3D-Kinematics of White Dwarfs from the SPY-Project

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Abstract. We present kinematics of a sample of 398 DA white dwarfs from the SPY project (ESO SN Ia Progenitor surveY) and discuss kinematic criteria for a distinction of thin disk, thick disk, and halo populations. This is the largest homogeneous sample of white dwarfs for which 3D space motions have been determined. Radial velocities and spectroscopic distances obtained by the SPY project are combined with our measurements of proper motions to derive 3D space motions. Galactic orbits and further kinematic parameters are computed. Our kinematic criteria for assigning population membership are deduced from a sample of F and G stars taken from the literature for which chemical criteria can be used to distinguish between thin disk, thick disk and halo. Our kinematic population classification scheme is based on the position in the $U$-$V$-velocity diagram, the position in the $J_z$-eccentricity diagram and the Galactic orbit. We combine this with age estimates and find seven halo and 23 thick disk white dwarfs.

1. Introduction

White dwarfs are presumably valuable tools in studies of old populations such as the halo and the thick disk, since the fraction of old stars among white dwarfs is higher than among main-sequence stars. An open issue is the fraction of white dwarfs in the thick disk and halo populations and their percentage of the total mass of the Galaxy. Studies of their kinematics can help to determine the fraction of the total mass of our Galaxy contained in the form of thick disk and halo white dwarfs which allows the role of white dwarfs in the dark matter problem to be studied.
The common problem of kinematic studies of white dwarfs is the lack of radial velocity measurements. Especially deviating conclusions derived from the white dwarfs of the Oppenheimer et al. (2001) sample demonstrate that different assumptions on the values of $v_{\text{rad}}$ can produce different fractions of halo and thick disk stars and thus have a strong impact on the determination of the white dwarf halo density. Therefore a sample of white dwarfs with known radial velocity measurements is needed in order to obtain the full 3D kinematic information. Pauli et al. (2003) presented a complete 3D kinematical study of 107 white dwarfs. Here we extend this investigation to about 400 stars.

2. 3D kinematics and population classification

The ESO Supernova Ia Progenitor survey (SPY, Napiwotzki et al., 2003) secured high resolution spectra of more than 1000 degenerate stars in order to test the double degenerate scenario for the SN Ia progenitors. The sharp NLTE absorption core of the Hα line allowed accurate radial velocities to be measured (Napiwotzki et al., in prep.). A spectroscopic analysis yielded atmospheric parameters, masses and gravitational redshift (see Koester et al., 2001). Proper motions for 202 stars have been measured whereas the rest was extracted from catalogs (USNO–B, UCAC2, the SuperCOSMOS Sky Survey, the Yale Southern Proper Motion, the revised NLTT and LHS catalogs). We calculate individual errors of kinematic parameters by means of Monte Carlo error propagation.

Pauli et al. (2003) presented a new population classification scheme based on the $U$-$V$-velocity diagram, the $J_{\text{Z}}$-eccentricity-diagram and the Galactic orbit. For the computation of orbits and kinematic parameters we used the code by Odenkirchen & Brosche (1992) based on the Galactic potential of Allen & Santilliian (1991). The classification scheme is based on a calibration sample of main-sequence stars.

Unlike for main-sequence stars the population membership of white dwarfs can not be determined from spectroscopically measured metallicities. Therefore we have to rely on kinematic criteria, which have to be calibrated using a suitable calibration sample of main-sequence stars. In our case this sample consists of 291 F and G main-sequence stars from Edvardsson et al. (1993) and Fuhrmann (2004, and references cited therein).

Halo and thick disk stars can be separated by means of their [Fe/H] abundances, they possess a higher [Mg/Fe] ratio than thin disk stars (see Pauli et al., 2003 for details). In Fig. 1 (top panel) $U$ is plotted versus $V$ for the main-sequence stars. For the thin disk and the thick disk stars the mean values and standard deviations ($3\sigma$) of the two velocity components have been calculated. The values for the thin disk are: $\langle U_{\text{ms}} \rangle = 3 \pm 35$ km s$^{-1}$, $\langle V_{\text{ms}} \rangle = 215 \pm 24$ km s$^{-1}$, The corresponding values for the thick disk are: $\langle U_{\text{ms}} \rangle = -32 \pm 56$ km s$^{-1}$, $\langle V_{\text{ms}} \rangle = 160 \pm 45$ km s$^{-1}$. Indeed, nearly all thin disk stars stay inside the $3\sigma_{\text{thin}}$-limit and all halo stars lie outside the $3\sigma_{\text{thick}}$-limit, as can be seen from Figure 1. In the $J_{\text{Z}}$-eccentricity-diagram three regions (A, B or C) can be defined (not shown here, but see Pauli et al. 2003) which host thin disk, thick disk and halo stars, respectively. The Galactic orbits of thin and thick disk stars and halo stars differ in a characteristic way allowing another classification criterion to be defined.
Figure 1. $U$-$V$-velocity diagram for the main-sequence stars (top) and for the white dwarfs (bottom); dashed lines: $3\sigma_{\text{thin}}$, $3\sigma_{\text{thick}}$-contours.
The halo candidates are all white dwarfs that are either situated outside the $3\sigma$-limit of the thick disk in the $U$-$V$-velocity diagram or that lie in Region C in the $J_Z$-eccentricity diagram and have halo type orbits. Seven white dwarfs fulfill these conditions and are therefore assigned to the halo. Two white dwarfs are on retrograde orbits characterized by a negative value of $V$ and $J_Z$.

Thick disk white dwarfs lie either outside the $3\sigma$-limit of the thin disk in the $U$-$V$-velocity diagram or lie in Region B in the $J_Z$-eccentricity diagram and have thick disk type Galactic orbits. Twenty-seven of them are classified as thick disk members. All the remaining are assumed to belong to the thin disk, leaving us with seven halo, 27 thick disk out of the 398 SPY white dwarfs.

Ages are another criterion for population membership. Halo and thick disk white dwarfs need to be old stars. Since the cooling ages of the of most white dwarfs in the SPY sample are small ($< 10^9$ yrs) they have evolved from long-lived, i.e. low mass stars and hence must themselves be of low mass. All halo and 23 of the 27 thick disk white dwarfs have sufficiently low masses and are therefore old. Hence we assign only these 23 white dwarfs to the thick disk, the others are either kinematically misclassified thin disk stars or runaway stars. This leaves us with a fraction of 1.8% halo and 5.8% thick disk white dwarfs.

3. Discussion

We have applied the classification scheme developed in Pauli et al. (2003) to kinematically analyze a sample of about 400 DA white dwarfs from the SPY project. Combining the three kinematic criteria position in the $U$-$V$-diagram, position in the $J_Z$-e-diagram and Galactic orbit with age estimates we have found seven halo and 23 thick disk members.

The velocity dispersions that for the thin disk white dwarfs are well compatible with the ones of Soubiran et al. (2003). The same is the case for the asymmetric drift and the velocity dispersions of the thick disk. For the halo white dwarfs $\sigma_U$ and $\sigma_V$ are similar to the values derived by Chiba & Beers (2000) for halo stars while our $\sigma_W$ is much smaller, probably due to low number statistics. Hence the kinematic parameters of the white dwarfs of the three different populations do not differ much from main-sequence samples.

Acknowledgments. M.A. is financially supported by FONDAP 1501 0003.

References

Fuhrmann, K. 2004, AN 325, 3
Odenkirchen, M., & Brosche, P., 1992, AN, 313, 69