A&A 439, 367–373 (2005)
DOI: 10.1051/0004-6361:20052826

Astronomy & Astrophysics

The HARPS search for southern extra-solar planets*

IV. Three close-in planets around HD 2638, HD 27894 and HD 63454

C. Moutou[1], M. Mayor[2], F. Bouchy[1], C. Lovis[2], F. Pepe[2], D. Queloz[2], N. C. Santos[3], S. Udry[2], W. Benz[4], G. Lo Curto[5], D. Naef[2,5], D. Ségransan[2], and J.-P. Sivan[1]

[1] Laboratoire d'Astrophysique de Marseille, Traverse du Siphon, 13376 Marseille Cedex 12, France
e-mail: claire.moutou@oamp.fr
[2] Observatoire de Genève, 51 ch. des Maillettes, 1290 Sauverny, Switzerland
[3] Centro de Astronomia e Astrofísica da Universidade de Lisboa, Observatório Astronómico de Lisboa, Tapada da Ajuda, 1349-018 Lisboa, Portugal
[4] Physikalisches Institut Universität Bern, Sidlerstrasse 5, 3012 Bern, Switzerland
[5] ESO, Alonso de Cordoba 3107, Vitacura Casilla 19001, Santiago, Chile

Received 7 February 2005 / Accepted 22 March 2005

Abstract. We report the discovery of three new planets, detected through Doppler measurements with the instrument HARPS installed on the ESO 3.6 m telescope, La Silla, Chile. These planets are orbiting the main-sequence stars HD 2638, HD 27894, and HD 63454. The orbital characteristics that best fit the observed data are depicted in this paper, as well as the stellar and planetary parameters. The planets' minimum mass is 0.48, 0.62, and 0.38 $M_{\rm Jup}$ for respectively HD 2638, HD 27894, and HD 63454; the orbital periods are 3.4442, 17.991, and 2.817822 days, corresponding to semi-major axis of 0.044, 0.122, and 0.036 AU, respectively. The observational data are carefully analysed for activity-induced effects and we conclude on the reliability of the observed radial-velocity variations as of exoplanetary origin. These three planets support the correlation between the star metallicity and the presence of planets (especially at short orbital distances), pointing towards the peculiar scenario of formation and migration of hot Jupiters.

Key words. stars: individual: HD 2638 – stars: individual: HD 27894 – HD 63454 – stars: planetary systems – techniques: radial velocities – techniques: spectroscopic

1. Introduction

Radial-velocity programs have so far been the main means to success in our present knowledge of extrasolar planets, with today (March 2005) about 150 known exoplanets in the mass and period ranges: [0.044–10] $M_{\rm Jup}$ and [1.2–3090] days (Udry et al. 2003b; Marcy et al. 2004; Schneider 2005). Among the known planets, 15–20% may be called "hot Jupiters", as their orbital distance is less than about one tenth of the Sun-Earth distance.

The HARPS[1] instrument (Pepe et al. 2003) has been in operation since October 2003 on the 3.6 m telescope in La Silla Observatory, ESO, Chile, and has already proven its ability to reach extremely small radial-velocity uncertainties (Santos et al. 2004a). One objective of the radial-velocity survey conducted by the HARPS scientific consortium is to discover jovian planets around a sample of targets that has been expanded in volume, from the original 50 pc of the CORALIE survey (Udry et al. 2000) to approximately 60 pc. This will further constrain the statistics on planetary parameters (mass, semi-major axis and eccentricity) and on the relationship between the planet's and the parent stars' characteristics, from which the formation and migration mechanisms could be refined. For this HARPS exploratory programme, individual Doppler measurements with a photon noise of 3 m s^{-1} were conducted on a thousand of stars, selected within ≃60 pc, excluding known binaries.

In this paper, we report the discovery of three new planets by the HARPS scientific consortium. Section 2 describes the characteristics of the parent stars, while Sect. 3 presents the Doppler measurements and discusses the planetary orbital solutions.

2. Parent stars characteristics

2.1. HD 2638

The HIPPARCOS data (ESA 1997) describe the star HD 2638 as a G5 with visual magnitude 9.44, color index $B-V = 0.886$ and distance to the Sun of 53.7 pc. The derived absolute magnitude is $M_v = 5.79$. With bolometric correction from Flower (1996),

* Based on observations made with the HARPS instrument on the ESO 3.6 m telescope at La Silla Observatory under programme ID 072.C-0488(E).
[1] High-Accuracy Radial-velocity Planet Searcher.

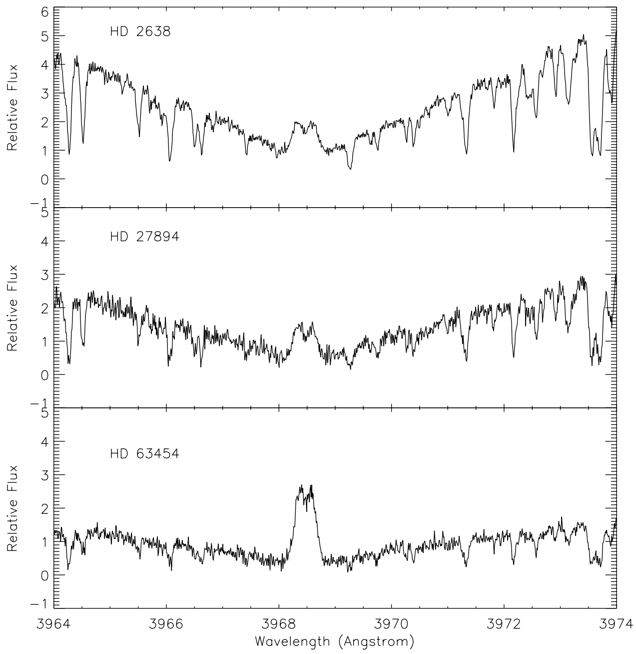

Fig. 1. The HARPS spectrum of the three stars HD 2638, HD 27894, and HD 63454 around the CaII H absorption line. The emission peak in the core of the absorption band is significant for HD 63454 but still shows a fair level of activity.

the derived absolute luminosity is 0.47 $L_{\odot}$. The stellar radius can then be estimated to be approximately 0.84 $R_{\odot}$ from the simple relationship between luminosity, temperature and radius. The analysis of HARPS spectra allows the stellar parameters to be determined, following the method described in Santos et al. (2004b): we derive $T_{\rm eff}$ = 5192±38 K, $\log g$ = 4.29±0.25, and [Fe/H] = +0.16 ± 0.05. This is another planetary system around a metal-rich star, so that this discovery strengthen the observed tendency of metal-rich stars to harbor planets (Santos et al. 2004b, for recent updates). A stellar mass of 0.93 $M_{\odot}$ is derived from the absolute magnitude, color index, and metallicity, after comparison with evolution models (Schaerer et al. 1993; Baraffe et al. 1998). The cross-correlation function gives an estimate of the projected stellar velocity $v \sin i$ = 1.1 km s^{-1}.

The spectral domain of the CaII absorption line (Fig. 1, top) shows a weak emission line at the bottom of the absorption, indicating a low activity level. The chromospheric activity indicator $\log(R'_{\rm HK})$ is –4.82, a value also typical of stars with low activity. From calibrations of main-sequence stars (Noyes et al. 1984), we can infer a rotational period of 37 days and system age of about 3 Gyr. Figure 2 shows how the star locates on the model evolutionary tracks (Baraffe et al. 1998).

2.2. HD 27894

The HIPPARCOS data describe the star HD 27894 as a K2 dwarf with visual magnitude 9.36, color index $B-V$ = 1.003, and distance to the Sun of 42.4 pc (ESA 1997). The derived absolute magnitude is M_v = 6.225 and the absolute luminosity is 0.356 $L_{\odot}$. This value infers a stellar radius of 0.83 $R_{\odot}$. The stellar parameters derived from HARPS spectra are

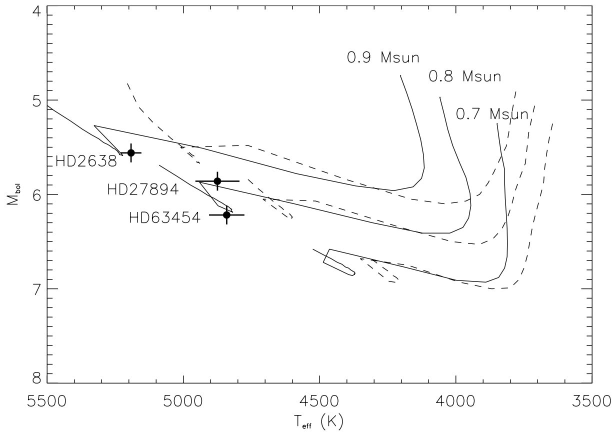

Fig. 2. The stars HD 2638, HD 27894, and HD 63454 over the evolutionary tracks calculated for 0.7, 0.8, and 0.9 $M_{\odot}$ metal-rich stars (Baraffe et al. 1998). The dashed lines are comparison tracks for solar-metallicity stars.

$T_{\rm eff}$ = 4875 ± 81 K, $\log g$ = 4.22 ± 0.26, and [Fe/H] = +0.30 ± 0.07. HD 27894 is significantly rich in heavy elements. At such metallicity, overall statistics on the planet-bearing star sample show that about 25–30% of the stars have a planet (Santos et al. 2001, 2004b). The stellar mass corresponding to the position of this star in the HR diagram is 0.8 $M_{\odot}$.

Parameters derived from the CaII spectral line both indicate a low activity level: $\log(R'_{\rm HK})$ = –4.90 and the emission peak at 3969 Å is weak. HD 27894 is a slow rotator with a period of 44 days and is characterized by a low activity. The calibrated relationship of Noyes et al. (1984) derives an age of 3.9 Gyr. The star thus lies on the main-sequence, again confirmed by comparison with the evolutionary tracks of metal-rich stars (Fig. 2).

2.3. HD 63454

HIPPARCOS data describe the star HD 63454 as a K4 dwarf with visual magnitude 9.37, color index $B-V$ = 1.006, and distance to the Sun of 35.8 pc (ESA 1997). The derived absolute magnitude is M_v = 6.60, and absolute luminosity is 0.256 $L_{\odot}$. The stellar parameters derived from HARPS spectra are $T_{\rm eff}$ = 4841 ± 65 K, $\log g$ = 4.23 ± 0.30, and [Fe/H] = +0.11 ± 0.07, again evidence of an enriched star. A stellar radius of 0.72 $R_{\odot}$ may be inferred, while the stellar mass is 0.8 $M_{\odot}$.

The core of the CaII line in the spectrum of HD 63454 shows a strong emission line, evidence of fairly high activity and a young age. The quantitative indicator $\log(R'_{\rm HK})$ is measured as –4.53, which corresponds to a rotational period of 20 days and age of 1 Gyr.

All stellar parameters are also summarized in Table 1. Figure 2 shows where the three stars are located in the HR diagram, compared to evolution tracks of 0.7, 0.8, and 0.9 $M_{\odot}$ metal-rich stars, from Baraffe et al. (1998). All three lie on the main sequence of enriched stars.

Table 1. Observed and inferred stellar parameters for the planet-hosting stars presented in this paper.

Parameter		HD 2638	HD 27894	HD 63454
Sp		G5	K2V	K4V
V	[mag]	9.44	9.36	9.37
$B-V$	[mag]	0.886	1.003	1.006
π	[mas]	18.62	23.60	27.93
M_V	[mag]	5.79	6.225	6.60
L	[$L_\odot$]	0.47	0.356	0.256
$T_{\rm eff}$	[K]	5192 ± 38	4875 ± 81	4841 ± 65
log g	[cgs]	4.29 ± 0.25	4.22 ± 0.26	4.23 ± 0.30
[Fe/H]	[dex]	+0.16 ± 0.05	+0.30 ± 0.07	+0.11 ± 0.07
M_*	[$M_\odot$]	0.93	0.8	0.8
$v \sin i$	[km s^{-1}]	1.1	≤1.5	1.9
$\log R'_{\rm HK}$		–4.82	–4.90	–4.53
Mt Wilson S		0.23	0.25	0.60
$P_{\rm rot}$	[days]	37	44	20
Age	[Gy]	3.0	3.9	1.0

Table 2. Orbital and physical parameters for the planets presented in this paper. For HD 63454, [a] relates to HARPS measurements, [b] to CORALIE measurements; Col. "HARPS+CORALIE" shows the combined orbital solution, while Col. "HARPS alone" shows the orbital solution using HARPS measurements alone. σ(O–C) is the residual noise after orbital fitting of the combined set of measurements.

Parameter		HD 2638 b	HD 27894 b	HD 63454 b HARPS+CORALIE	HD 63454 b HARPS alone
P	[days]	3.4442 ± 0.0002	17.991 ± 0.007	2.817822 ± 0.000095	2.817 596 ± 0.00015
T	[JD-2 400 000]	53 323.206 ± 0.002	53 275.46 ± 0.48	53 111.129 ± 0.005	53 111.148 ± 0.011
e		0.0	0.049 ± 0.008	0.0	0.0
V	[km s^{-1}]	9.6279 ± 0.0003	82.9023 ± 0.0003	33.8411 ± 0.0006	33.8405 ± 0.0005
ω	[deg]	0.0	132.9 ± 9.7	0.0	0.0
K	[m s^{-1}]	67.4 ± 0.4	58.1 ± 0.5	64.3 ± 0.7	64.4 ± 0.6
$a_1 \sin i$	[10^{-4} AU]	0.2133	0.9601	0.1664	0.1669
$f(m)$	[10^{-9} $M_\odot$]	0.1092	0.3648	0.0775	0.07815
$m_2 \sin i$	[$M_{\rm Jup}$]	0.48	0.62	0.38	0.38
a	[AU]	0.044	0.122	0.036	0.036
$N_{\rm meas}$		28	20	$26^a + 31^b$	26
$S\,pan$	[days]	401	403	$330^a + 57^b$	330
σ (O–C)	[m s^{-1}]	3.3	4.0	7.1	6.5

3. Radial velocity data and orbital solutions

3.1. HD 2638

Observation of HD 2638 with HARPS took place between October 2003 and January 2005. We gathered a total of 28 data points over 434 days with an average individual noise of 1.7 m s^{-1} (Fig. 3). This error includes the photon noise and calibration noise, estimated around 0.8 m s^{-1}. Note that this does not represent the ultimate noise level of the instrument; as said earlier, the objective of this program is to reach 3 m s^{-1} accuracy. We observed periodic variations in the radial velocity of the star. The best Keplerian orbital solution is characterized by a period of 3.4442 ± 0.0002 days and a semi-amplitude of the variations K = 67.4 ± 0.4 m s^{-1}. All planetary parameters are listed in Table 2.

The residual noise to the fit is 3.3 m s^{-1}. This residual radial-velocity error significantly exceeds the photon and calibration noise recorded in each individual HARPS measurement, probably due to a combination of two effects: the stellar activity and short-term stellar oscillations. Due to the very low instrumental noise achieved with HARPS, our data are indeed sensitive to the low-amplitude oscillations of main-sequence stars (Mayor et al. 2003; Bouchy 2005), as shown by the high time-sampling observations of HD 160691 (Bouchy et al. 2005).

From the optimal orbital solution and measured parameters of the parent star, the derived minimum mass of the planet is $m_2 \sin i$ = 0.48 $M_{\rm Jup}$. The eccentricity is 0, meaning an orbit circularized by tidal effects. Given the period and derived stellar mass, an orbital distance of 0.044 AU is obtained. The equilibrium temperature of this hot Jupiter planet, assuming an albedo of 0.3, would be on the order of 1100 K (Guillot et al. 1996).

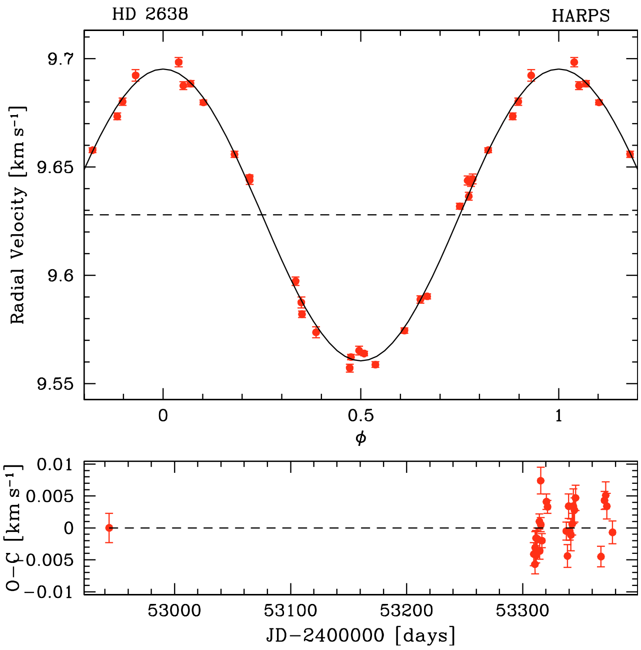

Fig. 3. The radial-velocity curve of HD 2638 obtained with HARPS. *Top*: with phase-folding; *Bottom*: individual radial-velocity measurements versus time.

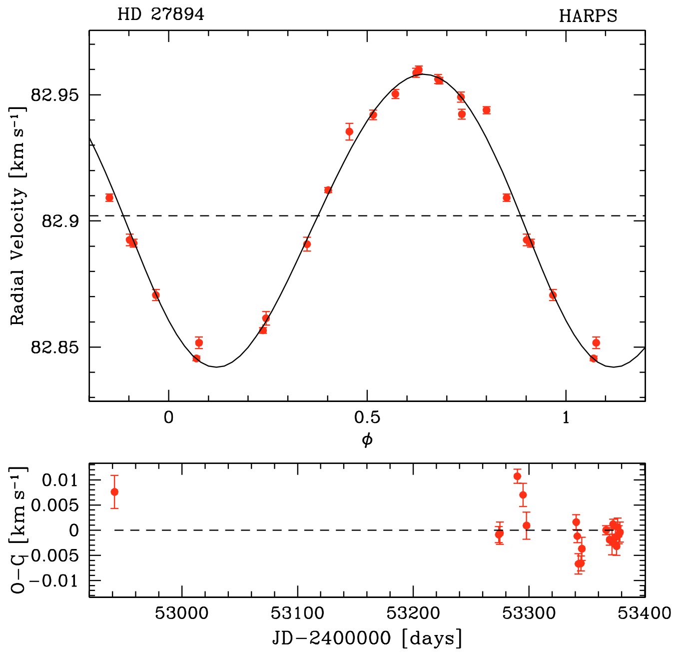

Fig. 5. The HARPS radial-velocity curve of HD 27894.

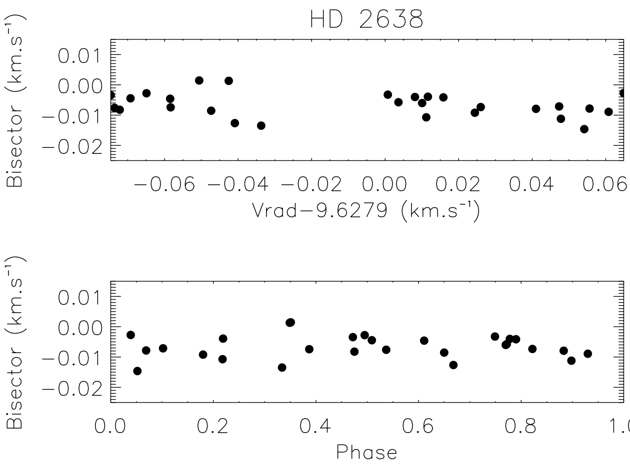

Fig. 4. The inverse bisector slope plotted against the radial velocity of HD 2638 (*top*) and against the planet phase (*bottom*). No correlation between these quantities is observed.

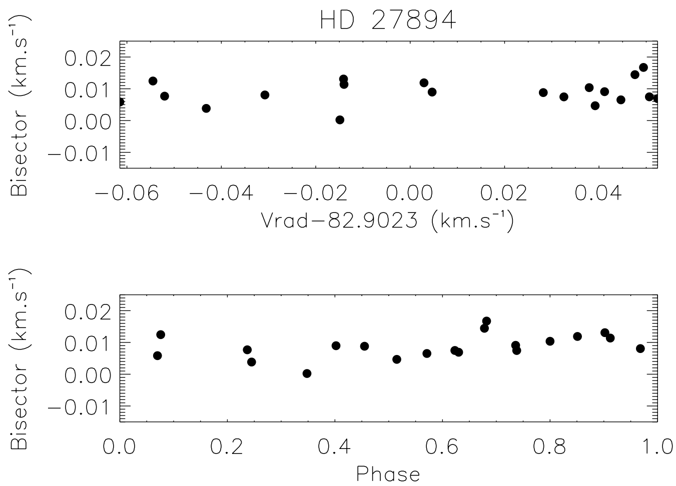

Fig. 6. The inverse bisector slope is plotted against the radial velocity of HD 27894 (*top*) and against the planet phase (*bottom*). No correlation between these quantities is observed.

In order to check for any radial-velocity fluctuations that would be induced by stellar activity, the line bisector behaviour was checked for. The method and its application are described in Queloz et al. (2001). Figure 4 (bottom) shows measurement of the inverse slope of the bisector of HD 2638 measurements, phased with the period of detected radial-velocity variations. The line bisector does not fluctuate at a similar period. No correlation was found between the line bisector and the radial-velocity variations (Fig. 4, top) nor between the line bisector and the residuals to the fit. We can thus exclude that the main periodic radial-velocity variations observed for this star were induced by stellar activity.

Finally, photometric observations were carried out on this system, in order to check for the occurence of planetary transits at phase 0.25. The short-period planet has a 10% probability of an alignment favorable to the transit observation. Relative photometry at a level of a few mmag was acquired at Observatoire de Haute Provence on the 120 cm telescope in the R filter, as well as at the Strömgren Automatic Telescope at ESO (Olsen et al. in prep.). No transit was found.

3.2. HD 27894

Twenty HARPS data points were registered over 437 days on the star HD 27894, between October 2003 and January 2005 (Fig. 5). The noise on individual measurements averages

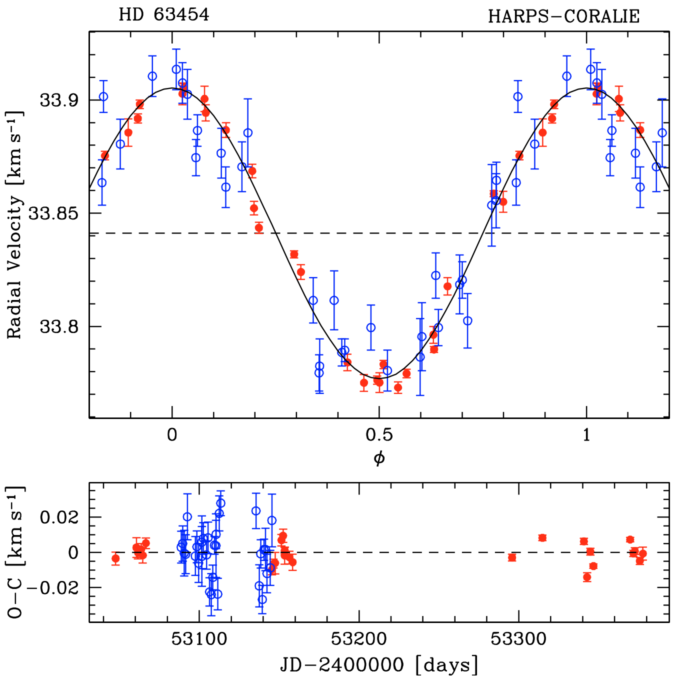

Fig. 7. The radial-velocity curve of HD 63454. Open circles show CORALIE data, while filled circles show HARPS data.

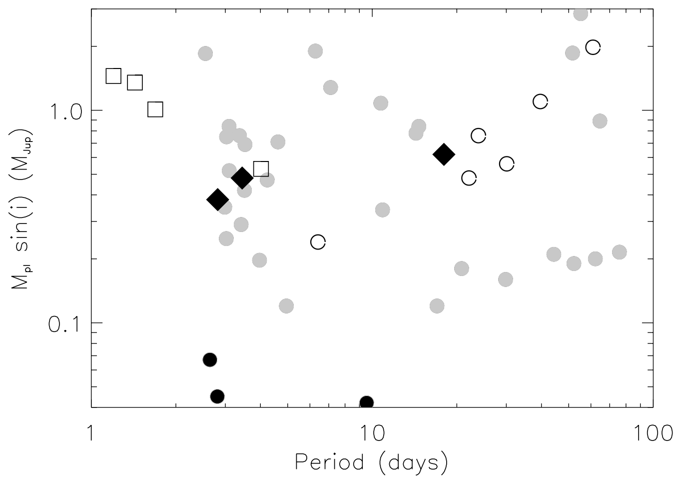

Fig. 9. The mass period diagram for all known short-period planets. Open circles stand for planets orbiting subsolar-metallicity stars while filled circles correspond to planets around metal-rich stars. Squares indicate those planets with unmeasured metallicity. The dark-filled circles show the lower-mass, possibly rocky planets. The three planets described in this paper are marked with a lozenge. The vast majority of planet-bearing stars are metal-rich in this corner of the (M, P) diagram, and the new HARPS planets support this observation.

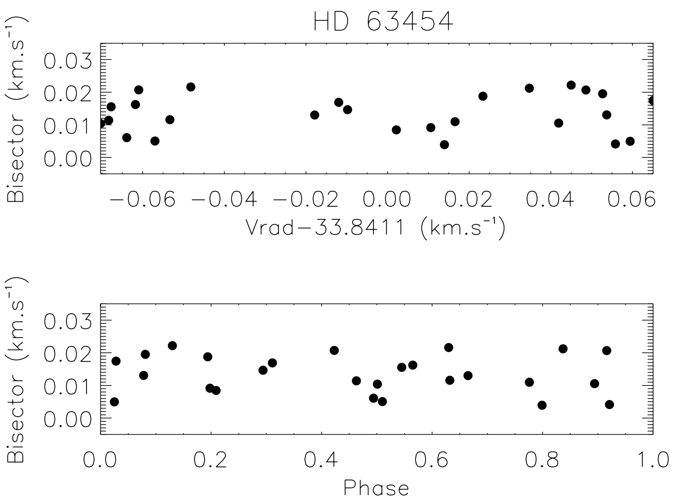

Fig. 8. The inverse bisector slope is plotted against the radial velocity of HD 63454 (*top*) and against the planet phase (*bottom*). No correlation between these quantities is observed.

1.8 m s^{-1}. The optimal Keplerian orbit to fit the data is characterized by a period of 17.991 ± 0.007 and semi-amplitude RV variations $K = 58.1 \pm 0.5$ m s^{-1}. The orbit is slightly elongated with eccentricity of 0.049 ± 0.008. The inferred minimum mass of the planet is 0.62 $M_{\rm Jup}$, and the semi-major axis of its orbit is 0.122 AU. The equilibrium temperature, estimated as above, is on the order of 550 K.

As previously described, the line bisectors of HD 27894 were checked for any fluctuation related to the radial-velocity periodic variations, but no correlation between the planet signal and the stellar activity was observed (Fig. 6).

3.3. HD 63454

The star HD 63454 was observed in February 2004 with HARPS, then followed during March and May 2004 with CORALIE, and finally observed again with HARPS in May 2004 and from October 2004 to January 2005. In total, there are 26 HARPS data points and 31 CORALIE data points, which are depicted in Fig. 7. The noise of individual measurements averages 3.0 m s^{-1} with HARPS and 10.3 m s^{-1} with CORALIE. With data points acquired with CORALIE, we focussed on better constraining the expected transit ephemeris for a photometric follow-up.

The orbital solution that fits both sets of data better is a circular Keplerian orbit with a period of 2.817822 ± 0.000095 days and a semi-amplitude $K = 64.3 \pm 0.7$ m s^{-1} when using data points from both instruments. The orbital solution issued from the HARPS data alone is not significantly different (see Table 2) since the CORALIE data set has larger noise and does not extend over a long period of time. The semi-major axis is 0.036 AU. The corresponding minimum mass for the planet is 0.38 $M_{\rm Jup}$ and the equilibrium temperature at such distance is about 800 K. The relatively large radial-velocity jitter residual to the fit (7.1 m s^{-1}) is most likely due to the significant activity level of the relatively young parent star.

The line bisector inverse slope measured in HARPS spectra shows no common behaviour with the planet (Fig. 8). This again excludes stellar activity as responsible for the main radial-velocity oscillation, thus confirming the short-orbit planet. Photometric follow-up at the Strömgren Automatic Telescope showed no planetary transit at the expected orbital phase, while the transit probability was 10%, similar to the planet around HD 2638.

HD 63454b is therefore another hot Jupiter-like planet with mass and period quite similar to the previously described planet orbiting HD 2638. Considering only massive planets, HD 63454b has the second shortest period detected in Doppler surveys so far, after HD 73256b (Udry et al. 2003a, P = 2.5486 days). Of similar periods, smaller than 3 days, the light planets GJ436b (Butler et al. 2004) and 55CnCe (McArthur et al. 2004) have also been found by the radial-velocity method, but the different mass regime possibly implies different constraints for the formation and inward migration.

In photometric surveys, comparatively, several planets have been discovered at periods shorter than 3 days. This may be due to the different biases of detection methods as discussed in Gaudi et al. (2005), although some theoretical options would explain the distributions observed in Doppler surveys (Udry et al. 2003b). More statistics will allow refining such studies.

4. Conclusion

The radial-velocity periodic variations observed on the three stars presented in this paper are convincing evidence of planetary companions. The data sets over more than one year allow a precise orbital solution to be fit. Residual errors on the fit are in the range 3–4 m s^{-1}. The photon noise uncertainty implies an external error source of 2–3 m s^{-1} due to intrinsic stellar activity and short-term acoustic oscillations. Smaller residual would be achieved if the individual measurements were obtained from the combination of several consecutive exposures, during which the stellar oscillations would be averaged out (Santos et al. 2004a; Bouchy 2005; Lovis et al. 2005). Robust diagnostics of the line bisector have shown that stellar activity alone would not produce the observed radial-velocity variation. These three new planetary systems were discovered during observations by the HARPS scientific consortium.

The three planets orbit metal-rich, late-type G or K dwarfs. They reinforce the link between the parent star's metallicity and the presence of a planet, recently updated in Santos et al. (2004b), and also the specific possibility that stars hosting hot jupiters may be particularly metal-rich (Gonzalez 1998; Queloz et al. 2000; Sozzetti et al. 2004). The orbital distances and minimum masses measured for the planets HD 2638b, HD 27894b, and HD 63454b lie within the populated parameter space of exoplanets (Fig. 9). Their long-term behaviour will be followed up with HARPS, in order to monitor the known planets and to search for more distant planets in the same systems.

Appendix: RV measurement tables

This appendix includes the three tables of individual radial-velocity measurements.

Acknowledgements. We would like to thank the Swiss National Science Foundation and the Portuguese Fundação para a Ciência e a Tecnologia for their support. This study benefited from the support of the HPRN-CT-2002-00308 European programme. We are grateful to the ESO staff for their help during observations.

Table A.1. Radial velocity values for HD 2638.

JD-2 400 000.	Radial Vel. [km s^{-1}]	Uncertainty [m s^{-1}]
52 943.6177	9.64449	2.29
53 309.6064	9.68763	1.77
53 310.6388	9.5821	1.55
53 310.7615	9.57373	2.54
53 311.5317	9.57449	1.24
53 311.7292	9.59033	1.21
53 312.5217	9.68021	1.70
53 314.5097	9.5623	1.17
53 314.7230	9.55877	1.28
53 315.5254	9.64377	2.07
53 315.7044	9.65785	1.05
53 316.6692	9.67984	1.14
53 320.5142	9.64522	1.24
53 321.5129	9.56389	1.01
53 337.6039	9.65592	1.35
53 338.6067	9.55718	1.85
53 339.6620	9.64302	1.91
53 340.6647	9.68852	1.41
53 341.6293	9.58747	2.54
53 342.6660	9.58888	1.70
53 343.6306	9.69233	2.74
53 344.6234	9.64393	1.87
53 345.5763	9.56528	2.02
53 367.5781	9.67339	1.56
53 370.5615	9.6319	1.39
53 371.5578	9.6984	2.07
53 372.5761	9.59725	1.99
53 377.5276	9.63646	1.82

Table A.2. Radial velocity values for HD 27894.

JD-2 400 000.	Radial Vel. [km s^{-1}]	Uncertainty [m s^{-1}]
52 941.8267	82.9354	3.27
53 273.8782	82.8912	1.61
53 274.8819	82.8706	2.21
53 289.8592	82.9439	1.36
53 294.8268	82.8517	2.25
53 297.8608	82.8614	2.74
53 340.7619	82.9599	1.53
53 341.7050	82.9556	1.25
53 342.7165	82.9423	2.04
53 344.7422	82.9092	1.49
53 345.6558	82.8925	2.28
53 366.6739	82.8455	0.91
53 369.6850	82.8566	1.14
53 371.6842	82.8908	2.67
53 372.6429	82.9122	0.98
53 374.6813	82.942	1.85
53 375.6820	82.9503	1.75
53 376.6256	82.9587	1.80
53 377.6168	82.9562	1.85
53 378.6536	82.9491	2.00

Table A.3. HARPS radial velocity values for HD 63454.

JD-2 400 000.	Radial Vel. [km s^{-1}]	Uncertainty [m s^{-1}]
53 047.6249	33.7751	3.66
53 060.6292	33.9005	5.57
53 061.6017	33.7841	3.63
53 063.5925	33.8867	3.33
53 064.6375	33.7752	4.37
53 066.5900	33.8686	3.04
53 145.5000	33.8522	3.02
53 146.4798	33.773	2.47
53 147.4632	33.8856	6.10
53 151.4550	33.824	3.32
53 152.4522	33.8177	3.78
53 153.4659	33.9027	4.81
53 153.4743	33.9054	1.94
53 156.4434	33.8943	3.62
53 158.4660	33.855	4.62
53 295.8806	33.7792	1.89
53 314.8410	33.8318	1.57
53 340.8087	33.7832	1.76
53 342.7792	33.8435	2.55
53 344.7872	33.8981	1.92
53 346.7883	33.7898	1.34
53 369.7367	33.8586	1.35
53 371.7621	33.7763	1.84
53 372.7287	33.8754	1.94
53 375.7693	33.8918	2.03
53 377.7790	33.7963	3.74

References

Baraffe, I., Chabrier, G., Allard, F., & Hauschildt, P. H. 1998, A&A, 337, 403

Bouchy, F. 2005, in Dome C Astronomy/Astrophysics Meeting (EDP Sciences), EAS Pub. Ser., 14, in press

Bouchy, F., Bazot, M., & Santos, N. 2005, A&A, submitted

Butler, R. P., Vogt, S. S., Marcy, G. W., et al. 2004, ApJ, 617, 580

ESA 1997, VizieR Online Data Catalog, 1239, 0

Flower, P. J. 1996, ApJ, 469, 355

Gaudi, S., Seager, S., & Mallen-Ornelas, G. 2005, ApJ, in press [arXiv:astro-ph/0409443]

Gonzalez, G. 1998, A&A, 334, 221

Guillot, T., Burrows, A., Hubbard, W. B., Lunine, J. I., & Saumon, D. 1996, ApJ, 459, L35

Lovis, C., Mayor, M., Bouchy, F., et al. 2005, A&A, 437, 1121

Marcy, G. W., Butler, R. P., Fischer, D. A., & Vogt, S. S. 2004, ASP Conf. Ser., 321, 3

Mayor, M., Pepe, F., Queloz, D., et al. 2003, Messenger, 114, 20

McArthur, B. E., Endl, M., Cochran, W. D., et al. 2004, ApJ, 614, L81

Noyes, R. W., Hartmann, L. W., Baliunas, S. L., Duncan, D. K., & Vaughan, A. H. 1984, ApJ, 279, 763

Pepe, F., Rupprecht, G., Avila, G., et al. 2003, in SPIE, 4841, 1045

Queloz, D., Henry, G. W., Sivan, J. P., et al. 2001, A&A, 379, 279

Queloz, D., Mayor, M., Weber, L., et al. 2000, A&A, 354, 99

Santos, N. C., Israelian, G., & Mayor, M. 2001, A&A, 373, 1019

Santos, N. C., Bouchy, F., Mayor, M., et al. 2004a, A&A, 426, L19

Santos, N. C., Israelian, G., & Mayor, M. 2004b, A&A, 415, 1153

Schaerer, D., Charbonnel, C., Meynet, G., Maeder, A., & Schaller, G. 1993, A&AS, 102, 339

Schneider, J. 2005, http://www.obspm.fr/encycl/encycl.html

Sozzetti, A., Yong, D., Torres, G., et al. 2004, ApJ, 616, L167

Udry, S., Mayor, M., Naef, D., et al. 2000, A&A, 356, 590

Udry, S., Mayor, M., Clausen, J. V., et al. 2003a, A&A, 407, 679

Udry, S., Mayor, M., & Santos, N. C. 2003b, A&A, 407, 369