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Determination of the C/M5+ Ratio in the Galactic Disk

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Abstract. A determination of the C/M5+ ratio, as a function of the galactocentric distance, in the galactic disk is presented. These results are based upon previous determinations of the space density for cool carbon stars and for late giant M stars in the Milky Way. Most of these results were obtained from objective-prism surveys in the near infrared using mainly Schmidt-type telescopes. The ratio C/M5+ appears to increase from 0.05 to 0.25 in the galactic disk, from the galactic center outwards. A mean value of 0.15 of this ratio for the Galaxy is suggested. Correlations between the C/M5+ ratio and currently known metal abundance gradients in the galactic disk are discussed.

1. Introduction

Interest in the study of the space distribution of the Red Giant stars in the Galaxy has grown primarily because they are relevant to our understanding of the process of stellar evolution, and the formation and evolution of stellar systems. The M, C , and S stars are evolved red objects of high luminosity and low surface temperature. Together, they represent the largest fraction of the stellar population on the Asymptotic Giant Branch (AGB) in the HR diagram, and are found mainly in the galactic disk.

Some relevant conclusions may be drawn, as derived from near-infrared objective-prism surveys, on the distribution of the Red Giant stars in the Galaxy: (1) Late M giants show preference for the general direction of the galactic center, as expected for almost all types of normal disk-population stars (see Blanco 1965 and discussion therein); (2) the surface density of carbon stars appears to be, on the contrary, significantly enhanced toward the galactic anticenter (Blanco 1965; Fuenmayor 1981); this asymmetry seems to be an actual, and important feature of galactic structure (Stephenson 1989); (3) carbon stars appear to be concentrated in the spiral arms (Westerlund 1971, Alksne et al. 1977) and seem to be indicators of an intermediate-age stellar population in the galactic disk. S stars will not be considered in this work.

Blanco et al. (1978) found that the number density ratio between cool carbon stars and M stars of spectral subtype later than M4 (henceforth the C/M5+ ratio) attains different values when determined toward directions such as the galactic bulge, the galactic anticenter and the Large and the Small Magellanic Clouds. Richer & Westerlund (1983) extended the determination of the C/M5+

ratio to a few dwarf spheroidal galaxies in the Local Group (see also Blanco & McCarthy 1984).

McCuskey & Mehlhorn (1963) and McCuskey (1969) have made determinations of the space density for the late M stars toward the direction of the galactic center and toward the anticenter as well. Fuenmayor (1981) made similar determinations for the cool carbon stars instead toward the same regions, using basically the same survey techniques. Based upon these results, a determination of the ratio C/M5+ in the plane of our Galaxy is presented in this paper.

2. The Distribution of the Late M and C Stars in the Galaxy

The chemical composition of the atmosphere of M stars is similar to that of the Sun. The atmospheric ratio $C/O < 1$ allows the formation of the stable CO molecule (undetectable in the visible), while the remnant oxygen forms metallic oxides, such as TiO and VO, whose bands are easily observed in the red and in the near-infrared spectral ranges. Carbon stars have an atmospheric ratio $C/O > 1$ probably due to contamination by products of the nucleosynthesis activity of the star core, raised to the atmosphere via convection instabilities (Iben 1975; Sugimoto & Nomoto 1975). The leftover carbon found in the atmosphere allows the formation of different molecular species, such as C2, CH, and CN, whose bands are well observed in the red and the near-infrared.

Results for the distribution of M and C stars in the Galaxy may be summarized as follows:

M stars: These stars may be subclassified into three categories or Natural Groups (McCarthy 1984) and are distributed in the Galaxy in the following manner: (a) Group 1: M1–M4, found preferentially on the spiral arms. (b) Group 2: M5–M6.5 and (c) Group 3: M7–M10 are found more uniformly distributed in the arms and interarm regions. Most of the M stars segregated on near-infrared objective-prism plates belong to the last two groups. C stars: These objects are considered to be spiral arm tracers.

3. The Surveys

McCuskey & Mehlhorn (MM, 1963) and McCuskey (M, 1969) compiled lists of stars of spectral types M5 or later, 920 stars in the direction of the galactic center and 493 stars towards the anticenter, respectively. Fuenmayor (1981) surveyed the same regions for carbon stars, compiling a list of 283 of these kind of objects. All these surveys were carried out using either the Warner and Swasey Burrell or the CTIO Curtis Schmidt-type telescopes, each equipped with a 4-degree objective prism. Carbon and late M stars were identified on either Kodak I-N or IV-N emulsions taken through a Schott RG8 (or equivalent) filter. This combination produced spectra with a dispersion of about 1700 Å/mm in the spectral range $\lambda\lambda$ 6800–8800. Spectra were unwidened and the exposure times ranged between 15 and 60 minutes. This technique allows the identification of carbon and late M stars up to a limiting magnitude $I = 13$.

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4. The C/M5+ Ratio

The procedure adopted here to characterize the carbon star disk population is to use the observed late M stars as the underlying normal star population. The run of the space density ratio C/M5+ with galactocentric distance would then give us a picture of the relative distribution of carbon stars in the galactic disk. Technical procedures, such as object identification, measurements of brightnesses and positions, estimation of interstellar absorption and the space density calculations have been laid down with sufficient detail in MM, M, and Fuenmayor (1981).

In both the MM and M papers the space density of the late M stars were determined using the fundamental integral equation of stellar statistics with appropriate corrections for interstellar absorption. They performed density calculations for a variety of absolute magnitudes and magnitude dispersion. Here I adopted their results for their average space density for all the low galactic latitude groups (see Fig. 8, in the MM paper, for the galactic center region; and Fig. 3, in the M paper, for the anticenter region).

In Table 1 the values for the space density of both the late M stars (as determined by MM and M) and the carbon stars (as determined by Fuenmayor 1981), toward the direction of the galactic center and the anticenter, are shown. The mean distance from the Sun, in kpc, are given in Column 1. The estimated space density values are given in units of stars per 10^6 kpc^{-3} (Columns 2 and 5 show the values for carbon stars and Columns 3 and 6 give the values for the M5+ stars). The computed C/M5+ ratios are shown in Columns 4 and 7.

The main results may be summarized as follows: (1) The C/M5+ ratio appears to have a mean value of 0.05 toward the galactic center and 0.25 toward the anticenter. (2) The C/M5+ ratio appears uncertain in the solar neighbourhood, up to distance of 2 Kpc, due to the relative smaller volume searched around the Sun. (3) A mean value of 0.15 seems to be suggested in Table 1.

Table 1. The Ratio C/M5+ in the galactic Disk.

Distance	C	M	C/M5+	C	M	C/M5+
1	0.012:	0.5:	0.02	0.100	2.0	0.04
2	0.006:	0.5	0.01:	0.039:	0.9:	0.04:
3	0.024	0.4	0.006	0.079	0.50	0.15
4	0.030	0.3	0.10	0.105	0.34	0.31
5	0.016	0.2	0.08	0.046	0.26	0.18
6	0.007	0.2	0.04	0.014	0.20	0.07

5. Discussion

In this paper a determination of the C/M5+ ratio in the galactic disk is presented. These results have been obtained from objective-prism surveys in the red and in the near-infrared. There seems to be a relative increase in the population of the cool carbon stars with galactocentric distance with respect to the underlying population of the late M giants.

There is well established evidence for an increase in the abundance of heavy elements with galacto-centric distance in the galactic plane (see, for example, Peimbert & Torres-Peimbert 1983, and discussion herein). Faúndes-Abans and Maciel (1986) have discussed evidence for a galactic radial gradient of the [He/H] and [O/H] indices, as derived from abundance analysis in Type II planetary nebulae in the Galaxy. A correlation between carbon star frequency and the metallicity index [Fe/H] has been studied by Richer & Westerlund (1983) for a few star systems of the Local Group: their plot show that the number of carbon stars per unit mass appears to increase with metallicity. Therefore, it appears to be a conclusive tendency for an increase of the C/M5+ ratio towards the outer regions of the Galaxy.

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