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Disk Thicknesses and Some Parameters of 108 Non-Edge-On Spiral Galaxies *

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Abstract We present disk thicknesses, some other parameters and their statistics of 108 non-edge-on spiral galaxies. The method for determining the disk thickness is based on solving Poisson's equation for a disturbance of matter density in three-dimensional spiral galaxies. From the spiral arms found we could obtain the pitch angles, the inclination of the galactic disk, and the position of the innermost point (the forbidden region with radius r_0 to the galactic center) of the spiral arm, and finally the thickness.

Key words: galaxy: disk — galaxies: fundamental parameters — galaxies: spiral — galaxies: structure

1 INTRODUCTION

Disk thickness is a very important parameter for disk galaxies. So, van der Kruit & Searle (1981a) proposed a model for the three-dimensional distribution of light in galactic disks. Under the assumption that a disk galaxy has a locally isothermal, self-gravitating and truncated exponential disk, the space-luminosity of this model was rewritten as

$$L(r,z) = L_0 e^{-r/h_r} \mathrm{sech}^2(z/z_0). \tag{1}$$

With this model, van der Kruit & Searle (1981a,b; 1982a,b) determined h_r and z_0 for seven edge-on spiral galaxies without an appreciable bulge. A detailed investigation of edge-on spiral galaxies by de Grijs et al. (1997) showed, however, that the vertical light profiles are much closer to the exponential than to the isothermal solution. A method for determining thicknesses of non-edge-on spiral galaxies was given by Peng (1988) on the basis of an asymptotic expression of the perturbed gravitational potential. Based on this method, Ma et al. (1997, 1998) obtained large numbers of disk thicknesses of spiral galaxies. By using the data of Ma et al. (1997, 1998), Ma et al. (1999) and Ma (2002) presented some statistical correlations. Zhao, Peng & Wang (2004) reinvestigated the method based on a rigorous expression of the perturbed gravitational potential, and an assumed value of 0.5 for the semi-empirical criterion η based on a comparison between the thickness H and r_0 for Milky Way and Andromeda Nebula (M31). In fact, we found that the thickness of a galactic disk is sensitive to the parameter η, i.e., η affects the calibration and accuracy of the method. However, the number of the samples (Milky Way and M31) is limited. So, Hu, Peng & Zhao (2006a) improved the method by comparison with the asymptotic expression given by Peng (1988) and the thicknesses obtained by Ma et al. (1998). The result shows that η should be 0.486, and the average of 0.5 and 0.486 is $\overline{\eta} = 0.493$. Based on this method, the disk thicknesses of 108 non-edge-on spirals were obtained by determining the winding parameter, the number of spiral arms, and the forbidden radius of the galaxies (based on fitting the pattern of spiral structure).

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2 THEORETICAL MODEL

The matter density distribution along the z-direction for a galactic disk was given by Parenago:

$$\rho(r,\phi,z) = \frac{\alpha}{2}\sigma(r,\phi)\exp(-\alpha \mid z \mid), \tag{2}$$

where α is the disk thickness factor, $H = 2/\alpha$ is interpreted as the equivalent thickness of the galactic disk, $\sigma(r,\phi)$ represents surface matter density of the disk galaxy, comprising a base surface density $\sigma_0(r)$ and a disturbance density $\sigma_r(r,\phi,t)$,

$$\sigma(r,\phi) = \sigma_0(r) + \sigma_r(r,\phi,t), \tag{3}$$

where $\sigma_0(r) = \sigma_0 \exp(-r/r_d)$.

Matter density disturbance of the galactic disk may be given by the logarithmic spiral (Peng 1988),

$$\sigma_r(r,\phi,t) = \sigma_m(r)\exp[i(\omega t - m\phi)], \tag{4}$$

$$\sigma_m(r) = \frac{A}{r}\exp(i\Lambda \ln r). \tag{5}$$

The perturbed gravitational potential for such a logarithmic density disturbance via the Poisson's equation for the galactic disk with finite thickness was given by Peng et al. (1978, 1979),

$$V_\alpha(r,\phi,z=0,t) = -2\pi GA\exp[i(\omega t - m\phi + \Lambda \ln r)]Re[g(\Lambda,m;\alpha r)], \tag{6}$$

where

$$g(\Lambda,m;\alpha r) = \exp(i\Lambda \ln 2)\frac{\Gamma(\frac{1+m+i\Lambda}{2})}{\Gamma(\frac{1+m-i\Lambda}{2})}\int_0^\infty J_m(x)\frac{\exp(-i\Lambda \ln x)}{x(1+\frac{x}{\alpha r})}dx, \tag{7}$$

where, $\Gamma(x)$ and $J_m(x)$ are the usual Gamma and Bessel functions, respectively. For an infinitely thin disk, Equation (6) has a simplified form given by Kalnajs (1971):

$$V_{\alpha\to\infty}(r,\phi,z=0,t) = -2\pi GA\exp[i(\omega t - m\phi + \Lambda \ln r)]\frac{1}{\sqrt{m^2+\Lambda^2}}. \tag{8}$$

When $\alpha r \gg 1$, the solution of Equation (6) may be reduced to a simply asymptotic expression given by Peng (1988),

$$V_{\rm asymptotic}(r,\phi,z=0,t) \approx -2\pi GA\exp[i(\omega t - m\phi + \Lambda \ln r)]\Big(\frac{1}{\sqrt{m^2+\Lambda^2}} - \frac{1}{\alpha r}\Big), \tag{9}$$

the zero of Equation (9) is given by

$$\alpha r = \sqrt{m^2+\Lambda^2}, \tag{10}$$

and the corresponding radius is

$$r_{\rm zero} = \frac{\sqrt{m^2+\Lambda^2}}{\alpha} = H_{\rm sc}\sqrt{m^2+\Lambda^2} = \frac{H}{2}\sqrt{m^2+\Lambda^2}. \tag{11}$$

In fact, quite a few authors have studied in detail the shape of spiral arms (Danver 1942; Kennicutt 1981; Puerari & Dottori 1992; García-Gómez & Athanassoula 1993; Seigar & James 1998a,b; Ma 2001a), and found that the arms are well represented by logarithmic spirals. In particular, Ma (2001b) found that the arms of our nearest neighbor M31 can be well fitted by the logarithmic spiral.

Peng (1988) noted that spiral arms may exist only in the region $r \geq r_0 = r_{\rm zero}$ according to the physical concept of density waves of Lindblad. The equivalent thickness of galactic disk is given by Peng (1988) as

$$H = \frac{2r_0}{\sqrt{m^2+\Lambda^2}}, \tag{12}$$

it is based on the asymptotic Equation (9) when $V_{\rm asymptotic}(r,\phi,z=0,t) = 0$.

Zhao, Peng & Wang (2004) gave a way of calculating the thickness factor ($\alpha = 2/H$) by fixing the ratio of the amplitude of the perturbed gravitational potential for a spiral galaxy with finite thickness to that of an infinitely thin disk at the forbidden radius r_0,

$$\eta = \frac{V_\alpha(\alpha, m, \Lambda, r_0)}{V_{\alpha\to\infty}(m, \Lambda, r_0)} = Re[g(\alpha r_0)]\sqrt{m^2 + \Lambda^2}, \tag{13}$$

at the value 0.5, found from the values of H and r_0 of Milky Way and Andromeda Nebula (M31) (see the results of Ma 2003 and Zhao, Peng & Wang 2004 for details). In fact, the scale height is sensitive to the value of η and it should be kept in mind that the value 0.5 was based on two objects.

Hu, Peng & Zhao (2006a) applied their method to re-calculate the thicknesses of the same set of 71 northern spiral galaxies, used by Ma et al. (1998) previously. By calculating Equation (13) η were obtained based on using the data given by Ma et al. (1998), the average value, $\overline{\eta}$, is 0.486. In this paper, we take the average value of 0.500 and 0.486, i.e., we set η at 0.493. This value was used in Hu, Peng & Zhao (2006b) where they determined the mass-to-light ratios of nearly face-on spiral galaxies, they obtained that the mass-to-light ratio in B-band is 4.86∼8.99 $M_\odot\,L_\odot^{-1}$ for NGC 1566 and 5.02∼6.90 $M_\odot\,L_\odot^{-1}$ for NGC 5247. These results are consistent with the value of 5.0∼10.0 $M_\odot\,L_\odot^{-1}$ for both given by both Bottema (1992) and van der Kruit & Freeman (1986). Once the forbidden radius r_0, pitch angle $\mu = \arctan(m/\Lambda)$ and the number of spiral arms m are known, we can calculate the disk thickness parameter ($H = 2/\alpha$) by Equation (13).

The structure of this paper is as follows. The theoretical model is presented in Section 2. The samples and the main measurement steps are described in Section 3. In Section 4 we give the parameters for obtaining the disk thicknesses of spiral galaxies. Some statistical properties are presented in Section 5, and a discussion is given in Section 6.

3 THE SAMPLES AND THE MAIN MEASUREMENT STEPS

Our sample contains 108 spiral galaxies, selected from the spirals in the Third Reference Catalog of Bright Galaxies (1991, $RC3$), and their images were taken from SDSS (Data Release 3). The following parameters of these spiral galaxies are listed in Table 1: T, a galactic mean numerical Hubble stage index; D_{25}^m, the major isophote diameter in the image in arcmin; D_{25}, the same corrected for disk inclination in kpc, B_T^0, the galactic total B magnitude, $M_{B_T^0}$, the absolute magnitude, and v, the mean radial velocity of the radio and optical redshifts of the galaxy corrected to the Galactic center. We can obtain the distance of the galaxy from Galactic center by $d = v/H_0$, where H_0 is the Hubble constant taken as $75\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$. For images with distinguishable spiral arms, we selected those with g-band magnitudes $m_g \le 17$, disk inclinations less than 80°, and $D_{25}^m \ge 0.3$ arcmin. We acquire the disk inclination γ and the winding parameter Λ by fitting a spiral arm directly to the image. The IDL software is used to display the image and to measure the parameters. The main steps of measurement and calculation (see Hu et al. 2006a) are as follows:

(1) Adjust the display task range so as to have clear images.

(2) Obtain an approximate disk inclination γ_a with the expression

$$\gamma = \arccos\sqrt{1.042\frac{d_{25}}{D_{25}} - 0.042} + 0.052, \tag{14}$$

where, D_{25} and d_{25} are the apparent major and minor isophote diameters taken from $RC3$.

(3) Measure the most inward point of the spiral arm (polar coordinates, ρ_0, θ_0) to obtain the forbidden radius. Hu, Shao & Peng (2006c) investigated the forbidden radius r_0 of nearly face-on spiral galaxies by subtracting the model surface brightness from the image, thus showing only the spiral arms pattern without the bulge contamination. In this paper, we measured 10 nearly face-on spiral galaxies by this method. For non-face-on and non-edge-on spiral galaxies, we tried to obtain an elliptical surface brightness model according to the disk inclination γ. We plot the average value of the pixels in the elliptical zone in the image according to γ, versus the radius r, and then attempt to fit a brightness model to the plot. Lastly, we subtract this brightness model from the image according to the inclination γ, and obtain the residual which only contains the spiral arms pattern. Figure 1 shows the spiral arms in the g-band so revealed in seven non-face-on and non-edge-on spiral galaxies. This method can only be used when the image of the galaxy is clear, showing clear spiral arms.

Table 1 Disk Diameter, Hubble Sequence, Magnitude and Radial Velocity of these 108 Spiral Galaxies

PGC	Other name	T	D_{25}^m	D_{25} (kpc)	B_T^0 (m)	$M_{B_T^0}$ (M)	v (km s^{-1})
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PGC 00281		1.0	0.3	0.98			1149
PGC 01862		3.0	1.1	25.72			5388
PGC 02391	NGC 195	1.0	1.0	20.69			4976
PGC 04992	NGC 497	4.0	1.3	66.25	13.04	–15.69	8173
PGC 05270		3.0	1.2	6.57	13.92	–16.95	1118
PGC 08165	NGC 820	3.0	1.1	23.53	13.07	–14.06	4495
PGC 09376		4.3	1.2	33.22			5924
PGC 09822		5.0	1.1	29.41			6602
PGC 10464	NGC 1084	5.0	1.5	17.46	10.90	–20.44	1391
PGC 10857		4.0	1.0	36.49	14.59	–12.39	8777
PGC 11767		6.0	1.1	43.88			8984
PGC 12466	NGC 1299	3.0	1.1	10.33			2319
PGC 12772	NGC 1324	3.0	1.3	45.77			5646
PGC 13535		6.0	1.3	37.58			5201
PGC 21120		7.0	1.4	7.05	13.16	–17.01	812
PGC 21336	NGC 2410	3.0	1.4	44.26	12.82	–15.54	4647
PGC 21900		0.0	1.0	25.97	14.34	–17.28	7010
PGC 22565	IC 2219	5.0	1.1	26.45	13.80	–16.54	5172
PGC 22805	NGC 2528	3.0	1.2	23.55	13.14	–15.36	3919
PGC 22957	NGC 2535	5.0	1.4	38.41	12.64	–15.08	4033
PGC 23512	NGC 2576	3.0	1.2	54.62	13.91	–14.11	8289
PGC 23752		4.0	1.1	39.67	14.06	–14.06	8906
PGC 24399		4.0	1.1	5.48			1202
PGC 24641		3.0	1.1	40.55			9103
PGC 24996	IC 2421	5.0	1.3	36.88	13.81	–10.31	4345
PGC 25376	NGC 2731	0.0	0.9	7.56	14.03	–17.92	2454
PGC 25609	IC 2434	0.0	1.2	42.90	13.68	–17.75	7138
PGC 25946	NGC 2776	5.0	1.5	30.91	11.96	–19.76	2638
PGC 26304		9.0	1.5	24.72	13.55	–18.60	2015
PGC 26338		6.0	0.9	27.60			8750
PGC 26666	NGC 2857	5.0	1.4	42.71	13.07	–16.52	4917
PGC 27216		2.0	1.1	22.21	13.95	–15.02	4762
PGC 27527	NGC 2942	5.0	1.4	38.18	13.01	–12.62	4395
PGC 27968		7.0	1.2	19.92	13.75	–17.51	2955

(4) Transform the galactic plane coordinate into the tangent plane of the celestial sphere coordinate. A logarithmic spiral can be written as

$$\rho(\theta, \gamma) = \rho_0 \frac{f(\theta_0, \gamma)}{f(\theta, \gamma)} \exp\left[\frac{m}{\Lambda} \cdot B(\theta, \gamma)\right], \tag{15}$$

where

$$f(\theta, \gamma) = \sqrt{\sin^2\theta + \cos^2\theta \cdot \cos^2\gamma}, \tag{16}$$

and

$$B(\theta, \gamma) = \arctan\frac{\tan\theta}{\cos\gamma} - \arctan\frac{\tan\theta_0}{\cos\gamma} + k\pi, \quad k \text{ is an integer}, \tag{17}$$

where (r_0, ϕ_0) and (ρ_0, θ_0) correspond to the innermost point of the spiral arm in the galactic plane and in the tangent plane coordinates, respectively. By fitting the imaged spiral arm with Equation (15) starting from (ρ_0, θ_0), we can obtain the approximate winding parameter Λ_a.

(5) Adjust γ around γ_a and Λ around Λ_a, until a good fit to the imaged arm is obtained.

(6) Obtain the thickness factor α from Equation (13), and hence the disk thickness $H = 2/\alpha$.

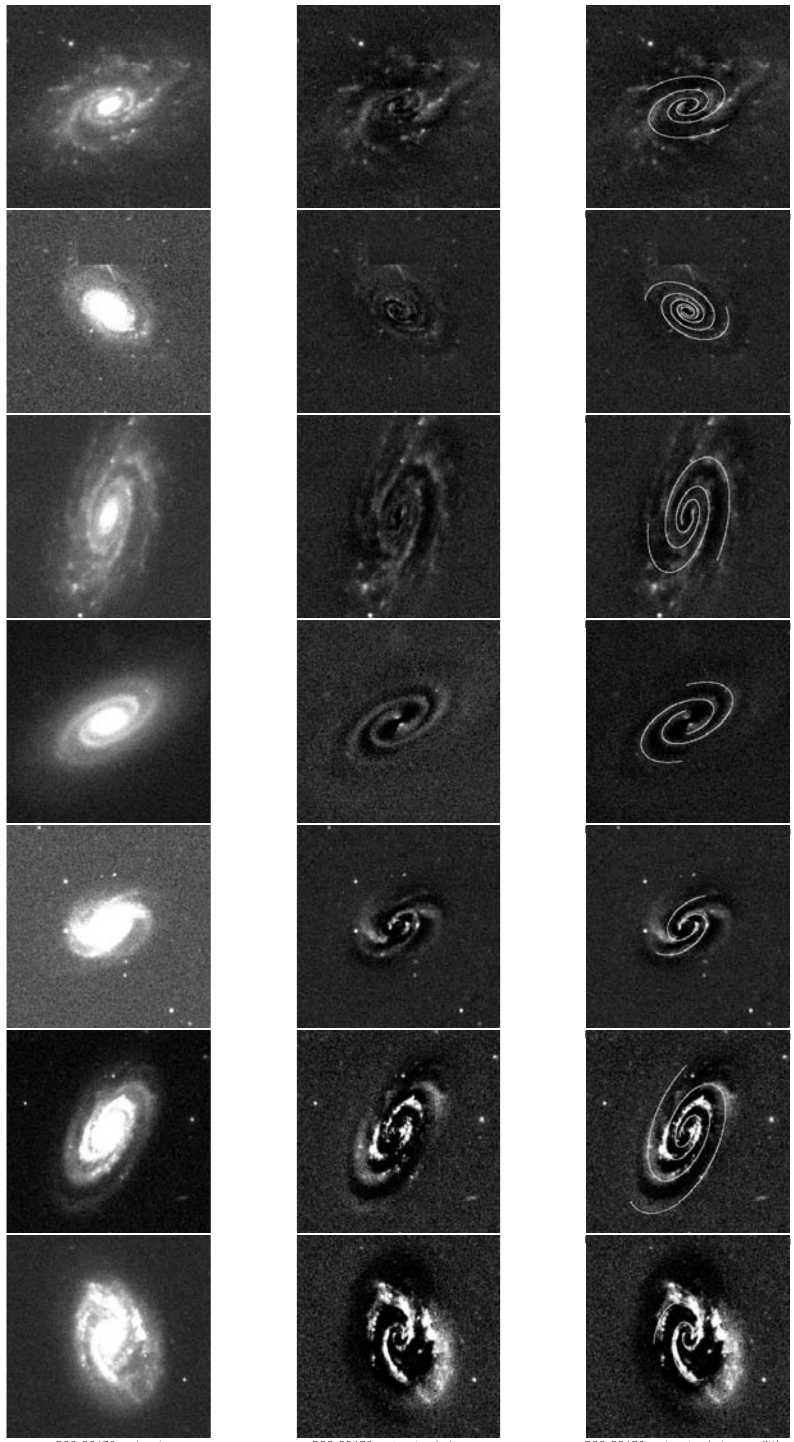

Fig. 1 From top to bottom, the images (g-band) of PGC 13535, PGC 26338, PGC 30386, PGC 40030, PGC 50430, PGC 51541 and PGC 52476. From left to right, Column 1: The original image. Column 2: Residual image after subtracting the base background. Column 3: Fitted spiral pattern.

Table 2 Disk Thicknesses and some Parameters of 108 Spiral Galaxies

PGC	m	γ	d	arm	r_0	$\Lambda\pm$ $d\Lambda/\Lambda$	μ	$H\pm$ dH/H
		(°)	(Mpc)		(kpc)		(°)	(kpc)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
PGC 00281	2	41.71	153.21	a	2.631	$6.37 \pm 20.4\%$	17.43	$0.777 \pm 23.6\%$
				b	2.532	$7.22 \pm 18.9\%$	15.48	$0.668 \pm 24.1\%$
PGC 01862	2	74.48	71.84	a	3.251	$9.83 \pm 25.7\%$	11.50	$0.644 \pm 32.8\%$
				b	3.090	$9.72 \pm 21.4\%$	11.63	$0.618 \pm 27.7\%$
PGC 02391	2	46.12	66.35	a	1.297	$5.11 \pm 18.2\%$	21.37	$0.456 \pm 21.3\%$
PGC 04992	2	60.73	108.97	a	5.008	$10.92 \pm 18.4\%$	10.38	$0.897 \pm 27.1\%$
				b	5.107	$10.36 \pm 22.6\%$	10.93	$0.962 \pm 30.2\%$
PGC 05270	2	75.63	149.15	a	5.827	$7.68 \pm 21.8\%$	14.60	$1.453 \pm 22.8\%$
				b	5.594	$7.92 \pm 16.7\%$	14.17	$1.356 \pm 23.4\%$
PGC 08165	2	58.00	59.93	a	2.312	$12.80 \pm 26.5\%$	8.88	$0.355 \pm 32.7\%$
				b	2.167	$12.36 \pm 21.6\%$	9.19	$0.345 \pm 28.4\%$
PGC 09376	2	78.98	163.67	a	9.886	$10.16 \pm 34.3\%$	11.14	$1.897 \pm 38.2\%$
				b	10.161	$10.94 \pm 26.2\%$	10.36	$1.817 \pm 29.5\%$
PGC 09822	2	28.60	88.03	a	2.527	$6.18 \pm 26.7\%$	17.93	$0.764 \pm 28.5\%$
				b	2.529	$6.28 \pm 36.4\%$	17.67	$0.756 \pm 41.2\%$
PGC 10464	2	57.58	18.55	a	0.735	$7.58 \pm 16.9\%$	14.78	$0.185 \pm 25.5\%$
				b	0.723	$7.61 \pm 20.8\%$	14.73	$0.182 \pm 27.7\%$
PGC 10857	2	74.48	117.03	a	2.527	$6.23 \pm 28.7\%$	17.80	$0.761 \pm 31.2\%$
				b	2.582	$6.46 \pm 25.1\%$	17.20	$0.753 \pm 28.3\%$
PGC 11767	2	69.33	119.79	a	2.838	$8.24 \pm 21.3\%$	13.64	$0.663 \pm 24.4\%$
				b	2.678	$8.51 \pm 19.5\%$	13.23	$0.607 \pm 22.1\%$
PGC 12466	2	59.42	30.92	a	1.023	$6.18 \pm 27.6\%$	17.93	$0.310 \pm 34.2\%$
				b	0.989	$7.92 \pm 24.1\%$	14.17	$0.240 \pm 29.7\%$
PGC 12772	2	70.70	75.28	a	3.672	$9.34 \pm 20.8\%$	12.09	$0.763 \pm 26.4\%$
				b	3.693	$9.51 \pm 23.1\%$	11.88	$0.754 \pm 27.1\%$
PGC 13535	2	55.58	69.35	a	1.741	$9.96 \pm 23.6\%$	11.35	$0.350 \pm 27.8\%$
				b	1.690	$9.98 \pm 20.4\%$	11.33	$0.339 \pm 24.9\%$
PGC 21120	2	56.61	10.83	a	0.475	$7.07 \pm 23.1\%$	15.80	$0.128 \pm 23.6\%$
				b	0.461	$7.12 \pm 26.5\%$	15.59	$0.123 \pm 27.1\%$
PGC 21336	2	77.75	61.96	a	6.104	$8.01 \pm 25.3\%$	14.02	$1.464 \pm 28.1\%$
				b	5.929	$8.11 \pm 20.6\%$	13.85	$1.406 \pm 24.7\%$

4 DISK THICKNESSES AND SOME OTHER PARAMETERS

In Table 2 the disk thicknesses of these galaxies and their relative errors are listed in Column 9. Some other parameters are also included, where m listed in Column 2 is the number of the spiral arms in one galaxy, γ the inclination of the galactic disk in degree, d the distance of a galaxy. Column 5 specifies whether the arm is an a-arm or b-arm; a-arm goes from left to right or top to bottom, b-arms goes the other way round. Column 6 lists the forbidden radii r_0. Λ is the winding parameter of the arm, and $\mu = \arctan(m/\Lambda)$, the pitch angle. The errors are derived from the formulae given by Hu, Peng & Zhao (2006a).

5 STATISTICAL PROPERTIES

5.1 Correlations of Disk Thickness, Disk Flatness and Forbidden Radius

Figure 2 shows three panels respectively for galactic disk thickness H versus forbidden radius r_0, disk flatness H/D_{25} versus r_0 and H/D_{25} versus H. The three correlations are all positive correlations, and the results of their linear regression analysis are listed in Table 3 (Column 2 shows the sample size). It can be noted that $F > F_{\alpha=0.05,N-2}$ in all three cases.

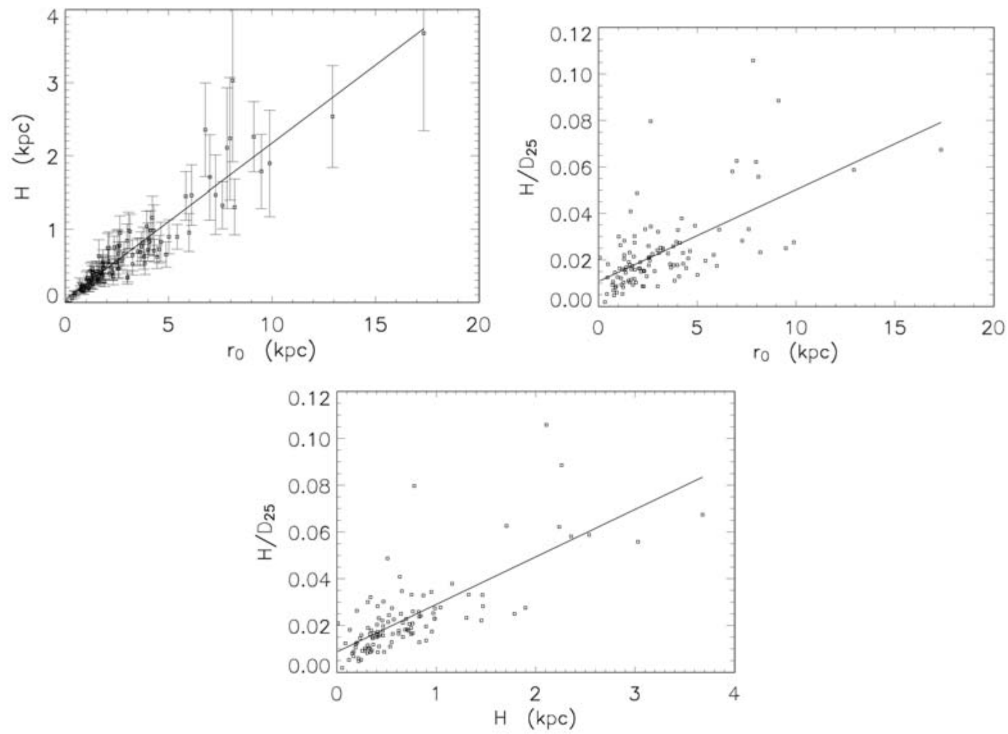

Fig. 2 Correlations of disk thickness, disk flatness and forbidden radius. Top left: disk thickness H vs. forbidden radius r_0; Top right: disk flatness H/D_{25} vs. r_0; Bottom: H/D_{25} vs. H.

Table 3 Linear Regression Analysis for the Correlations of H, H/D_{25} and r_0

(1)	N (2)	b (3)	b_0 (4)	$F_{\alpha=0.05,N-2}$ (5)	F (6)
H vs. r_0	108	0.214	0.037	3.90	684.15
H/D_{25} vs. r_0	108	0.004	0.011	3.90	70.34
H/D_{25} vs. H	108	0.020	0.009	3.90	132.46

5.2 Correlations of Disk Thickness, Disk Flatness and Forbidden Radius with Disk Diameter

The three panels of Figure 3 show the plots of H, H/D_{25} and r_0 versus the disk diameter D_{25}, and their parameters of linear regression analysis are listed in Table 4. We can see that the disk thickness H and the forbidden radius r_0 are positively correlated with with the disk diameter D_{25}: the larger the galactic disk diameter, the thicker the galactic disk, and the larger the forbidden radius. On the other hand, there seems to be no correlation between the disk flatness and disk diameter. The plots suggest that a galaxy with a larger disk diameter contains a thicker galactic disk and has a larger forbidden radius.

5.3 Correlations of Winding Parameter and Pitch Angle with Forbidden Radius

The two panels of Figure 4 show the correlations of the winding parameter Λ and the pitch angle μ with the forbidden radius r_0, and Table 5 gives their parameters of linear regression analysis. We find a positive correlation between Λ and r_0, and a negative correlation between μ and r_0.

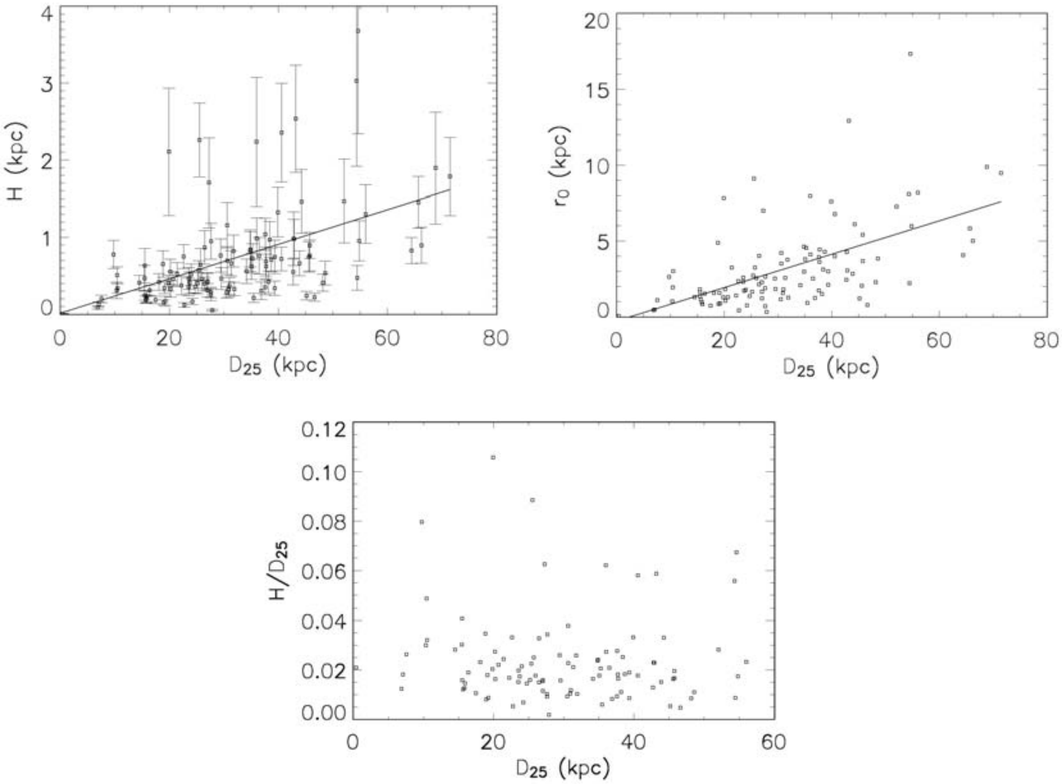

Fig. 3 Correlations of disk thickness H, forbidden radius r_0 and disk flatness H/D_{25} with disk diameter D_{25}. Top left: H vs. D_{25}; Top right: r_0 vs. D_{25}; Bottom: H/D_{25} vs. D_{25}.

Table 4 Results of Linear Regression Analysis of the Correlations of H, H/D_{25} and r_0 with D_{25}

(1)	N (2)	b (3)	b_0 (4)	$F_{\alpha=0.05,N-2}$ (5)	F (6)
H vs. D_{25}	108	0.022	0.013	3.90	36.82
r_0 vs. D_{25}	108	0.110	–0.274	3.90	51.57
H/D_{25} vs. D_{25}	108			3.90	0.45

Table 5 Results of Linear Regression Analysis of the Correlations of μ and Λ with r_0

(1)	N (2)	b (3)	b_0 (4)	$F_{\alpha=0.05,N-2}$ (5)	F (6)
μ vs. r_0	94	0.652	7.471	3.90	10.66
Λ vs. r_0	94	–0.876	15.639	3.90	9.53

5.4 Some Parameters versus the Absolute Magnitude, $M_{B_T^0}$

Figure 5 plots various parameters against the absolute magnitude $M_{B_T^0}$, and their linear regression analysis results are given in Table 6. The absolute magnitudes listed in Column 7 of Table 1 were obained from de

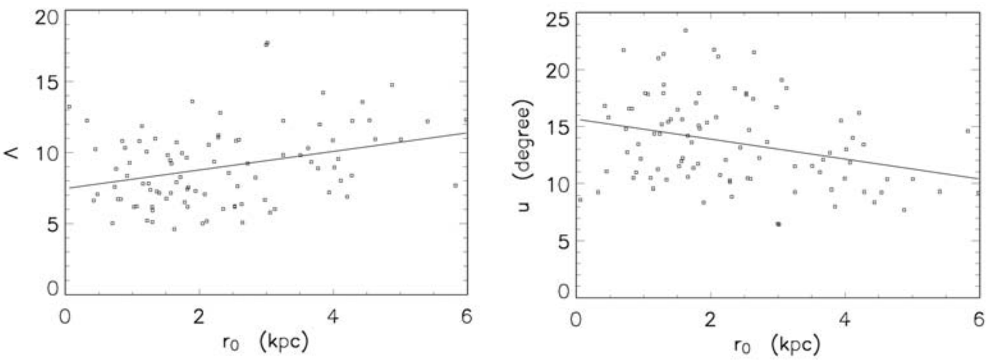

Fig. 4 Correlations of the winding parameter Λ and the pitch angle μ with the forbidden radius r_0. Left: μ vs. r_0; Right: Λ vs. r_0.

Vaucouleurs et al. (1991, RC_3) with

$$M_{B_T^0} = B_T^0 - 5\,\mathrm{lg}(10^6 d) + 5, \tag{18}$$

where B_T^0 is surface brightness in $magnitude$ in the B system listed in Table 1, Column 6, $d = v/H_0$ in Mpc is the distance of a galaxy from the Galactic Center, v is the weighted mean radial velocity listed in Column 8. H_0 is Hubble constant. As shown in Figure 5 and Table 6, as the absolute magnitude increases (gets fainter), the disk thickness deceases, and so do D_{25} and r_0. However, the disk flatness is not well correlated with the absolute magnitude, and the pitch angle and winding parameters seem to be independent of the absolute magnitude, also.

Table 6 Linear Regression Analysis for Correlations of some Parameters with $M_{B_T^0}$

(1)	N (2)	b (3)	b_0 (4)	$F_{\alpha=0.05,N-2}$ (5)	F (6)
H vs. $M_{B_T^0}$	77	–0.139	–0.975	3.96	11.67
H/D_{25} vs. $M_{B_T^0}$	77			3.96	0.001
D_{25} vs. $M_{B_T^0}$	74	–11.23	–99.67	3.97	129.18
r_0 vs. $M_{B_T^0}$	77	–0.678	–4.993	3.96	14.08
μ vs. $M_{B_T^0}$	77			3.96	0.03
Λ vs. $M_{B_T^0}$	77			3.96	0.052

6 DISCUSSION

We have calculated the effective disk thicknesses and some other parameters of 108 spiral galaxies. Of these, 17 galaxies were measured and calculated in five different bands (u, g, r, i and z), the others were selected to have measurements in the g-band. The forbidden radii of these 17 galaxies were obtained by the methods in Hu et al. (2006c) and in this paper. We also present some statistical properties of these spiral galaxies. Our main conclusions and comments are as follows:

1. We find that as the forbidden radius gets larger, the galactic disk gets thicker and the disk flatness increases; that as the disk diameter gets larger, the galactic disk gets thicker and the forbidden radius gets larger, i.e., the entire spiral galaxy becomes larger and bigger when the forbidden radius and galactic disk thickness get larger.
2. The larger the forbidden radius is, the smaller the pitch angle, and the bigger the winding parameter, which is consistent with the Hubble sequence.

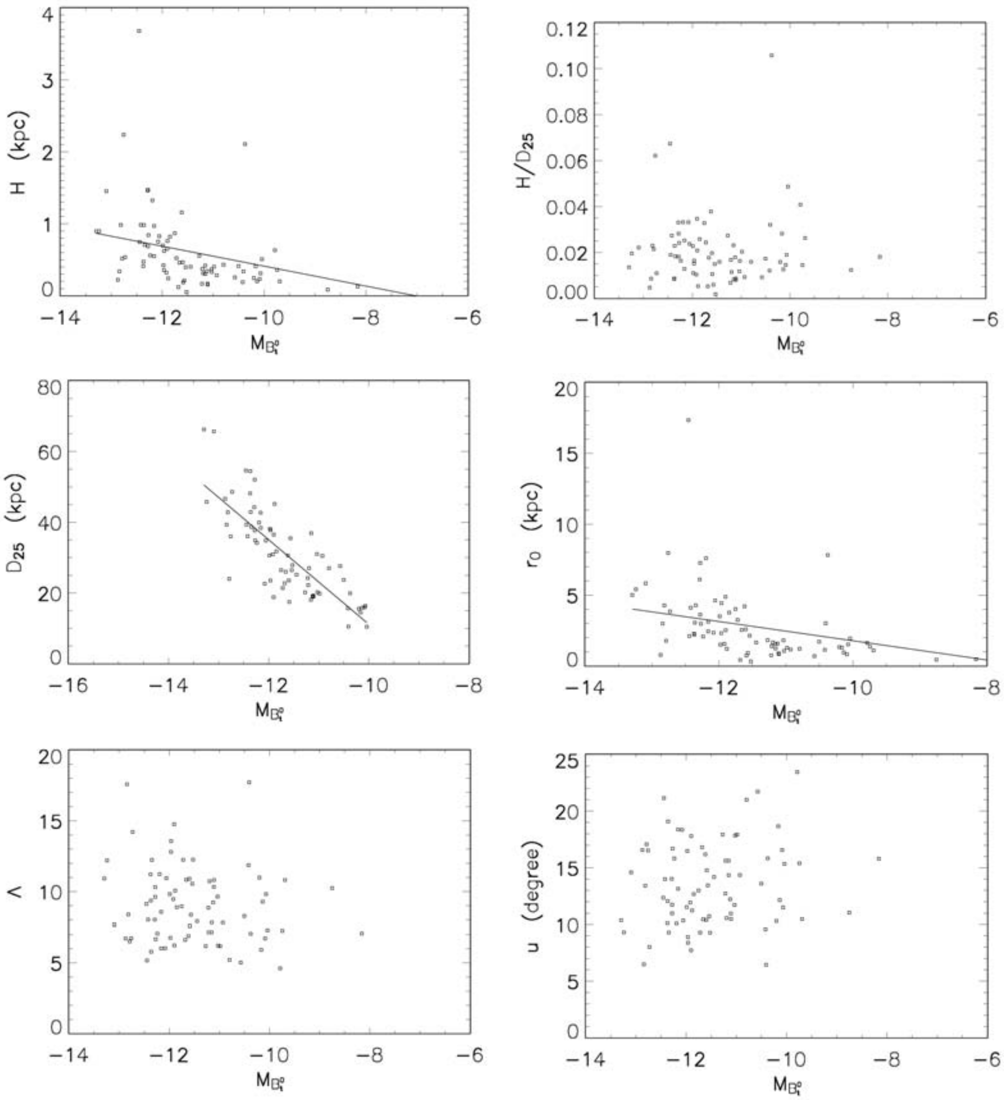

Fig. 5 Correlations of some parameters with absolute magnitude $M_{B_T^0}$.

3. The disk thickness and diameter correlate well with the galactic absolute magnitude. The thicker and the larger the galactic disk is, the smaller the galactic absolute magnitude. However, the disk flatness is not well correlated with the absolute magnitude, perhaps the reason is that the galactic absolute magnitude correlates with the bulk of the galaxy, but not the disk flatness. When the galactic absolute magnitude gets smaller, the forbidden radius becomes larger, i.e., the larger the forbidden radius is, the brighter the galaxy.
4. As listed in Table 2, the parameters of the a-arms are consistent with the parameters of the b-spiral arms, their differences are very small, i. e., the structure of an ordinary spiral galaxy is nearly symmetrical.
5. Table 7 compares our results with the results of Ma et al. (1998) for four galaxies in common. We see that the forbidden radii r_0 of these four galaxies obtained by Ma et al. (1998) are larger than ours. This is due to the bulge light contamination (Bulge contamination was eliminated in our procedure). In practice, the most inward points of the spiral arms obtained in this paper are closer to the galactic centre, i.e., the forbidden radii r_0 are smaller, in consequence, the disk thicknesses become smaller.

Table 7 Comparison between our results and of Ma et al. (1998) for four galaxies

PGC (1)	arm (2)	r_0 (kpc) (3)	Λ (4)	H (kpc) (5)
PGC 24996	Ma et al. (1998)	3.37	7.39	0.88
	a (this paper)	1.240	7.82	0.304
	b (this paper)	1.207	7.43	0.310
PGC 25946	Ma et al. (1998)	2.44	8.04	0.59
	a (this paper)	1.563	9.46	0.321
	b (this paper)	1.540	9.63	0.311
PGC 26666	Ma et al. (1998)	3.85	8.42	0.89
	a (this paper)	2.438	8.56	0.550
	b (this paper)	2.398	8.63	0.537
PGC 35105	Ma et al. (1998)	2.22	6.41	0.66
	a (this paper)	1.809	9.64	0.365
	b (this paper)	1.925	9.38	0.398

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