Proc. VI Serbian-Bulgarian Astronomical Conference, Belgrade 7-11 May 2008, Eds. M. S. Dimitrijević, M. Tsvetkov, L. Č. Popović, V. Golev Publl. Astr. Soc. "Rudjer Bošković", No. 9, 2009, 381-386

PHYSICAL CHARACTERISTICS OF PLANET-HOSTING STARS AND OPTIMIZATION OF THE EXTRASOLAR PLANET SEARCHES

DONKA PETKOVA[1], PETKO NEDIALKOV[2] and VLADIMIR SHKODROV[3]

[1]*Faculty of Science, University of Shumen, 9700 Shumen, Bulgaria*
e-mail: d.petkova@shu-bg.net
[2]*Department of Astronomy, University of Sofia, 1164 Sofia, Bulgaria*
e-mail: japet@phys.uni-sofia.bg
[3]*Institute of Astronomy, Bulgarian Academy of Sciences, 1784 Sofia, Bulgaria*
e-mail: shkodrov@astro.bas.bg

Abstract. We compared the physical properties (mass, age, projected rotational velocity and metallicity) of the planet-hosting stars and stars without (detected) planets, from the radial-velocity searches conducted by the California & Carnegie group and the team at the Anglo-Australian Telescope to improve the preliminary sample selection for planet searches.

1. THE STAR SAMPLE AND ITS SPATIAL PROPERTIES

The sample of stars (hereafter, CCA) probed by the California & Carnegie group (Cumming, Marcy and Butler 1999) and the team at the Anglo-Australian Telescope (Tinney et al. 2001) for planets is described in detail in Wright et al. (2004) and at http://www.phys.unsw.edu.au/~cgt/planet/aapslist.html. We reviewed its properties in detail earlier (Petkova et al. 2008). Summarizing, it contains ~1330 HIPPARCOS stars of spectral types FGK v or iv and Mv. A luminosity class was tentatively assigned to 467 stars with missing classification in the Hipparcos catalog. The location of the sample stars on the Hertzsprung-Russell diagram is shown in Fig. 1, and their positions in Galactic coordinates - in Fig. 2. Note that some of the stars without planets may still host undetected yet planets. Here we consider only hot giant planets, refraining from conclusions about Earth mass planets.

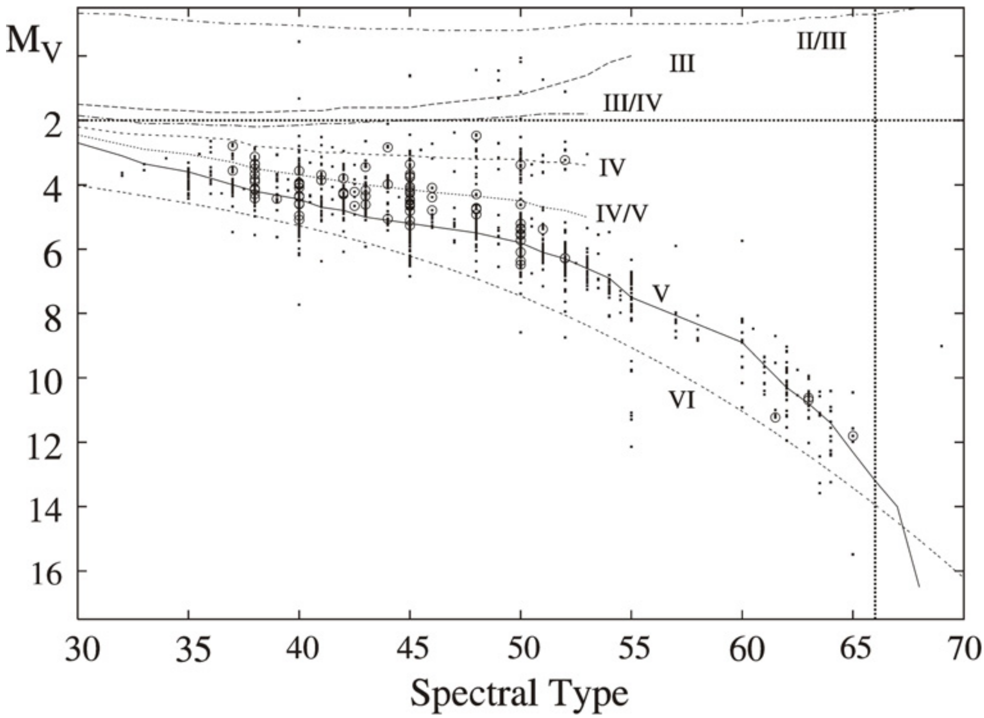

Figure 1: Absolute magnitude versus spectral type for the initial CCA sample (dots). Along the abscissa 30 stands for F0, 40 - for G0, etc. Planet-hosting stars are marked with open circles. The adopted luminosity calibrations for various luminosity classes are from Houk (1978). The total number of stars between the limits determined by the luminosity classes III/IV and VI is 1333.

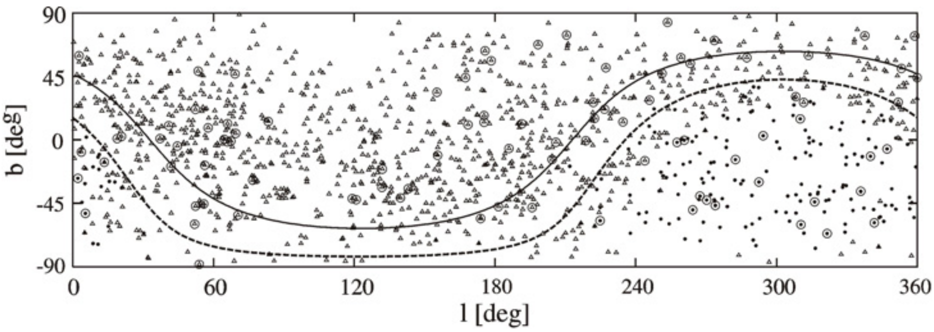

Figure 2: Spatial distribution of the sample stars in Galactic coordinates (l,b). The triangles are the stars from the California & Carnegie search and the dots are the stars from the Anglo-Australian Telescope search. Open circles mark 91 stars detected with planets. The solid line represents the equatorial plane at $\delta = 0^o$, and the dashed line shows $\delta = -20^o$.

First, we applied the Kolmogorov-Smirnov (K-S, hereafter) test to the compare the positions of the stars with and without planet along the Galactic *z*-coordinate, their luminosity classes and spectral types. The results are reported in Table 1. The typical rate of finding planets is ~7 %. As seen in Fig. 1, there are no detected planets around stars with M_V=6.5-10.5 mag and spectral types from *K*4 to *K*8, despite the fact that at least several planets are expected to be detected there. This negative result could be due to the worse statistics in these range.

Table 1. Summary of the Kolmogorov-Smirnov test results for the compared properties of the stars from the CCA sample: probability to reject the H_0 hypothesis for the *z*-coordinate, luminosity and spectral type distributions.

Selection condition	Stars with no planets	Stars with planets	*z*-coordinate [pc]	M_V [mag]	Spectral type	Shown in figure No.
all stars	1241	91	0.976	0.00004	0.00002	1, 2 & 3
single stars	1067	86	0.997	0.00007	0.00011	-
$2^m \leq M_V \leq 6.5^m$	784	87	0.754	0.115	0.062	-
*F*2 ÷ *K*3 spec. type	814	87	0.835	0.040	0.021	-

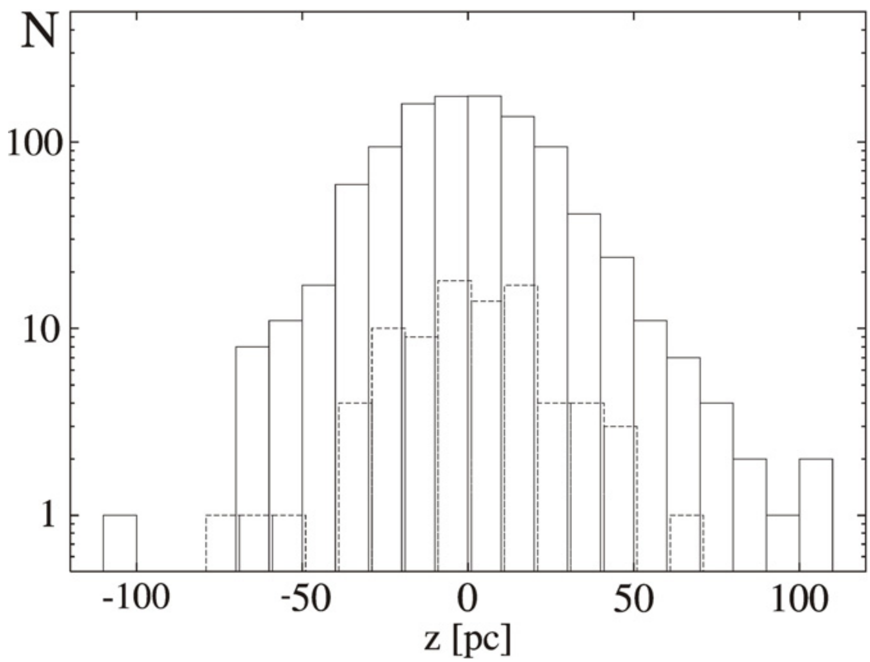

Figure 3: Galactic *z*-coordinate distributions of the CCA sample stars with (dashed line) and without (solid line) planets. Note that the two distributions have similar slopes.

The distributions along the Galactic *z*-coordinate of the stars with and without planets is shown in Fig. 3. The average *z*-coordinates of the two sub-samples are statistically indistinguishable from zero suggesting a shift with respect to the Galactic mid-plane, similar to that of the Sun. Both sub-samples are strongly concentrated toward the mid-plane with an exponential scale-heights of ~40 pc - probably an observational bias towards closer stars because the late type dwarfs are known to have much larger (~350 pc) scale-height (Gilmore and Reid, 1983). Quantitatively, the similar spatial distributions of the two subsets is confirmed by the high values of K-S test probability (see Tab. 1) for z-coordinate - in contrast with the values for the luminosity and the spectral type distributions which appears to be significantly different.

2. SPECTRAL SYNTHESIS MODELLING OF THE SAMPLE STARS

We cross-identified the CCA stas with the (Spectroscopic Properties of Cool Stars Catalog (SPOCS, hereafter) to obtain two independent estimates of the physical parameters of the sample stars based on uniform high-quality spectroscopic observations, reduction and analysis. We used the stellar evolutionary models from Valenti and Fisher (2005; VF2005) and Takeda et al. (2007; TF2007). The projected rotational velocity is plotted versus the metallicity in Fig. 4, the age-metallicity relation is shown in Fig. 5 and the age-mass relation is shown in Fig. 6. The results of K-S test are summarized in Table 2.

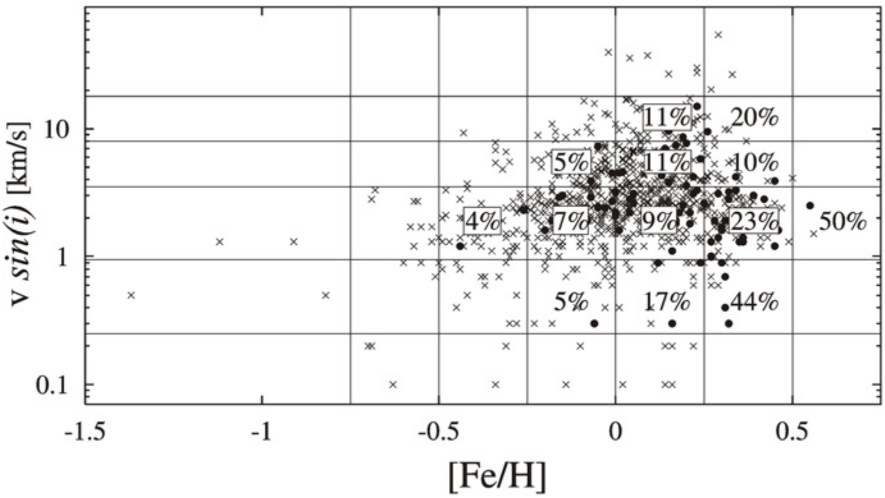

Figure 4: Projected rotational velocity versus the metallicity for 809 stars without planets (inclined crosses) and 87 stars with planets (circles). The physical parameters were derived from the VF2005 stellar evolutionary models.

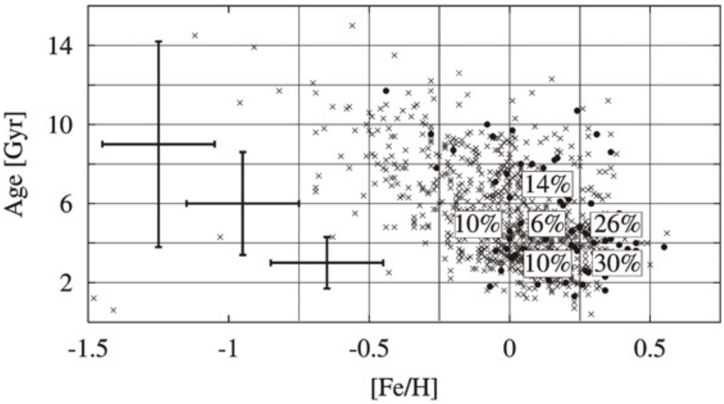

Figure 5: Age-metallicity relation. The details are the same as in Fig. 4.

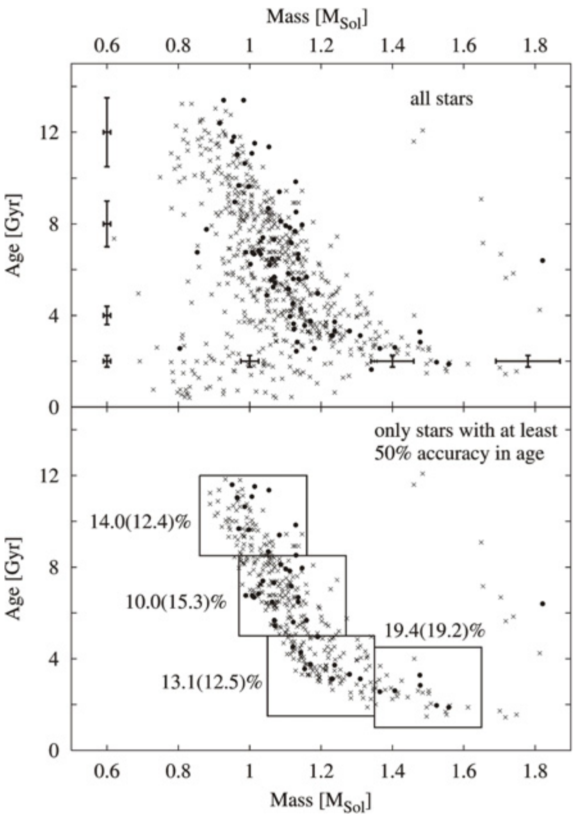

Figure 6: Age-mass relation. The symbols are the same as in Fig. 4. The upper panel shows all stars with available age from the TF2007 models and the bottom panel shows only the stars with well-defined ages. The typical errors are indicated with bars. The rate of successful detections in several selected boxes are given on the bottom panel. The rate for all stars is given in brackets.

Table 2. Summary of the Kolmogorov-Smirnov test results for the compared physical properties of the stars from the SPOCS catalog: probability to reject the H_0 hypothesis for the metallicity, projected rotational velocity, age and mass distributions

Models	Selection condition	Stars with no planets	Stars with planets	Fe/H]	v sin(i) [km s^{-1}]	Age [Gyr]	Mass [M$_\odot$]	Shown in figure No.
VF2005	available age	809	87	0.00000	0.628	0.059	-	4 & 5
VF2005	σ_{age}/age ≤ 0.5	109	17	-	-	0.836	-	-
VF2005	v sin(i) ≤ 11 km s^{-1}	786	86	0.00000	0.775	-	-	-
VF2005	[Fe/H] ≥ 0	451	67	0.00003	0.046	-	-	-
TF2007	available mass	832	86	-	-	0.059	0.042	6
TF2007	σ_{age}/age ≤ 0.5	375	47	-	-	0.924	0.996	-
TF2007	σ_{age}/age ≤ 0.25	184	22	-	-	0.304	0.953	-

The application of a single selection criterion such as an upper limit or a minimum accuracy level results in similar distributions as indicated by the probability values of K-S test. It can be satisfied for all considered physical parameters except for the metallicity which appears to be crucial to separate the planet hosting stars from those without companion planets. Thus, we confirm that the stars with solar or higher metallicity have greater probability of harboring gas giant planets.

In the future we plan to consider the velocity space of the stars in our effort to search for significant differences between the stars with and without planets. These efforts may improve the probability for detection of a planet around a specific star.

Acknowledgements

This work was partially supported by the following grants: VU-NZ-01/06, VU-F-201/06 & VU-F-205/06 of the Bulgarian Science Foundation.

References

Cumming, A., Marcy, G. W., Butler, R. P.: 1999, *Astrophys. J.*, **526**, 890.
Gilmore, G., Reid, N.: 1983, *Mon. Not. R. Astron. Soc.*, **202**, 1025.
Houk, N.: 1978, *Michigan Catalogue of two-dimensional spectral types for the HD stars*, Vol. 2, Ann Arbor: Dept. of Astronomy, Univ. Michigan.
Petkova, D., Nedialkov, P., Shkodrov, V.: 2008, *Bulg. AJ*, **10**, (in press).
Takeda, G., Ford, E. B., Sills, A., Rasio, F. A., Fischer, D. A., Valenti, J. A.: 2007, *ApJS*, **168**, 297;
Tinney, C. G., Butler, R. P., Marcy, G. W., Jones, H. R. A., Penny, A. J., Vogt, S. S., Apps, K., Henry, G. W.: 2001, *Astrophys. J.*, **551**, 507.
Valenti, J. A., Fischer, D. A.: 2005, *ApJS*, **159**, 141.
Wright, J. T., Marcy, G. W., Butler, R. P., Vogt, S. S.: 2004, *ApJS*, **152**, 261.