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THE BRIGHTEST STARS IN GALAXIES AS DISTANCE INDICATORS

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I. INTRODUCTION

The brightest stars in galaxies have been used as distance indicators since Hubble(1936). However, the accuracy of the brightest stars for distance estimates has been controversial. Recently, Rozanski and Rowan-Robinson(1994) argued large errors in the distance determination : 0.58 mag and 0.90 mag, respectively, for the brightest red stars and the brightest blue stars, while Karachentsev and Tikhonov(1994) suggested much smaller errors in the distance determination : 0.37 mag for the brightest red stars and 0.46 mag for the brightest blue stars. The reasons for these conflicting results are not yet known.

We have investigated the accuracy of this method using a sample of 17 galaxies(LMC, SMC, NGC 6822, IC 1613, M31, IC 10, M33, WLM, NGC 3109, Sextans B, Sextans A, NGC 300, LeoA, NGC 2403, M81, IC 4182, M101) for which Cepheid distances are known and reliable photometry of the brightest stars are available(Figure 1).

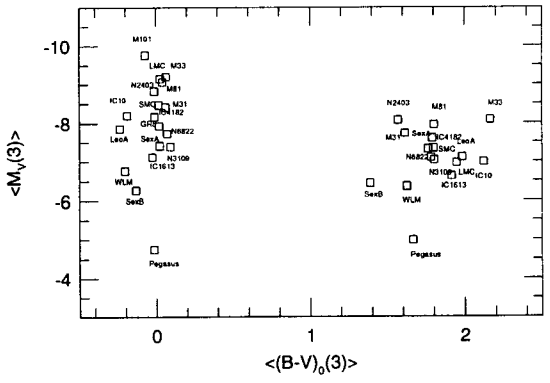

Fig. 1.— Color-magnitude diagrams for the mean magnitudes and colors of three BSG and RSG in galaxies.

II. ESTIMATING THE DISTANCES TO GALAXIES USING THE BRIGHTEST STARS

(a) The Theoretical and Observational Basis

Theoretically the upper limit of the masses of the stars in galaxies is set to be $\approx 100 M_{\odot}$ by the radiative pressure("Eddington Limit").

Observationally there appears to be an upper limit to the luminosities of the supergiants in nearby Local Group galaxies($M_{Bol} \approx -12$mag for the BSG and $M_{Bol} \approx -10$mag for the RSG : Humphreys 1983)

(b) The Method

The luminosities of the three brightest stars in galaxies are converted to absolute magnitudes and plotted against the absolute magnitude of the parent galaxies. If the magnitudes of the stars and galaxies have some correlation, the relation must be considered in the estimates of the distances to the galaxies. If the relation is obtained as $< M_*(3) >= aM_{gal} + b$, the distance modulus and the error in the distance determination are $\mu_0 = \frac{1}{1-a} m_* - \frac{a}{1-a} m_{gal} - \frac{b}{1-a}$ and $\delta\mu_0 = \frac{\sigma}{1-a}$ (σ : regression error), respectively.

III. RESULTS

We have obtained the relations of the luminosities of the three brightest stars and the $M_{B(gal)}$ of the parent galaxies. The calibrations are listed in Table 1 for the red supergiants and in Table 2 for the blue supergiants.

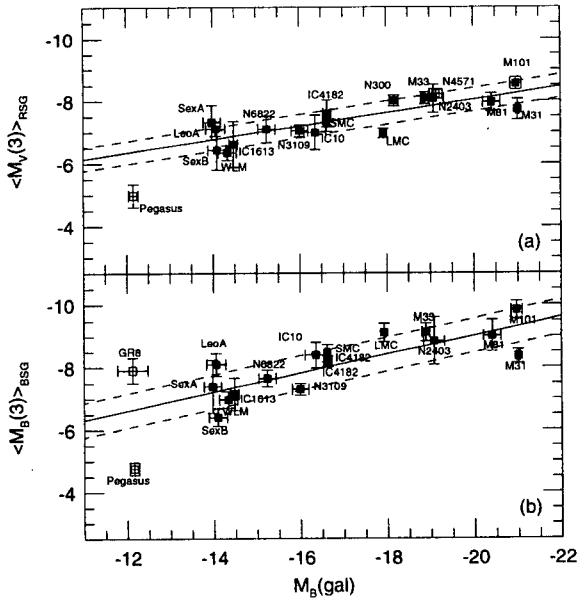

Fig. 2.— (a) The mean V magnitude of the three brightest RSG versus $M_{B(gal)}$. $< M_V(3) >_{RSG}= 0.21 M_B^T - 3.84$, $\sigma =$ 0.37mag, $\delta\mu_0 =$ 0.47mag. (b) The mean B magnitude of the three brightest BSG versus $M_{B(gal)}$. $< M_B(3) >_{BSG}=$ $0.30 M_B^T - 3.02$, $\sigma =$ 0.55mag, $\delta\mu_0 =$ 0.79mag.

Table 1. Calibration of the red supergiants

Filter	a	b	σ	$\delta\mu_0$	N^t
B	0.18 ± 0.04	-2.51 ± 0.72	0.38	0.46	15
V	0.21 ± 0.04	-3.84 ± 0.64	0.37	0.47	17
J	0.13 ± 0.06	-8.16 ± 1.12	0.45	0.52	9
H	0.14 ± 0.06	-8.67 ± 1.11	0.45	0.52	9
K	0.15 ± 0.05	-8.72 ± 0.91	0.40	0.47	11

^{t} : Number of the galaxies

Table 2. Calibration of the blue supergiants

Filter	a	b	σ	$\delta\mu_0$	N^t
B	0.30 ± 0.06	-3.02 ± 0.96	0.55	0.79	16
V	0.32 ± 0.05	-2.69 ± 0.94	0.54	0.79	16

^{t} : Number of the galaxies

Table 3. Calibration of the red supergiants for seven common galaxies

Filter	a	b	σ	$\delta\mu_0$	N^t
B	0.17 ± 0.08	-2.65 ± 1.40	0.51	0.61	7
V	0.18 ± 0.07	-4.43 ± 1.17	0.42	0.51	7
J	0.06 ± 0.06	-9.31 ± 0.96	0.34	0.36	7
H	0.07 ± 0.05	-9.86 ± 0.88	0.32	0.34	7
K	0.10 ± 0.05	-9.50 ± 0.83	0.30	0.33	7

^{t} : Number of the galaxies

Table 4. Comparison with previous results for the red supergiant

Authors	a	b	$\sigma(M_V)$	$\delta\mu_0$
This study	**0.21±0.04**	**-3.84±0.64**	**0.37**	**0.47**
Piotto et al. (1992)	0.21 ± 0.02	-4.01 ± 0.38	$\gtrsim$0.30	$\gtrsim$0.38
Rozanski & Rowan-Robinson (1994)	0.21 ± 0.03	-4.10 ± 0.38	0.46	0.58
Karachentsev & Tikhonov(1994)	0.19	-4.52	0.30	0.37

Table 5. Comparison with previous results for the blue supergiant

Authors	a	b	$\sigma(M_V)$	$\delta\mu_0$
This study	**0.30±0.06**	**-3.02±0.96**	**0.55**	**0.79**
Piotto et al. (1992)	0.36 ± 0.04	-2.29 ± 0.64	0.56	0.88
Rozanski & Rowan-Robinson (1994)	0.28 ± 0.04	-3.45 ± 0.62	0.65	0.90
Karachentsev & Tikhonov(1994)	0.35	-2.50	0.30	0.46

In addition the accuracies of the red supergiant for distance estimates for seven common galaxies(LMC, NGC 6822, IC 1613, M33, Sextans A, NGC 2403, M31) are 0.61, 0.51, 0.36, 0.34, 0.33 mag, respectively, for the B, V, J, H, K band, showing the errors in the distance determination are reduced when the red supergiants are observed at the longer wavelength(Table 3).

IV. SUMMARY AND CONCLUSION

The errors in the distance determination based on our sample are 0.47mag and 0.79mag, respectively, for the brightest red stars and the brightest blue stars(Figure 2). The result of our calibration is compared to those of previous results in Table 4 and Table 5. In conclusion, the brightest red stars are considered to be useful for determining the distances to galaxies.

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