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Planet Host Stars: Mass, Age and Kinematics

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Abstract We determine the mass, age and kinematics of 51 extra-solar planet host stars. The results are then used to search for signs of connection of the data with metallicity and to investigate the population nature. We find that the increase in mean metallicity with stellar mass is similar to that in normal field stars, so it seems unsuitable to use this relation as a constraint on the theory of planet formation. The age and kinematic distributions seem to favour the metallicity of extra-solar planet host stars being initial. Although the kinematic data of these stars indicate their origin from two populations – the thin and the thick disks, kinematics may not help in the maintenance of the planet around the host. Stars with planets, brown dwarfs or stellar companions are sorted into three groups and re-investigated separately for their formation mechanism. The main results indicate that stars with $M_2 < 25M_{\rm J}$ have [Fe/H] > -0.1 and a wide period range, but there are no other differences. Thus, there does not seem to be any physically distinguishable characteristics among the three star groups.

Key words: stars: masses, ages — stars: kinematics – planetary system

1 INTRODUCTION

In the past years, we were thrilled to the reports of discoveries of many planets around stars. These planetary systems outside the solar system (if exist) provide not only an independent test of the formation theory of the solar system but also a chance to search for extraterrestrial life in the universe. Many studies have been made to identify the particularities of these stars, among which spectroscopic studies (e.g. Gonzalez et al. 2001; Santos et al. 2001; Zhao et al. 2001) showed that these stars are generally more metal-rich than the average of nearby solar-type stars ([Fe/H] ~ -0.2). The explanations for the high metallicity are twofold: either the metallicity is enhanced by the process of planet formation, or a metal-rich star favours the formation of a planet and thus the high metallicity could be primordial. Other features of these stars such as age and kinematic behaviours as well as the mass distribution may help to clarify this issue.

The properties above are important because of two reasons at least. First, Lauglin (2000) suggested that the link between the high metallicity and the presence of the planetary system

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may be mass dependent in the sense that the enhanced metallicity by the accretion of H-deficit material during the formation of the planet is significant only for stars with higher mass, i.e., $M > 1.3M_{\odot}$. Based on the general understanding of the stellar and galactic chemical evolution, we may expect that the presently observed high mass stars tend to be slightly metal-richer when compared with the mean value of low mass stars. By comparing the mass-[Fe/H] relation between stars with and without planet components, we can estimate how significant this enhanced effect is. Secondly, it was supposed that the absence of planet-bearing star in the globular cluster 47 Tucanae ([Fe/H]=−0.7) (e.g. Brown et al. 2000) could be due to the disturbance of protoplanetary disks by some dynamical effect in a dense cluster. Inspired by this, we attempt to investigate if the kinematics of the parent stars will have any influence on the presence of planet stars. For example, one might suspect that a lag in the Galactic rotation could favor the maintenance of a planetary system in metal-poor stars. In this work, we attempt to derive the mass, age and kinematics for as many of planet host stars as possible based on the available material in the literature. With these data, we present the mass distribution of these stars to see if this is special, and investigate how the presence of planets can be maintained as the star ages, as well as searching for any possible relation between the stellar dynamical history and planetary presence. Determining the kinematic properties and stellar age can also help to decide which stars are intrinsically metal-poor and which are significantly enhanced in metallicity, and hence providing an estimation of the net metallicity excess by planet formation. All these characteristics are useful to test the scenarios of planet formation and help to search for other new information on these stars. Since it is also suggested that these planet host stars may be brown dwarfs or stellar companions, we attempt to sort these stars into three groups based on the data available in the literature, and to inspect if there are differences among the three groups of companions.

2 SOURCES OF DATA

When we started this work, there were 51 stars with companion masses below 13 $M_{\rm J}$ in the extra-solar planet catalog (http://www.obspm.fr/Catalogs). These stars are referred as group A, while our group B includes 11 stars with their minimum masses in the range of 17∼60 $M_{\rm J}$, even though most of them were suspected to be stellar companions according to Halbwachs et al. (2000). We now describe the data that are used in our study, including those on stellar metallicity, effective temperature and absolute magnitude. At the outset Gl229 is excluded because of lack of data. The main sources for spectroscopic metallicity are: Zhao et al. (2001) for 15 stars, Bulter et al. (2000, table 4) for 25 stars and Santos et al. (2001) for six stars. Additional sources are: Edvardsson et al. (1993) for HD 6434, Gonzalez et al. (1998) for HD 114762 and the fourth version of [Fe/H] catalog (Cayrel de Strobel et al. 1997) for HD 89707 and HD 160691. Photometric [Fe/H] for the remaining stars are derived from Strömgren indices based on the calibration of Schuster & Nissen (1989).

The effective temperatures are derived from Strömgren $uvby\beta$ (Olsen 1983, 1993) or $B-V$ (Hipparcos catalog: ESA, 1997) data based on the calibration of Alonso et al. (1996). The temperature for HD 177830 derived from $B-V$ makes it significantly below the main sequence in the HR diagram, and so we adopt the temperature estimated from its spectral type and assume that it is a dwarf. If β is available, reddening is estimated based on the calibration of Olsen (1988) and reddening correction is applied to all stars with $E(b-y) > 0.015$.

The absolute magnitudes, $M_{\rm V}$, are derived from Hipparcos parallaxes except for BD–10 3166 and HD 98230 which were not included in the Hipparcos survey. With the temperature and mass determined in this work, and the gravity estimated in Castro et al. (1997), we estimate Mv by using relations of $g \sim M/R$ and $L \sim R^2 {T_{\rm eff}}^4$ for BD–10 3166. Photometric $M_{\rm V}$ is derived for HD 98230 based on Strömgren indices and the calibration of Edvardsson et al. (1993).

3 THE METHOD

With the derived effective temperature and absolute magnitude, the stellar mass and age are determined by a comparison of the star's position in the HR diagram with the calculated evolutionary tracks and isochrones of Girardi et al. (2000). As pointed out by Girardi et al. (2000), there is a systematic shift between these tracks and those of VandenBerg et al. (2000). We choose the former because they cover a higher metallicity range of $Z = 0.03$, which is required for these planet host stars. Since we aim to perform an internally consistent analysis, different sets of theoretical tracks will not affect our results. In the kinematics calculations, parallax, proper motion and radial velocity are required. The proper motions are taken mainly from Hipparcos catalog and the data of BD–10 3166 and HD 98230 are taken from SIMBAD survey. We use radial velocities from Duflot et al.(1995), Grenier et al. (1999), Barbier-Brossat & Prtit (1990), Gonzalez et al. (2001), and use Doppler shifts based on the spectra of stars in Zhao et al. (2001). A fraction of stars have no published radial velocities available and these are omitted from our kinematics study. We calculate the galactic space velocity (U, V, W) and orbital parameters ($R_{\rm max}$, $R_{\rm min}$ and $Z_{\rm max}$) using the methods presented in Johnson & Soderblom (1987) and Allen et al. (1991). The calculation is based on the values $R_{\rm LSR}$=8.5 kpc, $V_{\rm rot}$=226 km s^{-1} (Edvardsson et al. 1993) and ($U_{\rm LSR}$, $V_{\rm LSR}$, $W_{\rm LSR}$) =(−10.0, 7.2, 5,2) km s^{-1} (Dehnen & Binney 1998). The results are presented in Table 1 and Table 2, which include the stellar parameters, mass, age, kinematics and information on the companions for stars in group A and B respectively.

4 DISCUSSION AND RESULTS

It is recently suggested that most of the planetary candidates are actually brown dwarfs in face-on orbits based on the astrometric excursions of the Hipparcos measurements (Han et al. 2001; Pourbaix 2001). Based on the inclination angle presented in these two papers, we calculate the mass of the companion, M_2, and re-sort the sample into three groups: if the companion mass $< 13M_{\rm J}$ it is referred to as a planet and will be indicated by an additional diamond in the figures following; if the mass falls in the range of 14–77 $M_{\rm J}$ it is classified as a brown dwarf and will be indicated by an additional plus sign. Stars without additional symbols have stellar companions. Since M_2 may still be uncertain, we keep the original division of group A (filled symbols) and B (open symbols) in the following figures.

4.1 Mass-Metallicity Relation

Lauglin argued that the formation of planetary system may enhance its metallicity by the accretion of H and He depleted material, and the process becomes more pronounced in stars with higher mass due to their shallower outer convection zone (Lauglin 2000). The author showed stellar mass increasing with stellar metallicity in a sample of 34 stars. In Figure 1, it is clear that stars with $M > 1.2M_\odot$ have [Fe/H] > 0.0, which makes the average metallicity increase with increasing mass. However, we doubt if this result can be used to support the

Table 1 Stellar Basic Parameters, the Companion Information, Kinematics for Stars in Group A

Star	$T_{\rm eff}$	$\log g$	[FeI/H]	M_1	Age	$U_{\rm LSR}$	$V_{\rm LSR}$	$W_{\rm LSR}$	$R_{\rm max}$	$R_{\rm min}$	$Z_{\rm max}$	M_2	M_p	a	P	e
HD/BD	(K)	(cgs)		($M_\odot$)	(Gyr)	(km s^{-1})			(kpc)			($M_{\rm J}$)	($M_{\rm J}$)	(AU)	(yr)	
–10 3166	5109	4.40	0.50	0.90	–	57.8	–29.7	–2.1	9.43	5.99	0.09		0.48	0.05	3.48	0.05
Gl876	3578	4.50	0.10	0.17	15.1	–0.6	0.2	–20.0	8.55	8.49	0.24	14.59	1.98	0.21	61.02	0.27
1237	5371	4.38	0.20	0.91	8.9	18.2	–16.1	–4.1	8.69	7.18	0.05	16.19	3.31	0.49	133.82	0.50
6434	5712	4.31	–0.54	0.80	–	–44.3	3.1	–95.5	11.06	7.82	2.56	274.98	0.48	0.15	22.09	0.30
9826	6116	4.07	0.12	1.20	4.8	–38.5	–17.1	–7.1	9.15	6.83	0.08	1.71	0.71	0.00	4.61	0.03
10697	5647	4.03	0.15	1.30	6.5	–45.3	–21.8	22.5	9.24	6.55	0.30	39.11	6.59	2.00	1083.00	0.12
12661	5717	4.33	0.41	1.04	6.8	–61.6	–24.3	4.7	9.70	6.12	0.07	55.94	2.83	0.79	264.50	0.33
13445	5176	4.72	–0.24	0.80	15.1	101.3	–16.1	60.6	11.86	6.01	1.38	14.51	4.00	0.11	15.78	0.05
16141	5735	4.14	0.02	1.00	10.0	–93.7	–39.8	1.7	10.43	5.14	0.03	126.05	0.22	0.35	75.82	0.28
17051	6011	4.31	0.11	1.04	4.6	16.3	4.4	31.9	9.25	8.21	0.45	23.58	2.26	0.93	320.10	0.16
19994	6042	4.05	0.17	1.33	4.0	10.3	–13.8	1.2	8.56	7.42	0.01	23.41	2.00	1.30	454.00	0.20
22049	5104	4.57	–0.12	0.81	–	–4.7	16.1	–10.6	9.85	8.48	0.13	8.23	0.86	3.30	2502.10	0.61
27442	4520	3.17	0.26	0.75	–	19.4	15.8	–3.1	10.06	8.33	0.04		1.43	0.18	437.00	0.02
37124	5513	4.37	–0.32	0.72	–	–31.8	–42.3	–37.0	8.78	5.74	0.54	119.18	1.04	0.58	155.00	0.19
38529	5586	3.92	0.28	1.37	3.0	2.3	–19.5	–26.6	8.52	7.17	0.34	464.10	0.81	0.13	14.41	0.28
46375	5189	4.25	0.34	0.83	–	–15.8	–16.4	16.1	8.64	7.22	0.19		0.25	0.04	3.02	0.01
52265	6023	4.30	0.11	1.30	5.1	45.5	–7.6	2.2	9.60	7.10	0.03	43.17	1.13	0.49	118.96	0.29
75289	6045	4.27	0.28	1.20	3.1	3.5	–26.1	11.6	8.49	6.68	0.13		0.42	0.05	3.51	0.05
75732	5082	4.26	0.26	0.80	–	10.3	–7.9	–14.5	8.61	7.83	0.17	120.33	0.84	0.11	14.65	0.05
82943	5878	4.37	0.32	1.11	5.2							35.67	2.24	1.16	442.60	0.61
83443	5170	4.50	0.38	0.80	–	4.1	–18.7	32.4	8.50	7.22	0.44		0.35	0.04	2.99	0.08
89744	6209	3.92	0.18	1.47	2.5	0.5	–24.4	–7.0	8.53	6.81	0.08	98.31	7.20	0.88	256.00	0.70
92788	5679	4.44	0.17	1.02	4.6	–26.4	–17.4	–13.8	8.86	7.00	0.17	54.48	3.80	0.94	340.00	0.36
95128	5788	4.31	0.03	1.00	8.9	14.6	2.8	9.1	9.03	8.19	0.11	2.70	2.41	2.10	1000.00	0.10
108147	6211	4.35	–0.02	1.20	2.5								0.34	0.10	10.88	0.56
114762	5832	4.15	–0.60	0.76	–	72.8	–64.2	65.2	9.49	4.58	1.36	146.71	11.00	0.30	84.03	0.33
117176	5436	3.95	–0.05	1.04	7.1	–23.1	–46.7	3.2	8.62	5.46	0.04	23.80	6.60	0.43	116.60	0.40
120136	6400	4.26	0.34	0.00	2.0	23.5	–13.6	0.5	8.82	7.25	0.01	246.38	3.87	0.05	3.31	0.02
121504	5837	4.32	0.00	1.00	7.9							169.98	0.89	0.32	64.60	0.13
130322	5263	4.51	–0.02	0.88	0.0	–0.3	–20.8	–4.0	8.50	7.02	0.05	309.40	1.08	0.09	10.72	0.05
134987	5735	4.40	0.23	1.05	6.8	8.1	–32.2	34.2	8.53	6.40	0.48	33.54	1.58	0.78	260.00	0.25
143761	5695	4.13	–0.29	0.86	15.1	–64.3	–30.6	28.5	9.66	5.88	0.41	126.05	1.10	0.23	39.65	0.03
145675	5250	4.42	0.36	0.83	–	–35.9	–1.8	–2.8	9.52	7.55	0.03	7.90	3.30	2.50	1619.00	0.35
160691	5792	4.31	0.16	1.08	6.3	–21.9	–5.2	2.2	8.97	7.71	0.03		1.97	1.65	743.00	0.62
162020	4728	4.00	0.11	0.71	–								13.73	0.07	8.42	0.28
168443	5387	3.94	–0.14	0.95	10.5	1.8	–58.0	–4.8	8.51	4.95	0.06	144.41	5.04	0.28	57.90	0.54
168746	5612	4.35	–0.05	0.92	12.6								0.24	0.07	6.40	9.00
169830	6278	4.08	0.21	1.40	3.0							99.78	2.96	0.82	230.40	0.34
177830	4830	4.50	0.00	0.97	6.6	–27.3	–1.2	11.7	9.25	7.81	0.15		1.28	1.00	391.00	0.43
179949	6084	4.30	0.06	1.30	4.0	0.0	0.0	0.0	0.00	0.00	0.00		0.84	0.05	3.09	3.00
186427	5628	4.18	0.06	0.91	12.6	–27.7	–24.5	5.6	8.80	6.59	0.07	12.31	1.50	1.70	804.00	0.67
187123	5712	4.30	0.09	0.98	10.7	–12.6	–11.0	–36.2	8.65	7.68	0.51		0.52	0.04	3.10	0.03
190228	5182	3.67	–0.40	1.04	5.2	9.2	–40.5	–28.7	8.54	5.89	0.38	45.56	5.00	2.31	1127.00	0.43
192263	4952	4.46	0.00	0.80	–	6.1	16.2	26.8	9.96	8.49	0.38	87.09	0.76	0.15	23.87	0.03
195019	5721	4.11	0.00	1.00	9.5	62.3	–71.6	–30.1	9.14	4.17	0.43	655.08	3.43	0.14	18.30	0.05
202206	5678	4.40	0.36	1.06	6.5							59.00	14.70	0.77	258.90	0.42
209458	5965	4.28	0.00	1.05	5.1	–4.4	–10.2	7.6	8.52	7.74	0.10		0.69	0.05	3.52	0.00
210277	5355	4.24	0.24	0.86	–	–19.5	–44.1	–6.8	8.59	5.61	0.08	17.48	1.28	1.10	437.00	0.45
217014	5619	4.26	–0.03	0.97	13.5	5.2	–22.8	21.7	8.51	6.91	0.27	269.29	0.47	0.05	4.23	0.00
217107	5455	4.23	0.30	0.98	13.8	–8.9	–4.3	17.4	8.61	8.05	0.21	183.36	1.28	0.07	7.11	0.14
222582	5674	4.25	0.00	0.92	11.2	–45.8	8.4	–6.6	10.37	7.62	0.09	60.75	5.40	1.35	576.00	0.71

above scenario because of two reasons. First, there are only a few stars with mass larger than 1.2 $M_\odot$ and many stars with the highest metallicity of [Fe/H] > 0.2 are mainly located in the mass range 0.8–1.1 $M_\odot$. Instead, it seems to be more pronounced that the scatter in metallicity at a given mass increases with decreasing mass. This can be easily explained by stellar evolution theory and chemical evolution effect: low mass stars have longer lifetimes than high mass stars, and so stars with low and high metallicities coexist until today; early formed (old) massive stars died as supernova explosions and left only recently formed (high metallicity) ones to be observed. In accordance with this view, we find that low mass stars with 0.8–1.1 $M_\odot$ cover an age range of 4–15 Gyr while stars with mass larger than 1.2 $M_\odot$ were formed 2–5 Gyr ago.

Table 2 Stellar Basic Parameters, the Companion Information, Kinematics for Stars in Group B

Star	$T_{\rm eff}$	$\log g$	[FeI/H]	M_1	Age	$U_{\rm LSR}$	$V_{\rm LSR}$	$W_{\rm LSR}$	$R_{\rm max}$	$R_{\rm min}$	$Z_{\rm max}$	M_2	M_p	a	P	e
HD/BD	(K)	(cgs)		($M_\odot$)	(Gyr)	(km s^{-1})				(kpc)		($M_{\rm J}$)	($M_{\rm J}$)	(AU)	(yr)	
–04 478	4250	4.50	0.00	0.62	–							263.80	21.00	0.700	240.92	0.28
18445	4810	4.25	–0.23	0.55	–							189.50	39.00	0.900	554.67	0.54
29587	5554	4.23	–0.63	0.68	–	125.6	–44.3	18.9	11.60	4.70	0.29	42.00	40.00	2.500	1050.00	0.00
89707	5887	4.28	–0.42	0.85	11.7	72.1	7.3	63.4	11.80	7.20	1.40	64.60	54.00	0.000	198.25	0.95
98230	5796	4.43	–0.29	1.05	4.0	–7.1	–29.1	–14.3	8.50	6.50	0.17		37.00	0.060	3.98	0.00
110833	4812	4.61	–1.01	0.60	–	8.7	–16.4	19.7	8.60	7.30	0.24	147.50	17.00	0.800	270.04	0.69
112758	5181	4.51	–0.34	0.60	–	69.4	–24.1	12.1	10.00	6.00	0.15	214.30	35.00	0.350	103.22	0.16
140913	5784	4.38	0.01	1.00	7.6	12.0	–8.9	8.8	8.60	7.70	0.11	178.70	46.00	0.540	147.94	0.61
217580	4801	4.50	–0.40	0.73	–	15.9	–45.0	21.7	8.60	5.60	0.27	173.40	60.00	1.000	454.66	0.52
283750	4600	4.50	–0.40	0.60	–							184.20	50.00	0.020	1.79	0.02

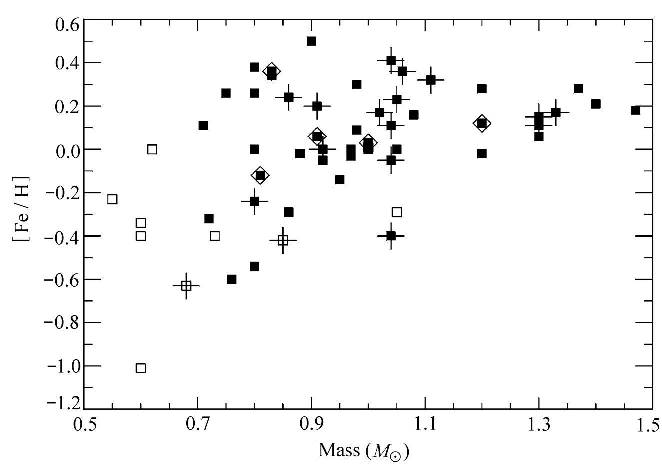

Fig. 1 Metallicity versus mass for planet host stars. Symbols are defined in the text.

Secondly, there exists a tendency for normal metal-poor, field stars to generally have a low average mass, as shown in Fig. 2. In this figure, triangles and squares indicate stars from Edvardsson et al. (1993) and Chen et al. (2000) respectively; open symbols denote stars with distances larger than 30 pc and filled circles, those within 30 pc. However, Lauglin (2000) compared the [Fe/H]-Mass relation with that of field stars with $d < 25$ pc and found a flat trend. We notice that their sample is limited in a narrow range of $0.9 < M < 1.4 M_\odot$ and $-0.4 <$ [Fe/H] < 0.4, and stars with low metallicity of [Fe/H] < -0.4 and with mass of 0.9-1.0 $M_\odot$ are absent in their figure. If we enlarge the mass and metallicity ranges, the mean metallcity will increase with mass for field stars, in agreement with stellar evolution and chemical evolution of the galaxy. Stars with $d > 30$ pc are denoted by open symbols in Fig. 2. If we exclude these stars, the result remains the same.

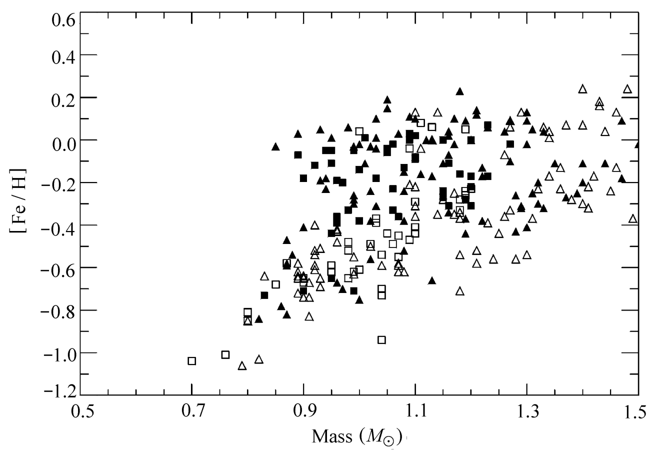

Fig. 2 Metallicity versus mass for normal field stars. Symbols are defined in the text.

The very recent work by Jorissen (2001) made such a comparison for a new volume-limited sample and concluded that planet host stars and normal stars show similar trends. This is consistent with the result of this work even after allowing for the different sets of tracks used for deriving the masses between the two works. Therefore, it may be unsuitable to use the potential relation between metallicity and mass of planet hosts as a constraint on the formation of planetary systems.

In addition, the age of these stars ranges from $\lesssim 1$ Gyr to $\gtrsim 15$ Gyr, with most occurring in the 3–5 Gyr range. This is also the case of normal stars. In particular, we find that the age-mass and age-metallicity relations are quite similar between the two samples. These results indicate that the metallicity of the planet host stars may be initial and thus there is no sign of enhanced metallicity with the formation of planets. Finally, the fact that there does exist stars with [Fe/H] < -0.4 (e.g. HD 6434 and HD 190228) in the sample of planet host stars provides an important clue to the analysis. In all, it seems that stars with planetary systems are not distinguished by any special characteristics.

4.2 Kinematics and Orbits

In order to obtain information about the nature and population membership of the planet host stars, we analyze their kinematic behaviours (see Fig. 3) and orbital properties.

It is clear that most stars have the space velocity of the thin disk, especially for stars with [Fe/H] > 0.0; the $U_{\rm LSR}$, $V_{\rm LSR}$, $W_{\rm LSR}$ range within -100 to 120, -70 to 20 and -100 to 75

$\mathrm{km\,s^{-1}}$, respectively. It seems to be a good correlation between the low metallicity and the high total velocity except for the most interesting star HD 110833 with the lowest metallicity and total velocity. In addition, HD 13445, HD 195019 and HD 16141 seem to show too high a total velocity for their metallicity. In addition, we find that HD 29587 and HD 114762 may belong to the thick disk with $V_{\rm LSR} < -40\,\mathrm{km\,s^{-1}}$ and [Fe/H]=-0.6 and an old age, while it is difficult to decide the population for HD 195019 and HD 168443 with their $V_{\rm LSR} < -50\,\mathrm{km\,s^{-1}}$ and ages around 10 Gyr but [Fe/H] > -0.2. Therefore, planet host stars appear to belong to at least two populations: the thin disk and the thick disk. And this is similar to normal field stars.

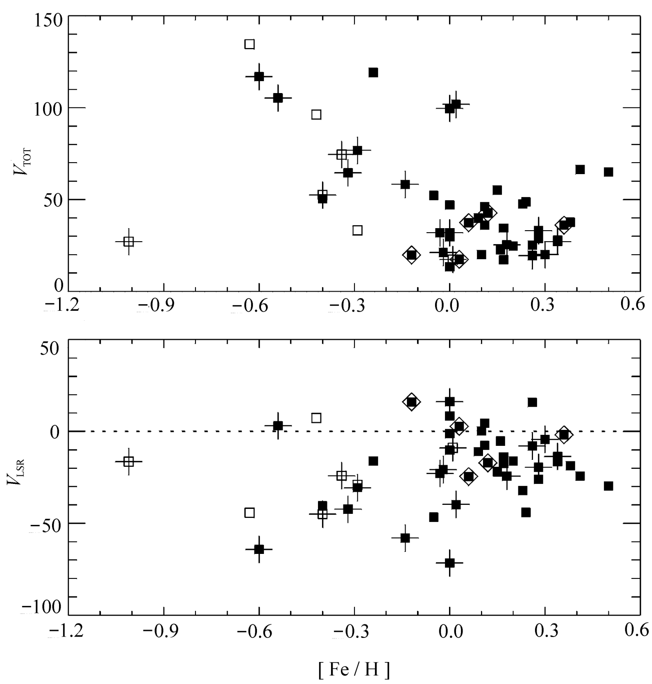

Fig. 3 Kinematics vs. metallicity

These stars have apogalactic distances of 8–12 kpc and perigalactic distances of 4–9 kpc. Moreover, most stars orbit within the range 6–10 kpc, except that HD 6434 has $R_{\rm max}$ of 11 kpc and HD 168443 has $R_{\rm min}$ below 5 kpc. There is a tendency for metal-poor stars showing the largest $R_{\rm max}$ and the smallest $R_{\rm min}$. In other words, a metal-poor star orbits a large range of the galactic radius during its life. However, a more evident feature seems to be the increasing dispersions of both space velocity and orbits of low-metallicity objects. Regarding the maximum distance from the galactic plane, four stars, HD 6434, 13445, 114762 and 89707, all metal-poorer than [Fe/H] ~ -0.4, come from $Z > 1.0$, while the other stars lie within 0.6 kpc.

It may be suspected that the high occurrence of negative $V_{\rm LSR}$ for [Fe/H] < -0.2 stars indicates that they may help to maintain the presence of the planet in metal-poor environments because they tend to avoid collision with nearby stars. Note, however, that the larger range of Galactic radius of metal-poor stars implies a higher probability of colliding with other objects during their long lives in orbits. Thus, it seems that the stellar dynamics of these metal-poor stars offers no preference for keeping planetary systems. Indeed, these kinematic trends are related to the chemical and dynamical evolution, so the stellar dynamics may be without any influence on the presence of planets.

4.3 Connection with Companion Information

By investigating the orbital parameters as a function of the planet masses listed in Fig. 4, we find that the maximum eccentricity, semi-major axis and thus period, decrease with M_2, while the lower limits of these quantities are independent of the values of M_2. The transition seems to be at $M_2 \sim 150M_{\rm J}$. Specifically, the eccentricity ranges from 0.0 to 0.8 for $M_2 < 150M_{\rm J}$, above which it seems to be $e < 0.3$ except for HD 38529. Both of the maximum semi-major axis and period span a wide range for $M_2 < 150M_{\rm J}$, but are confined to low values for large M_2. Note that HD 195019 has M_2 outside the range of the figures, its details can be found in Table 1. In particular, the low eccentricity and short period orbits for stars with $M_2 > 150M_{\rm J}$ and the wide range for smaller M_2 are interesting, because these seem to be in agreement with the suggestion that stellar binaries have orbital eccentricities ~ 0 for $P < 10$ days and any value between 0 to 1 for longer periods. In addition, we find that stars of group A have larger values than the others at a given M_2. It still remains unclear if this result is due to some kind of

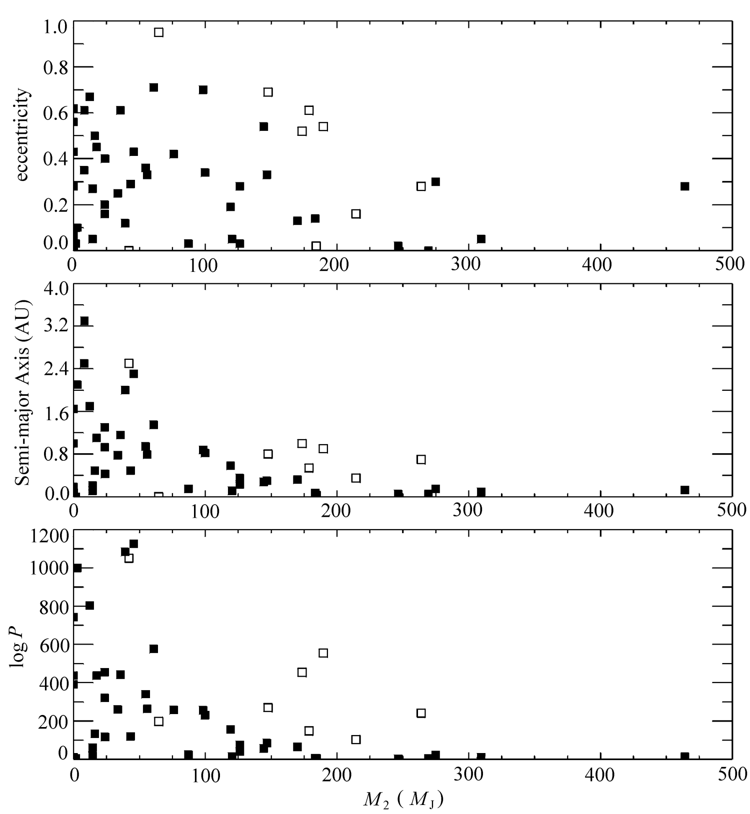

Fig. 4 Orbital parameters vs. the companion mass.

physical mechanism, or is caused by systematic uncertainties in the method used to acquire the inclination angles of the stars of group B.

In Fig. 5, we present the primary mass and metallicity as a function of the companion mass. There is a tendency for stars with low primary masses to be associated with large companion masses, though there are a few exceptions, e.g., HD 195019 has both M_1 and M_2 quite large; some intermidate mass stars with 0.7-1.1 $M_\odot$ have companion masses from $< 13M_\mathrm{J}$ to 300 M_J. We examine the relation between [Fe/H] and M_2, and find that stars with low companion masses have a high mean [Fe/H]: stars with $M_2 < 25M_\mathrm{J}$ have [Fe/H] > -0.3, while those with $M_2 > 25M_\mathrm{J}$ cover a large range of metallicity. Our results either imply a potential negative correlation between M_1 and M_2, or suggest that a low mass companion imposes a stronger influence on the metallicity of its primary. If the latter, it seems to favor the suggestion that planet host stars do have higher metallicity; but the former alternative seems to be more acceptable, because our results show no correlation between [Fe/H] and period, between e and period, or between eccentricity and semi-major axis. Thus, if the derivation of the inclination angle for planet host stars is correct, our conclusion will be that there is no difference in the formation of companions for the three group stars in the sense that there is a smooth transition from large to small companions.

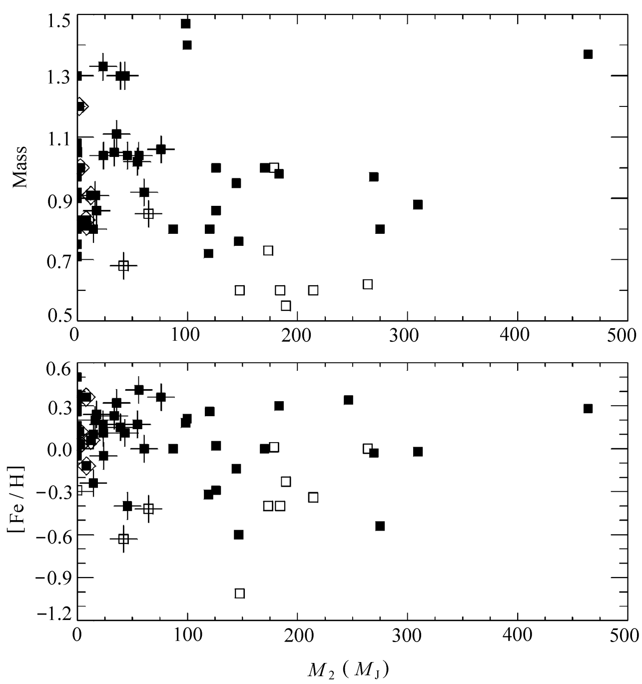

Fig. 5 Mass and metallicity of host star vs. the companion mass.

5 CONCLUDING REMARKS

Based on the available data in literature, we have derived the atmospheric parameters, masses, ages and kinematics of 51 planet host stars. Combined with the data on the companions, we aim to investigate any correlation among the parameters and their connection with the companion data. The main conclusions are: (1) The [Fe/H]–Mass relation is the same for planet host stars and normal field stars, so this relation cannot be used to test the scenario of planetary formation. (2) The age and kinematics seem to indicate that the metallicities of those "planet" host stars are initial. (3) The kinematics does not show any special characteristics, and so would not help to maintain the presence of planets. (4) Based on the companion masses derived from the published inclinations, we search for particularities in some interesting relations and find a smooth transition among the different companion mass ranges of planets, brown dwarfs and stellar objects. It seems that stars with different companion masses have a common origin of formation.

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