Searching for undetected companions in the Qatar-1 system through transit timing variations

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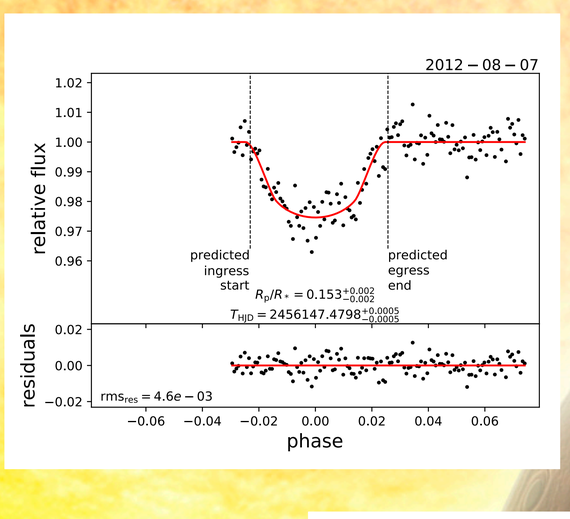
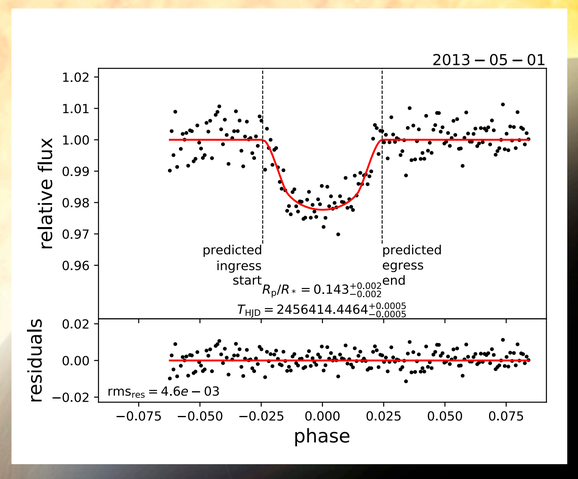
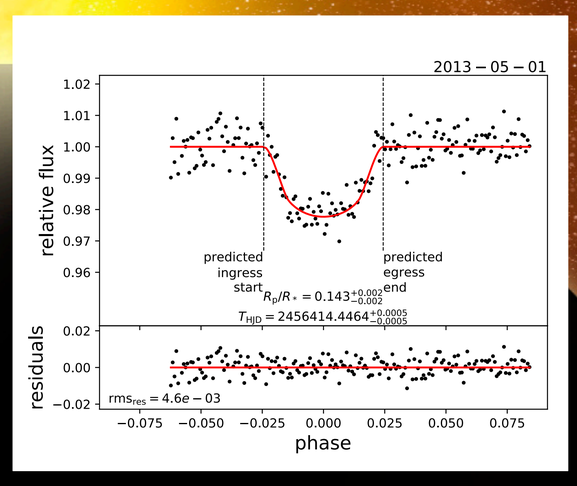
ABSTRACT

With a hot Jupiter (M=1.09 Jupiter masses, R=1.16 Jupiter Radii) on a period of 1.42 days and an apparent V magnitude of 12.86, Qatar-1 system is one of the best systems that host transiting exoplanets for characterisation from the northern hemisphere (RA: 20:13:32, DEC: +65:09:43). Qatar-1 b was initially reported to feature transit timing variations with a period of about 190 days that could be the result of either a weak perturber in resonance with Qatar-1 b, or a massive body in the brown dwarf regime (von Essen et al. 2013). However, more recent observations suggest that there are no significant transit timing variations with a semi-amplitude of approximately 25 seconds (Collins et al. 2017). In this study we present five additional transit observations of Qatar-1 b from the Holomon Astronomical Station. Despite the small number of new observation, we demonstrate the stability of the instruments throughout five years and the potential of adding more observations in the future, concerning either Qatar-1 b or other exoplanets. The precise estimation of the ephemeris of exoplanets is mandatory for future characterisation missions and long-term observations from small telescopes can contribute.

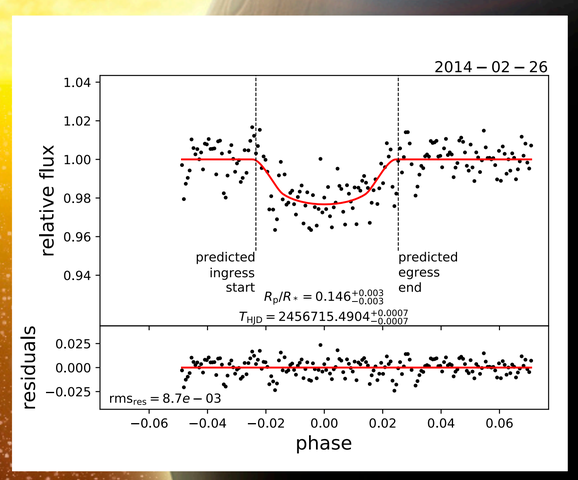


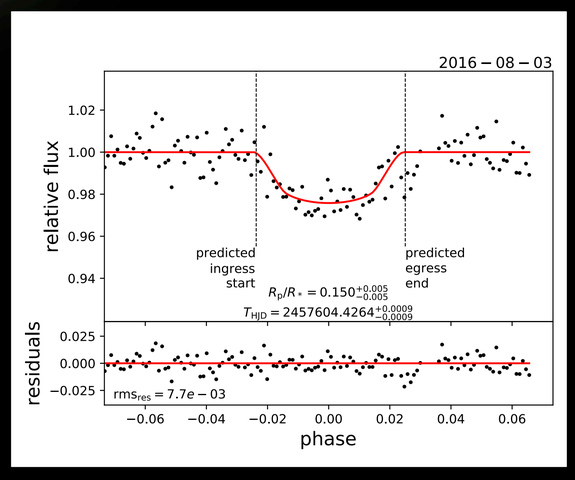




Parameter	Symbol	Circular
Transit epoch	T_0	5518.4102 ± 0.0002
Orbital period	P	1.420033 ± 0.000016
Planet/star area ratio	$(R_p/R_*)^2$	0.02117 ± 0.00045
Transit duration	t_T	0.06716 ± 0.00077
Impact parameter	b	$0.696^{+0.021}_{-0.024}$
Stellar reflex velocity	K_1	$0.218^{+0.015}_{-0.016}$
Centre-of-mass velocity offset	$\Delta\gamma$	$0.118\,794^{+0.000\,052}_{-0.000\,053}$
Orbital eccentricity	e	0.0 (fixed)
Longitude of periastron	ω	–
Orbital inclination	i	$83.47^{+0.40}_{-0.36}$
Orbital semimajor axis	a	$0.023\,43^{+0.000\,26}_{-0.000\,25}$
Planet radius	R_p	1.164 ± 0.045
Planet mass	M_p	$1.090^{+0.084}_{-0.081}$
Planet surface gravity	$\log g_p$	$3.265^{+0.044}_{-0.045}$
Planet density	ρ_p	$0.690^{+0.098}_{-0.084}$
Planet temperature	T_{eq}	1399 ± 42

Parameters of Qatar-1 b from Alsubai et al. (2011).

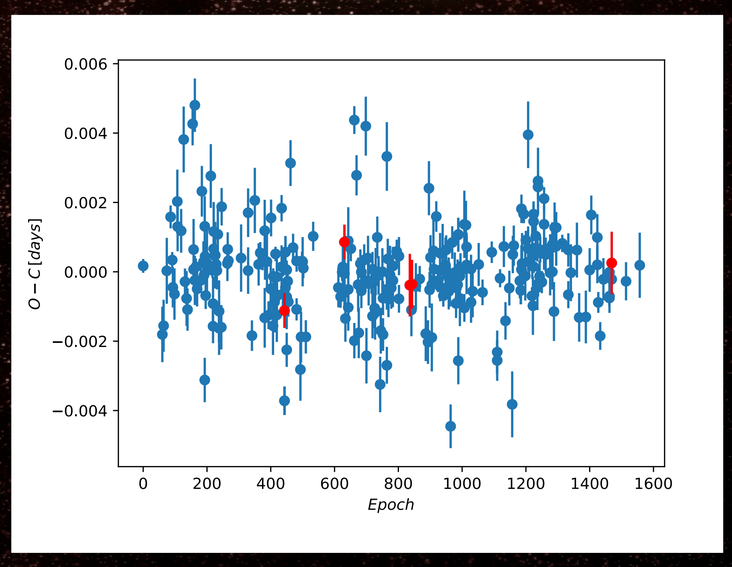




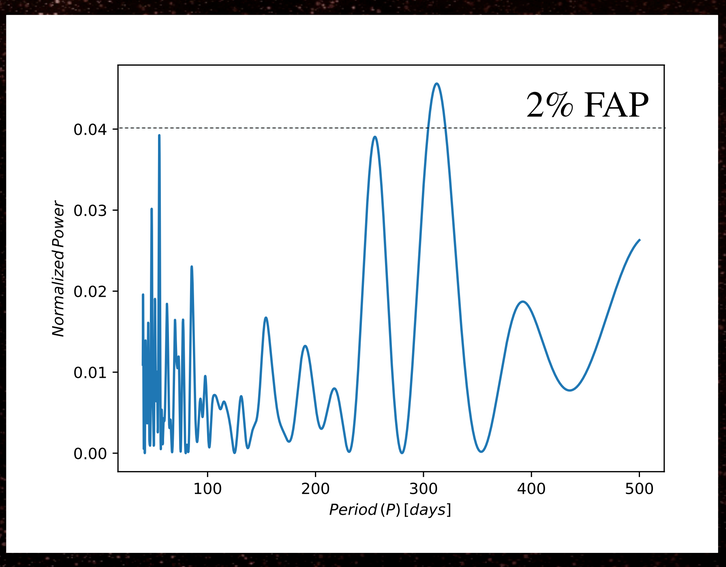
Qatar 1b was detected in 2012 by Alsubai et al. (see Table above). In 2013 von Esssen et al. suggested that Qatar-1 b may undergo timing variations, caused by an additional, non transiting planet orbiting that same star. The authors analysed 26 transit light-curves of Qatar-1 b between 2011 and 2012, and detected a periodicity in the O-C diagram at 187 +/- 17 days, with the false-alarm probability (FAP) of 0.05%. Later, Maciejewski et al. (2015) and Collins et al. (2017) analysed 18 (each) additional transit light-curves, but they did not detect aany significant periodicity. Finally, Püsküllü et al. (2017) reported a periodicity of 83.75 +/- 0.48 days in the O-C diagram, but with a FAP of nearly 5%.

We observed five transits of Qatar-1 b from the Holomon Astronomical Station between 2012 and 2016 (Figures above) and performed an analysis on all the currently available measurements of the mid-transit times, including those from the open database of ETD (http://var2.astro.cz/ETD/). We have re-determined the ephemeris of the planet (T_0 = 2455518.41079 +/- 0.00017 days (BJD), P = 1.4200246 +/- 0.0000002 days) and found a peak in the periodogram of the O-C diagram at 312 +/- 20 days with a FAP of 1.7%. For these calculation we used the generalised Lomb-Scarge periodogram (Zechmeister & Kürster, 2009) and the bootstarp method.. In our transit light-curve analysis only the mid-transit times and the radii ratios were fitted. We note an inconsistency in the Rp/R* ration int eh first observation, which we believe is the result of flat-fielding issues conserning this particular observation.

References:
Alsubai et al. (2011), MNRAS, 417, 709-716
Covinio et al. (2013), A&A, 554, A28
von Essen et al. (2013), A&A, 555, A92
Maciejewski et al. (2015), A&A, 557, A109
Collins et al. (2017), ApJ, 153, 78
Püsküllü et al. (2017), New Astron, 55, 39-47
Zechmeister & Kürster (2009), A&A, 496, 577



OC diagram for all the reported mid-transit times (published papers & ETD), relatively to the updated ephemeris:
T_0 = 2455518.41079 + 1.4200246 E
In red, the observations from the Holomon Astronomical Station are plotted.



Generalised Lomb-Scargle periodogram of the OC diagram with the most significant peak at 312 +/- 20 days with a False-Alarm Probability of 1.7%.