Astronomy & Astrophysics manuscript no. hip11952final
February 14, 2013
© ESO 2013

arXiv:1302.3093v1 [astro-ph.EP] 13 Feb 2013

The GAPS Programme with HARPS-N@TNG II: No giant planets around the metal-poor star HIP 11952 *

S. Desidera[1], A. Sozzetti[2], A.S. Bonomo[2], R. Gratton[1], E. Poretti[3], R. Claudi[1], D.W. Latham[4], L. Affer[5], R. Cosentino[6,7], M. Damasso[8,9,2], M. Esposito[10,11], P. Giacobbe[12,2], L. Malavolta[8,13], V. Nascimbeni[8,1], G. Piotto[8,1], M. Rainer[3], M. Scardia[3], V.S. Schmid[14], A.F. Lanza[6], G. Micela[5], I. Pagano[6], L. Bedin[1], K. Biazzo[15], F. Borsa[3,16], E. Carolo[1], E. Covino[15], F. Faedi[17], G. Hébrard[18], C. Lovis[13], A. Maggio[5], L. Mancini[19], F. Marzari[20,1], S. Messina[6], E. Molinari[7,21], U. Munari[1], F. Pepe[13], N. Santos[22,23], G. Scandariato[6], E. Shkolnik[24], J. Southworth[25]

[1] INAF – Osservatorio Astronomico di Padova, Vicolo dell'Osservatorio 5, I-35122, Padova, Italy
[2] INAF – Osservatorio Astrofisico di Torino, Via Osservatorio 20, I-10025, Pino Torinese, Italy
[3] INAF – Osservatorio Astronomico di Brera, Via E. Bianchi 46, I-23807 Merate (LC), Italy,
[4] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138
[5] INAF – Osservatorio Astronomico di Palermo, Piazza del Parlamento, Italy 1, I-90134, Palermo, Italy
[6] INAF – Osservatorio Astrofisico di Catania, Via S.Sofia 78, I-9512, Catania, Italy
[7] Fundación Galileo Galilei - INAF, Rambla José Ana Fernndez Pérez, 7 38712 Breña Baja, TF - Spain
[8] Dip. di Fisica e Astronomia Galileo Galilei – Università di Padova, Vicolo dell'Osservatorio 2, I-35122, Padova, Italy
[9] Osservatorio Astronomico della Regione Autonoma Valle d'Aosta, Fraz. Lignan 39, 11020, Nus (Aosta), Italy
[10] Instituto de Astrofisica de Canarias, C/Via Lactea S/N, E-38200 La Laguna, Tenerife, Spain
[11] Departamento de Astrofisica, Universidad de La Laguna, E-38205 La Laguna, Tenerife, Spain
[12] Dipartimento di Fisica, Università di Trieste, Via Tiepolo 11, I-34143 Trieste, Italy
[13] Observatoire Astronomique de l'Université de Geneve, 51 ch. des Maillettes - Sauverny, 1290, Versoix, Switzerland
[14] Instituut voor Sterrenkunde, K.U. Leuven, Celestijnenlaan 200D, 3001 Leuven, Belgium
[15] INAF – Osservatorio Astronomico di Capodimonte, Salita Moiariello 16, I-80131, Napoli, Italy
[16] Dipartimento di Scienza e Alta Tecnologia, Università dell'Insubria, Via Valleggio 11, 22100 Como, Italy
[17] Department of Physics, University of Warwick, Gibbet Hill Road, Coventry, CV4 7AL, UK
[18] Institut d'Astrophysique de Paris, UMR7095 CNRS, Univ. P. & M. Curie, 98bis bd. Arago, F-75014 Paris, France
[19] Max-Planck-Institut für Astronomie, Königstuhl 17, D-69117, Heidelberg, Germany
[20] Dipartimento di Fisica e Astronomia Galileo Galilei – Università di Padova, Via Marzolo 8, Padova, Italy
[21] INAF - IASF Milano, via Bassini 15, I-20133 Milano, Italy
[22] Centro de Astrofísica, Universidade do Porto, Rua das Estrelas, 4150-762 Porto, Portugal
[23] Departamento de Física e Astronomia, Faculdade de Ciências, Universidade do Porto, Portugal
[24] Lowell Observatory, 1400 W. Mars Hill Road, Flagstaff, AZ 86001, USA
[25] Astrophysics Group, Keele University, Staffordshire, ST5 5BG, UK

Received / Accepted

ABSTRACT

In the context of the program Global Architecture of Planetary Systems (GAPS), we have performed radial velocity monitoring of the metal-poor star HIP 11952 on 35 nights over about 150 days using the newly installed high resolution spectrograph HARPS-N at the TNG and HARPS at ESO 3.6m telescope. The radial velocities show a scatter of 7 m s^{-1}, compatible with the measurement errors for such a moderately warm metal-poor star ($T_{\rm eff} = 6040 \pm 120$ K; [Fe/H] $= -1.9 \pm 0.1$). We then exclude the presence of the two giant planets with periods of 6.95 ± 0.01 d and 290.0 ± 16.2 d and radial velocity semi-amplitudes of 100.3 ± 19.4 m s^{-1} and 105.2 ± 14.7 m s^{-1}, respectively, which had recently been announced. This result is important considering that HIP 11952 was thought to be the most metal-poor star hosting a planetary system with giant planets, thus challenging some models of planet formation.

Key words. (Stars:) individual: HIP 11952 — planetary systems — techniques: radial velocities

1. Introduction

The identification of planets around stars with abundances of heavy element significantly lower than the Sun represents a relevant test for models of the formation of planetary systems. On the one hand, assuming stellar metallicity ([Fe/H]) to be a natural proxy for the actual heavy metal content of the primordial circumstellar disk, the core-accretion scenario for giant planet formation predicts

---

Send offprint requests to: S. Desidera

* Based on observations made with the Italian Telescopio Nazionale Galileo (TNG) operated on the island of La Palma by the Fundacion Galileo Galilei of the INAF at the Spanish Observatorio del Roque de los Muchachos of the IAC in the frame of the program Global Architecture of Planetary Systems (GAPS). Based on observations collected at the La Silla Observatory, ESO (Chile): Program 185.D-0056.

that the planet frequency $f_{\rm p}$ should increase with higher [Fe/H] (Ida & Lin 2004; Mordasini et al. 2009a), as the increased surface density of solids facilitates the growth of embryonic cores, thus greatly enhancing the formation of gas giant planets around more metal-rich stars. Indeed, there exist theoretical expectations for threshold values of [Fe/H] below which giant planets cannot form, [Fe/H] $\simeq -0.5$ (Johnson & Li 2012; Mordasini et al. 2012). On the other hand, gas giant planet formation by gravitational instability is less sensitive to the disk metal content, thus $f_{\rm p}$ is expected to be independent of [Fe/H] (Boss 2002).

The observational evidence of a strong dependence of $f_{\rm p}$ on [Fe/H] for giant planets (Santos et al. 2004; Fischer & Valenti 2005) is commonly considered as supporting the core-accretion mechanism (Mordasini et al. 2009b). No significant trends of f_p with [Fe/H] are observed for low-mass planets (Neptunes and super-Earths) in radial-velocity (RV) surveys, for the metal abundance range $-0.5 \leq$[Fe/H]$\leq +0.1$ (Mayor et al. 2011; Sousa et al. 2011). This result was recently confirmed by statistical analyses of *Kepler* transiting planet candidates (Buchhave et al. 2012). Moreover, low-mass planets seem to be rare around super-metal-rich stars (Jenkins et al. 2012).

The $f_{\rm p}$–[Fe/H] relation for giant planets is firmly established on a solid statistical basis for [Fe/H] > 0.0. In this regime, a simple power-law fit with $\alpha \times 10^{\beta[\rm Fe/H]}$, and β in the range 1.5–2.0, well represents the observed trend (e.g Fischer & Valenti 2005; Sozzetti et al. 2009; Johnson et al. 2010). Stars with [Fe/H] $\sim +0.3$ appear 4–5 times more likely to host a giant planet than solar-metallicity dwarfs. At [Fe/H] $\simeq 0.0$, f_p is in the neighbourhood of 3–5%. The situation is however less clear for [Fe/H] < 0.0, and recent studies (Mortier et al. 2012) indicate the possibility that a power law might not describe correctly the relation in the low-metallicity regime.

The uncertainties still apparent in statistical studies stem primarily from the relatively limited sample sizes of metal-poor stars in large RV surveys. Attempts at mitigating this limitation have been made in the past, with experiments focusing on RV searches for giant planets around about 250 metal-poor stars carried out by Sozzetti et al. (2006, 2009) with Keck/HIRES and Santos et al. (2011) using HARPS on the ESO 3.6m telescope. The outcome of the first survey was a null result, while the HARPS survey yielded three detections at the metal-rich end ([Fe/H] ~ -0.5) of the sample (Santos et al. 2007, 2010). Another project started in June 2009 around a sample of 96 metal-poor stars with the FEROS spectrograph. Detections have been reported from this survey of a short-period ($P = 16$ d) giant planet around the metal-poor horizontal branch star HIP 13044 (Setiawan et al. 2010) and of a two-planet system orbiting the F dwarf HIP 11952 (Setiawan et al. 2012, hereafter S12).

The HIP 11952 system is of particular interest. The primary is a high-proper-motion, nearby ($d = 112$ pc), relatively bright ($V = 9.85$) early F-type dwarf (possibly a subgiant), with [Fe/H] $= -1.9 \pm 0.1$ (S12). The two planets reported by S12 have $P = 6.95 \pm 0.01$ d and and minimum masses $m_2 \sin i = 0.78 \pm 0.16$ $\rm M_J$ and 2.93 ± 0.42 $\rm M_J$, respectively. The HIP 11952 system, with a metallicity ten times lower than the second-lowest metallicity giant-planet hosting dwarf, poses a severe challenge to the core-accretion model (Johnson & Li 2012; Mordasini et al. 2012).

HIP 11952 was included in our program focusing on known planetary systems within the framework of the long-term project *Global Architecture of Planetary Systems* (GAPS) recently started in open time using HARPS-N at the Telescopio Nazionale Galileo (TNG). A description of the program is provided in Covino et al. (A&A to be submitted). We aimed at a) improving the quality of the orbital solutions reported by S12, and b) looking for evidence of lower-mass companions. In this Letter, based on RV measurements with typical internal errors 5–10 times lower than the originally published FEROS values, we report a non-detection of both giant planets announced by S12.

2. HARPS-N

HARPS-N is an échelle spectrograph covering the visible wavelength range between 383 and 693 nm (Cosentino et al. 2012). It is a near-twin of the HARPS instrument mounted at the ESO 3.6-m telescope in La Silla (Mayor et al. 2003). It was installed at the TNG in spring 2012. After instrument commissioning in late spring and summer 2012, it was offered for open time programs starting in August 2012.

The instrument is located in a thermally-controlled room, within a vacuum-controlled enclosure to ensure the required stability, and is fed by two fibres at the Nasmyth B focus of the TNG. The second fibre can be used for simultaneous calibration (currently with a Th-Ar hollow-cathode lamp) or for monitoring of the sky depending on the science goal and target brightness. Both fibres have an aperture on the sky of 1 arcsec. The spectra are recorded on an E2V 4k4 CCD 231 with a 15 μm pixel size. The resulting sampling is about 3.3 pixels (FWHM) and the spectral resolution is about 115,000. Early observing tests yielded an instrument total efficiency of $\varepsilon = 7\%$ at 550 nm, including losses due to the Earth's atmosphere and the telescope mirrors.

A failure of the red side of the CCD in late Sept 2012 caused the observations between Sept 29th and Oct 25th 2012 to be performed using the blue side only. A new CCD was installed at the beginning of November 2012, and observations after this date were performed with the full spectral range. The possible impact of the observations taken with only half of the spectral range is discussed in § 4.

3. Observations and data reduction

HIP 11952 was observed with HARPS-N on 25 nights from 2012 Aug 7 to 2013 Jan 6. The Th-Ar simultaneous calibration was used in all observations. The drift correction with respect to the reference calibration was almost always below 1 m s^{-1}. The integration time of 900 s adopted for all the observations led to a typical S/N ratio of $\sim$ 70–80 per pixel on the extracted spectrum at 460 nm. Additional observations on 14 nights in two runs from 2012 Dec 11 to 2013 Jan 5 were also gathered at the ESO 3.6m telescope using HARPS. An integration time of 1200 s was adopted.

RV measurements, and their internal errors, were obtained using the online pipelines of HARPS and HARPS-N, which are based on the weighted cross-correlation function (CCF) method (Baranne et al. 1996; Pepe et al. 2002). The G2 mask was adopted (the earliest-type one available). The median of the internal errors is $\sigma_{\rm RV} = 5.8$ m s^{-1} for HARPS-N (full CCDs in use) and $\sigma_{\rm RV} = 5.6$ m s^{-1} for HARPS. The relatively large RV errors are due to the paucity of spectral lines of such a moderately warm, metal-poor star. The HARPS-N spectra between JD 2456199 and 2456228 were acquired with only the spectral orders falling on the blue side of the CCD. Besides the increase of the RV uncertainties due to the lower number of lines (median $\sigma_{\rm RV}$ = 8.3 m s^{-1}), using only half of the spectral range also introduced a systematic RV zero-point shift, with possible additional shifts due to the slight change in dispersion and spectral resolution required for the optimisation of the échelle grating angle. We estimated such a shift by deriving the RVs of full-chip spectra including only the spectral orders on the blue side of the CCD, i.e. with $\lambda < 534.75$ nm. The average offset is 7.4 ± 0.9 m s^{-1}, the half-chip RVs being higher. Such a shift is consistent with RV differences observed for other stars in the GAPS program using the same mask. Additional offsets should also be present between the RVs obtained with HARPS and HARPS-N, as they cover slightly different spectral ranges, and possibly for the RVs taken with the new HARPS-N CCD since focus adjustments were made and chip properties may be different. However, from the available data, these offsets appear below the measurement uncertainties.

4. Analysis

The relative RV time series is shown in Fig. 1. We report in Table 1 the full dataset. We included the correction of +7.4 m s^{-1} for the half-chip RVs. We anticipate that, whilst this has an obvious impact when attempting to search for RV variations with an amplitude close to the measurement uncertainties or to investigate the existence of a long-term trend, the main result of the paper is entirely unaffected by this procedure. The RV measurement obtained on 2012 Nov 12 (the blue open circle at JD 2456244.5992 in the upper panel of Fig .1), immediately after operations were resumed with the new HARPS-N CCD in place, is not included in the analysis as it has discrepant values of CCF contrast and activity index, pointing to a temporary calibration problem with the new setup.

The offset-corrected scatter (6.9 m s^{-1}) is consistent with the internal errors. Considering our sampling, RV variations with periods and semi-amplitudes ($\sim$ 100 m s^{-1}) close to those reported in Setiawan et al. (2012) are clearly ruled out. A Lomb-Scargle periodogram of the RVs does not indicate any significant periodicities in the range 2–400 days (Fig. 2). The confidence levels in Fig. 2 were obtained by random permutations as in Desidera et al. (2011).

Furthermore, there are neither significant periodicities nor correlations of the RVs with the CCF FWHM, the CCF contrast, and the bisector velocity span, as obtained by the instruments' pipelines, as well as with the Ca II H&K activity indicator, measured as in Desidera et al. (2006). S12 also suggest that HIP 11952 could be a pulsating variable. This possibility would be of great relevance, since in this case the RV measurements should primarily show the effect of the pulsation. The power spectra of the HIPPARCOS and ASAS (All-Sky Automated Survey; Pojmanski 2002) photometric data are very noisy due to their poor spectral windows, but no significant periodic signal is detected.

Our RVs do not show significant long-term trends. To further constrain the existence of a stellar companion on a long-period orbit, we considered the 14 RVs obtained by Latham et al. (2002) with the CfA Digital Speedometers (DS) between 1984 and 1998. Typical errors are 0.7 km s^{-1} and no obvious trend in the RVs over that time span is apparent. Furthermore, Latham (private communication) obtained five new RVs with the Tillinghast Reflector Echelle Spectrograph (TRES) at the FLWO observatory over a span of eight nights during December 2012 with typical errors of 0.1 km s^{-1}. The average velocity for these RVs, when shifted to the velocity zero point of the CfA DS (determined from extensive observations of standard stars), is 23.90 ± 0.05 km s^{-1} (uncertainty of the mean), compared to 23.64 ± 0.25 km s^{-1} for the 14 old RVs from the CfA DS. The probability that the star has a constant velocity, given the internal errors of the 19 observations, is P(χ^2) = 0.47. Thus there is no evidence for a secular drift in the velocities of HIP 11952 over a span of 29 years.

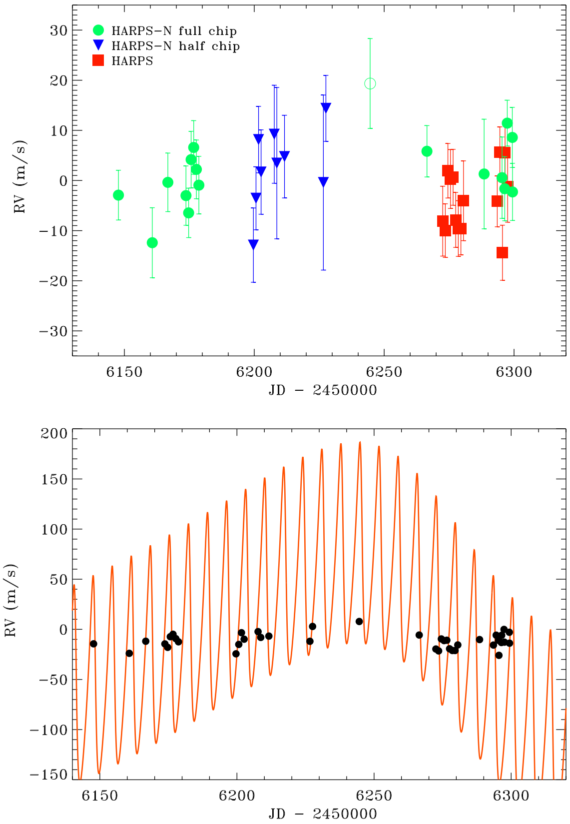

Fig. 1. Relative RVs of HIP 11952 obtained with HARPS-N and HARPS. In the upper panel, green circles represent full-chip HARPS-N data, blue triangles blue-chip HARPS-N data and red squares HARPS data. An offset of −7.4 m/s was applied to the blue-chip data. The open green circle is not included in the analysis. In the lower panel the predicted RV signature of the two planets by S12 is overplotted as a solid line.

Following Sozzetti et al. (2009), upper limits on the minimum mass of possible planetary companions with $3 \leq P \leq 350$ days and eccentricity $e < 0.6$ were derived from our data with 99% confidence level, based on the F-test and χ^2 statistics (Fig. 3). They show that both the inner and outer planets claimed by S12 are ruled out by our observations, at the 6-σ and 4-σ level, respectively. Actually, this test excludes at the given level of confidence *any* planet with masses and periods as given by S12, whatever their orbital parameters. Planets with masses, periods and other

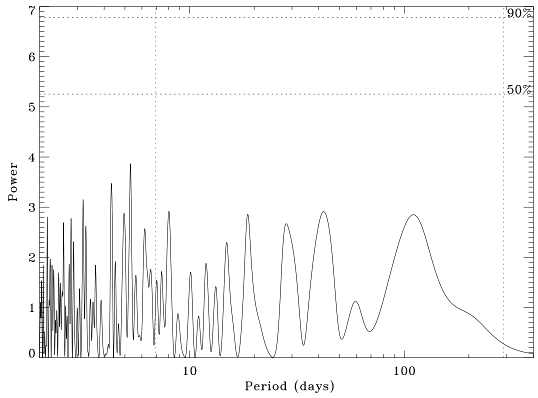

Fig. 2. Lomb-Scargle periodogram of RVs of HIP 11952 obtained with HARPS-N and HARPS. Confidence levels from the bootstrap simulations are shown. The vertical dotted lines mark the periodicities identified by S12 based on FEROS RVs.

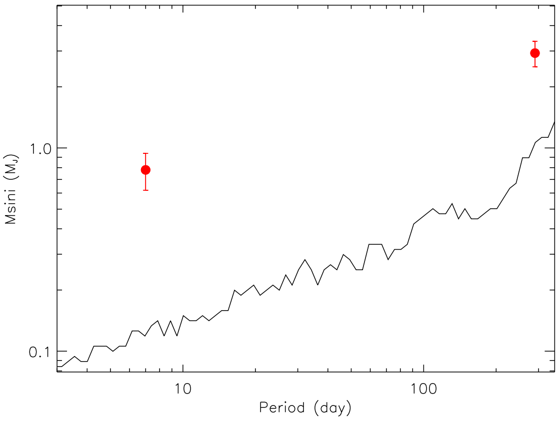

Fig. 3. Upper limits on the minimum mass of possible planetary companions around HIP 11952 with 99% confidence level from HARPS-N and HARPS data. Filled circles show the mass and period of the two planets claimed by S12 that are clearly incompatible with our data.

orbital parameters as given by S12 are excluded at higher levels of confidence by our data.

5. Discussion and conclusions

Based on high-precision RV measurements carried out with HARPS-N and HARPS we found no evidence of the two giant planets with $P = 6.95$ d and $P = 290$ d, and projected masses 0.78 ± 0.16 M_J and 2.93 ± 0.42 M_J, respectively, announced by S12 orbiting the metal-poor star HIP 11952. Saturn-mass and Jupiter-mass planets with periods shorter than 30 and 250 days, respectively, are also excluded. Our observations are within the measurement errors, that are about 5–10 times lower than those of the FEROS observations, thanks to the optimised performance of HARPS-N in delivering RVs and the larger telescope aperture. This case shows that care should be taken in interpreting RV variations as indicating orbital motion, as stellar and instrumental effects could impact the measurements, particularly when inferred RV amplitudes are only slightly larger than the measurement accuracy.

Our result has important consequences, as it clears the observational sample of a system that constituted a severe challenge to the core-accretion model of giant planet formation. A giant planet system around HIP 11952 was indeed very hard to explain within the context of the most recent calculations based on this mechanism (Johnson & Li 2012; Mordasini et al. 2012).

On the one hand, giant planets formed by core accretion are expected to be very rare around low-metallicity dwarfs, and the observational evidence presented here directly supports this view. On the other hand, low-mass planets can theoretically form around metal-poor stars, so it is highly desirable to obtain statistically useful observational inferences on the actual value of f_p for Super-Earths and Neptunes across orders of magnitude in the host stars' metal content. New programs to search for low-mass planets around metal-poor stars (such as the on going ESO large program 190.C-0027 on HARPS and our dedicated GAPS program on HARPS-N) will then allow for a significant improvements in our knowledge of the relative roles of competing planet formation processes.

Acknowledgements. We thank the TNG staff for help in the preparation of the observations and R. Smareglia and collaborators for the kind assistance with the data retrieval from TNG archive. This work was partially funded by PRIN-INAF 2010. NCS acknowledges the support by the ERC/EC under the FP7 through Starting Grant agreement n. 239953, as well as the support from Fundação para a Ciência e a Tecnologia (FCT) through prog. Ciência 2007 funded by FCT/MCTES (Portugal) and POPH/FSE (EC), and in the form of grants ref. PTDC/CTE-AST/098528/2008 and PTDC/CTE-AST/120251/2010.

References

Baranne, A., Queloz, D., Mayor, M., et al. 1996, A&AS, 119, 373
Boss, A. P. 2002, ApJ, 567, L149
Buchhave, L. A., Latham, D. W., Johansen, A., et al. 2012, Nature, 486, 375
Cosentino, R., Lovis, C., Pepe, F., et al. 2012, in Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series, Vol. 8446, Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series
Desidera, S., Carolo, E., Gratton, R., et al. 2011, A&A, 533, A90
Desidera, S., Gratton, R. G., Lucatello, S., Claudi, R. U., & Dall, T. H. 2006, A&A, 454, 553
Fischer, D. A. & Valenti, J. 2005, ApJ, 622, 1102
Ida, S. & Lin, D. N. C. 2004, ApJ, 616, 567
Jenkins, J. S., Jones, H. R. A., Tuomi, M., et al. 2012, ArXiv e-prints
Johnson, J. A., Aller, K. M., Howard, A. W., & Crepp, J. R. 2010, PASP, 122, 905
Johnson, J. L. & Li, H. 2012, ApJ, 751, 81
Latham, D. W., Stefanik, R. P., Torres, G., et al. 2002, AJ, 124, 1144
Mayor, M., Marmier, M., Lovis, C., et al. 2011, ArXiv e-prints
Mayor, M., Pepe, F., Queloz, D., et al. 2003, The Messenger, 114, 20
Mordasini, C., Alibert, Y., & Benz, W. 2009a, A&A, 501, 1139
Mordasini, C., Alibert, Y., Benz, W., Klahr, H., & Henning, T. 2012, A&A, 541, A97
Mordasini, C., Alibert, Y., Benz, W., & Naef, D. 2009b, A&A, 501, 1161
Mortier, A., Santos, N. C., Sozzetti, A., et al. 2012, A&A, 543, A45
Pepe, F., Mayor, M., Galland, F., et al. 2002, A&A, 388, 632
Pojmanski, G. 2002, Acta Astron., 52, 397
Santos, N. C., Israelian, G., & Mayor, M. 2004, A&A, 415, 1153
Santos, N. C., Mayor, M., Benz, W., et al. 2010, A&A, 512, A47
Santos, N. C., Mayor, M., Bonfils, X., et al. 2011, A&A, 526, A112
Santos, N. C., Mayor, M., Bouchy, F., et al. 2007, A&A, 474, 647
Setiawan, J., Klement, R. J., Henning, T., et al. 2010, Science, 330, 1642
Setiawan, J., Roccatagliata, V., Fedele, D., et al. 2012, A&A, 540, A141

Table 1. Radial velocities of HIP 11952. The last column indicates the instrument and CCD status: F is HARPS-N original full chip; H is HARPS-N half chip only (blue side); N is HARPS-N new chip; S is HARPS at ESO 3.6m. The tabulated RVs do not include any offset between the data obtained with different observational setups.

BJD -2450000	RV ($km\ s^{-1}$)	error ($km\ s^{-1}$)	Instrument/CCD
6147.72121	24.2530	0.0050	F
6160.74007	24.2435	0.0070	F
6166.74103	24.2556	0.0058	F
6173.72276	24.2529	0.0059	F
6174.73851	24.2495	0.0049	F
6175.69620	24.2601	0.0056	F
6176.68467	24.2625	0.0053	F
6177.71773	24.2582	0.0059	F
6178.68027	24.2550	0.0058	F
6199.65825	24.2505	0.0074	H
6200.67111	24.2598	0.0063	H
6201.65011	24.2715	0.0066	H
6202.61782	24.2650	0.0084	H
6207.70025	24.2726	0.0098	H
6208.68055	24.2668	0.0151	H
6211.64234	24.2681	0.0082	H
6226.61110	24.2629	0.0175	H
6227.58001	24.2777	0.0066	H
6244.59921	24.2753	0.0090	N
6266.46650	24.2618	0.0051	N
6272.54203	24.2478	0.0070	S
6273.54629	24.2459	0.0054	S
6274.53914	24.2579	0.0054	S
6275.53456	24.2562	0.0059	S
6276.53597	24.2566	0.0056	S
6277.54178	24.2481	0.0055	S
6278.54057	24.2464	0.0056	S
6279.53845	24.2464	0.0052	S
6280.53859	24.2519	0.0080	S
6288.48127	24.2573	0.0109	N
6293.54512	24.2518	0.0051	S
6294.53344	24.2616	0.0050	S
6294.86975	24.2565	0.0081	N
6295.53899	24.2415	0.0055	S
6295.91839	24.2543	0.0064	N
6296.53505	24.2615	0.0062	S
6296.88798	24.2674	0.0046	N
6297.53385	24.2547	0.0071	S
6299.33693	24.2645	0.0060	N
6299.40581	24.2537	0.0057	N

Sousa, S. G., Santos, N. C., Israelian, G., Mayor, M., & Udry, S. 2011, A&A, 533, A141
Sozzetti, A., Torres, G., Latham, D. W., et al. 2006, ApJ, 649, 428
Sozzetti, A., Torres, G., Latham, D. W., et al. 2009, ApJ, 697, 544