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Physical Parameters of Late Type Spiral Galaxies - III. Mass and Mass to Luminosity Ratio of NGC 7793*

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Abstract

The mass distribution and other related quantities were calculated by fitting the observed rotation curve(Davoust and de Vaucouleur 1980) to Brandt and Belton's mass distribution model. One of n values for mass model is determined as 1.5(Vm = 95 kms $^{-1}$) and two pairs of them are determined as 0.8(Vm = 95 kms $^{-1}$) and 2.0 and 0.8(Vm = 55 kms $^{-1}$) and 2.0 because of the hump in observed rotation curve.

Total masses and integrated mass to luminosity ratios are 1.8×10^{10} $M_{\odot}$, 1.5×10^{10} $M_{\odot}$, 1.4×10^{10} $M_{\odot}$, and 6.57, 5.33, 5.26 for three cases according to n values. Integrated mass to luminosity ratio in Holmberg radius is 3.44, 3.26, 3.00 in good agreement with the typical value of Sd type suggested by Faber and Gallagher(1979). Presented halo masses which are fifty percent of total masses and halo mass to luminosity ratios given as 75.83, 53.50, 58.75 are values less than Turner's(1976).

I. Introduction

The mass and mass distribution of the disk galaxy were first studied by Bobcock for M31, and various mass models were made is 1960s. To get the mass and mass distribution of a galaxy, it is necessary to have the accurate rotation curve of a galaxy. From the study of the dynamical stability of a flat galaxy, Ostriker and Peables(1973) suggested the existence of massive halo.

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Robert(1975) got the rotation curve far outside of the optical radius in a galaxy using the 21 cm observation. His observations indicate that the outside rotation curve of a galaxy is flat and this was confirmed from the study of 6 edge on galaxies by Krumm and Salpeter(1977). Rubin et al. (1978) studied several Sa to Sc galaxies and their rotation curves show flat until 50 Kpc in radius. The maximum velocities have a correlation with the morphological type of galaxies, but no connection with the lumonosity type and radii of galaxies.

The mass distribution of NGC 7793 was obtained by Agüero(1979) until R = 2′67 and Davoust and de Vaucouleurs(1980) calculated the mass distribution and M/L value until R = 5′38. In this paper we tried to calculate the total mass, mass distribution, integrated luminosity and other dynamical parameters using the Brandt and Belton's disk model.

II. Rotation curve

The rotation curve of NGC 7793 was obtained from 3 HII regions. The radial distance R and the angle from the line of node were corrected to the inclination and position angle of this galaxy. The used lines to get the rotation velocity were H_α and H_β emission lines and the [OI] sky lines(5577 Å and 6400 Å) were used as the standard.

The system velocity of NGC 7793 was Vo = 220 kms^{-1} from the 21 cm observation by Lewis and Robinson(1973), and it was revised as Vo = 215 kms^{-1} by Carranza and Agüero(1977) and Vo = 221 kms^{-1} by Davoust and de Vaucouleurs(1980) from the observation of H_α interferometer. In this paper we used Vo = 221 kms^{-1} as the system velocity of NGC 7793. The calculated radial and rotation velocities are in Table 1 and we add these values to the Davoust and de Vaucouleurs' rotation curve. In Figure 1 the rotation curve shows a steep increase from centre to R = 50″, and afterward it increases slowly to the maximum velocity(V_m = 95 kms^{-1}) at R = 4′1. The rotation curve of NGC 7793 has a hump near R = 50″.

From the de Vaucouleurs correlation between the maximum rotation velocity and the radial distance to that velocity using the luminosity index(1977), we can get the maximum velocity as V_m = 96 kms^{-1} and radial distance R_m = 7′16. These values are similar to that of our rotation curve result.

The general rotation velocity as a function of a radial distance in a certain galaxy can be expressed by Brandt and Belton as

$$V(\tilde{\omega}') = \frac{A\tilde{\omega}'}{[1 + B^n(\tilde{\omega}')^n]^{3/2n}}$$

Table 1. Calculated radial & rotational velocity from H II regions observations

		$H_{23}(3\text{-}6)$	$H_{29}(3\text{-}5)$	$H_{29}(1\text{-}6)$	$H_{5/6}(2\text{-}6)$	$H_{5/6}(3\text{-}5)$
R		1′.5	2′.3	2′.3	3′.9	3′.9
θ		121°	160°	160°	314°	314°
	Hα	135	126	92	238	260
radial velocity	Hβ	267	244	206	318	330
			185	149	278	295
mean kms^{-1}		201	167		287	
rotation velocity kms^{-1}		49	72		118	

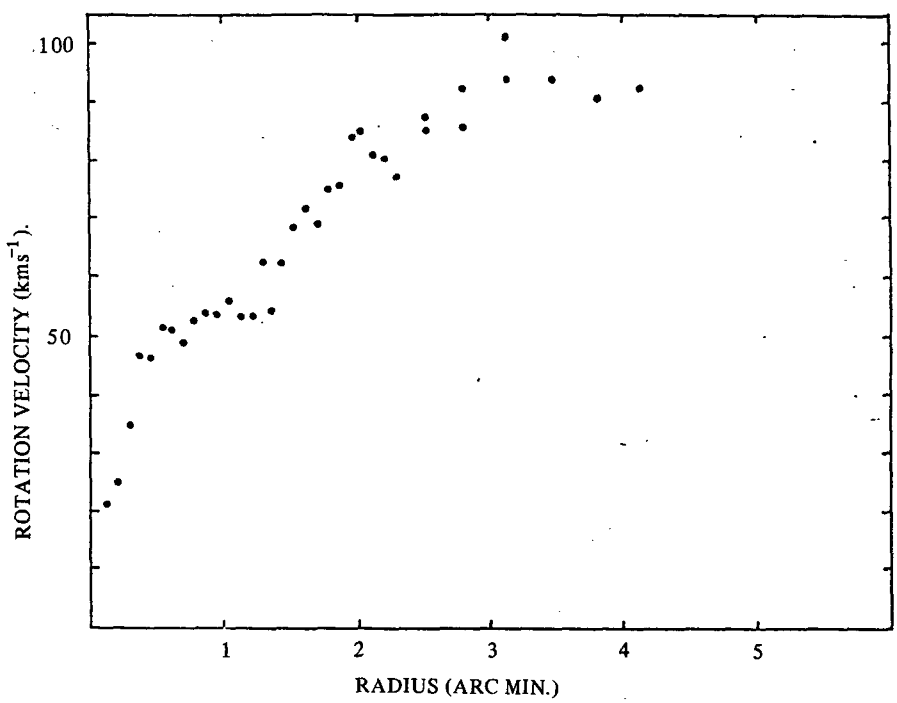

Fig. 1. Rotation curve of NGC 7793.

where $\bar{\omega}$ is the radial distance, and A and B are the rotation curve constant. The observed rotation curve of NGC 7793 was fitted to the model rotation curve, and n value was chosen from this fitting. There is a hump in the rotation curve of NGC 7793, so we tried 3 methods for the better fitting to the model curve. First method is the mean curve fitting without considering a hump, and

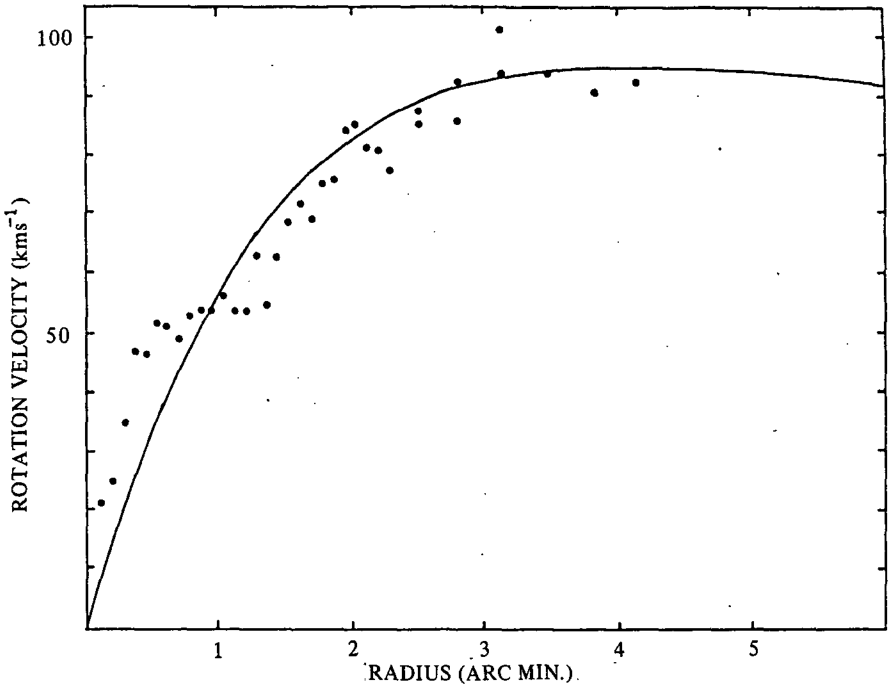

Fig. 2-a. Observed Rotation curve fitting to the model curve for case 1.

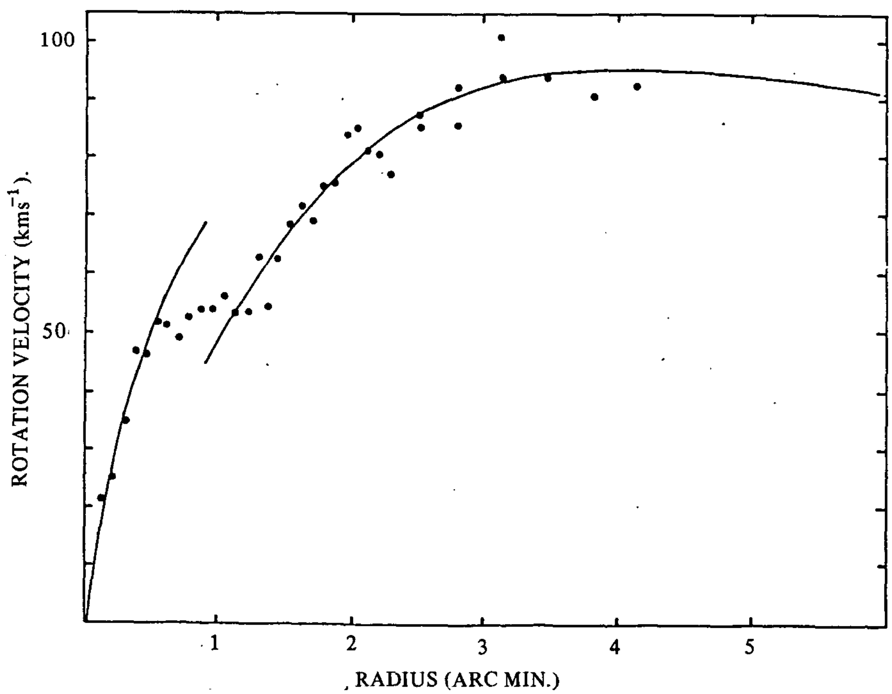

Fig. 2-b. Observed Rotation curve fitting to the model curve for case 2.

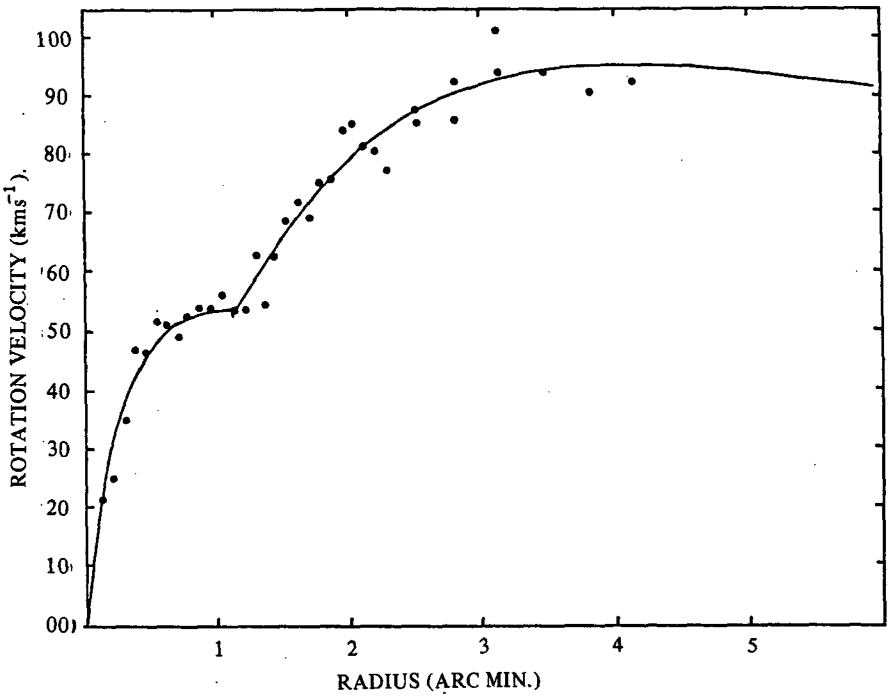

Fig. 2-c. Observed Rotation curve fitting to the model curve for case 3.

we can get n = 1.5 as in Figure 2-a. However it is not enough to fit with one n value, so we used two component model which has V_m = 95 kms^{-1} and R_m = 4.'1. Using this model we can have n = 0.8 until R = 0.'84 and n = 2.0 after this radial distance. The third method is the same as in method two except we assume that the rotation is different before and after the hump. Before the hump we assume the rotation as V_m = 55 kms^{-1}, R_m = 1.'37 and V_m = 95 kms^{-1}, R_m = 4.'1 after the hump. The fitting result is n = 0.8 before the hum] and n = 2.0 after the hump as in Figure 2-c.

III. Mass distribution

The mass distribution and the total mass were calculated using the Brandt and Belton's flat disk model. The mass, space density and surface density distributions of NGC 7793 are listed in Table 2, for 3 cases. The integrated homoeoid mass is plotted against to the radial distance as in Figure 3, and will be formulated as follow for each cases;

case 1	$M(R) \propto R^{2.67}$,	$R < 3'$(2.7 Kpc)
case 2	$M(R) \propto R^{1.98}$,	$R < 5'$(4.6 Kpc)
case 3	$M(R) \propto R^{2.09}$,	$R < 4'$(3.6 Kpc)

The total mass of NGC 7793 is 1.8 x 10^{10} $M_{\odot}$, 1.5 x 10^{10} $M_{\odot}$ and 1.4 x 10^{10} $M_{\odot}$ for each cases. In the case 3 we can get 3.3 x 10^9 $M_{\odot}$ until to the radial distance R = 2.43 Kpc, which mass is comparable to the Agüero's one(where his mass is 3.2 x 10^9 $M_{\odot}$).

For the mass of the inner part of NGC 7793, our result(0.3 x 10^7 $M_{\odot}$ for R = 40 pc) shows some difference with Aguero's one(0.4 x 10^8 $M_{\odot}$ for R = 40 pc). This difference may be as a result of the assumption of the normal circular motion in the central part of NGC 7793.

Table 2. Mass, space and surface density distributions of NGC 7793 (Case 1)

R	ω	M*	M**	Σ	ρ	V.T.	M/L*	M/L*
0.04	0.01			4.1	77	360		1.15
0.18	0.05	0.00018	0.0035	4.0	74	367	1.30	1.16
0.36	0.10	0.0018	0.019	3.9	68	390	1.86	1.59
0.89	0.25	0.023	0.085	3.2	49	444	1.88	1.98
1.78	0.50	0.11	0.23	2.0	25	541	1.93	2.21
2.67	0.75	0.24	0.41	1.3	13	684	2.66	3.35
3.56	1.00	0.38	0.56	0.82	6.9	820	2.55	4.46
4.45	1.25	0.50	0.69	0.56	4.0	949	2.86	6.71
5.34	1.5	0.61	0.81	0.38	2.5	1027	3.14	6.90
6.23	1.75	0.70	0.89	0.27	1.6	1124	3.36	13.85
7.12	2.00	0.79	0.97	0.20	1.1	1250	3.59	21.69
8.90	2.50	0.91	1.1	0.14	0.56	1687	3.99	67.96
10.68	3.00	1.0	1.2	0.078	0.27	1950	4.31	170
14.24	4.00	1.2	1.3	0.039	0.10	2600	4.82	1696
17.80	5.00	1.3	1.4	0.021	0.044	3231	5.11	17500
21.37	6.00	1.4			0.023			
24.93	7.00	1.4			0.012			
28.49	8.00	1.4			0.0093			
32.05	9.00	1.5			0.0068			
35.61	10.00	1.5			0.0044			
53.41	15.00	1.6			0.00073			
71.22	20.00	1.6			0.00030			
106.83	30.00	1.7			0.00004			

Table 2. Mass, space and surface density distributions of NGC 7793 (case 2)

R	ω	M*	M**	Σ	ρ	V.T.	M/L*	M/L**
0.04	0.01			8.0	442	123		2.24
0.18	0.05	0.0010	0.0063	7.1	296	162	2.33	2.06
0.36	0.10	0.0057	0.032	6.3	202	211	3.14	2.57
0.89	0.25	0.043	0.11	4.0	80	339	2.43	2.47
1.78	0.50	0.12	0.25	2.1	25	583	2.10	2.32
2.67	0.75	0.26	0.40	1.4	14	667	2.60	3.61
3.56	1.00	0.39	0.58	0.84	7.2	764	2.64	4.57
4.45	1.25	0.52	0.70	0.51	3.9	879	2.90	6.12
5.34	1.5	0.62	0.78	0.36	2.4	1029	3.02	6.53
6.23	1.75	0.71	0.85	0.24	1.5	1091	3.21	12.31
7.12	2.00	0.78	0.91	0.18	0.94	1286	3.37	19.52
8.90	2.50	0.91	1.0	0.10	0.45	1515	3.66	48.54
10.68	3.00	0.99	1.1	0.063	0.25	1703	4.01	130
14.24	4.00	1.1	1.2	0.027	0.076	2455	4.38	1174
17.80	5.00	1.1	1.2	0.014	0.030	3182	4.38	11667
21.37	6.00	1.2			0.015			
24.93	7.00	1.2			0.0085			
28.49	9.00	1.3			0.0049			
32.05	9.00	1.3			0.0037			
35.61	10.00	1.3			0.0028			
53.41	15.00	1.3			0.00049			
71.22	20.00	1.4			0.00017			
106.83	30.00	1.4			0.00003			

Table 2. Mass, space and surface density distributions of NGC 7793 (case 3)

R	ω	M*	M**	Σ	ρ	V.T.	M/L*	M/L**
0.04	0.01	0.00003	0.00024	7.4	1068	47	1.71	2.07
0.18	0.05	0.0016	0.0063	5.5	407	92	2.33	1.60
0.36	0.10	0.0068	3.6	3.6	187	130	1.57	1.47
0.89	0.25	0.031	0.051	1.3	38	232	1.13	0.802
1.78	0.50	0.11	0.18	2.1	25	583	1.51	2.32
2.67	0.75	0.24	0.33	1.4	14	667	2.14	3.61
3.56	1.00	0.37	0.51	0.84	7.2	764	2.32	4.57
4.45	1.25	0.50	0.63	0.51	3.9	879	2.61	6.12
5.34	1.50	0.60	0.71	0.36	2.4	1029	2.75	6.53
6.23	1.75	0.69	0.78	0.24	1.5	1091	2.94	12.31
7.12	2.00	0.76	0.84	0.18	0.94	1286	3.11	19.52
8.90	2.50	0.89	0.94	0.10	0.45	1515	3.44	48.54

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R	ω	M*	M**	Σ	ρ	V.T.	M/L*	M/L**
10.68	3.00	0.97	1.0	0.063	0.25	1703	3.87	130
14.24	4.00	1.1	1.1	0.027	0.076	2455	4.16	1174
17.90	5.00	1.1	1.2	0.014	0.030	3182	4.38	11667
21.37	6.00	1.2			0.015			
24.93	7.00	1.2			0.0085			
28.49	8.00	1.3			0.0049			
32.05	9.00	1.3			0.0037			
35.61	10.00	1.3			0.0028			
53.41	15.00	1.3			0.00049			
71.22	20.00	1.4			0.00017			
106.83	30.00	1.4			0.00003			

M* : homoeoid mass ($10^{10}M_\odot$), M**; cylinder mass ($10^{10}M_\odot$), Σ, surface density ($10^2 M_\odot/pc^2$)
ρ : space density (10^{-24} g/cm^3), V.T.: vertical thickness (pc), M/L: integrated M/L
M/L** local M/L.

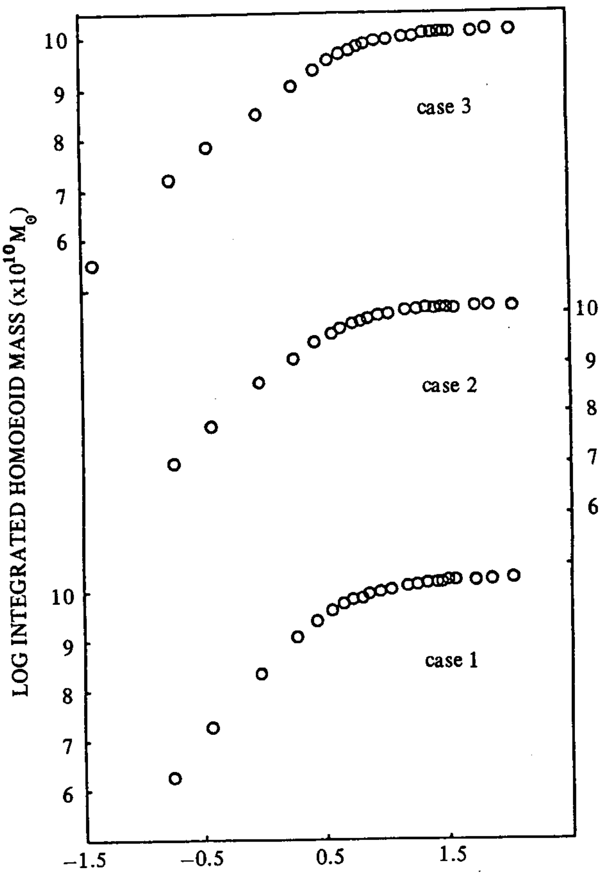

Fig. 3. The radial integrated homoeoid mass distribution.

The surface density distribution is plotted as in Figure 4. The central surface density is 410 $M_{\odot}/pc^2$, 810 $M_{\odot}/pc^2$ and 810 $M_{\odot}/pc^2$ for each cases and it drops 2.1 $M_{\odot}/pc^2$, 1.4 $M_{\odot}/pc^2$ and 1.4 $M_{\odot}/pc^2$ at the radial distance R = 16.2 Kpc respectively.

The central space density in NGC 7793 is 1.1 $M_{\odot}/pc^3$, 7.9 $M_{\odot}/pc^3$ and 23.4 $M_{\odot}/pc^3$ for each cases and this value was compared with the Agüero's result in Table 3. The space density distribution is plotted against to the radial distance in Figure 5. If we assume the boundary of NGC 7793

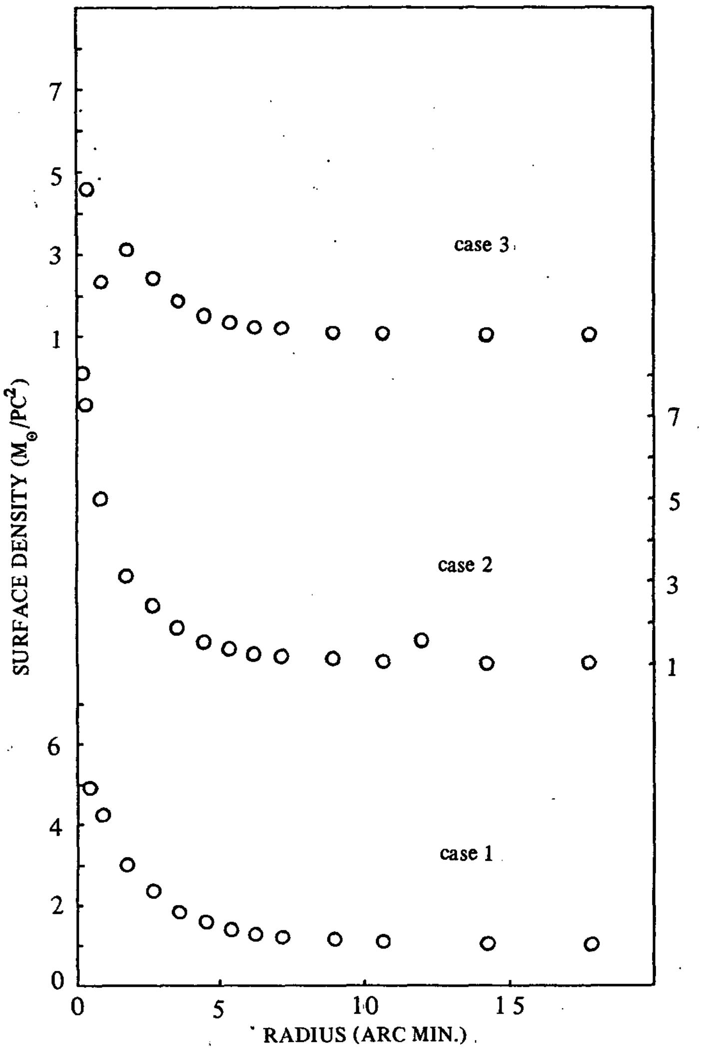

Fig. 4. Surface density distribution.

Table 3. Comparison with Agüero's result of the space density

	this study			Agüero (1979)
	case 1	case 2	case 3	
R=0.1Kpc	1.11 $M_{\odot}/pc^3$	5.37	10.52	13.10
R=1 Kpc	0.63	0.98	0.49	1.5
R=2.4 Kpc	0.19	0.21	0.21	0.10

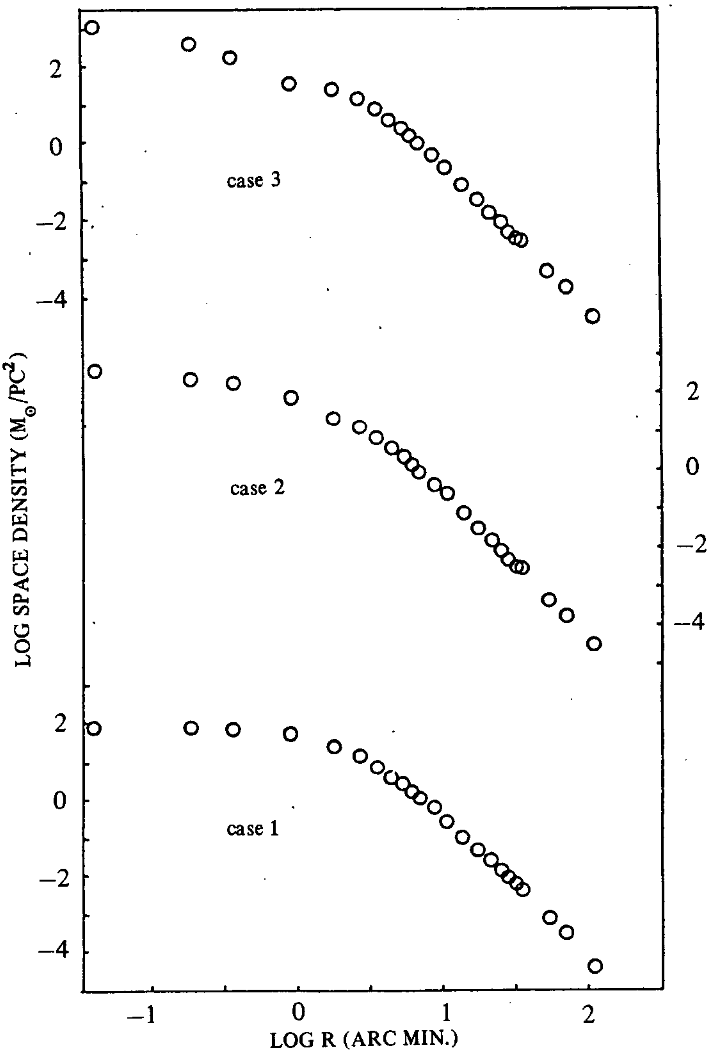

Fig. 5. Space density distribution.

as the mean space density of the universe ($\rho = 10^{-30}$ gcm^{-3}), then the radius will be 0.32 Mpc, 0.27 Mpc and 0.27 Mpc for each cases. However these values are too big to consider as a true radius of NGC 7793 because NGC 55 is apart only 7°5(about 0.4 Mpc) from NGC 7793. This also tells us that the mean density of the Sculptor Group is higher than the mean density of the universe.

The vertical thickness at certain place in a galaxy can be derived as the value of the ratio of the surface density to the space density. The vertical thickness to the radial distance is plotted in Figure 6, and the result show that all in 3 cases the vertical thickness increases from centre to the outer region.

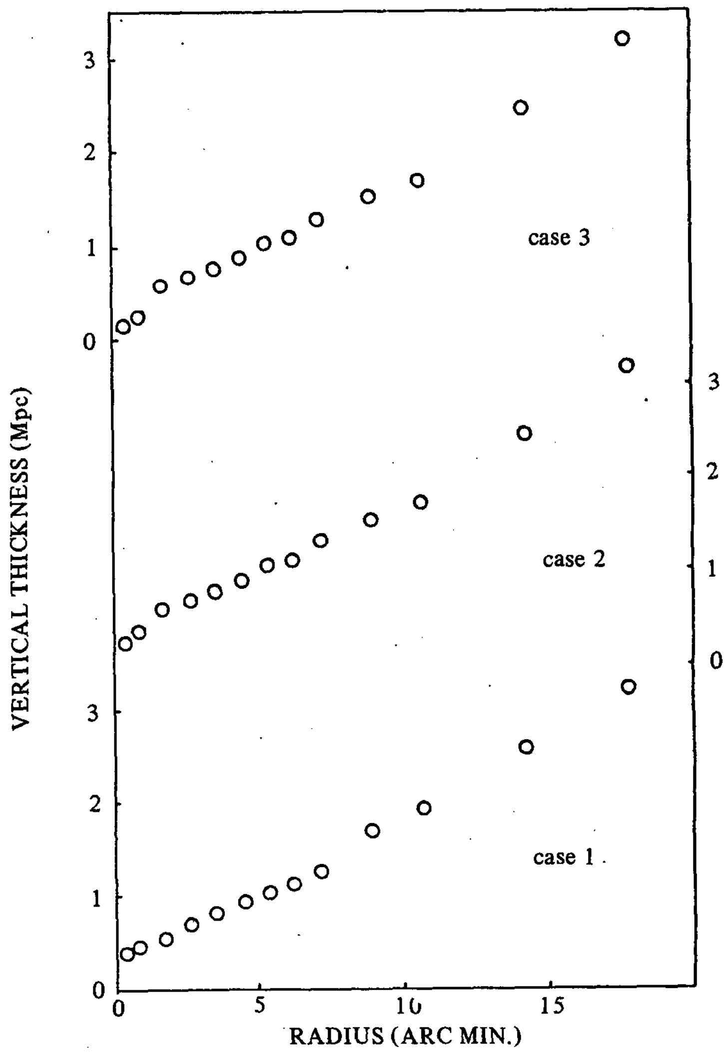

Fig. 6. Vertical thickness distribution.

Table 4. The integrated mass and the M/L ratio for each region of NGC 7793

		mass ($10^9 M_\odot$)	luminosity ($10^9 L_\odot$)	M/L
Nuclear region	case 1	0.018		1.29
(o <R <0.12 Kpc)	case 2	0.035	0.014	2.5
	case 3	0.04		2.86
disk	case 1	8.5		3.26
(0.12 <R <5.28Kpc)	case 2.	8.2	2.6	3.15
	case 3.	7.4		2.85
halo	case 1	9.1		75.83
(R >5.28Kpc)	case 2	6.4	0.12	53.50
	case 3	7.1		58.75

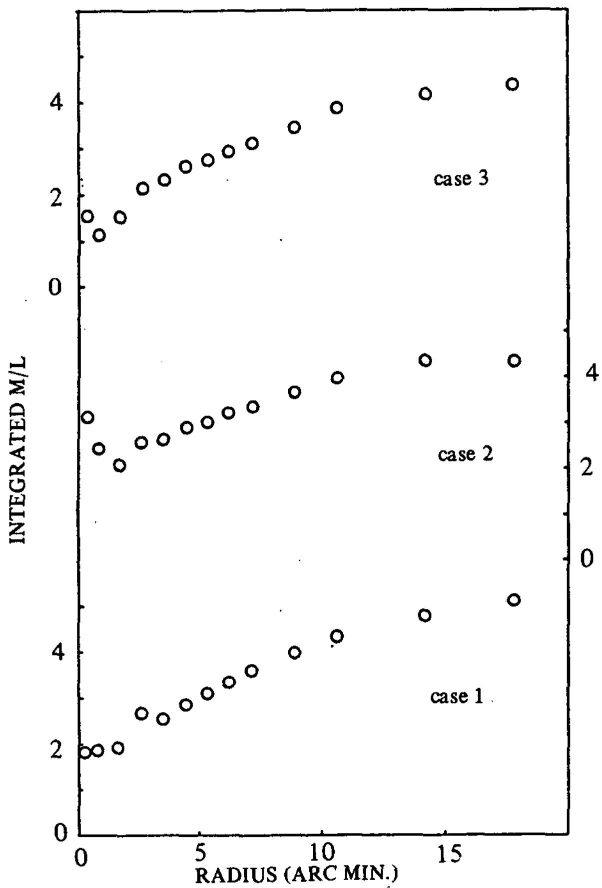

Fig. 7. The radial M/L distribution.

The integrated M/L ratio of NGC 7793 to the Holmberg's radius R = 6.44 is 3.44 for case 1, 3.26 for case 2 and 3.00 for case 3. These values coincide with the M/L value of the Sd type suggested by Faber and Gallagher(1979). We listed M/L values for each region of NGC 7793 in Table 4. The integrated M/L ratio to the disk by Davoust and de Vaucouleurs(1980) is 2.74, which is comparable with our value (we have 3.26, 3.15 and 2.85 for each cases). We also plot the M/L values to the radial distance in Figure 7.

IV. Discussion

From the model fitting calculation, the mass of NGC 7793 was derived as 1.5 x 10^{10} $M_{\odot}$. The integrated mass to luminosity ratio was 3 and this value is the typical one for Sd type galaxy. The mass of the halo is similar to that of the disk of NGC 7793, and the M/L of the halo is about 60. This result indicates that more than 50% of the total mass of NGC 7793 is in the dark halo and the M/L value of the halo is higher than the average M/L of this late type galaxy. This may come to the conclusion of the existence of the massive halo in NGC 7793.

Acknowledgment

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