Multiplicity of stars hosting transiting exoplanets

Carolina Bergfors (MPIA/IoA University of Cambridge), Wolfgang Brandner (MPIA), Sebastian Daemgen (U. Toronto), Stefan Hippler (MPIA), Beth Biller (MPIA), Ian Crossfield (MPIA) bergfors@ast.cam.ac.uk

Planets in binary star systems

Planets born in binary or multiple star systems may tell us about several steps in planet formation and dynamical evolution from their observed properties and how these correlate with binary characteristics (see e.g. Eggenberger et al. 2008, 2011; Desidera & Barbieri 2007).

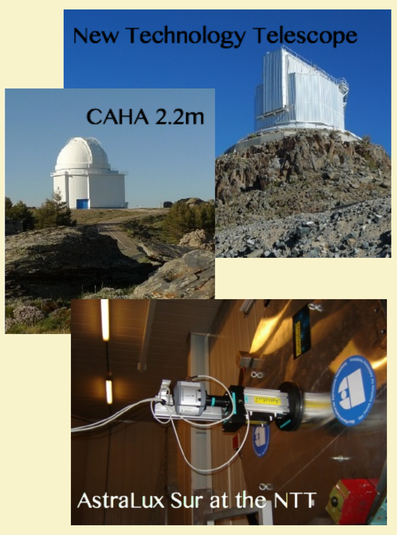
For transiting exoplanets valuable properties such as true mass, density and the spin-orbit alignment can be measured, which makes them particularly useful for constraints on planet formation, migration mechanisms and atmospheric properties.

Binary companions or other unrelated nearby stars appear to be common within ~2" separation of stars suspected to host transiting exoplanets (Lillo-Box et al. 2012;Adams et al. 2012, 2013; Guenther et al. 2013).

Some of these blending stars may elude detection in light curve analysis and seeing-limited observations. If not recognized and accounted for, the blending stars affect planetary and stellar parameters derived from the transits and eclipses.

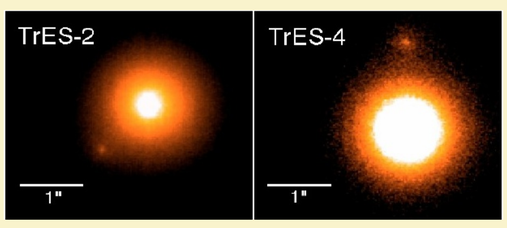
Here we present a survey to detect such companions to transiting exoplanet host stars.

The AstraLux binary TEP host survey



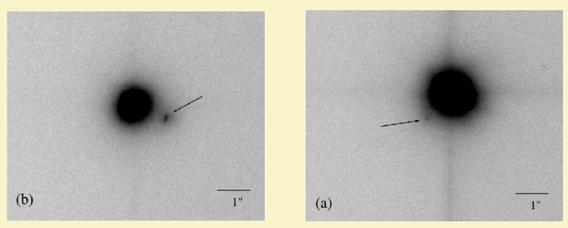
- The AstraLux Binary TEP Host Survey is a high resolution Lucky Imaging search for stellar companions to hosts of transiting exoplanets (TEPs) discovered in ground-based surveys
- We used the two AstraLux instruments, AstraLux Norte at the 2.2m telescope at the Calar Alto Observatory, Almería, Spain, and AstraLux Sur at NTT, La Silla, Chile to observe 31 hosts of transiting exoplanets and investigate multiplicity properties among these stars.

New companions to TEP hosts



TrES-2 and **TrES-4** companion candidates,

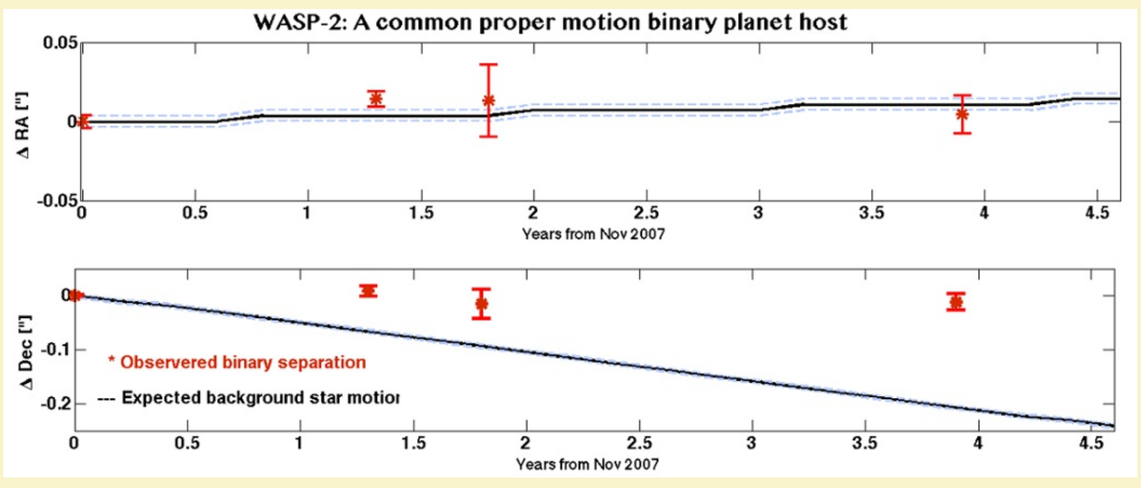
Daemgen et al. 2009



WASP-12 and **HAT-P-8** companion candidates,

Bergfors et al. 2013

- 5 candidate companions were detected within 1" and 2 at wider separations. These include the previously unknown companion candidates to WASP-12, HAT-P-8, TrES-2 and TrES-4.
- We could confirm common proper motion for the candidate TEP binaries TrES-4 and WASP-2 (discovered by Collier-Cameron et al. 2007)

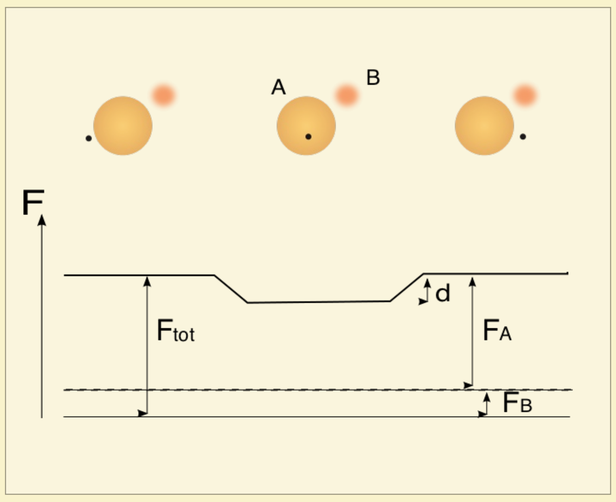


Above: The common proper motion of the WASP-2 companion candidates could be confirmed from observations over a time baseline of 4 years.

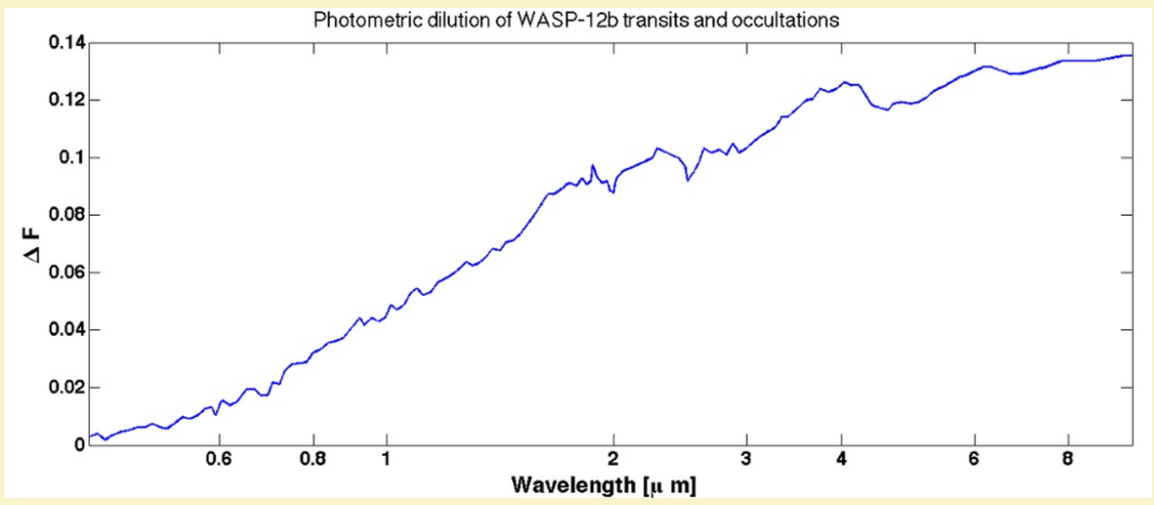
- Although the AstraLux observations are typically sensitive to companions 2 mag fainter than the TEP host at projected separation 40 AU at the average distance of 200 pc, no companion candidates were found closer than 100 AU
- Our Bayesian analysis suggests that the companion star fraction (CSF) is similar to solar-type stars in general, but that the binary separation is on average larger for planet host stars
- The binary companion candidates WASP-12 and HAT-P-8 were recently confirmed to share common proper motion with the planet hosts, and to be binary systems themselves (Bechter et al. 2013)

Blending by a secondary star

- The presence of an unresolved secondary star within the photometric aperture, whether physical companion or chance alignment, contributes flux to the transit light curve and affects the accuracy with which stellar and planetary parameters can be derived. The blend affects transit depth and the light curve profile, and may require a correction of derived planetary and stellar parameters ranging from a few to several tens per cent (see Seager & Mallen-Ornelas, 2003; Daemgen et al., 2009; Buchhave et al. 2011).



Above: Cartoon illustrating the effect of an additional star within the photometric aperture on the transit depth.



Above: Flux ratio $F_{Mdwarf}/F_{WASP-12}$. The photometric dilution as a function of wavelength is derived using the BT-Settl/PHOENIX atmospheric model (Allard et al. 2011) constrained by Keck/NIRSPEC spectroscopy of the M dwarf companion together with AstraLux Sur, IRTF/SpeX and Subaru/MOIRCS photometry of WASP-12 (see Crossfield et al. 2012).

- The M-dwarf companions to WASP-12 are ~4 mag fainter than the planet host at optical wavelengths. Correcting for the contributed companion flux increases the planet radius by ~1% — of the same order as the estimated errors. At longer wavelengths the effect is larger and may affect photometric properties of the planet WASP-12b significantly. Measured transit and eclipse depths are diluted by up to 10% in the near infrared and up to 15% at longer wavelengths (see Crossfield et al., 2012).

Conclusions and future work

- High resolution imaging of stars suspected of hosting transiting exoplanets is of high importance for characterisation of exoplanet systems. These observations efficiently detect fainter nearby stars that may affect derived stellar and planetary parameters such as Rp/R*, a/R*, b, Mp and atmospheric properties if not accounted for. Future follow-up spectroscopic and astrometric observations will provide more detailed knowledge about the properties of these candidate binary/multiple planetary systems.

References:

Adams et al. 2012, AJ 144, 42
Adams et al. 2013, AJ 146, 9
Allard et al. 2011, ASPCS 448, 91
Bechter et al. 2013, arXiv 1307.6857
Bergfors et al. 2011, IAUS 276, 397
Bergfors et al. 2013, MNRAS 428, 182
Buchhave et al. 2011, ApJS 197, 3
Collier Cameron et al. 2007, MNRAS 375, 951
Crossfield et al. 2012, ApJ 760, 140
Daemgen et al. 2009, A&A 498, 567
Desidera & Barbieri 2007, A&A 462, 345
Eggenberger et al. 2008, ASPCS 398, 179
Eggenberger et al. 2011, IAUS 276, 409
Guenther et al. 2013, A&A 556, 75
Lillo-Box et al. 2012, A&A 546, 10
Seager & Mallén-Ornelas 2003, ApJ 585, 1038