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RADIAL COLOR GRADIENT IN A GLOBULAR CLUSTER 1. M68

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Abstract

Stars in M68 from the observed color-magnitude diagrams with CCD were integrated to find any radial gradient. The result shows that M68 has a slightly bluer core. The main cause of these calculated radial color variations seems to come from the random distribution of giants.

I. Introduction

Globular clusters are usually believed to be chemically homogeneous of metal weak stars and the oldest objects in the Galaxy. However there is now several evidence that some clusters are not homogeneous. Among these inhomogeneities, chemical inhomogeneities are quite clear from the observations of individual stars in globular clusters. 「CH stars are found in M22(McClure and Norris 1977), M55(Smith and Norris 1982), M2(Zinn 1981) and ω cen(Cohen and Bell 1986), and the existence of CH stars was interpreted as a internal mixing hypothesis(Smith and Demarque 1980), chemical enrichment of different mass stars(Norris and Freeman 1983) and the separate mixing event from N-enriched giants(Cohen and Bell 1986).」

In the metal poor clusters like M13, M92, NGC 6397 and M15, all the observed weak G-band stars are asymptotic giant branch stars(Zinn 1973; Norris and Zinn 1977). This phenomenon was interpreted as the result of stellar evolution which may come from the mixing of CNO processed material to the surface(Norris and Zinn 1977 ; Mallia 1978). CN bimodality was found in 47 Tuc(Norris and Freeman 1979), NGC 6752(Norris *et al.* 1981), M71(Smith and Norris 1982 ; Smith and Penny 1989), M5(Smith and Norris 1983), NGC 6934(Smith and Bell 1986) and NGC 6637(Smith 1989). This phenomenon was interpreted as a result of the primodial N abundance enhancement(Hartwick and McClure 1980) and the existence of two generations of stars in clusters. Smith(1986) suggested the abundance inhomogeneity in ω Cen was a result of the supernovae explosion in the early time of the cluster. On the other hand the systematic radial color gradient and CN bimodality in 47 Tuc were supposed to result from the interior stellar mixing or stellar wind enrichment of massive stars(Briley *et al.* 1988 ; Smith and Penny 1988).

Giant stars in ω Cen. M22, 47 Tuc, NGC 6352, NGC 6397, NGC 6752, M15 and M4 show CN abundance variations(Hesser *et al.* 1976 ; Mallia 1978 ; Mallia and Pagel 1981 ; Norris and Freeman 1983 ; Bell *et al.* 1983 ; Trefzger *et al.* 1983 ; Smith and Suntzeff 1989). These variations were interpreted as the meridional circulation due to the internal rotation of a star (Sweigart and Mengel 1979). Mallia and Pagel(1981) assumed that the chemical inhomogeneity comes from supernovae ejecta and color gradient was set up by the inhomogeneous collapse. In this study we integrated all the observed stars to find any radial color gradient in M68.

Ⅱ. Used Materials and Luminosity Function

Photometric data observed by McClure *et al.*(1987) were used to get the radial integrated color in M68. In this study we only used stars which are brighter than $m_v=22$mag to avoid the completeness and crowding problems. Figure 1 shows the luminosity function of M68. From this luminosity function we can estimate the slop of the present mass function as $X=1.6$. This slop value is typical among the metal weak globular clusters. In Table 1 we counted number of stars of each branch in every arc minute. In this count we used $m_v=18.75$ as the turn-off magnitude.

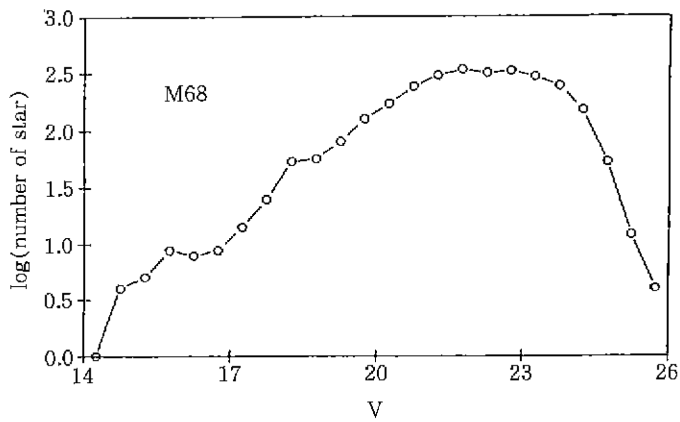

Fig. 1. Luminosity function of M68, which comes from the C-M diagram by McClure *et al.*(1987).

Table 1. The number of stars of each branch in M68

radial distance(arcmin)	2−3	3−4	4−5	5−6	6−7	7−9
horizontal branch	3	1	1	1	1	0
giant branch	39	39	22	20	12	12
main sequence(V<22)	526	805	689	503	299	22

Ⅲ. Radial Integrated Color

All stars in Table 1 were integrated to get the total integrated B-V color in each region. These integrated B-V colors are displayed in Figure 2 with the errors. From this figure we can see that M68 has the bluer central region than the outer one. The difference in the integrated color is about 0.07, which is quite large to compare with that observed in M30(Piotto *et al.* 1988).

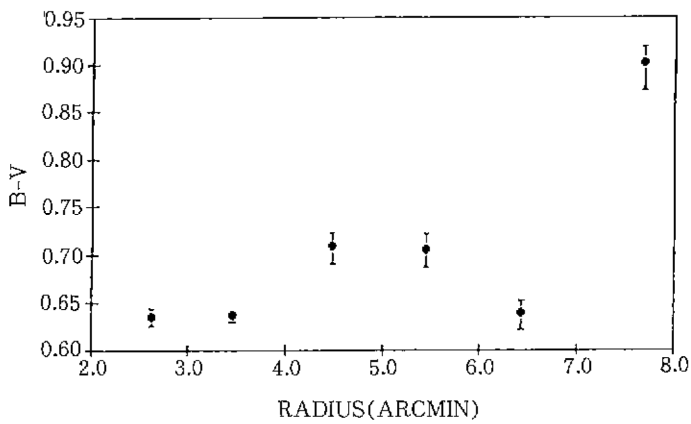

Fig. 2. The integrated B-V colors in every arcmin in M68.

Figure 3 is the radial variation of the integrated colors of giant and horizontal branch stars. Like the total integrated colors the radial color tends to be bluer in the central region. However the integrated color of main sequence stars does not show this kind of tendency as in Figure 4. The integrated color of M.S. remains constant along the radial distance from 2 arcmin to 8 arcmin. This result indicates that the radial color gradient in M68 comes from the integrated

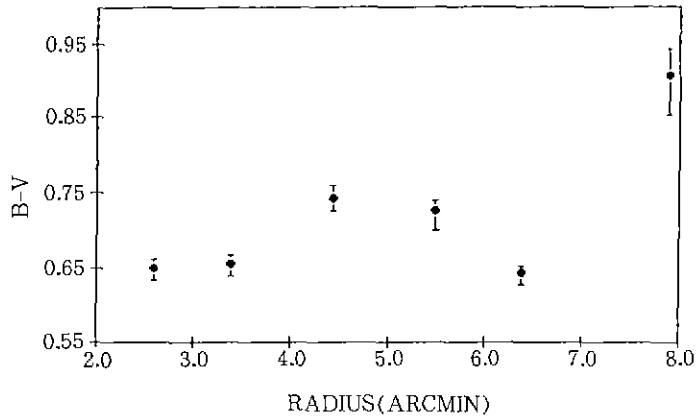

Fig. 3. Integrated B-V colors of giants and horizontal branch stars.

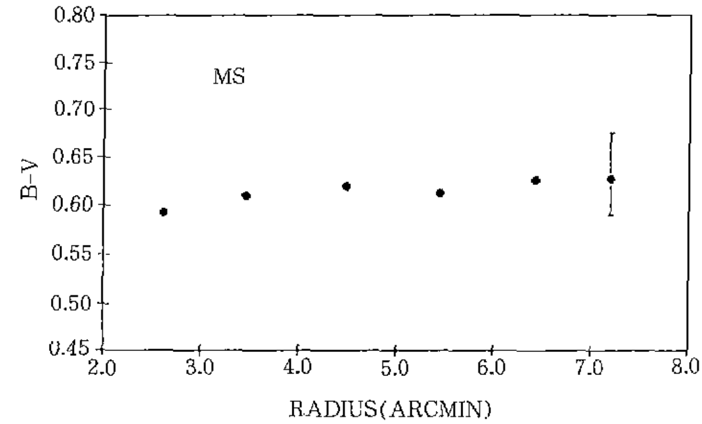

Fig. 4. Integrated colors of main sequence stars. These colors do not show any radial variation.

color of giant stars.

Distributions of each branch stars are displayed in Figures 5 to 7. Figure 5 is the number ratio of giant stars to the total. Here we can see that the number of giant stars increases slightly from 5 arcmin to the centre. However the number ratio of main sequence star to the total(in Figure 6) is constant to the radial distance except 7 to 9 arcmin region, where only 5 main sequence stars are presented in this region. This result is in coincidence with the radial integrated color in Figure 4. Figure 7 clearly shows that radial color gradient in M68 is the result of the concentration of giant stars in the central region.

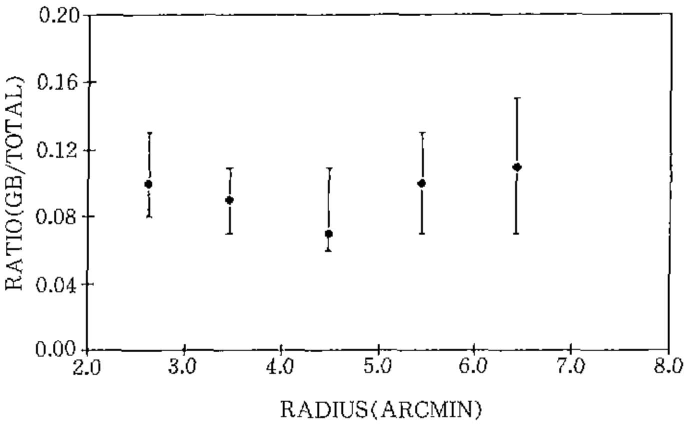

Fig. 5. The number ratio of giant stars to the total.

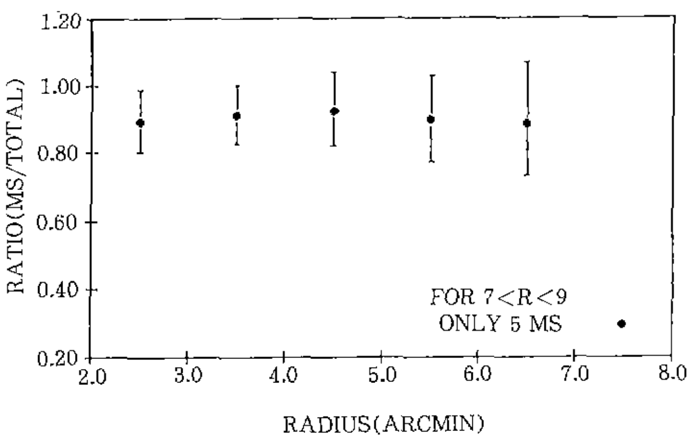

Fig. 6. The number ratio of main sequence stars to the total.

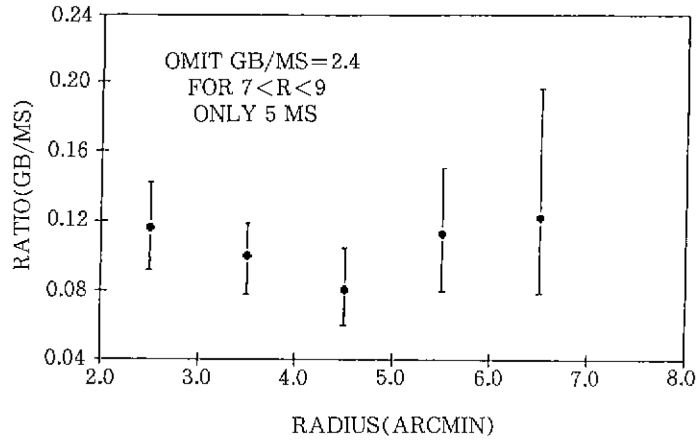

Fig. 7. The number ratio of giants to main sequence stars.

Ⅳ. Conclusion

The integrated color of each radial distance in M68 shows that there exists the radial color gradient in a sense of bluer central region by about 0.07mag in B-V. This color gradient is supposed to come from the excess of giant stars in the central region. This supposition is possible through the integration of giant stars luminosities and the number ratio of giant to total stars in M68.

The radial integrated B-V colors of giant stars clearly show that the radial color gradient in M68 comes from the giant star, not from the main sequence star. This tendency was also found in the number ratio of giant to total stars. The number of giant stars increases from 5 arcmin to the center, which is indentical to that of the integrated color of giant stars.

Acknowledgements

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