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First Results from SuperWASP

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Abstract.
We present a summary of the first results from the SuperWASP survey, including the detection of two new transiting exoplanets. We summarise our

candidate selection procedure and the process by which we eliminated many false positives prior to radial velocity observations carried out with the Sophie spectrograph at the Observatoire de Haute-Provence. These data confirmed the discovery of two new transiting hot Jupiters, while rejecting 23 other targets. The two confirmed planets, WASP-1b & -2b, respectively orbit F7V and K1V host stars with periods of 2.52 d and 2.15 d. The mass of WASP-1b is constrained to the range 0.80–0.98 M_{Jup} and the planet appears to be 'bloated' with a radius of at least 1.33 R_{Jup}. WASP-2b has a mass between 0.81–0.95 M_{Jup} and a radius in the range 0.65–1.26 R_{Jup}.

1. Introduction

The SuperWASP Project (SW) is an ultra-wide field photometric survey of stars between $V\sim$8–15 mag, the primary science goal being to search for transiting exoplanets. The WASP Consortium currently operate two robotic observing stations, one on La Palma, Canary Islands and one at the South African Astronomical Observatory. Both stations are equipped with eight, 2K$\times$2K back-illuminated e2v CCDs fronted by 200mm Canon f/1.8 lenses, resulting in a total field of view of over 480 sq. deg. Both stations are task-dedicated and observe every clear night of their respective observing seasons. They spend most of their time cycling between $\sim$8–12 of designated planet-hunting fields visible in a given night, returning to each field once every $\sim$8 mins. Several hours at the start of each night are dedicated to individual observations spanning the entire visible sky. These data are sent to Consortium institutions in the UK for reduction with our custom-written data pipeline. The resulting high-precision photometric output is uploaded to SuperWASP's dedicated archive held at Ledas, University of Leicester. The project is fully described by Pollacco et al. (2006) and more information can be found at *www.superwasp.org*. The northern station (hereafter SW-N) observed between 2004 May–September with a complement of five cameras. Here we present the first results from our search for transits in this dataset.

2. Transit Candidate Selection

SW-N obtained lightcurves for $\sim$6.7 million stars during the 2004 season. The SysRem algorithm developed by Tamuz, Mazeh & Zucker (2005) was applied to remove residual trends in the lightcurves of stars brighter than V=13 mag with more than 500 datapoints spanning at least 10 nights, prior to invoking the optimised BLS transit-hunting algorithm developed by Cameron et al. (2006). Of the $\sim$1 million stars qualifying for this search, $\sim$44,000 were automatically selected by the algorithm. A team of people performed a visual inspection of all these lightcurves, selecting those objects showing a believable transit-like signature. Candidates were required to have (a) a signal-to-red noise $>$ 8.0 (Pont Zucker & Queloz 2006), (b) a period $>$1.05 days, (c) at least 3 detected transits, (d) a ratio of transit to 'antitransit' brightening $>$2.0 (see Burke et al. (2006)) and (e) a signal-to-noise of ellipsoidal variation $<$8.0. A list of surviving objects was then submitted to the Variable Star Investigator tool (Wilson et al. 2006), which provided colour information for each object from, among other sources, the 2MASS and Tycho-2 catalogues, allowing spectral types to be estimated. Postage-stamp images from Tycho-2, 2MASS and DSS allowed the degree of blending to be assessed. The software estimates the minimum companion object radius and calculates the duration expected for a planetary transit given these system parameters. This information was used to make the final selection of ∼360 objects, which are being published in a series of papers (Christian et al. (2006), Lister et al. (2006), Street et al. (2006)). A full discussion of the selection procedure can be found in these papers and in Enoch et al. (2006).

3. Candidate Follow-up Program

As it would be time-consuming to obtain full radial velocity (RV) follow-up of all the candidates produced by such a large survey, a multi-instrument follow-up programme was devised for 2004 in order to pre-select the best targets. This included 10 nights on the Isaac Newton Telescope with the IDS spectrograph, 9 nights on the Kitt Peak 2.1m using the Goldcam spectrograph, 2 nights on the Telescopio Nazionale Galileo with the SARG spectrograph and 7 nights on IAC-80, Tenerife. Single-exposure spectra were obtained for all the candidates and used to check the spectral typing and to eliminate spectroscopic blends and objects showing rotational broadening. Photometric observations were used to obtain higher resolution images and multi-colour lightcurves. Radial velocity observations of 25 targets in total were made in collaboration with the Geneva Planet Search Team using the newly-commissioned Sophie spectrograph on the Observatoire de Haute Provence 1.93m. Of these, 23 objects were found to be either giants, rapid rotators, spectroscopic binaries or exhibited no RV variation. The most likely explaination for the latter case is that the SW photometry is contaminated by light from a blended binary. Two stars were confirmed to host planets.

4. Two New Transiting Planets

Table 1 lists the fundamental parameters for both new systems. The Sophie RV data are presented in Figures 1 & 2, together with the target's lightcurve. The 2004 SW photometry of WASP-1 was supplemented with data from the 0.35m Schmidt-Cassegrain Telescope at the Volunteer Observatory in Knoxville, Tennessee. Observations of the transit on 2006 October 2 UT were taken through an R-band filter with the SBIG ST10XME CCD camera. Additional R-band photometry of a WASP-2 transit on 2006 September 12/13 UT was obtained with the 60cm telescope at the Observatoire François-Xavier Bagnoud at St. Luc.

Full details of the modelling procedure used to determine the system parameters are presented in Cameron et al. (2006). However, we note that our preliminary analysis of the extracted Sophie spectra in comparison with the stellar evolution models of Girardi et al. (2000) produce a range of possible M_* and R_*. In addition, the degeneracy between the impact parameter b and R_*/a is unresolved with the available photometry. Our analysis therefore adopted two values of b at the extreme ends of the range, 0 and 0.8, and estimated the corresponding system parameters via a minimum-χ^2 fit to the data. Models

Table 1.: Planetary system parameters

Parameter	WASP-1b	WASP-2b
Transit HJD	2453912.514±0.001	2453991.5146±0.0044
Period (d)	2.51995±0.00001	2.152226±0.000004
γ (kms^{-1})	-13.503±0.009	-27.863±0.007
K_1 (ms^{-1})	115±11	155±7
a (AU)	0.0369–0.0395	0.0296–0.0318
$b = a\cos i/R_*$	0–0.8	0–0.8
R_P/R_*	0.093–0.104	0.119–0.140
R_*/a	0.168–0.260	0.086–0.132
N_{df}	961	1013
χ^2	1420–1449	1627.2–1647.1
N_{RV}	7	9
χ^2_{RV}	11.6	13.4
M_* ($M_\odot$)	(1.06–1.39)	(0.73–0.94)
M_P (M_{Jup})	(0.80–0.98)±0.11	(0.81–0.95)±0.04
R_P (R_{Jup})	1.33–2.53	0.65–1.26
M_* ($M_\odot$)	$1.15^{+0.24}_{-0.09}$	$0.79^{+0.15}_{-0.04}$
R_* ($R_\odot$)	$1.24^{+0.68}_{-0.20}$	0.78±0.06
Star T$_{eff}$ (K)	6200±200	5200±200
Star $\log g$	4.3±0.3	4.3±0.3
Spectral Type	F7V	K1V

with b>0.8 were found to give visibly worse fits. The best fitting models are superimposed in Figures 1 & 2.

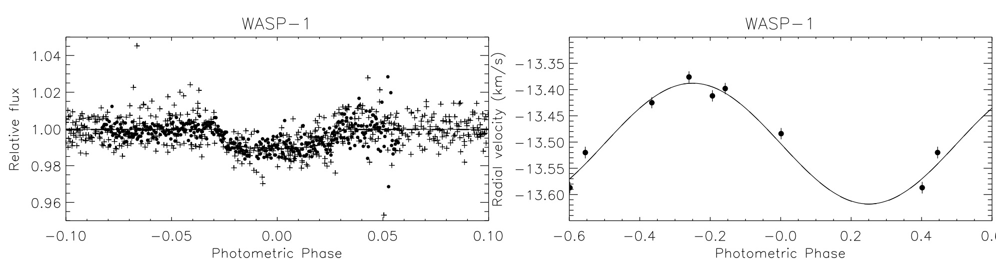

Figure 1.: WASP-1: radial velocity curve from Sophie, OHP-1.93m, photometry from SW and the 0.35m at Volunteer Observatory, Knoxville.

Immediately following the RV confirmation, adaptive optics imaging of the two objects was obtained with NAOMI on the William Herschel Telescope, La Palma. WASP-1 was imaged on 2006 Sept. 6, with a corrected FWHM of 0.25 arcsec. This revealed a companion object at a separation of 4.7 arcsec, 3.7 mag fainter in H-band than target. As the Sophie fibres have an aperture of 3 arcsec, it is unlikely that this object caused any contamination of those data. WASP-2 was imaged on 2006 Sept. 7, achieving a corrected FWHM of 0.2 arcsec using the OSCA coronagraph system. The star also has a companion, at a separation of 0.7 arcsec and 2.7 mag fainter in H. AO observations were repeated during a transit event on 2006 Sept. 10, during which the companion showed no drop in flux, so it is not likely to be the cause of the transit and radial velocity variation. Line bisector analysis of the cross-correlation function (Queloz et al. 2001) was performed on the Sophie observations, and no significant variation was found.

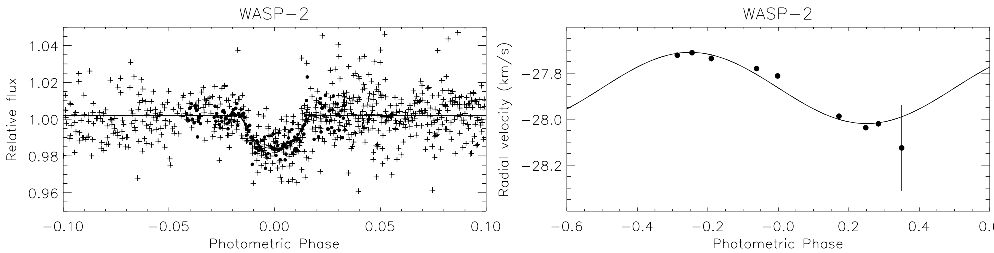

Figure 2.: WASP-2: radial velocity curve from Sophie, OHP-1.93m, photometry from SW and the 60cm at Observatoire François-Xavier Bagnoud.

5. Comparison of the Properties of Known Transiting Planets

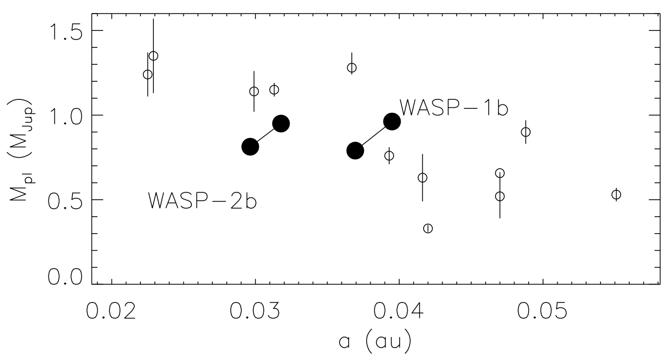

Figure 3.: Mass .vs. orbital separation for the known transiting exoplanets (from http://obswww.unige.ch/∼pont/TRANSITS.htm).

Figure 3 represents both SW planets with two connected points denoting the extremities of the parameter ranges. It can be seen that WASP-1b falls in the gap between two clusters of known transiting planets. Although the sample size is limited, there appears to be a trend for higher-mass objects in closer orbits (Mazeh, Zucker, & Pont 2005). While the radius of WASP-1b is presently poorly constrained, it appears to be a member of a growing cluster of 'bloated' planets currently challenging theories of planetary evolution. WASP-2b meanwhile appears to have an unusually low mass for its orbital radius and could be close to the limiting mass boundary. It is therefore a prime target for studies of planetary mass-loss and survival at close orbital separations.

6. Conclusions

The SuperWASP Project has discovered 2 new transiting planets from its first season of operation, confirmed by the first observations with the new Sophie spectrograph at OHP. SW stations are now operating in both hemispheres to search for new candidates. At time of writing, the Consortium has not yet completed follow-up observations for all our 2004 season high-priority candidates so conclusions regarding the frequency of transiting systems will be the subject of a later publication.

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