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LARGE-SCALE STRUCTURAL CHARACTERISTICS AND PHOTOMETRY OF NGC 3031 DETERMINED FROM EQUIDENSITY CURVES

W. HOEGNER, Z. KADLA, N. RICHTER, A. STRUGATSKAYA

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The method of integral equidensity curves was applied for determining the large-scale structure of the galaxy NGC 3031. Altogether 49 equidensity curves were obtained from four UBVR plates taken with the two-meter telescope of the Tautenburg Observatory. The axial ratio and position angle of the major axis in dependence on the apparent distance to the center of the galaxy were derived. These dependences are the same in all the investigated wavelength regions. The relative surface brightness in UBV in dependence on the semi-major axis was determined by means of a photographic wedge printed on the original photographs. A comparison with photoelectric measurements in V and B enabled a determination of fhe zero-point and to obtain the apparent surface brightness.

The newly developed method for obtaining integral equidensity curves [1] provides a rapid and relatively simple means for studying the large-scale structure of extended celestial objects. The possibility of obtaining these curves from photographs taken in various wavelength regions enables the comparison of structural features of an object as defined by stars of different spectral types. It is proposed to apply this method to the investigation of globular clusters and elliptical and spiral galaxies.

The purpose of this article is to illustrate the possibilities of such investigations, the results of measurements of UBVR ($\lambda_{R_{ef}} = 6800$ A) equidensity curves of the Sb type galaxy NGC 3031 (M 81) being used as an example (Fig. 1). Altogether 49 equidensity curves were obtained from plates taken with two meter Tautenburg telescope. Data on the plates used are given in Table 1. The equidensity curves in B are very

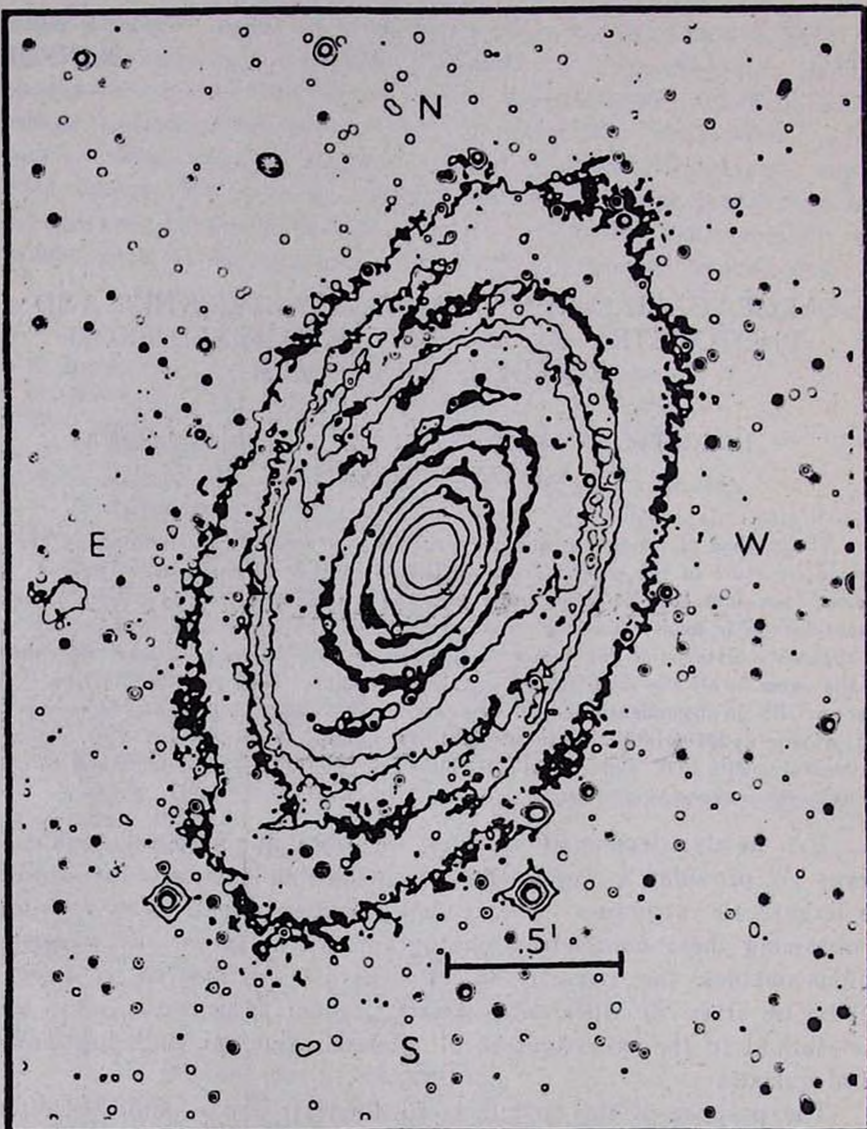

Fig. 1. Equidensity curves in B magnitudes.

similar to the isophotes of M 81 in blue light found from direct measurements by E. Dennison [2] using an automatic isophotometer.

The x and y coordinates of 72 points through 5° were measured on each equidensity curve. Each curve was then approximated by an ellipse and the parameters of the ellipse calculated with the Minsk-22 computer at Pulkovo. The derived results are given in Table 2, where R is the mean distance of the equidensity curve from the center of the

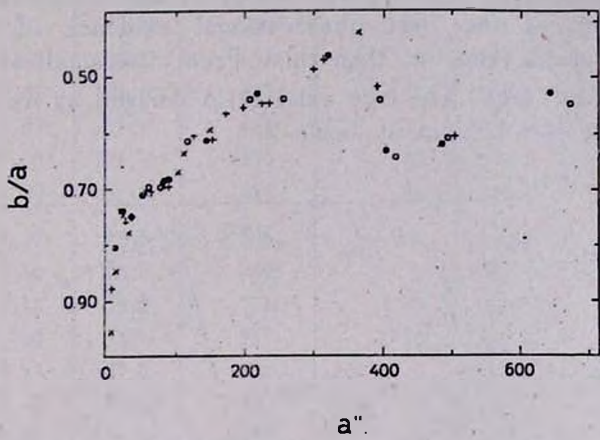

Fig. 2. The apparent axial ratio b/a plotted against the semi-major axis a (in seconds of arc). + — R, ○ — V, ● — B, × — U.

galaxy, a -- the semi-major axis, b/a — the apparent axial ratio, φ — the position angle of the major axis and $\sigma_{b/a}$ and σ_{φ} — the corresponding mean errors. The dependence of b/a and φ on a are illustrated in Figs. 2 and 3, which show that the variations of these parameters are the same for all the studied wavelength regions. They also indicate that

Table 1

Tautenburg Plate No.	Emulsion + Filter	System	Exposure (*min*)	Date	Observer
2714	ZU 2+UG 2	U	100	1968 March 1/2	Hoegner
2713	ZU 2+GG 13	B	60	1968 March 1/2	Hoegner
2426	103a-G+GG 11	V	60	1967 March 8/9	Hoegner
2432	103a-E+RG 1	R	71	1967 March 12/13	Hoegner

the values of these parameters derived in different studies will depend on the angular diameter of the galaxy on the photographs used for the investigation.

The true flattening $1 - b_0/a_0$, where b_0 is the polar axis and a_0 the equatorial diameter, can be determined from the formula

$$\left(\frac{b_0}{a_0}\right)^2 = \frac{(b/a)^2 - \sin^2 i}{\cos^2 i}.$$

The tilt angle i for this galaxy was determined by Danver [3] by means of experimental photographic projection and found to be equal to 30°8, which corresponds to $b/a = 0.512$. Three of the measured equidensity curves, located at the first observational evidence of spiral arms, have a value of b/a smaller than this. From the smallest value $b/a = 0.419$, we find 24°8. The true axial ratio derived by using this value is given in the last column of Table 2.

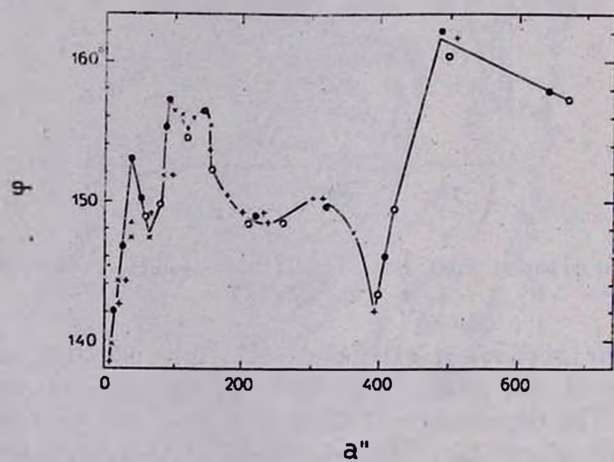

Fig. 3. The position angle of the major axis plotted against the semi-major axis a (in seconds of arc). + — R, ○ — V, ● — B, × — U. The line drawn through the data points has been put in to illustrate the trend of the points.

The rotation curve of this galaxy was determined by G. Münch from observations of H II regions [4]. A comparison with the curve found for b/a shows that both curves have a similar trend and that the maxima of both curves are located at the same distance from the center of the galaxy.

A photographic wedge was printed on the original photographs enabling an estimation of the relative surface brightness of each of the equidensity curves. Photoelectric measurements in UBV of the surface brightness of M 81 were made in two directions by S. Simkin [5], the data extending to just beyond the first visible indications of a

Table 2

	R *mm*	a''	b/a	$\sigma_{b/a}$	φ	σ_φ	b_0/a_0
1	2	3	4	5	6	7	8
U	0.62	6.6	0.954	±0.000	151°.5	±0°.0	0.944
	1.23	13.7	845	0	139.8	0.0	808
	1.92	22.8	742	1	144.2	0.1	674
	2.83	33.4	773	4	147.3	0.7	715
	4.94	61.6	703	8	147.4	0.8	622
	6.88	86.1	691	8	151.6	0.8	605
	7.87	101.6	667	11	156.5	0.9	572
	8.37	111.9	634	13	156.2	1.0	524
	11.05	151.2	594	13	155.6	0.9	464
	21.30	362.9	419	24	147.9	0.9	000
B	1.29	13.8	0.806	±0.000	142.2	±0.0	0.758
	2.16	25.6	739	1	146.7	0.1	670
	3.19	38.2	751	5	153.0	0.5	686
	4.38	53.7	711	10	150.1	1.0	633
	6.92	87.4	684	7	155.4	0.7	594
	7.34	92.7	682	7	157.2	0.6	593
	10.67	143.5	613	10	156.5	0.7	493
	15.26	220.0	533	6	148.9	0.3	363
	20.49	320.9	464	15	149.8	0.6	220
	30.91	405.8	632	29	146.2	1.4	521
	36.76	487.5	620	10	162.4	0.7	503
	44.32	644.9	526	6	158.1	0.3	350
V	4.89	60.7	0.694	±0.005	148.6	±0.5	0.609
	6.63	82.6	693	6	149.6	0.6	608
	8.96	118.5	614	10	154.5	0.7	494
	11.47	154.1	598	6	152.3	0.4	470
	14.68	209.0	541	5	148.4	0.3	377
	18.07	257.5	538	9	148.5	0.5	372
	27.63	397.5	539	25	143.4	1.3	373
	31.99	419.2	643	13	149.5	1.0	537
	37.05	495.8	608	10	160.4	0.6	485
	47.36	673.7	546	10	157.4	0.5	386

Table 2 (cont.)

1	2	3	4	5	6	7	8
R	0.81	8.8	0.878	±0.000	138.6°	±0.0°	0.850
	1.61	19.1	736	0	142.4	0.0	666
	2.35	27.7	756	1	144.2	0.1	693
	3.19	38.3	747	2	149.0	0.3	681
	5.25	65.6	703	3	148.3	0.3	622
	7.32	91.7	696	5	151.8	0.5	612
	8.71	117.2	619	8	155.2	0.6	502
	9.32	126.5	606	8	155.8	0.5	482
	11.24	151.1	610	6	153.6	0.4	488
	12.30	173.2	568	5	150.5	0.3	422
	13.98	199.5	555	6	149.2	0.3	401
	15.83	227.0	548	8	149.0	0.4	389
	16.03	234.4	547	18	148.6	1.0	387
	19.36	299.7	486	11	150.2	0.5	270
	20.01	314.7	471	12	150.2	0.5	237
	26.05	393.2	516	22	142.2	1.1	332
	37.41	508.9	603	8	161.9	0.5	478

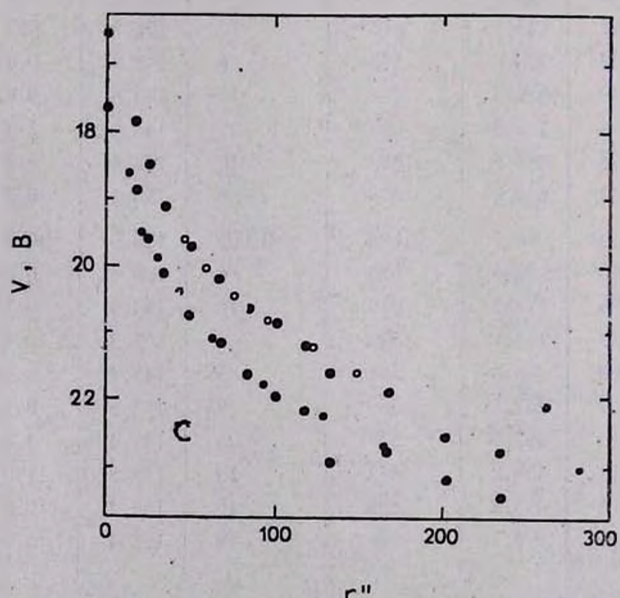

Fig. 4. The apparent V and B surface brightness in dependence on the distance r (position angle $\varphi=90°$) from the center of the galaxy. The large dots are values obtained from photoelectric measurements by S. Simkin. The open circles are V magnitudes and the small dots B magnitudes determined from equidensity curves.

spiral arm. In order to convert our relative values of surface brightness to apparent surface brightness as found from measurements given in [5] we used the data measured with a diaphragm size of 6.6 sec of arc given in table IV of that paper. We assumed that these measurements were made through the center of the galaxy in the west-east direction and computed the corresponding values of the projected semi-major axis of the measured equidensity curves in that direction, i. e. $\varphi = 90°$. The values of B and V in dependence on the distance r from the center of the galaxy at $\varphi = 90°$ found in the present investigation were com-

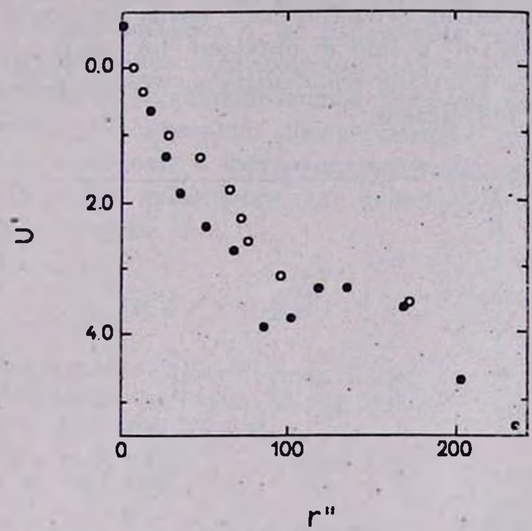

Fig. 5. The apparent surface brightness in U magnitudes (arbitrary zero-point). in dependence on the distance r (position angle $\varphi = 90°$) from the center of the galaxy. Large dots — photoelectric measurements by S. Simkin, open circles — values obtained from equidensity curves.

pared with those given in [5] by adjusting the zero-point. As seen from Fig. 4 the fit of the curves is satisfactory to $r = 168.0$, the mean deviation of our magnitudes being $\pm 0^m09$. The corresponding data for the U magnitudes are given in Fig. 5. Here our values differ significantly from those obtained in [5] and as it was not possible to fit the curves we were not able to convert our values of relative surface brightness in U to apparent U magnitudes. The graph thus only illustrates the variations of U with r found in both investigations.

The variations of the UBV surface brightness in dependence on the semi-major axis are in Fig. 6. The magnitudes on the ordinate axis do not apply to the plotted points for the U magnitudes for reasons stated above. The sudden variation in the U magnitudes at $61'' < a < 85''$ coincides with an abrupt variation in the position angle of the semi-major axis in Fig 3. The following variation in U again coincides with the beginning of an abrupt variation in φ.

The method of equidensity curves permits the evaluation of the variations of surface brightness in all directions from the center of the galaxy if these values are known for any one direction. In all the graphs given in this paper the measured semi-major axes, which have different position angles, were used as the abscissa. The values of the various characteristics plotted as ordinates can easily be found for a given φ by using the values of a and b obtained for each equidensity curve and given in Table 2, as the equidensity curves of M 81 are satisfactorily approximated by ellipses.

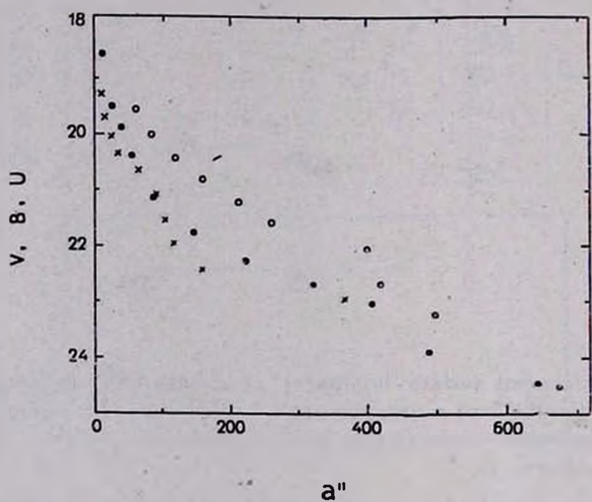

Fig. 6. The derived apparent surface brightness plotted against the semi-major axis a. Open circles designate V magnitudes, dots — B magnitudes. The crosses correspond to U magnitudes as explained in the text.

A more detailed analysis of the data obtained will be forthcoming as we derive more information on different types of celestial objects by means of integral equidensity curves.

Обсерватория им. К. Шварцшильда,
Таутенбург, ГДР
Пулковская обсерватория

КРУПНОМАСШТАБНЫЕ СТРУКТУРНЫЕ ХАРАКТЕРИСТИКИ И ФОТОМЕТРИЯ NGC 3031 МЕТОДОМ ЭКВИДЕНСИТ

В. ХЁГНЕР, З. КАДЛА, Н. РИХТЕР, А. СТРУГАЦКАЯ

Метод интегральных эквиденсит был применен для определения крупномасштабной структуры галактики NGC 3031. Используя четыре пластинки, снятые в UBVR двухметровым телескопом Таутенбургской обсерватории, были получены 49 эквиденсит, по которым были найдены зависимости между отношением полуосей b/a, а также позиционного угла большой полуоси φ, от расстояния от центра галактики. Эти зависимости оказались одинаковыми для всех рассматриваемых длин волн. Впечатанный калибрированный фотометрический клин позволил определить относительную поверхностную яркость в UBV в зависимости от a. Сравнение с фотоэлектрическими измерениями дало возможность определить нуль-пункт для перехода к видимой поверхностной яркости в системе V и B.

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