POPULATIONS AMONG HIGH-VELOCITY EARLY-TYPE STARS

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ABSTRACT

Previous studies indicate the existence of early-type stars located far from the galactic plane with ages, abundances and kinematics inconsistent with the standard models. In the aim of providing an insight into the different populations of early-type stars, a sample of high velocity stars in the solar neighbourhood has been gathered from the Hipparcos Catalogue. Parallaxes and proper motions collected by the satellite together with complementary photometric and/or spectroscopic data allow us to study the kinematics of these stars and to separate the halo from the disk populations. We denote a striking trend for the high-velocity disk stars to go toward the galactic anticentre, suggesting that they do not belong to the tail of the usual Population I velocity distribution.

Key words: early-type stars; blue horizontal branch; high-velocity stars.

1. INTRODUCTION

In terms of the standard picture of galactic evolution and structure, early-type stars belong to the thin disk. However, a long-standing anomaly has been the existence of a population of early-type stars with near-solar metallicities and main-sequence surface gravities, but high velocities and/or standing at large distances away from the plane (Rodgers 1971, Rodgers et al. 1981, Lance 1988a, Lance 1988b).

A-type main sequence lifetimes are much too short for normal disk dispersive mechanisms to scatter the stars so far from the galactic plane. Different hypotheses have been proposed to explain the origin of the high velocity A-stars: they are misidentified abnormal or evolved stars, they are randomly ejected young disk stars, they were formed from a mixture of Galactic gas and gas accreted during the merger of a small satellite galaxy with the Milky Way.

In the temperature range corresponding to A-type stars can be distinguished:

- main Sequence (MS) A-type stars, which are young, 1 to 3 $M_\odot$ solar-like metallicity stars;
- blue Horizontal Branch (BHB) A stars, which are evolved, post-red-giant-branch, low-mass (< 1 $M_\odot$), metal-poor stars ([Fe/H] < -1.0), belonging to the halo population.

2. SAMPLE DETERMINATION

Some years ago, Stetson (1981a) undertook a search for possible early-type high-velocity stars passing through the solar neighbourhood. Our sample is composed of 312 of his candidate early-type high-velocity stars, which were selected because of their large proper motions both in the Smithonian Astrophysical Observatory Catalogue and in some other surveys. It is mainly composed of A and F-type stars.

Both parallaxes and proper motions collected by Hipparcos are used to derive the space velocities. Radial velocities were taken from different sources: WEB (Duflot et al. 1995), Barbier-Brossat (1997), Grenier (1997) or computed from observations made at the Observatoire de Haute-Provence using the Élodie spectrometer and a cross-correlation method.

The galactic space velocity components U, V, W, in a Galactic rest frame were calculated taking into account the correlations between the Hipparcos astrometric data (Meillon et al. 1997). U is positive toward the Galactic centre. The adopted corrections for the solar motion are (9,12,7) km s^{-1} and the rotation velocity of the LSR about the Galactic centre is taken to be 220 km s^{-1}.

The major part of the uncertainty on the space velocity is due to the uncertainty on the parallax.

[Fe/H] values were computed using the *uvby*-β Strömgren photometry or come from the compilation carried out by Cayrel de Strobel et al. (1997). Strömgren photometry data are taken from the literature.

3. SEPARATION IN POPULATIONS

The distribution of the 120 stars, for which both metallicity index and galactic rotational velocity are available, in the V–[Fe/H] diagram (Figure 1a and Table 1a) shows two discrete populations. In order to isolate both populations (assumed to be Gaussian in V as well as in [Fe/H]), we have used the

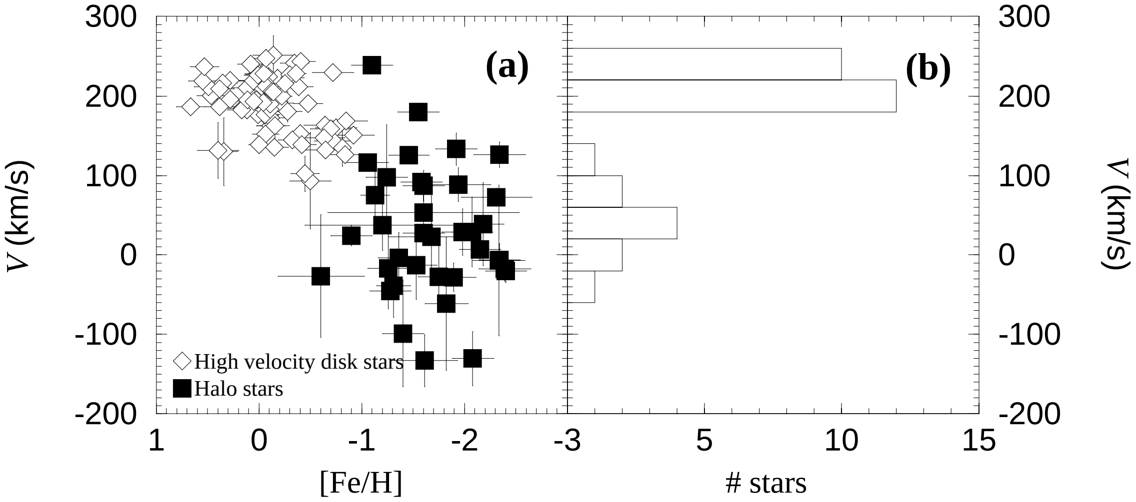

Figure 1. (a) Separation of the 120 stars in Gaussian populations in the (V, [Fe/H]) plane using the SEMMUL algorithm. (b) Histogram in V for the 32 bluest stars of the sample (B− V < 0.2).

SEMMUL (Stochastic, Expectation, Maximisation, MULti-dimensional) algorithm developed by Celeux & Diebolt (1986). The aim of the SEMMUL algorithm is to resolve the finite mixture density estimation problem under the maximum likelihood approach, using a probabilistic step. SEMMUL gives the probability of belonging to a population, taking into account the individual errors on the V and [Fe/H] (Arenou 1993). This can lead to misclassification in the overlap area (the star near [Fe/H]= -1.1 dex, $V = 240$ km s^{-1} is probably misclassified).

Table 1. (a) characteristics of the populations separated by SEMMUL in the (V, [Fe/H]) plane. (b) characteristics of the populations on each side of V = 160 km s^{-1}, for the stars bluer than B− V = 0.2.

Population		#	$\langle V\rangle$	σ_V	$\langle$[Fe/H]$\rangle$	$\sigma_{\rm [Fe/H]}$
(a)	disk	82	185 ± 6	54 ± 4	-0.12 ± 0.04	0.34 ± 0.03
	halo	38	18 ± 16	99 ± 11	-1.6 ± 0.07	0.47 ± 0.05
(b)	disk	22	219 ± 4	21 ± 3		
	halo	10	48 ± 16	49 ± 11		

The populations found by SEMMUL roughly correspond to those found by Nissen & Schuster (1991) who separated their high-velocity and metal-poor F-G stars in the (V, [Fe/H]) plane by the line:

$$V = -145.83\,[\mathrm{Fe/H}] - 43.75$$

Due to the overlaps in both coordinates, it is not possible to separate the populations by [Fe/H] or V alone.

We now limit the sample to the bluest stars of the total sample, i.e. those whose $B - V < 0.2$ (which corresponds to B and A-type stars), with available kinematics. This sub-sample contains 32 stars with computed spatial velocity. As we can see in Figure 1b, there is no more overlap in V in the velocity distribution. So we used the V-component of the spatial velocity as a population criterion, allowing us to use the 16 stars without [Fe/H] parameter (as in Figure 1b) and thereby double the number of stars.

The two groups lie on each side of the point $V \sim$ 160 km s^{-1} (Table 1b), one spreads around $V \sim$ 48 km s^{-1} while the other one sharply peaks at the LSR rotational velocity. The blue halo stars and the high velocity disk stars are examined in Sections 3.1. and 3.2.

3.1. Blue Horizontal Branch Stars

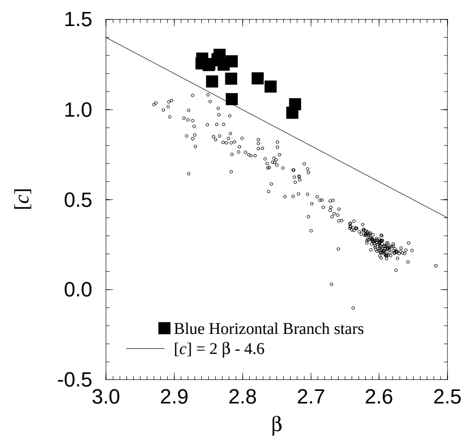

Figure 2. [c] vs β for all the stars with Strömgren photometry. The solid line represents the boundary separating evolved stars from MS stars.

Stetson (1991) used the following criterion to identify BHB stars:

$$[c] > 2.0\,\beta - 4.6 \text{ (where } [c] = c_1 - 0.2(b-y))$$

The stars that lie around $V \sim 48$ km s^{-1} in Figure 1b are all in the appropriate zone of the $[c]$–β dia-

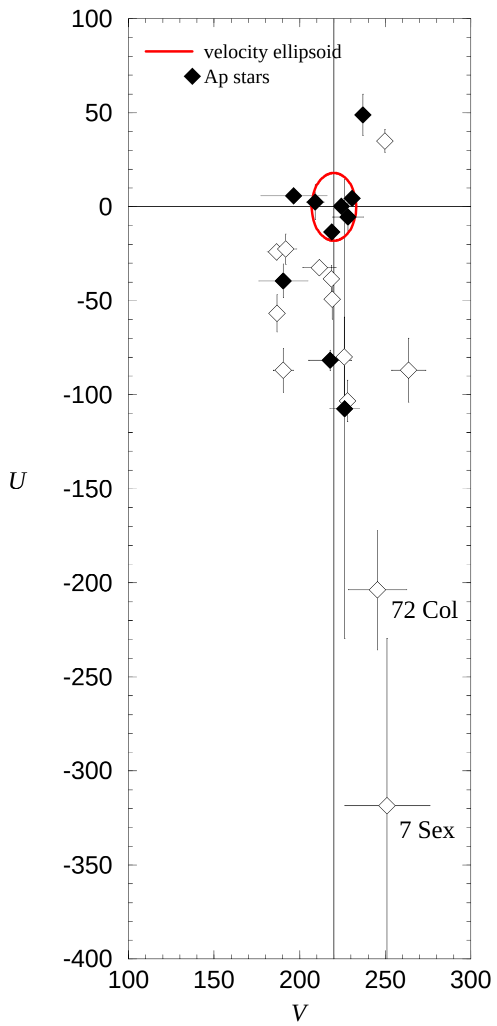

Figure 3. Velocity distribution in the (V,U) plane for the high velocity disk stars with B-V<0.2. Filled diamonds are peculiar stars. The solid line is the velocity-ellipsoid for normal field A-type stars.

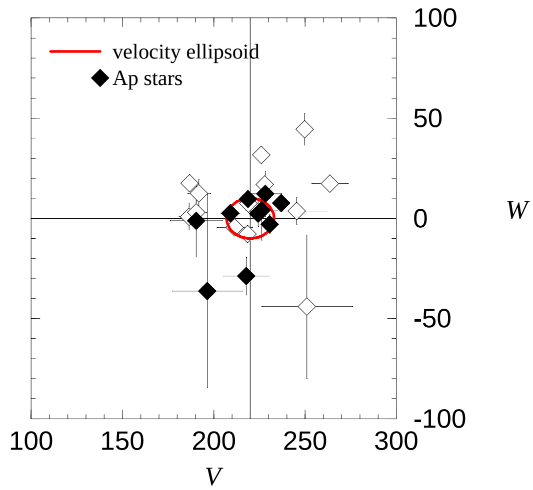

Figure 4. Velocity distribution in the (V,W) plane for the high velocity disk stars with B-V<0.2. Filled diamonds are peculiar stars. The solid line is the velocity-ellipsoid for normal field A-type stars.

gram (Figure 2), while the stars that follow the LSR rotational velocity lie below the separation line. So the stars that lie around $V \sim 48$ km s^{-1} are blue horizontal branch stars.

The two bluest stars of this sub-sample (HIP 106917 and Feige 86) are subdwarf B-type stars (de Boer et al. 1997).

3.2. High Velocity Disk Stars

Figures 3 and 4 show the distribution in both the (U,V) and (W,V) planes for the 22 high velocity stars whose galactic rotational velocity V is close to 220 km s^{-1}. The ellipsoid of field A-stars is taken from Sabas (1997) and plotted in the same graphic.

The filled diamonds in Figures 3 and 4 represent high-velocity Ap stars taken from the list gathered by Jaschek et al. (1983). These 10 stars are listed in Table 2.

The two fastest stars in U component are:

- ⋆ HIP 48414 (7 Sextantis) is a A0Vs-type star. It was identified as an old-disk horizontal-branch star by Rodgers & Wood (1970), which was confirmed by the result of Adelman & Philip (1992),
- ⋆ HIP 28756 (72 Columbae) is the bluest star of our 22 high velocity disk stars, and the most massive ($M = 7.054 \pm 0.443$ M$_{\odot}$, Table 4). It is known as a runaway B3V-type star (Van Albada 1961, Blaauw 1961).

Table 3 regroups the velocity elliposoid parameters for the stars plotted in Figures 3 and 4. Table 4 shows the luminosity, gravity and mass for the non Ap stars, computed using the models from Bertelli et al. 1994. The distribution in U velocity is clearly asymetric compared to the field stars (Figure 3), with most of the stars going toward the galactic anticenter ($U < 0$). The Ap stars have quite the same asymetry. Even this sub-sample is quite entangled. Some of the stars lie within the boundaries of the normal A-type stars velocity ellipsoid, or certainly belong to its distribution tail. But the asymetry of the U distribution let us think that there are more than distribution tail stars.

Table 2. High-velocity Ap stars.

HIP	Spectral Type
4995	A0 Sr Cr Eu
5150	A3 Sr Cr
20837	B9 Si
31851	B8 Si
35167	B9 Si
77657	B8 Si
78756	B9 Si Cr Eu
81842	B9 Si
101323	B9 Si
106873	A0 Si

Table 3. Velocity-ellipsoid parameters (in km s^{-1}) for the high-velocity disk stars (†: the 22 stars; ‡: the sample without 72 Col and 7 Sex), the high-velocity Ap stars, and for normal A-type disk stars.

Population	$\langle U \rangle$	σ_U	$\langle V \rangle$	σ_V	$\langle W \rangle$	σ_W
high veloc.†	-54 ± 16	78 ± 11	219 ± 4	21 ± 3	3 ± 4	19 ± 3
high veloc.‡	-35 ± 9	43 ± 7	217 ± 4	20 ± 3	5 ± 4	17 ± 3
Ap stars	-18 ± 14	44 ± 10	218 ± 5	14 ± 3	-3 ± 5	15 ± 3
normal		18 ± 1		13 ± 1		10 ± 1

Table 4. Parameters for 14 of the high-velocity disk stars computed using the models from Bertelli et al. 1994.

HIP	$\log L/L_\odot$	$\log g$	$M/M_\odot$
1383	1.307 ± 0.185	4.180 ± 0.132	2.006 ± 0.136
10205	1.173 ± 0.112	4.200 ± 0.038	1.982 ± 0.035
15978	1.331 ± 0.133	4.239 ± 0.092	2.066 ± 0.105
28756	3.436 ± 0.164	3.959 ± 0.137	7.054 ± 0.443
47918	1.383 ± 0.156	4.193 ± 0.104	2.105 ± 0.112
48414	2.617 ± 0.271	3.377 ± 0.209	3.672 ± 0.456
50196	1.098 ± 0.044	4.103 ± 0.037	1.612 ± 0.059
50453	1.071 ± 0.147	4.277 ± 0.081	1.801 ± 0.075
63556	1.464 ± 0.206	3.894 ± 0.158	2.100 ± 0.199
66541	2.744 ± 0.311	4.297 ± 0.027	5.083 ± 0.188
68868	1.187 ± 0.187	4.320 ± 0.065	1.950 ± 0.090
68983	1.181 ± 0.156	4.200 ± 0.012	1.991 ± 0.037
87118	1.347 ± 0.095	3.956 ± 0.076	1.949 ± 0.099
99775	1.329 ± 0.132	4.066 ± 0.098	2.071 ± 0.096

4. DISCUSSION

The high-velocity early-type stars in the solar neighbourhood are a mixture of different stellar populations: blue horizontal halo stars passing near the sun and high-velocity disk stars. The high-velocity disk stars studied here show a predominance of negative U-velocity (toward the galactic anticentre). This cannot be explained by the distribution tail of disk stars or stochastic events such as runaway stars, which privilege no direction. Nearly half of these stars are Ap stars. Abt (1985) concluded that most of cluster B3 to A2-type blue stragglers were Ap stars, which may indicate a link between the two phenomena. Shields & Twarog (1988) found that the blue stragglers provide a more than adequate explanation of the high-velocity early-type stars. Glaspey et al. (1994), by studying the lithium abundance, suggested that the high-latitude A-type stars observed by Rodgers and collaborators (Rodgers 1971, Rodgers et al. 1981) consist essentialy of blue stragglers.

The next step in this work will be to include a sample of faint blue stars observed by Tycho at high galactic latitude. This sample requires an absolute magnitude calibration to compute the individual distances. The kinematical study of this sample, located further from the galactic plane, together with the present sample, will allow us to disentangle the complete mixture that compose the high-velocity early-type stars.

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