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Multiplicity of Population II stars

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Abstract. We report preliminary results of a multiplicity survey of about 200 known Population II stars that were identified in the HIPPARCOS catalog. This survey will enable us to test the hypothesis if the different initial star formation conditions in the galactic halo compared to the galactic disk might lead to differences in the binary frequency or in the distributions of periods and mass ratios.

1. Introduction

The frequency of binary stars and the distribution of their periods and mass ratios is – along with the Initial Mass Function – one of the key characteristics of the star formation process. Studies of binaries among nearby solar-type main-sequence stars show that about 53 % of the stars are binary or multiple systems (Duquennoy & Mayor 1991). Recent surveys of low-mass pre-main-sequence stars in the star-forming region Taurus-Auriga found a binary frequency of 80 – 100 %, depending on how the extrapolation to unresolved systems is carried out (Leinert et al. 1993; Ghez et al. 1993; Köhler & Leinert 1998). Studies of southern star-forming regions, e.g. Scorpius-Centaurus, give similar results (e.g. Simon et al. 1995; Brandner & Köhler 1998; Köhler et al. 2000).

All these studies dealt with Population I stars that formed within the galactic disk. Pop. II stars formed in the galactic halo, i.e. in a different environment, and differences in the initial star formation conditions might lead to differences in the binary frequency or the distributions of periods and mass ratios.

We have identified a list of stars with precise metallicities and radial velocities (Carney et al. 1994; Norris 1986) in the HIPPARCOS catalogue. We then selected about 200 Halo stars, based on their low metallicities ($[m/H] < -1.4$) or kinematical properties (Jahreiss et al. 1997, Fuchs et al. 1999). Their typical distance from the Earth is about 100 pc.

We observed 63 of these stars with the 3.5 m telescope on Calar Alto, and 11 additional stars with the NTT on La Silla. In all cases, speckle interferometry in the K band was used. These observations are sensitive to binaries with separations in the range $0.13''$ (the diffraction limit of the telescope) and about $3''$ (limited by the field of view of the camera). To search for binaries that are separated by more than 3″ we used the 1.23 m and 2.2 m telescopes on Calar Alto for direct imaging in the K band. In total 168 stars have been observed this way.

2. Initial Results

Among the stars observed up to now, we find 23 binaries, 3 triples, and one quadruple, i.e. 32 companion stars. Five stars were discovered by speckle interferometry, 27 by direct imaging.

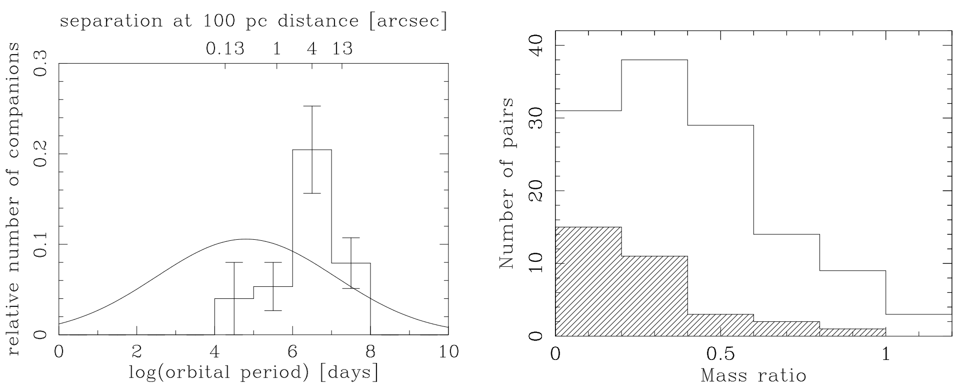

Figure 1. Left: the binary period distribution of stars discovered in our survey (histogram) compared to that of Population I main-sequence stars (Gaussian curve, Duquennoy & Mayor 1991). The height of each bin shows the number of companion stars with orbital period in a given interval divided by the total number of systems observed. Therefore, triple systems are represented as two pairs. Right: mass ratio distributions of Population I main-sequence stars (open histogram, Duquennoy & Mayor 1991) and Population II stars (hatched histogram).

2.1. Period Distribution

To compare our results to the survey of Population I main-sequence stars by Duquennoy & Mayor (1991), we have to convert the angular separations of our binaries into orbital periods. To convert the angular separation into a linear separation, we make use of the distances measured by HIPPARCOS. Since it is impossible to compute the orbital period of a given binary from only one measured separation, we follow the approach of Leinert et al. (1993) and Köhler & Leinert (1998), who rely on statistical arguments.

Figure 2 shows the period distribution of the companion stars we discovered. According to this preliminary data, the peak of the period distribution of Population II stars is shifted to longer periods with respect to the distribution of Population I stars. This result has to be taken with caution, since only a limited number of stars has been observed with a resolution sufficient to discover binaries with periods shorter than $\approx 10^6$ days, therefore the statistical errors are large.

This shift in the peak of the period distribution is quite surprising, since one would expect that some binaries have been disrupted in stellar encounters when the Halo stars cross the galactic plane. This would preferentially destroy wide binaries and thus shift the peak to smaller separations and periods.

2.2. Mass Ratio Distribution

Another important characteristic of star formation is the distribution of mass ratios of the binary stars. To convert our measured flux ratios into mass ratios, we use the models of Baraffe et al. (1997). A linear fit to their models gives a relation that allows us to convert the measured flux ratios into mass ratios. The resulting distribution is shown in figure 2. The mass ratio distribution of Population I stars (Duquennoy & Mayor 1991) is shown for comparison.

The distribution of Population I stars has a maximum at about 0.3, while the distribution of Population II stars is rising towards smaller mass ratios. One should be aware that the results of Duquennoy & Mayor contain corrections for undetected companions, without these corrections, the peak would be even more pronounced. On the other hand, the histogram for Population II stars contains only binaries that have actually been detected and no corrections.

If this difference in the distribution of mass ratios is true, it would indicate that the formation of Population I and Population II stars occured under different initial conditions. However, given the small number of Population II binaries, this result is still uncertain.

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