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CN BAND DISTRIBUTIONS OF THE STARSON THE RED GIANT BRANCH IN THE GLOBULAR CLUSTERS M3 AND M13

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ABSTRACT

Among the sample of red giant stars in the globular clusters M3 and M13 whose CN bands (3883 Å) have been measured by various authors, the stars on the red giant evolutionary state are selected to have their CN band distributions. It is found that all stars brighter than M_V = 0, are CN-strong in M3, while all stars except IV-29 are CN-strong in M13. It hints that the onset of meridional mixing is related with the RGB bumps of the clusters.

I. INTRODUCTION

It has been known that the red giants in the globular clusters M3 and M13 show different distributions of CN band strength(Suntzeff 1981; Norris and Smith 1984). The CN-strong stars are more frequent in M13, while the CN-weak stars are more common in M3. These clusters are well known for the second parameter problems, which come from the facts that they have different horizontal mophologies although their metallicities are almost same.

The surface abundances of C, N, O, Na, and Al have been found to vary star-to-star among the globular cluster giants. As the origin of these intracluster inhomogeneities, the non-canonical internal mixing during the red giant evolution phase and primordial inhomogeneities have generally been suggested. The mixing theory can explain the anticorrelations between C and N, O and N, and O and Na, but the C depleted Main Sequence star in M92(Carbon et al. 1982) still requires a primordial origin. The mixing theory predicts that the CN anormaly should be confined to the upper RGB. Then what causes the CN strong stars are more frequent in M13 while the CN weak stars are more common in M3 ? It seems that the reasons are related with the mixture of the AGB branch stars among the red giant stars and the different magnitude distribution in the red giant sample of two clusters. In this study we have collected all CN band (3883 Å band) measurements for giant stars in the globular clusters M3 and M13 and reanalyzed them to see the CN band distribution for stars only on the red giant branch of the evolutionary state. Section II describes how to make all different CN index measurements into one index

system and a reanalysis of the CN index distribution only for stars on red giant evolution in both clusters is discribed in section III following with the section IV of summary and conclusion.

II. CN(3883) INDEX DATA

We have collected all measurements of CN band of 3883 Å for red giants stars of M3 and M13 globular clusters from Suntseff(1981), Norris and Smith(1984), Smith et al.(1996), and Lee(1998). Lee(1998) have measured CN bands of 3883 Å and 4215 Å together with CH band for 10 red giants of the M3 globular cluster.

Four stars of her sample stars are overlapped the stars of Smith et al (1996), who have measured the CN bands and CH bands for red giants of M13 as well as M3. The same index definitions for CN and CH bands were used by both authors. While only the spectra for stars were observed by different telescope-spectroscope combinations with the similar resolutions. Lee(1998) has showed that both systems are different only by zero point of each index. So all indices for CN band of 3883 Å are transformed to Lee's system.

The m_{cn} index of Suntzeff(1981) for λ 3883 CN band can be transformed to S(3839) index of Smith et al(1996) by the the following relation.

$$S(3839) \text{ of Smith et al.(1996)} = -0.164 + 1.20\, m_{cn}$$

It has been derived by three overlapping stars of both samples.

The relation between S(3839) index of Norris and Smith (1984) and m_{cn} of Suntzeff(1981) was adopted from Norris and Smith(1984).

$$S(3839) \text{ of Norris and Smith(1984)} = 0.958\, m_{cn} - 0.157.$$

The S(3839) of Smith et al(1996) can be transfered to Lee's CN(3883) index by adding 0.25. The collected stars of M3 and M13 are plotted on the color-magnitude diagrams with the fiducial branch lines. For M3, data for the fiducial lines are adopted from Ferraro et al (1997), while for M13 data for them are from Paltrinieri et al(1998). Although Paltrinieri et al (1998) did not give data for the mean ridge line for AGB in M13, their figure2 hints AGB line. Therefore the boundary line for AGB is drawn by eye.

Figure 1 is CMD for M3 and figure 2 is for M13. In figure1 of M3 CMD, stars in blueward of AGB line could be all AGB stars, while those in redward of RGB line could be all RGB stars, but those in between two lines could be either AGB or RGB. But for M13 case, the line for AGB is a sort of boundary for AGB stars since some kind of gap among the distribution of stars make author to draw that line. Therefore the blueward of the AGB

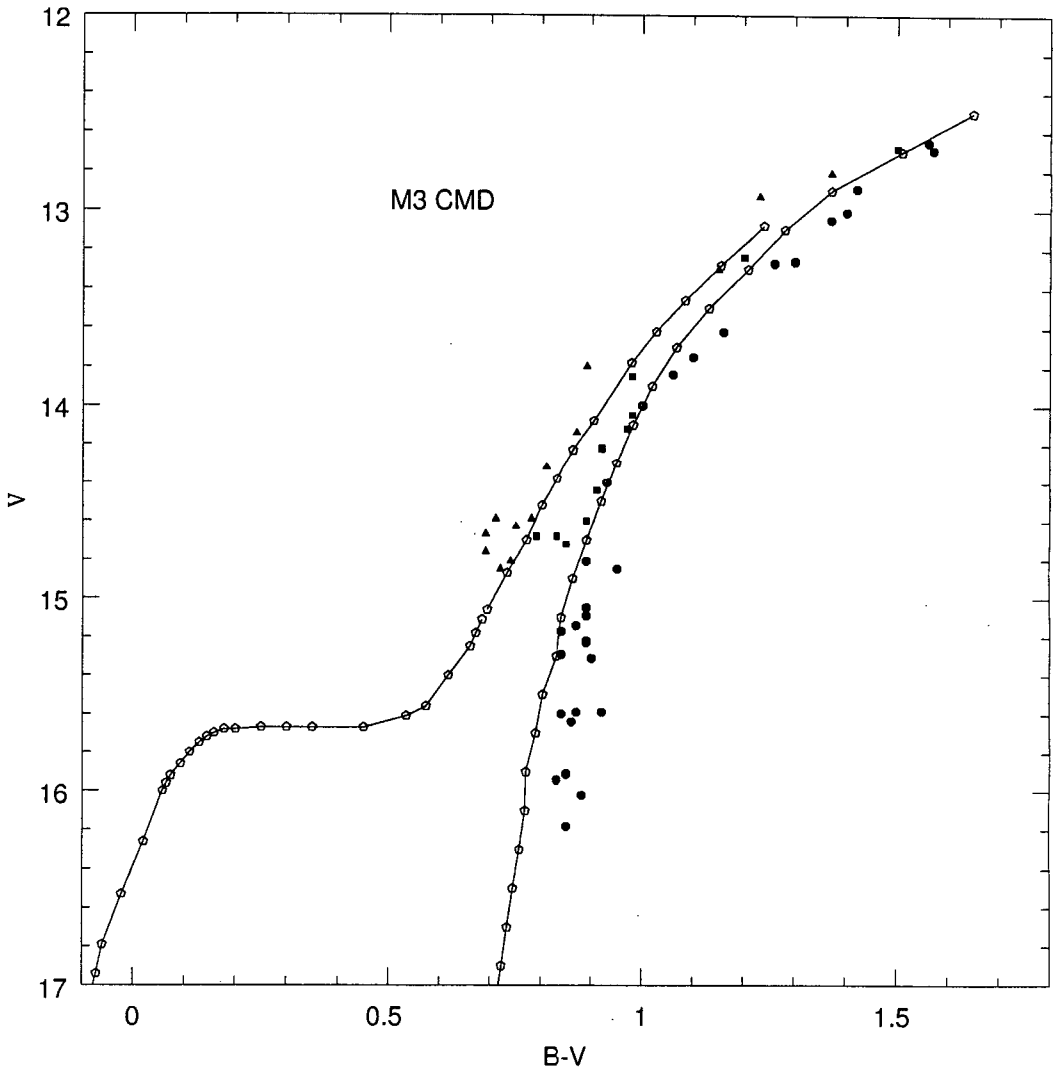

Fig 1. Color-Magnitude Diagram of M3

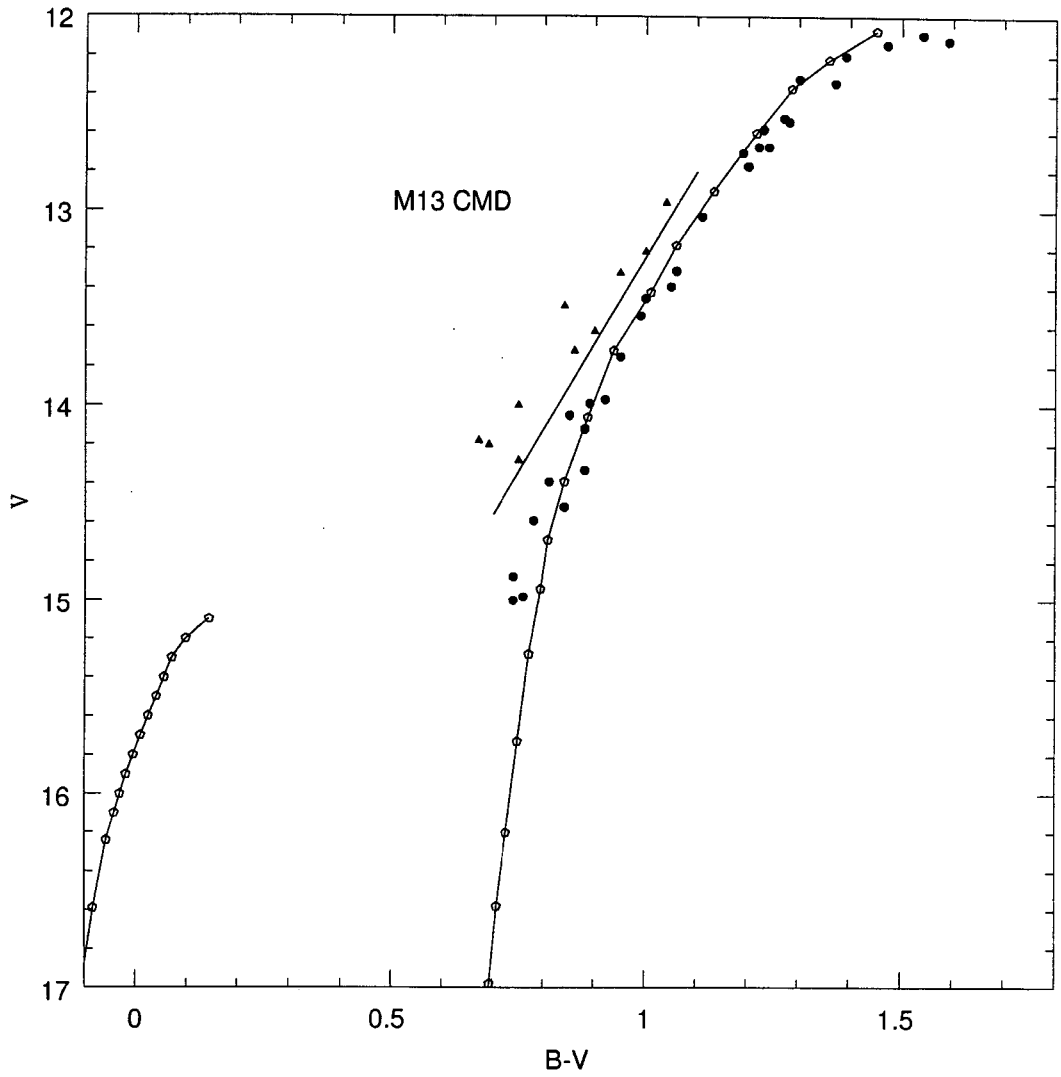

Fig 2. Colar-Magnitude Diagram of M13

boundary line, all could be AGB stars, while the remaining stars could be all RGB stars.

In figures 3 and 4 of CN(3883) index versus M_V, all collected stars in M3 and M13 are plotted. The distance modulus (m - M) of 15.05 and 14.35 for M3 and M13 are adopted from Peterson (1993). Triangles are AGB stars, squares stars in between two lines in case of M3, and circles RGB stars.

The CN(3883) distributions of them could be interpreted as a kind of bimodal distributions. However it hints that removal of the AGB stars and stars with uncertain identity could obscure the bimodality of the distributions. Especially it is clearly seen in M13. But it is seen in M3 too.

III. CN BAND DISTRIBUTIONS OF THE STARS ON THE RED GIANT BRANCH

The stars in the redward of the RGB fiducial line of M3 are selected for the sample of the stars on the red giant branch. While for M13, the stars in the redward of the eye estimated line of AGB are selected for the sample for them. The CN(3883) indices for the sample stars are listed in table 1 and 2 for M3 and M13 respectively, with V, (B - V), M_V, and remarks of another name or nitrogen abundance [N/Fe] determined by Smith et al.(1996).

The CN distribution of the stars on the red giant branch in figure 5 and 6 shows that all stars brighter than M_v = 0 in M3 are CN-strong with CN(3883) index larger than 0.25, while all stars except IV-29 and II-76 in M13 are found to be CN index larger than 0.25. However the star, II-76 with CN(3883) index of 0.24 is found by Smith et al (1996) that its N abundance, [N/Fe], is enhanced to around 0.56. Therefore except IV-29 all red giant stars in M13 are CN strong stars. For M3, the red giant bump has been found as a clump of stars at V around 15.05 by Fusi Pecci et al. (1990), and V around 15.45 by Ferraro et al. (1997). Therefore, if the distance modulus of (m - M) = 15.05 (Peterson 1993) is adopted, the absolute magnitude of red giant bump is around M_v = 0 ~ 0.4. It suggests that the enhencement of surface nitrogen abundance, if it is due to the meridional mixing suggested by Sweigart and Mengel(1979), is related with the red giant bump. For the case of M13, RGB bump of V = 14.70 has been found with the distance modulus of (m - M) = 14.35. Therefore, if the onset of mixing is related with the red giant bump, then all stars brighter than M_V = 0.35 should be CN-strong which is seen in figure 6. And the star, IV-29 may be a star in the state of just before mixing.

However the CN band distributions for stars fainter than the red giant bump show a wide spread of CN index, especially in M3. It suggests a premodial spread of CN band strength.

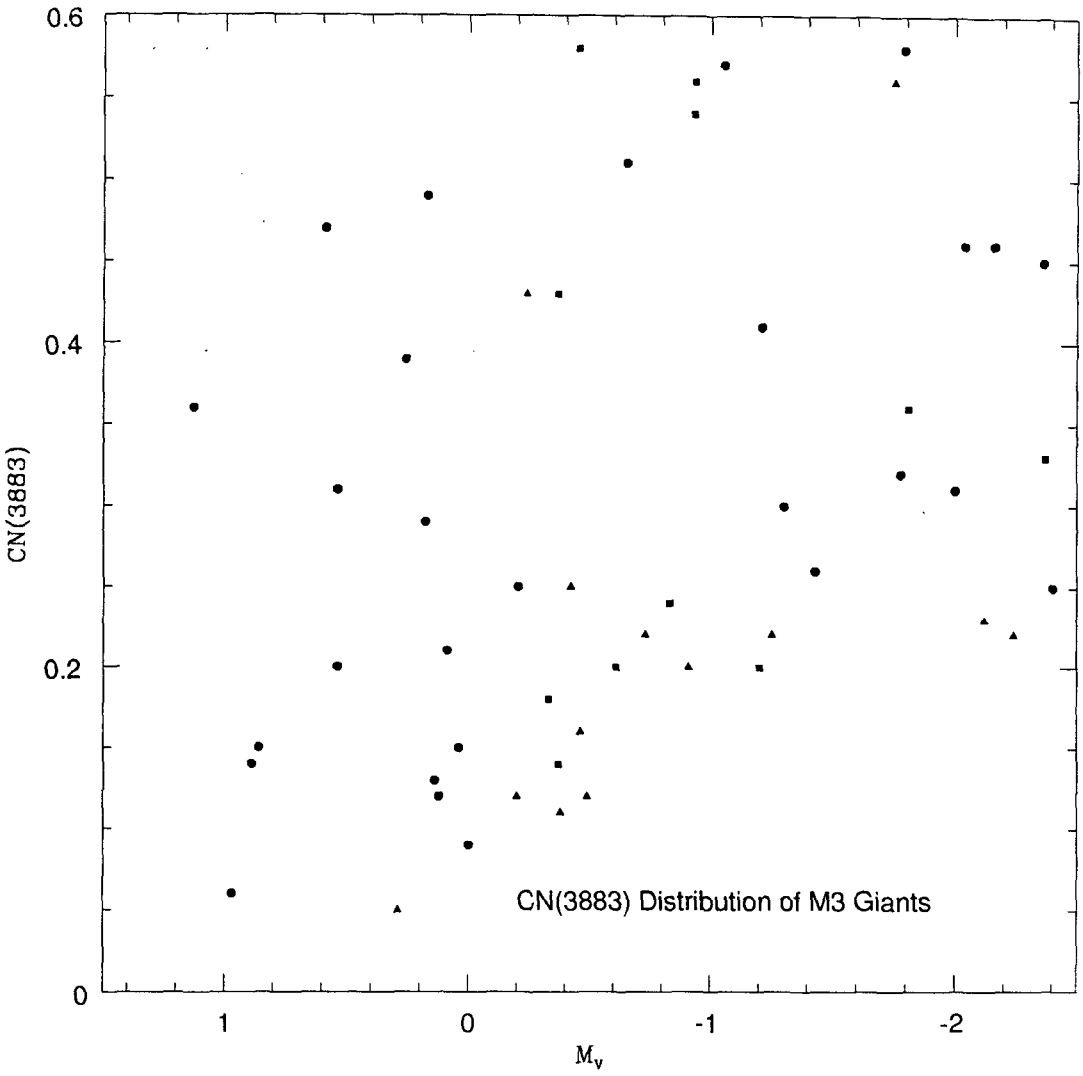

Fig 3. CN Band Distribution of the Red Giant Stars in M3

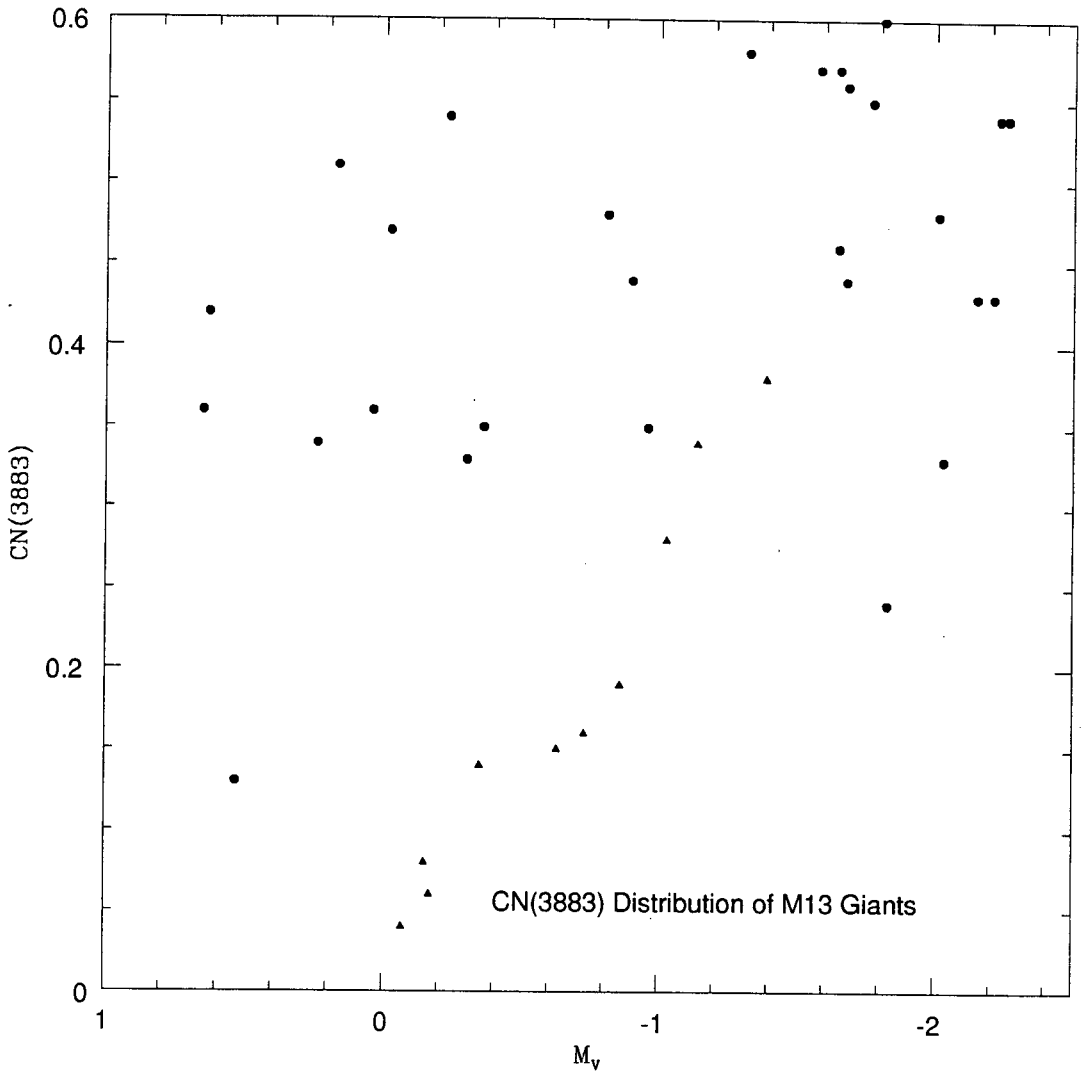

Fig 4. CN Band Distribution of the Red Giant Stars in M13

Table 1. Data for stars on the red giant branch of M3

Star	V	$(B-V)$	M_V	CN(3883)	remark
VZ164	13.75	1.10	-1.30	0.30	···
VZ238	12.69	1.57	-2.36	0.45	AA, V138, [N/Fe]=1.01
VZ265	13.26	1.30	-1.79	0.58	IV-101
VZ297	12.89	1.42	-2.16	0.46	[N/Fe]=1.14
VZ1000	13.01	1.40	-2.04	0.46	[N/Fe]=0.84
VZ1331	15.22	0.89	0.17	0.49	110
VZ1397	12.65	1.56	-2.40	0.25	[N/Fe]=0.45
I- 5	15.31	0.90	0.26	0.39	19
I-17	15.59	0.92	0.54	0.20	20
I-21	13.05	1.37	-2.00	0.31	···
II-3	15.29	0.84	0.14	0.13	···
III-15	15.17	0.84	0.12	0.12	···
III-33	14.40	0.93	-0.65	0.51	···
IV-27	14.00	1.00	-1.05	0.57	···
V-12	15.14	0.87	0.09	0.21	406
VI-14	15.59	0.87	0.54	0.31	···
VI-21	15.94	0.83	0.89	0.14	48
VI-22	15.91	0.85	0.86	0.15	45
VI-23	16.18	0.85	1.13	0.36	47
VI-30	15.64	0.86	0.59	0.47	64
A	13.27	1.26	-1.78	0.32	···
AC	14.81	0.89	-0.24	0.25	···
AT	15.60	0.84	0.55	0.05	···
BC	13.84	1.06	-1.21	0.41	···
BF	13.62	1.16	-1.43	0.26	···
D	15.05	0.89	0.00	0.09	···
L	15.09	0.89	0.04	0.15	···
M	16.02	0.88	0.97	0.06	···
H	14.85	0.95	-0.20	0.25	434
639	15.23	0.89	0.18	0.29	···

Table 2. Data for stars on the red giant branch of M13

Star	V	$(B-V)$	M_V	CN(3883)	remark
I-12	13.54	0.99	-0.81	0.48	···
I-13	12.54	1.28	-1.81	0.60	···
I-18	13.97	0.92	-0.40	0.72	···
I-49	13.99	0.89	-0.36	0.35	···
I-65	14.05	0.85	-0.30	0.33	···
II- 4	14.59	0.74	0.24	0.34	···
II- 6	14.39	0.81	0.04	0.36	···
II-33	12.67	1.22	-1.68	0.44	[N/Fe]=0.79
II-34	12.34	1.37	-2.01	0.48	[N/Fe]=1.23
II-57	12.70	1.19	-1.65	0.51	[N/Fe]=0.98
II-67	12.12	1.59	-2.23	0.54	[N/Fe]=1.39
II-69	15.00	0.74	0.65	0.36	···
II-76	12.52	1.27	-1.83	0.24	[N/Fe]=0.59
III- 7	13.45	1.00	-0.90	0.44	···
III-18	12.77	1.20	-1.58	0.59	[N/Fe]=1.10
III-52	12.67	1.20	-1.68	0.56	···
III-56	12.14	1.47	-2.21	0.43	[N/Fe]=1.18
III-59	12.58	1.23	-1.77	0.55	[N/Fe]=1.11
III-63	12.20	1.39	-2.15	0.43	[N/Fe]=1.02
III-73	12.32	1.30	-2.03	0.33	[N/Fe]=0.79
IV-25	12.09	1.54	-2.26	0.54	[N/Fe]=1.22
IV-28	13.03	1.11	-1.32	0.58	···
IV-29	14.88	0.74	0.53	0.13	···
IV-78	14.12	0.88	-0.23	0.54	···
A1	13.39	1.05	-0.96	0.35	···
A10	14.33	0.88	-0.02	0.47	···
J3	13.31	1.06	-1.04	0.64	···
J37	14.52	0.84	0.17	0.51	···
J45	14.98	0.76	0.63	0.42	···
X24	13.75	0.95	-0.60	0.44	···

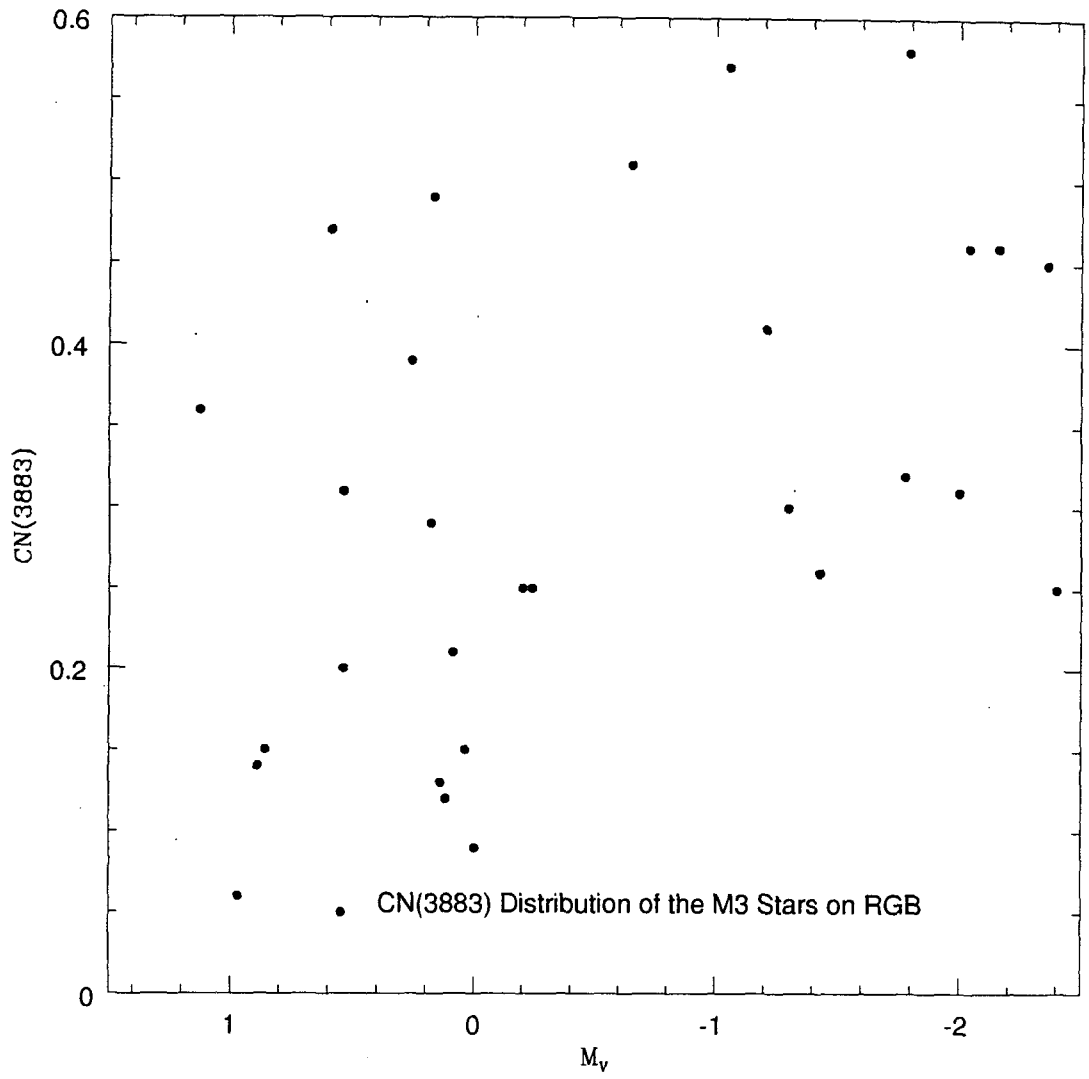

Fig 5. CN Band Distribution of the Stars on the Red Giant Branch in M3

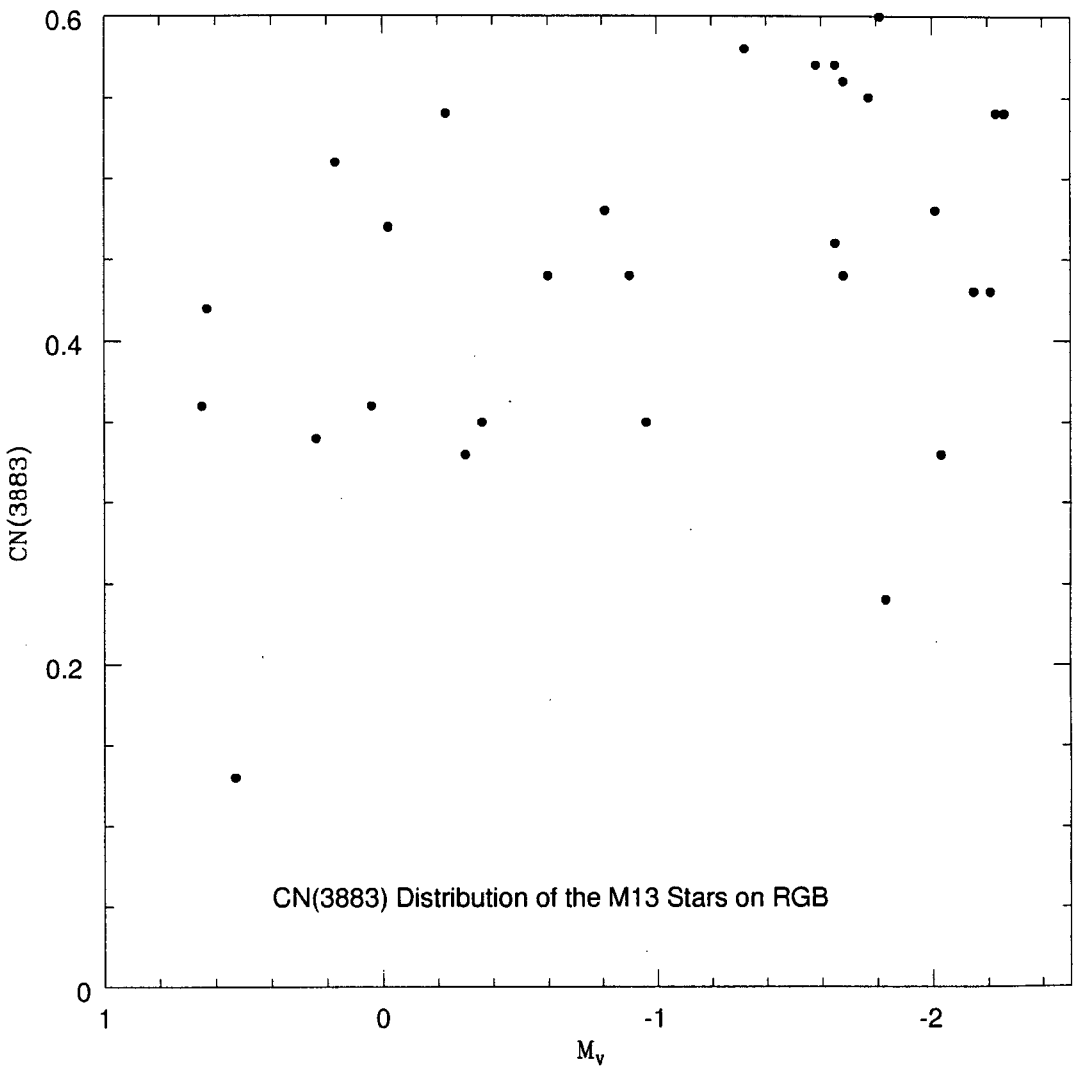

Fig 6. CN Band Distribution of the Stars on the Red Giant Branch in M13

IV. SUMMARY AND CONCLUSION

CN band distributions of the stars on the red giant branch of the globular clusters M3 and M13 are found not to be bimodal from the sample of stars restricted to the stars on that evolutionary state. The distributions show the stars brighter than $M_V \sim 0$, are all CN-strong in M3, while the stars brighter than $M_V \sim 0.4$ are all CN-strong in M13. This result indicates that the onset of non-canonical mixing could be related with the red giant bump. The red giant bump is found to be around M_V around 0.0 ~ 0.4 for the globular cluster M3, while $M_V \sim 0.35$ for the case of M13 globular cluster.

The wide spread distributions of CN band for stars fainter than the red giant bump suggest primodial inhomogeneities of nitrogen abundances.

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