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High cadence near-infrared transit timing observations of extrasolar planets

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Abstract. Currently the only technique sensitive to Earth mass planets around nearby stars (that are too close for microlensing) is the monitoring of the transit time variations of the transiting extrasolar planets. We search for additional planets in the systems of the hot-Neptune GJ-436 b, and the hot-Jupiter XO-1 b, using high cadence observations in the J and K_S bands, with the SofI and ISAAC instruments from La Silla Paranal Observatory. New high-precision transit timing measurements were used to derive new ephemeris. No statistically significant timing deviations were detected. We demonstrate that the high cadence ground based near-infrared observations are successful in constraining the mean transit time to 30 sec, and are a viable alternative to space missions.

1. Description

We present the first results from our timing study of individual transits of extrasolar planets with infrared detectors, using the *FastPhot* mode available in SofI@NTT, and ISAAC@VLT in La Silla - Paranal Observatory, which provides us with an unprecedented time resolution of 0.05-0.3 sec, and minimum "dead" time for readout (0.1%), generating a series of data cubes, with the target and one reference star in each windowed frame. The analyzed planets were the hot-Jupiter XO-1 b, and the hot-Neptune GJ-436 b.

2. Results

Figure 1 shows a light curve of planet XO-1 b with an exposure time of 0.08 sec. The total number of data points is $\sim 190,000$. In the best fitting model determination, the error calculation was developed with a Bootstrapping simulation which takes into account the presence of red noise in the data (Cáceres *et al.* 2009). The O-C diagram for the hot-Neptune GJ-436 b is also shown. These observations were taken on 17 May 2007, with the SofI@NTT at La Silla, in poor weather conditions. About 25,000 data points were collected using an exposure time of 0.24 sec, and for the best fitting model, we select stellar parameters from Gillon *et al.* (2007), and planetary parameters from Torres *et al.* (2007).

An individual transit timing accuracy of 30 sec is achieved. The data show some TTVs (Transit Time Variations) of up to 98 sec. However, these deviations are consistent with zero, within their respective uncertainties. Further observations with higher accuracy are necessary to better constrain the properties of these system and to address the question of whether they contains other planets.

The new ephemeris thus obtained are:

$$\text{XO-1 b:} \qquad T_C = 2453808.91682(13) + E \times 3.9415128(28)\text{HJD}$$

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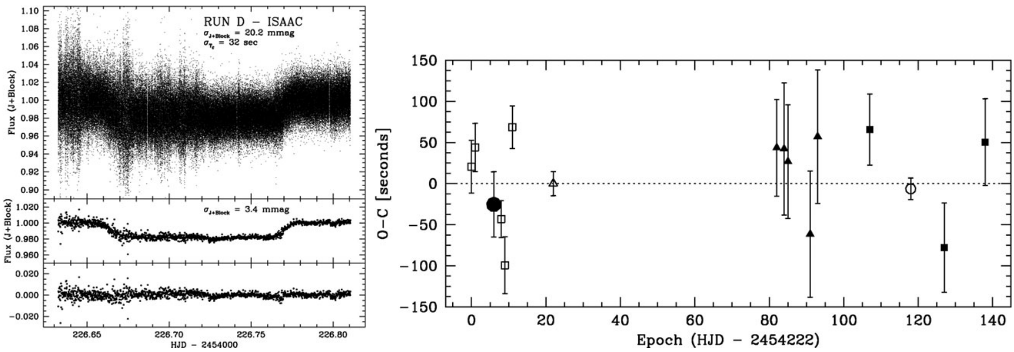

Figure 1. *Left.* A high cadence transit light curve for the transiting planet XO-1 b, taken with ISAAC@VLT the night of May 5, 2007. The best fitting model is shown, with planetary and stellar parameters taken from Holman *et al.* (2006) and McCullough *et al.* (2006) respectively. *Right.* The O-C diagram for our timing measurement of the transiting planet GJ 436b, and the data in the literature (see Cáceres *et al.* 2009 for more details).

$$\text{GJ-436 b:} \qquad T_C = 2454222.61588(12) + E \times 2.6438986(16)\text{HJD}$$

3. Conclusions

We achieve transiting timing accuracies of about 30 sec for individual transits. We find no significant evidence for perturbations of the orbital motion of GJ-436 b nor XO-1 b by other bodies in the system. Of course, a proper test of this hypothesis will require monitoring of multiple transits with the same or even higher accuracy. We demonstrate that the ground-based high-cadence observations of transiting extrasolar planets is an excellent technique for constraining the parameters of extrasolar planetary systems, because of the statistical significance of the obtained timing measurements. The timing precision is comparable with the space-based observations, making this method a good alternative to space missions, with their high cost and limited lifetime.

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