Planets from the WTS/RoPACS projects

Roberto Saglia

MPE/LMU (saglia@mpe.mpg.de)

Cappetta, Koppenhöfer, Steele, Zendejas (MPE, Germany), **Pinfield (PI), Barnes, Campbell, Catalan, Goulding, Jones, Marocco, Napiwotzki, Sipocz** (CAR, Herts, UK), **Hodgkin (PI), Kovacs, Mislis** (IoA, Cambridge, UK), **Barrado, Bajo, Cruz, Galvez Ortiz, Sarro Baro, Solano, Stoev** (CAB, Madrid, Spain), **Martin, Lodieu, Murgas, Palle, Tata** (IAC, Tenerife, Spain), **Pavlenko, Ivanyuk, Kuznetsov** (MAO, Ukraine), **Birkby, Nefs, Snellen,** (Leiden Observatory, The Netherlands), **del Burgo** (INAOE, Mexico), **Fossati**, **Haswell** (Open University, UK), **Pollacco** (Queens University, UK), the WTS consortium, and members of the EC funded **RoPACS** INT

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Outline

- **Introduction:** The WFCAM Transit Survey and RoPACS
- **Discoveries:** the giant planets WTS-1 b and WTS-2 b
- **Discussion:** upper limits on the fraction of M-dwarfs with giant planets
- **Conclusions**

Hot Jupiters around M-Dwarfs?

- In the core accretion paradigm, gas giants are formed by accumulating gas on the solid core from the disk. This does not work easily around low mass stars because of time scale differences (Laughlin et al. 2004, Ida & Lin 2005). The protoplanetary disk dissipates before the runaway gas accretion phase is reached. The predicted frequency of giant planets should decrease towards lower primary masses. Neptunes and rocky planets should be common around low mass stars.
- Gravitational instability models can produce gas giants quickly (if the protoplanetary disk is massive enough to become unstable, Boss 2006)

Not many planets around M-dwarfs known:

- Johnson et al. (2007) find 3 Jupiters around 169 M dwarfs using RVs (1.8%).

- Two transiting planets found around M dwarfs from the ground (Gillon e tal. 2007, Charbonneau et al. 2009). The Kepler Mission identifies 9 high-quality candidates around 1086 cool stars ($3600K<T_{eff}<4100$), Howard et al. 2011

→search for transits in the NIR

sensitive to rocky planets in the habitable zone of M-dwarfs

The WFCAM Transit Survey (WTS)

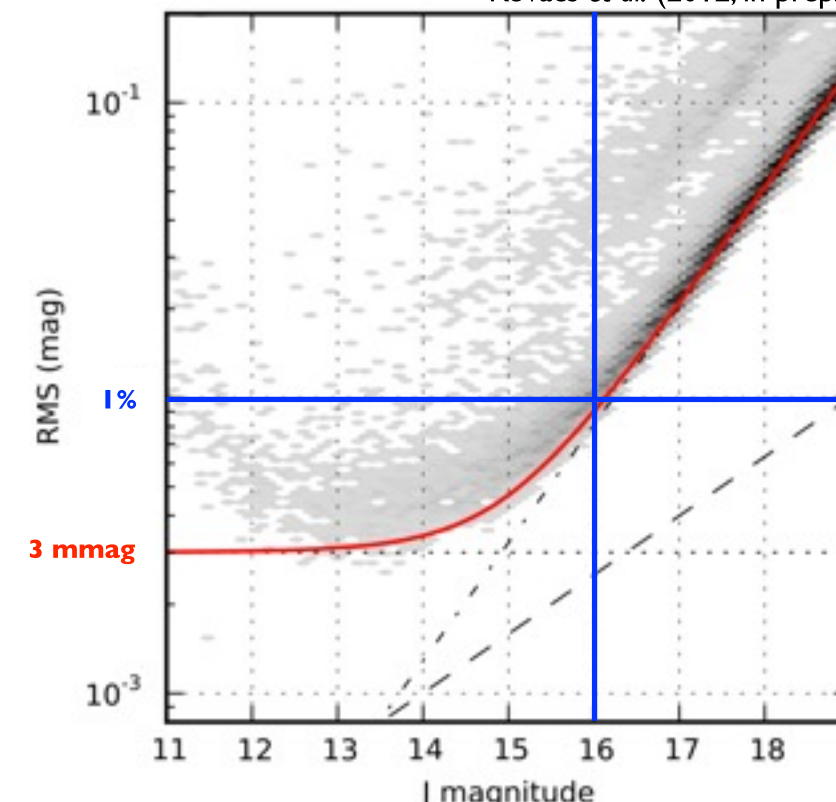
- M-dwarf ongoing variability survey (started in August 2007) designed primarily to:

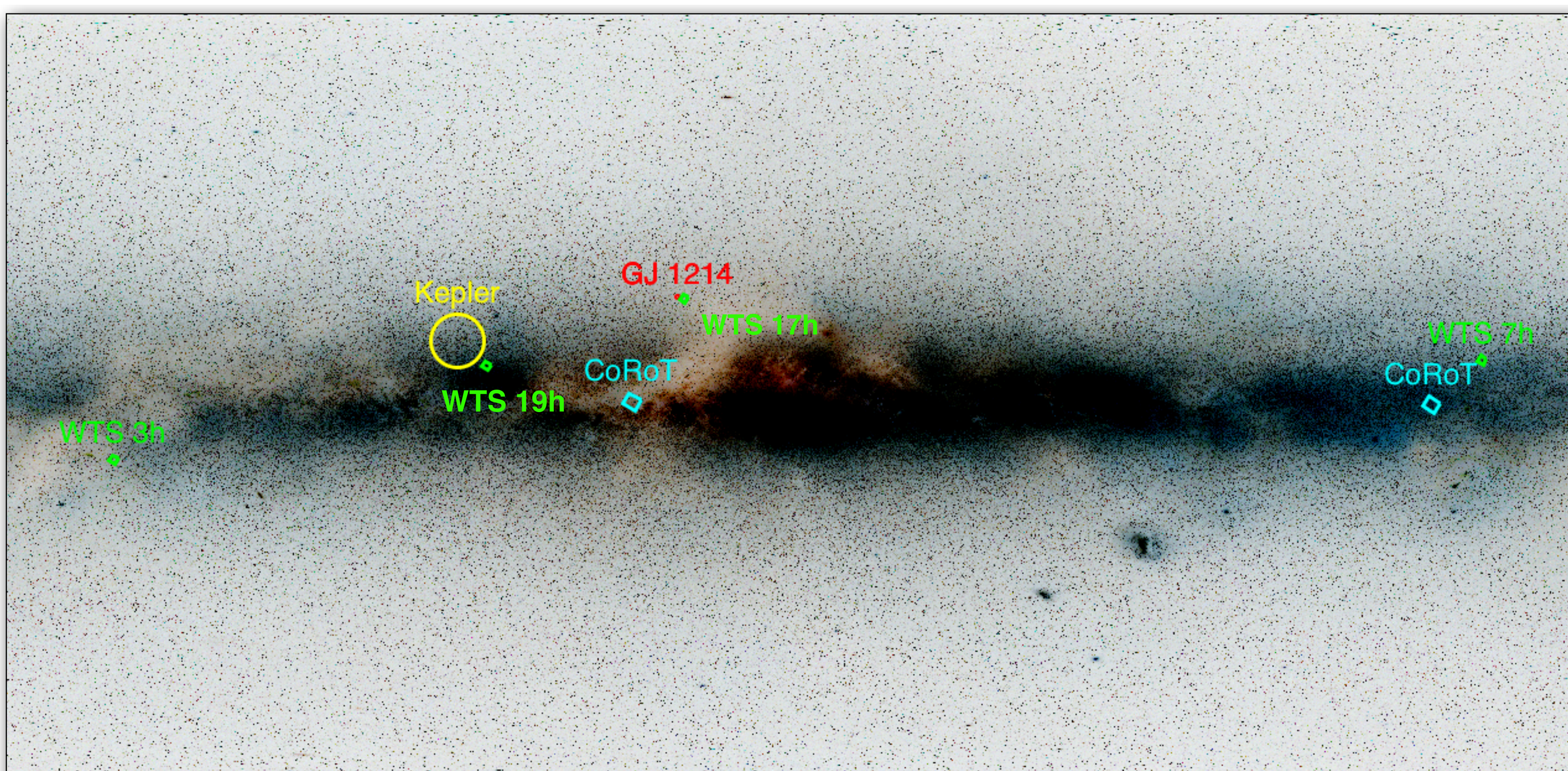
  i) tightly constrain the M-dwarf hot Jupiter fraction

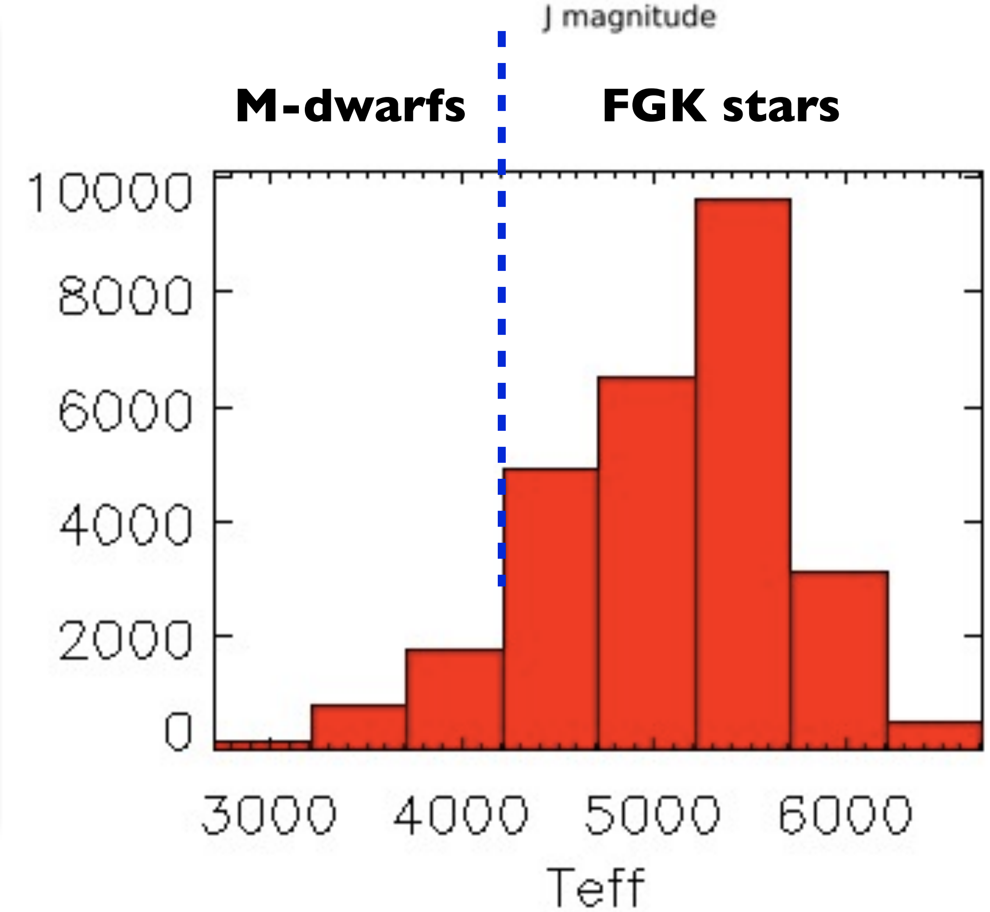
  ii) calibrate low-mass stellar evolution models with M-dwarf eclipsing binaries

- UKIRT+WFCAM wide-field view of four fields (4x1.5 = 6 sq. deg)
- Infrared J-band (1.25μm) near peak of M-dwarf SED
- Poor seeing/sky back-up program - efficient but non-standard observing pattern, one field always visible

Kovacs *et al.* (2012, in prep.)







Light curves and analysis

• CASU Data reduction pipeline
• Aperture photometry (and difference imaging) light curves
• Box-fitting search for transits

More than 1000 epochs in the 19h field

• Multi-band (ugrizYJHK) spectral typing
• i-band light curve for interesting candidates
• low-resolution spectroscopy for better typing and detection of high amplitude radial velocity variations (binaries)

• high-resolution (HET) spectroscopy for precise radial velocity measurements

Rocky Planets Around Cool Stars (RoPACS)

RoPACS is a Marie Curie Initial Training Network funded by the European Community. It involves 6 nodes:

- University of Hertfordshire (UH), Hertfordshire - The coordinating node (PI D. Pinfield)
- Institute of Astronomy (IoA), Cambridge
- Institute de Astrofísica de Canarias (IAC), Tenerife
- Max-Planck Institut für Extraterrestriche Physik (MPE), Munich
- Laboratory of Stellar Astronomy and Exoplanets (LAEX-CAB), Madrid
- Main Astronomical Observatory (MAO), Kiev

+ Astrium

RoPACS supports 12 PhD students and 4 PostDocs. The project will end in November 2012 with a Conference on:

Hot planets and Cool Stars

http://www.mpe.mpg.de/events/ropacs-2012

MPE,(Garching) 12-16 November 2012

Nefs et al. 2012, ***Four ultra-short period eclipsing M-dwarf binaries in the WFCAM Transit Survey,*** MNRAS, 425, 950

Birkby et al. 2012, ***Discovery and characterisation of detached M-dwarf eclipsing binaries in the WFCAM Transit Survey,*** MNRAS, in press, astro-ph/1206.2773

Cappetta et al. 2012, ***The first planet detected in the WTS, an inflated hot-Jupiter in a 3.35 days orbit around a late F-star*** MNRAS, in press,

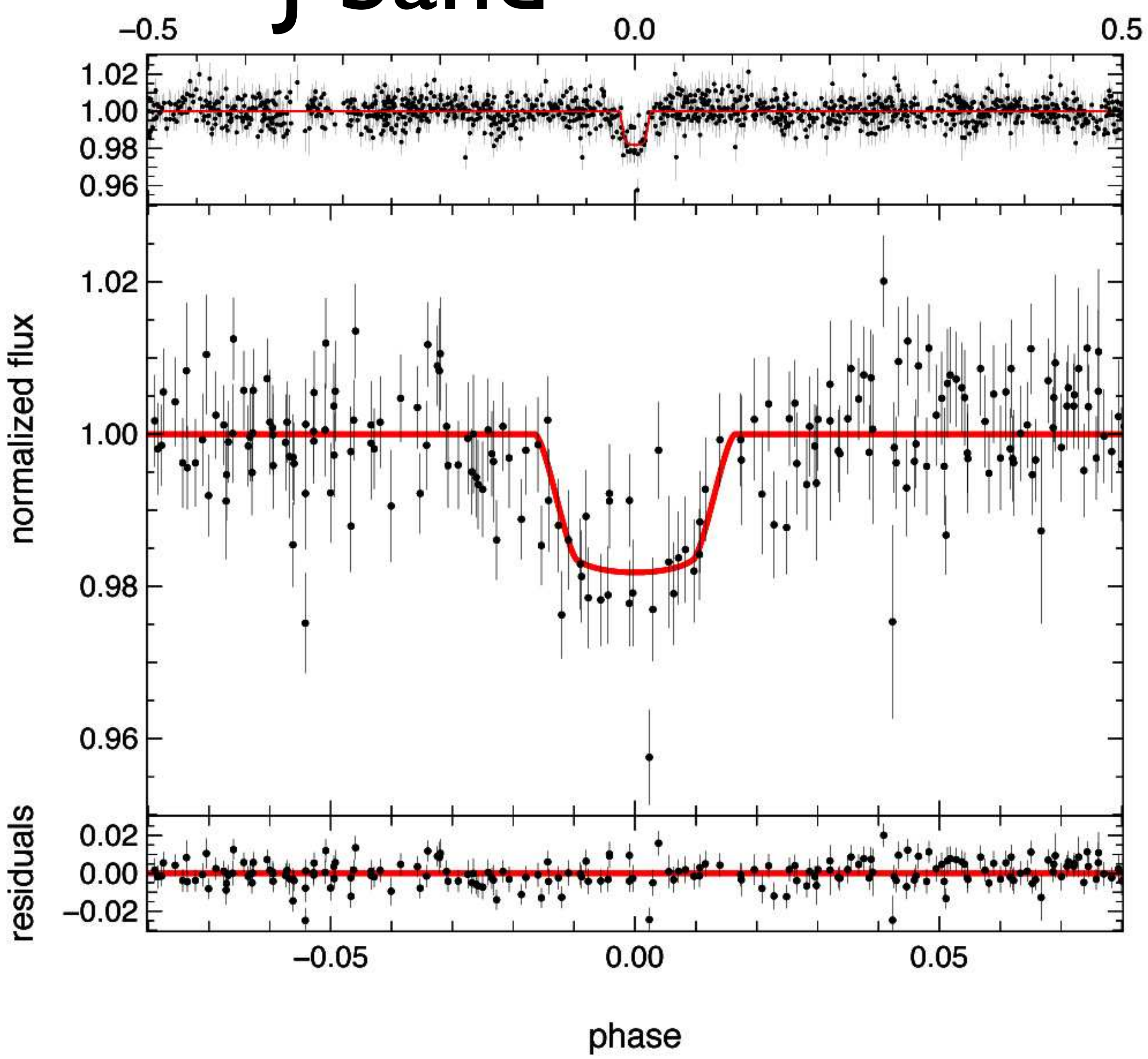
Kovacs et al. 2012, ***A sensitivity analysis of the WFCAM Transit Survey for short-period giant planets around M dwarfs*** MNRAS, submitted

Birkby et al. 2012, ***WTS-2b: an inflated hot Jupiter in a tight orbit around a K3V star***, in prep.

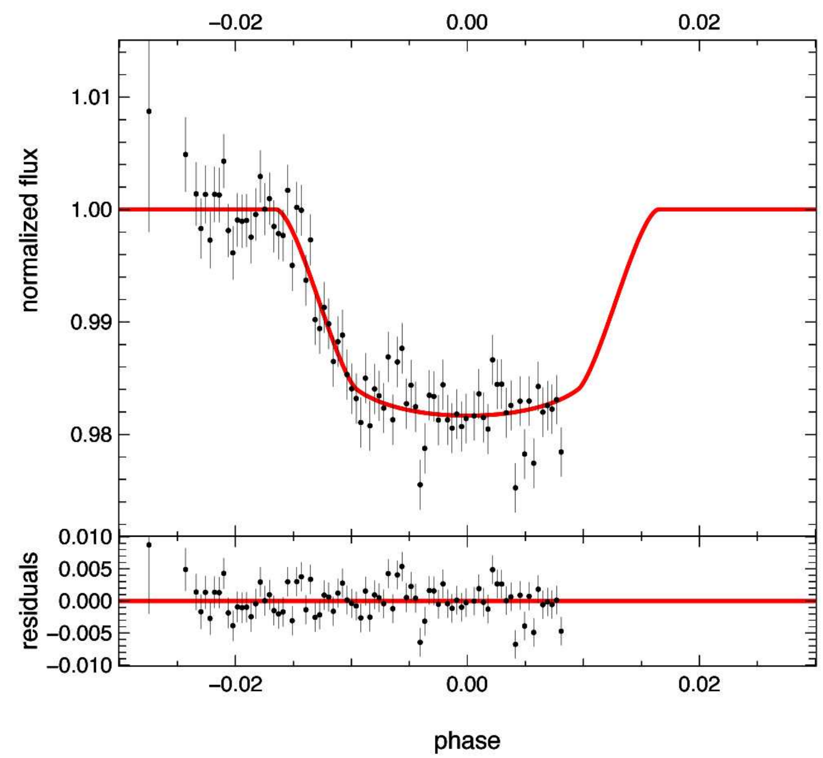
Detections in the WTS: WTS-1b

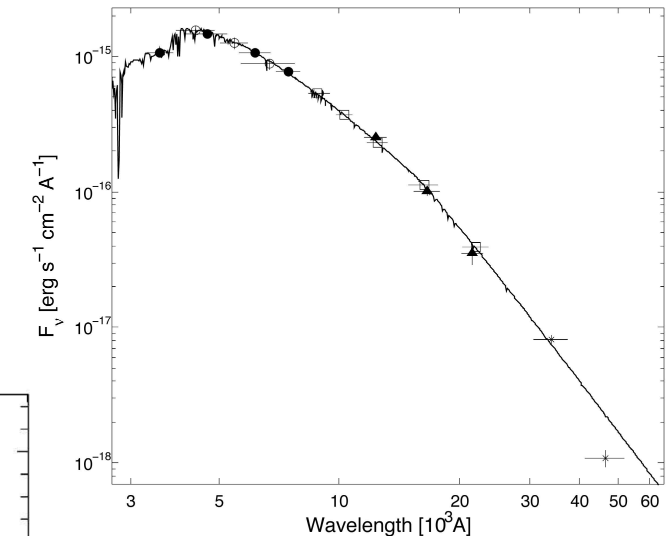
WTS-1 b (J=15.4, i=16.2, g=16.8), F7V

J band



i band





$T_{\rm eff}$	6250 ± 200 K
$\log\ g$	4.4 ± 0.1
[Fe/H]	[-0.5, 0] dex
M_s	$1.2\pm0.1\ M_\odot$
R_s	$1.15^{+0.10}_{-0.12}\ R_\odot$

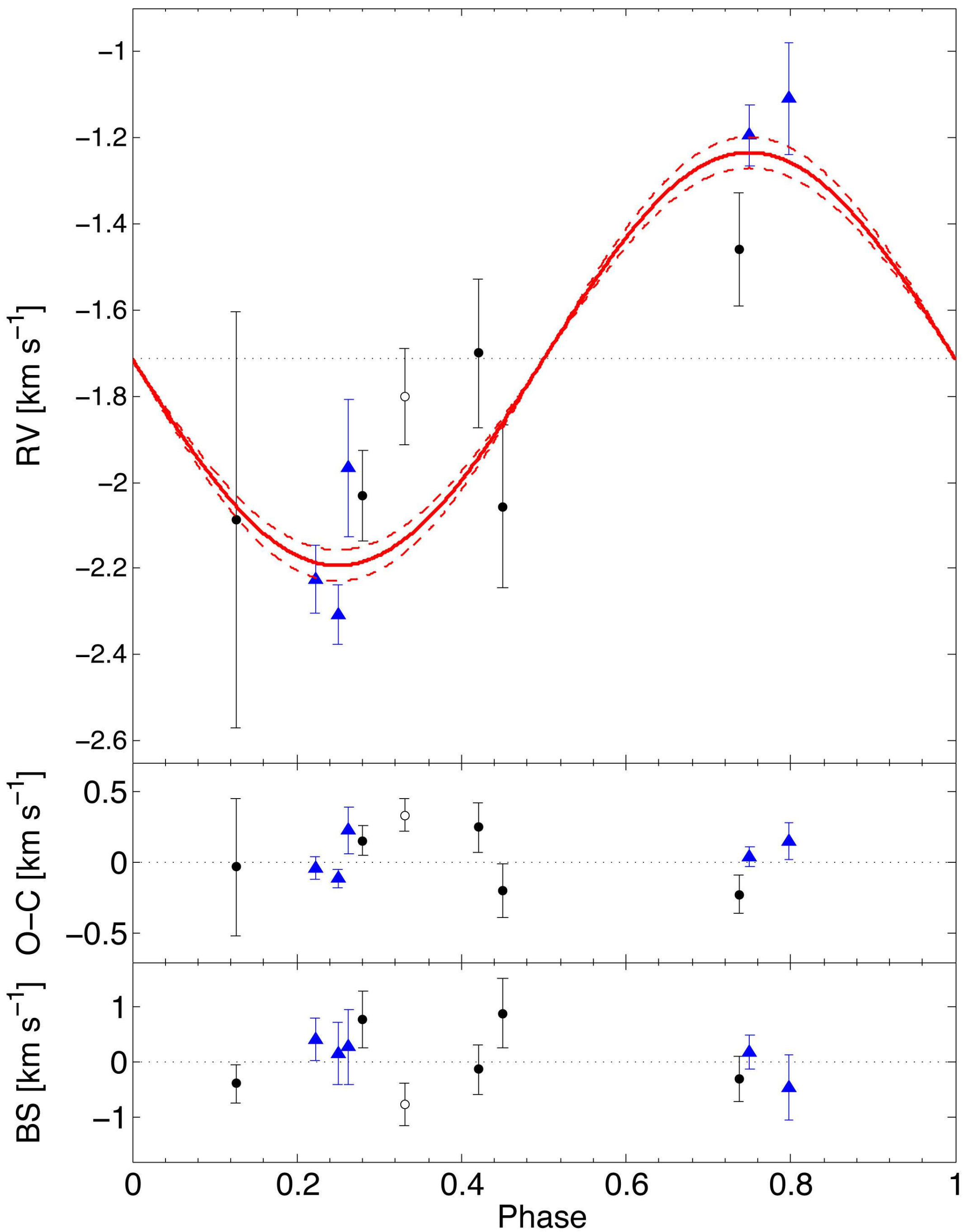
Simultaneous MCMC fitting of *J* and *i*-band with the Mandel & Agol models

Evidence against a blended background eclipsing binary:
- consistent transit depths between J and i band
- consistent stellar density from the light curve and spectroscopy

Cappetta et al. 2012, MNRAS, in press

Radial Velocities

HET Spectroscopy



No correlation between bisectors and phase within the errors - further evidence *against* a blended background eclipsing binary

$$P_{orb} = 3.352059^{+1.2\times10^{-5}}_{-1.4\times10^{-5}} \text{ days}$$

$$t_0 = 2\,454\,318.7472^{+0.0043}_{-0.0036} \text{ HJD}$$

$$R_p/R_s = 0.1328^{+0.0032}_{-0.0035}$$

$$\rho_s = 0.79^{+0.31}_{-0.18}\ \rho_{sun}$$

$$\beta_{impact} = 0.69^{+0.05}_{-0.09}$$

M_p — $4.01\pm0.35\ M_J$

R_p — $1.49^{+0.16}_{-0.18}\ R_J$

a — 0.047 ± 0.001 AU

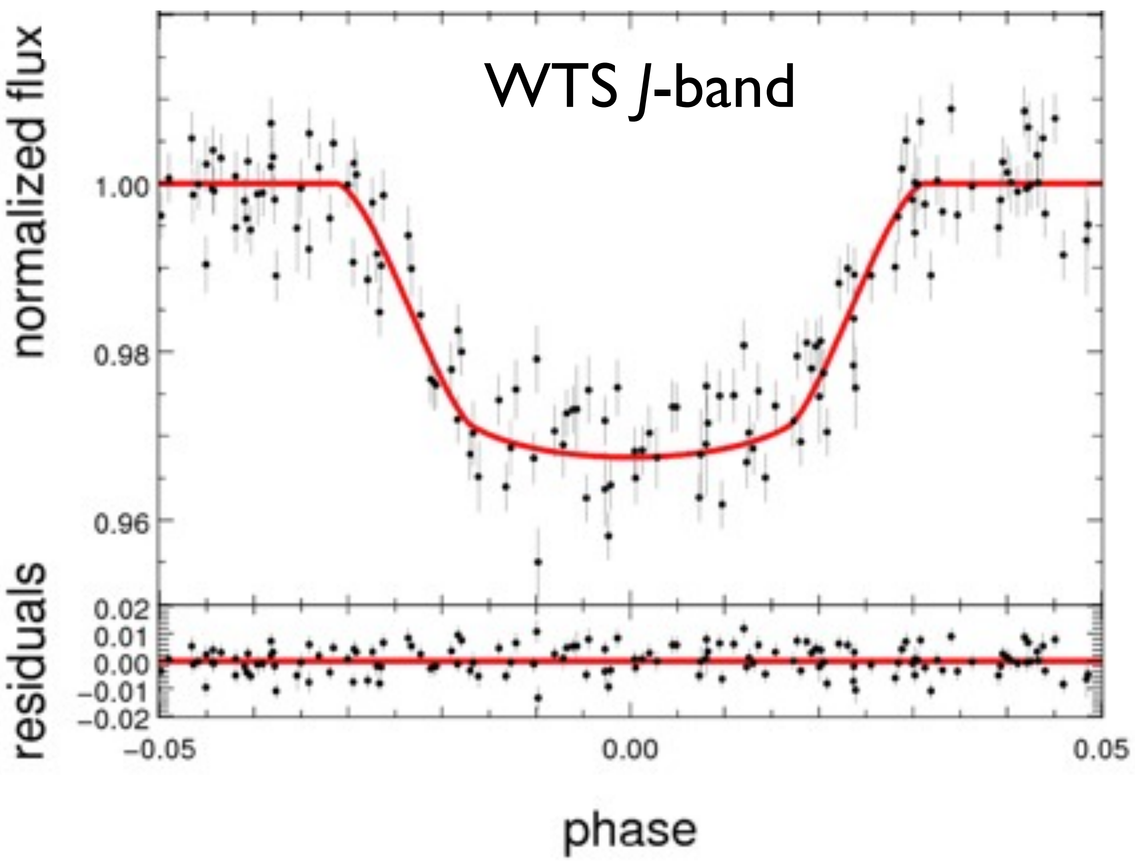
e — < 0.1 (C.L.$=$ 95%)

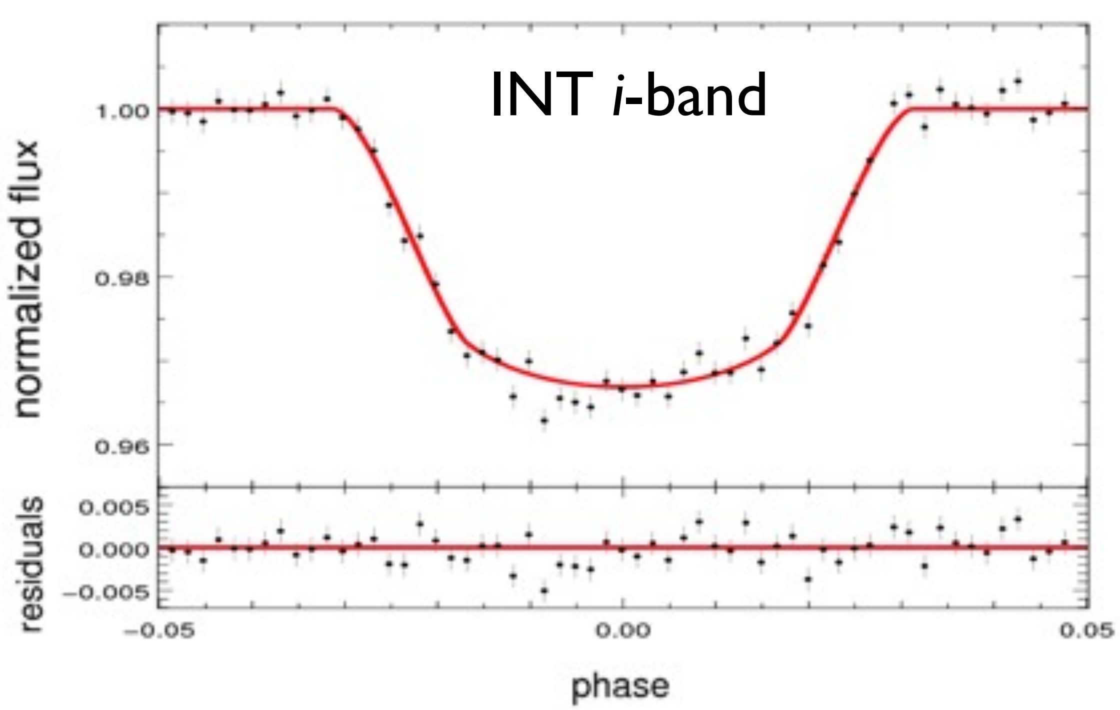
inc — $85.5^{+1.0}_{-0.7}$ deg

ρ_p — $1.61\pm0.56\ g\ cm^{-3}$, $1.21\pm0.42\ \rho_J$

T_{eq}[a] — 1500 ± 100 K

Detections in the WTS: WTS-2b





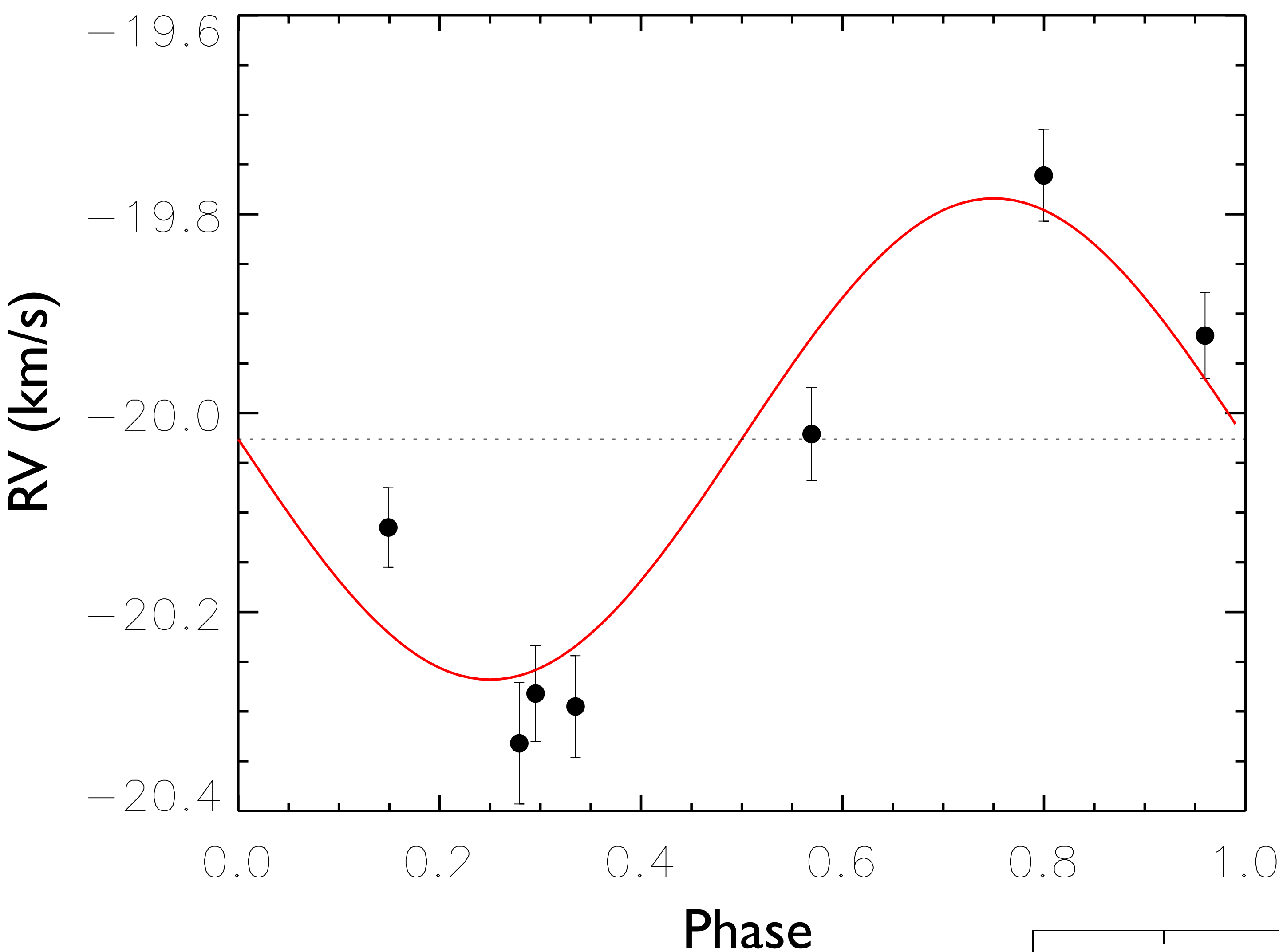
WTS-2b:
J=13.87, i=15.15, K3V

Parameter	
P (days)	$1.0187070^{+4.10e-07}_{-5.07e-07}$
T_0 (HJD)	$2454317.81308^{+0.00048}_{-0.00039}$
e	0 (fixed)
i (°)	$82.99^{+0.41}_{-0.36}$
$R_P/R_\star$	$0.1751^{+0.0013}_{-0.0014}$
R_P (R_J)	$1.3564^{+0.0361}_{-0.0384}$
$R_\star$ ($R_\odot$)	$0.794^{+0.016}_{-0.017}$
$\bar{\rho}_\star$ ($\rho_\odot$)	$1.697^{+0.117}_{-0.101}$
b	$0.617^{+0.019}_{-0.023}$
a(AU)	0.01877
Duration (hrs)	1.540
$M_\star$ ($M_\odot$)	0.85 (fixed)

Birkby et al. 2012, in prep.

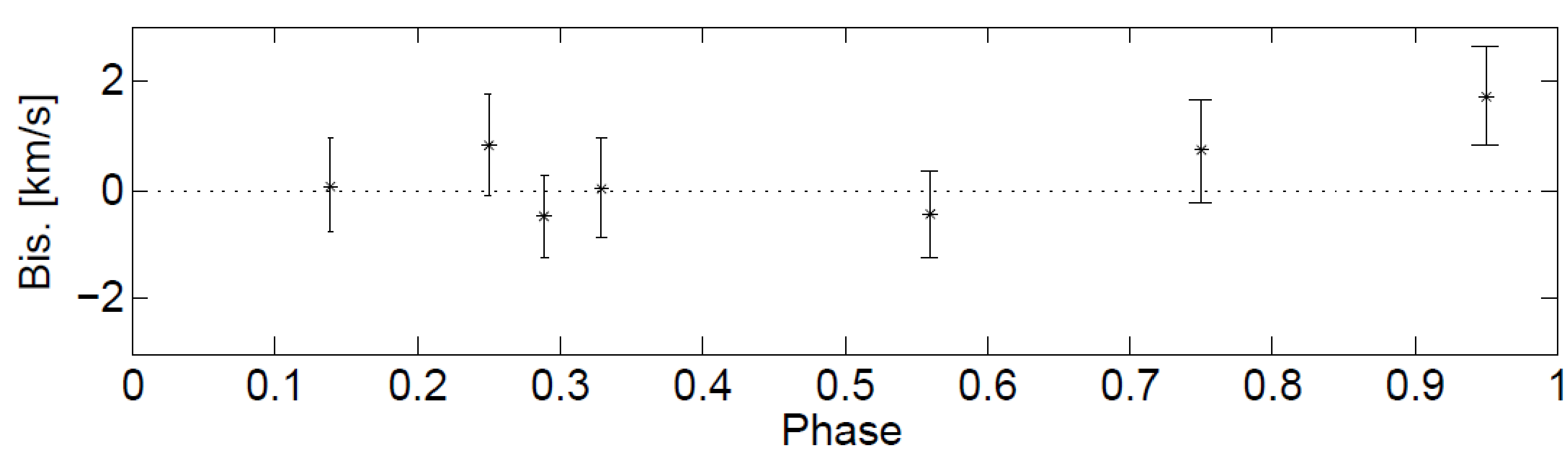
Radial Velocities

HET Spectroscopy



Parameter	
K (km/s)	-0.242 ± 0.027
V_{sys} (km/s)	-20.026 ± 0.021
e	0 (fixed)
M_P (M_J)	1.08 ± 0.11
ρ_P	$0.43\rho_J$
χ^2_ν	1.46

No correlation between bisectors and phase within the errors - further evidence *against* a blended background eclipsing binary



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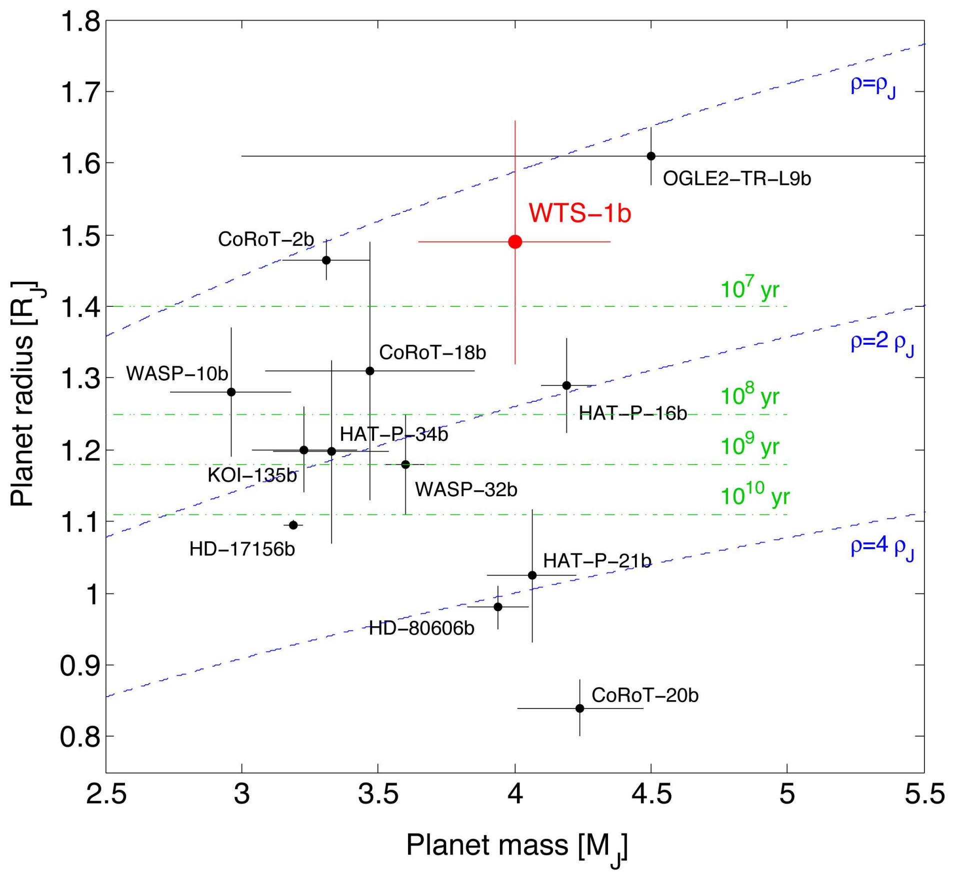
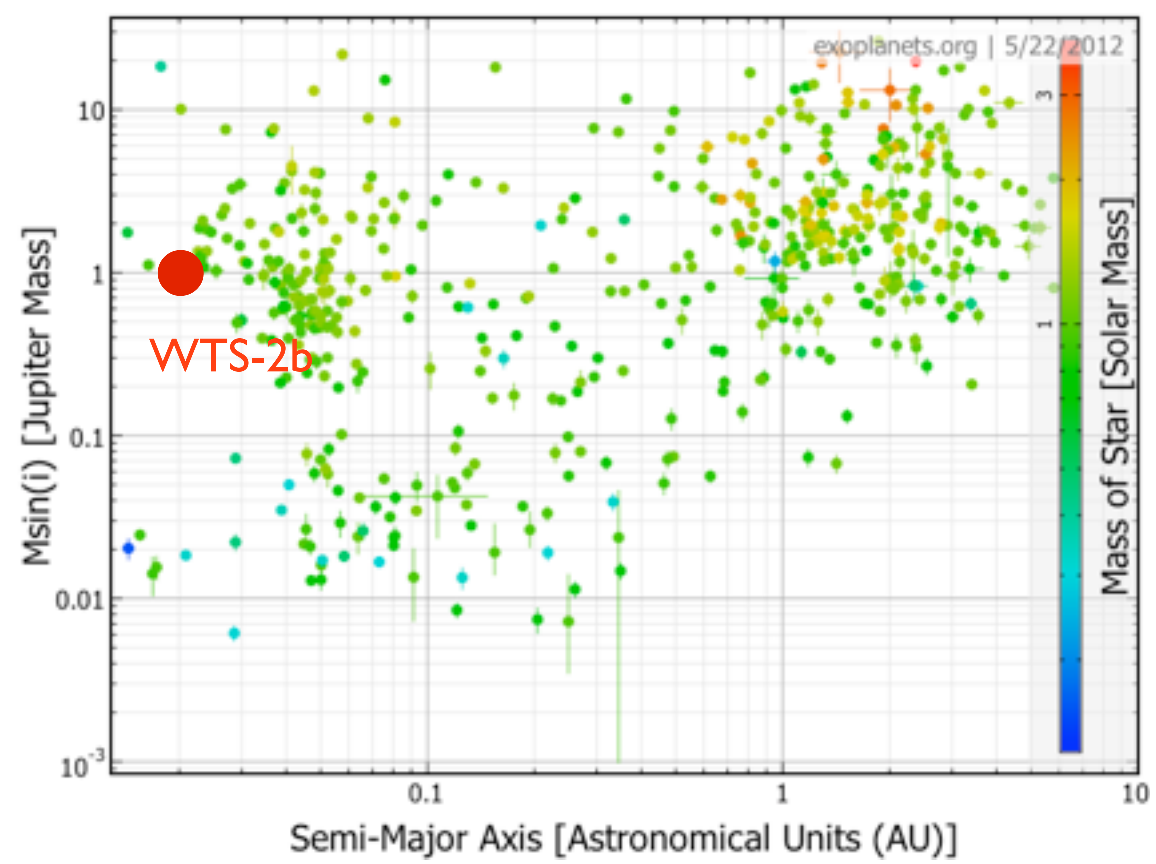




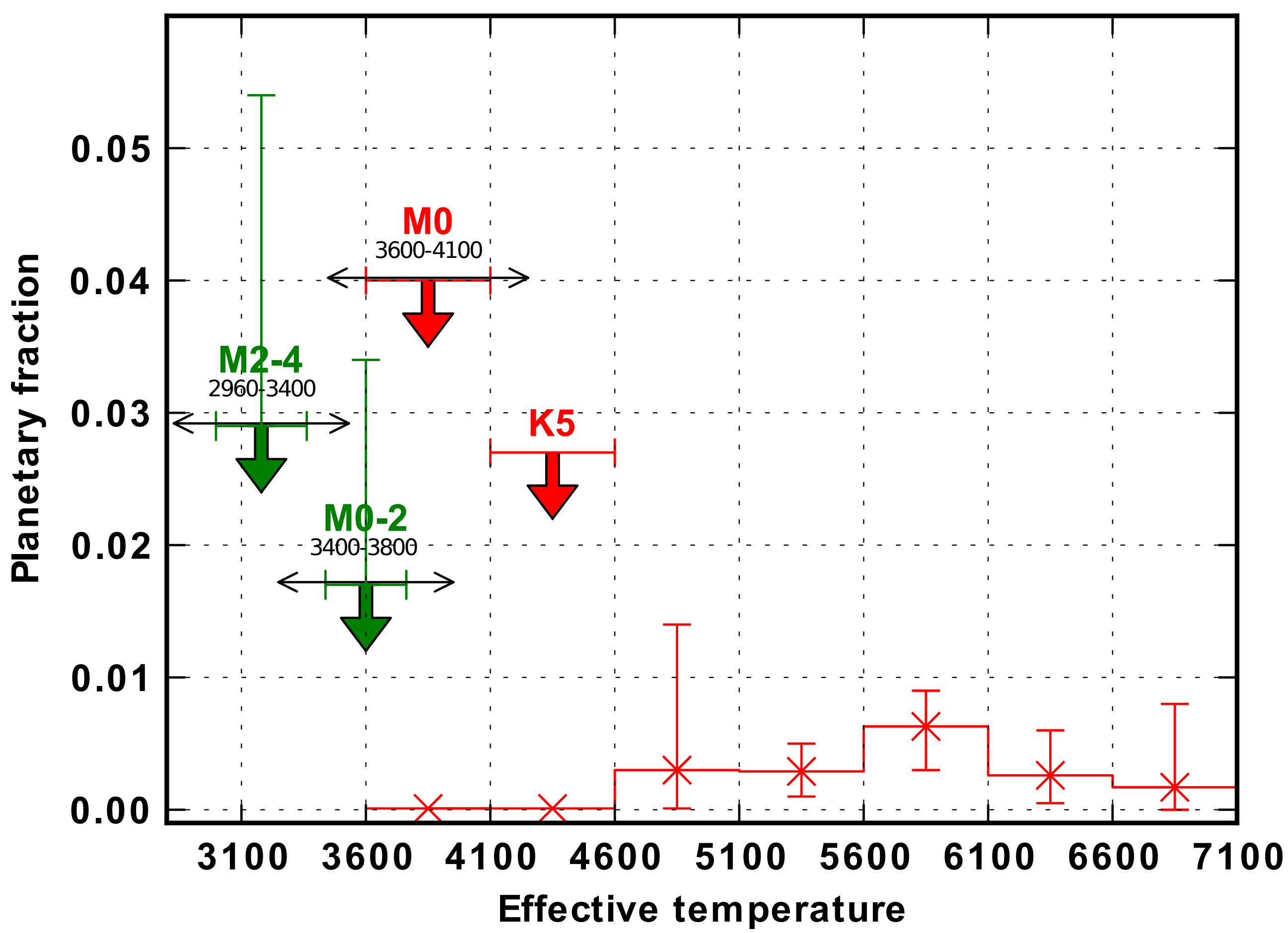
WTS-1b: one of the largest radius anomalies among the known hot Jupiters in the mass range 3-5M_J

WTS-2b: a short-period hot Jupiter around a sub-solar mass star that favours a substantially higher Q (efficiency of tidal dissipation) value than predicted by theory.

Planets around M-Dwarfs

- 19h field: 2844 M0-2, 1679 M2-4 to J=17

No planet candidates around the M-dwarf sample in the 19h field→more stringent upper limit on the hot Jupiters fraction (with periods less than 10 days) than Kepler.



Still not possible to discriminate between formation theories.

Potentially up to 31 hot Neptunes present in the 4 fields, but with high false alarm rate.

Kovacs et al. 2012, submitted to MNRAS

Conclusions

- Ground-based infrared transit surveys with irregular observing patterns are capable of finding exoplanets.
- WTS-1b and 2b are hot Jupiters around an F7V and a K3V star.
- The fraction of M-dwarfs with hot Jupiters with periods less than 10 days is less than 2-3%.
- Larger M-dwarf samples are needed to put stronger constraints →PanPlanets