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Metallicity Distribution of F-dwarf Stars in the Solar Neighbourhood

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Abstract. A volume-limited sample of F-dwarfs is chosen from Knude (1989) with low radial velocity as well as distance from the sun and compared with the expected model metallicity [Fe/H] distributions, taking the possible chemical inhomogeneity into account. There is found to be an agreement between the two within the error limits of small sampling.

Key words: Metallicity distribution—F-dwarfs—star formation.

1. Introduction

The metallicity distribution of the G-dwarfs in the solar neighbourhood has played a central role in our understanding of the chemical evolution of the solar neighbourhood. Since the main-sequence life time of G-dwarfs is above 9 Gy, most of them, once formed, could not die during the evolution of the disc. This is obviously not true for F-dwarfs, whose main-sequence life time could be anything between 5.5 and 9 Gy. By now, we have a fairly consistent model of chemical evolution of the solar neighbourhood, which agrees with the age-metallicity relation, G-dwarf metallicity distribution, history of star formation, the initial mass function of stars, various proportions of the mass distribution in the form of gas, stars and dead stellar remnants to make up for the dynamical estimate of mass in the solar neighbourhood, the occurrence rates of supernova, etc.

The motivation for finding a reasonably volume-limited metallicity distribution of F-dwarfs are three-fold:

1. The observed distribution should be consistent with the known age-metallicity relation and history of the star formation rate (SFR).
2. We tacitly assume that the birth function of stars $C(m, t)$, which is a function of both stellar mass (say, m in units of solar mass $M_\odot$) and time of formation (say, t, with its origin at the epoch of the formation of the disc; assumed to be t_d= 13 Gy ago), can be written as a product of two functions, say $\Psi(t)$ and $\xi(m)$, thus allowing m and t to act as separable coordinates for the function $C(m,t)$. This assumption is justifiable only if the motivation number (1) is simultaneously justified.
3. There were several attempts in the past to obtain F-dwarf metallicity (in fact, [Fe/H]) distributions in the solar neighbourhood, but either they lacked completeness

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in a sample volume or solid angle, or no ambiguous criterion to distinguish a halo star from a disc star apart from the metallicity itself. Knude has recently measured the radial velocity W, [Fe/H] and the radial distance z from us for a complete magnitude limited sample of 183 dwarf stars covering the solid angle within the Galactic latitude $b \geqslant 70°$ and belonging to the spectral class A5–G0. If we do not discriminate the sample stars on the basis of radial velocity (which is in the present case a measure of the component of velocity perpendicular to the disc) and the distance, the metallicity distribution appears to be bimodal. A bimodal distribution was also obtained more than a decade ago by Marsakov & Suchkov (1980) for F-dwarfs. However, a single-peaked distribution was obtained by Rana & Basu (1990) from a sample of data compiled from various sources which was neither volume-limited nor magnitude-limited, and therefore, no firm conclusions could have been drawn apart from showing that the data reasonably satisfied the criteria (1) and (2) in the context of a chemically inhomogeneous model of stellar birth function. While the chemical inhomogeneity of the interstellar medium as well as of stars in open clusters and in open fields, even on length scales as short as 100 pc around the sun, cannot be ignored as the accuracy of the determinations of [Fe/H] has considerably improved in recent years, it can very well wash out the bimodality, which were not too far separated in the metallicity bins.

2. Criterion for data selection and results

We took the data set of Knude (1989) as the basis set, which considered a $uby\beta$ photometric catalogue of 183 A5–G0 main sequence stars brighter than $V = 11.5$ mag and with the Galactic latitude $b > 70°$. The table listed the effective surface temperature, [Fe/H], radial velocities, age, distance and colour difference, for most of the stars. Knude had constructed the histograms for age, metallicity and radial velocity (which is essentially equivalent to the component of velocity perpendicular to the plane of the disc) for the entire sample. However, for the sake of having a completeness in volume (here solid angle) as well as assuring ourselves about the disc population I type of stars only, we restricted the sample to radial distance $\leqslant$ 100 pc, $-$ 0.75 dex $\leqslant$ [Fe/H] $\leqslant$+ 0.35 dex, and the magnitude of radial velocity not exceeding 40 km s^{-1}. The size of the sample reduced to 62 stars, of which we could choose only 54, because for the rest 8 stars no measured value of [Fe/H] was quoted. Fig. 1 shows the histogram of [Fe/H] distribution thus obtained, with the error bars reflecting only $\sqrt{N}$ for individual metallicity bins.

It is apparent from Fig. 1 that the metallicity distribution of the F-dwarfs (actually over A5–G0) in the solar neighbourhood does not appear to be bimodal.

The range of the main sequence spectral types A5 to GO implies the mass range of the stars to be 1.88 $M_\odot$ through 1.10 $M_\odot$ (Svechnikov & Taidakova 1984) and correspondingly their main-sequence life times between 4.2 and 8.7 Gy (Maeder & Meynet 1989), with an average life time of the sample stars being 7.0 Gy (say, = $\overline{t_m}$). We then took a model of inhomogeneous chemical evolution as suggested in Rana & Basu (1990) (see equation (11) therein) and the evolution of SFR from (a) Rana & Basu (1992) and (b) Soderblom *et al.* (1991). For individual bins (say, the ith bin) of metallicity between say, z_1 and z_2, where $z \equiv$ [Fe/H], the number of stars at the

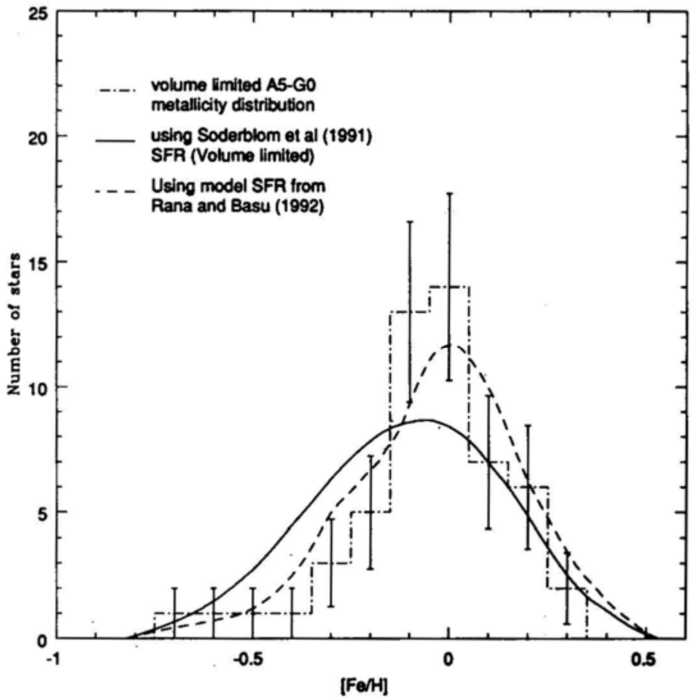

Figure 1. The [Fe/H] distribution of a volume limited sample of 54 A5–G0 stars in the solar neighbourhood of the disc, selected from Knude (1989), and compared with the expected model distributions of the same normalised to the same total of 54 stars.

present epoch are given by

$$N_i(z_1, z_2) = \frac{1}{\sigma_z\sqrt{2\pi}} \int_{z_1}^{z_2} \int_{\bar{z}(t_d)-\bar{z}(t_m)}^{\bar{z}(t_d)} C(\bar{z}) \exp\left[-\frac{1}{2}\frac{(z-\bar{z})^2}{\sigma_z^2}\right] d\bar{z}\, dz \tag{1}$$

such that $\Sigma N_i = 54$, and the age metallicity relation (AMR) $\bar{z}(t)$ = [Fe/H] (t) is implicit in the stellar birth function $C(\bar{z})$. The AMR has also been taken from Rana & Basu (1992) for the sake of consistency. The value of σ_z is adopted to be 0.2 dex.

The solid curve (a) and the dashed curve (b) in Fig.. 1 were computed using equation (1) above and the two SFRs as stated in the above paragraph. The fit for the case (b) seems to be better than that for (a), even though both the fits were found to be agreeing with the data set chosen in the present work. The whole distribution could also be fitted with a single Gaussian form, but then the width of the distribution would be too large compared to errors of individual observation.

3. Conclusion

The metallicity distribution for the F-dwarfs derived from the sample of Knude (1989) with the extra conditions $|v_z| \leqslant 40$ kms^{-1}, distance $z \leqslant 100$ pc, and -0.75 dex $\leqslant$ [Fe/H] $\leqslant +0.35$ dex, is found to be unimodal and agreeing reasonably well with the theoretical expectations from a chemically inhomogeneous model of evolution of the solar neighbourhood.

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