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Red clump stars in the Galactic field

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Abstract.
Red clump of giants is a prominent feature of the HR-diagramme of the Milky Way. Presently, when the high-resolution spectral analyses are available for about a half from a complete sample of about 600 clump stars located within a distance of about 125 pc, the metallicity distribution and some other stellar parameters in the Galactic red clump are re-examined. The majority of clump stars investigated concentrate at the near-solar metallicity value with a small scatter of ±0.2 dex, which indicate that nearby clump stars are relatively young objects originated in the local disk during the last few Gyr of its history. Further investigations are needed in order to understand mixing processes in evolved stars of different masses and metallicities as well as for separation which stars in the red clump are in the H- or He-core burning stages of evolution.

Keywords. Stars: abundances, stars: horizontal-branch, Galaxy: fundamental parameters

1. Introduction

In 1970 it was predicted that the red clump stars should be abundant in the solar neighbourhood (Cannon 1970). Many photometric studies have tried with unequal success to identify such stars in the Galactic field. As early as in 1970, B. Strömgren suggested to use the *uvby* photometric system for the identification of red horizontal branch stars (RHB) as well. It was shown that the c_1 index works well as a luminosity indicator for giants and supergiants. Also it was shown that the m_1 index measures metal-abundances even for K giants. Gustafsson & Ardeberg (1978) have showed that $c_1, (b-y)$ and $m_1, (b-y)$ diagrams can provide quite clean samples of RHB stars. Studies using the photometric systems like UBV, *Geneva*, *Strömgren*, *Vilnius* and *DDO* were slowly enlarging the number of identified red clump stars, however in order to fully confirm the prediction of Cannon, we had to wait till the *Hipparcos* flight. See Tautvaišienė (1996) for a short review.

The presence of red clump stars in the solar neighbourhood was clearly demonstrated in the HR diagrammes by Perryman et al. (1995). The *Hipparcos* catalogue (Perryman et al. 1997) contains about 600 clump stars with parallax error lower than 10%, and hence an error in absolute magnitude lower than 0.12 mag. This accuracy limit corresponds to a distance of about 125 pc within which the sample of clump stars is complete.

In Fig. 1, we show a diagram constructed for the stars with $\sigma_\pi/\pi < 0.1$ and $\sigma_{B-V} <$ 0.025 mag. On the giant branch, a distinct red clump is present at $B-V \approx 1.0, M(H_p) \approx$ 1.0 mag. Stars investigated by means of high-resolution spectroscopy are indicated by coloured circles.

It is important to investigate their distributions of masses, ages, colours, magnitudes and metallicities, which may provide useful constraints to chemical evolution models of the local Galactic disk. Moreover, clump stars may be useful indicators of ages and distances for stellar clusters and the Local Group galaxies as well as excellent targets for the analysis of mixing processes in evolved low-mass metal-abundant stars.

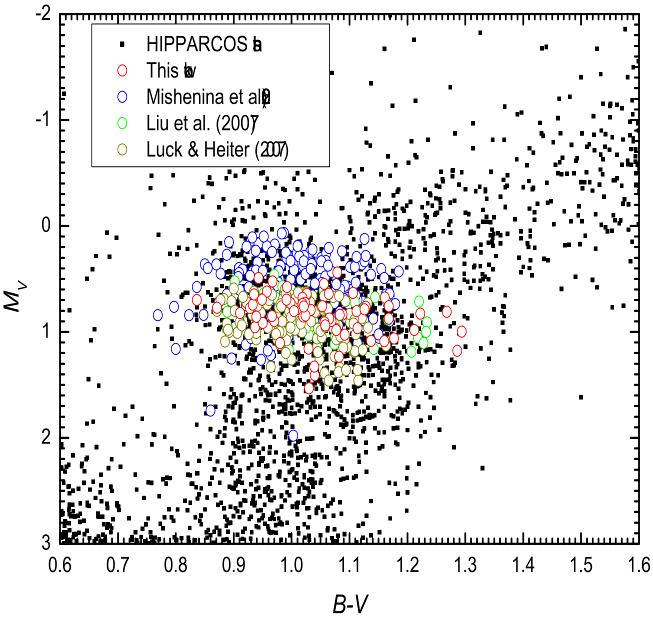


Figure 1. Colour-magnitude diagramme for the *Hipparcos* catalogue. Stars investigated by means of high-resolution spectroscopy are indicated by coloured circles.

2. High-resolution spectral analyses

A spectroscopic analysis of 671 Galactic field metal abundant giants, with clump stars among them, was done by McWilliam (1990). However, as it was pointed out later by McWilliam & Rich (1994), the McWilliam (1990) study is hampered by the narrow wavelength (6550 – 6800 Å) coverage and the lack of metal-rich model atmospheres, which caused an underestimation of metallicities for metal rich stars. This was confirmed by Tautvaišienė et al. (2005). The mean difference of [Fe/H] according to 35 common stars in these studies is $[\mathrm{Fe/H}]_{McW90} - [\mathrm{Fe/H}]_{T05} = -0.13 \pm 0.07$.

The main atmospheric parameters and Li, C, N, O, Na, Mg, Si, Ca and Ni abundances in 177 clump giants of the Galactic disk were determined by Mishenina et al. (2006) on a basis of spectra (R=42 000) obtained on the 1.93-m telescope of the Haute-Provence Observatoire (France).

A sample of 63 red clump stars, mainly located in the southern hemisphere, was investigated by Liu et al. (2007). Abundances of O, Na, Mg, Al, Si, Ca, Ti, Fe and Ba were investigated on a basis of spectra (R=48 000) obtained on the 1.52-m telescope of the ESO (La Silla, Chile).

A spectroscopic analysis of a sample of 298 nearby giants, with red clump stars among them, was done by Luck & Heiter (2007). The spectroscopic data for this work have a resolution of R=60 000, and spectral coverage from 4750 to 6850 Å. In the luminosity and effective temperature diagramme in their Fig. 20 there is a sample of 138 red clump stars located between luminosity from 1.5 to 1.8 and effective temperatures from 4700 K to 5200 K.

A sample of 64 red clump stars is under investigation in our study, the first results of which are published by Tautvaišienė et al. (2003, 2005, 2006). The main atmospheric parameters and abundances of more than 20 chemical elements are investigated. The spectra of 16 stars were observed on the HIRES (R=45 000) spectrograph of the 10-m Keck telescope. The spectra for 17 stars were obtained at the Nordic Optical Telescope (La Palma) with the 2nd optical camera of the SOFIN échelle spectrograph (R=60 000). The spectra for 18 stars in the interval from 6220 Å to 6270 Å were obtained at the Elginfield Observatory (Canada) with the 1.2 m telescope and the high-resolution spectrograph (R=100 000). The spectra of 18 more stars were observed with the long camera of the 1.22-m Dominion Astrophysical Observatory telescope's coudé spectrograph (R=40 000). The observational data were supplemented by spectroscopic observations (R=37 000) of red clump stars obtained on the 2.16 m telescope of Beijing Astronomical Observatory (China) taken from the literature (Zhao et al. 2001).

3. Metallicity distribution in the Galactic Clump

There have been several attempts to derive typical metallicities for *Hipparcos* clump stars (Jimenez et al. 1998; Girardi & Salaris 2001, Tautvaišienė et al. 2005).

Presently, when the high-accuracy metallicity determinations are available for about a half from a complete sample of about 600 clump stars located within a distance of about 125 pc, the metallicity distribution in the Galactic red clump can be re-examined. In Fig. 2, we present the metallicity distributions obtained in the samples of Galactic clump stars investigated in this study (64 stars), by Liu et al. (2007, 63 stars), Luck & Heiter (2007, 138 stars) and Mishenina et al. (2006, 177 stars). In the study by Mishenina et al. a special attempt was made to include the metal-deficient stars, so the distribution slightly reflects this selection effect.

The samples of stars investigated have some common stars which allow to compare the results. The comparisons of our [Fe/H] values to other determinations give the following results: $[\mathrm{Fe/H}]_T - [\mathrm{Fe/H}]_{LH} = +0.01 \pm 0.06$ (16 stars), $[\mathrm{Fe/H}]_T - [\mathrm{Fe/H}]_L = +0.04 \pm 0.10$ (8 stars), $[\mathrm{Fe/H}]_T - [\mathrm{Fe/H}]_M = +0.01 \pm 0.12$ (24 stars), where T - this work, LH - Luck & Heiter, L - Liu et al., M - Mishenina et al. The comparison of results of Luck & Heiter and Liu et al. gives $[\mathrm{Fe/H}]_{LH} - [\mathrm{Fe/H}]_L = -0.04 \pm 0.04$ (9 stars). The largest systematic difference is between metallicities obtained by Luck & Heiter and Mishenina et al. $[\mathrm{Fe/H}]_{LH} - [\mathrm{Fe/H}]_M = +0.07 \pm 0.07$ (41 stars). There are only 3 stars to compare between Liu et al. and Mishenina et al. $[\mathrm{Fe/H}]_L - [\mathrm{Fe/H}]_M = -0.02 \pm 0.06$.

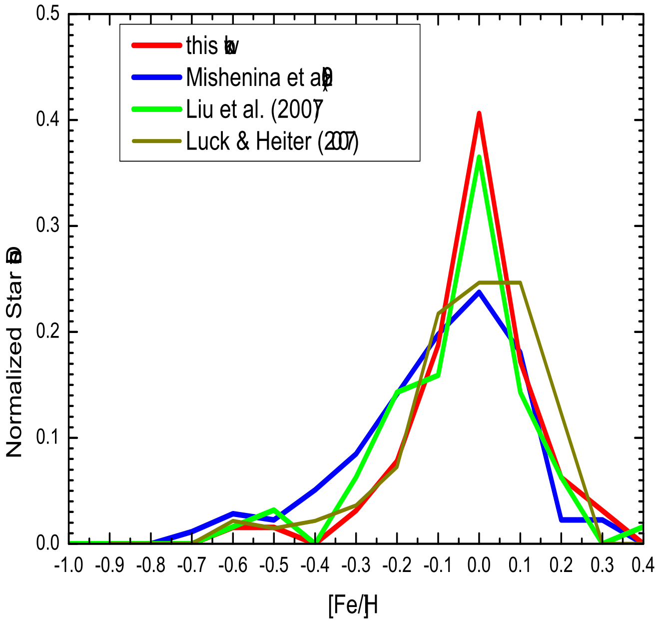
In Fig. 3, the metallicity distribution in the sample of 344 Galactic clump stars (the metallicity values were averaged for the common stars investigated in this study, by Mishenina et al., Liu et al. and Luck & Heiter) is presented.

The metallicity range is from +0.4 to −0.8 dex, however the majority of stars concentrate at the near-solar metallicity value with a small scatter of ±0.2 dex, which indicate that nearby clump stars are (in the mean) relatively young objects originated in the local disk during the last few Gyr of its history.

An other interesting question is what fraction of stars in the red clump are the first-ascent giants and what fraction of them are helium-core burning stars. Among useful indicators to answer this question are investigations of carbon abundances.

4. Carbon abundances

In Fig. 4 we compare the carbon abundances in the samples of Galactic clump stars investigated in this study, Luck & Heiter (2007) and by Mishenina et al. (2006) with



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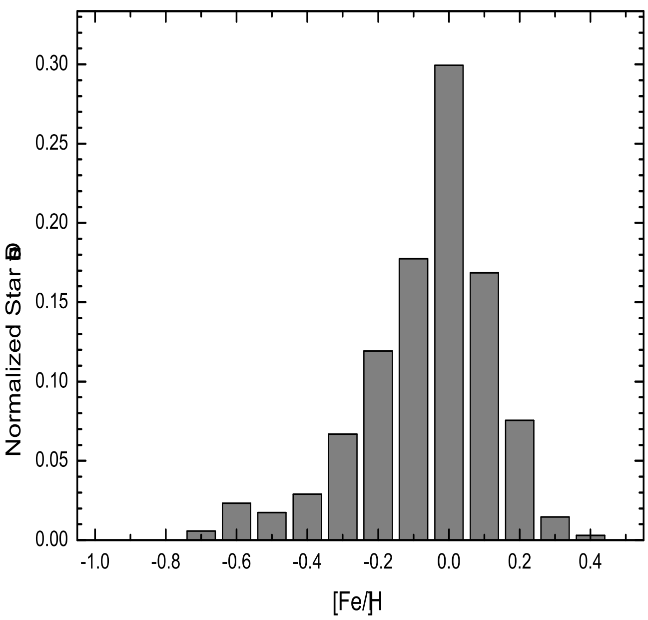

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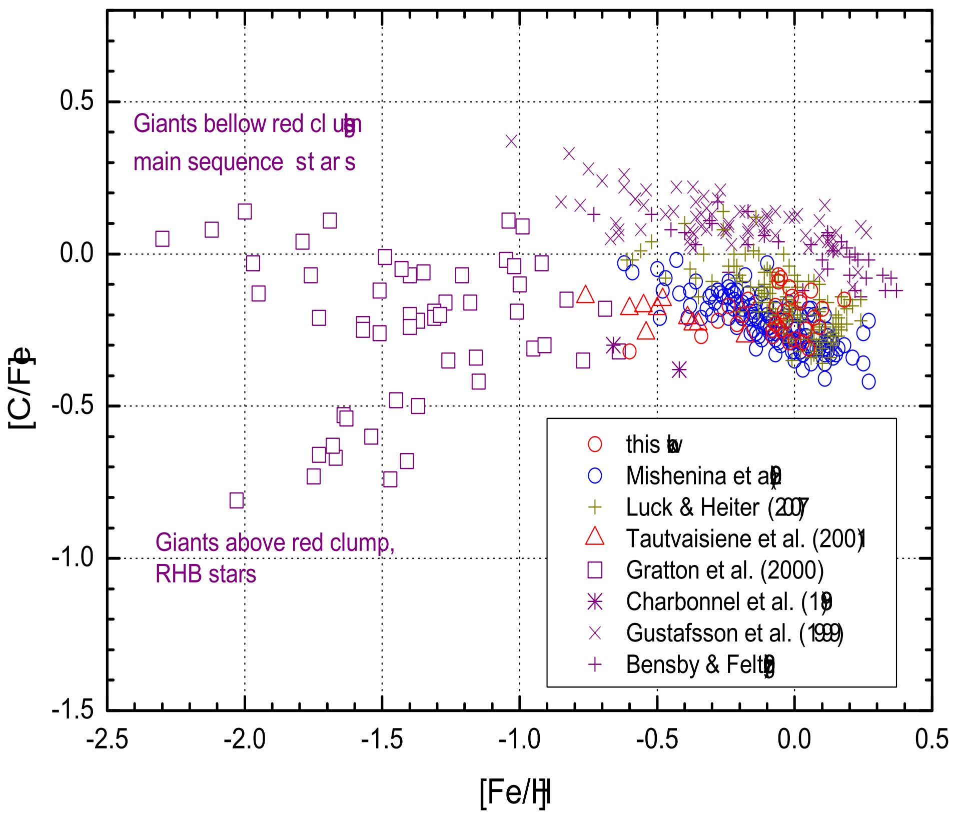

Figure 4. Comparison of carbon abundances in the samples of Galactic clump stars investigated in this study, Luck & Heiter (2007) and by Mishenina et al. (2006) with results obtained in dwarfs (Bensby & Feltzing 2006, Gustafsson et al. 1999), as well as in red-horizontal branch stars investigated by Tautvaišienė et al. (2001) and Charbonnel et al. (1998); and unevolved and evolved stars investigated by Gratton et al. (2000).

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The [C/H] value determinations in our work and Mishenina et al. are in a very good agreement $[C/H]_T - [C/H]_M = +0.00 \pm 0.09$ (17 stars). Luck & Heiter have received the larger [C/H] values: $[C/H]_{LH} - [C/H]_T = +0.14 \pm 0.14$ (9 stars), and $[C/H]_{LH} - [C/H]_M = +0.14 \pm 0.09$ (33 stars).

In comparison to the field dwarfs, the results show that [C/Fe] in the clump stars investigated is lowered by about 0.3 dex. An interesting result is quite a steep increase of [C/Fe] towards the lower [Fe/H]. Most probably this is caused by the initial stellar carbon abundances since the dwarf stars also show quite a similar [C/Fe] trend.

However, some questions still remain. After the so-called red-giant-branch bump, stars with masses below $2-2.5\ M_\odot$ start to exhibit lowered than after the 1^{st} dredge-up [C/Fe] ratios because of extra-mixing (c.f. Boothroyd & Sackmann 1999). The available results do not allow to exhibit such an effect, first of all because of the rather low accuracy of stellar mass determinations. It is surprising to see that in the work by Luck & Heiter only two stars are more massive than 2 $M_\odot$, while in Mishenina et al. the masses of stars equally span till 3 $M_\odot$. As follows from the analyses of metal-deficient red horizontal-branch stars (see the same Fig. 4), in the more metal-deficient and less massive stars the underabundance of [C/H] in comparison to dwarfs gradually increases.

Further investigations are needed in order to understand mixing processes in evolved stars of different masses and metallicities as well as for separation which stars in the red clump are in the H- or He-core burning stages of evolution.

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