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The CORALIE survey for Southern extra-solar planets

III. A giant planet in orbit around HD 192263*

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Abstract. A new extra-solar planet has been discovered in the context of the CORALIE survey at La Silla Observatory. This new planetary candidate orbits the star HD 192263 in an almost circular orbit at a distance of 0.15 AU, producing a 24.13 day periodic radial-velocity variation, with a semi-amplitude of 62 m s^{-1}. The derived minimum mass of the planet is 0.73 $M_{\rm Jup}$.

Key words: techniques: radial velocities – solar system: general – stars: individual: HD 192263 – planetary systems

1. Introduction

After the first announcement of a planet around 51 Peg (Mayor & Queloz 1995), many extra-solar planets have been discovered around solar-type stars. The list counts now more than 20 planetary candidates that exhibit very different (minimum) masses and orbital characteristics. A good review about the major properties of the new worlds can be found in Marcy et al. (1999).

A long term extra-solar planet search programme started in June 1998 with the CORALIE high-resolution ($\lambda/\Delta\lambda \approx$ 50 000) fiber-fed echelle spectrograph mounted on the Nasmyth focus of the new 1.2-m Euler Swiss telescope at La Silla (ESO, Chile). The survey makes use of a large volume-limited sample of stars (see Udry et al. 1999, 2000 for further details). This will give us the possibility of studying extra-solar planet characteristics and their occurrence as well has the parent star parameters in a statistical perspective, without being limited by sampling biases.

With CORALIE, the spectra are reduced online, and radial-velocities are computed by a cross-correlation of the spectra with a numerical template. The resulting cross-correlation dip minimum gives us very precise (few m s^{-1}) radial-velocity determinations.

After 1 year of measurements, 3 extra-solar planets have been announced in the context of the CORALIE survey (Queloz et al. 2000, Paper I; Udry et al. 2000, Paper II). In this paper we report the discovery of a 4$^{\rm th}$ planetary-mass companion discovered with CORALIE this time orbiting the star HD 192263 (see also Santos et al. 1999b). This new planetary candidate has a (minimum) mass well within the planetary mass range and adds another extra-solar planet to the now extensive list.

While it is too early for statistical studies with the actual (low) number of extra-solar planets found within the CORALIE survey, the next sections will focus on discussing the main characteristics of the new planet and of its parent star. In Sect. 2 we present the stellar parameters for HD 192263 as well as the radial-velocity measurements and the obtained orbital solution. In Sects. 3 and 4 we discuss the results, showing that the planetary interpretation is the best and only really capable of explaining the observed radial-velocity variations.

2. A planet around HD 192263

HD 192263 (HIP 99711, BD $-$01 3925, ADS 13547 A) is a high proper-motion early K dwarf in the constellation Aquila (Eagle), with a V magnitude of 7.79. Its colour index is $B-V$ = 0.938, as listed in the Hipparcos catalogue (Perryman et al. 1997) – Table 1. From the precise parallax measured by the Hipparcos satellite (π=50.27 $\pm$ 1.13 mas) its distance from the Sun is 19.9 pc, and its absolute magnitude not corrected for extinction is $M_{\rm v}$=6.30.

Olsen (1984) obtained $ubvy$-photometry of HD 192263, and from his values, the derived metallicity index is [Fe/H] = $-$0.20 $\pm$ 0.16 (calibration taken from Schuster & Nissen 1989). A similar value is obtained from the calibration of the surface of the CORAVEL cross-correlation dip ([Fe/H] = $-$0.14, Pont 1997), confirming that the star is slightly metal deficient with regards to the Sun. From the Geneva photometry, a value of [M/H] = $+$0.13 is derived (Grenon, private communication).

The values of $\log g$ and $T_{\rm eff}$ derived from the $ubvy$-photometry are 4.54 ± 0.11 and 4842 K, respectively (Olsen 1984). Flower (1996) calibrated the relation between $B-V$ and both the bolometric correction (BC) and $T_{\rm eff}$[1]. Using his calibration, we obtain a value of $T_{\rm eff}$ = 4965 K. An intermediate value $T_{\rm eff}$ = 4936 K is obtained from the Geneva photometry (Grenon, private communication). From Flower's BC calibration and $T_{\rm eff}$

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* Based on observations collected at the La Silla Observatory, ESO (Chile), with the echelle spectrograph CORALIE at the 1.2-m Euler Swiss telescope

[1] His tables have the wrong values; the good values were obtained from the author.

Table 1. Stellar parameters for HD 192263.

Parameter	Value	Reference
Spectral type	K2V	colour-index; M_v
Parallax [mas]	50.27 ± 1.13	Hipparcos
Distance [pc]	19.9	Hipparcos
m_v	7.79	Hipparcos
$B-V$	0.938	Hipparcos
$T_{\rm eff}$ [K]	4840	*ubvy*-photometry
$M_{\rm v}$	6.30	–
Luminosity $[L_\odot]$	0.34	*ubvy*, Flower (1996)
Mass $[M_\odot]$	0.75	–
$\log R'_{\rm HK}$	−4.37	Santos et al. (1999a)
$v\ \sin i$ [km s^{-1}]	1.8±1.2	CORAVEL
[Fe/H]	−0.20/−0.14	*ubvy*-photometry/ CORAVEL

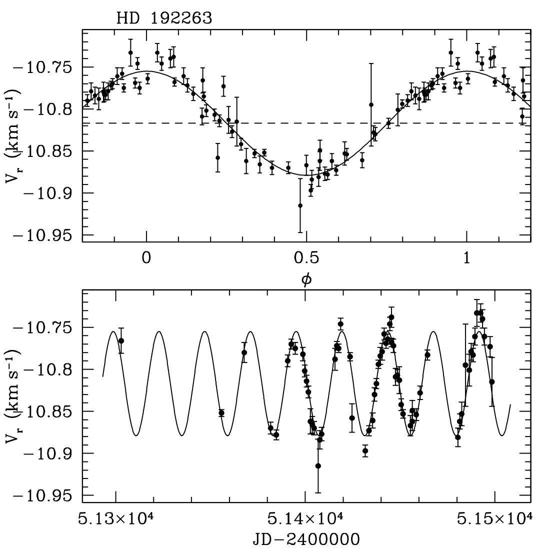

Fig. 1. *Top*: Phased orbital motion of HD 192263. The solid line represents the best Keplerian solution; *bottom*: temporal radial-velocity diagram, showing the 64 measurements over a span of about 7 months. In both diagrams, the error bars represent the photon-noise error.

obtained from the *uvby*-photometry, we find $M_{\rm bol}$ = 5.91, and L = 0.34 $L_\odot$. These values, compatible with a K2V/K3V star, slightly correct the K0V spectral type commonly quoted in the literature. In Table 1 we present the major physical properties of HD 192263.

In the Hipparcos Input Catalogue (Turon et al. 1992), HD 192263 is classified as the A component of a quadruple system, where the distance to the closer component (the close pair BC) is of 71.1 arcsec. According to the New General Catalogue of Double Stars (ADS – Aitken 1934), the proper motion of the BC pair is similar to that of the A component. There is, however, some confusion in the ADS catalogue about the identification of the D component (two candidates). To try to disentangle this identification problem, and to identify which (if any) of the components are physically associated, radial-velocity measurements are being obtained. Nevertheless, at the distance of HD 192263, the separation between the primary (A) and the secondary components (BC) corresponds to about 1400 AU, and so no perturbation from the binary companion is expected for the planetary orbit. From CORAVEL measurements taken between 1984 and 1989 there is no evidence for a stellar companion around HD 192263.

Table 2. Orbital elements of the fitted orbit and main planetary properties.

P	24.13	$\pm$ 0.09	d
$a_1\ \sin i$	0.0205	$\pm$ 0.0008	Gm
T	2451491.71	$\pm$ 0.28	d
$e^\dagger$	0.0		
V_r	−10.817	$\pm$ 0.002	km s^{-1}
$\omega^\dagger$	0.0		degr
K_1	62	$\pm$ 2	m s^{-1}
$f_1(m)$	$5.900 \cdot 10^{-10}$	$\pm\, 0.661 \cdot 10^{-10}$	$M_\odot$
$\sigma(O-C)$	13		m s^{-1}
N	64		
$m_2\ \sin i$	0.73		$M_{\rm Jup}$
a	0.15		AU

† With the eccentricity fixed at 0; when the eccentricity is let free, we obtain a value of 0.05 ± 0.04, consistent with a circular orbit according to the Lucy & Sweeney (1971) test.

Using CORALIE measurements, a periodic radial-velocity variation was found. The 64 high-precision radial-velocity measurements were obtained between May and November 1999, and cover about 9 orbital cycles, allowing us to derive an accurate orbital solution (Table 2).

In Fig. 1 we can see a phase-folded and a temporal radial-velocity plot of the measurements. The measurements have in average a precision of about 10 m s^{-1} due to photon noise. The derived orbital parameters (best least-square fit) show that the planet orbits its parent star in an almost circular orbit, with a period of 24.13 days, inducing a velocity semi-amplitude of 62 m s^{-1}. Given the orbital period and the mass of the parent star (0.75 $M_\odot$ from its colour index), the derived semi-major axis is 0.15 AU, and for the minimum mass of the companion we obtain 0.73 $M_{\rm Jup}$ (Table 2).

3. Discussion

Activity-related processes, like spots or inhomogeneous convection, can induce radial-velocity variations (Saar & Donahue 1997). These intrinsic variations can prevent us from finding planets (when the perturbation is higher than the planetary signal) or induce false detections (if they result in a periodic signal over a few rotational periods). Although HD 192263 is a slow rotator ($v\ \sin i$ = 1.8 km s^{-1} from the width of the CORAVEL cross-correlation dip, Benz & Mayor 1984) it is slightly active, as shown by the value of $S_{\rm COR}$ = 0.77 $\pm$ 0.02 (the flux in the center of the Ca II H line divided by the flux in a continuum window, as described by Santos et al. 1999a), corresponding to $\log R'_{\rm HK}$ = −4.37. The age estimated from the Geneva evolutionary tracks (Charbonnel et al. 1999) suggests the star may be young, which is consistent with its activity level.

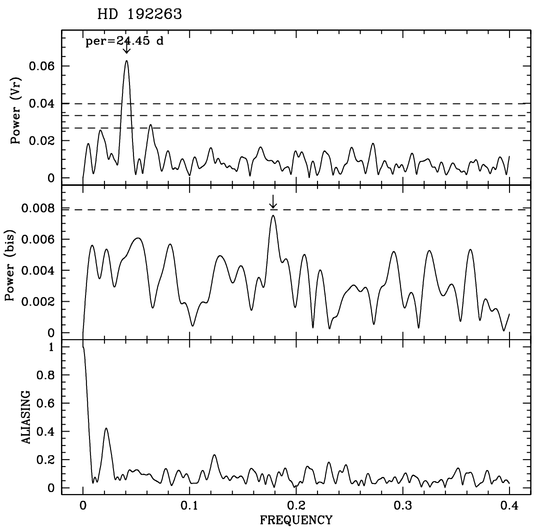

Fig. 2. *Top*: Fourier Transform of the radial velocity data. The horizontal dashed lines represent the false-alarm probability levels of 50% (lower line), 1% (middle line), and 0.1% (upper line); *center*: Fourier Transform of the inverse slope of the bisector of the cross-correlation dip. The dashed line represents the 50% false-alarm probability level; *bottom*: aliasing window.

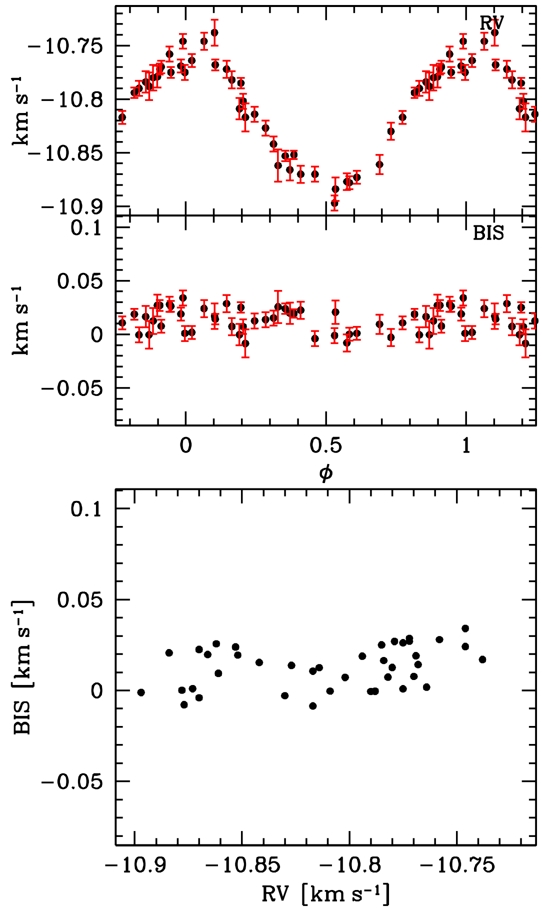

Fig. 3. Phased radial-velocity (upper pannel) and bisector inverse slope (middle pannel) values for HD 192263. The vertical scale of both panels is the same. The error-bars represent the photon-noise errors. In the lower panel we plot the values of the bisector inverse slope against the radial-velocity.

Given the low $v \sin i$ value for the star, a huge spot would probably be required to produce the observed radial-velocity variations. Such a spot would be detected by precise photometry measurements and/or in the analysis of the inverse slope of the bisector of the cross-correlation dip (Queloz et al., in preparation). However, the photometry shows the star has been stable to some milli-magnitudes over the span of the Hipparcos and Geneva measurements (958 and 395 days, respectively). Furthermore, and like in the case of HD 130322 (which has also a significantly high chromospheric-activity index – Paper II), the Fourier Transform (*FT*) of the bisector data presents no significant variation, in particular not with a period similar to the radial-velocity variation period.

In Fig. 2 we show the *FT* of the radial-velocity data (*top*) as well as of the bisector data (*center*). The lower plot shows the aliasing window. The *FT*s were computed using the Deeming method (Deeming 1975, 1976). In the plots, the horizontal lines refer to the false-alarm probabilities. These were computed using a Monte-Carlo simulation where random radial-velocity and bisector values were chosen, with the same temporal distribution and rms as our "real" data. While the *FT* of the radial-velocity data shows a conspicuous peak with a 24.5 day period, no significant periodicity is seen in the bisector analysis: the higher peak, corresponding to a period of 5.61 days, has a false-alarm probability of about 63%.

The absence of a correlation between the radial-velocity and the bisector variations is well illustrated in Fig. 3, where we plot the radial-velocity and bisector inverse slope phased data points (top and middle panels, respectively). In the lower panel we plot the values of the bisector inverse slope of the cross-correlation dip as a function of the radial-velocity values. We can easily see that there is no variation of the bisector coherent with the observed radial velocity.

The observed 13 $\mathrm{m\,s^{-1}}$ residuals around the orbital solution are very close to the mean photon-noise value of 10 $\mathrm{m\,s^{-1}}$ and the small excess can probably be explained by the activity level of the star. These facts seem to rule out the possibility that the source of radial-velocity variation is intrinsic stellar-activity, and lead us to conclude that the planetary explanation is the only really capable of explaining the observed periodic radial-velocity variation.

Nevertheless, it is interesting to verify that with such a high activity level (as expressed by the R'_{HK} index), the observed O−C residuals are very low (13 $\mathrm{m\,s^{-1}}$ including photon noise errors and probably intrinsic variation). This supports the idea that for K dwarfs the perturbations induced by activity-related phenomena are less conspicuous than for F or G dwarfs (Saar et al. 1998; Santos et al. 1999a).

An analysis of the radial-velocity residuals $(O-C)$ around the orbital solution shows no other periodicity or trend is present in the γ-velocity, at least over the limited 162-day span of our measurements.

4. Conclusions

Noyes et al. (1984) showed that for solar-type dwarfs, the value of the chromospheric activity index $R'_{\rm HK}$ is correlated with the rotational period. Knowing the value of the $v \sin i$, this relation can then be used to estimate the value of the inclination of the stellar rotational axis to the line of sight. From Noyes calibration we estimate a value of $P_{\rm rot}$ = 9.5 days for HD 192263. Considering collinear spin axes for the stellar rotation and planet orbital motion, and taking a typical value for the radius of a K2V dwarf ($R_\star$ = 0.8 $R_\odot$), the value of $v \sin i$ of 1.8 $\pm$ 1.2 km s^{-1} implies a companion mass of at most 5.2 $M_{\rm Jup}$, clearly inside the planetary mass range.

Considering that the planet has an albedo of 0.35 (Jupiter value) and that it orbits the K2V parent star at a distance of 0.15 AU, its equilibrium temperature is around 480 K (e.g. Guillot et al. 1996).

The high-metallicity content of the parent stars of extra-solar planets was quickly noticed after the first extra-solar planets were discovered (e.g. Gonzalez 1998). This fact is becoming sharper as more planets are found and may be related to the planet formation process and evolution. HD 192263 has a rather normal [Fe/H] metallicity index for solar neighbourhood dwarfs, but is slightly metal poor compared with the other stars with planetary companions. Its position in the deficient tail of the metallicity distribution of stars with giant planets is not very significant, and we can probably classify it as a "normal" planetary host star.

After 1 year of measurements, this is the fourth extra-solar planet candidate detected in the context of the CORALIE southern survey (Paper I; Paper II; this paper). The planet around HD 192263 was confirmed by Dr. G. Marcy and collaborators shortly after the announcement (private communication). Their orbital parameters are very similar to ours, except for the eccentricity, for which they find a value of 0.22 (Vogt et al. 2000).

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