Follow Up of Transiting Hot Jupiters with the OpenScience Observatories

Conference or Workshop Item

Follow Up of Transiting Hot Jupiters with the OpenScience Observatories

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ABSTRACT

We have been using the Open University OpenScience Observatories (OSO) to undertake follow up observations of known transiting hot Jupiters for the past three years. Here we present recent system characterisation and transit timing results for WASP-52b and HAT-P-23b and report on the performance of the observatory.
The OSO consists of two 0.4 meter class telescopes (PIRATE and COAST) used for undergraduate distance learning and research (Kolb et al 2018). The telescopes, located at Teide Observatory on Tenerife at an altitude of 2390m, can be operated remotely in real time for teaching or fully autonomously via an automated scheduler. Teide Observatory provides an excellent location with typical seeing of 0.6" and an average 280 clear nights per year. Our new observations, supplemented with additional data from a telescope located in the UK and previously published results, show that HAT-P-23b is slightly less inflated than previously reported and not eccentric. We find that a linear ephemeris is the best fit to the available timing data. For WASP-52b we slightly prefer a quadratic ephemeris indicative of period change. Further observations through the 2020-21 observing season should discriminate between the linear and quadratic ephemerides.

The OpenScience Observatories are part of The Open University's The OpenSTEM Labs initiative

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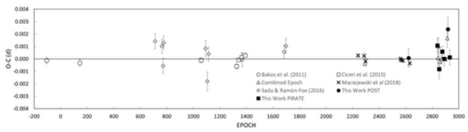
HAT-P-23b

HAT-P-23b Transit Measurements

Previous studies have disagreed whether HAT-P-23b is an inflated hot Jupiter on an eccentric orbit (Bakos et al. 2011, Ciceri, et al. 2015). We obtained 11 new transit observations with PIRATE, complemented by 6 observations made with POST, a 0.4m UK located telescope.

Data reduction and photometry was carried out using AstroImageJ (Collins et al. 2015) and the transits modelled using ExofastV2 (Eastman et al. 2019) with radial velocity, broadband photometry and Gaia parallax data from the literature. In our analysis we confirm HAT-P-23b is likely inflated and on a circular orbit.

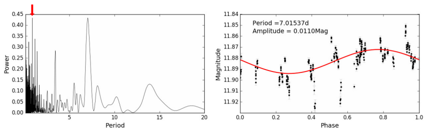


Above. Best fit linear ephemeris to our data (filled symbols) and data from the literature (open symbols).

- $e = 0.027^{+0.029}_{-0.019}$, consistent with a circular orbit.
- $R_P = 1.308^{-0.044}_{-0.043}\, R_J$, 4% smaller than previously reported.

Concurrent Host Star Monitoring

Motivated by a suspected ~3% variation in HAT-P-23 brightness (Sada et al. 2016) we obtained monitoring observations covering 50 nights over a 93 day period consecutive with our transit observations. We detected a clear 7.015d periodic variation, though with a smaller amplitude than expected, which we attribute to stellar rotation due to surface spots.

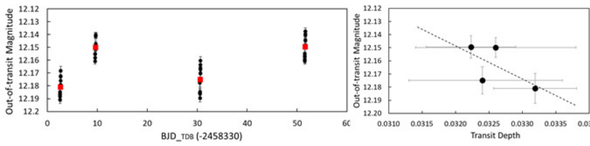


Left, Lomb-Scargle periodogram and phase folded measurements of HAT-P-23. Red arrow Indicate the one day observing cadence alias. Right, data phase folded over rotation period of 7.015 days.

WASP-52b

WASP-52b Transit Measurements

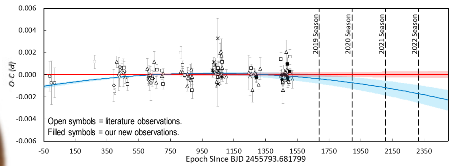
WASP-52b is a $0.4M_J$ hot Jupiter orbiting an active host star. We obtained 8 new transits with the OSO telescopes with 5 transits obtained using POST. Our new transit observations show no obvious signs of spot crossing events typical in the literature, e.g. Mancini et al (2017). We do detect an ≈0.3 mag variation in the host star brightness from out-of-transit data and find a tentative trend towards deeper transits with decreasing host star brightness. Together these indicate WASP-52 is still active but the spot latitude has migrated away from the transit chord.



Far Left, Out of transit magnitude of WASP-52 where red points indicate mean nightly value. Left, tentative correlation between brightness and transit depth.

WASP-52b Transit Timing

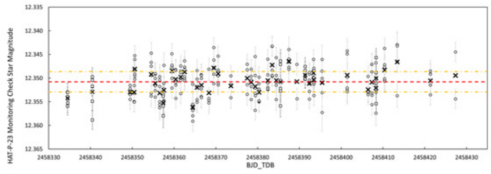
Our analysis of the new transit mid-times and reanalysis of those from the literature slightly prefer a quadratic ephemeris with $\Delta\chi^2_\nu$ =0.07 and ΔBIC = 1.53 compared to a linear ephemeris. We calculate a period change $^{\delta P}/_{\delta t} = -38.6 \pm 4\, msyr^{-1}$ and find that orbital decay due to tidal interaction is unlikely. A plausible explanation is transit mid-time errors introduced through undetected spot crossing events. We predict further observations through the 2021 season will be able to confirm or refute this suspected period change (below).



Observatory

Photometric Stability

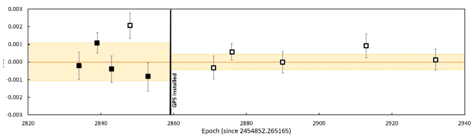
- Between two and six measurements of HAT-P-23 obtained each available night.
- 50 nights of observations over a 93 day period.
- 95% of observation made at airmass < 1.4.
- Average nightly measurement scatter was 0.007 mag.
- 1σ uncertainty for the mean nightly check star magnitude over the entire 93 day period was 0.0022 mag.



Check star used in the HAT-P-23 monitoring made with PIRATE. Open circles are the individual nightly measurements, filled squares are the monitoring values taken on nights transits were obtained from the out-of-transit data. Crosses are the nightly mean values. The red dashed line shows the mean check star magnitude and the orange dot-dash lines is the 1σ uncertainty (2.2mMag) of these mean nightly values.

Transit Timing

In July 2018 the OSO telescopes were upgraded with GPS shutter timing control, providing mili-second exposure timing. After the addition of GPS timing control the 1σ uncertainty of the O-C determinations for HAT-P-23b transits improved almost three fold. At the same time the calculated mean O-C value before and after the upgrade, remained consistent to within 7 seconds, well within the typical transit mid-time measurement uncertainties.

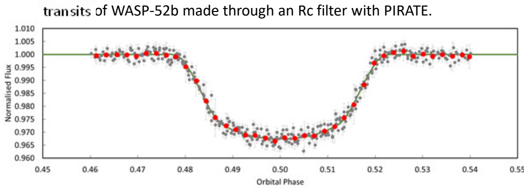


Ten full transit measurements of HAT-P-23b obtained with PIRATE, before and after addition of GPS controlled camera shutter timing. Filled squares are observation made with 2x2 on-chip binning, open squares are without binning. The orange shaded area shows the 1σ uncertainty on the O-C values, highlighting the improved precision after upgrade.

Performance

Photometric Performance

The excellent photometric performance of the telescopes at the OSO can be seen in the lightcurve below which is a phase fold of five complete transits of WASP-52b made through an Rc filter with PIRATE.



The grey dots are the photometric measurements analysed using AstroImageJ (Collins et al. 2015) and the green line is the transit model calculated using Exofast V2 (Eastman et al. 2019). The red dots are 3-minute bins of the data which achieves an average out-of-transit RMS of 575ppm. This compares excellently with measurements of WASP-52b made with the 1.54m DK telescope with out-of-transit RMS residuals for individual transits of 594ppm (Mancini et al, 2017).

References

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