SYSTEMATIC PROPERTIES OF GALAXIES: IMPLICATIONS FOR GALAXY FORMATION

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1. INTRODUCTION

We have compiled a data base of V-band two-dimensional luminosity distribution for 261 galaxies in the Virgo and the Ursa Major regions (Watanabe 1983) using the 105-cm Schmidt telescope at the Kiso Observatory, Tokyo Astronomical Observatory. This is one of the largest collections of homogeneous surface photometry available to date, though the sample is biased for bright and large galaxies with $m(V)\lesssim 14$mag and/or $D_{26}\gtrsim 2'$. Among the sample galaxies we have selected some 200 certain members ($V_0<3500$km/s) of the Virgo cluster and the Ursa Major clouds and performed various analyses on them to investigate systematic properties of galaxies. The two clusterings lie at nearly equal distance of $(m-M)\sim 31.1$ (Aaronson and Mould 1983). In the present paper we discuss the result of spheroid(bulge)/disk decomposition and velocity-luminosity relation for galaxies.

2. SPHEROID(BULGE)/DISK DECOMPOSITION

We use an empirical model consisting of a $R^{1/4}$-law spheroid and an exponential disk whose radial luminosity distribution is given by,

$$I(R) = I_{0,S}\ \mathrm{dex}[-3.33\{(R/R_{0,S})^{1/4}-1\}] + I_{0,D}\exp(R/R_{0,D}). \qquad (1)$$

Main results obtained from decomposition for 167 galaxies are summarized in the following:

(1) We find a difference in the parameter correlation, $\log R_0$ versus $\mu_0=-2.5\log I_0$, between elliptical galaxies and bulges of disk galaxies. Bulges are, on the average, less luminous in absolute magnitude and have both fainter μ_0 and larger R_0 even at the same absolute magnitude than ellipticals. This result, together with the kinematical difference (e.g. Davies et al. 1983), may suggest different formation history for ellipticals and bulges.

(2) Bulge parameters cover very wide ranges (1.9dex in $\log R_0$ and 10mag in μ_0) while disk parameters are confined within (relatively) narrow ranges (0.7dex and 4mag, respectively). It seems that some self-

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regulating mechanism is working in the process of disk formation under varying influences of bulges.
Details of the analysis is published elsewhere (Kodaira et al. 1986).

3. VELOCITY-LUMINOSITY RELATION AND LOG D_{26} VERSUS SB DIAGRAM(DSBD)

If $M(R_{dyn})$ is the dynamical mass of a galaxy within a radius R_{dyn}, the dynamical velocity at that radius is expressed by definition as,

$$V_{dyn}^2 \propto G\ M(R_{dyn})/R_{dyn}. \tag{2}$$

We introduce a 'photometric velocity parameter' defined by,

$$V_{ph}^2 = a' \cdot L(R_{ph})/R_{ph} = a \cdot B \cdot D, \tag{3}$$

where $L(R_{ph})$ is the luminosity integrated within the photometric radius R_{ph}, B the mean surface brightness within R_{ph}, D the photometric diameter $2R_{ph}$, and a' and a are dimensional scaling factors to yield the relationship, $V_{dyn}^2=(M/L)V_{ph}^2$, with the same dimension for V_{dyn} and V_{ph}. Here (M/L) is a measure of mass-to-luminosity ratio of the galaxy defined by,

$$\left(\frac{M}{L}\right)= \frac{M(R_{dyn})}{L(R_{dyn})}\ \frac{L(R_{dyn})}{R_{dyn}}\ \left(\frac{L(R_{ph})}{R_{ph}}\right)^{-1} \tag{4}$$

This (M/L) can be considered to be the physical mass-to-luminosity ratio within R_{dyn} multiplied by a correction factor due to the difference between R_{dyn} and R_{ph}.

We compute V_{ph} using our photometric data. As V_{dyn} we use the 21-cm linewidth of neutral hydrogen compiled by Richter and Huchtmeier (1984) and the central velocity dispersion σ compiled by Whitmore et al.(1985) for spirals and ellipticals, respectively. Thus the meaning of V_{dyn} is quite different between spirals and ellipticals. However, *differential* behavior of (M/L) within spirals and within ellipticals can be derived. Fig. 1 shows (M/L) plotted against luminosity. We find no obvious dependence of (M/L) on L for spirals while there is a well-defined systematic dependence of $(M/L) \propto L^{0.4}$ for ellipticals.

Kodaira et al.(1983) introduced the diameter versus surface brightness diagram (DSBD) as a diagnostic tool to investigate the nature of galaxies and found

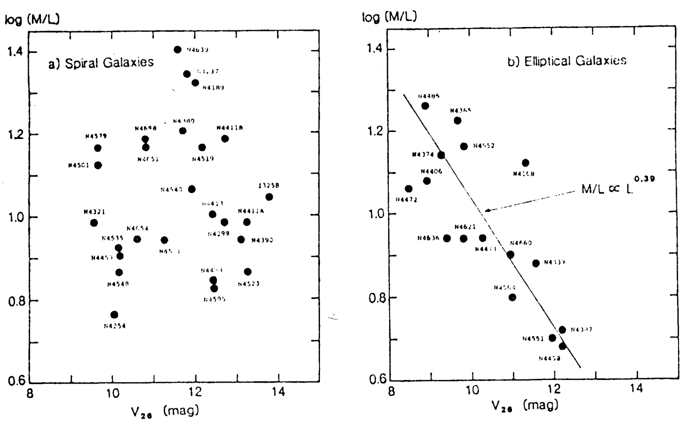

Fig.1 log(M/L) plotted against apparent magnitude.

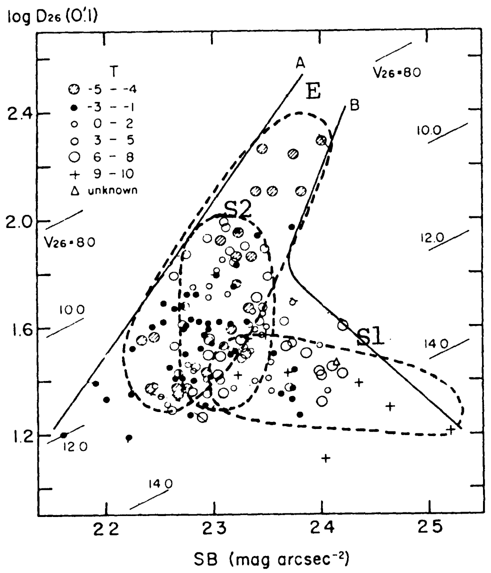

Fig.2 Sequential distributions of galaxies in DSBD.

that ellipticals and spirals are sequentially distributed in DSBD. Fig.2 illustrates the distributions. If we characterize the distributions by the gradient, $\beta=\Delta(\log D_{26})/\Delta(SB)$, we obtain the velocity-luminosity relation of,

$$L \propto V_{dyn}^{\gamma}, \tag{5}$$

with

$$\gamma=2(1-5\beta)[\alpha(1-5\beta)+(1-2.5\beta)]^{-1}, \tag{6}$$

using the exponent of $(M/L)\propto L^{\alpha}$ relation derived above. For the elliptical branch denoted as E in Fig.2, we have $\beta\sim0.6$ and $\alpha\sim0.4$. These values lead to $L\propto\sigma^3$, which agrees well with the observation (e.g. Tonry 1981; Dressler 1984). Spirals appear to form two branches denoted as S1($\beta\sim0$) and S2($\beta\sim\infty$) in Fig.2. With $\alpha\sim0$ for spirals we obtain $L\propto V_H^2$ for S1 and $L\propto V_H^4$ for S2, respectively. It should be noted that most of gradients of Tully-Fisher relation reported so far lie between -10(γ=4) and -5(γ=2).

The present analysis suggests that the functional form of velocity-luminosity relation is determined by both the shape of the sequential distribution in DSBD, i.e., the diameter-mean surface brightness relation, and the systematic dependence of (M/L) on L. Although DSBD is a purely photometric diagram, it may contain essential information on kinematical properties of galaxies as well.

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