First Results from the CHEPS*: Exoplanets and the Discovery of an Eccentric Brown Dwarf in the Desert†

J.S. Jenkins¹, H.R.A. Jones², K. Goździewski³, C. Migaszewski³, J.R. Barnes²,
M.I. Jones¹, P. Rojo¹, D.J. Pinfield², A.C. Day-Jones², S. Hoyer¹

¹Department of Astronomy, Universidad de Chile, Casilla 36-D, Santiago, Chile, email: jjenkins@das.uchile.cl
²Center for Astrophysics, University of Hertfordshire, College Lane Campus, Hatfield, Hertfordshire, UK, AL10 9AB
³Toruń Centre for Astronomy, Nicolaus Copernicus University, Gagarina 11, 87-100 Toruń, Poland

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ABSTRACT

We report the discovery of a brown dwarf on an eccentric orbit and with a semimajor axis that places it in the brown dwarf desert region around the star HD191760. The star has a spectral type of G3IV/V and a metallicity ([Fe/H]) of 0.29 dex. HD191760 adds to the small number of metal-rich stars with brown dwarf companions. The brown dwarf (HD191760b) is found to have an orbital period of 505.57 ± 0.40 days and semimajor axis of 1.35 ± 0.01 AU, placing it firmly in the brown dwarf desert. The eccentricity of HD191760b is found to be 0.63 ± 0.01, meaning it reaches as close as 0.5 AU from the host star. Dynamical simulations indicate that no inner planets could reside at separations beyond ~0.17 AU due to the disastrous gravity imposed by HD191760b. In addition to these first results we also refine the orbits found for the exoplanets around the stars HD48265, HD143361 and HD154672. All 1-planet solutions are in agreement with those previously published by the Magellan Planet Search.

Key words: stars: low-mass, brown dwarfs – planetary systems – techniques: radial velocities

1 INTRODUCTION

Since the first few extrasolar planets (hereafter exoplanets) were detected (Mayor & Queloz 1995; Marcy & Butler 1996a; Marcy & Butler 1996b) it became readily apparent that planets preferred metal-rich environments (Gonzalez 1997). This discovery has been placed in the framework of giant planet formation through core accretion of gas depleted materials left over from the formation of the parent star (e.g. Kornet et al. 2005; Alibert et al. 2005). This hypothesis has been extensively tested by different methods and analysis techniques, most recently by Fischer & Valenti (2003), and remains the most plausible scenario for the increased probability of planet detection around metal-rich stars. The competing theory is based on the concept that planets migrate through the proto-planetary disks from which they formed (Lin & Papaloizou 1986; Trilling et al. 2002). It has been hypothesized that the stellar atmosphere is polluted after formation through infall of migrating planets onto the stellar surface. However, Pinsonneault et al. (2001) modelled the infall of material onto stellar atmospheres at the ZAMS and found that 10 M⊕ worth of gas depleted material could raise the metallicities ([Fe/H]) of G dwarfs to ~0.3 dex, whereas the same material falling on an F dwarf would increase the metallicity to ~0.6 dex. In their large sample (>1000 stars) of consistent metallicities, Fischer & Valenti found no correlation between the depth of convective zones of exoplanet host stars and their metallicity, indicating that infall of planets or gas depleted material can not explain the over abundance of metal-rich atmospheres for exoplanet host stars.

Whatever the scenario that leads to exoplanet host stars being rich in metals, it is clear that such stars have a higher probability of hosting exoplanets. Fischer & Valenti have determined that the fraction of planets increases with increasing metallicity proportional to the square of the number of iron atoms in the stellar photosphere. This correlation is being exploited by a number of planet search projects like the N2k, Keck, etc who bias their samples, or subsets thereof, towards the most metal-rich stars. We are exploiting this
correlation also, by searching around the most metal-rich solar-type stars in the southern hemisphere as part of our CHEPS project. The CHEPS target list is compiled from the analysis of [Jenkins et al. 2008] by utilising high S/N high resolution spectra, acquired using the FEROS spectrograph [Kaufer et al. 1999]. The targets were selected to have [Fe/H] $\geq$ 0.1 dex and all have $B - V$ colours in the range 0.5–0.9 (Spectral Types of late-F to mid-K). Along with the metallicity bias we are also focusing on the most inactive stars. The Ca II HK line cores were used in Jenkins et al. to measure the log$R'_{HK}$ activity index [Noyes et al. 1984] which has been shown to be a useful proxy to the level of noise (aka jitter) in radial-velocity time series [Saar & Donahue 1997; Saar et al. 1998; Wright 2005]. We therefore selected our primary sample to include all stars with log$R'_{HK}$ $\leq$ -4.5, which allows for the lowest levels of radial-velocity jitter in our dataset.

2 OBSERVATIONS

We present data from six observing runs using the ESO-HARPS instrument [Mayor et al. 2003] on the 3.6m telescope in La Silla Chile. HARPS is a fiber-fed cross-dispersed echelle spectrograph. The instrument employs two 1" on sky fibers, one on object and one on the Thorium-Argon (ThAr) calibration source, which feed the light to the spectrograph to be re-imaged on two 2k4 CCD chips. A total of 72 orders are spread over the two CCD’s, 36 object and 36 calibration source, with an instrumental resolution ($R$) of $\sim$115,000. 29 observations were made of HD191760, with 8 for HD48265 and 6 each for both HD143361 and HD154672, all using our standard observational procedure, which aims to observe each star for a fixed integration time of 15 minutes in order to integrate over the strongest p-mode oscillations that all solar-like stars exhibit [O'Toole et al. 2008]. Also to attempt to increase our efficiency to the detection of short period exoplanets, and in particular low mass exoplanets, we intensively monitor the stars on short timescales to search for potential planetary signals, including for HD191760.

The reduction and analysis of all stars are performed in near real time at the telescope, using the latest version of the HARPS-DRS [Pepe et al. 2004]. The DRS (Data Reduction Software) performs all functions of the reduction and analysis, from bias removal, order localisation, flatfielding, cosmic ray removal, scattered light subtraction, extraction and blaze correction, to determination of the radial-velocities, barycentric Julian dates and internal uncertainties through cross-correlation with stellar templates and the reference ThAr calibration orders. Due to the high quality mechanical, thermal and pressure stabilisation of HARPS, the drift over a single night is found to be less than 1 m/s. Such a system provides internal uncertainties below 1 m/s, meaning our short term precision is dominated by stellar activity induced jitter (e.g. [Saar et al. 1998]).

3 HD191760 CHARACTERISTICS

Table 1 lists the stellar characteristics of the star HD191760. [Houk 1978] lists the star’s spectral type as G3IV/V, which is in agreement with the value adopted by Hipparcos [Perryman et al. 1997; van Leeuwen 2007] and also with the derived distance from the Hipparcos main sequence ($\Delta M_V$; Jenkins et al. 2008). All Hipparcos astrometry was obtained using the AstroGrid tool which lists the new catalogue values from van Leeuwen with increased astrometric precision. The kinematic catalogue of [Nordström et al. 2004], later updated by [Holmberg et al. 2007], includes observations of HD191760 through Str"omgren filters and calibrations based on the infrared flux method [Alonso et al. 1996] to derive various stellar characteristics. They also used parallax measurements from Hipparcos, along with Padova evolutionary tracks [Girardi et al. 2000] to determine evolutionary parameters for their sample. We have also derived various parameters for a number of stars in preparation for our metallicity based planet search, both by high resolution FEROS spectra and precise photometry. We used the Hipparcos optical magnitudes, along with 2MASS photometry, to measure the effective temperatures of our stars by the infrared flux method [Blackwell et al. 1990]. We used these temperatures to interpolate a grid of high resolution Kurucz model atmospheres [Kurucz 1993], built using WITA6 [Pavlenko 2000], to determine the stellar metallicity. Yonsei-Yale (Y2) isochrones [Demarque et al. 2004] were then interpolated using these temperatures, metallicities and an estimate for the alpha-enhancement parameter that was obtained by the locus of points in Edvardsson et al. [1993] and Pagel & Tautvaisiene [1995].

The properties of HD191760 derived by Holmberg et al. and this work mostly agree within the formal uncertainties. Their metallicity value of 0.12$\pm$0.10 dex is found to be smaller than our value of 0.29$\pm$0.07 dex and [Holmberg et al. 2008] show that there is a small systematic offset between their metallicities and those published in Jenkins et al. due to the differing effective temperature scales employed. Fig. 1 shows the position of HD191760 on an HR-diagram, along with the Y2 isochrones in steps of 0.1M$_\odot$ (solid curves) and higher resolution steps of 0.01M$_\odot$ (dashed curves). The position of the star, given the bolometric luminosity of 2.69$\pm$0.2L$_\odot$, effective temperature of 5821$\pm$82K and [Fe/H] of 0.29$\pm$0.07 dex, is best explained by a star of mass 1.28$^{+0.02}_{-0.02}$M$_\odot$, where the uncertainties are dominated by the uncertainty on the Hipparcos parallax. Our estimate for the age of the star is 4.1$^{+0.8}_{-0.4}$Gyrs. The large lower error bars arise due to the position of the star close to the main sequence turnoff. The surface gravity (log$g$) value of 4.13$^{+0.05}_{-0.04}$dex is consistent with a star evolving onto the subgiant branch.

As part of the analysis we performed to select our target sample we also extracted chromospheric activity indices from measurements of the level of emission in the Ca II HK lines. The log$R'_{HK}$-index has been shown to correlate well with the level of noise (aka jitter) in precise radial-velocity datasets (e.g. [Santos et al. 2000; Wright 2005]). Fig. 2 shows the Ca II H line core of HD191760 (top) along with the other three planet-host stars we present data for in §5. Our low derived value of log$R'_{HK}$=−5.17 is highlighted from the deep central line core, or lack of core re-emission, of HD191760.

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Figure 1. Evolutionary Y2 mass tracks are shown in steps of 0.1 $M_\odot$ (solid curves) and finer steps of 0.01 $M_\odot$ (dashed curves) for effective temperatures and bolometric luminosities. HD191760 is represented by the error bars and its position is consistent with a mass of 1.28 $\pm$ 0.02 $M_\odot$ and an age of 4.21 $\pm$ 0.8 Gyrs. The masses of the solid curves are shown for reference.

Table 1. Stellar parameters for HD191760.

| Parameter                  | HD191760 |
|----------------------------|----------|
| Spectral Type              | G3IV/V   |
| $\log R'_{HK}$             | -5.17    |
| Hipparcos $N_{obs}$        | 99       |
| Hipparcos $\sigma$         | 0.011    |
| $\pi$ (mas)                | 12.25 $\pm$ 0.90 |
| $\Delta M_V$              | 1.107    |
| $L_V/L_\odot$              | 2.69 $\pm$ 0.20 |
| $M_*/M_\odot$ - H07        | 1.14 $\pm$ 0.08 |
| $M_*/M_\odot$ - Here       | 1.28 $\pm$ 0.02 |
| $R_*/R_\odot$              | 1.62 $\pm$ 0.10 |
| $T_{eff}$ (K) - H07        | 5794 $\pm$ 76 |
| $T_{eff}$ (K) - J08        | 5821 $\pm$ 82 |
| [Fe/H] - H07               | 0.12 $\pm$ 0.10 |
| [Fe/H] - J08               | 0.29 $\pm$ 0.07 |
| $\log(g)$                 | 4.13 $\pm$ 0.05 |
| $U,V,W$ - H07 (km/s)       | -29,-21,15 |
| $v\sin i_{R'_{HK}}$ (km/s) | 3.47     |
| $v\sin i_{H07}$ (km/s)     | 2        |
| $v\sin i_{CCF}$ (km/s)     | 2.33 $\pm$ 0.05 |
| $P_{rot.}$ $R'_{HK}$ (days)| 25.2   |
| $P_{rot.}$ $CCF$ (days)    | 35.1     |
| Age $R'_{HK}$ (Gyrs)       | 9.9      |
| Age (Gyrs) - H07           | 5.6 $\pm$ 0.9 |
| Age (Gyrs) - Here          | 4.1 $\pm$ 0.8 |
| Jitter - $log R'_{HK}$ (m/s)| 1.50    |

H07 relates to Holmberg et al. (2007), J08 is the reference for Jenkins et al. (2008) and Here labels values derived in this work.

4 ORBITAL SOLUTION FOR HD191760

The 29 Doppler velocities for HD191760 were measured in six observing runs, four of which spanned five nights in duration, with the final two points acquired through ESO Directors Discretionary Time. All velocities and bisector span values (BVS) are listed in Table 2, note that the two large deviant BVS values are from our two lowest quality spectra which were interrupted by clouds, significantly lowering the S/N, meaning the construction of the CCF was much poorer than the rest of the high S/N spectra acquired. Panel (a) in Fig. 3 shows these velocities with the best fit Keplerian solution to the data. Due to the scheduling of the runs the orbit is firmly constrained by the final two data points. Before the final two data points were acquired, a resonant double planet solution could describe the dataset just as well. Such system ambiguities could be common in radial-velocity datasets, particularly at low eccentricities (Anglada-Escude et al. 2008). However, in this case the system configurations were so contrasting that one data point was enough to decouple them, and with an eccentricity of around 0.63 and no indication of any trend in the third ob-
Table 2. Radial-velocities for HD191760

| BJD (-2454000) | RV (m/s) | Uncertainty (m/s) | BVS (m/s) | RV-αBVS (m/s) |
|----------------|----------|-------------------|-----------|----------------|
| 250.90047      | -30662.99| 0.88              | 9.49      | -235.23        |
| 253.89490      | -30689.15| 0.70              | 3.20      | -257.01        |
| 365.50781      | -30575.97| 1.37              | 9.45      | -148.19        |
| 365.73781      | -30577.79| 0.62              | 5.68      | -147.39        |
| 367.49679      | -30540.86| 0.38              | 3.66      | -109.04        |
| 367.72155      | -30535.38| 0.73              | -0.09     | -100.95        |
| 368.69981      | -30519.40| 0.53              | -0.94     | -84.39         |
| 368.74111      | -30498.29| 1.86              | 30.70     | -85.31         |
| 369.19468      | -30503.67| 0.77              | -1.71     | -68.12         |
| 369.62706      | -30504.89| 0.50              | 0.91      | -68.16         |
| 369.68610      | -30497.67| 0.51              | 2.50      | -65.07         |
| 369.74838      | -30497.94| 0.63              | -0.93     | -62.93         |
| 577.77658      | -30045.01| 0.82              | 7.41      | 384.19         |
| 577.90446      | -30051.42| 0.40              | 5.55      | 379.07         |
| 578.77151      | -30047.07| 0.54              | 6.49      | 382.77         |
| 578.90713      | -30049.68| 0.48              | 6.46      | 380.18         |
| 579.74685      | -30048.12| 0.56              | 3.12      | 384.07         |
| 579.90348      | -30049.27| 0.41              | 5.07      | 381.57         |
| 580.74769      | -30052.14| 0.60              | 6.86      | 377.44         |
| 580.89930      | -30051.97| 0.51              | 5.94      | 378.25         |
| 581.76210      | -30049.85| 0.39              | 5.45      | 380.71         |
| 581.91331      | -30052.58| 0.36              | 7.26      | 376.73         |
| 723.53335      | -30373.95| 3.17              | 93.78     | -4.90          |
| 724.58539      | -30400.36| 0.34              | 7.46      | -11.19         |
| 725.53823      | -30446.88| 0.44              | 8.10      | -18.15         |
| 726.53101      | -30452.77| 0.43              | 7.76      | -23.81         |
| 727.53134      | -30458.24| 1.09              | 1.25      | -24.74         |
| 812.52135      | -31646.47| 1.02              | 12.07     | -1220.52       |
| 813.53608      | -31679.70| 1.16              | 10.27     | -1252.50       |

5 POTENTIAL FOR FURTHER COMPANION OBJECTS

In order to map out a strategy for future radial-velocity observations of this star, or indeed to decide if further study is warranted, we decided to look for additional hidden companions in the data. This seems plausible given that the signal describes a fairly wide orbiting companion near the planetary mass boundary, therefore it is reasonable to assume there are other companions in the system with significantly lower mass that would induce a secondary orbital signature with a lower amplitude. Therefore we performed a search for additional companion planets in the system even though the current dataset is rather limited.

First, we tested a hypothesis that the radial-velocity signal may be produced by an additional planet with an intermediate period orbit. We performed the search for additional planets using the genetic algorithm with MEGNO penalty.
ably below the hydrogen burning limit. An inclination 

regime ($M \sin i$) gives rise to a true mass of $M=52.19 M_J$, a low eccentricity of $\sim 0.17$ and a semimajor axis of $\sim 0.22$ AU. Such a configuration gives rise to a reduced rms of 1.84 m/s and could be hidden in the current dataset. However, as shown in Fig. 3, the entire region around the hypothetical planet is extremely chaotic and therefore it is extremely unlikely that such a planet could reside at this location. The two panels of this figure represent stability maps in the semimajor axis-eccentricity plane in terms of the so called Spectral Number indicator of formally chaotic motions (Michtchenko & Ferraz-Mello 2001, top panel) and the maximum eccentricity indicator (the right-hand panel), i.e. the maximum eccentricity attained during the integration period indicating the degree of geometric instability (large max $e$, means collisions). Both maps were computed over $10^5$ years that corresponds to $\sim 50,000$ revolutions of the outer companion. The figure shows that we must rule out, not only this potential companion, but also all companions in the vicinity of this parameter space. Actually, the strongly unstable zone ends at $\sim 0.17$–0.18 AU, and it is unlikely any other planet could survive the disastrous, short-term perturbations of the brown dwarf companion beyond that limit.

6 DISCUSSION

6.1 Brown Dwarf Companion

The constrained orbital parameters for HD191760b place the minimum mass of the companion in the brown dwarf regime ($M \sin i = 38.17 \pm 1.02 M_J$). Also the orbital semimajor axis is found to be 1.35 AU, well inside the brown dwarf desert region. This so called brown dwarf desert was coined due to the paucity of such objects around solar-like stars with semimajor axes of $< 3$ AU (Marcy & Butler 2000). They showed that fewer than 0.5% of surveyed stars within 3 AU on Doppler programs at the time had brown dwarf companions, whereas 5% of these stars harbor exoplanets. Therefore, since our sample is small (100 stars) we may not statistically expect to detect any brown dwarf desert companions and this object may have an actual mass above the hydrogen burning limit (\sim 80 M_J) after inclination effects are considered. For stars with randomly distributed inclinations, 68% are found to fall within 47° (Marcy & Butler 1996a), giving rise to a true mass of $M = 52.19 M_J$, comfortably below the hydrogen burning limit. An inclination $i$ of, or below, 28.5° is required in order for HD191760b to be a true stellar companion and such a scenario has an $a$ priori probability of only 12.1%. Also there is no binarity flag as of the latest update of the Hipparcos astrometry (van Leeuwen 2007). In addition, a visual inspection of the HARPS spectra does not reveal any evidence for additional stellar lines from an unseen companion and there was no extension of the acquisition image at the telescope to indicate another stellar component, ruling out the possibility of extremely high inclinations. However, such a scenario would agree with the results of Stamatellos & Whitworth (2009) who suggest that brown dwarfs form by disk fragmentation in such systems and that short period radial-velocity companions are preferentially low mass stars. This scenario would agree well with the high orbital eccentricity of the system and could also explain a recent similar discovery from Wittenmyer et al. (2009). Interferometry could be used to help rule out a lower mass stellar companion.

Another way to probe the inclination is to study the rotation velocity along with the activity index from the CaHK lines. The rotation velocity of this star is found to be $2.33 \pm 0.05$ km/s, using a similar method to that explained in Santos et al. (2002) (the uncertainty is the standard deviation of the 25 measured cross correlation full widths at half maximum), which for the determined radius we find gives an upper limit to the rotation period of 35 days. The estimated rotation period from the $\log R'_{\text{HK}}$-rotation period correlation (Noyes et al. 1984) is 25.2 days, which is inclination independent and should represent the equatorial rotation period, assuming that the orbital and rotation axes are aligned in the same plane. Assuming the rotation period from the activity relation holds then we estimate the system has a sin $i = 0.67$, which gives an inclination of $\sim 42°$. Such an inclination would give rise to an actual mass of $57 M_J$, which is still comfortably below the hydrogen burning limit. However, the $log R'_{\text{HK}}$ activity index was formulated for stars on the main sequence and may be gravity dependent so would not be fully applicable to this star. Also the use of this index should be made only after a number of stellar cycles have been observed, which allows one a robust estimate of the mean $\log R'_{\text{HK}}$. We have applied the value quoted in Jenkins et al. (one measurement), not the mean, so we do not know the spread, which can vary at the $\pm 0.1$ dex level (see Jenkins et al. 2006), and can not apply this to the uncertainty on the relationship itself, which Noyes et al. quote as $0.08$ dex for the convective turnover time.

6.2 Benchmarkability?

Since HD191760 is found to be evolving off the main sequence onto the sub-giant branch the age estimates for the system can be fairly well constrained. Holmberg et al. (2007) estimate an age of $5.6^{+0.2}_{-0.3}$ Gyrs in good agreement with our estimated value of $4.1^{+0.2}_{-0.5}$ Gyrs, the main differences arising due to the differing metallicities, and hence masses, found for this star. The mean of the two estimates gives rise to an age of $4.9^{+1.1}_{-0.9}$ Gyrs, clearly a fairly old and evolved star. Such an age means that this system could provide a benchmark, evolved system, to test brown dwarf evolutionary models. Given there is a lack of well constrained age estimates for the older population of brown dwarf stars, if one can attain photometry or spectroscopy of the brown dwarf in this system then this could provide a well constrained metallicity and age to use in comparison with current evolutionary models of brown dwarfs (e.g. Baraffe et al. 2003; Burrows et al. 2000). Again interferometry may allow such studies to be
Table 3. Radial-velocities for HD48265, HD143361 and HD154672

| BJD (-2454000) | RV (m/s) | Uncertainty (m/s) |
|----------------|----------|-------------------|
| HD48265        |          |                   |
| 365.824572     | 23394.21 | 3.47              |
| 366.874164     | 23399.40 | 3.50              |
| 367.852214     | 23395.69 | 3.45              |
| 580.522907     | 23449.18 | 3.45              |
| 581.553905     | 23450.06 | 3.45              |
| 724.833698     | 23413.42 | 3.45              |
| 725.817765     | 23414.08 | 3.44              |
| 726.779101     | 23411.87 | 3.47              |
| HD143361       |          |                   |
| 250.745318     | -437.90  | 2.39              |
| 253.769447     | -436.44  | 2.32              |
| 367.556628     | -474.74  | 2.22              |
| 368.537299     | -474.20  | 2.24              |
| 578.788567     | -534.13  | 2.18              |
| 581.807762     | -531.75  | 2.19              |
| HD154672       |          |                   |
| 248.713853     | -3796.59 | 4.79              |
| 250.731312     | -3794.42 | 2.25              |
| 367.595129     | -3653.29 | 2.15              |
| 368.618599     | -3651.00 | 2.22              |
| 578.811238     | -3797.81 | 2.14              |
| 581.870548     | -3808.85 | 2.13              |

performed on this system. Once the inclination is pinned
down and the nature of the companion is confirmed as sub-
estellar then we can also use the HARPS spectra to obtain a
further age constraint from the strength of the lithium line
(see Melo et al. 2006). This would provide an additional, and
independently determined, age estimate to further constrain
the system. In addition, further atomic abundances could be
garnered for the star to aid in constraining the metallicity
and abundance nature of brown dwarf model atmospheres.
Such an abundance study is already underway.

7 REFINED ORBITS FOR THE PLANETS
AROUND HD48265, HD143361 AND
HD154672

Due to some overlap in our target sample with that of
the Magellan Planet Search, we can update a few of the
recent planet discoveries announced by this program with
additional velocities we have found at HARPS. Table 3
shows our absolute Doppler velocities for the three planet
host stars HD48265, HD143361 and HD154672. For all of
these stars we have acquired observations in three observing
runs with overall baselines around one year in duration.
Fig. 5 shows the best fits to all three stars using Systemic
(Maschieri et al. 2009), with the Magellan velocities in black
(blue) and our HARPS values in grey (green). We show the updated orbital solutions in columns 3, 4 and 5 of Table 3, and in general they agree well with the published results in both Minniti et al. (2009)

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Figure 5. The radial-velocity Keplerian fits to the stars HD48265 (top), HD143361 (middle) and HD154672 (bottom). Plotted in blue are the literature values from the Magellan program and in green are the new data points from here.
value of 1.37 up to 3.33. Given the baseline between the two data sets this might argue for an additional companion in the system, however currently both a search in the periodogram of the residuals to the 1-planet fit and the addition of a linear trend do not reveal anything significant. Indeed, although this appears to be the best fit solution, there is no significant power anywhere in the periodogram when combining the two data sets. Finally, for HD143361b we find good agreement with the published results, again with a slightly reduced orbital period of 1057 days and eccentricity of 0.15. This relates to an M sin i of 3.12 MJ, in good agreement with the 3 Mj found by Minniti et al. and with a lower rms of 3.37 m/s. For a 1-planet solution none of these three systems exhibit significant trends in the residuals and hence present no evidence, as yet, for additional longer period planets in the system. Note the uncertainties shown in Table. 4 are derived from the updated relation of [Wright 2005] (private communication) and the low level of each is highlighted in Fig. 2 where no Ca ii H line core emission is seen in any of these three stars (HD48265: top-middle, HD143361: lower-middle and HD154672: bottom).

8 SUMMARY
We announce the first four radial-velocity detections from the CHEPS on the ESO-HARPS instrument. The highlight is the discovery of an eccentric brown dwarf in the desert orbiting the metal-rich G3IV-V star HD191760. For the best fit solution, HD191760 is found to have a mass of 38.17 ± 1.02 Mj, an orbital period of 505.65 ± 0.42 days and an eccentricity of 0.63 ± 0.01, and this discovery adds to the small list of metal-rich stellar-brown dwarf binary systems. Our dynamical simulations show that no additional planets could exist inside the orbit of the brown dwarf with semimajor axes larger than around 0.17 AU due to the destructive tidal forces of the brown dwarf.

Finally, we also confirm the exoplanet detections of HD48265b, HD143361b and HD154672b from the Magellan program by employing 1-planet Keplerian solutions to the data. We show updated orbits by adding eight velocities for HD48265 and six velocities each for HD143361 and HD154672. All orbital parameters are in agreement with the published results by [Minniti et al. 2009] and [López-Morales et al. 2008]. Both HD143361b and HD154672b show lower rms by the addition of our data, however the best fit for HD48265b shows an increased rms and $\chi^2$. Since the star is shown to be chromospherically inactive this indicates that additional radial-velocities are required to probe for further companions in this system.

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Table 4. Orbital parameters for HD191760b, HD48265b, HD143361b and HD154672b.

| Parameter               | HD191760b     | HD48265b     | HD143361b     | HD154672b     |
|-------------------------|---------------|--------------|---------------|---------------|
| Orbital period $P$ (days) | 505.65±0.42   | 700±8        | 1057±20       | 163.9±0.1     |
| Velocity amplitude $K$ (m/s) | 1047.83±38.71 | 28.3±9.0     | 65.1±26.3     | 226.52±9.22   |
| Eccentricity $e$         | 0.63±0.01     | 0.18±0.13    | 0.15±0.17     | 0.61±0.02     |
| $\omega$ (°)            | 200.37±0.28   | 309±27       | 237±55        | 266±2         |
| $T_0$ (JD-2,450,000)     | 4835.65±2.06  | 4486±50      | 3746±147      | 4520±1        |
| $M \sin i$ ($M_J$)       | 38.17±1.02    | 1.16±0.38    | 3.12±1.44     | 5.02±0.17     |
| Semimajor axis $a$ (AU)  | 1.35          | 1.51         | 2.00          | 0.60          |
| rms (m/s)                | 2.00          | 6.756        | 3.37          | 3.37          |
| $\chi^2$                | 1.04          | 3.33         | 2.42          | 2.14          |
| $N_{\text{Obs}}$         | 29            | 25*          | 18            | 22            |

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