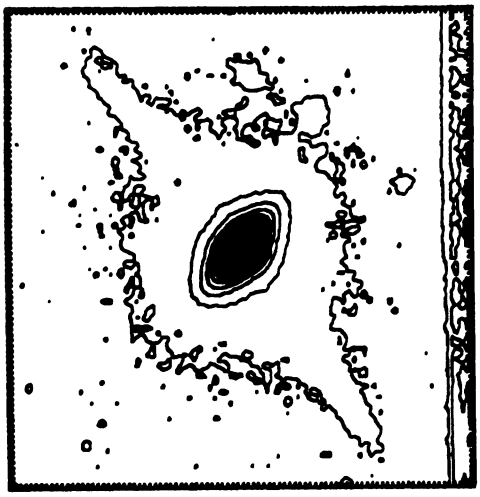

FIG. 3.—A contour map of the red image of UGC 7576

accurate photometry from these images on the Cousins broad-band system. Using multiaperture integrations with various centers in and around the galaxy, we obtain $R = 14.4$ as a *total* magnitude, and $B - R = 1.75$ inside a centered diameter of 8.″4. From the photometry of Persson, Frogel, and Aaronson (1979) and the transformations of Bessell (1979), it is clear that this color is typical of early-type galaxies. For the lower surface brightness, disk-like portion of the galaxy we obtain the following results: $R = 16.7$, $B - R = 1.0 \pm 0.1$, and $U - B = 0.0 \pm 0.2$. Within these limits, there is no apparent color gradient in the disk. The above results are entirely consistent with an interpretation of the galaxy as a spiral with a large bulge-to-disk ratio. By contrast, the $U - B$ color of the jet in M87 is -0.5 (Kinman, Grasdalen, and Rieke 1974). Note that the absolute blue magnitude of UGC 7576 is -18.5, similar to that of the Large Magellanic Cloud.

Subsequently, we obtained multiaperture photoelectric photometry using the 1.3 m telescope at Kitt Peak National Observatory (KPNO). These results agree well with those from the CCD images, although the photoelectric data allow a somewhat better determination of the central $U - B$ color. From these observations, we derive $B - V = 1.0$ and $U - B = 0.4$ through a 23″ aperture, centered on the bulge. These colors are normal for early-type galaxies of the absolute magnitude of UGC 7576 (cf. Sandage 1972).

We have also carried out surface photometry on the red CCD image. Figure 3 is a contour plot with lowest contour set at $\mu_R = 25$ mag arcsec^{-2}. According to Figure 3, the apparent axial ratio of the bulge is 0.57 in the inner parts but increases to almost unity at large radius. This may in part be due to the influence of the disk. In Figure 4 we show a major axis profile of the disk. Away from the bulge, this profile is remarkably flat but not dissimilar to some of Kormendy's (1977) compact galaxies. A de Vaucouleurs law can be fitted to the bulge with an effective radius of approximately 3 kpc. The central surface brightness of any exponential fitted to the disk, however, is extremely low ($\mu_B = 23.5$–24.5), even by the standards of Kormendy's objects. If the object is truly edge-on, the flatness of this profile might be consistent with the suggestion of Sofue *et al.* (1982) that the disk may in fact be a ring (cf. NGC 2683, 4650A). As a diameter measurement, we adopt an isophote between the de Vaucouleurs and Holmberg isophotes at $\mu_R = 24.5$ (assuming $B - R = 1.0$) to obtain $D = 75''$. The linear diameter of the disk is therefore 30 kpc.

The H I and dynamical properties of the system can also be compared with those of normal spirals. Using the results of the previous section and a total B-magnitude of 16.0, we obtain $M_{\rm H\,I}/L_B = 0.5$ and $M/L = 30$ in solar units. Comparison with the samples of Bothun, Schommer, and Sullivan (1982) and Fisher and Tully (1975) indicates that UGC 7576 is a rather gas-rich galaxy for its red color with a very high mass-to-light ratio. There are galaxies known with this combination of properties, e.g., UGC 12423 (Bothun, Balick, and Skillman 1982). The latter is morphologically a quite different specimen, however.

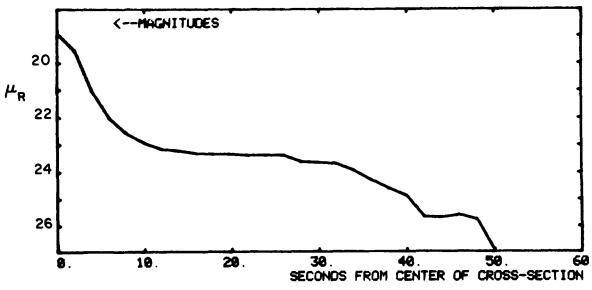

FIG. 4.—A folded major axis profile of UGC 7576. Intensity averaging was carried out over 3″ diameter apertures.

The high mass-to-light ratio of this object raises a question as to the location of UGC 7576 in the Fisher-Tully diagram. With an infrared photometer on the 1.3 m telescope at KPNO we measured $H^c_{-0.5} = 12.2$ (see Aaronson *et al.* 1980). At our adopted distance, the predicted apparent magnitude is 11.53 (Aaronson *et al.*, eq. [8]). UGC 7576 is therefore between 1 and 2 σ underluminous relative to the standard infrared Fisher-Tully relation. The $H - K$ color through a 23″ aperture was 0.16 ± 0.05, which is an intermediate color for galaxies.

Although Figure 2 goes very deep (the stars 20″ west of the galaxy have $R = 19.6$ and 20.0), there is no obvious extended source of the second H I peak at 11,000 km s^{-1}. There are two faint galaxies ($R = 17.2$ and 19.0) 1.8′ west of UGC 7576, however, on the edge of the Arecibo beam. It is possible that one of these may be the source of this emission. Although the redshift and position of UGC 7576 locate it in the Coma Supercluster, it is clear from the results of Wakamatsu and Arp (1982) that a wide range of redshifts is present among the prominent galaxies in this field.

IV. DISCUSSION

The photometric and 21 cm properties of UGC 7576 support the suggestion of Sofue *et al.* (1982) that the object is an edge-on view of a disk galaxy. The symmetry of the system and the identity of the optical and radio redshifts reject the alternative notion that the system could be a chance superposition of two unrelated galaxies. In terms of the former model, the *peculiar* properties of UGC 7576 are: (1) its prominent bulge inclined at 75° to the major axis of the disk; (2) its high mass-to-light ratio; and (3) the low surface brightness of the disk and the slight warp in its geometry.

The first of these properties requires that we look for some special mechanism to explain the formation of this system. Quite apart from the major axis alignment, it is not a normal spiral: the bulge-to-disk ratio of approximately 7 is in itself unusual. S0s have large bulge-to-disk ratios; but UGC 7576 is gas rich, and its disk is not red. Tohline, Simonson, and Caldwell (1982) have studied the relaxation of gas disks accreted by elliptical galaxies. They conclude that for accreted gas disks with the geometry of UGC 7576: (1) the "bulge" is intrinsically prolate (cigar-shaped); (2) the relaxation time scales at distances of 10 kpc (25″) from the galaxy's center are of the order of 1 Gyr; and (3) galaxies with the supposedly prolate geometry of UGC 7576 are not particularly rare.

The colors of the disk place the following relevant constraints on any such theory for the formation of this system. For any value of the internal reddening in the disk (and assuming that the stellar population is of solar composition), a substantial fraction of the disk stars must have been formed less than 3 Gyr ago. This constraint is obtained using the two-color ($B - V, V - R$) relation of Bessell (1979) and the models of Searle, Sargent, and Bagnuolo (1973). At the same time, provided that the internal reddening is no larger than the edge-on value adopted by Fisher and Tully (1981) [$E(B - V) = 0.28$ mag], a substantial portion of the disk is older than 0.1 Gyr. As far as one can tell by comparison of the U and R images, there are no obvious regions of very recent star formation in the disk. In this respect, UGC 7576 contrasts strongly with NGC 4650A (Laustsen and West 1980), an object which may be dynamically similar.

The key to a better understanding of the nature of this galaxy lies in spatially resolved information on its kinematics. We suspect, but cannot prove at present, that the H I gas is located in the disk, and we know nothing directly about the geometry or means of support of the bulge. A spectroscopic study of the internal dynamics of this system is clearly the next step.

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