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Letter to the Editor

Evidence against the young hot-Jupiter around BD +20 1790⋆,⋆⋆

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ABSTRACT

Context. The young active star BD +20 1790 has been inferred to host a substellar companion from radial-velocity measurements that detected the reflex motion induced on the parent star.
Aims. We attempt to completely characterize the radial-velocity signal in order to assess its nature.
Methods. We used the CORALIE spectrograph to obtain precise ($\sim$10 m s^{-1}) radial-velocity measurements of this active star, while characterizing the bisector span variations. We took particular care to correctly sample both the proposed planetary orbital period, of 7.8 days, and the stellar rotation period, of 2.4 days.
Results. We measure a smaller radial-velocity signal (with peak-to-peak variations <500 m s^{-1}) than reported previously, and of different amplitude for two different campaigns. A periodicity similar to the rotational period is found in the data, as well as a clear correlation between radial velocities and bisector span. These results imply that the radial-velocity variations of the star are photospheric in origin and not caused by a barycentric movement movement of the star, and contradict the previous detection of a hot-Jupiter.

Key words. instrumentation: spectrographs – methods: observational – techniques: radial velocities – planetary systems – stars: individual: BD +20 1790 – stars: activity

1. Introduction

Since the discovery of the first exoplanet around 51 Peg by Mayor & Queloz (1995), the radial-velocity method (RV) has established itself as the workhorse for exoplanet detections. It allowed the detection of more than 3/4 of all planets we know and was instrumental in shaping the body of knowledge we gathered on the subject (Udry & Santos 2007).

However, many open questions remain. For instance, the planetary formation process is a subject of great debate. As a consequence, a positive detection of a planet around a young star would be highly valuable; it would place a stringent upper limit on the timescale of planet formation, providing a strong observational constraint for the models to comply with. To address this question, several RV surveys have targeted young objects, only to find that extrasolar planets around these hosts are very rare (Setiawan et al. 2007). Since young stars exhibit high photospheric and chromospheric activity, these surveys are in addition plagued by stellar activity effects. The detection of an RV signature steming from atmospheric phenomena is very common and false planetary detections around very young stars have been made by Prato et al. (2008) and Huélamo et al. (2008) among several others.

Hernán-Obispo et al. (2010) provided compelling evidence of a planet around the young active star BD +20 1790, interpreting its RV observations as evidence that a massive hot-Jupiter orbits the star. Targeting primarily stellar activity characterization, several high-frequency RV data sets had been obtained, scattered across and spanning six years. The main limitations of these were the inadequacy of the time sampling for a planetary search campaign and the low RV precision of the measurements. Nevertheless, an extensive characterization of stellar activity and careful discussion were presented. The authors showed that some spectral/activity indicators exhibited variation on a timescale of the rotation period (2.8 days) but none on a timescale of the reported RV variation (7.8 days). This supported the planetary hypothesis, which was considered as the most likely explanation of the RV variations.

Following the announcement of the planet, we started an intensive RV campaign targeting BD +20 1790 with the CORALIE spectrograph. In this paper, we analyze our measurements. In Sect. 2, we present an overview of the parameters both of the star and of the putative planet. In Sect. 3, we describe the results of our campaign and discuss them in Sect. 4. We finish by stating our conclusions in Sect. 5.

⋆ Based on observations collected with CORALIE echelle spectrograph mounted on the Euler 1.2 m Swiss telescope at La Silla, Chile.
⋆⋆ Radial velocity data are only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/513/L8

2. An overview of the star and planet properties

The star BD +20 1790 is a K5Ve star of magnitude $V = 9.9$. It has an effective temperature of 4410 K and an age of 35–80 Myr. The derivation of these values and the host star properties are described in detail in Hernán-Obispo et al. (2010). The measured photometric period of 2.801 ± 0.001 days and the $v \sin i$ of 10.03 ± 0.47 km s^{-1} are of particular importance to us.

The high activity level of the star is attested by the detection of transient absorption features in the spectra and strong optical flare events. The duration of both phenomena was several hours. The authors estimated the flare occurrence corresponded to 40% of the total observing time and showed that a flare was associated with an increase in the scatter of the bisector span values.

The RV presented by Hernán-Obispo et al. (2010) has a peak-to-peak amplitude of ~2 km s^{-1}. The periodogram of their data showed a 7.78 days peak with a false-alarm probability of 0.35%. The fit of a Keplerian function led to a semi-amplitude of 0.8–0.9 km s^{-1}, depending on the allowed range for orbital eccentricity. This value was much higher than the uncertainty in the individual measurements, of 100–200 m s^{-1}.

The authors analyzed the different spectroscopic activity indicators – H_α, H_β, Ca II IRT, and Ca II H & K – and found that none exhibited significant variation with a periodicity similar to that of the proposed orbit, and only H_α yielded a periodicity similar to that of the photometric period. The authors also concluded that the RV variations induced by a star spot would have an amplitude roughly 2 times smaller than that measured and thus could not explain the measured RV. The bisector signal showed no correlation with RV, and a planetary origin was attributed to the signal.

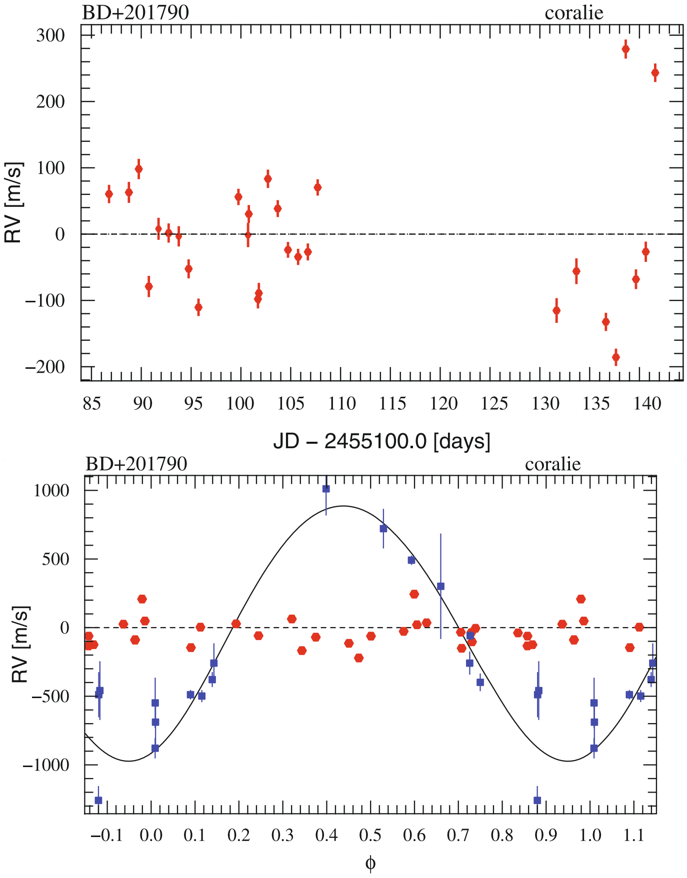

Fig. 1. CORALIE RV measurements for BD +20 1270. The measured RVs are plotted as a function of time (*top pannel*) and phase-folded on the orbit announced by Hernán-Obispo et al. (2010), (*bottom panel*). The published RV measurements and error bars are presented as well (square symbols).

3. Radial velocity measurements and analysis

We obtained a set of 28 CORALIE RV measurements, spanning 55 days. CORALIE is the fiber-fed echelle spectrograph mounted at the Swiss telescope at La Silla observatory. High-precision RV measurements are obtained by cross-correlating the spectra with a template mask (Baranne et al. 1996; Pepe et al. 2002). The observations are reduced online, allowing a real-time calculation of the RV and photon noise estimation. Previous campaigns showed that CORALIE can reach a long-term precision of 5–6 m s^{-1} (e.g. Segransan et al. 2010). We also calculated the bisector velocity span of the cross-correlation function, following the procedure described in Queloz et al. (2001). To do so, we calculate the line that bisects the cross-correlation function; the *bisector top* and the *bisector bottom* are defined as the average bisector values for the ranges of 10 to 40% and 60 to 90% of the line depth, respectively. The bisector span (henceforth BIS) is then the inverse of the slope of the line that connects the *bisector top* to the *bisector bottom*.

Our data points were obtained during two observing campaigns. The first set contains 20 measurements spanning 21 days, from 21 December 2009 to 10 January 2010; the second has 8 measurements obtained in a mission of 10 days, from 4 to 14 February 2010. The precision of the RVs is dominated by the photon noise contribution, with an average precision of 12.28 m s^{-1}. The weighted rms of the data is 101.7 m s^{-1} and the peak-to-peak amplitude is 464.9 m s^{-1}. The data are presented in Fig. 1 (top panel).

We first note the different amplitudes of the RV variation for the two campaigns. In the first campaign, the RVs have a weighted rms of 61.12 m s^{-1} and a peak-to-peak amplitude of 208.6 m s^{-1}, while for the second these values are 172.8 m s^{-1} and 464.9 m s^{-1}, respectively. The average uncertainties in the measurements are very similar, 12.02 and 13.04 m s^{-1}, respectively, and cannot account for the amplitude discrepancy. In both cases, the RV variations are smaller than those reported by Hernán-Obispo et al. (2010) by a factor of 10 and 5, respectively, and cover time spans of three times the published orbital period for the first campaign, and one time for the second. A phase-folded plot onto the announced orbit depicts this discrepancy very well (Fig. 1, bottom panel). We only considered the first of the two proposed orbits, but they only differ slightly and the same conclusions hold.

However, the weighted rms is well in excess of the average measurement precision. To reliably detect the presence of a periodic signal in the data, we used two different approaches. The first was the "string-length" method described in Dworetsky (1983). This method delivers the orbital period that minimizes the sum of the lengths of line segments in a (RV_i, ϕ_i) diagram. It is suitable for randomly spaced observations in small data sets, such as ours, and is very efficient in detecting single planets in eccentric orbits. Using it, we find a period of 2.790 days (and a T_0 of JD = 2 455 238.6). If only the data from the first campaign are used, the period changes slightly to 2.765 days. The phase-folded RV measurements for both data sets and periods are shown in Fig. 2. We note that while the two data sets exhibit different RV amplitude variations, the periodicity of the signal is not significantly affected by the inclusion of the data from

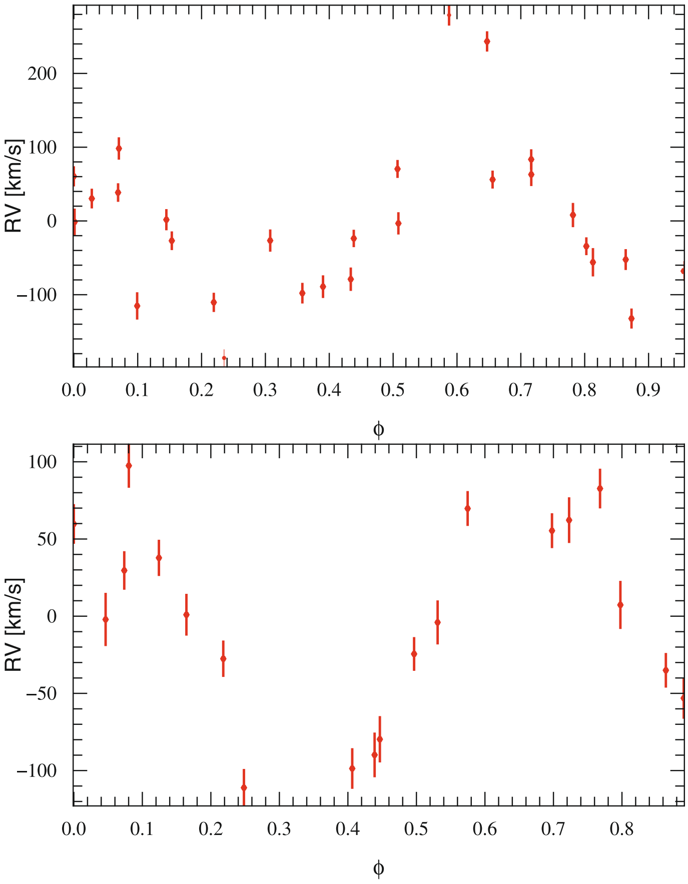

Fig. 2. CORALIE RV measurements for BD +20 1270 folded onto a 2.790 period (*top*), and the data from the first campaign only folded onto a 2.765 period orbit (*bottom*).

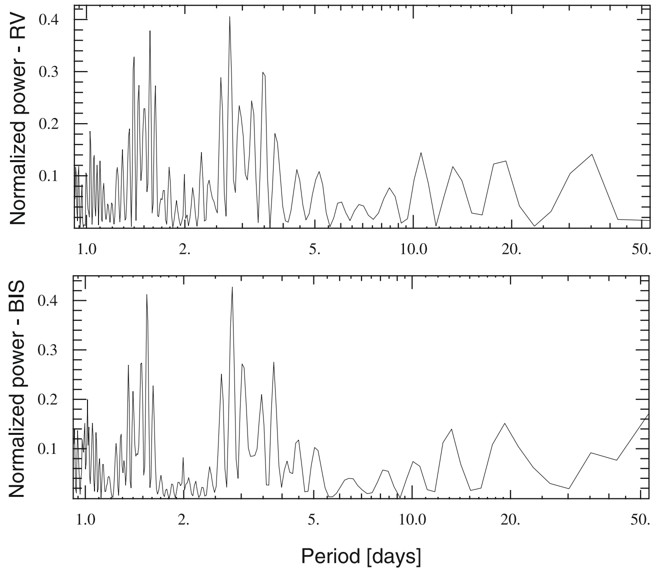

Fig. 3. Generalized Lomb-scargle periodogram for BD +20 1790 RV (*top*), and BIS (*bottom*).

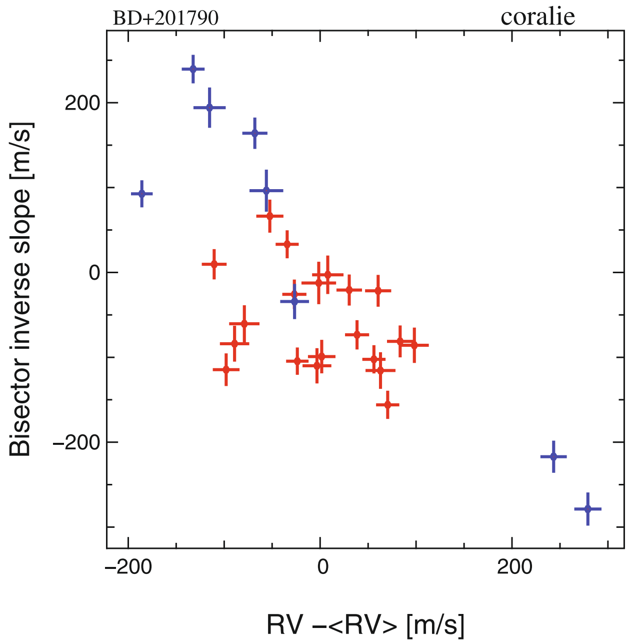

Fig. 4. Correlation between RV and BIS. The red points correspond to the data from the first campaign and the blue points the data corresponding from the second. The BIS error bars are approximated by twice the photon error on the corresponding RV.

the second campaign. In particular, the data from the first campaign show a well-defined variation when phase-folded (bottom panel).

We also computed the generalized Lomb-Scargle periodogram (as implemented by Zechmeister & Kürster 2009), which identified 1.55 and 2.8 day signals in both the RVs and the BIS (Fig. 3). The 1.55 day signal is the alias of the 2.8 day signal created by the 1 day sampling. The BIS shows a significant variation, similar to and correlated to that of the RV. The BIS-RV plot is presented in Fig. 4; we note that the data from the second campaign exhibits extreme values of both RV and BIS. A linear least squares fit delivers a slope of –0.826. The Pearson's correlation factor is –0.747, and Monte Carlo simulations indicate that the probability of obtaining this value or one lower from two random non-correlated distributions with 28 points is $<10^{-4}$ and thus negligible.

4. Discussion: signal produced by a spot?

In spite of the high-precision and temporal cadency of our RV measurements, we found no evidence of the planetary signal reported by Hernán-Obispo et al. (2010). Instead of an orbit with peak-to-peak amplitude of 1800 m s^{-1} and period of 7.8 days, we detected an RV signal with peak-to-peak variation of 460 m s^{-1} and a periodicity of 2.8 days. Moreover, the amplitude of this signal is not constant, doubling between the first campaign and the second one.

We attempted to quantify the likelihood that our points originate in the announced orbit. We proceeded as follows because the error propagation in the published T_0 value until today ensures that the phase cannot be predicted accurately. We considered a set of 28 data points randomly distributed over the entire phase, and calculated the RV for each point, and the rms of the set of measurements. We note that no instrumental error is added to the curve, so this provides a lower limit to the rms. The simulation was repeated 10 000 times. All values were well in excess of the measured RV of 101 m s^{-1} rms, and we concluded that the probability of the two data sets being compatible is lower than 10^{-4}.

Two arguments imply that the RV variations originate in photospheric effects:

- the similarity between the RV periodicity found in the data and the announced photometric period;
- the correlation between BIS and RV.

The hypothesis that the RV on BD+20 1790 was caused by stellar phenomena was discarded by Hernán-Obispo et al. (2010), who detected a RV signal with a periodicity that differed from the rotational period. Using rules of thumb of Saar & Donahue (1997) and Desort et al. (2007), the authors showed that the amplitude of the signal created by a spot was expected to be no larger than $\sim$600 m s^{-1}. Even though this value is too small to explain their RV variation, it can easily account for what we detect. The BIS of our measurements is also significantly correlated with the RV, the data of the second campaign clearly exhibiting a much higher simultaneous RV and BIS variation.

5. Conclusions

We have presented strong evidence that the RV variation of the star BD +20 1790 is caused by stellar atmosphere phenomena rather than being induced by an unseen companion. These conclusions have been drawn from high-cadence, precise RV (at $\sim$10 m s^{-1} level) data that correctly sampled the previously proposed orbit. Instead of reproducing this orbit, we detected a lower RV variation of variable amplitude. The RV signal is correlated with BIS and exhibits a periodicity very similar to the reported photometric period.

This work shows the importance of correctly sampling the phase of a candidate orbit. The conjugated effect of starspots and stellar jitter can otherwise be mistaken for a planetary signature.

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References

Baranne, A., Queloz, D., Mayor, M., et al. 1996, A&AS, 119, 373
Desort, M., Lagrange, A.-M., Galland, F., Udry, S., & Mayor, M. 2007, A&A, 473, 983
Dworetsky, M. M. 1983, MNRAS, 203, 917
Hernán-Obispo, M., Gálvez-Ortiz, M. C., Anglada-Escudé, G., et al. 2010, A&A, 512, A45
Huélamo, N., Figueira, P., Bonfils, X., et al. 2008, A&A, 489, L9
Mayor, M., & Queloz, D. 1995, Nature, 378, 355
Pepe, F., Mayor, M., Galland, F., et al. 2002, A&A, 388, 632
Prato, L., Huerta, M., Johns-Krull, C. M., et al. 2008, ApJ, 687, L103
Queloz, D., Henry, G. W., Sivan, J. P., et al. 2001, A&A, 379, 279
Saar, S. H., & Donahue, R. A. 1997, ApJ, 485, 319
Segransan, D., Udry, S., Mayor, M., et al. 2010, A&A, 511, A45
Setiawan, J., Weise, P., Henning, T., et al. 2007, ApJ, 660, L145
Udry, S., & Santos, N. C. 2007, ARA&A, 45, 397
Zechmeister, M., & Kürster, M. 2009, A&A, 496, 577