A NEARLY POLAR ORBIT FOR THE EXTRASOLAR HOT JUPITER WASP-79b

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Introduction

Over 800 [1] extrasolar planets have been discovered as of May 2013. Determining their structure, composition, and other bulk properties is necessary if we are to understand the processes involved in the formation and migration of planets. In collaboration with the HATSouth team, the Exoplanetary Science group at UNSW is utilizing the CYCLOPS2 fiber feed at the Anglo-Australian Telescope to carry out Doppler spectroscopy of candidate transit planet systems arising from HATSouth transit searches. Our team has also carried out measurements of the Rossiter-McLaughlin (RM) effect for WASP-79b, a recently discovered very bloated hot Jupiter from the WASP Southern Hemisphere transit survey [2]. WASP-79b has a mass M_P of 0.90 ± 0.09 M_J, radius R_P of 1.70 ± 0.11 R_J, and orbits an F5 star with T_{eff} = 6600 ± 100K [2]. We detect a clear radial velocity anomaly due to the RM effect and from these measurements determine that WASP-79b is in a nearly polar orbit (Addison et al. submitted ApJL).

Rossiter-McLaughlin Effect

- This effect is caused by the modification of the stellar spectrum produced as a transiting planet occults a small region of the stellar disk of its host star.
- The result is asymmetric distortions in the stellar line profiles that produces a radial velocity anomaly (an example of this is shown in Figure 3 for WASP-79) [3] [4].
- By measuring the RM effect, one can estimate the projected rotational velocity of the stellar disk ($v\sin i$)$_\star$ and the projected spin-orbit angle (λ) between the planetary orbital axis and the stellar spin axis [5].
- Measuring the spin-orbit angles provides us with clues into the mechanisms driving planetary migration and observed spin-orbit misalignments.

Model & Data Reduction

- We developed a model, called the Exoplanetary Orbital Simulation and Analysis Model (ExOSAM), to determine the magnitude of the RM effect and accurately measure λ.
- ExOSAM simulates the orbital position of a planet at the time of each observation.
- Then it computes the velocity from the motion of the star due to the orbiting planet and the in-transit lightcurve including the velocity anomaly due to the RM effect.
- Best-fitting values for λ and ($v\sin i$)$_\star$ are derived using a grid search and minimizing χ^2 between the observed RV and modeled RV.
- 1σ levels for λ and ($v\sin i$)$_\star$ determined through the $\Delta\chi^2$ method.
- Data was reduced by computing a wavelength solution from a reference ThAr image that was distorted to account for difference between the reference ThAr arc, and the ThXe calibrations obtained from each stellar image.
- RV's for each of the 16 fibers and 18 orders are calculated using the IRAF task, *fxcor*, by cross-correlation with a spectrum of a bright template star (HD86264) of similar spectral type (see Figure 1 for example Gaussian fit).

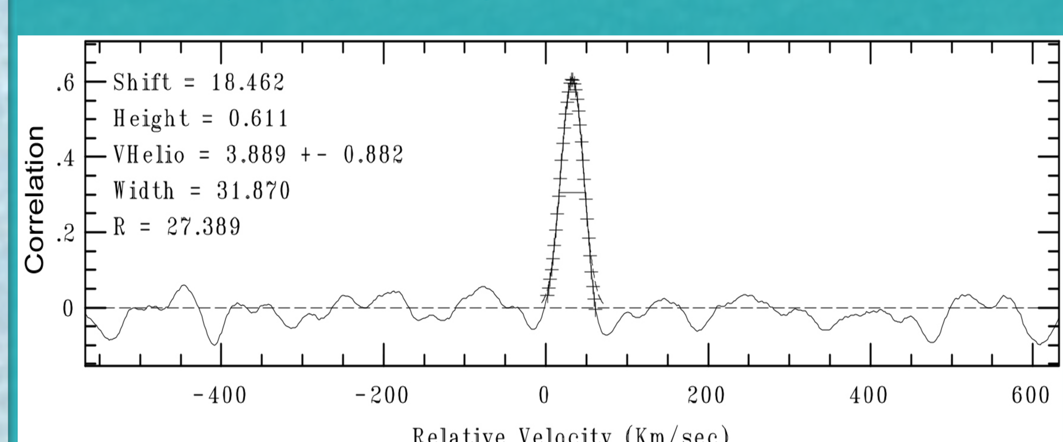


Fig. 1. – Output of the Cross-correlation function from the IRAF task, *fxcor*. A Gaussian has been fitted to the CCF from which velocities are computed.

Observing with CYCLOPS2 on the AAT

- Cassegrain-fed optical-fiber bundle unit which feeds the UCLES echelle spectrograph.
- It reformats a 2.5" diameter aperture into an equivalent slit of dimensions 0.6" wide and 14.5" long [6] as shown in Figure 2.
- Replaces CYCLOPS CLASSIC (15 fibers with 3 inoperative) with a new fiber bundle that has 16 functioning fibers, 10% higher throughput, and an extra fiber for the simultaneous ThXe arc calibrations.
- Each fibre delivers λ/Δλ = 70,000 over 19 echelle orders in the wavelength range 4550-7350 Å when used in UCLES 79 line/mm grating configuration.
- Simultaneous ThXe eliminates the need for object observations to be bracketed by arc wavelength calibrations and the error from interpolating two bracketed arc exposures.
- Collaborating with the HATSouth transit search team to follow up transiting planet candidates with RV and RM effect measurements.
- Three transiting planets have been discovered by the HATSouth survey using data taken with CYCLOPS2 (HATS-1b [7] and HATS-2b [8], HATS-3b (Bayliss et al. submitted ApJ)).

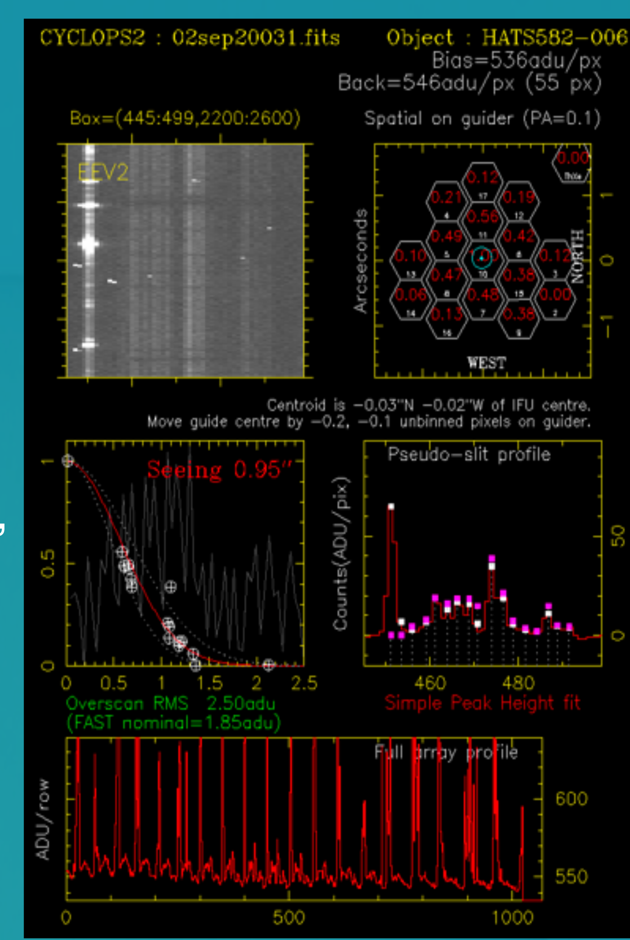
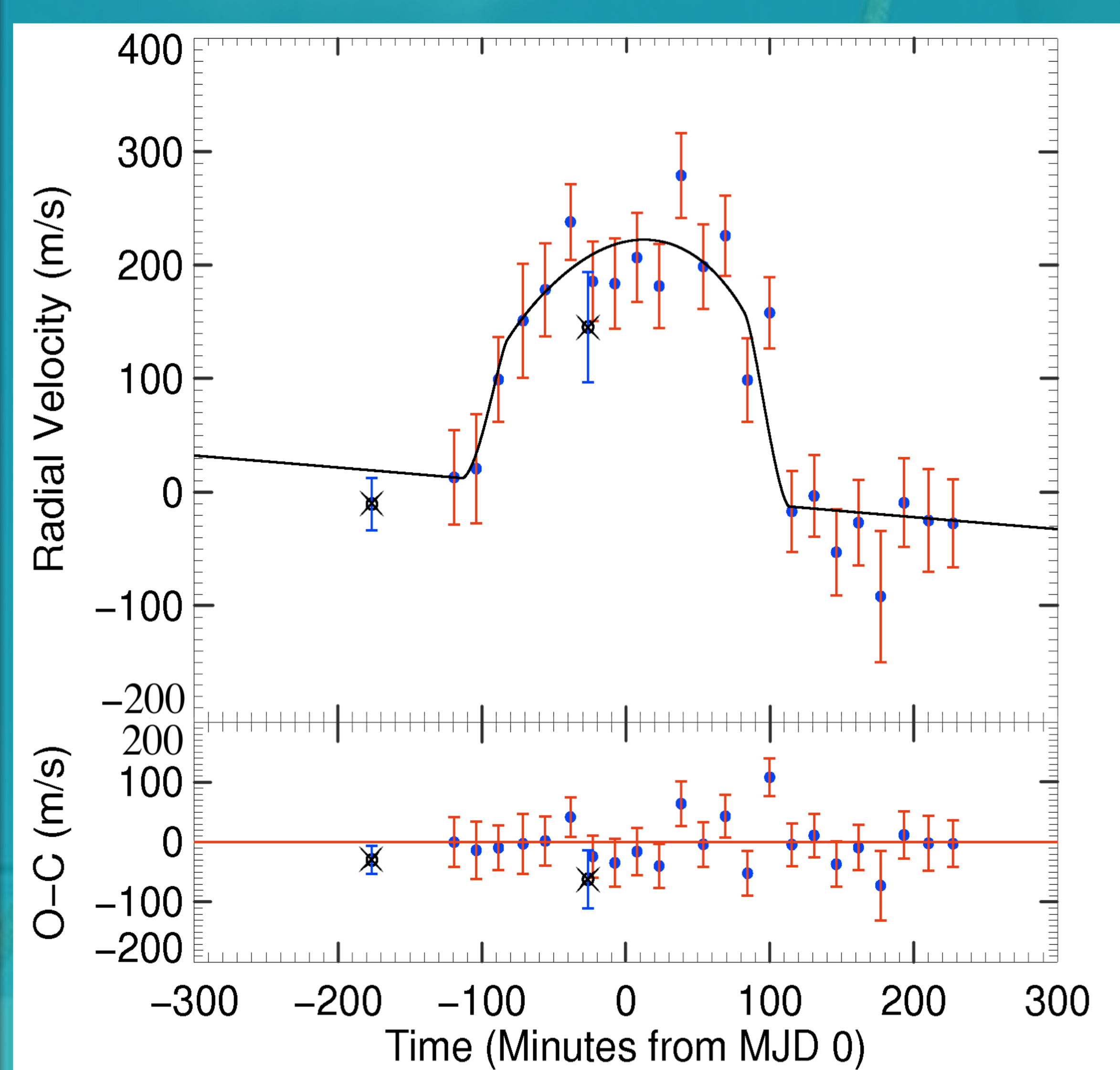


Fig. 2. – Post-processing window showing a section of the raw spectra, layout of the IFU with an estimated location of the central intensity of light, seeing profile, and a profile of the illuminated fibers.

Results!



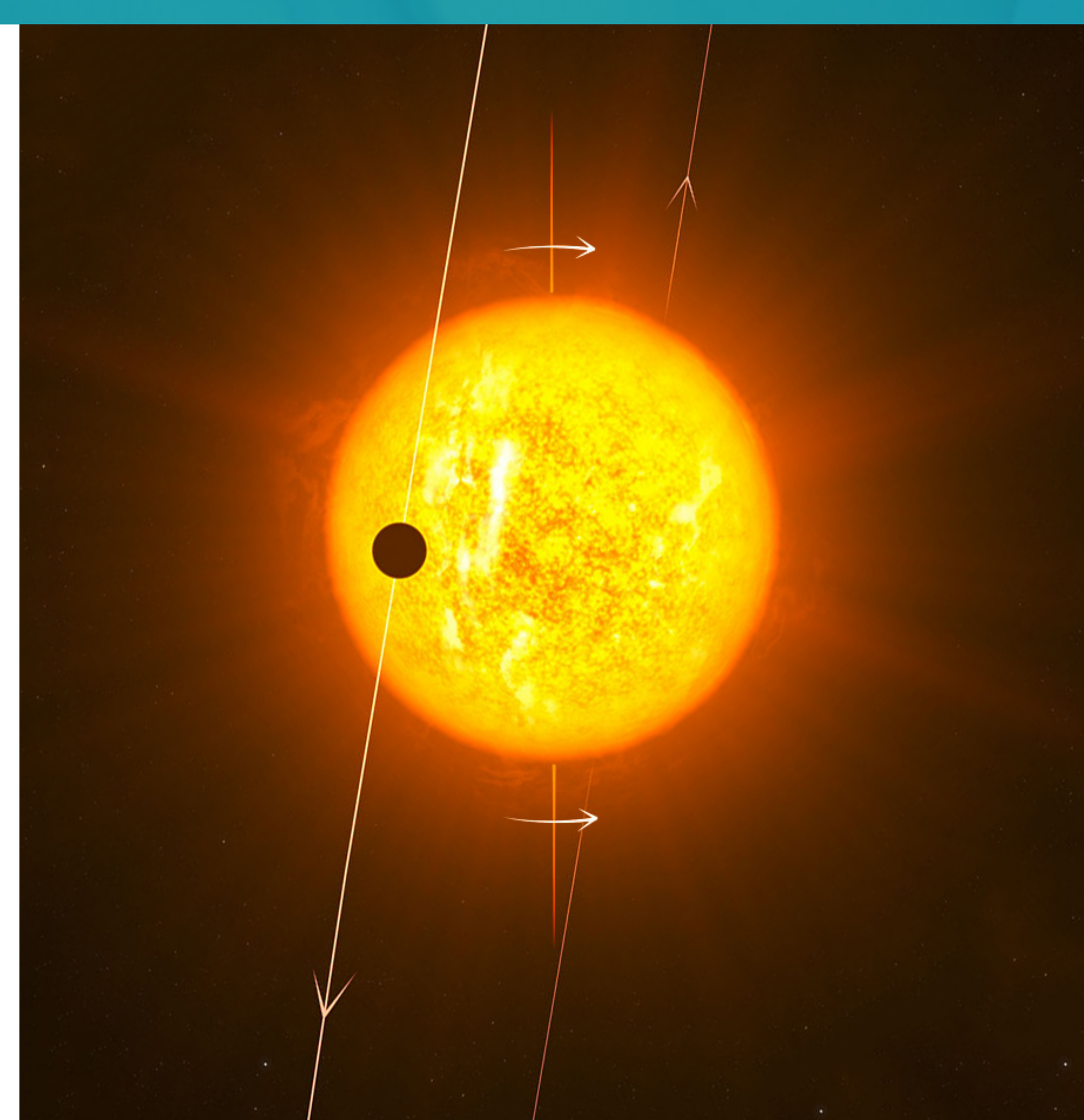


Fig. 3. – Spectroscopic radial velocities of the WASP-79b transit. RV plotted as a function of time along with best fitting model and corresponding residuals. The filled blue circles with red error bars are RV's we measured while the two black open circles overlaid with an x and with blue error bars are previously published RV's from Smalley et al.

Fig. 4. – Illustration of WASP-79b in a nearly polar orbit around its host star. The planet transits across only the blue-shifted hemisphere (the side rotating towards us) which causes an anomalous red-shift in the stellar absorption lines.

- RM effect clearly detected as a positive "hump-shaped" anomaly (Figure 3).
- Planet transits only blue-shifted hemisphere and is in a nearly polar orbit (as shown in Figure 4).
- We determined that λ=−106±9° and ($v\sin i$)$_\star$=17.5±1.4kms^{-1}.
- Independently measured ($v\sin i$)$_\star$ by fitting a rotationally broadened Gaussian to a least-squares deconvolution profile from each spectral order.
- From this method, ($v\sin i$)$_\star$=18.2±0.2 kms^{-1}.
- Both ($v\sin i$)$_\star$ measurements agree with Smalley et al. value of 19.1±0.7 kms^{-1}.
- 9 systems are in near-polar orbits, 7 in retrograde orbits, and 29 show substantial misalignments out of 70 systems with spin-orbits measured [9].
- Very long tidal dissipation timescale (τ_{mcz}=1.6×10^{11}yr), longer than 95% of systems examined by Albrecht et al.
- This system is consistent with the observed trend of hot stars (T_{eff}>6250K) hosting planets in spin-orbit misalignment [10].

References

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