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New transiting exoplanets from the SuperWASP-North survey

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Abstract. The Wide Angle Search for Planet (WASP) project is one of the leading projects in the discovery of transiting exoplanets. We present 1) the current status of the WASP-North survey, 2) our recent exoplanet discoveries, and 3) we exemplify how these results fit into our understanding of transiting exoplanet properties and how they can help to understand exoplanet diversity.

Keywords. planetary systems, techniques: photometric, techniques: radial velocities

1. The SuperWASP-North survey

The SuperWASP-North observatory in La Palma consists of 8 cameras each with a Canon 200-mm f/1.8 lens coupled to an Andor e2v 2048×2048 pixel back-illuminated CCD (Pollacco *et al.* 2006). This configuration gives a pixel scale of 13.7″/pixel which corresponds to a field of view of 7.8×7.8 square degrees per camera.

In October 2008, we introduced an electronic focus control and we also started stabilisation of the temperature of the SuperWASP-North camera lenses. Prior to this upgrade, night-time temperature variations affected the focal length of the WASP lenses altering the FWHM of stars. This introduced trends in the data that mimic partial transits, especially at the beginning and end of the night when the temperature variation is more extreme. These effects are not corrected by the SYSREM (Tamuz *et al.* 2005; Cameron *et al.* 2006) and FTA (Kovacs *et al.* 2005) detrending algorithms because they are position-dependent and do not affect all stars in the same manner. To reduce this source of systematic noise, heating strips were placed around each lens so that their temperature is maintained above ambient at 21 degrees. In addition, we significantly improved the focus of each of the lenses, and now can be done remotely. This upgrade has been crucial to improve the signal-to-noise of WASP light-curves, allowing the detection of planets, previously hidden in the RMS scatter of the data (e.g. WASP-38b; Barros *et al.* 2011). Moreover, from January 2008 both instruments, WASP-South and SuperWASP-North, have been monitoring an equatorial region of sky ($-20 \leqslant \mathrm{Dec} \leqslant +20$) significantly increasing the amount of data collected on each planet candidate. This has been a key element, together with our improvents to the SuperWASP-North system, for the detetion of the most recent WASP planets. The WASP planet detection rate is better than 1 planet for every 6–7 candidates.

1.1. *Follow-up campaign*

We perform our spectroscopic follow-up campaign using the higly pressure-stabilised Echelle spectrographs SOPHIE mounted on the 1.93m telescope of the Observatoire de Haute Provence (Perruchot *et al.* 2008; Bouchy *et al.* 2009), and CORALIE on the 1.2m Swiss Euler telescope at ESO La Silla Observatory in Chile (Baranne *et al.* 1996; Queloz *et al.* 2000; Pepe *et al.* 2002). In addition, we also use the Fiber-Fed Echelle spectrograph (FIES) mounted on the 2.56m Nordic Optical Telescope in La Palma.

We obtain high precision high signal-to-noise transit light-curves of WASP planets using the LCOGT 2.0m Faulkes-North and South telescopes situated on Haleakala, Hawaii, and Siding Springs, Australia, respectively; the robotic 2.0-m Liverpool Telescope (LT) equipped with the RISE frame transfer CCD, located on La Palma (Gibson *et al.* 2008; Steele *et al.* 2008), and finally the Euler-Swiss telescope in La Silla.

2. New SuperWASP discoveries

Here we present an overview of the newly discovered WASP planets.

2.1. *WASP-37b*

WASP-37b is a hot Jupiter planet with a radius of $R_{pl} = 1.16^{+0.07}_{-0.06}$ R_{Jup}, a mass of $M_{pl} = 1.80 \pm 0.17 M_{Jup}$ and an orbital period of P=3.6 days (Simpson *et al.* 2011). It has a high surface gravity compared to other planets with similar orbital periods (log $g_{pl} = 3.48^{+0.03}_{-0.04}$) see also Southworth (2010). WASP-37b is orbiting a very old (age$\sim$11 Gyr) metal poor ([Fe/H]=-0.4±0.12 dex) star, firmly in the tail of the metallicity distribution for exoplanet host stars, which is probably a member of the thick disc population. Even if theoretical models of Fortney *et al.* (2007) and Baraffe *et al.* (2008) do not cover the age range of the system, because planetary radii are thought to decrease with age, we find that WASP-37b has an inflated radius and probably no core. This is consistent with the correlation between core mass and metallicity (Guillot *et al.* 2006; Burrows *et al.* 2007). More details on the system, follow-up spectroscopy and photometry are presented in Simpson *et al.* (2011).

2.2. *WASP-38b*

WASP-38b (Barros *et al.* 2011) is a long period (P= 6.87d), massive ($2.69 \pm 0.06 M_{Jup}$) planet in an eccentric orbit (e = 0.031). WASP-38b does not suffer from the radius anomaly mentioned above ($R_{pl} = 1.09 \pm 0.03 R_{Jup}$) and according to Fortney *et al.* (2008) belongs to the 'pL' class of planets, which show no temperature inversion in their atmosphere. WASP-38b is the forth exoplanet with P$>$ 6 days discovered in a ground-based transit survey (the remaining three are WASP-8b, Queloz *et al.* 2010, HAT-P-15b Kovacs *et al.* 2010, and HAT-P-17b Howard *et al.* 2010). The smaller transit probability, the longer duty cycle and transit duration of these systems, coupled with the restricted observing time from a single site make long period systems more challenging to detect. In the case of WASP-38b, it has been crucial to reduce the systematic noise in the WASP light-curve which ultimately allowed the discovery of the planet. However, we note that from radial velocity surveys there appears to be a depletion of planets between $\sim$0.1-1AU (Udry *et al.* 2003). Details of the system, as well as, follow-up spectroscopy, and photometry are presented in Barros *et al.* (2011).

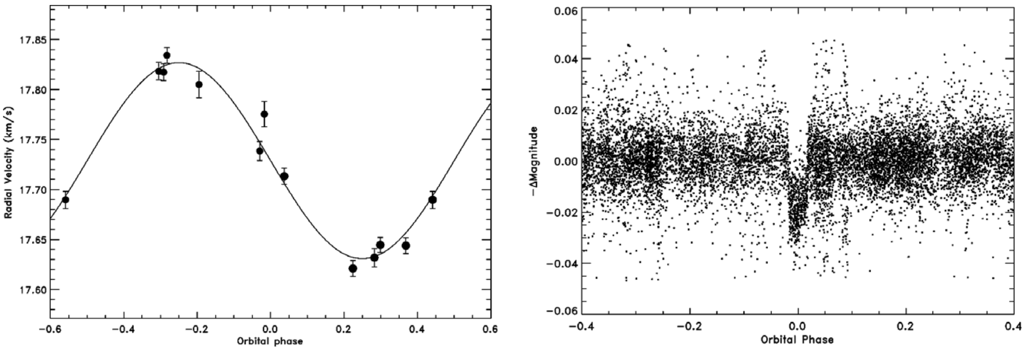

Figure 1. Left-panel, WASP-35b radial velocity curve FIES and CORALIE data. Right-panel WASP discovery light-curve. Follow-up photometry is scheduled for WASP-35b.

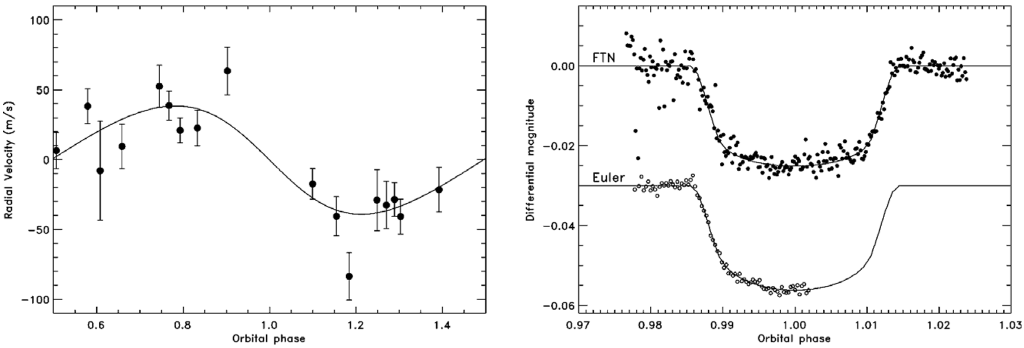

Figure 2. Left-panel, WASP-39b radial velocity curve SOPHIE and CORALIE data. Right-panel, FTN and Euler light-curves.

2.3. *WASP-35b, WASP-39b and WASP-40b*

WASP-35b, WASP-39b and WASP40b are all sub-Jupiter mass planets found in the joint equatorial region of sky observed simultaneously by both WASP telescopes. Figure 1 shows the radial velocity follow-up curve and the WASP discovery photometry of WASP-35b. This is the first WASP planet identified in the joint equatorial region and it is a sub-Jupiter mass planet with an estimated mass of $\sim 0.7 M_{Jup}$ and radius $\sim 1.3 R_{Jup}$ orbiting a slightly metal poor star every 3 days (Enoch *et al.* in prep.). We present our discovery of WASP-39b in Figure 2. This is a Saturn mass planet, orbiting a late G type star every $\sim$4 days. From the data presented above we obtained a preliminary estimate of the planetary mass of $\sim 0.3 M_{Jup}$ and radius of $\sim 1.3 R_{Jup}$. This suggest that WASP-39b is a very low density planet with an inflated radius (Faedi *et al.* in prep).

Finally, in Figure 3 we present the radial velocity and photometry follow-up data of WASP-40b. WASP-40b is orbiting a late G/early K dwarf star with an orbital period of $\sim$3 days, and has an estimated mass of $\sim 0.6 M_{Jup}$ and radius of $\sim 1 R_{Jup}$. The radial velocity residuals of WASP-40b, after subtracting the fitted model, also suggest the presence of an additional signal. However more data are needed before any conclusion can be drawn (West *et al.* in prep).

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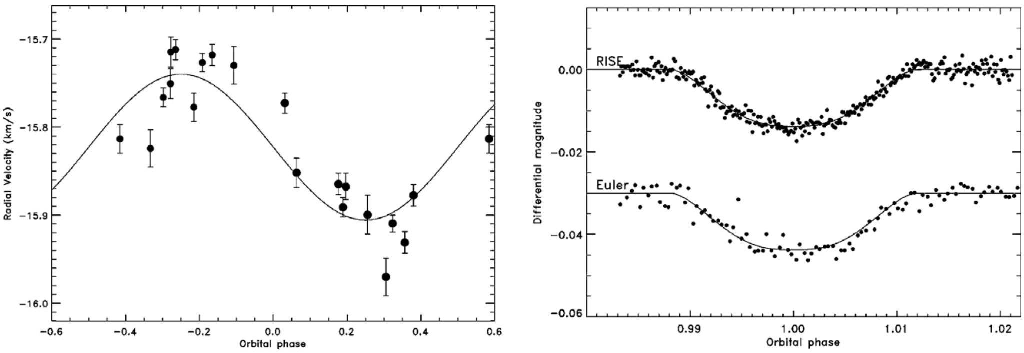

Figure 3. Left-panel, WASP-40b radial velocity curve SOPHIE and CORALIE data. Right-panel, follow-up photometry with RISE and Euler.

3. Conclusion

We have discussed the improvement brought to the SuperWASP-North system, and our observing strategy, which allowed the detection of the transiting extra-solar planets presented in this proceedings. These newly discovered planets are extremely important to the understanding of planetary formation, and evolution, and will help to constrain theoretical models. For example, WASP-39b is a Saturn-mass planet orbiting a late G star with a highly inflated radius, >20% larger than the R_{pl} obtained by comparison with the Fortney *et al.* (2007) model for a coreless planet of a similar mass and orbital distance. WASP-40b instead, is a slightly more massive planet, orbiting a late G/Early K star, and does not appear to show the radius anomaly. In addition, WASP-38b is one of the longest period transiting planet discovered from ground and WASP-37b is one of the older stars, with a very low metallicity, hosting a transiting planet suggesting that giant planet formation was taking place when the Milky Way was still relatively young. To date in the WASP archive there are 150-200 planet candidates which will be followed up in the forecoming seasons. We thus expect, more interesting systems to be dicovered by SuperWASP in the near future.

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