CHEMISTRY AND KINEMATICS IN THE SOLAR NEIGHBOURHOOD

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ABSTRACT

We probe the thin and thick galactic disc properties through the kinematics and chemical properties of a sample of red clump stars.

Key words: Stars: kinematics; Galaxy: disc; Galaxy: fundamental parameters; Galaxy: kinematics and dynamics; Galaxy: structure; Solar neighbourhood.

1. INTRODUCTION

This paper is the extension of the previous works published by Soubiran et al. (2003) and Siebert et al. (2003) to probe the properties and the distribution of red clump stars within 100 pc from the Sun and at larger distances towards the north galactic pole.

2. THE SURVEY

To study the kinematics properties of the galactic disc and to determine the vertical force perpendicular to the galactic plane, we measure the vertical spatial distribution and the vertical velocity distribution of a test stellar population. As far as possible, this test population must be homogeneous and unbiased with selection criteria independent of velocities and distances. It must also be in a stationary state. For this purpose, we use a sample of red clump stars, extending to larger distances from the galactic plane the NGP sample previously analysed in Soubiran et al. (2003) and Siebert et al. (2003).

This sample is built from a preliminary list of red clump candidates, a list based on the Tycho-2 star catalogue (Høg et al. 2000) for which we select all stars in a restricted range of colour ($B-V$ within 0.9 and 1.1) in two fields in directions close to the North Galactic Pole. This preliminary list is dominated by red clump stars: our high resolution spectroscopic observations allow us to determine the absolute magnitudes and to confirm and separate the red clump stars from other stars. We have also improved the local counterpart sample of red giants by measuring and determining the radial velocities and metallicities for a complete set of 203 Hipparcos red clump stars.

2.1. The Hipparcos Red Clump Stars

We select the 203 nearby red clump Hipparcos stars with a parallax larger than 10 mas, an equatorial latitude larger than -20°, a $B_J - V_J$ Johnson colour within $0.9 - 1.1$ (the Johnson magnitudes being determined from the Tycho-2 B_T and V_T magnitudes applying Equation 1.3.20 from ESA (1997)):

$$\begin{aligned} V &= V_T - 0.090\,(B_T - V_T) \\ B - V &= 0.850\,(B_T - V_T) \end{aligned} \quad (1)$$

and an absolute magnitude $M_{\rm Vj}$ within 0.0–1.3. Most of these stars were observed with the echelle spectrograph Elodie in February 2003, October 2003 and February 2004 at the Observatoire de Haute Provence (France). The signal-to-noise ratios range from 150 to 200. We have measured and determined their radial velocity, the [Fe/H] and α element abundances (Mishenina et al. 2004; Kovtyukh et al. 2004)). Abundances of Fe, Si and Ni have been determined from equivalent widths under LTE approximation whereas abundances of Mg have been determined under NLTE approximation using equivalent widths of 4 lines and profiles of 5 lines.

The atmospheric parameters, including metallicity, and abundances of some elements were determined for studied stars. The detailed description of the parameters and abundances determination will be published later. Here we describe briefly the basic assumptions. The processing of spectra and measurement of equivalent width of lines is carried out with the program DECH20 (Galazutdinov 1994). For the determination of the effective temperature we use a technique similar to the one used by Gray (1994) to analyse giants. It is based on the line-depth ratios for lines with the various potentials of excitation of the low level. The surface gravity $\log g$ was determined with different methods. The method using

the condition of ionisation balance for iron and the definition of $\log g$ by means of fitting of wings of a Ca I line. For the gravity determination we also apply a method of ionisation balance: we have selected about 100 Fe I and 10 Fe II unblended lines based on the synthetic spectra calculations with the software STARSP (Tsymbal 1996). As shown in Allende Prieto (1999), in the metallicity range $-1.0 <$ [Fe/H] < 0 there is an approximate agreement between the spectroscopic and trigonometric gravities. They also found that the wings of strong lines are the reliable indicator of the gravity, which give values of $\log g$ in agreement with those carried out using the parallaxes. To determine more confident surface gravity we used also the profile fitting of Ca I line at 6162 $\AA$, which is carefully investigated in the work (Cayrel et al. 1996). For the determination of the metallicity [Fe/H] we have taken the value of the iron abundance determined with lines of neutral iron constrained by the large number of lines present in the spectra of giants. The iron abundances was determined with equivalent width of lines applying the program of Kurucz WIDTH9. The obtained values of the effective temperature $T_{\rm eff}$, of the gravity $\log g$ and the metallicity [Fe/H] have been compared with results from other authors (Cayrel et al. 1996; Zhao et al. 2001)).

2.2. NGP K Giants

The distant K giant sample is drawn from the Tycho-2 star catalogue. We have applied the same criteria given in Soubiran et al. (2003) to build the list of red clump candidates, just extending the limiting apparent magnitudes to fainter stars. In summary, we have extracted from the Tycho-2 catalogue, stars in two fields close to the north galactic pole. The first field is circular with a 10° radius and is centred towards the galactic direction $b = +90^\circ$. The second field is also circular (radius 15°) and centred on the galactic direction ($l = 35.5^\circ, b = +80^\circ$) (we have removed stars close to the Coma open cluster direction, $l = 221^\circ, b = 84^\circ$, inside a 4.5° radius circle). The total area effectively covered by our samples is 720 square degrees.

From these two fields, we select stars with a $B_J - V_J$ colour within 0.9–1.1. For the first field we keep stars with an apparent magnitude V_J within 7 and 10.6 and for the second one with V_J within 7. to 9.5. About 500 candidates have been observed with the echelle spectrograph Elodie at OHP with a median S/N ratio of 20. This low S/N is sufficient to obtain the stellar parameters, $T_{\rm eff}$, gravity and [Fe/H] metallicity, and also the absolute magnitude by comparison and fitting to high resolution spectra within the TGMET library (Katz et al. 1998). The determined absolute magnitudes are then used to identify the real red clump giants and remove the dwarfs and subgiants.

3. DISCUSSION

Nearly 700 Tycho-2 stars have been observed in the solar neighbourhood at distances smaller than 100 pc or in a 720 square degree field in the direction of the North Galactic Pole. Absolute magnitudes, effective temperatures, gravities and metallicities have been estimated, as well as distances and 3D velocities. Abundances of Fe, Si and Ni have been determined from equivalent widths under LTE approximation, whereas abundances of Mg have been determined under NLTE approximation. Most of these stars are clump giants and span typical distances from 0 pc to 800 pc to the galactic mid-plane. This new sample, free of any kinematical and metallicity bias, is used to investigate the vertical distribution of disc stars.

The old thin disc and thick disc populations are deconvolved from the velocity-metallicity distribution of the sample and their parameters are determined. The thick disc is found to have a moderate rotational lag with respect to the Sun with a mean metallicity of [Fe/H] = -0.48 ± 0.05 and a high local normalization of $15\pm7\%$. We also determine both the gravitational force law perpendicular to the Galactic plane and the total surface mass density and thickness of the Galactic disc. The surface mass density of the Galactic disc within 800 pc derived from this analysis is $\Sigma\ (|z| < 800\ {\rm pc}) = 76\ \ {\rm M}_\odot\ {\rm pc}^{-2}$.

The thickness of the total disc mass distribution is dynamically measured for the first time and is found to be 390 pc in relative agreement with the old stellar disc scale height. All the dynamical evidence concerning the structure of the disc (its local volume density i.e., the Oort limit, its surface density and its thickness) are compatible with our current knowledge of the corresponding stellar disc properties. This result implies that the dark matter component of our Galaxy cannot be distributed in a flat or disc-like component but must be distributed in a round halo.

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