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ABUNDANCE VARIATION AMONG GIANT STARS IN THE CENTRAL PART OF 47 TUC

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ABSTRACT

Four stars in the central region of 47 Tuc were observed spectroscopically using IPCS. The observed result showed that two asymptotic giant branch stars have the excess of nitrogen compared with the red giant branch stars, which indicates that the radial colour gradient in a globular clursters, at least for 47 Tuc, comes from the abundance gradient among the giant stars.

I. INTRODUCTION

Although globular clusters are usually believed to be homogeneous aggregates of metal weak star (apart from the mass segregation), there is now several evidences that some clusters are not homogeneous. (See Chun and Freeman 1979, paper I). In paper I we have observed the radial colours of 24 globular clusters, and 7 of them showed the radial colour (B-V and U-B) gradient from centre to outer region. Among them, 47 Tuc has been observed as a radial spots measurement and we regard this cluster as a typical radial colour gradient cluster.

From the spots measurement we found that 47 Tuc has colour gradient both in B-V ($\approx$ 0.10) and U-B ($\approx$ 0.15) in a sense that the central region is redder than outer one (Fig. 1). This gradient was reproduced through the luminosity function of 47 Tuc (these variations must be associated with the radial change in the stellar population of these clusters, because globular clusters have no detectable gas or dust), and from the star count of 47 Tuc we have found that the brightest giants and asymptotic giant branch stars ($m_V \leqslant 13.5$) are more centrally concentrated than the fainter ones.

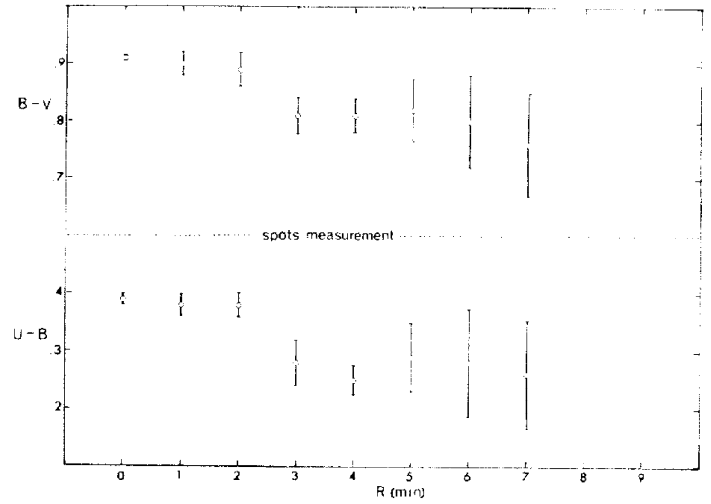

Fig. 1.
The results of spot measurements for B-V and U-B. Radial colour changes about 0.1 mag. are found in B-V and U-B.

These two observational results (radial colour and distribution gradient) do not match with the general picture of globular clusters, where globular clusters are dynamically fully relaxed structure and well mixed state.

This may indicate that globular clusters are not chemically homogeneous objects, even their structures are near the steady state and their distribution are in Maxwellian.

The main purpose of this paper is to see whether we can find the parameter of this inhomogeneity in a globular cluster.

II. OBSERVATION AND REDUCTION

From the colour-magnitude diagram of the inner part of 47 Tuc (Chun and Freeman 1978), four stars were chosen to compare their spectra. Figure 2 shows the position of these four stars in C-M diagram. From this diagram it seems that two of them are 1st giant branch stars (red giant brach) and the others are 2nd giant branch (asymptotic giant branch).

The Characters of these four stars are shown in Table 1. The columns show (i) is the star identification, (ii) the branch type, where GB indicates the red giant branch star and AGB is the asymptotic giant branch star, (iii), (iv)V and B-V values for these four stars, (v) M_{bol}, bolometric magnitude from Eggen (1972); (vi), (vii) the luminosity of B and V expressed in solar unit, distance modulus m-M = 13.4 (Sandage, 1964) was used; (viii) the colour temperature of these four stars.

Observations were made at Anglo-Australian Observatory, Siding Spring, Australia using the 150-inch telescope; Image Photon Counting System (so called Boksenberg system) was employed with a dispersion of 10 Å /mm.

Figure 3a, b are the spectra of two GB and two AGB stars. The reduction was made from these spectra. The equivalent widths of the Hδ-W(Hδ)-, CaI-W(CaI), G-band-W(G)-, FeI-W(FeI)-, blue CN-W (CN) and Hr-W(Hr)- were measured for each spectrum. To make a uniform measurement of each equivalent width we take each line strength as the following absorption feature as some examples.

W (G) : absorption feature between 4280Å and 4315A
W (Hr) : absorption feature between 4332Å and 4348Å

Each line strength index is defined as follows:

$$S(\mathrm{CaI}) = \frac{W(\mathrm{CaI})}{W(H\delta)}$$

$$S(G) = \frac{W(G)}{W(H\delta)}$$

$$S(\mathrm{CN}) = \frac{W(\mathrm{CN})}{W(H\delta)}$$

$$S(\mathrm{FeI}) = \frac{W(\mathrm{FeI})}{W(H\delta)}$$

$$S(\mathrm{Hr}) = \frac{W(\mathrm{Hr})}{W(H\delta)}$$

The results of the measures for two GB stars (F 125 and F 126) and two AGB stars (F 191 and F 349) are summarized in Table 2. Here the line strength comes from the measured S (CaI), S (G) S (CN), S (FeI) and S (Hr) indices. The tabulated error is the calculated standard deviation of the 5 measurements for each line strength.

The most striking result from this measurement is the abundance variation of blue CN among the GB and AGB stars, where GB stars do not show the CN feature. However we could not make any conclusion for the

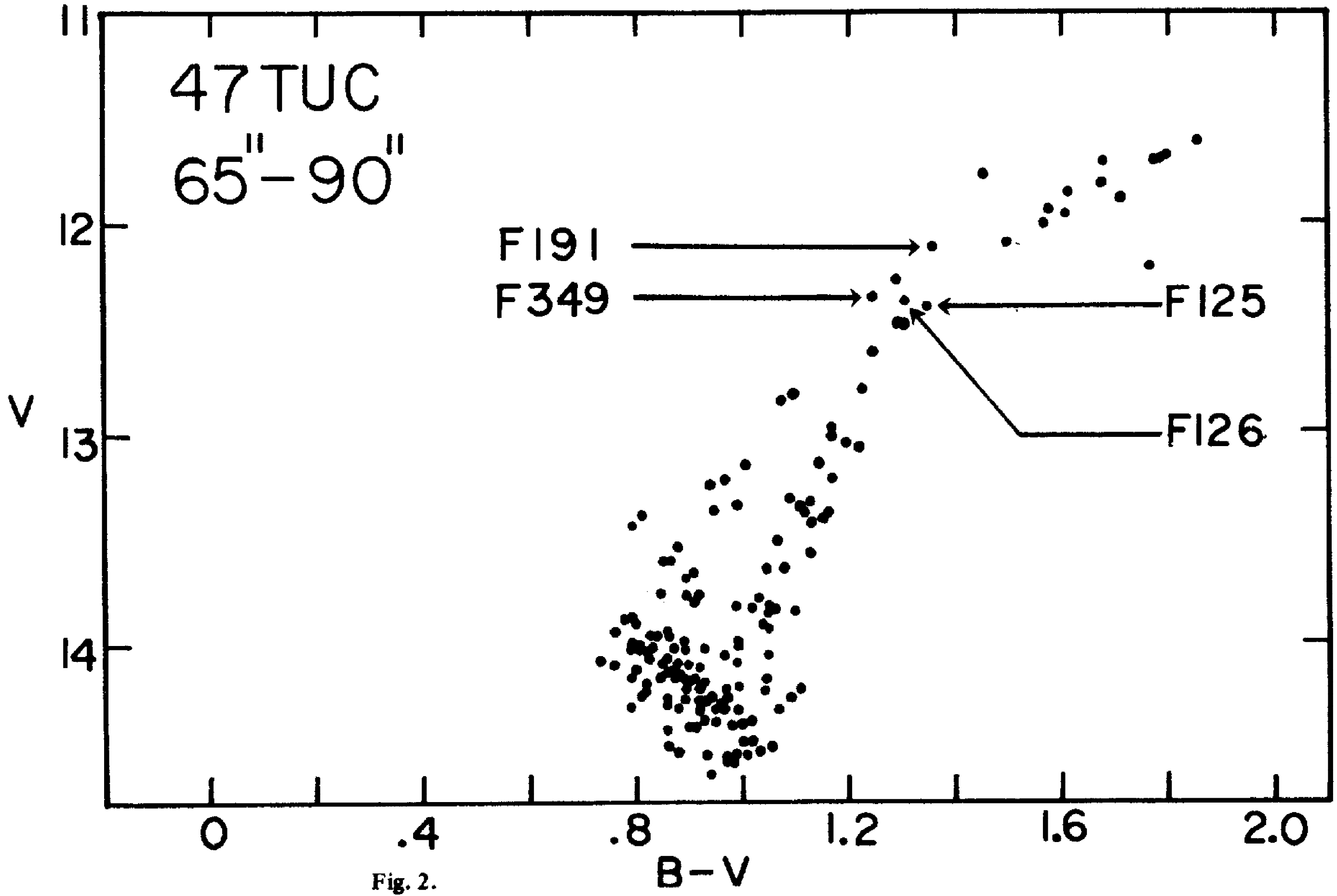

Fig. 2.
Local colour-magnitude diagram for the most inner region 65'' ⩽ R ⩽ 90'' of 47 Tuc. Four observed stars (two red giants and two asymptotic giants) are shown.

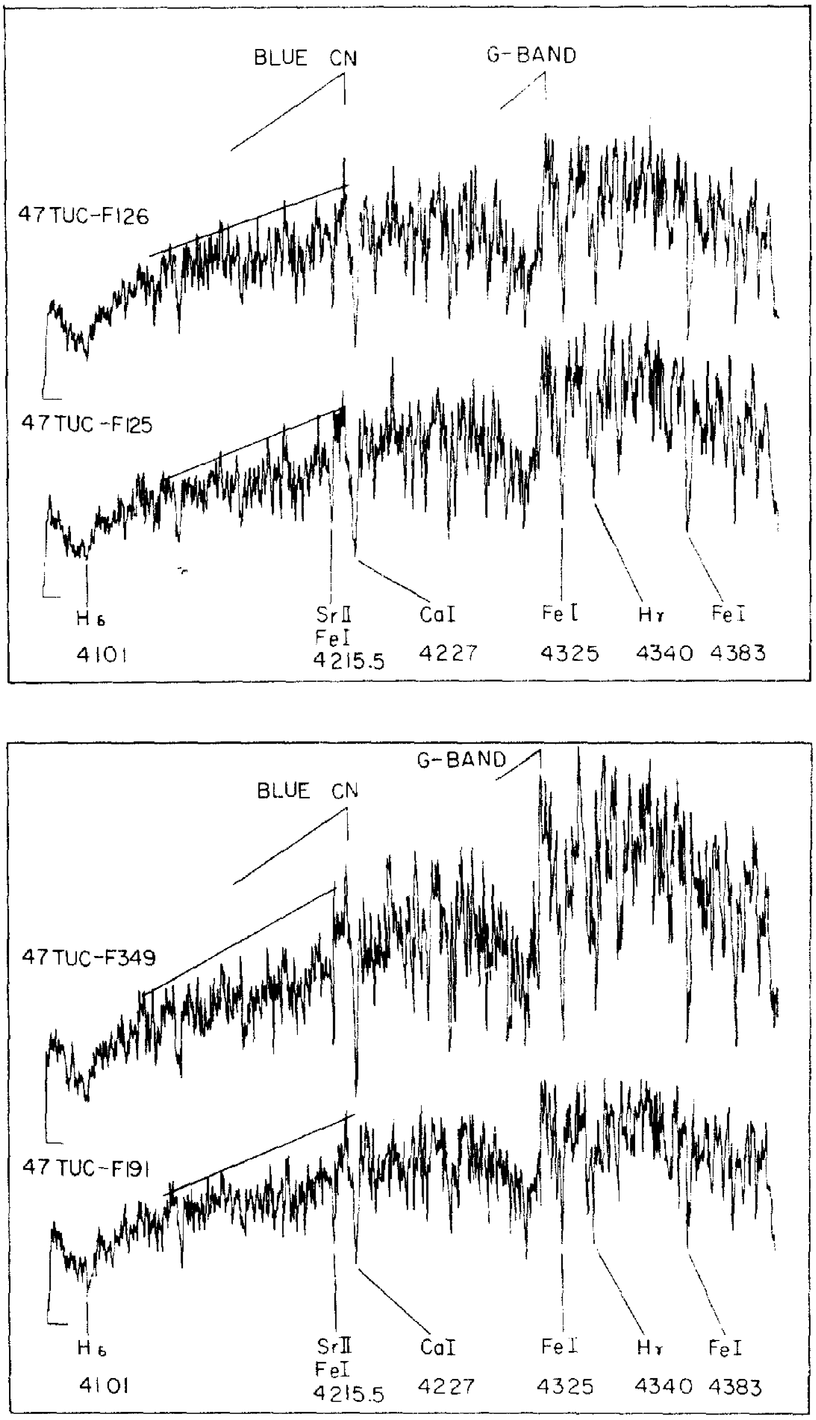

Fig. 3a, b
Spectra of two red giant stars (F125 and F126) and two asymptotic giant stars (F191 and F349). Note the different of blue CN band feature between the red giant and asymptotic giant branch.

Table 1

Star		V	B-V	Mbol	(L⊙)B	(L⊙)V	T_c(°K)
F 125	GB	12.38	1.35	-2.41	711	211	3904
F 126	GB	12.36	1.31	-2.29	637	215	3989
F 191	AGB	12.11	1.36	-2.42	718	270	3883
F 349	AGB	12.34	1.25	-2.00	488	219	4124

Table 2

star	Giant Branch		Asymptotic Giant Branch	
Index	F 125	F 126	F 191	F 349
S (CaI)	2.09 ± 0.03	2.19 ± 0.04	1.72 ± 0.08	2.68 ± 0.38
S (CN)			2.75 ± 0.13	5.87 ± 0.64
S (Hr)	2.08 ± 0.02	1.75 ± 0.03	1.93 ± 0.09	2.17 ± 0.11
S (FeI)	1.89 ± 0.04	1.86 ± 0.05	1.74 ± 0.09	2.68 ± 0.53
S (G)	7.27 ± 0.17	8.09 ± 0.18	7.79 ± 0.31	10.74 ± 1.39

variation of G-band, even one of AGB stars shows a strong G-band feature.

III. DISCUSSION

From the correlation between the radial colour gradient and the relaxation time, Chun and Freeman (1980) interpreted the radial colour gradient as a radial mass loss gradient in a cluster. What processes could lead to this radial dependence of mass loss? Renzini (1975) has reviewed mass loss theories; among the possibilities are (i) radial gradient of abundance, in the sense that Z decreases with radius, (ii) if the helium core population II red giants are rotating rapidly, then a radial gradient of core angular velocity (increasing with radius) could produce the gradient of mass loss.

If the discussion so far is correct, we must now explain why the number of the brightest AGB stars per unit luminosity decreases with radius. Here is one possible explanation. Consider the post-HB evolution of a globular cluster star. On the zero-age (ZAHB) it has two main components: the helium burning core (mass; 0.1-0.5 $M_\odot$ from theory: Rood 1970; Sweigart and Gross 1974) and the hydrogen-rich envelope. Present belief is that its total mass is determined by the amount of mass loss that occurs in the time between the star leaving the main sequence and arriving on the ZAHB (Iben and Rood 1970; Demarque and Mengel 1972). When the He-core burning ceases, the star ascends the second giant branch. From the theory (Gingold 1974, and reference therein), it is clear that the maximum luminosity that the star reaches, before evolving away to the blue, depends on the envelope mass. Now say, for simplicity, that all ZAHB stars have the same core mass, and assume that for some reason the amount of mass loss depends on the position in the cluster, in the sense that stars which spend most of their time near the cluster centre have lost the least mass. The result of this radial gradient in mass loss would then be a radial gradient in the number of the brightest AGB stars per unit luminosity.

From the observation, the blue CN-band in AGB stars shows the strong feature compared with the CN in GB stars, which indicates that nitrogen abundance in AGB stars in more than GB stars in the region where the radial colour becomes redder in a cluster. This result makes it possible to explain the radial colour gradient as the mass loss gradient, and this gradient comes from the increase of AGB stars in the centre of a cluster, where the abundance of AGB stars is more than GB stars.

This result is important to explain the following points: (i) it suggests that clusters could produce their own metals, as do galaxies. This may explain why there appears to be no population II objects with abundance [Fe/H] significantly less than 0.01 of the solar value (Butler 1975, and other reference therein); (ii) this in turn may mean that clusters are self-contained sites of nuclear evolution.

IV. CONCLUSION

Following points were made through this investigation.

(1) In 47 Tuc, which has a radial colour gradient, there is an abundance variation between the red giant branch and the asymptotic branch where the radial integrated colour becomes red.

(2) The abundance variation between these two branches comes from the difference of the blue CN-band and possibly from the G-band.

(3) Asymptotic giant branch has more nitrogen and possibly carbon than the red giant branch.

(4) We may conclude that the radial colour gradient in 47 Tuc comes from the excess of the number density and the abundance (nitrogen and possibly carbon) of asymptotic giant branch stars in the central part of this cluster.

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