Mon. Not. R. astr. Soc. (1990) **244**, *Short Communication*, 16P–19P

A new satellite galaxy of the Milky Way in the constellation of Sextans

M. J. Irwin, P. S. Bunclark, M. T. Bridgeland and R. G. McMahon
Institute of Astronomy, Madingley Road, Cambridge CB3 0HA

Accepted 1990 March 12. Received 1990 March 8

SUMMARY

A new Sculptor-type dwarf elliptical galaxy at a distance of 85 kpc has been found in the constellation of Sextans. The discovery was made from APM measures of UK Schmidt atlas glass copy IIIaJ survey plates. Photographic B_J, R colour–magnitude diagrams reveal a pronounced 'red' horizontal branch and a well-defined asymptotic giant branch typical of dwarf spheroidal systems.

1 INTRODUCTION

The seven dwarf elliptical satellite galaxies of the Milky Way are among the smallest and faintest galaxies known. All seven dwarf ellipticals were found by visual inspection of photographic plates. Their surface brightness is so low that all have been discovered from the concentration of resolved stars, over and above that of the foreground component of our own Galaxy. These dwarfs, also known as Sculptor-type systems, or dwarf spheroidal galaxies, range in diameter from about 1 to 5 kpc, and have absolute magnitudes in the range from −12 down to −8. Taken together with the dwarf irregulars, these galaxies are by far the most numerous members of the Local Group and, despite their unassuming appearance, hold the key to many questions of galaxy formation, structure and evolution.

Sculptor, the first of the dwarf ellipticals to be discovered, was found by Shapley in 1938, who then located a second such system in the constellation of Fornax (Shapley 1938). In spite of continued survey work by Shapley and others, discovery of additional satellite galaxies had to await the Palomar Schmidt Telescope photographic survey of the northern sky in the 1950s. Harrington & Wilson (1950) found two more systems in Leo and a further two in Draco and Ursa Minor were listed by Wilson (1955). Carina, the last of the satellite dwarf galaxies to be found, was discovered by Cannon, Hawarden & Tritton (1977) on plates taken for the southern photographic sky survey with the UK Schmidt Telescope (UKST). At that time, deep IIIaJ plates for 90 per cent of the southern sky, not already covered by the Palomar survey, had been visually examined and there seemed little prospect of finding more satellite galaxies. However, with the advent of fast measuring machines such as APM (Kibblewhite *et al.* 1984) and COSMOS (MacGillivray & Stobie 1984), it is possible to take the existing plate material and probe a little deeper.

2 THE SEXTANS DWARF ELLIPTICAL GALAXY

The new galaxy is illustrated in Plate 1. It was found as part of a comprehensive monitoring program of APM measures of UKST sky survey plates. To the scanning machine the galaxy appears both as an excess in the local number density of faint images due to the resolved stellar component, and a local enhancement in the 'sky' background density on the plate due to the unresolved component. For such nearby objects, the resolved stellar signature is more obvious than any unresolved component, and it was this former attribute that led directly to the discovery. The distribution of all images detected in the south-west quadrant of the discovery plate (J12465c – UKST field 854) is shown in Fig. 1(a), where the new galaxy is readily visible. Fig. 1(b) shows an isodensity contour map of the images classified as stellar down to the plate limit ($B_J \sim 22.5$). Similar patterns of detected images are often found to have a non-astronomical origin, so the reality of the feature was verified by measuring a IIIaF survey plate (OR11589) taken at the same field centre. The object is also visible near the edge of survey field 853.

The galaxy lies in the constellation of Sextans at $10^{\mathrm{h}}10^{\mathrm{m}}\!.5$, $-01°22'$ (1950), or $l = 243\overset{\circ}{.}5$, $b = 42\overset{\circ}{.}3$ and after the usual convention we propose to call it the Sextans dwarf elliptical galaxy. This constellation is already somewhat crowded with Local Group members. The marginal Local Group members Sextans A and Sextans B, at distances of about 1.5 Mpc, are within 10°, whilst the outer halo galactic globular cluster PAL3 (also occasionally known as Sextans C), at a distance of 95 kpc, is only 4° away on the sky, although it is unlikely to be dynamically associated with Sextans. Interestingly, Sextans lies in the same plane defined by the other Milky Way satellite galaxies. It is possible to trace the resolved image component to a diameter of 90 arcmin (Fig. 1), and

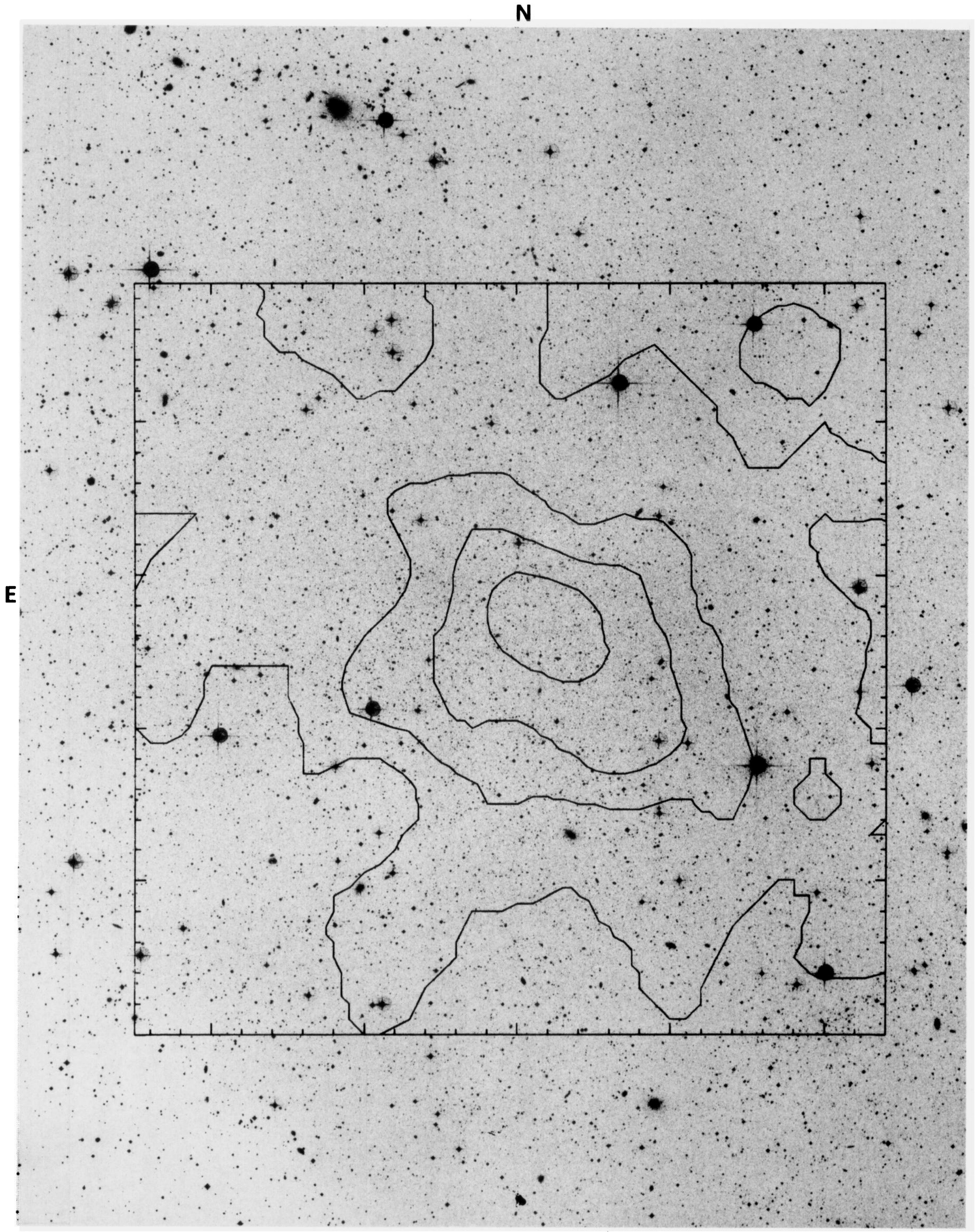

Plate 1. The Sextans dwarf elliptical galaxy from a IIIaJ plate (J10658c) taken on the UK 1.2-m Schmidt Telescope. Overlaid is an isodensity contour map of the stellar distribution covering $1° \times 1°$ of the region. Contour levels start at 1.5 stars/arcmin^2 and increase in steps of 0.5 stars/arcmin^2. It is straightforward to trace the dwarf galaxy to a diameter of $\sim 1.5°$. This plate was produced by the Photolabs at the Royal Observatory Edinburgh, © 1990, from a negative due to the UK Schmidt Telescope Unit.

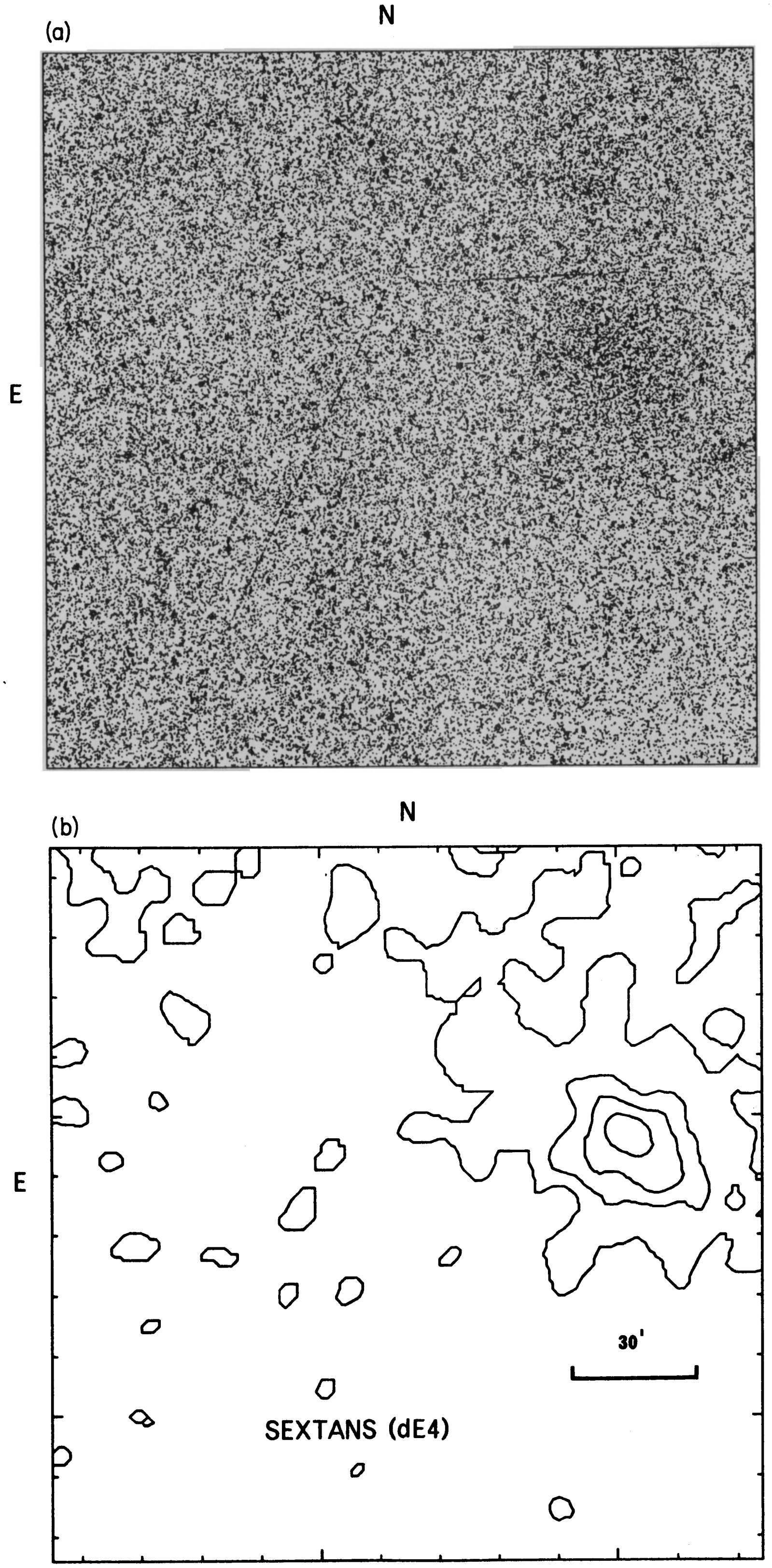

Figure 1. (a) The upper diagram shows the south-west quadrant of the UKST EJ atlas glass copy discovery plate as seen by the APM image analysis software. Each detected object is drawn at the size it appears at the analysis isophote. In addition to the satellite trails, note the enhanced number of images to the right of centre of the picture. The excess images to the south-west and north of the new galaxy are due to background clusters of galaxies. (b) The lower panel shows an isodensity contour map for those images classified as stellar down to the plate limit ($B_J \sim 22.5$). Contour levels start at 1.5 images/arcmin^2 and increase in steps of 0.5 images/arcmin^2. The satellite trails have been removed and only a small residual contamination is evident from the background clusters of galaxies.

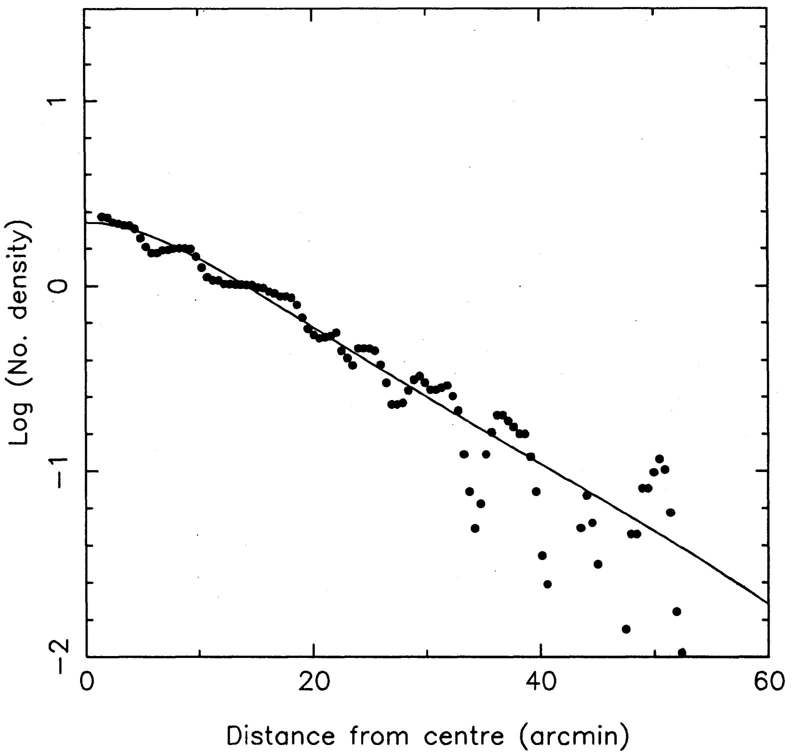

Figure 2. Filled circles are the measured stellar radial number density distribution, after correcting for foreground contamination of 1.35 stars/arcmin^2. The solid line is a King (1962) profile with core and tidal radii of 15 and 90 arcmin, respectively.

standard image analysis of the stellar isophote map gives an ellipticity of 0.4 and a position angle for the major axis of 56°, measured from north through east. A King (1962) model fit to the radial background-corrected stellar density profile, obtained by averaging the stellar density within elliptical annulii, gives formal core and tidal radii of 15 and 90 arcmin, respectively. This is illustrated in Fig. 2. It is also possible to trace the spatial extent of the galaxy visually on the discovery plate using a low-power microscope. To the eye, Sextans is completely resolved into stars and has all the usual morphological attributes of a dwarf spheroidal galaxy: very low surface density, a low degree of central concentration, isotropic distribution of stars, and no evidence for any gas or dust. There are no obvious globular clusters visible within the environs of the galaxy.

Colour–magnitude diagrams obtained by combining the B_J and OR plate data for UKST field 854 are shown in Fig. 3. The method described by Bunclark & Irwin (1983) was used to linearize the photographic magnitude scale, thereby circumventing the need at this stage for an accurate external calibration sequence. A preliminary external calibration for the magnitude scale, accurate to ~0.25 mag, was derived from measurements of the sky background level and by comparing the observed stellar number densities with those expected from galactic models. Colours accurate to 0.1 mag were obtained by the requirement that the galactic foreground stellar 'ridge' lines had the appropriate colour for a field at these galactic coordinates (see, for example, Irwin, Demers & Kunkel 1990). The colour–magnitude diagram for Sextans is typical of the dwarf spheroidal galaxies. There is a pronounced red horizontal branch with an extended blue tail at $R \sim 19.8$ and a well-defined asymptotic giant branch reaching to $R \sim 16.0$. There is no indication of a population of the very red carbon stars present in other dwarf spheroidal systems, most notably Fornax (Aaronson & Mould 1980). The assumption that the red horizontal branch has an intrinsic $M_V = 0.5$ gives an equivalent $M_R \simeq 0.2$, implying a distance modulus of 19.6. Corrections for reddening in this direction are negligible (Burstein & Heiles 1982), implying that Sextans is at a distance of 85 ± 10 kpc and has a major-axis diameter of 2 kpc. Integration of the resolved star contribution (equivalent to using a limiting isophote of $B_J \sim 25.5$) out to an effective radius of 45 arcmin indicates that Sextans has an apparent magnitude of $B_J \sim 12$ and, consequently, an absolute magnitude of $M_B \sim -8$.

3 DISCUSSION

As a preliminary step toward investigating the stellar population of Sextans, we used the APM archive measures of UKST plates of Carina to produce an equivalent B_J, R colour–magnitude diagram for Carina. Apart from relative image densities, the colour and magnitude distribution of images is remarkably similar, suggesting that both galaxies have had comparable evolutionary histories. Since all the dwarf spheroidal systems of the Milky Way have both old (RR lyrae) and intermediate age populations (carbon stars) present, it would be surprising if Sextans proved to be an exception. Indeed, the presence of a red horizontal branch is indicative of an intermediate-age stellar population (Da Costa 1986; Aaronson 1986).

Further natural questions to consider are: why was Sextans not found before and are there any more satellite ellipticals waiting to be found? UKST IIIaJ survey plates reach a limit-

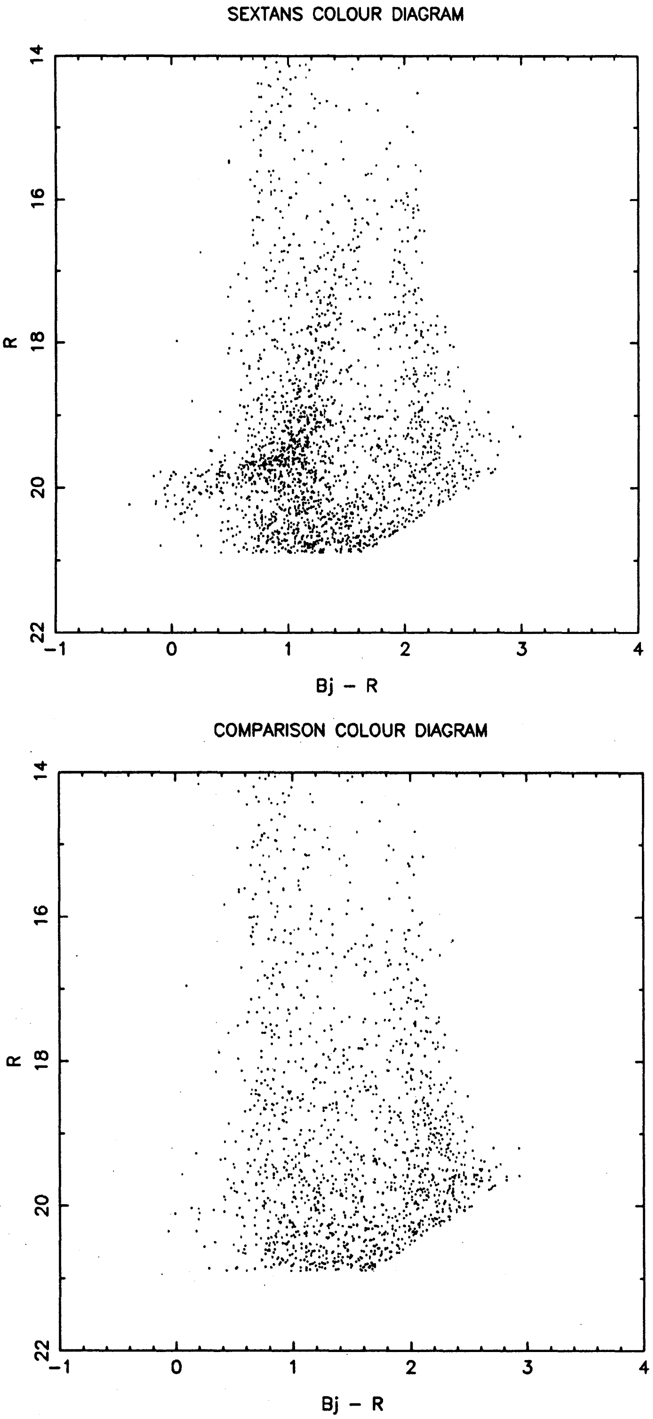

Figure 3. Colour–magnitude diagrams for a 1 degree^2 region centred on Sextans and a comparison region of similar area. A pronounced horizontal branch and asymptotic giant branch typical of dwarf spheroidal galaxies is readily visible.

ing magnitude of $B_J \sim 22.5$ and coverage of the southern sky is essentially complete. On plates like these, the central resolved stellar number density in Sextans is 3.0 arcmin^{-2} averaged over a 2×2 arcmin^2 box. Of this, 1.35 arcmin^{-2} is caused by foreground contamination from our Galaxy. For Carina, the last dwarf elliptical to be discovered visually, the corresponding stellar number densities are 6.0 and 2.2 arcmin^{-2}. This gives a peak signal-to-noise ratio for Carina of about 2.6, whilst for Sextans it is 1.4. We also know that Carina and Sextans subtend a similar angle on the sky and, apart from relative numbers of images, have strikingly similar colour–magnitude diagrams. Consequently, Sextans is much harder to see visually, simply because of the factor of 2 less contrast. In the northern sky, Draco and Ursa Minor represent the limit of what can be found visually on the old Palomar Sky survey plates. Although similar in size and luminosity to Carina, they are more favourably placed with respect to the galactic plane for visual identification.

Since both of the best currently available sky surveys have been carefully searched visually for nearby dwarf galaxies, to find more systems we require either a machine-based survey using the existing material, or the advent of a deeper sky survey in the north, such as the new Palomar Sky Survey. At the present time, the APM has surveyed approximately half of the southern sky for various astronomical projects. A by-product has been the discovery of this new satellite dwarf elliptical. We are currently engaged in measuring the old Palomar Sky Survey for a variety of projects. It will be interesting to see if any more nearby dwarf galaxies materialize in the north. Statistically, there should be a few more to find.

ACKNOWLEDGMENTS

We thank the UKSTU for providing the excellent quality plate material essential for the survey, and Duncan Waldron of the ROE photolabs for producing prints of these plates. The APM is a National Astronomy Facility supported by the Science and Engineering Research Council.

REFERENCES

Aaronson, M., 1986. *Stellar Populations, STScI Symp. Series No. 1,* p. 45, eds Norman, C. A., Renzini, A. & Tosi, Baltimore.
Aaronson, M. & Mould, J., 1980. *Astrophys. J.,* **240,** 804.
Bunclark, P. S. & Irwin, M. J., 1983. *Proc. Statstical Methods in Astronomy* ESA SP-201, p. 195, ed. Rolfe, E. J., Strasbourg.
Burstein, D. & Heiles, C., 1982. *Astr. J.,* **87,** 1165.
Cannon, R. D., Hawarden, T. G. & Tritton, S. B., 1977. *Mon. Not. R. astr. Soc.,* **180,** 81P.
Da Costa, G. S., 1986. *The Harlow Shapley Symposium on Globular Cluster Systems in Galaxies, IAU Symp. No. 126,* p. 217, eds Grindlay, J. & Philip, A. G. D., Cambridge, MA.
Harrington, R. G. & Wilson, A. G., 1950. *Publs astr. Soc. Pacif.,* **62,** 118.
Irwin, M. J., Demers, S. & Kunkel, W. E., 1990. *Astr. J.,* **99,** 191.
Kibblewhite, E. J., Bridgeland, M. T., Bunclark, P. S. & Irwin, M. J., 1984. *Astronomical Microdensitometry Conference* NASA-2317, p. 277, ed. Klinglesmith, D. A., NASA, Washington D.C.
King, I., 1962. *Astr. J.,* **67,** 471.
MacGillivray, H. T. and Stobie, R. S., 1984. *Vistas Astr.,* **27,** 433.
Shapley, H., 1938. *Nature,* **142,** 715.
Wilson, A. G., 1955. *Publs astr. Soc. Pacif.,* **67,** 27.