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CHEMICAL INHOMOGENEITIES AMONG GIANT STARS IN NGC 3201*

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ABSTRACT

Nine giant star's spectra in NGC 3201 were obtained using the image tube in Sutherland. From the analysis of these spectra we found the increase of Ca I and CH abundances with decreasing the radial distnace, but CN, Ca II and Fe abundances do not show this. Dependence of the calculated parameters seems to exist among CN, Ca I, Ca II and CH abundances.

I. INTRODUCTION

NGC 3201 locates in a relatively low galactic latitude and is less centrally concentrated (concentration class x) that it is possible to observe the central region of this cluster. The radial velocity of NGC 3201 is 493 km/sec which is the highest velocity among globular clusters and its motion retrogrades to the Galactic centre. The central relaxation time is 2.1×10^8 years which is much shorter than its life time and we can assume that this cluster is fully relaxed. In Table 1 we listed some parameters of NGC 3201.

NGC 3201 has a low metal abundance (integrated spectrum is F9 by Kukarkin (1974)) and its C-M diagram is similar to those of M3 (sandage 1970), M72 (Dickens 1972) and NGC 6723 (Menzies 1974). In the nuclear region (inside the core radius $r_c = 1'.1$) the number density of the red giant branch (RHB) is less concentrated than the blue giant branch stars (BHB) and RR Lyrae stars concentrate more in the outer region like M3 (Woolf 1964) and ω Cen (Dickens and Woolley 1967).

From the spectroscopic observation of NGC 3201, Smith and Norris (1982) found a bimodal cyanogen distribution among giant stars. Infrared photometry of Da Costa, Frogel and Cohen shows that there exists anomaly among giant stars. In this paper we observed 9 giant stars spectroscopic method and tried to find out any radial abundance gradient and abundance anomaly.

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Table 1. Properties of NGC 3201.

Coordinate	α; $10^h\ 15^m.5$ (1950) δ; $-46°.09'$ (1950) ℓ; $277°.2$ (1950) b; $+8°.6$ (1950)	
Absolute Magnitude(M_V)	$-7^m.40$	Harris and Racine (1979)
Concentration Parameter (C)	1.52	Harris and Racine (1979)
Tidal Radius (r_t) pc	45.7	Harris and Racine (1979)
Central Surface Brightness (m_v)	$9^m.49$	Harris and Racine (1979)
Relaxation Time (year)	2.13×10^8	Hans and Madore (1981)
Age (year)	1.2×10^{10}	Lee (1977)
Radial Velocity (km/sec)	493	Hartwick and Sargent (1978)
Velocity Dispersion (km/sec)	3.72	Hans and Madore (1981)
Escape Velocity (km/sec)	15.45	Hans and Madore (1981)
Distance Modulus $(m-M)_0$	$13^m.68$ $13^m.57$ $13^m.35$	Alcaino (1976) Lee (1977) Da Costa *et al.* (1981)

II. OBSERVATION

From the C-M diagram (Lee 1977), 9 giant stars were chosen to get spectra. Observations were made at Sutherland in South Africa using 74 inch telescope. Image tube and 1.4 inch camera were used to get these spectra. Baked IIa-O plates were used and the dispersion was 67 Å/mm. The observed slit width and the exposured time are listed in Table 2.

Observed spectra were scanned using the Joyce Loebel microdensitometer which is connected with NOVA. Spectra of 9 giant stars are displayed in Figure 1.

III. REDUCTION

To get the relative abundance of certain elements, we used the definition of spectral indices suggested by Suntzeff (1980) as

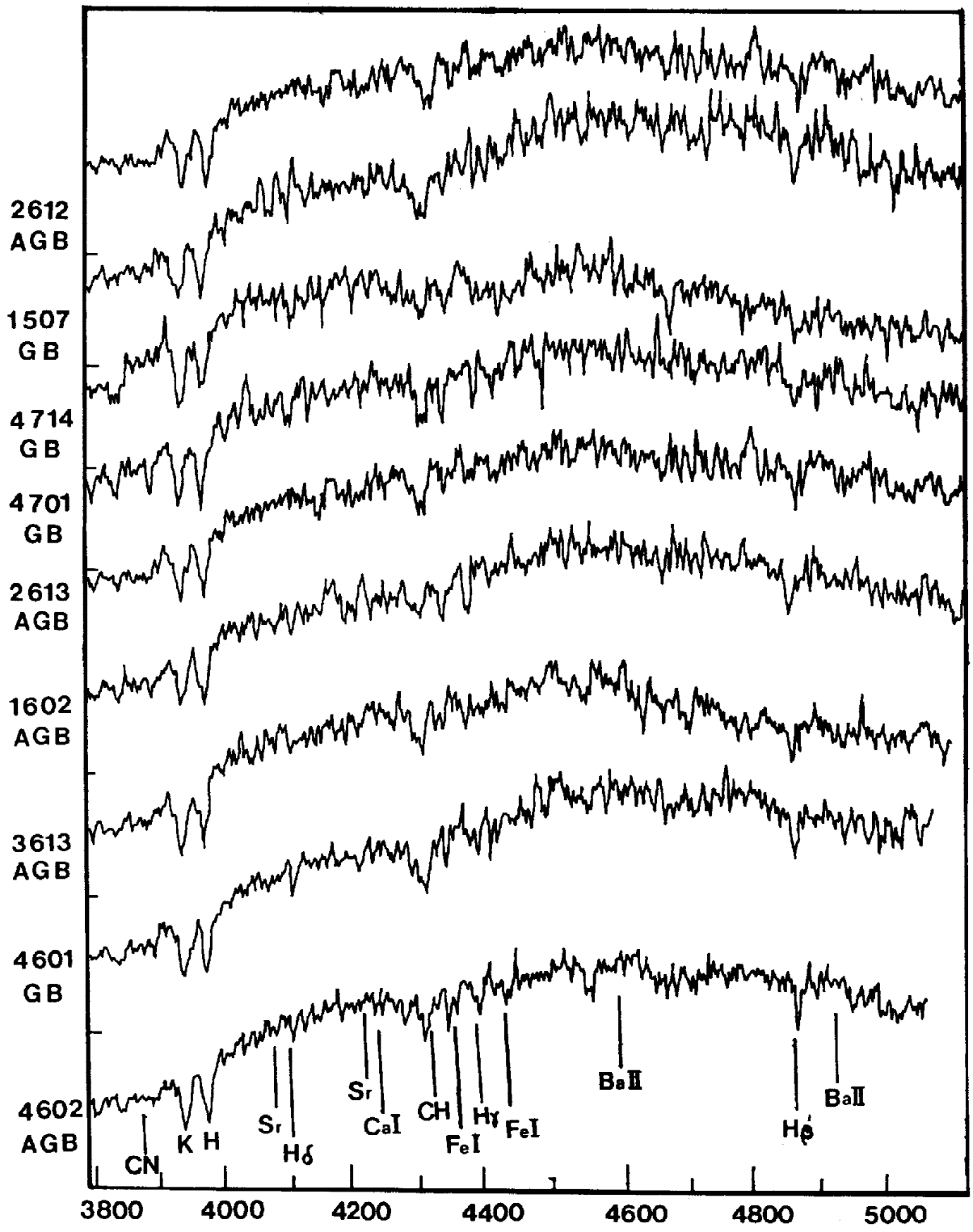


Fig. 1. Spectra of 9 giant stars.

Table 2. Spectroscopic Observational Data.

Star name	slit (μm)	exposure time (min)
1507	300	20
4601	150	20
4701	300	20
4714	300	15
1602	300	25
2612	100	19
2613	300	20
3613	100	11
4602	150	15

Table 3. Wavelength Characters of the Spectral Indices.

Band	λ_c (Å)	$\Delta\lambda$ (Å)
CN	3840	140
HK	3965	110
HK_{cont}	4075	110
CaI	4226	30
CH	4275	80
CH_{cont}	4335	40
Fe	4397	85
Fe_{cont}	4530	60

$$m_{HK} = -2.5 \log \frac{\langle F_{3965} \rangle}{\langle F_{4075} \rangle}$$

where

$$\langle F_{3965} \rangle = \int_{3910}^{4020} F_\lambda \, d\lambda / 110$$

$$\langle F_{4075} \rangle = \int_{4020}^{4130} F_\lambda \, d\lambda / 110$$

Cantema *et al.* (1982) defined the total flux of a feature as

$$F = \int_{\lambda_c - (\Delta\lambda/2)}^{\lambda_c + (\Delta\lambda/2)} F_\lambda \, d\lambda$$

and the corresponding magnitude per unit wavelength as

$$m = -2.5 \log (F/\Delta\lambda)$$

The bandpass, central wavelength and halfwidth of the calculated spectral indices are listed in Table 3. Spectral indices are defined as

$$\begin{aligned} m_{HK} &= HK - HK_{cont} \\ m_{CN} &= CN - HK_{cont} \\ m_G &= CH - CH_{cont} \\ m_{Ca} &= CaI - CH_{cont} \\ m_{Fe} &= Fe - (Fe_{cont} + CH_{cont})/2 \end{aligned}$$

where the line and continuum intensities were measured in the range of wavelength as

CN	:	3789-3910
HK	:	3910-4020
HK_{cont}	:	4020-4130

Table 4. Calculated Spectral Indices.

Star	group	m_{HK}	m_{CN}	m_G	m_{Ca}	m_{Fe}	M_V
1507	GB	0.44	0.66	0.11	0.06	0.03	0.47
4601	GB	0.46	0.68	0.12	0.03	0.05	0.57
4701	GB	0.37	0.61	0.02	−0.04	0.03	0.30
4714	GB	0.34	0.63	0.03	−0.10	0.09	0.11
1602	AGB	0.34	0.63	0.02	0.00	0.00	0.53
2612	AGB	0.45	0.74	0.08	0.06	0.03	−0.30
2613	AGB	0.39	0.64	0.08	0.07	0.04	0.39
3613	AGB	0.48	0.82	0.07	0.00	0.03	0.22
4602	AGB	0.43	0.65	0.09	0.00	−0.01	0.39

CaI : 4211-4241
CH : 4235-4315
CH_{cont} : 4315-4355
Fe_{cont} : 4500-4560
Fe : 4354.5-4439.5

The calculated spectral indices are listed in Table 4. The 1st column is the star's identification and the 2nd column is the classification of giant stars grouping into red giant branch stars (GB) and asymptotic giant branch stars (AGB) from the C-M diagram by Lee (1977). The spectral indices are in columns 3 to 7 and the absolute magnitudes (M_V) are in column 8 assumming $(m-M)_V=13.35$.

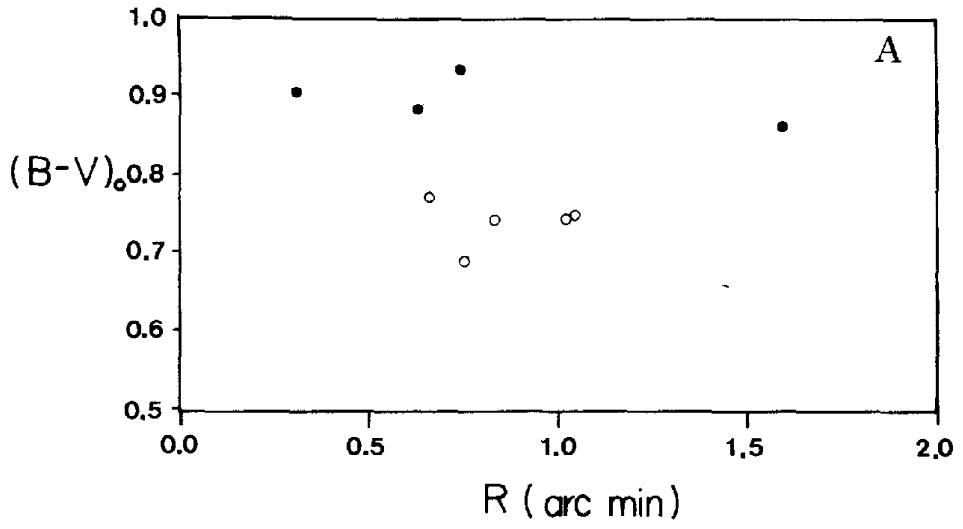
IV. DISCUSSIONS

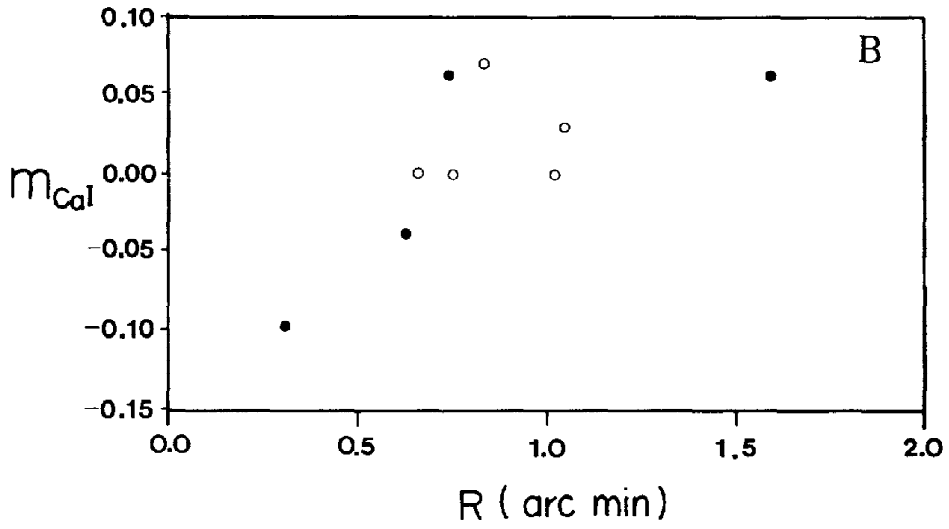
To find any correlation among parameters of giant stars in NGC 3201, we checked them in 3 methods. First we tried to find out any radial changes of each parameter. In Figures 2a-2f, we plotted $(B-V)_0$, m_{Ca}, m_{CN}, m_G, m_{HK} and m_{Fe} against the radial distance in NGC 3201. Filled circles denote GB and AGB is symbolized as unfilled circle. From these diagrams GB stars have more spectral indices in m_{Ca}, m_G, m_{HK} to the increased radial distance. However, we could not find any correlation in m_{CN}-R and m_{Fe}-R diagrams.

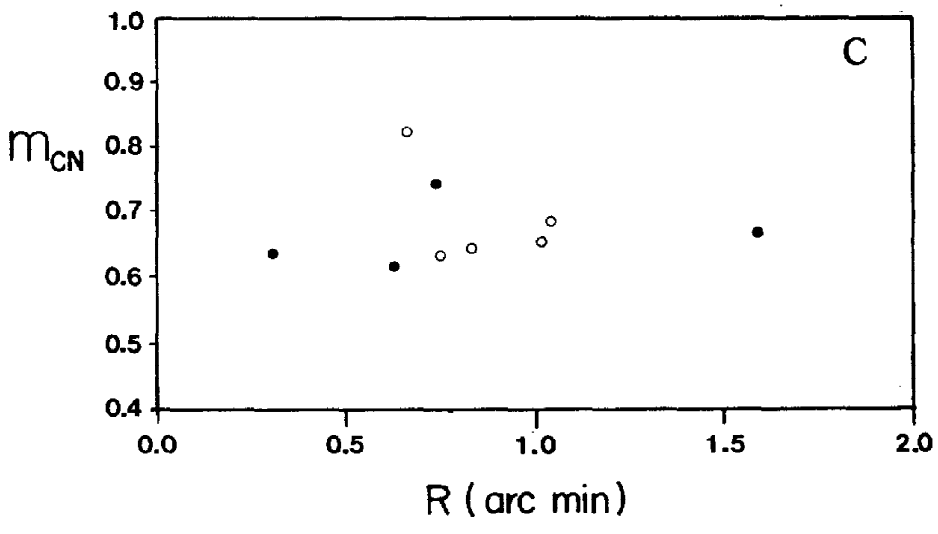
Among the spectral indices, we made m_{CN}-m_{HK}, m_{CN}-m_{Ca}, m_{CN}-m_G, m_G-m_{Ca} and m_G-m_{HK} diagrams as in Figures 3a-3e. All of these diagrams show the marginal correlation between the spectral indices except m_{CN}-m_G diagram in Figure 3c. Figure 3c shows that m_{CN} has a correlation with m_G for the smaller m_{CN} index (<0.7), but it shows an anticorrelation for the larger m_{CN} index.

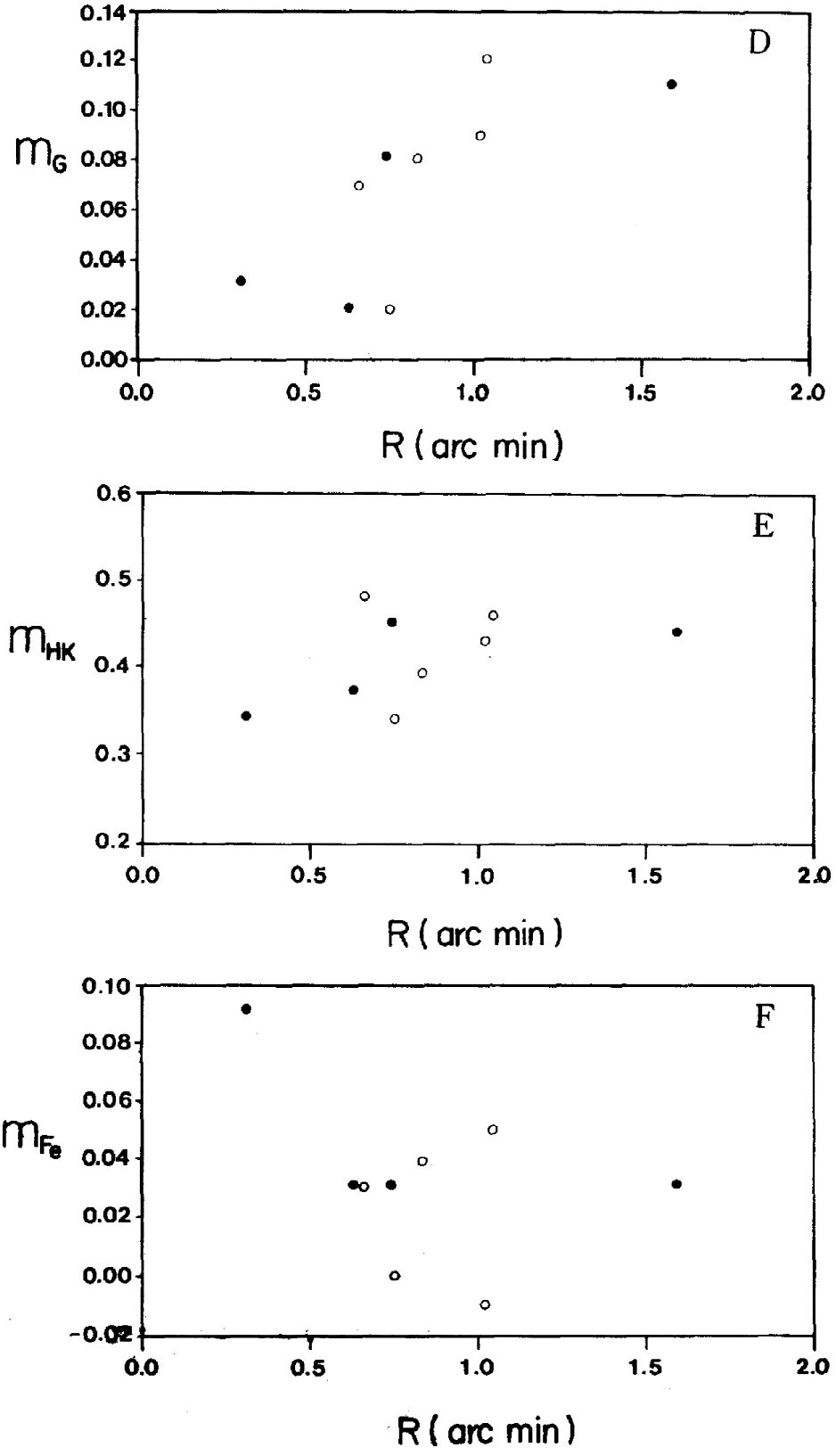
Thirdly, we plotted absolute magnitudes against the spectral indices as in Figures 4a to 4c. All of these diagrams do not show any correlation.

Figures 2 indicate that the abundances of Ca and CH are more in the central region of NGC

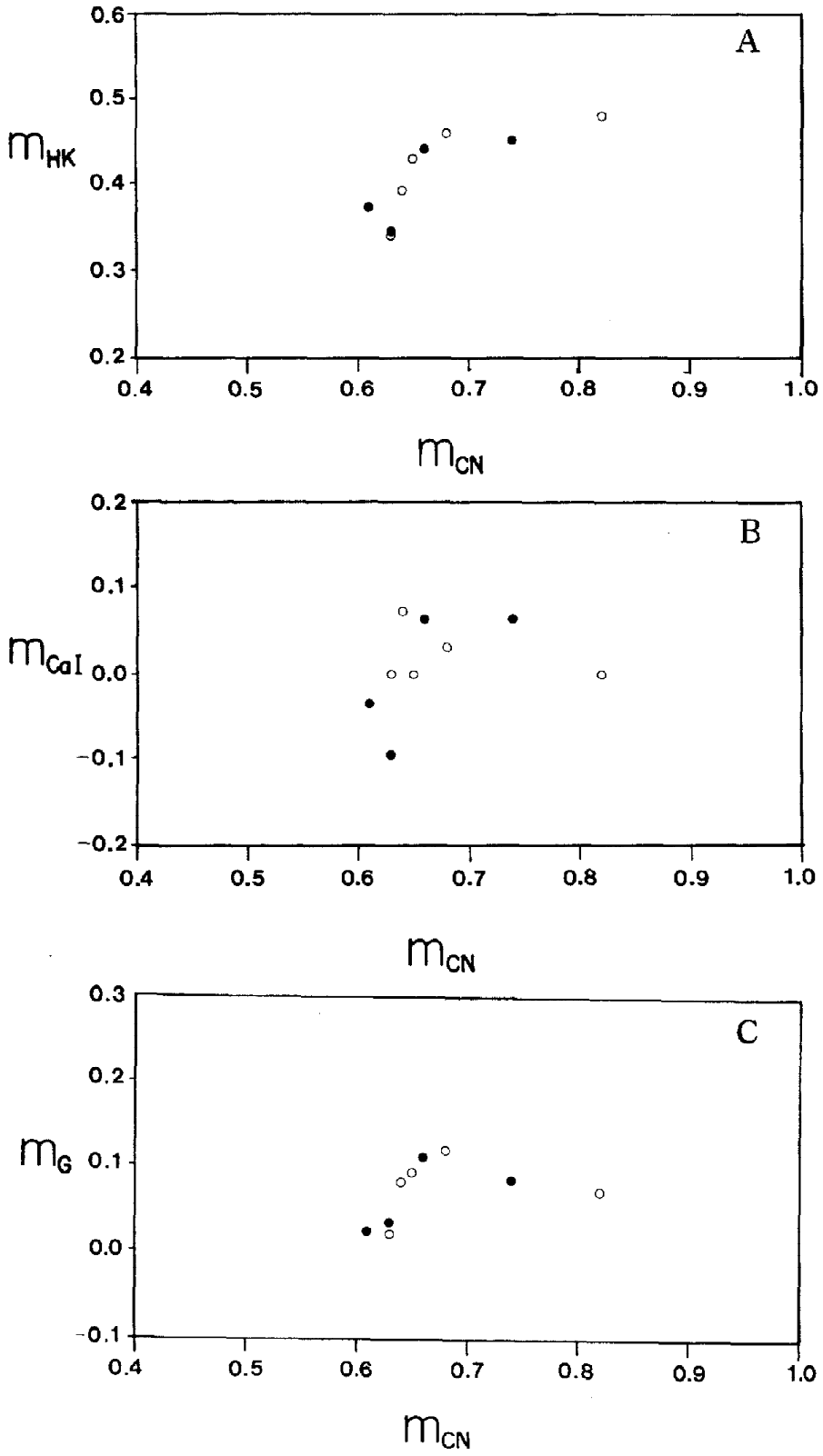

A
(B-V)o
1.0
0.9
0.8
0.7
0.6
0.5
0.0
0.5
1.0
1.5
2.0
R (arc min)

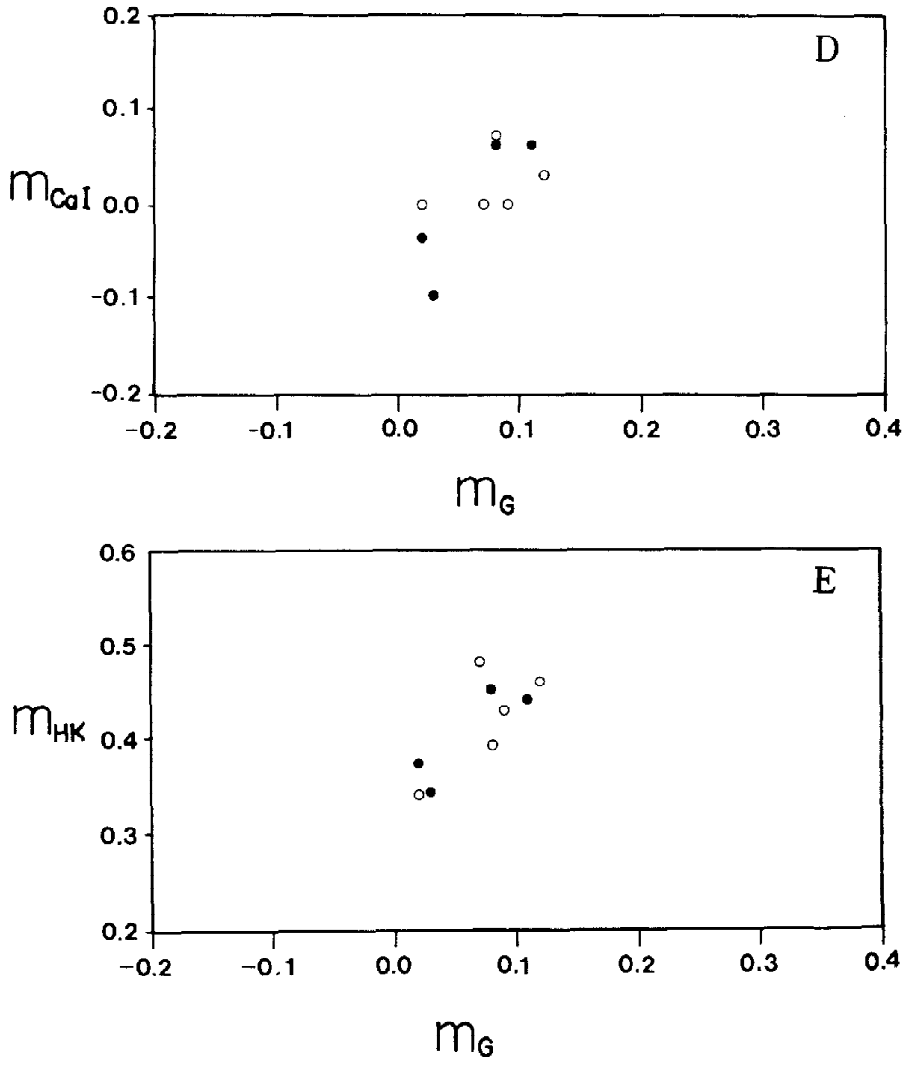

B
mCaI
0.10
0.05
0.00
−0.05
−0.10
−0.15
0.0
0.5
1.0
1.5
2.0
R (arc min)


C
mCN
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.0
0.5
1.0
1.5
2.0
R (arc min)



Figs. 2a-2f. Spectral indices to the radial distance for 4 GB and 5 AGB stars.

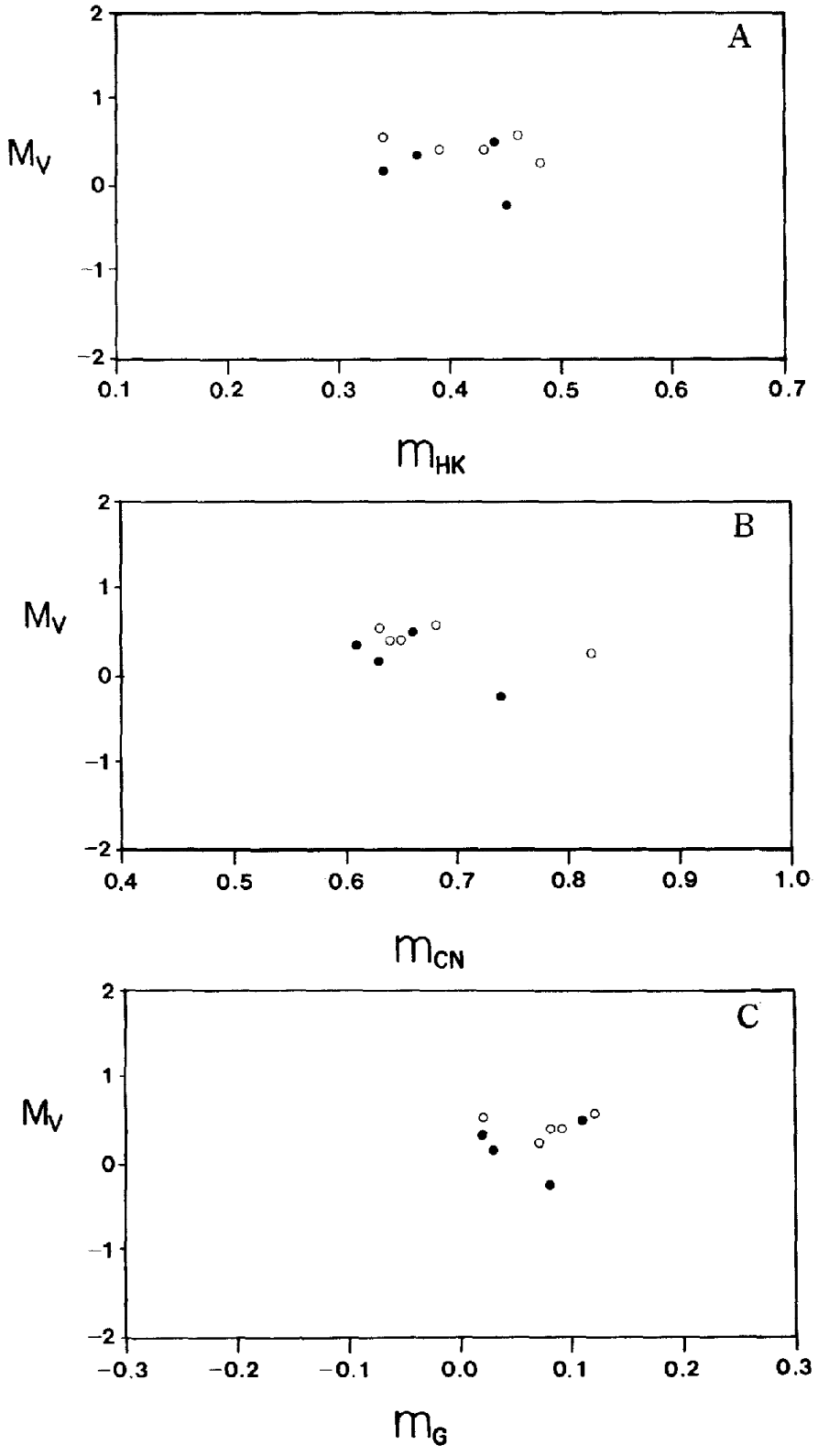

A
m_{HK}
0.6
0.5
0.4
0.3
0.2
0.4
0.5
0.6
0.7
0.8
0.9
1.0
m_{CN}
B
m_{CaI}
0.2
0.1
0.0
−0.1
−0.2
0.4
0.5
0.6
0.7
0.8
0.9
1.0
m_{CN}
C
m_G
0.3
0.2
0.1
0.0
−0.1
0.4
0.5
0.6
0.7
0.8
0.9
1.0
m_{CN}



Figs. 3a-3e. Correlation between spectral indices.

3201 at least for GB stars. This makes a possible conclusion that GB stars in NGC 3201 show a radial abundance gradient in a sense that heavier metal GB stars are more centrally concentrated than the light element GB stars. However, we could not find any radial CN element variation among GB and AGB stars. This means the radial abundance gradient in NGC 3201 mainly comes from carbon not nitrogen.

Figure 3a shows a correlation between elements of CN and Ca II H & K. We assume that this correlation mainly comes from the Ca II K line which is sensitive to the abundance. Figure 3c shows an anticorrelation between CN and CH abundances, which can be understood as a bimodal cyanogen distribution among giant stars found by Smith and Norris (1982).



Figs. 4a-4c. Absolute magnitudes and spectral indices' diagrams.

V. CONCLUSION

From the spectral analyses of 9 giant stars in NGC 3201 we found the abundance inhomogeneities among these stars. These inhomogeneities are revealed as the variation of Ca and CH spectral indices. The radial abundance gradient is in NGC 3201 in a sense that the carbon rich giants are more centrally concentrated than the carbon poor giants.

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