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Transit variations in WASP-3

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Abstract

The variations in the period and duration of the transits of exoplanets allow us to obtain some of their orbital properties. Here we investigate the variations in the transit parameters of WASP-3 over a period of time that covers more than three years. Apart from providing complementary information on the geometrical configuration of the system, the investigation of transit duration (TDV) can also provide indirect evidence of the presence of additional planets. The WASP-3 system constitutes the first example for which the TDV have been tracked over a long period of time, allowing for the easier detection of secular variations of the orbital parameters. This work shows that the effects of nodal precession are clearly discernible in the TDV of WASP-3, as the theory predicts. We also confirm the presence of strong transit time (TTV) in a shorter time scale but in this case the periodicity of the signal is not so clear.

1 Introduction

WASP-3 b is a well known hot, Jupiter-class planet. First detected by [7] it is so close to its parent star as to only 0.031AU and it is one of the most hottest transiting planets. The combination of a high stellar rotation velocity and a non completely alination between the orbital plane and the stellar rotation axis makes WASP-3 a good target to identify the effect of orbital precession using variations between different transits. Variations of transit duration (TDV) is the best way to search for this effect in that case of a circular orbit. However, to detect such signal in TDV it is necessary to accumulate a large number of transits. Also, the existence of a second planet may be derived from transit time variations (TTV) within a periodicity of ~ 127 days.

We present in this work observations of new transits for WASP-3 with the aim to verify the TTV periodicity. In addition, the long-term variations of the transit duration for this object is studied.

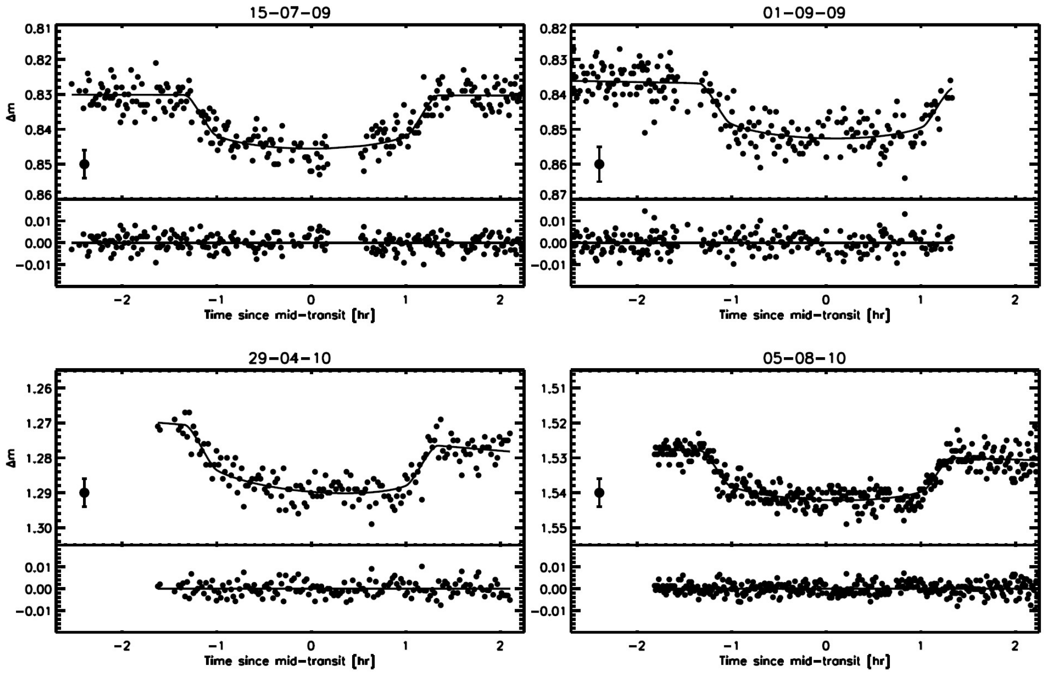

Figure 1: Photometric light curves of the observed transits together with the models that best fit the data (solid line). At the bottom of each curve are shown the residuals of the fits. The error bar displayed in the left corner indicates the estimated uncertainty of the photometric measurements for each transit.

2 Observations

Our 50 cm telescope located at the Calar Alto Observatory (Spain) was used to obtain the photometric series of WASP-3. It is a Cassegrain configuration telescope that uses a 4008×2672 Finger Lakes Instrumentation (FLI) ProLine PL11002M Interline CCD camera. The FOV is about 24×16 arcmin, for a plate scale of 0.37 arcsec per pixel (9 μm pixel size). In order to avoid oversampling of the stellar profile (the seeing conditions was typically of 2 arcsec) the binning mode was permanently set to 2×2. All the images were taken using the R filter of the Johnson-Cousins standard system. A total of five transits of WASP-3 were observed between July 2009 and August 2010.

Data were automatically processed by the system once the observations were finished using standard CCD reduction routines and the computation of differential aperture photometry with the CCD-corrected images [3].

3 Results and discussion

The light curves obtained from observations were fitted with theoretical transit models by using the codes available from the Exoplanet Transit Database [8]. The best fits and residuals

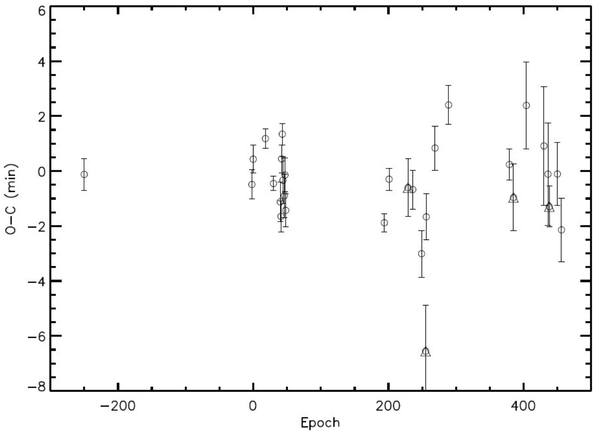

Figure 2: The observation minus calculation (O − C) values that result if the mid-transit times of WASP-3 are calculated with the same linear ephemeris. The values derived from the new transits are plotted with triangles.

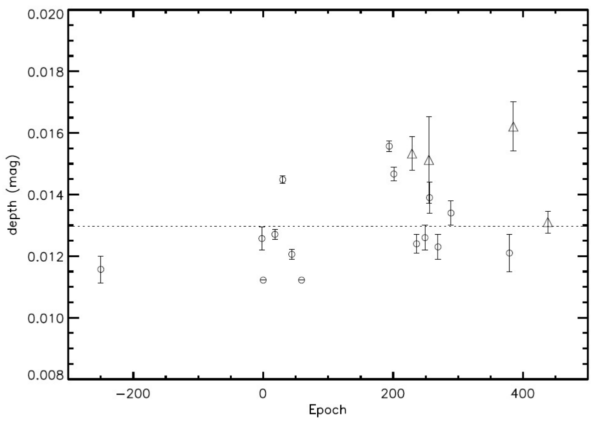

Figure 3: The transit depth that has been reported for different epochs. Triangles denote measurements from this work. The dotted line indicates the mean depth level used as a reference value for comparison.

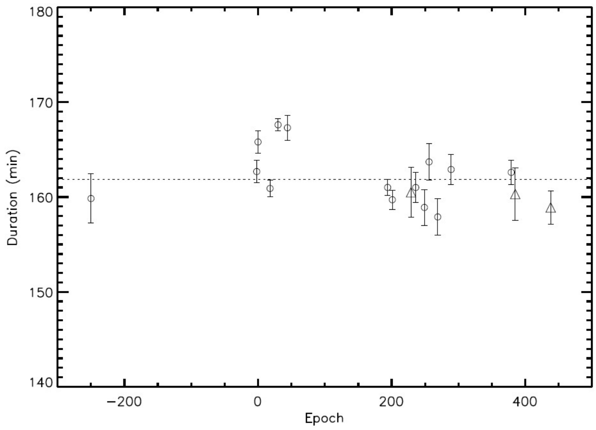

Figure 4: TDV over different epochs. Triangles denote measurements from this work. The dotted line shows the overall sample mean.

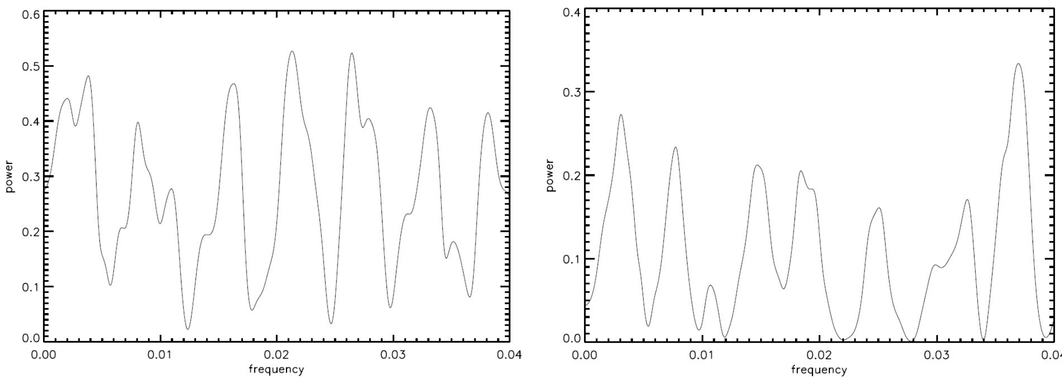

Figure 5: The generalised Lomb-Scargle periodogram for the TDV (*left panel*) and the TTV (*right panel*).

are shown in Fig. 1. A linear fit of the epoch, T_0, and period, P, from the measured mid-transit times gave:

$T_0 = 2454605.55990 \pm 0.00009$ BJD

$P = 1.8468343 \pm 0.0000005$ d

The period here derived is consistent with previous works. The resulting transit variations are shown in Fig. 2 for TTV, Fig. 3 for depth, and Fig. 4 for TDV. From these figures it is clear that there is a relatively higher scatter in the distributions of both the depth and TTV in comparison with the duration. Taking the average of all the measurements we obtained a mean depth of 0.0130 mag (continuous dotted line in Fig. 3).

We have investigated the periodicity of the TDV and TTV using a generalised Lomb-Scargle periodogram of the sample of transit duration measurements that are shown in Fig. 5. The periodograms show several peaks with a similar level of significance that may have its origin in some additional variability components apart from that expected for a strictly Keplerian orbit. With some further analysis and eliminating some fictitious peaks we can obtain transit duration variations with an amplitude of ~ 4 min. Also, we find evidence for a periodicity of ~ 68 P for TTV in agreement with [6]. However, this would not be evidence of a second planet as they propose because the same periodicity seems to be also present in the TDV.

Acknowledgments

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