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Physical Parameters of Late Type Spiral Galaxies – II. Surface Brightness Distribution of NGC7793 *

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Abstract

Isophotes and surface brightness distribution were obtained for the late type normal spiral galaxy NGC 7793 (morphological type SA(s)d) which is one of the Sculptor group. The calculated total luminosity B_T is obtained as 9.44 and the corrected face on magnitude B_T° is 9.10. The revised distance to this galaxy $\Delta = 3.1$ Mpc (de Vaucouleurs and Davoust 1980) is used for calculating the absolute magnitude $M_T^\circ = -18.36$. From the isophotes, the position angle to the major axis is 101°, the mean axial ratio is $q = b/a = 0.65$, and the inclination is $i = 50°$. The concentric indices $C_{21} = 1.69$ and $C_{32} = 1.50$ are well agreed to the average value of Sd type galaxies.

I. Introduction

In this paper, we study the surface photometry for NGC 7793 which is the faintest spiral galaxy among five major galaxies in sculptor group. This study will contribute to the analysis of luminosity distribution in NGC 7793.

The nuclei of this galaxy is bright and small, and it has many OB knots and HII regions in spiral arms (Davoust and de Vaucouleurs 1980). Sharpley classified NGC 7793 as a typical late Sd and it was reclassified as SA(s)d (t = 7) which is somewhat later than M33, SA(s)cd (t = 6). The luminosity class of this galaxy is L = 6.5 (van den Bergh 1963) and the luminosity index is $\Lambda_c = 1.34$.

The distance to the Sculptor group $\Delta = 2.5$ Mpc in RC2 (de Vaucouleurs *et al.* 1976; Second Reference Catalogue of Bright Galaxies) is not the best estimate for NGC 7793. The revised distance $\Delta = 3.1$ Mpc to NGC 7793 is estimated by de Vaucouleurs and Davoust from the new photometric data. At the adopted revised distance, the scale factor is $1' = 0.91$ kpc.

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Galaxies have their characteristic surface luminosity profile according to their internal content, and the estimate of surface luminosity distribution is very important to study the structure and the dynamics of galaxies. In this paper we determine the geometric and physical parameters from the isophotes and the surface luminosity distribution profile of NGC 7793, and through the extrapolation of the exponentially decayed luminosity profile we correct the total magnitude of the galaxy. The detailed surface photometry of NGC 7793 is studied by de Vaucouleurs and Davoust in a continuing series of detailed photographic photometry of large southern galaxies. The main catalogue elements of NGC 7793 are listed in Table I.

Table I. The catalogue elements of NGC 7793

R. A. (1950)[1]	$23^h55^m.26$
Decl. (1950)[1]	$-32^\circ\ 52'.1$
Galactic ℓ, b[1]	$4^\circ.53, -77^\circ.17$
Supergalactic L, B[1]	$261^\circ.3, +3^\circ$
Type[1]	SA (S) dm (T=8)
Luminosity Class[2]	III-IV to IV (L=6.5)
Inner Dimension[3] (Dixdi)	$6'.6 \times 4'.7$
Outer Dimension[3] (Doxdo)	$9'.2 \times 6'.8$
Inner Axis Ratio[3] (Ri)	0.71
Outer Axis Ratio[3] (Ro)	0.74
Isophotal Diameter[1] (D25)	$9'.1 \pm 0'.7$
Axis Ratio[1] ($R25^{-1}$)	0.72 ± 0.04
Corrected Isophotal Diameter[1] (D_o)	$8'.7 \pm 0'.7$
Effective Aperture[4] (Ae)	$3'.16 \pm 0.22$
Total B Magnitude[1] (B_T)	9.64 ± 0.11
Corrected B Magnitude[1] (B_T^o)	9.30
Apparent Distance Moduls[4] (M_b)	27.23 ± 0.2
Galactic Extinction[1] (A_b)	0.23
Corrected Distance Modulus[4] (μ_o)	27.0 ± 0.2
Distance[1]	2.5 Mpc
Heliocentric Radial Velocity[1] (V)	209 ± 5 Kms^{-1}
Corrected Velocity[1] (V_o)	214 Kms^{-1}
Hydrogen Index[4] (HI)	1.71

1 : RC2, 2 : van den Bergh (1963)
3 : de Vaucouleur and Davoust (1980)
4 : de Vaucouleur (1978)

II. Reduction

Surface luminosity distribution is estimated from the scanning of ESO 349 plate using the PDS microdensitometer in ANU (Austrailia National University). The diameter of aperture for scanning is 17 μm (1."15), and the separation between the central points of apertures is 10 μm (0".68). The scanning was performed to the entire region 14'.1 x 14'.1 with the scanning speed 40 (ANU PDS unit). The detailed description about the system of ANU PDS and microdensitometer has given in Kim (1983).

III. Isophotes

The isophote of inner region (1'.13 x 0'.45) is shown in Figure 1. The equivalent radius of nuclear region and its effective radius are determined as 7".8 and 5". These can be compared with 24".1 and 6" in the study of de Vaucouleurs and Davoust. The isophote of outer region is shown in Figure 2 (3'.46 x 3'46). Some of the peaks or islands in the outer parts are star clouds, OB knots, and HII regions.

From the Figure 2 the position angle in radius 1'.72 from the center along the major axis is derived as 101°. Detailed variation of position angle along radius has given by de Vaucoulerus and Davoust(1980), and Chun (1986) in Figure 3. Our result is well fitted to the chun's. The results of de Vaucouleurs and Davoust (1980), and Chun (1986) are well agreed to each other after 1'.5 in radius from the center. They determine the average position angle of NGC 7793 as 97°.0 and 97°.3 respectively. In these results rapid variation is shown near 1', so we can suppose that the rotation to 2' is different from the rotation of outer part.

The variation of ellipticity along the major axis is shown in Figure 4. In the studies of de Vaucouleurs and Davoust (1980), and Chun (1986), the axis ratio b/a decreases from $\sim$ 1' in the nucleus to a minimum $(b/a)_{min} \approx 0.58$ near $a_{min} \approx 4'.5$ and increases again in the outer region to $\sim$ 0.68 near $a \approx 6'.5$. Our result shows the variation of ellipticity in inner region particularly. In our study the axis ratio increases from the center to a maximum $(b/a)_{max} \approx 0.83$ near $a_{max} \approx$ 0'.8 and also decreases like other results. The mean ellipticity derived as 0.65 ($0 < a < 3'.5$) and is comparable with 0.61 ($4' < a < 5'.4$) (de Vaucouleurs and Davoust 1980) and 0.65 ($0 < a <$ 6'.5) (Chun 1986).

The inclination can be computed by equation (1)

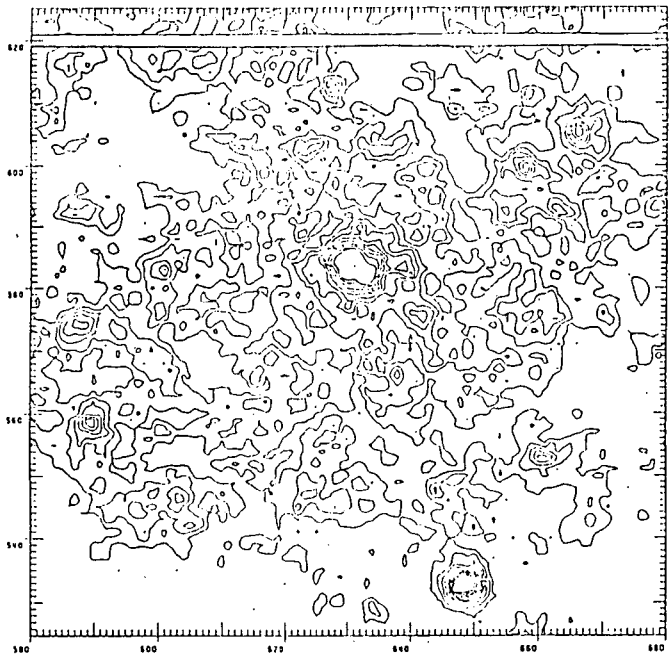

Figure 1. Isophote of inner region of NGC 7793 (1′.13 x 0′.45).

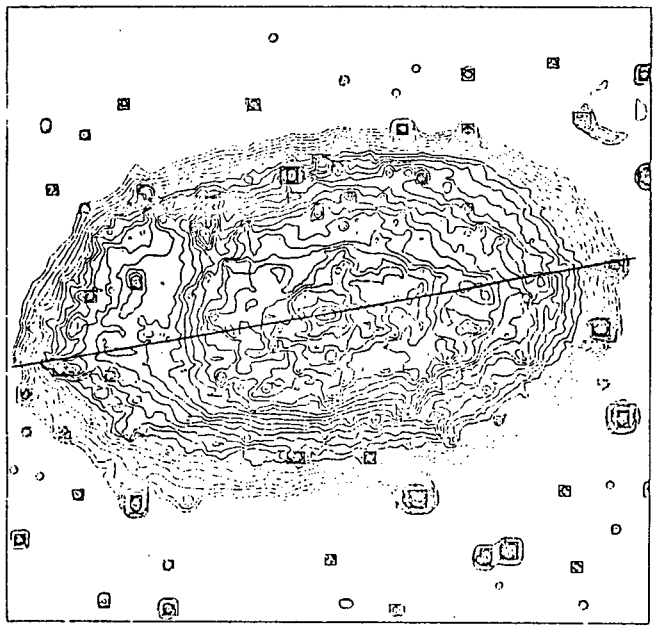

Figure 2. Isophote of outer region of NGC 7793 (3′.46 x 3′.46).

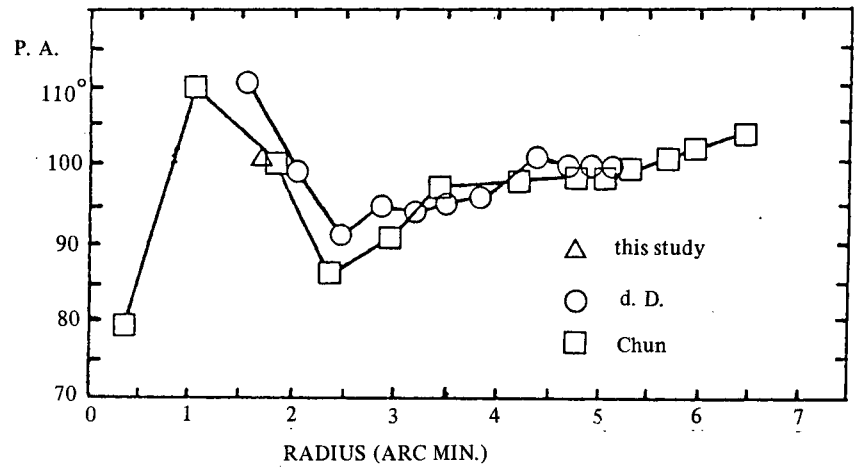

Figure 3. Variation of the position angle along the radius.

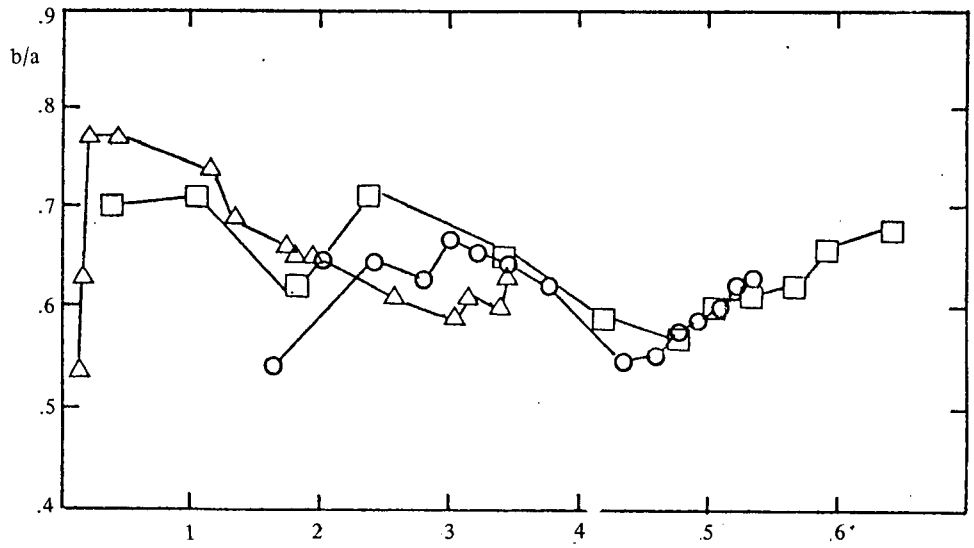

Figure 4. Variation of the ellipticity along the major axis. Symbols have the same meaning as in Figure 3.

$$\cos^2 i = (q^2 - q_o^2)/(1 - q_o^2) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where q_o is true axis ratio c/a. From the five flattest Sd galaxies in RC2, We adopt $q_o = 0.12$. The results are in Table II. The variation of the inclination along the equivalent radius is shown in Figure 5, and in this Figure the result of us is compared with those of de Vaucouleurs and Davoust (1980), and Chun (1986). The orientation parameters of NGC 7793 are collected in Table III.

Table II. Ellipticity and inclination of NGC 7793

a′	b/a	i (deg.)
0.11	0.54	58.0
0.16	0.63	51.5
0.22	0.77	40.0
0.33	0.72	44.4
0.44	0.77	40.0
0.64	0.83	34.2
0.95	0.75	41.8
1.17	0.74	42.6
1.33	0.69	46.8
1.65	0.60	53.7
1.74	0.66	49.2
1.83	0.65	50.0
1.95	0.65	50.0
2.32	0.58	55.1
2.58	0.61	53.0
2.87	0.56	56.5
2.96	0.56	56.5
3.00	0.57	55.9
3.04	0.59	54.4
3.10	0.60	53.7
3.16	0.61	53.0
3.24	0.61	53.0
3.41	0.60	53.7
3.45	0.63	51.5

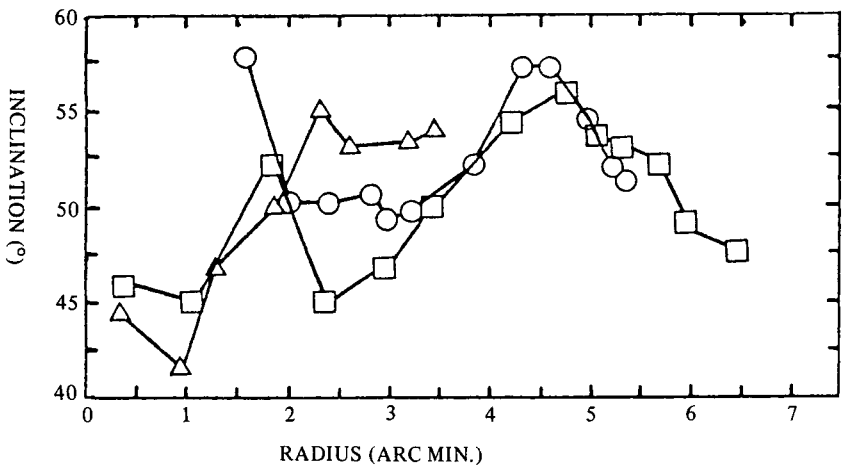

Figure 5. Variation of the inclination along the radius. Symbols have the same meaning as in Figure 3.

Table III. Orientation parameters of NGC 7793

	b/a	position angle (°)	inclination (°)
this study	0.65	101	50
d. D. (1980)	0.61	97.0	53
Chun (1986)	0.65	97.3	50

d. D : de Vaucouleurs and Davoust

IV. Luminosity Profiles and Photometric Parameters

Geometric parameters can be obtained from the isophotes, but luminosity distribution profile is needed for physical parameters of the galaxy. Detailed process of calculation for physical parameters and the correction contained here are well described in RC2 and Kim (1983).

IV-1. Spheroidal Component

The luminosity profile of NGC 7793 has the typical shape of type II in Freeman's classification of disk galaxies, and it has shallow spheroidal component. Figure 6 which is the luminosity profile of spheroidal component shows the limit of this component as near $R^* = 0'.13$. In this component surface brightness to $R^{*1/4}$ is distributed as equation (2).

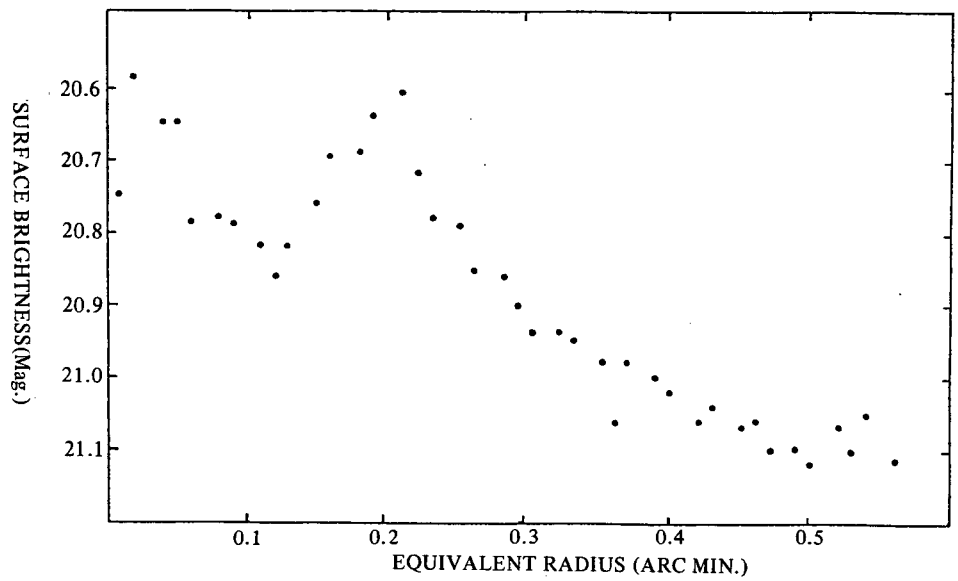

Figure 6. Luminosity profile of the spheroidal component.

$$U(R^*)_{CB} = 1.283\ R^{*1/4} + 20.09 \qquad (2)$$

In equation (2), surface brightness in center and in effective radius ($Re^* = 0'.086$) are calculated as 20.09 mag. arcsec^{-2} and 20.78 mag. arcsec^{-2}.

The fractional luminosity of the spheroid is $K_{sp} = L_{sp}/L_T = 0.005$. This low value is consistent with the Sd classification and is comparable with $K_{sp} = 0.15$ in NGC 253, type Sc and $K_{sp} = 0.01$ in M33, type Scd (de Vaucouleurs and Davoust 1980).

The luminosity distribution and integrated luminosity for spheroidal component are given in Table IV. Where the first and the second raws denote the major and minor axis of the integrated ellipse, and the third, fourth, fifth, and sixth raws mean relative intensity, equivalent radius, surface brightness, and integrated magnitude.

Table IV. Mean luminosity distribution of inner part in NGC 7793

A″	B″	I	R*′	$U_B$mag./□″	TTL	A″	B″	I	R*′	$U_B$mag./□″	TTL
1.0	0.7	1.989	0.01	20.75	18.87	21.0	15.1	1.676	0.30	20.94	13.27
2.0	1.4	2.322	0.02	20.59	18.23	22.0	15.8	1.672	0.32	20.94	13.18
3.0	2.2	2.191	0.04	20.65	17.37	23.0	16.6	1.655	0.33	20.95	13.10
4.0	2.9	2.191	0.05	20.65	16.75	24.0	17.3	1.609	0.35	20.98	13.02
5.0	3.6	1.926	0.06	20.79	16.31	25.0	18.0	1.505	0.36	21.06	13.94
6.0	4.3	1.934	0.08	20.78	16.31	26.0	18.7	1.615	0.37	20.98	12.87
7.0	5.0	1.922	0.09	20.79	15.63	27.0	19.4	1.586	0.39	21.00	12.80
8.0	5.8	1.875	0.11	20.82	15.35	28.0	20.2	1.550	0.40	21.01	12.73
9.0	6.5	1.804	0.12	20.86	15.12	29.0	20.9	1.505	0.42	21.06	12.67
10.0	7.2	1.870	0.13	20.82	14.90	30.0	21.6	1.526	0.43	21.04	12.61
11.0	7.9	1.984	0.15	20.76	14.69	31.0	22.3	1.483	0.45	21.07	12.54
12.0	8.6	2.092	0.16	20.70	14.48	32.0	23.0	1.475	0.46	21.06	12.49
13.0	9.4	2.115	0.18	20.69	14.30	33.0	23.8	1.447	0.47	21.10	12.43
14.0	10.1	2.217	0.19	20.64	14.12	34.0	24.5	1.448	0.49	21.10	12.37
15.0	10.8	2.271	0.21	20.61	13.95	35.0	25.2	1.415	0.50	21.12	12.32
16.0	11.5	2.055	0.22	20.72	13.81	36.0	25.9	1.487	0.52	21.07	12.27
17.0	12.2	1.941	0.23	20.78	13.69	37.0	26.6	1.448	0.53	21.10	12.22
18.0	13.0	1.923	0.25	20.79	13.57	38.0	27.4	1.520	0.54	21.05	12.17
19.0	13.7	1.814	0.26	20.85	13.46	39.0	28.1	1.438	0.56	21.11	12.11
20.0	14.4	1.810	0.28	20.86	13.36	40.0	28.8				12.07
		1.736	0.29	20.90							

IV-2. Exponential Component

Figure 7 shows the exponential component from R* = 0′.21 to 5′.83. We eliminate the data in calculation after 5′.83 having large scatter. Luminosity distribution law of de Vaucouleurs (Mihalas and Binney 1982) in exponential component is in equation (3).

$$U(R^*)_{CD} = U(0)_{CD} + 1.0857\,\alpha\,R^* \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

where α^{-1} is the scale length of galaxy. In NGC 7793 equation (3) is replaced by equation (4).

$$U(R^*)_{CD} = 20.61 + 0.914\,R^* \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

From equation (3) and (4), we know the surface brightness in center $U(0)_{CD}$ is 20.61 mag. arcsec^{-2} in good agreement with the value 20.05 mag. arcsec^{-2} of de Vaucouleurs and Daboust. The scale length (α^{-1}) 1′.19 (1.08 kpc) is comparable with 0′.68 of Freeman (1970) and 1′.59 of de Vaucouleurs and Davoust (1980).

The luminosity ratio of disk to bulge is derived as large value as 199. The concentric indices

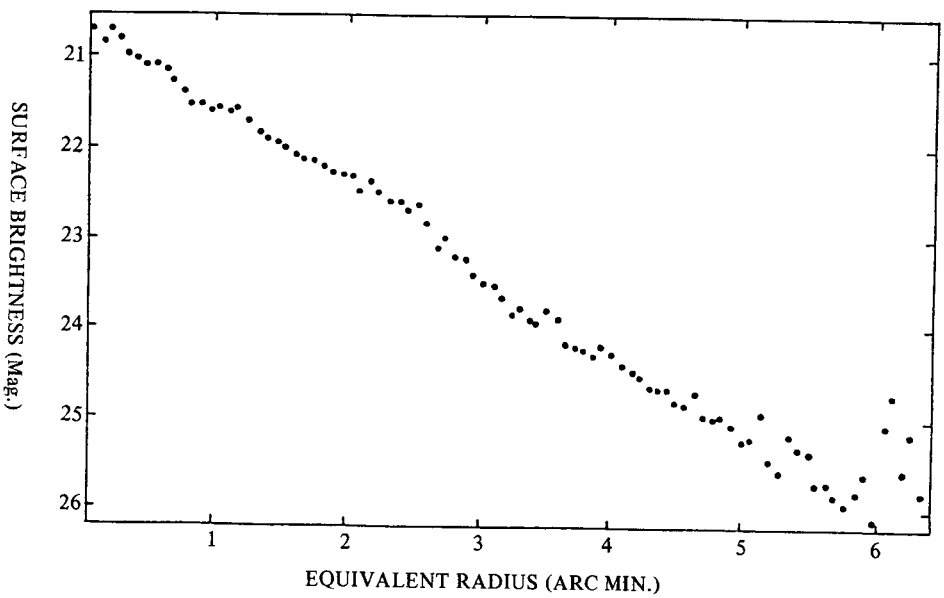

Figure 7. Luminosity profile of the exponential component.

Table V. Mean luminosity distribution of outer part in NGC 7793

A″	B″	I	R*′	$U_B$mag./□″	TTL
5.0	3.6	2.111	0.05	20.69	16.31
10.0	7.2	1.876	0.11	20.82	14.90
15.0	10.8	2.147	0.18	20.67	14.95
20.0	14.4	1.904	0.25	20.80	13.36
25.0	18.0	1.670	0.32	20.94	12.94
30.0	21.6	1.551	0.99	21.02	12.61
35.0	25.2	1.479	0.46	21.08	12.32
40.0	28.8	1.462	0.53	21.09	12.07
45.0	32.4	1.434	0.60	21.11	11.84
50.0	36.0	1.252	0.67	21.26	11.66
55.0	39.6	1.096	0.74	21.40	11.50
60.0	43.2	0.090	0.81	21.51	11.37
65.0	26.8	0.981	0.88	21.52	11.25
70.0	50.4	0.923	0.96	21.59	11.33
75.0	54.0	0.957	1.03	21.55	11.02
80.0	57.6	0.927	1.10	21.58	10.91
85.0	61.2	0.963	1.17	21.54	10.80
90.0	64.8	0.840	1.24	21.69	10.71
95.0	68.4	0.732	1.31	21.84	10.63
100.0	72.0	0.706	1.38	21.88	10.56
105.0	75.6	0.665	1.45	21.45	10.49
110.0	79.2	0.636	1.52	21.99	10.43
115.0	82.8	0.593	1.59	22.07	10.37
120.0	86.4	0.569	1.66	22.11	10.31
125.0	90.0	0.535	1.73	22.14	10.26
130.0	93.6	0.532	1.80	21.18	10.20
135.0	97.2	0.495	1.87	22.26	10.16
140.0	100.8	0.486	1.94	22.28	10.11
145.0	104.4	0.461	2.02	23.34	10.07
150.0	108.0	0.418	2.09	22.45	10.03
155.0	111.6	0.451	2.16	22.36	9.98
160.0	115.2	0.396	2.23	22.50	9.95
165.0	118.8	0.363	2.30	22.60	9.91
170.0	122.4	0.362	2.37	22.60	9.88
175.0	126.0	0.336	2.44	22.68	9.85
180.0	129.6	0.354	1.51	22.63	9.81
185.0	133.2	0.297	2.58	22.82	9.79
190.0	136.8	0.231	2.65	23.09	9.76
195.0	140.4	0.254	2.72	22.99	9.74
200.0	144.0	0.007	2.79	23.21	9.72

Table V. continued

A″	B″	I	R*′	$U_B$mag./□″	TTL
205.0	147.6	0.201	2.86	23.24	9.70
210.0	151.2	0.172	2.83	23.41	9.68
215.0	154.8	0.157	3.01	23.51	9.67
220.0	158.4	0.152	3.08	23.55	9.65
225.0	162.0	0.136	3.15	23.67	0.64
230.0	165.6	0.117	3.22	23.84	0.63
235.0	169.2	0.123	3.29	23.77	0.62
240.0	172.8	0.111	3.36	23.89	9.61
245.0	176.4	0.108	3.43	23.92	9.59
250.0	180.0	0.121	3.50	23.79	9.58
255.0	183.6	0.110	3.57	23.89	9.57
260.0	187.2	0.085	3.64	24.18	9.56
265.0	190.8	0.083	3.71	24.20	9.55
270.0	194.4	0.081	3.78	24.23	9.54
275.0	198.0	0.076	3.85	24.30	9.54
280.0	201.6	0.082	3.92	24.21	9.53
285.0	205.2	0.079	4.00	24.26	9.52
290.0	208.8	0.069	4.07	24.40	9.51
295.0	212.4	0.064	4.14	24.48	9.50
300.0	216.0	0.061	4.21	24.55	9.46
305.0	219.0	0.055	4.28	24.64	9.49
310.0	223.2	0.054	4.35	24.67	9.48
315.0	226.8	0.054	4.42	24.67	9.48
320.0	230.4	0.047	4.49	24.82	9.47
325.0	234.0	0.046	4.56	24.83	9.46
330.0	237.6	0.042	4.63	24.71	9.46
335.0	241.2	0.041	4.70	24.96	9.45
340.0	244.8	0.039	4.77	25.02	9.45
345.0	248.4	0.041	4.84	24.96	9.44
350.0	252.0	0.038	4.91	25.06	9.44
355.0	252.0	0.032	4.99	25.23	9.44
360.0	259.2	0.033	5.06	25.22	9.43
365.0	262.8	0.042	5.13	24.95	9.42
370.0	266.4	0.027	5.20	24.43	9.42
375.0	270.0	0.023	5.27	25.58	9.42
380.0	273.6	0.034	5.34	25.18	9.41
385.0	277.2	0.030	5.41	25.30	9.41
390.0	280.8	0.028	5.48	25.70	9.40
395.0	284.4	0.021	5.55	25.70	9.40
400.0	288.0	0.021	5.62	25.70	9.40
405.0	291.6	0.018	5.96	25.85	9.40
410.0	295.2	0.016	5.76	26.96	9.39
		0.019	5.83	25.83	

C_{21} and C_{32} is determined as 1.69 and 1.50, respectively, and these values are slightly smaller than average values of its type. The luminosity distribution and integrated luminosity for exponential component are given in Table V. Where the meanings of the raws are the same as in Table IV.

IV-3. Total magnitude and Integrated luminosity.

The total magnitude was determined by linear extrapolation (i.e. exponential in intensity) of the equivalent luminosity profile (Figure 7) beyond the last level of Table V. The extrapolation correction is only 4.6% or 0.05 magnitude, and the total magnitude is B_T = 9.51 given in de Vaucouleurs and Davoust and B_T = 9.70 given in RC2.

The fractional integrated luminosity curve K(r*) is shown in Figure 8. The equivalent effective radius, defined by fractional integrated luminosity K(r*) = ½, is r_e^* = 1′.93 = 1.76 kpc corresponding values for M33 r_e^* = 9′.8=2.06 kpc (de Vaucouleurs 1959, △ = 0.72 Mpc) and for the LMC r_e^* = 2′.87 = 2.3 kpc (de Vaucouleurs 1960, △ = 0.046 Mpc). The effective surface brightness at r_e^* is μ_e = 22.28 mag. arcsec^{-2}, against 22.83 in M33 and 23.69 in the LMC.

The face-on apparent magnitude corrected for galatic extinction A_B = 0.23 and internal extinction A(i) = 0.11 is B_T° = 9.10, which gives an absolute magnitude $M_T^\circ(B)$ = −18.36 if △ = 3.1 Mpc. This is intermediate between the corresponding values for M33 (−18.51) and the LMC

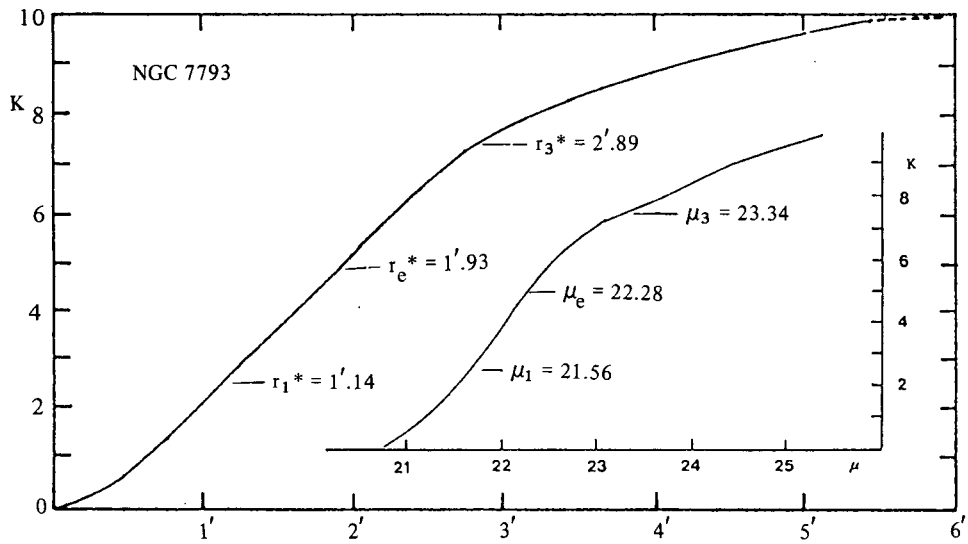

Figure 8. Relative integrated luminosity curve of NGC 7793. K is the fraction of the total luminosity.