OBSERVATIONS OF THE TRANSITING EXOPLANET WASP-33b

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ABSTRACT

Photometric observations of the transiting exoplanet WASP-33b have produced a high-quality light curve. The data has been modelled to determine the system parameters, which confirm that WASP-33b is a bloated hot Jupiter, with a radius up to 30% larger than expected. The data also shows evidence for host star pulsation (Figure 1) with a potential connection to the orbital period.

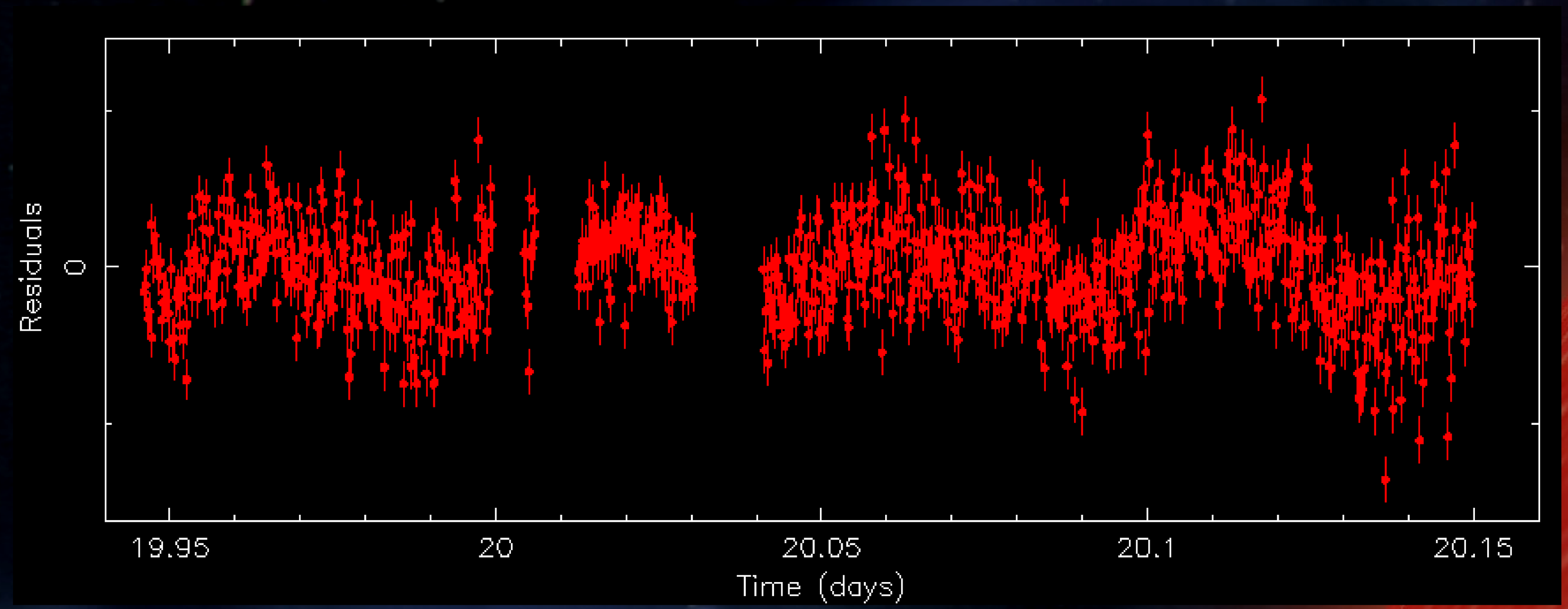

Figure 1: Out-of-transit pulsations seen in the host star WASP-33. A possible tidal link has been suggested between the stellar pulsations and the orbiting planet [1], making it an interesting target for follow-up photometry.

THEORY AND MOTIVATION

Figure 2 schematically shows the transit of a planet across the face of a star. The dip is caused by the obscuration of light from the star by the planet. The depth and duration of the dip are determined by the planet and star radii, orbital inclination, orbital period and orbital separation.

The study of exoplanet transits is important because it provides:

- an estimate of the physical size (radius) of an extra-solar planet
- determinations of orbital inclination, thus constraining mass estimates
- an opportunity to probe properties such as the density and composition of planets
- validation of models of star and planet formation
- examination of the atmospheric composition through transit spectroscopy
- possibility to uncover tracers of extra-solar life, if it exists

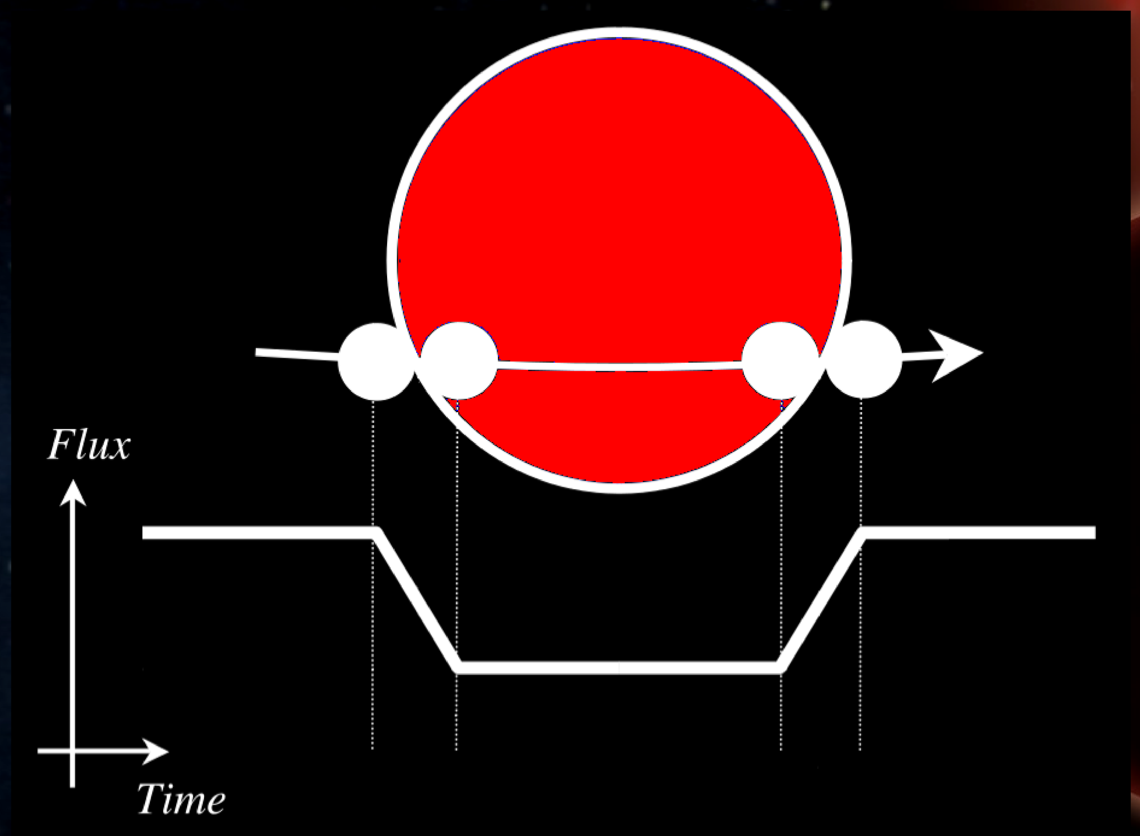

Figure 2: An illustration of the transit of an exoplanet across the face of a star, neglecting limb-darkening for simplicity [2].

DATA COLLECTION AND ANALYSIS

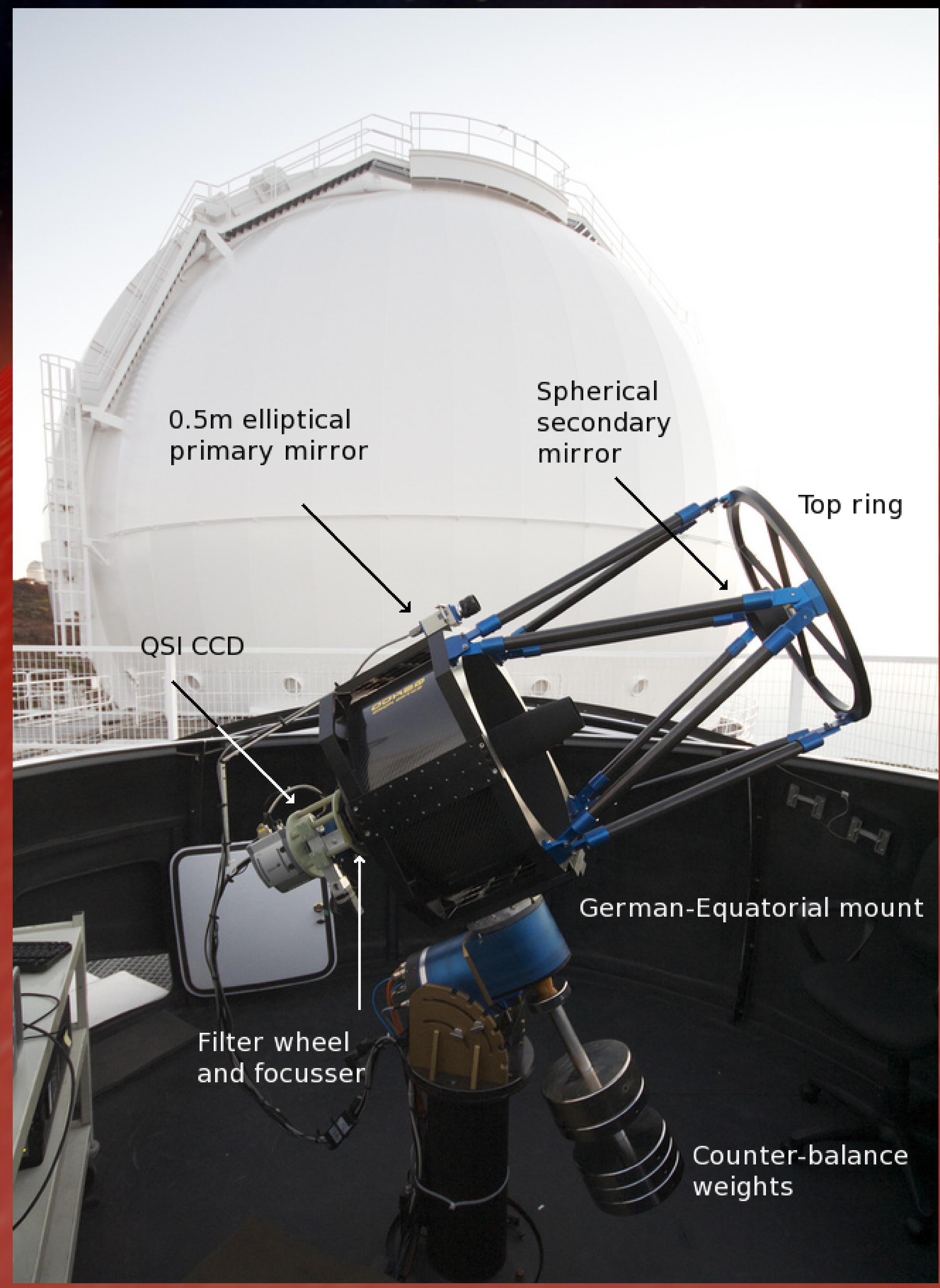

Figure 3: The pt5m [3], uses a German-Equatorial mount, which introduces the need for meridian reversal.

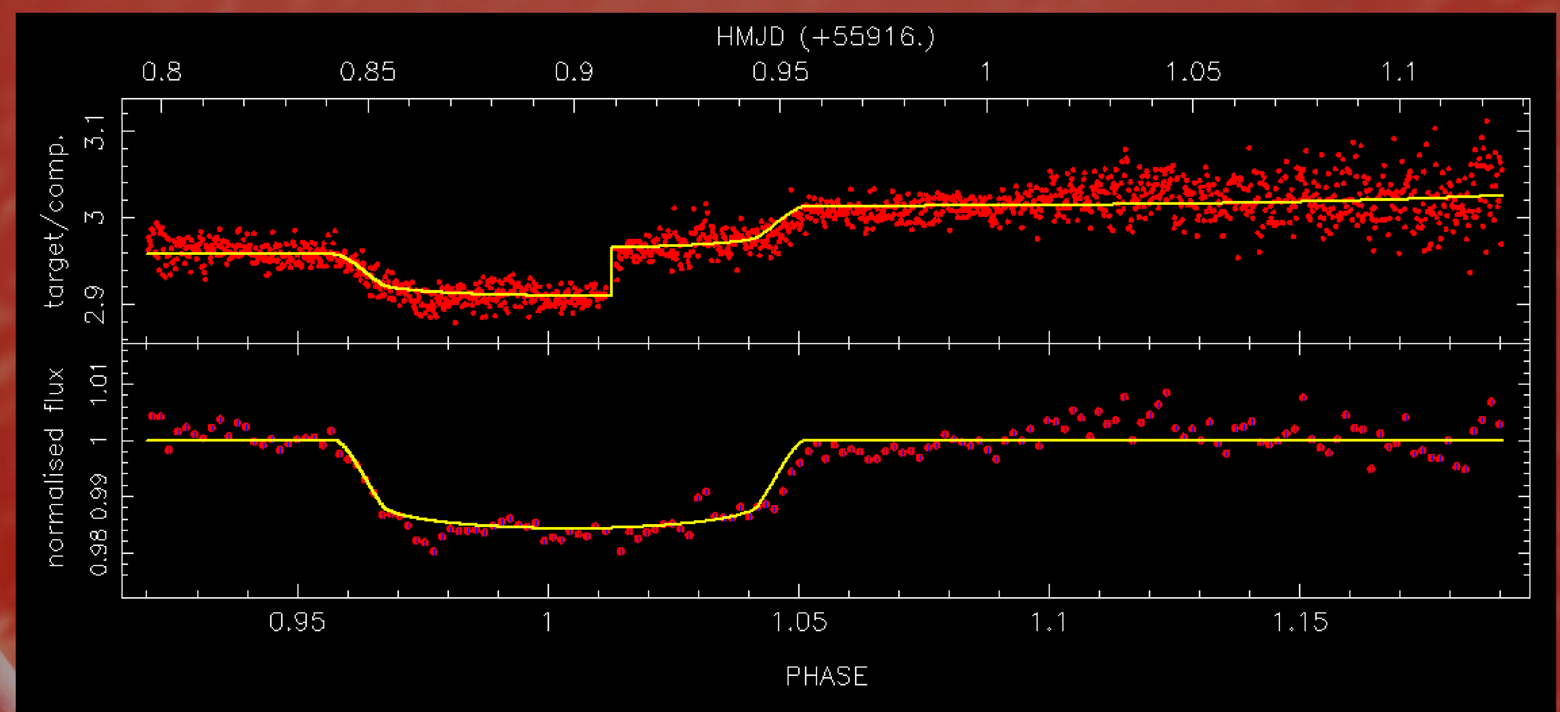

Figure 4: An example light curve from the night of 2011-12-21, with the upper panel showing the step in flux introduced by the meridian reversal. The lower panel shows the data after the removal of the step. The yellow line represents the best-fit model.

The method for data collection and processing followed these steps:

- 17 observations of transits made with the 0.5m 'pt5m' on La Palma (Figure 3)
- normalise and remove step in flux by modelling each dataset individually with best-guess parameters from the literature and χ^2-minimisation (Figure 4)
- combine, fold and bin the data to produce final light curve (Figure 5)
- model the final light curve allowing the system parameters to vary
- estimate errors using the prayer-bead technique

RESULTS AND CONCLUSIONS

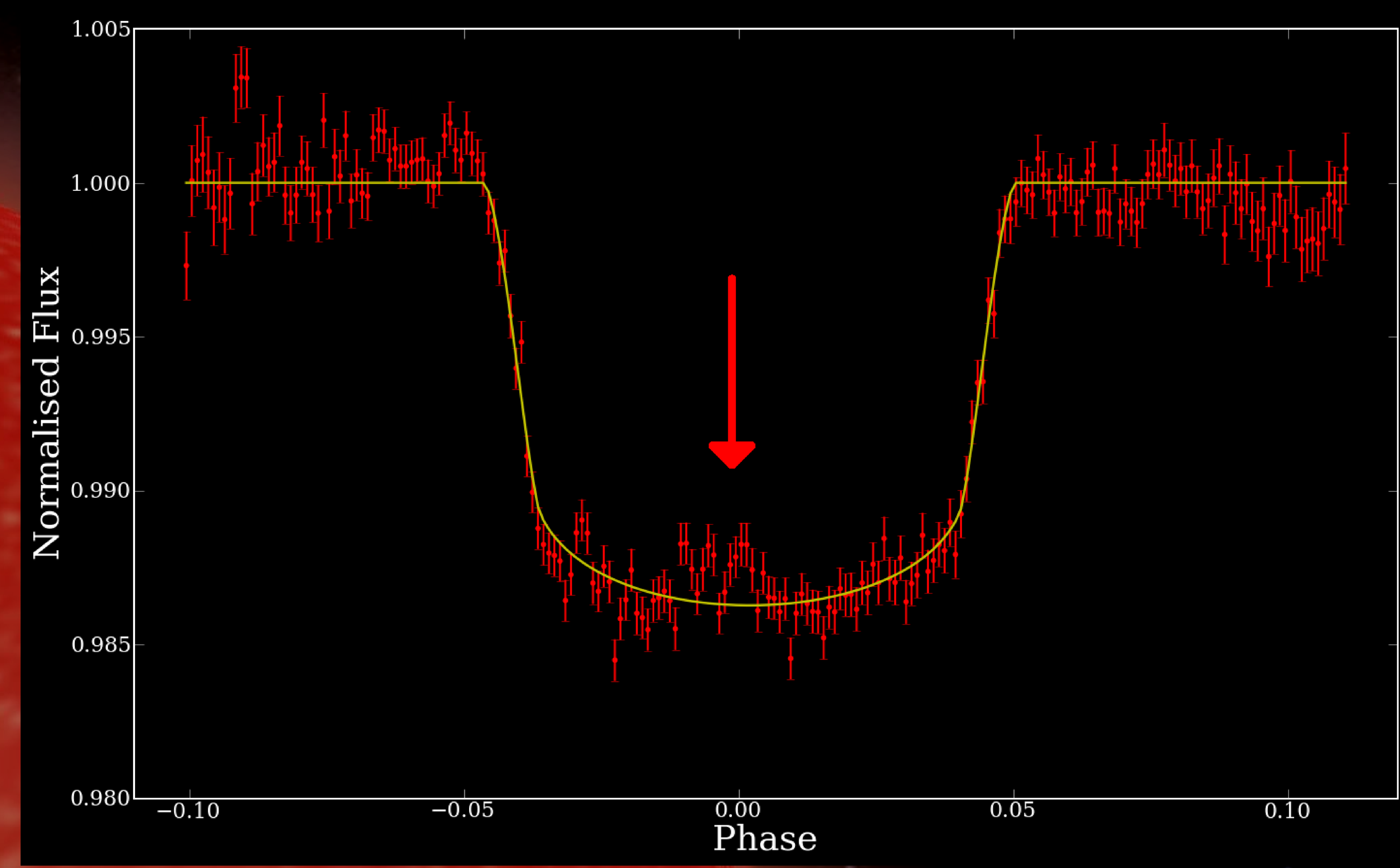

Figure 5: The data from all 17 transits (points) is fitted with a model transit (line). The arrow identifies the prominent bump caused by pulsation.

The combined light curve, Figure 5, shows a prominent bump in the floor of the transit dip, likely to be caused by the pulsation of the host star. This could confirm the existence of tidally induced pulsations which resonate with the orbital period.

Table 1: System parameters found either in the literature [4][5], calculated from transit mid-times*, or determined by modelling the final light curve**.

Stellar Effective Temperature (K)	7430$\pm$ 100
Stellar Rotation Speed, $\nu \sin i$ (kms^{-1})	86.05$\pm$ 0.11
Projected Obliquity (°)	$-$107.7$\pm$ 1.6
Planet Brightness Temperature at 0.91μm (K)	3620$\pm$ 200
Orbital Semi-Major Axis, a (au)	0.02555$\pm$ 0.00017
Orbital Period (days) *	1.2198694$\pm$ 0.0000018
Radius of Planet (R_{jup}) **	1.601$\pm$ 0.012
Orbital Inclination (°) **	87.0$\pm$ 0.4

A selection of parameters of the WASP-33 system are shown in Table 1, including those determined by the modelling of the light curve. The planetary radius suggests that WASP-33b is 15-30% larger compared to the H/He planetary models of Fortney et al [6]. The most likely cause of this is the young age of the system ($<$500 Myr [7]), meaning the planet could hold some leftover thermal energy from formation, which may inflate the radius.

The fact that this hot, massive planet has been discovered orbiting with high obliquity around a rapidly rotating star, is a blow to the theories of hot Jupiter formation which involve binary mergers, or disk migration, as these theories expect the spin-orbit alignment and older stellar ages.

FUTURE WORK

- remove modelled transit shape from each dataset
- find the most prominent pulsation modes using chi-squared minimisation
- search for harmonics between pulsation period and orbital period

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