TRANSMISSION SPECTROSCOPY USING ULTRACAM

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AND

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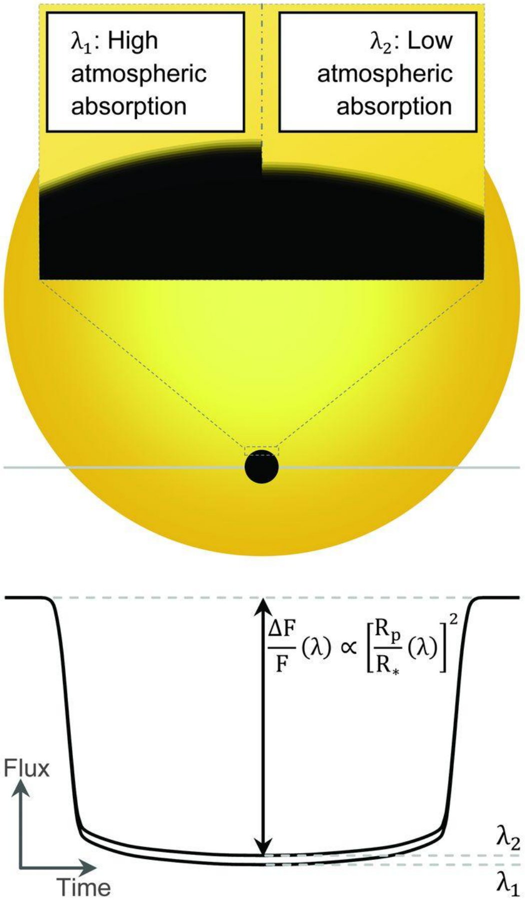
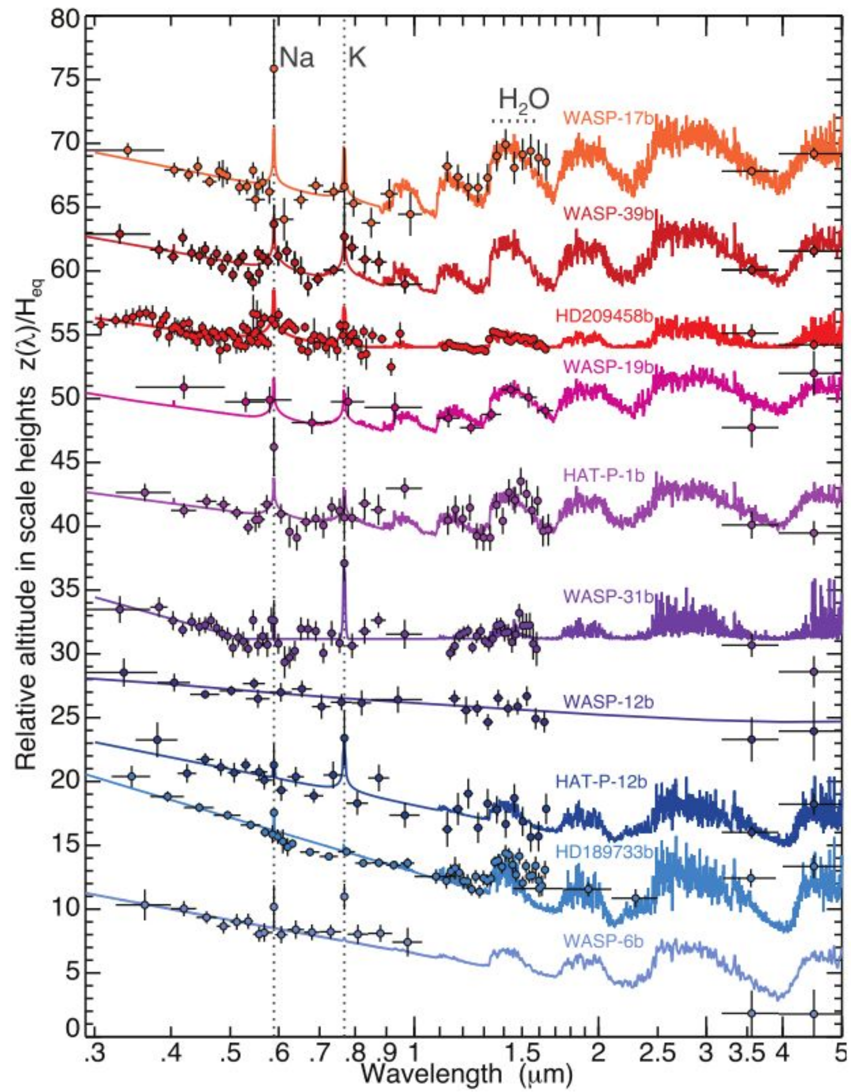
Image credit: NASA, ESA, and G. Bacon (STScI)

Transmission Spectroscopy



de Wit & Seager 2013



Sing et al. 2016

ULTRACAM

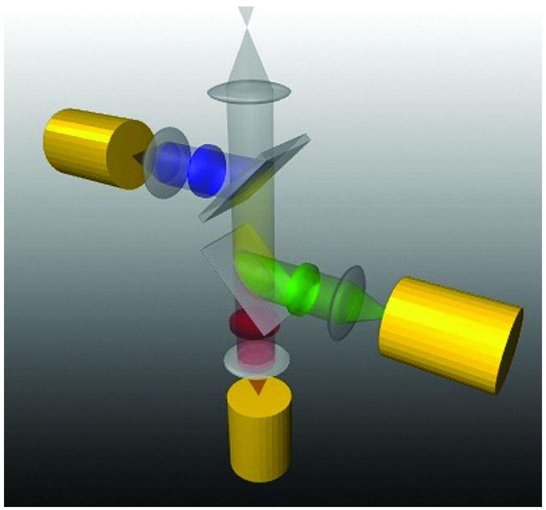
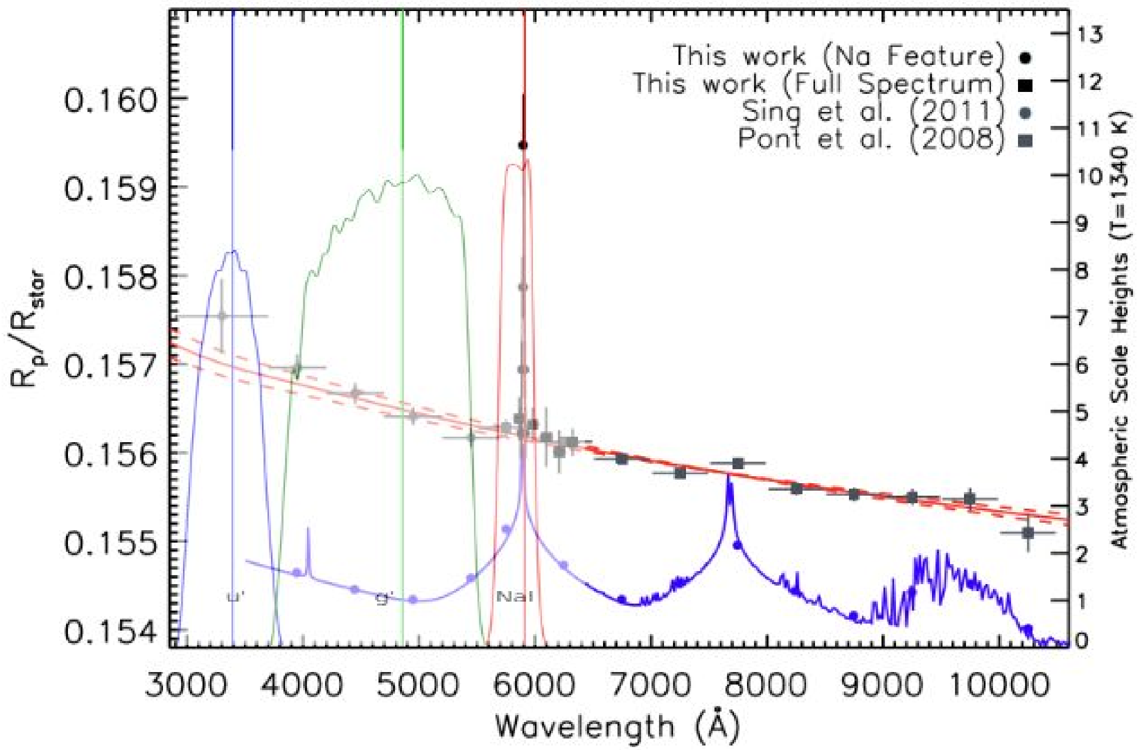


Image credit: http://www.ing.iac.es/



Huitson et al. 2012

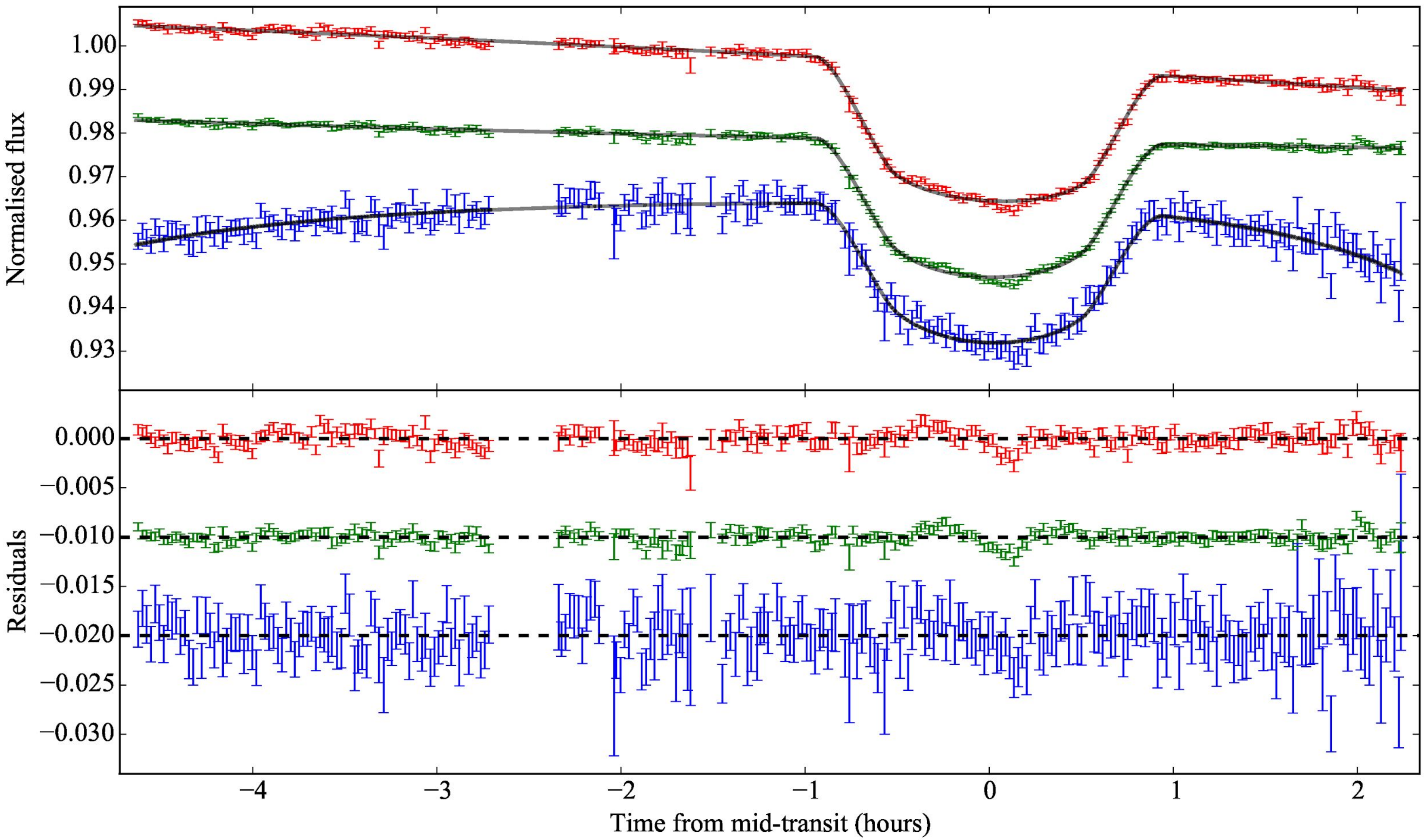
Our targets - inflated hot Jupiters

- Choose our targets on a figure of merit
- Low density
  - ---> Low surface gravity
- High temperature
- Low mean molecular mass
  - ---> Large scale height, H = (k*T)/(mu*g)
- Large transit depth
- Nearby comparison star with similar magnitude and colour

WASP-52b

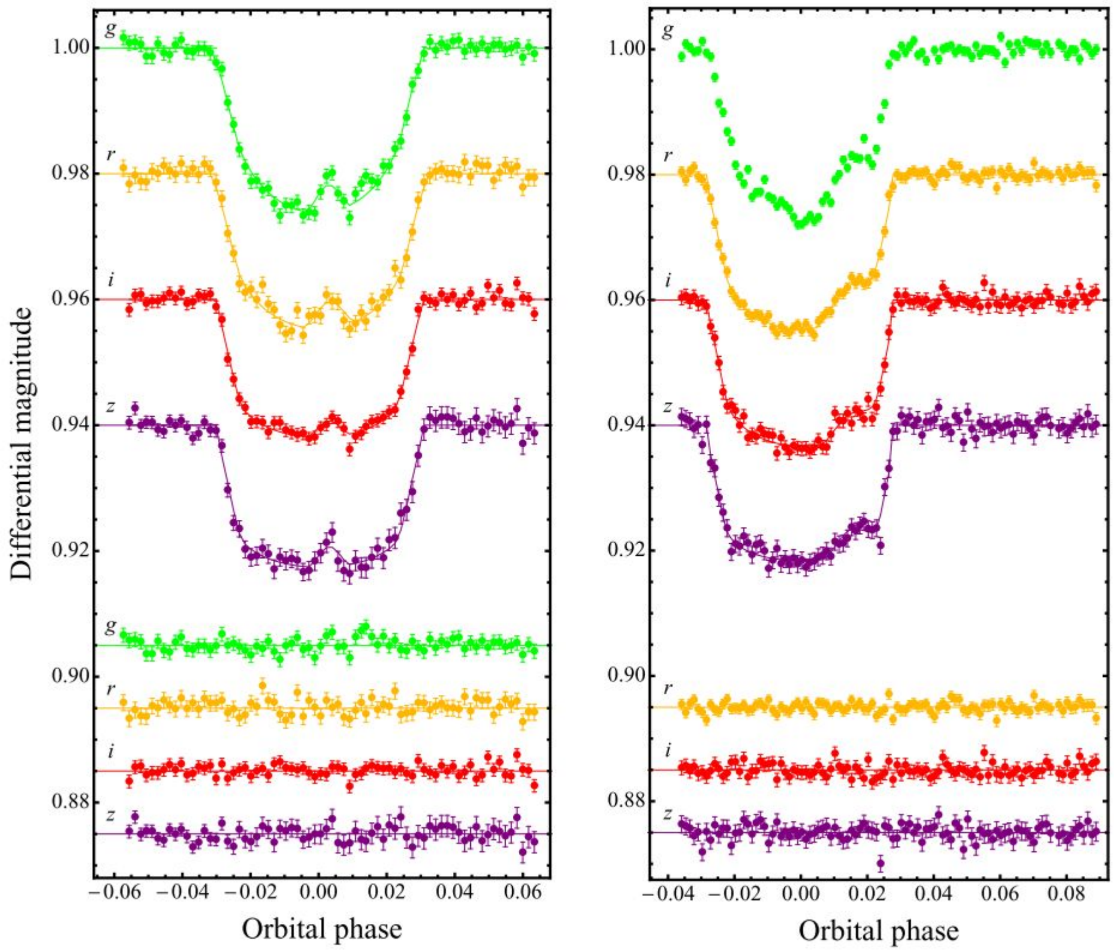
- Low density .... 0.29 gcm^-3
  - ---> Low surface gravity...................................... Logg = 2.81
- High temperature .... 1315 K
- Low mean molecular mass 2.3
  - ---> Large scale height, H = (k*T)/(mu*g) .... 731 km
- Large transit depth .... 2.7 %
- Nearby comparison star with similar magnitude and colour
  - WASP-52: V = 12.2; B - V = 0.82
  - Comparison: V = 10.6; B - V = 0.86
- The expected transmission signal is 3 times larger than that of HD 189733b

Light curve fitting - Mandel & Agol MCMC



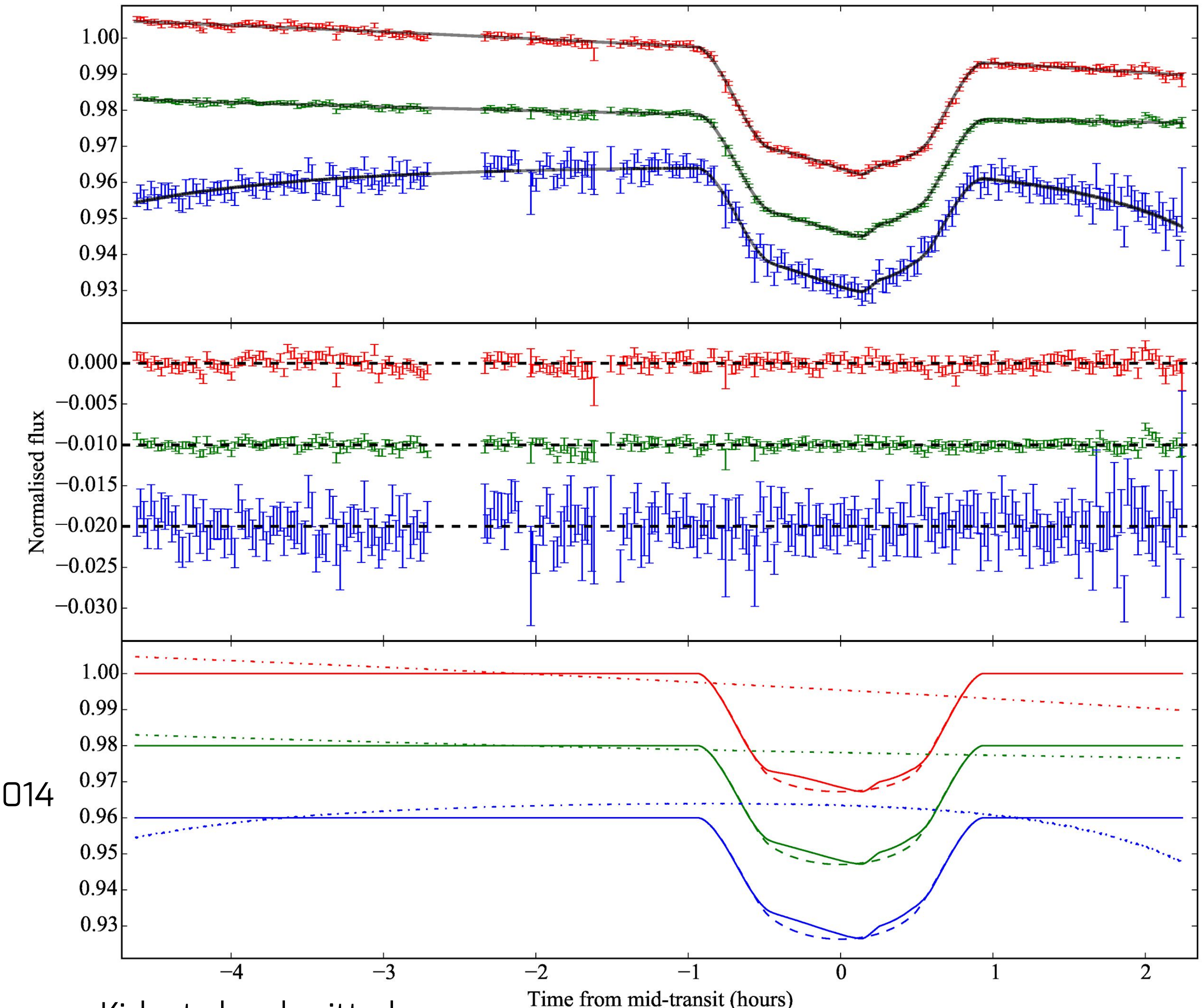
Kirk et al. submitted

Previous spot detection



Mohler-Fischer et al. 2013

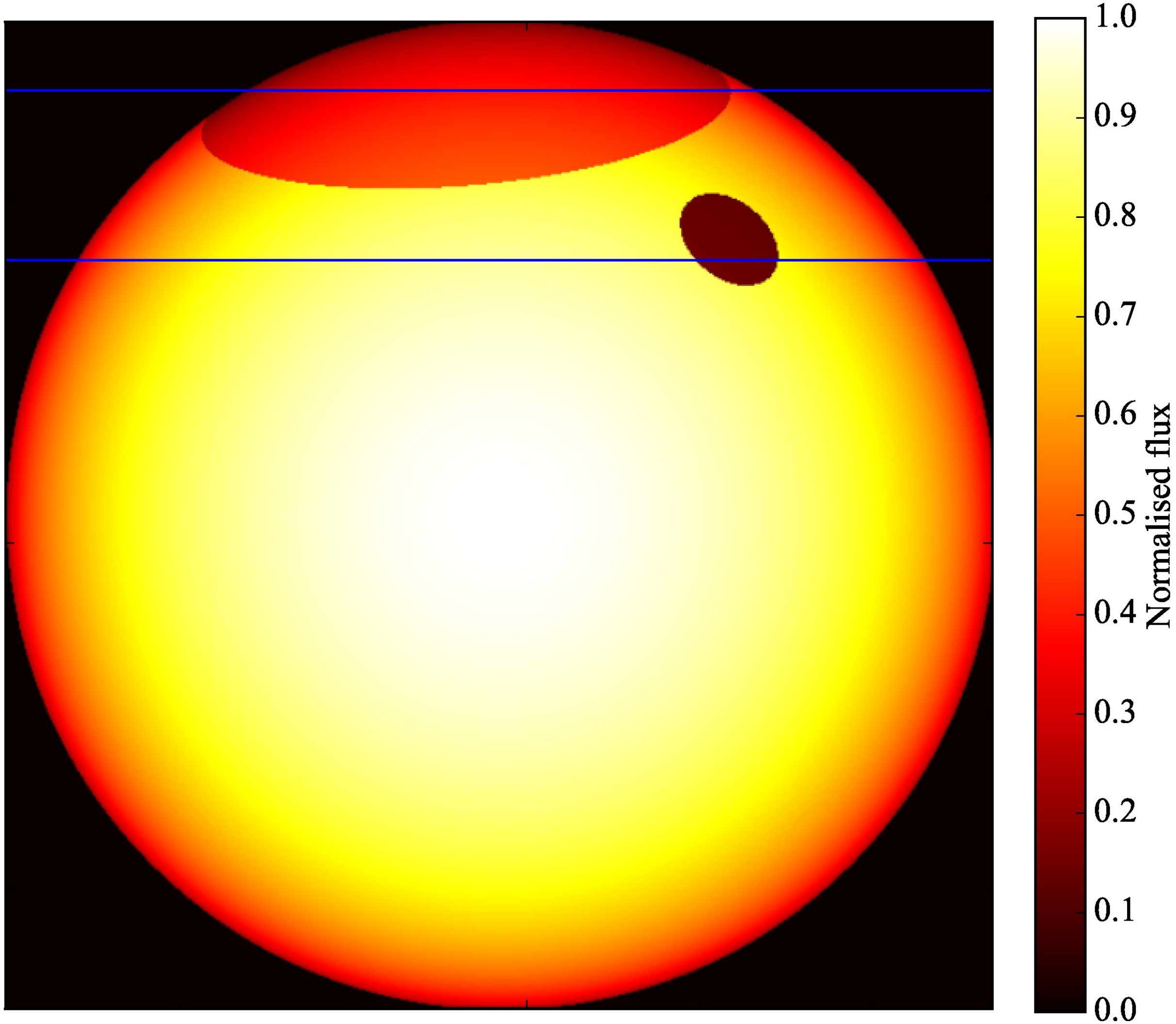
Spot modelling



SPOTROD
Beky et al. 2014

Kirk et al. submitted

Spot arrangement



Kirk et al. submitted

Spot contrasts

Spot filling factor

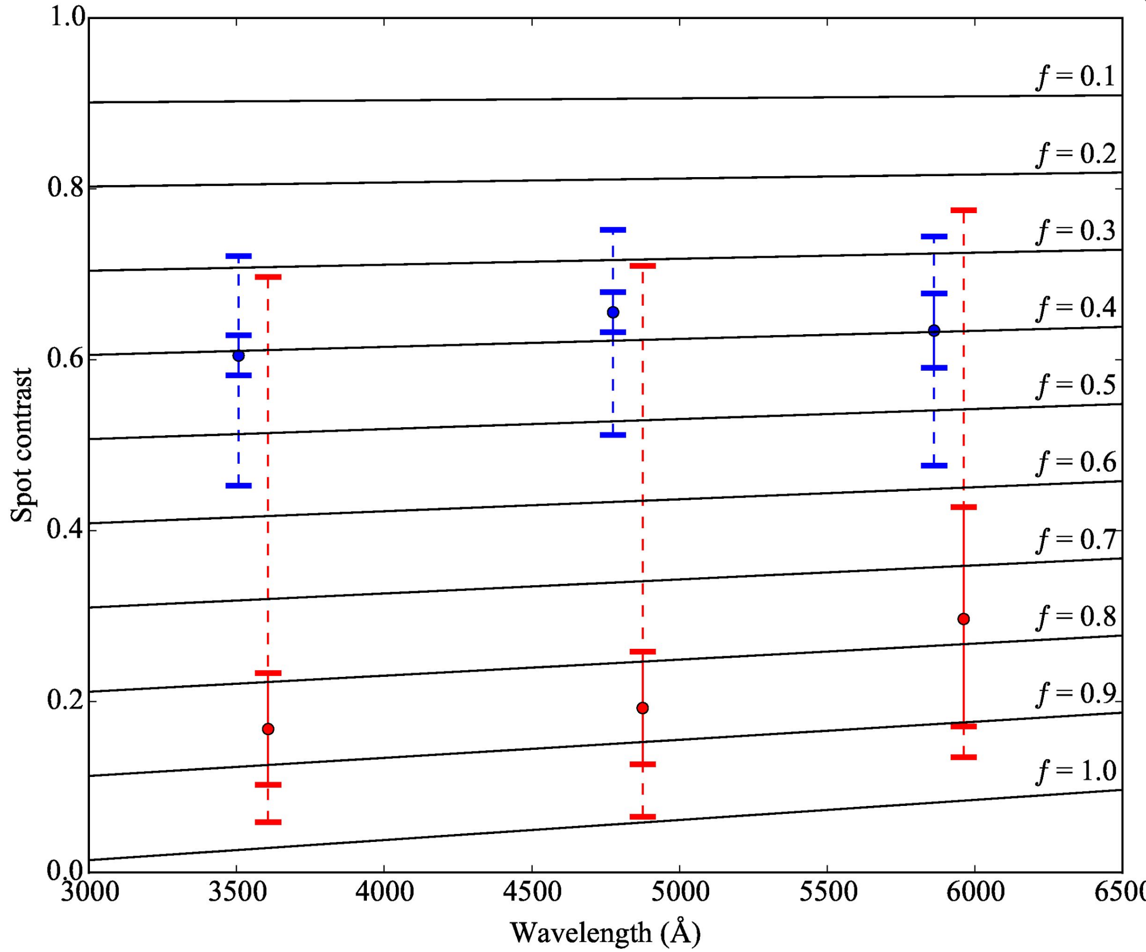
Spot flux

Spot contrast

$$\rho = \frac{fF_{\bullet}(\lambda) + (1-f)F_{*}(\lambda)}{F_{*}(\lambda)}$$

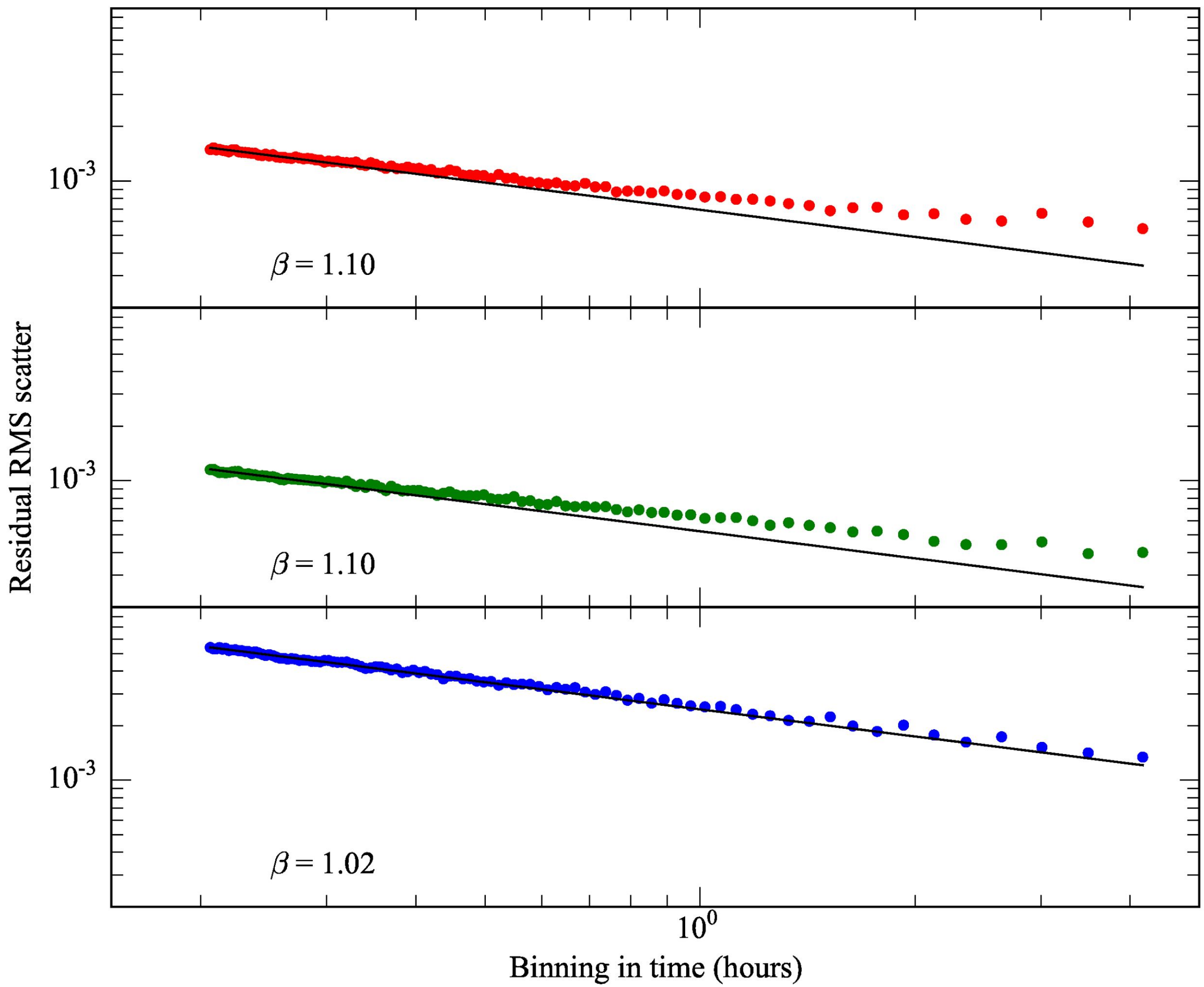
Stellar flux

$\Delta T = 1500K$



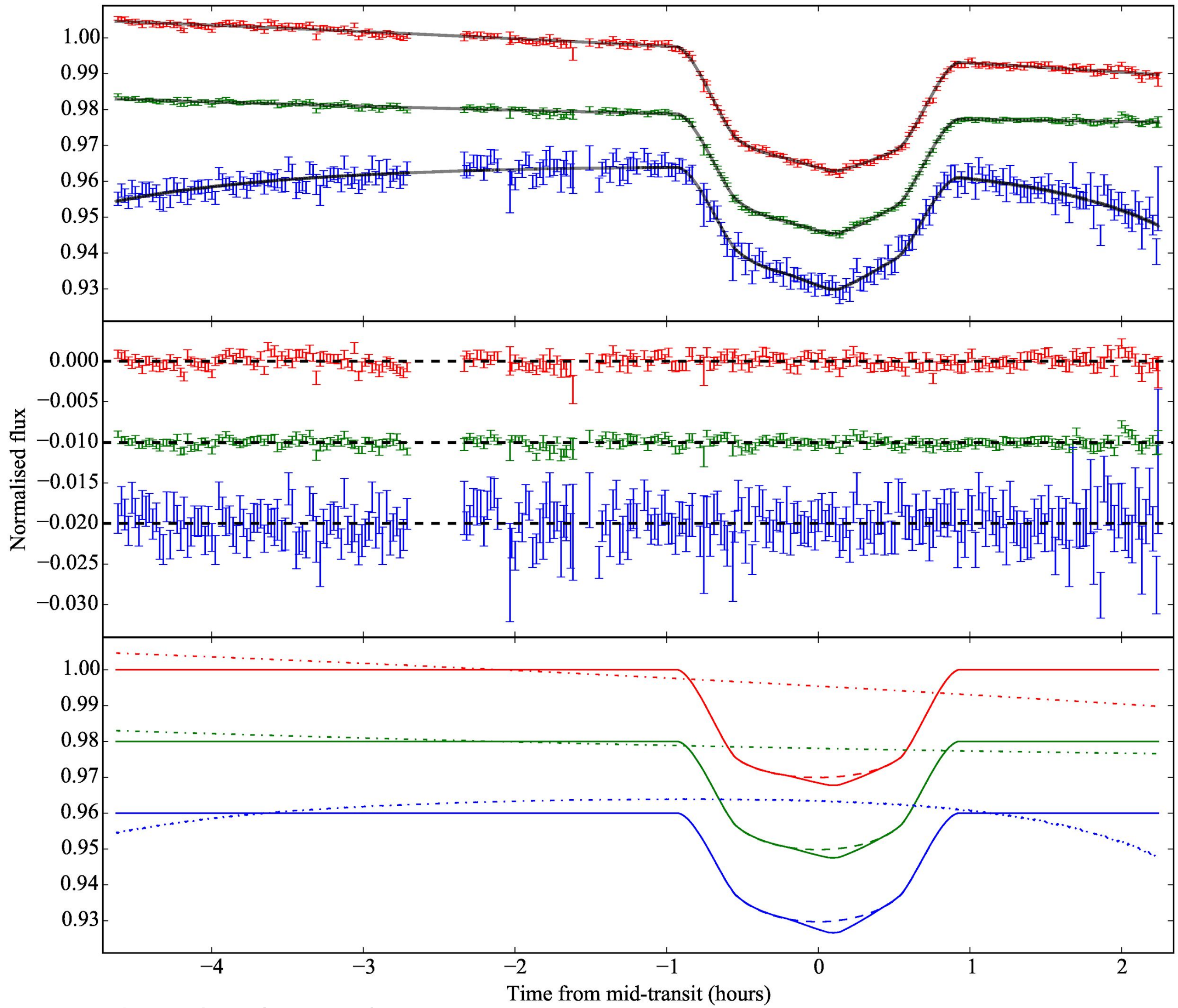
Kirk et al. submitted

Noise in the residuals



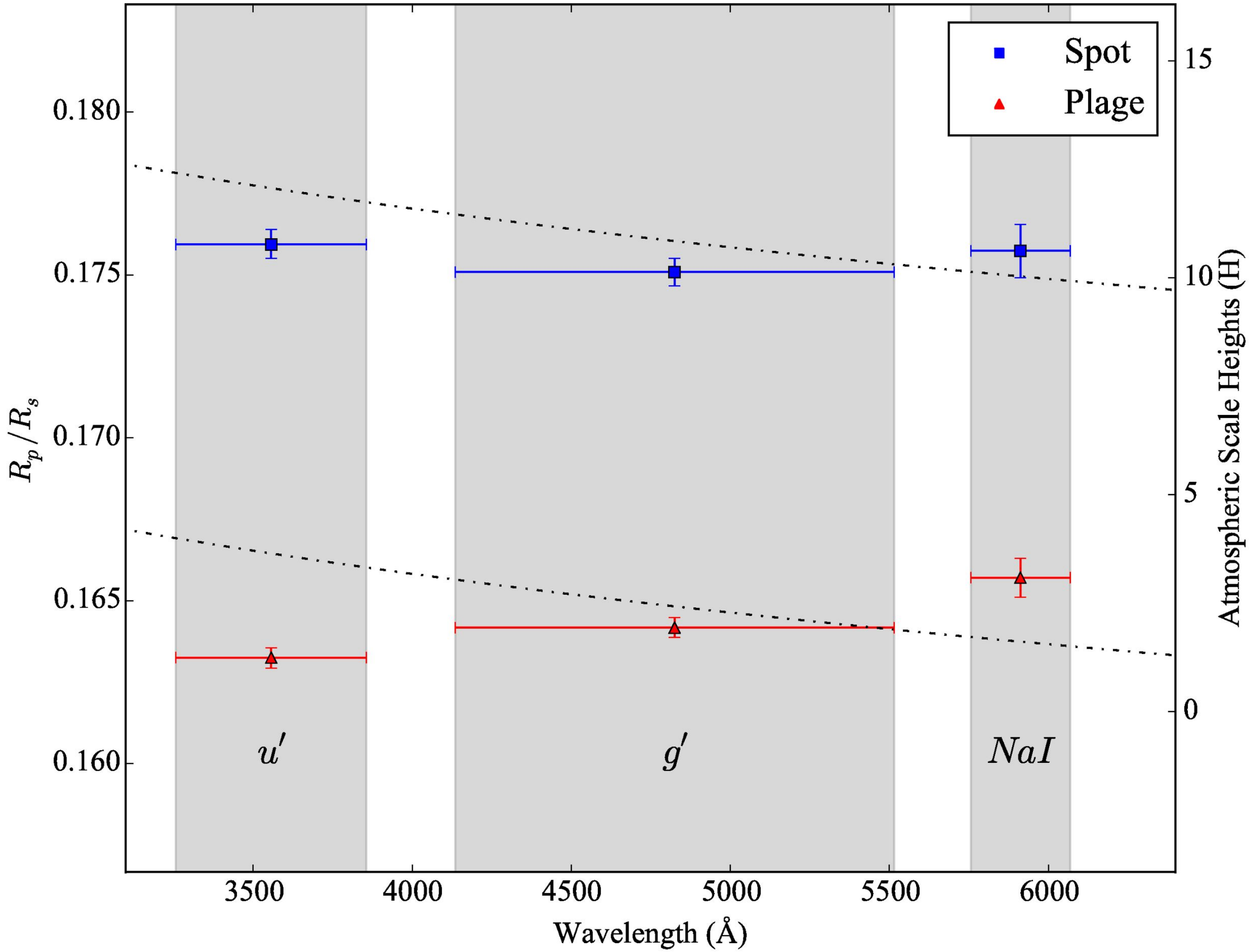
Kirk et al. submitted

Plage modelling



Kirk et al. submitted

Transmission spectrum



Kirk et al. submitted

Derived system parameters

Table 2. Comparison between derived system parameters from this work with WASP-52b's discovery paper (Hébrard et al. 2013).

Parameter (units)	Symbol	This work (Spots)	This work (Plage)	Hébrard et al. (2013)
Orbital period (days)	P	—	—	1.7497798 ± 0.0000012
Semi major axis (AU)	a	—	—	0.0272 ± 0.0003
Transit epoch (HJD-2450000.0) (days)^a	T_0	6178.62742 ± 0.00005	6178.62740 ± 0.00004	5793.68143 ± 0.00009
Scaled stellar radius ^{a}	R_*/a	0.1431 ± 0.0009	0.1383 ± 0.0008	0.1355 ± 0.0020
Impact parameter (R_*) ^{a}	b	$0.656\ ^{+0.006}_{-0.007}$	$0.593^{+0.008}_{-0.009}$	0.60 ± 0.02
Orbital inclination ($^\circ$) ^{a}	i_p	84.62 ± 0.07	85.30 ± 0.08	85.35 ± 0.20
Transit duration (days)^b	t_T	0.0777 ± 0.0006	0.0772 ± 0.0006	0.0754 ± 0.0005
Planet/star area ratio ^{b}	$(R_p/R_*)^2$	0.0306 ± 0.0005	0.0270 ± 0.0002	0.0271 ± 0.0004
Stellar density ($\rho_\odot$)^b	ρ_*	1.50 ± 0.03	1.66 ± 0.03	1.76 ± 0.08
Stellar mass ($M_\odot$) ^{b}	M_*	0.75 ± 0.01	0.698 ± 0.008	0.87 ± 0.03
Stellar radius ($R_\odot$) ^{b}	R_*	0.795 ± 0.009	0.750 ± 0.007	0.79 ± 0.02
Planet radius (R_J) ^{b}	R_p	1.35 ± 0.02	1.20 ± 0.01	1.27 ± 0.03
Planet surface gravity (cgs)	$\log g_p$	2.75 ± 0.02	2.83 ± 0.02	2.81 ± 0.03
Planet density (ρ_J)	ρ_p	0.157 ± 0.008	0.215 ± 0.009	0.22 ± 0.02
Planet mass (M_J)	M_p	0.39 ± 0.01	0.37 ± 0.01	0.46 ± 0.02
Stellar surface gravity (cgs) ^{b}	$\log g_*$	4.513 ± 0.004	4.532 ± 0.003	4.582 ± 0.014
Stellar reflex velocity (km s^{-1})	K_1	—	—	0.0843 ± 0.0030
Orbital eccentricity	e	—	—	0 (fixed)
Planetary equilibrium temperature (K)	T_P	—	—	1315 ± 35

^{a} fitted parameter.
^{b} derived from the transit light curve alone.

Kirk et al. submitted

Future - NGTS

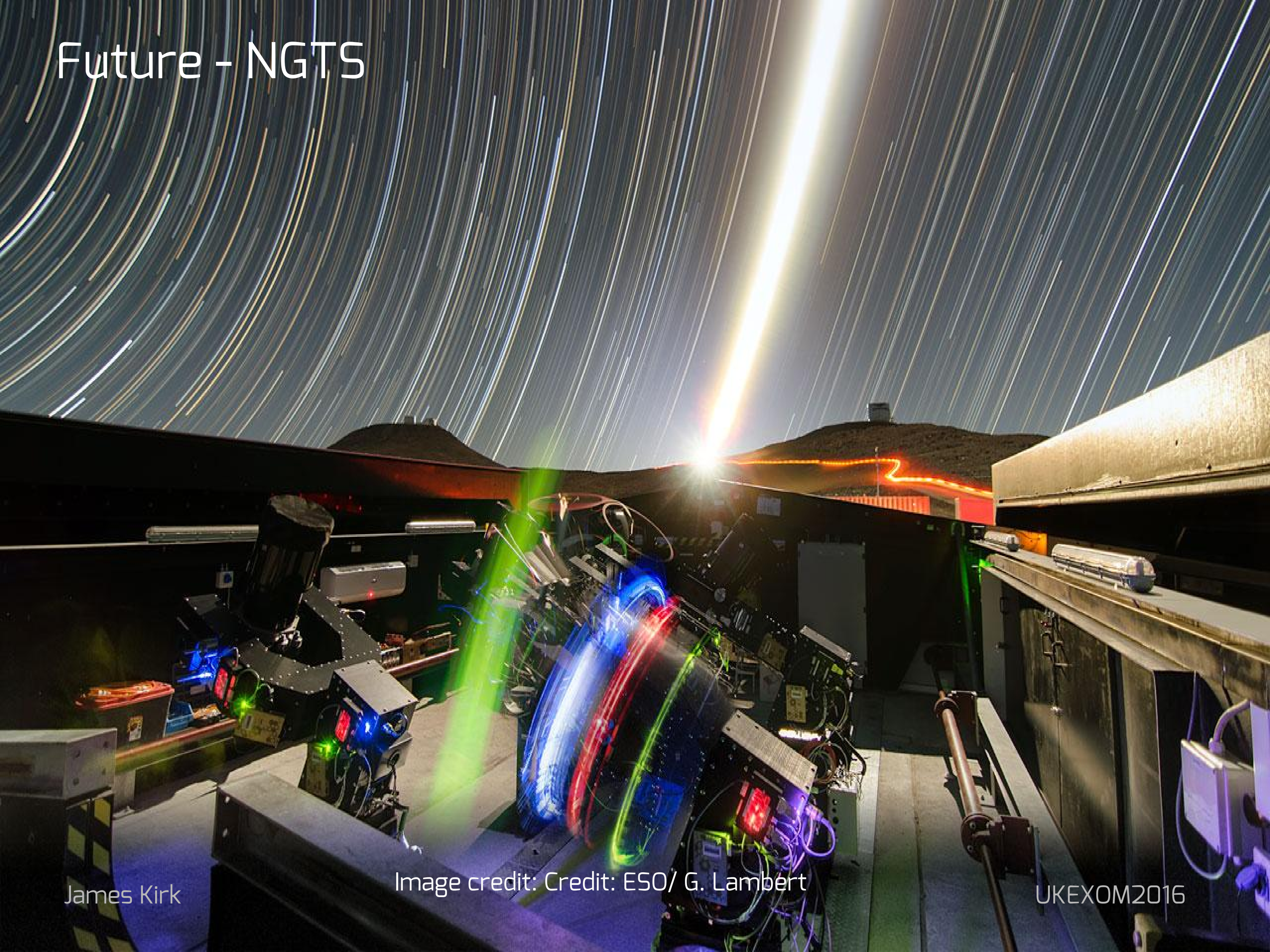


Image credit: Credit: ESO/ G. Lambert

Summary

- Ground-based broadband transmission spectroscopy can provide high precision transmission spectra
- WASP-52b has been found to have an atmosphere inconsistent with Rayleigh scattering or clear atmosphere models
- The effects of occulted regions of stellar activity, including plages, can lead to significant differences in the derived transit parameters
- Future surveys, such as NGTS, will provide further exceptional candidates for ground-based characterisation extending down towards Neptune size planets

Image credit: Starfleet Command