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CNO abundance pattern in the red clump stars of the Milky Way

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Abstract. *Hipparcos* orbiting observatory has revealed a large number of helium-core- burning "clump" stars of the Galactic field. These low-mass stars exhibit signatures of extra-mixing processes that require modeling beyond the standard stellar theory. In this contribution we overview available results of ^{12}C, ^{13}C, N and O abundances obtained by high-resolution spectra for clump stars and discuss them in the light of current predictions of stellar evolution models.

Keywords. Stars: abundances, stars: evolution, stars: horizontal-branch

1. Introduction

Cannon (1970) has predicted that red clump stars should be abundant in the solar neighborhood. Since then, many photometric studies in *UBV*, Geneva, Strömgren, Vilnius and *DDO* systems have tried to identify such stars in the Galactic field (see Tautvaišienė (1996) for a short review), however in order to fully confirm the prediction, we had to wait till the *Hipparcos* flight. The *Hipparcos* catalog contains about 600 clump stars within a distance of about 125 pc. Now it is important to investigate their distributions of masses, ages, colors, magnitudes and metallicities, which may provide useful constraints to chemical evolution models of the local Galactic disk.

Moreover, the clump stars may be useful targets for investigations of mixing processes in evolved low-mass metal-abundant stars. A sample of about 100 red clump stars is under investigation in our study, the preliminary results are published by Tautvaišienė *et al.* (2009) and references therein. This presentation is devoted to investigations of ^{12}C, ^{13}C, N and O abundances in the red clump stars of the Milky Way.

2. High-resolution spectral analyses

The spectra of our sample of stars were observed at the Nordic Optical Telescope (La Palma) with SOFIN échelle spectrograph ($R = 60\,000$). The observational data were supplemented by spectroscopic observations ($R = 37\,000$) taken from the literature (Zhao *et al.* 2001). Abundances of carbon were studied using the C_2 Swan (0,1) band head at 5635.5 Å. The wavelength interval 7980–8130 Å with strong CN features was analysed in order to determine nitrogen abundances and ^{12}C/^{13}C isotope ratios. The oxygen abundances were determined from the [O I] line at 6300 Å.

Abundances of C, N and O 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 oxygen 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 nearby giants, with red clump stars among them, was done by Luck & Heiter (2007). In the luminosity and effective temperature diagram 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. From spectra of resolution $R = 60\,000$ abundances of C, N and O were determined.

3. Carbon, nitrogen, and oxygen abundances

Up to date analyses of clump stars of the Galaxy show the following characteristics: [Fe/H] range from +0.4 to −0.8 dex with the majority of stars concentrated at the solar metallicity value with a scatter of ±0.2 dex; [C/Fe] range from −0.4 to 0.1 dex with the maximum at −0.25 dex; [N/Fe] range from 0.0 to +0.5 dex with the maximum at +0.25 dex; [O/Fe] range from −0.2 to 0.3 dex with the maximum around the Solar value. The oxygen abundances have slight systematic differences in the available studies.

The observational results of [C/Fe] and [N/Fe] we compared with theoretical trends of the 1^{st} dredge-up computed using the STAREVOL code and presented in the paper by Mishenina *et al.* (2006). The nitrogen overabundances in the clump stars are in agreement with the modeled, however carbon in the observed sample is depleted more than the theoretical model of Mishenina *et al.* (2006) predicts. The modelled trends were computed using the standard mixing length theory. Neither overshooting, nor undershooting was considered for convection. The atomic diffusion and rotational-induced mixing were also not taken into account.

C/N and $^{12}C/^{13}C$ ratios we compared with the theoretical models by Boothroyd & Sackmann (1999) and found a good agreement with the observational data. These models include the deep circulation mixing below the base of the standard convective envelope, and the consequent "cool bottom processing" (CBP) of CNO isotopes. The comparison shows that according to $^{12}C/^{13}C$ isotope ratios, the stars fall into two groups: the one with carbon isotope ratios altered according to the 1^{st} dredge-up prediction, and the other one with carbon isotope ratios altered by extra mixing. The stellar positions in the $^{12}C/^{13}C$ versus stellar mass diagram as well as comparisons to stellar evolutionary sequences in the luminosity versus effective temperature diagram show that stars fall to groups of helium-core-burning and first accent giants in almost equal numbers. In the paper by Mishenina *et al.* (2006), according to nitrogen abundance values, there were found 21 clump giants, about 54 clump candidates and about 100 usual giants.

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