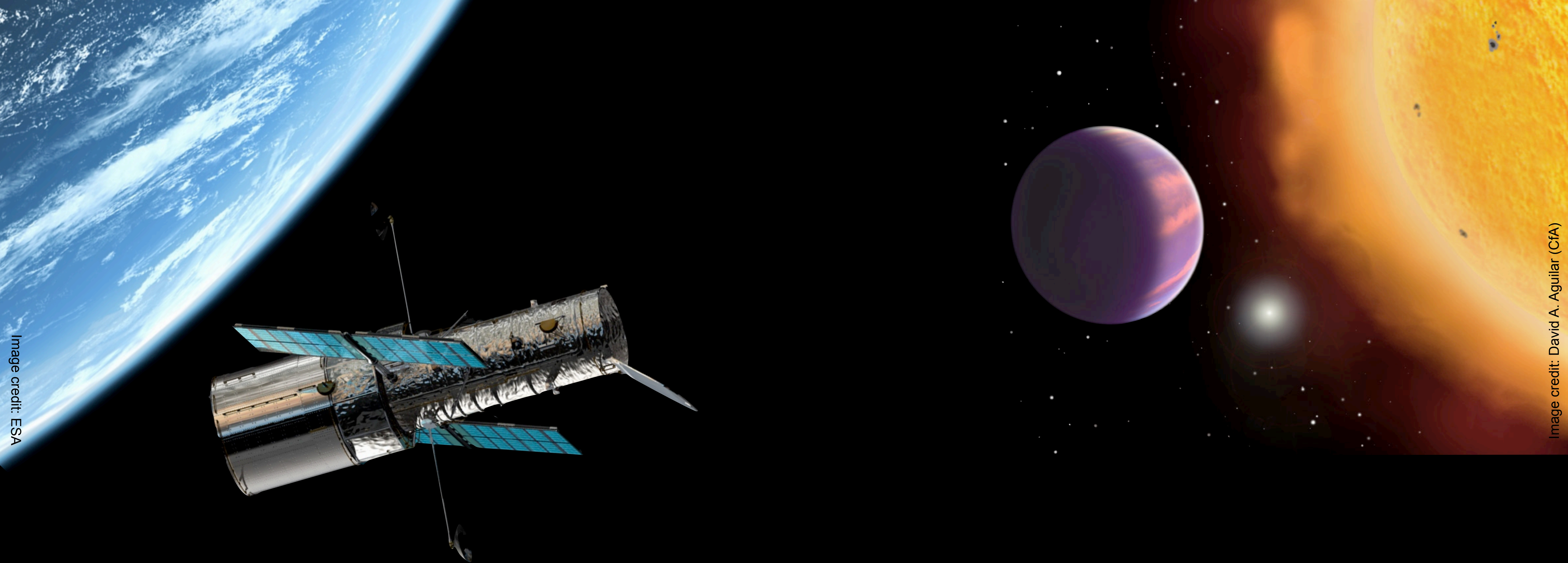

HST Transmission Spectral Survey: observations, analysis and results

Nikolay Nikolov
and the *HST* Team

UNIVERSITY OF EXETER
erc European Research Council
Established by the European Commission
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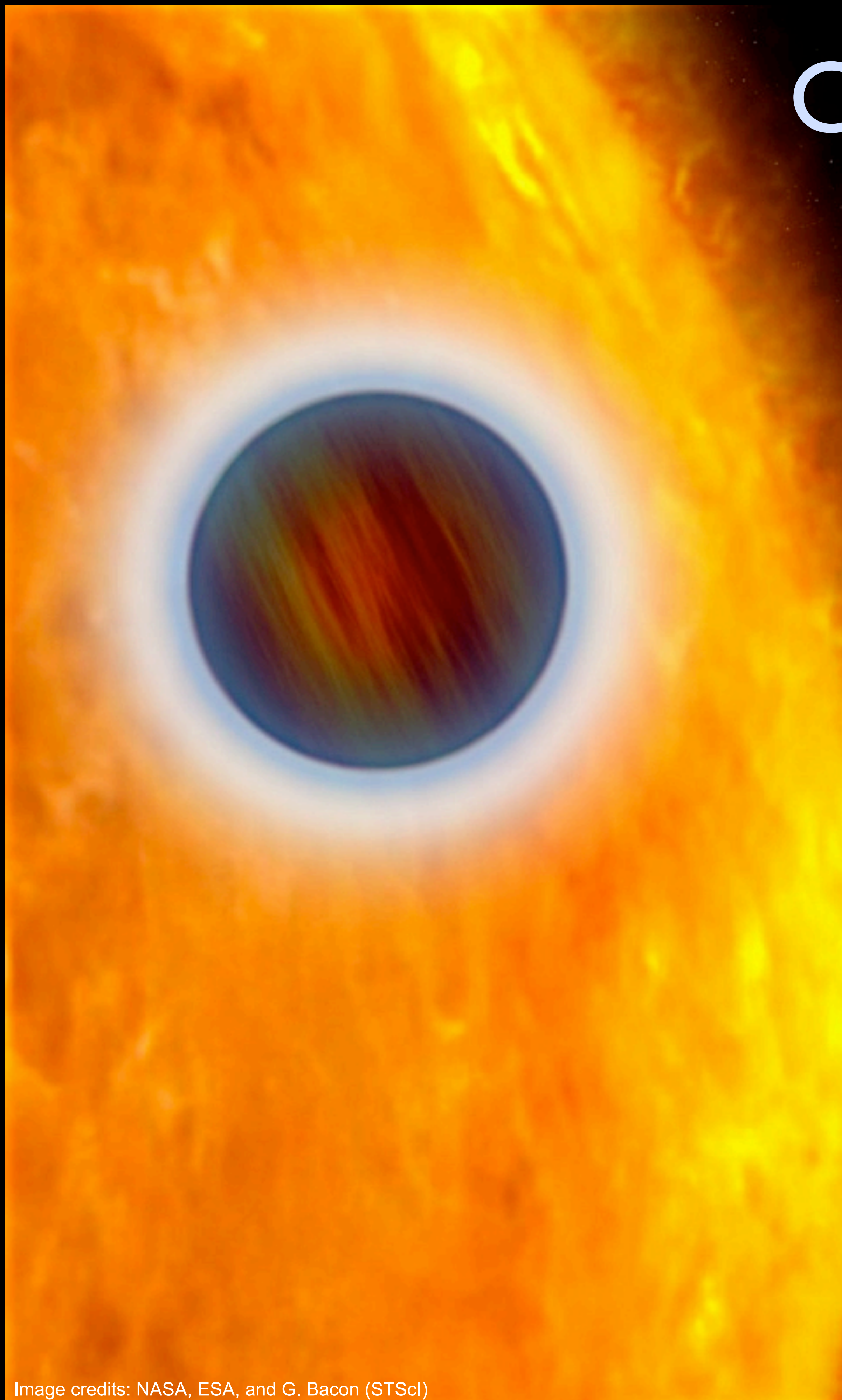
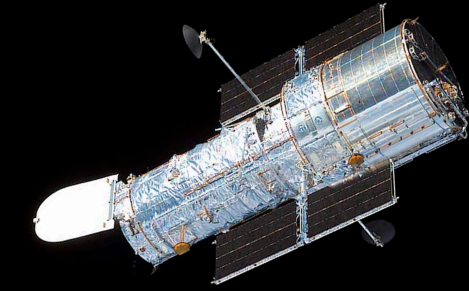


Image credits: NASA, ESA, and G. Bacon (STScI)

Collaborators:



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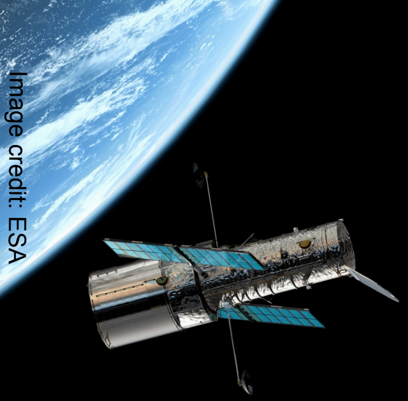
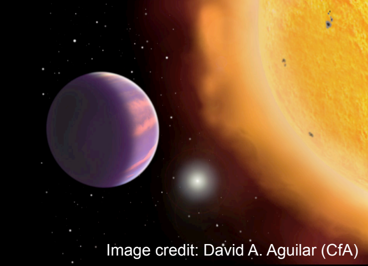


Large *HST* program (126 orbits, PI D.K. Sing) for 8 planets with T_{eq} = 1000-3000 K



STIS: optical G430L & G750L (0.3-1 µm)
WFC3: near-IR G141
Spitzer/IRAC 3.6 µm and 4.5 µm

Published results for:
WASP-19b, WASP-12b,
HAT-P-1b, WASP-31b, WASP-6b;
two more in preparation;

Aims: *(i) compare atmospheric properties;*
(ii) detect strong absorbers (e.g. Na, K, TiO, hazes, clouds, etc.);
(iii) probe atmospheric diversities.

Table 1. Hot-Jupiter Target List (T_{eff} is estimated equilibrium temperature)

	Target	Period (days)	R_{planet} (Jup)	M_{planet} (Jup)	T_{eff} (K)	g (m/s²)	Irradiation (ergs/s/cm²)	V_{mag}	H (km)
	Hat-P-12b	3.21	0.96	0.21	1080	5.7	2.2E+08	12.8	680
Nikolov et al. 2015	Wasp-6b	3.36	1.22	0.50	1340	8.3	5.2E+08	11.9	580
	Wasp-39b	4.05	1.27	0.28	1360	4.3	5.00E+08	12.1	1140
Wakeford et al. 2013, Nikolov et al. 2014	Hat-P-1b	4.46	1.20	0.53	1500	9.1	7.3E+08	10.4	580
Sing et al. 2015	Wasp-31b	3.4	1.54	0.48	1800	5.02	1.50E+09	11.7	1280
Ballester et al. in prep.	Wasp-17b	3.74	1.74	0.49	1860	4.0	1.9E+09	11.6	1670
Huitson et al. 2013	Wasp-19b	2.15	1.15	1.31	2319	16.6	4.10E+09	12.3	501
Sing et al. 2013	Wasp-12b	1.09	1.79	1.41	2800	11.0	1.0E+10	11.69	930

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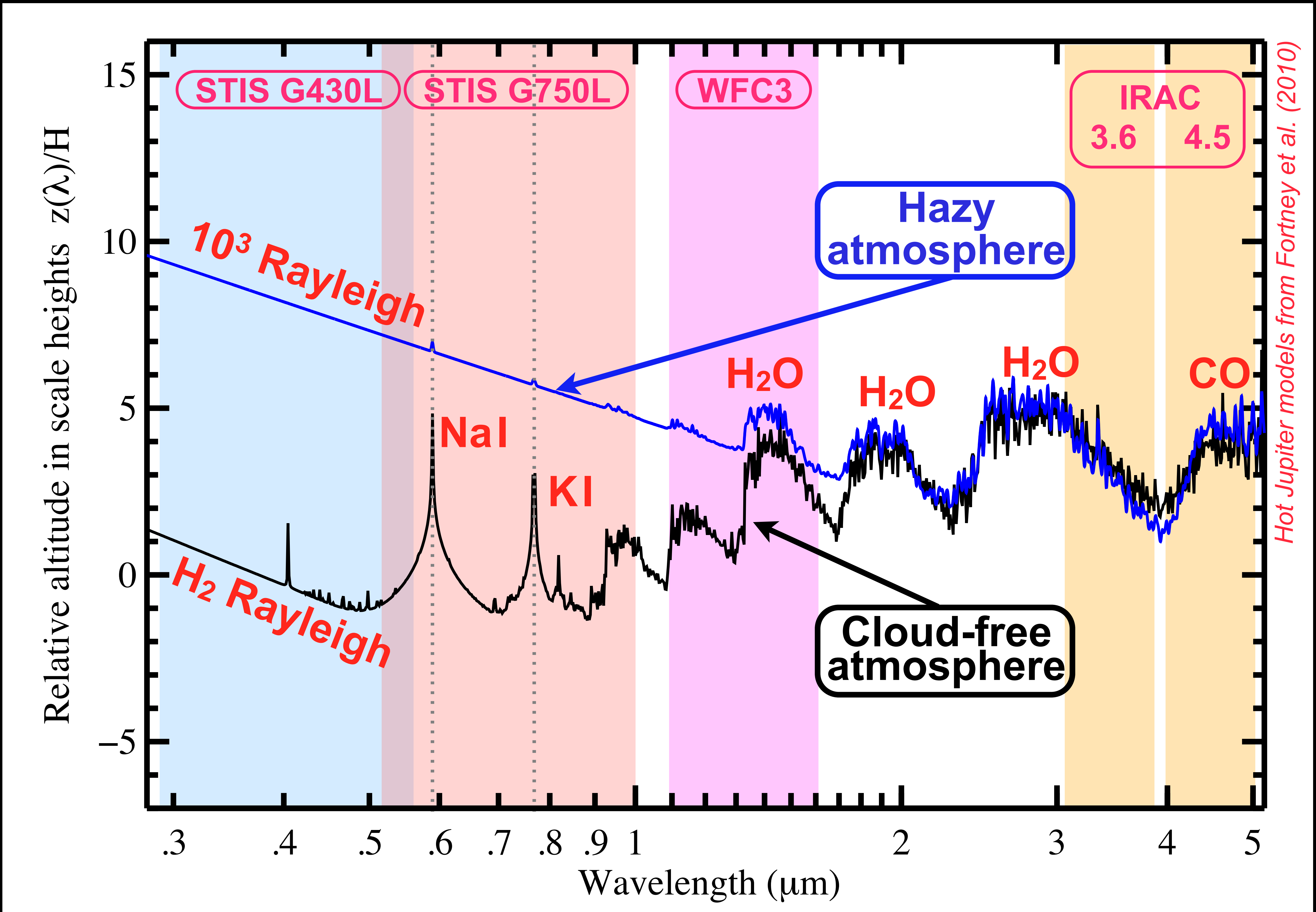
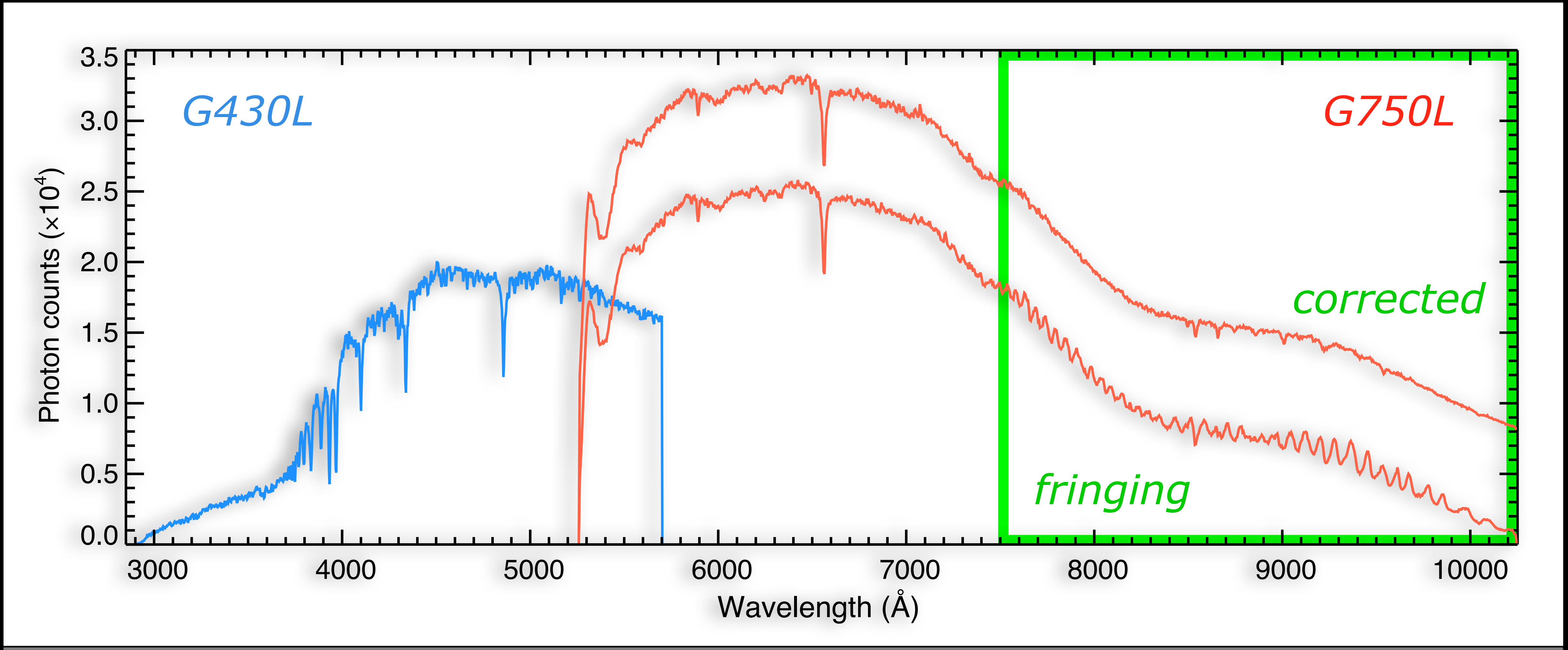


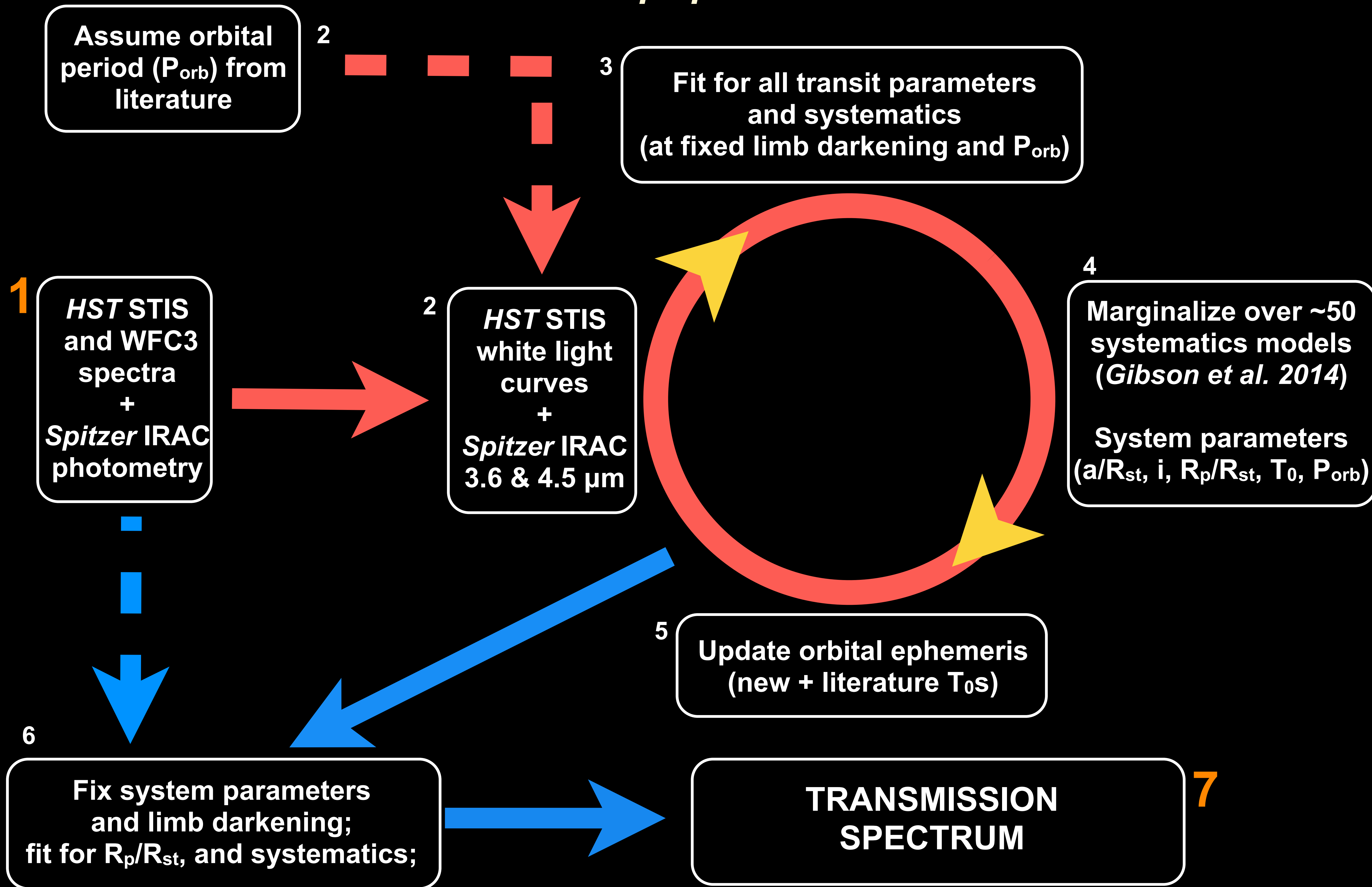
STIS G430L
STIS G750L
WFC3
IRAC
3.6
4.5
Hazy atmosphere
10³ Rayleigh
H₂ Rayleigh
NaI
KI
H₂O
H₂O
H₂O
CO
Cloud-free atmosphere
Relative altitude in scale heights z(λ)/H
Wavelength (μm)
Hot Jupiter models from Fortney et al. (2010)

HST STIS



G430L
G750L
corrected
fringing
Photon counts (×10⁴)
Wavelength (Å)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
3000
4000
5000
6000
7000
8000
9000
10000

Our pipeline



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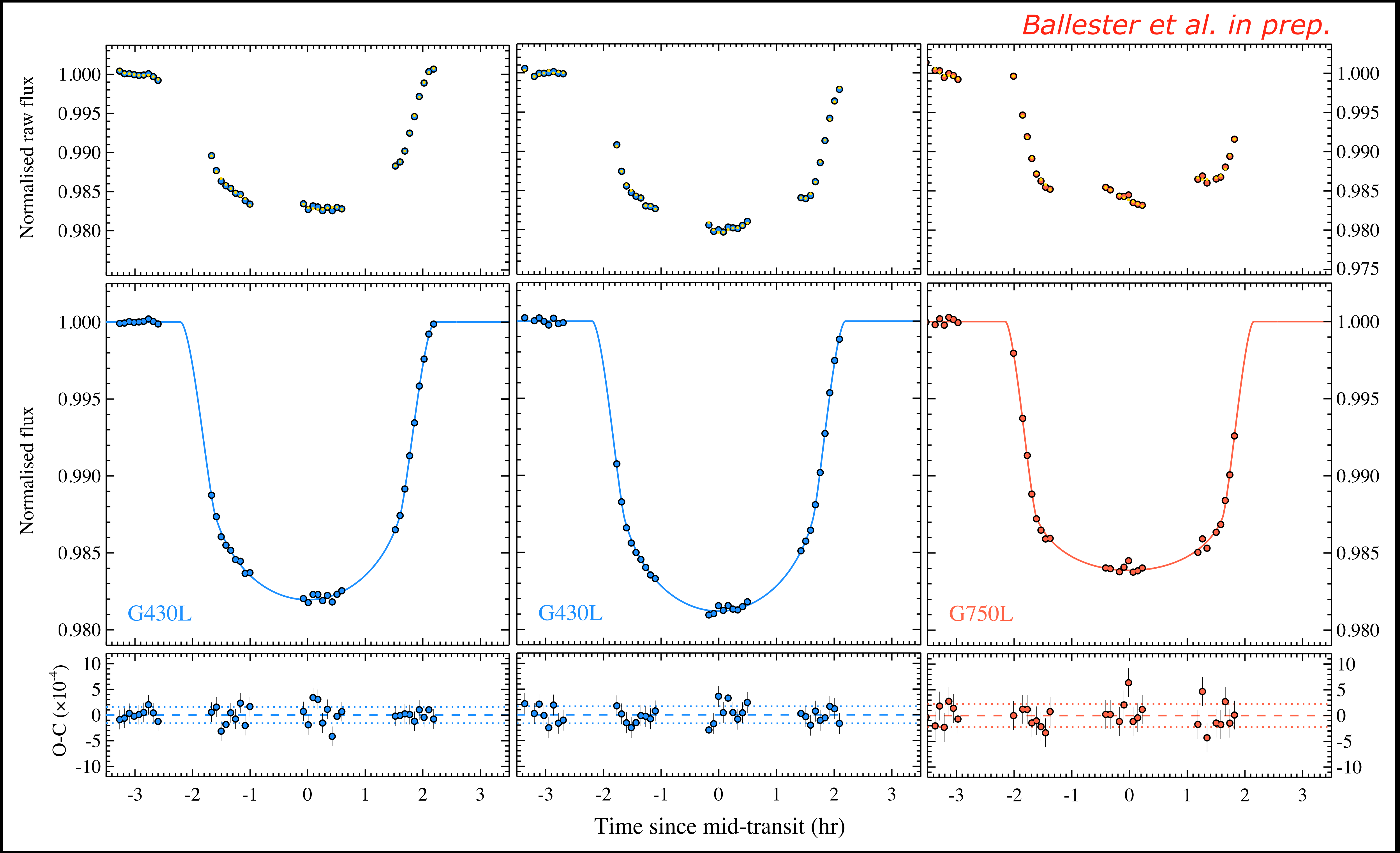
HST STIS



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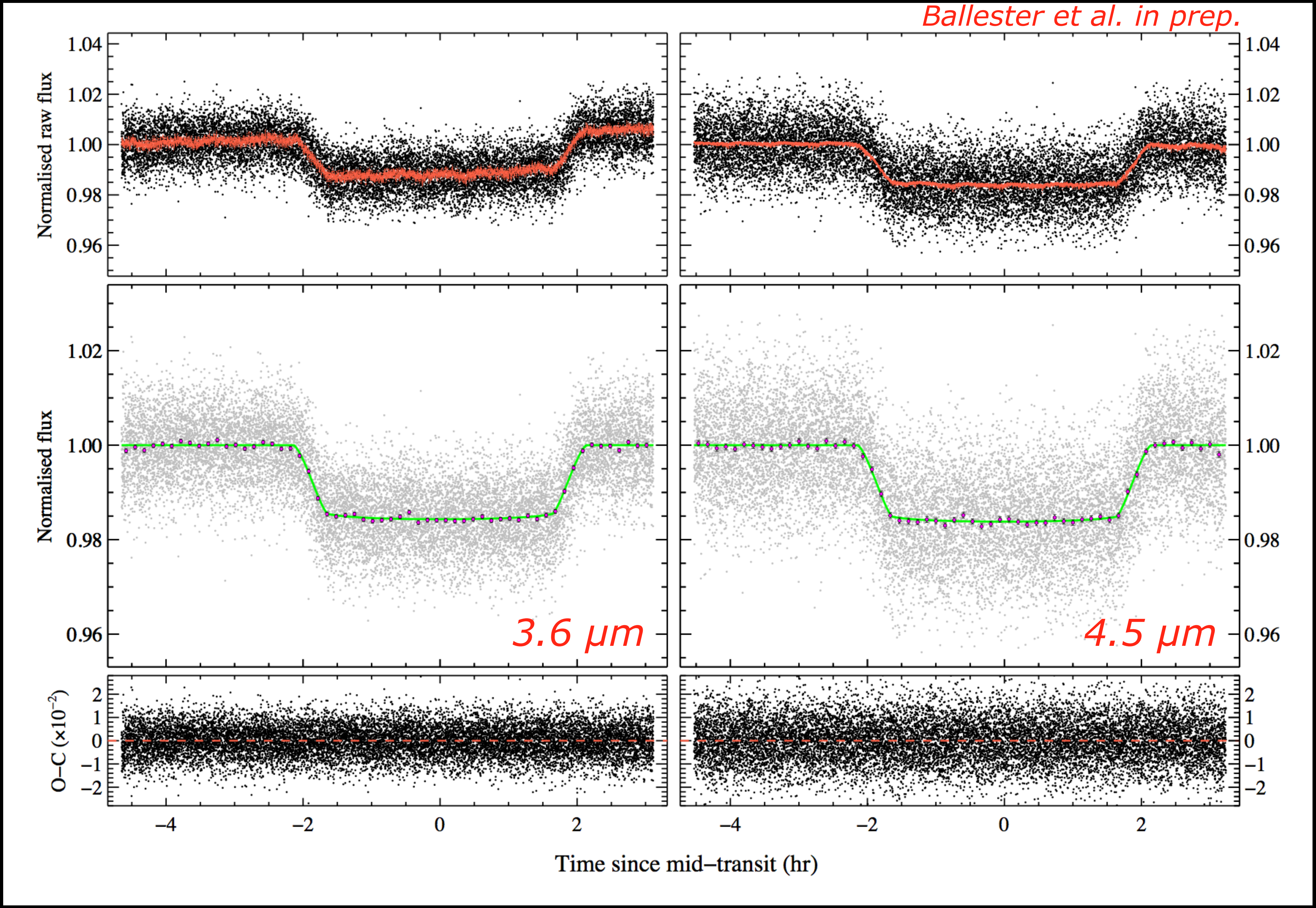
Spitzer IRAC



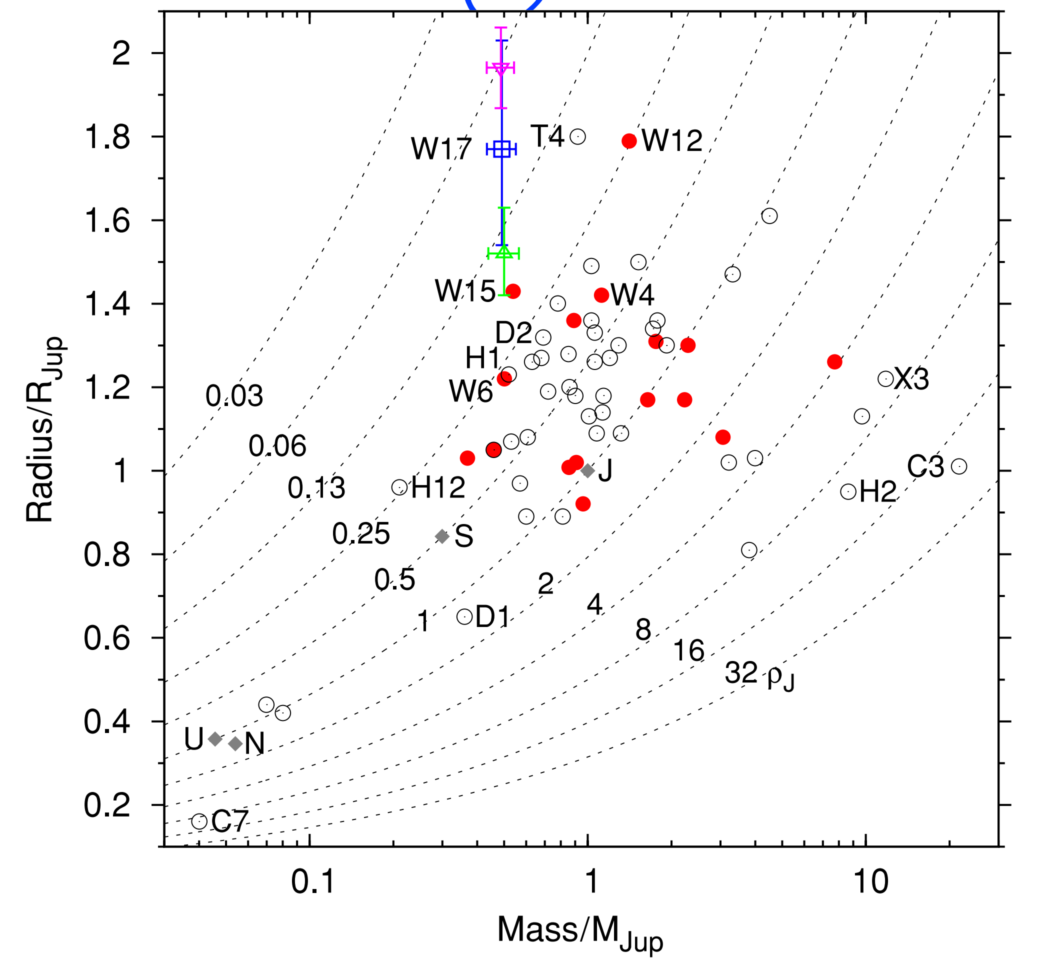
Three facts for WASP-17b

Orbital Period ~ 3.7 d
Mp ~ 1.6 M_{Saturn}, Rp ~ 2 $R_{Jupiter}$
~ 6 % Jupiter density

T(4.5 μm) = 1880+/-50 K
T(8 μm) = 1580+/-150 K
low albedo; efficient T redistrib.

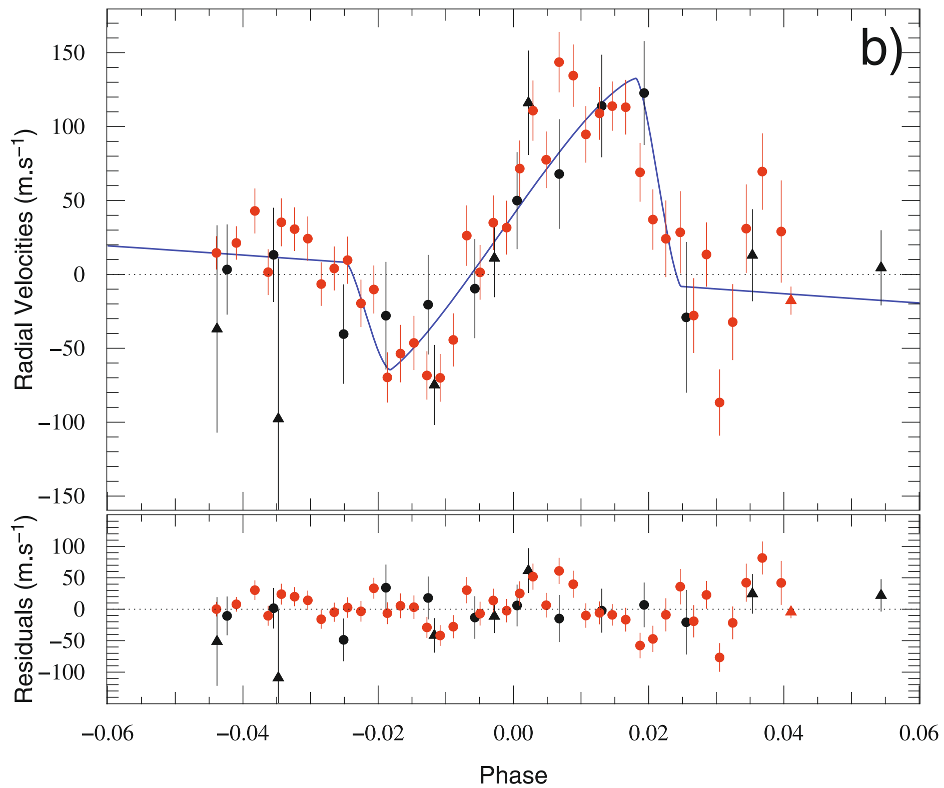
Parent star:
Sp type: F6, V = 11.6

(1) Bloated radius



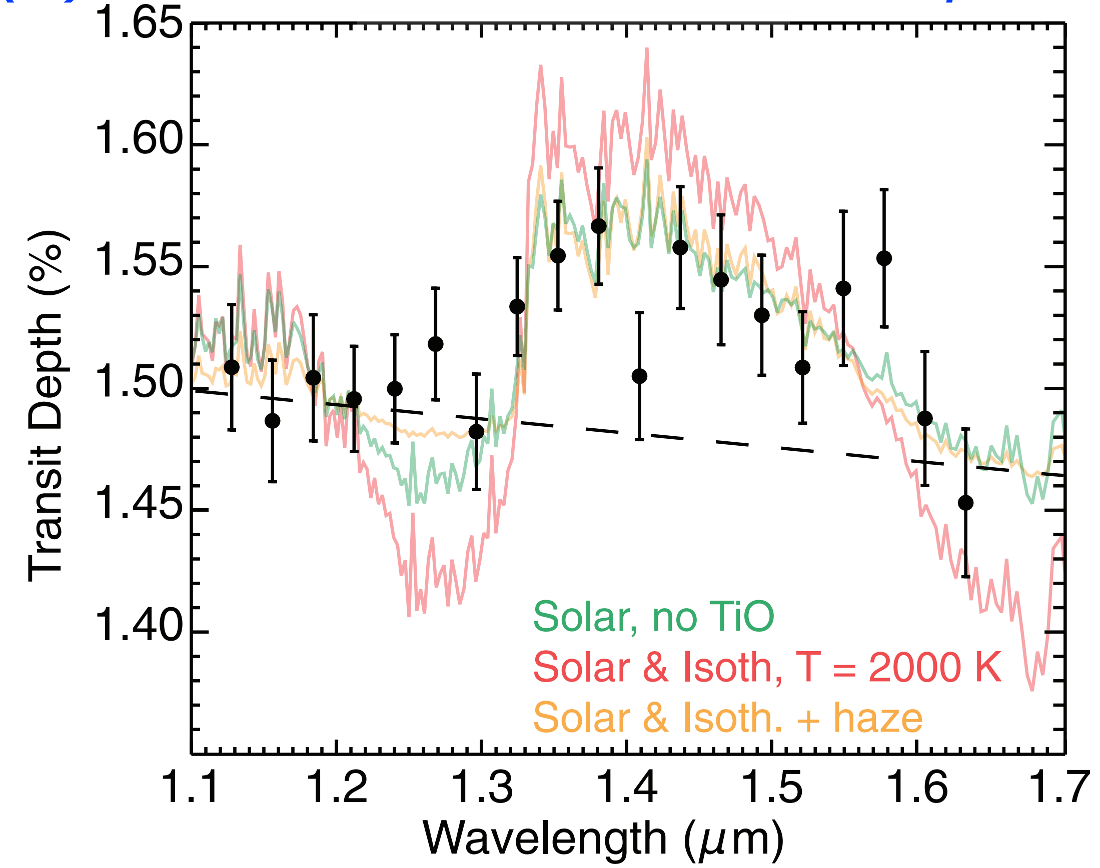
Anderson et al. 2010, 11

(2) Retrograde orbit



Triaud et al. 2010
Bayliss et al. al. 2010

(3) NaI and H_2O in the atmosphere

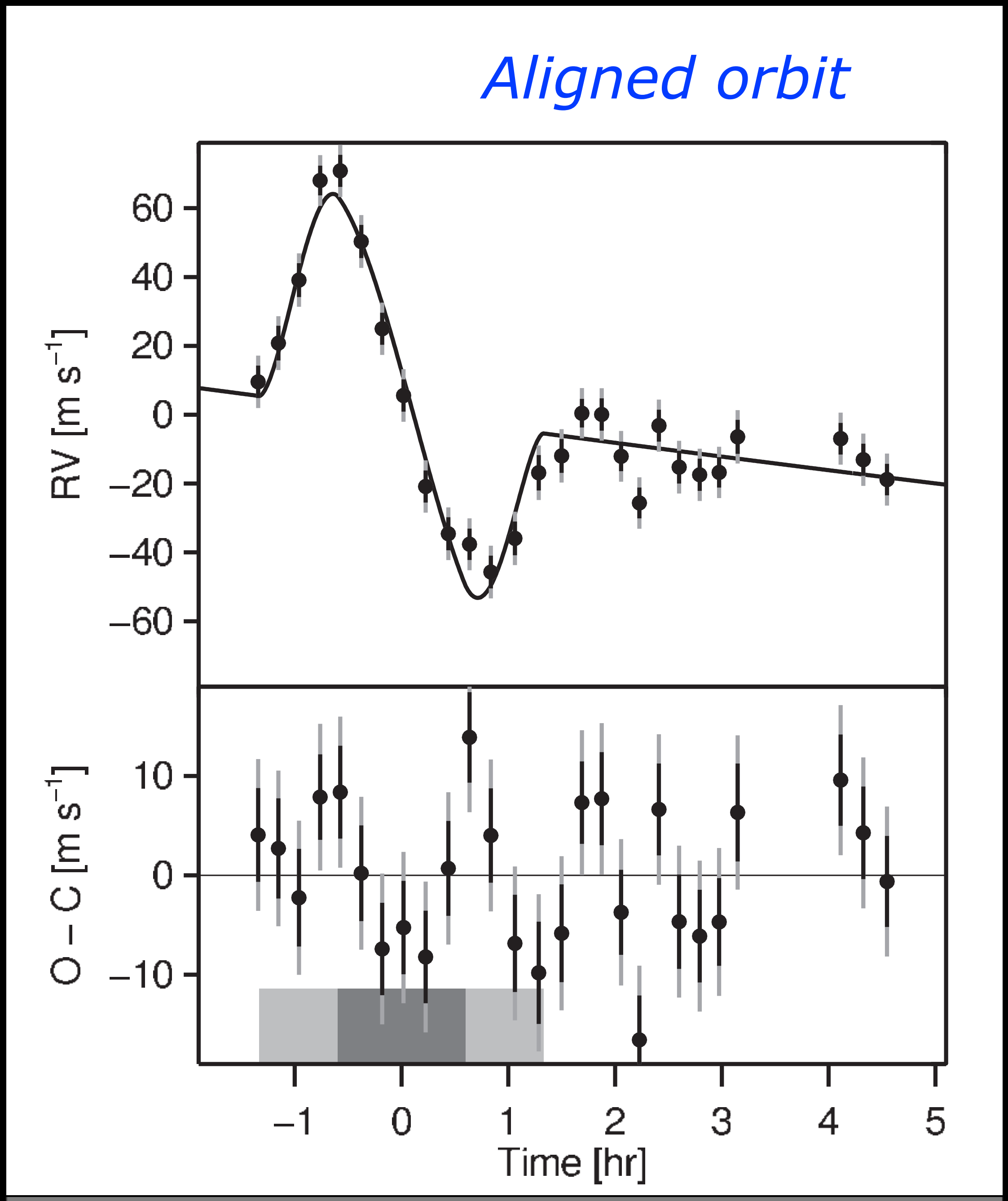


Wood et al. 2011, Zhou et al. 2012
Mandel et al. 2013

WASP-17b

Ballester et al. in prep.

Quick facts for WASP-31b



Anderson et al. 2010

Orbital Period ~ 3.4 d

Mp ~ 0.5 $M_{Jupiter}$

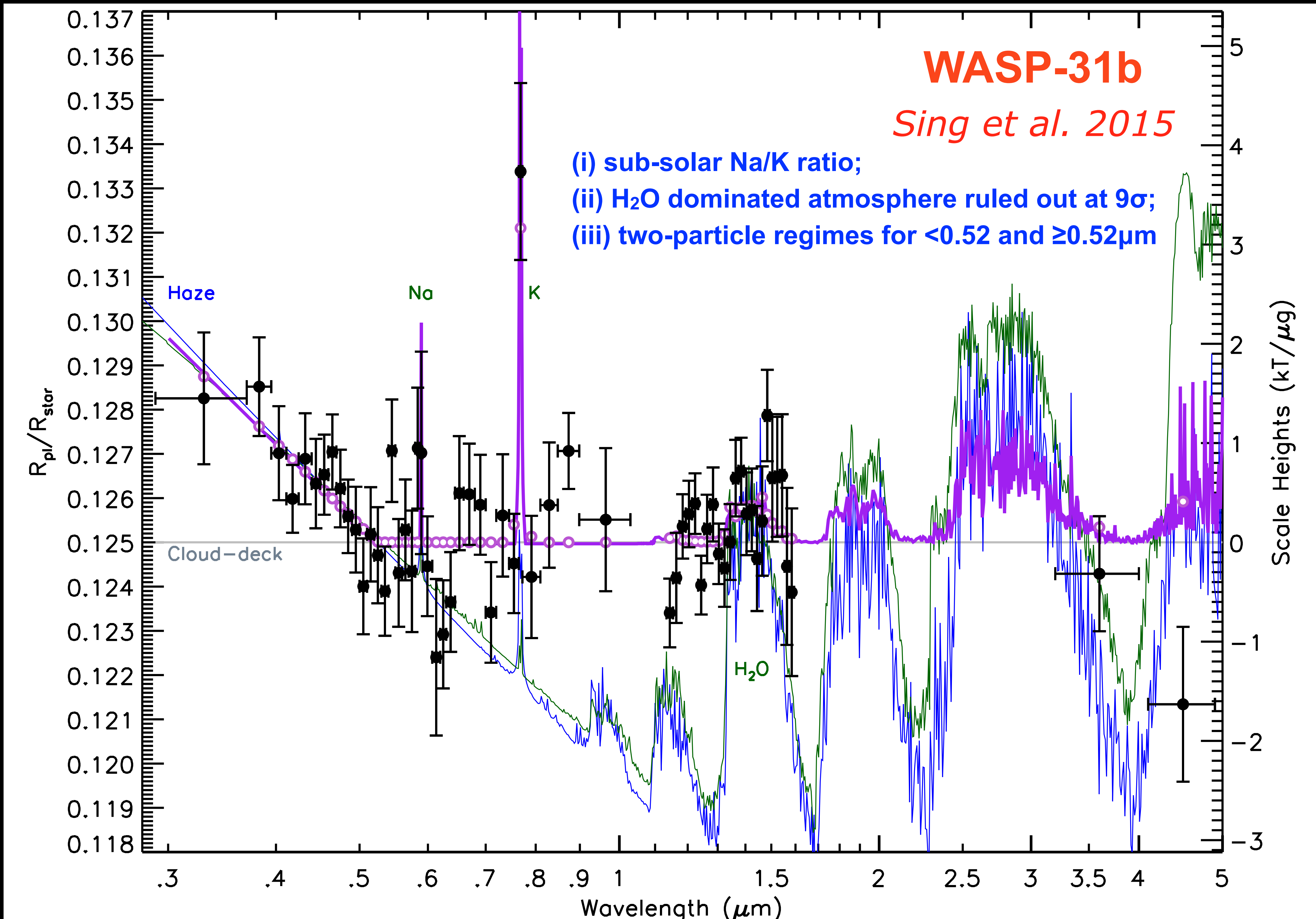
Rp = 1.5 $R_{Jupiter}$

13 % Jupiter density

T_{eq} = 1600 K, H~1200 km

Parent star

Sp type: F6, V = 11.7



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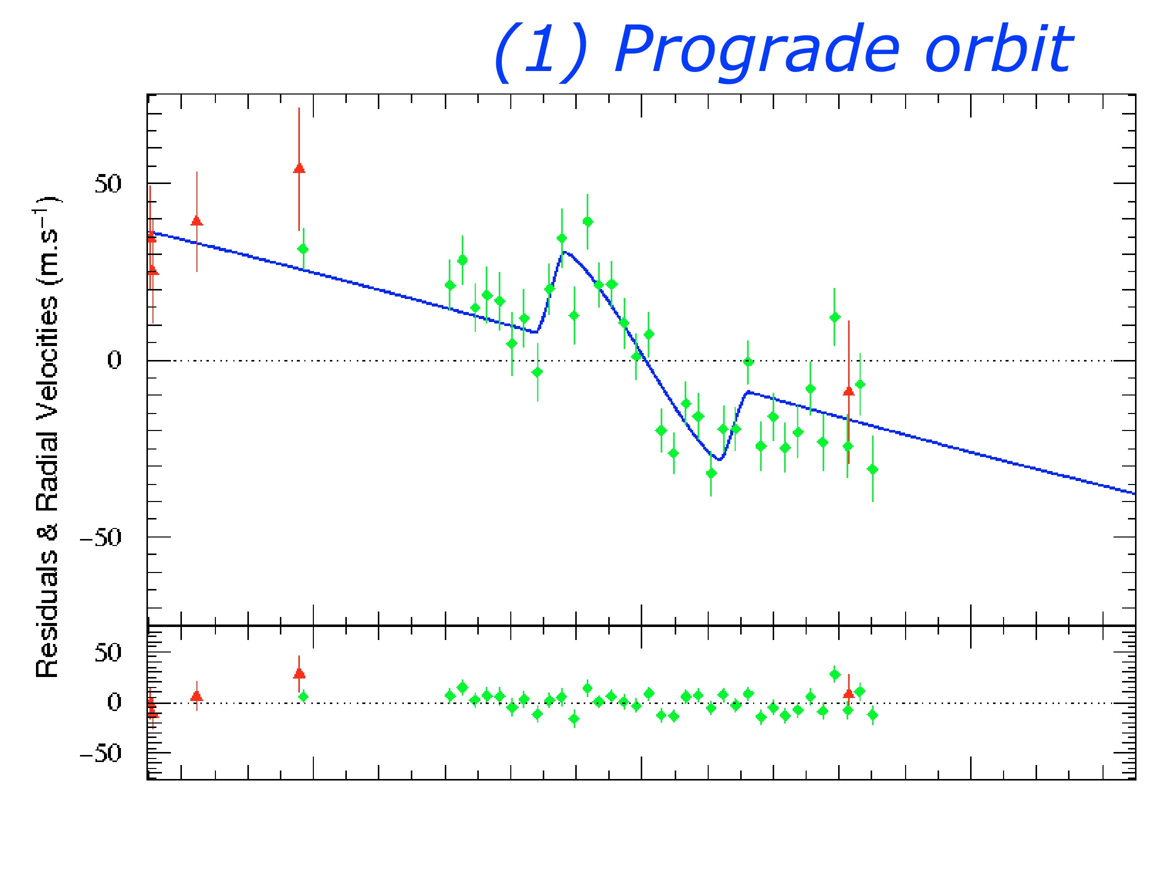
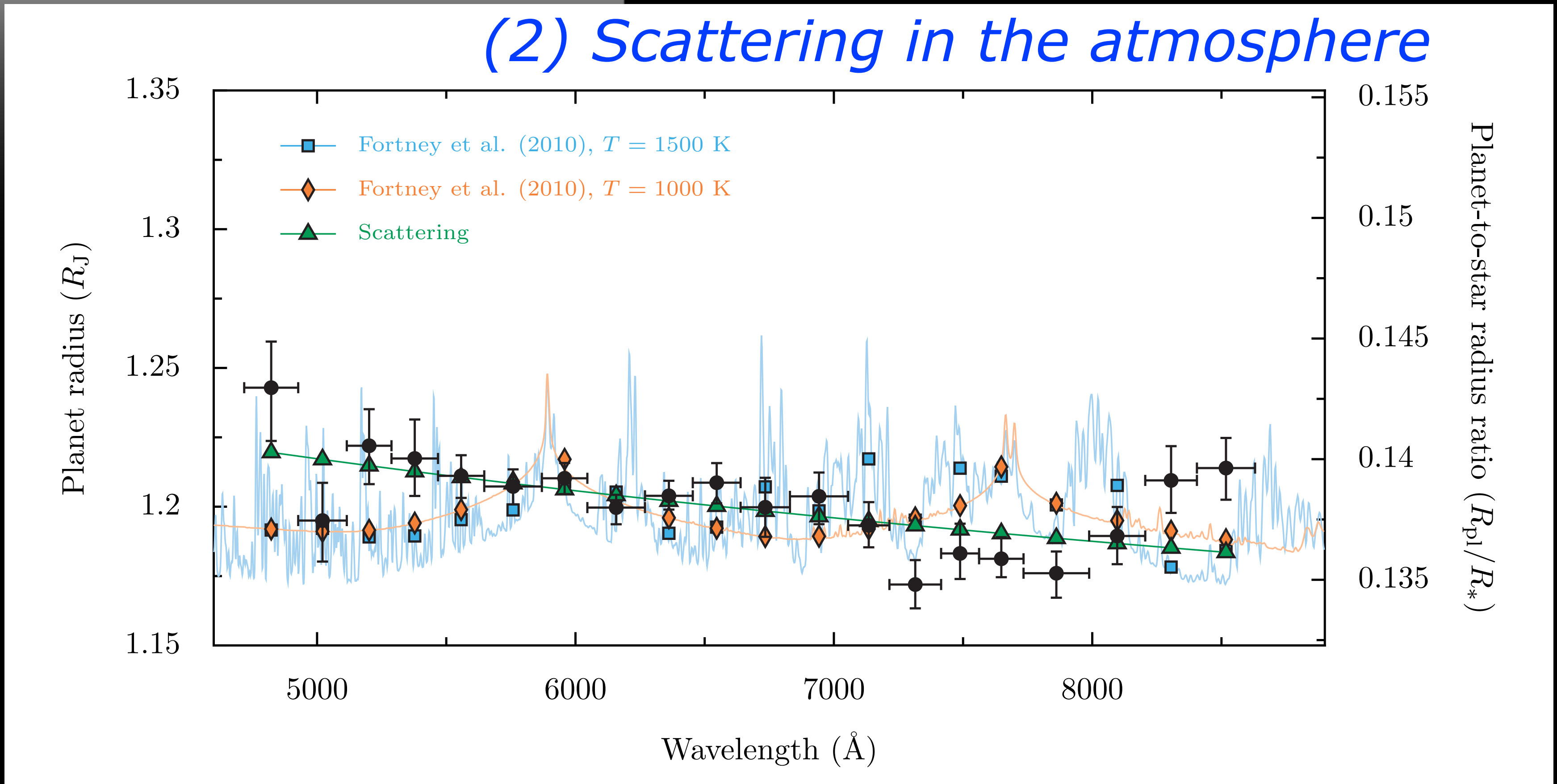
Two facts for WASP-6b

Orbital Period ~ 3.4 d
Mp ~ 0.5 $M_{Jupiter}$
Rp ~ 1.2 $R_{Jupiter}$
T_{eq} = 1145 K

Parent star
Sp type: G8, [Fe/H]=-0.2
V = 11.9



Gillon et al. 2009



Jordan et al. 2013

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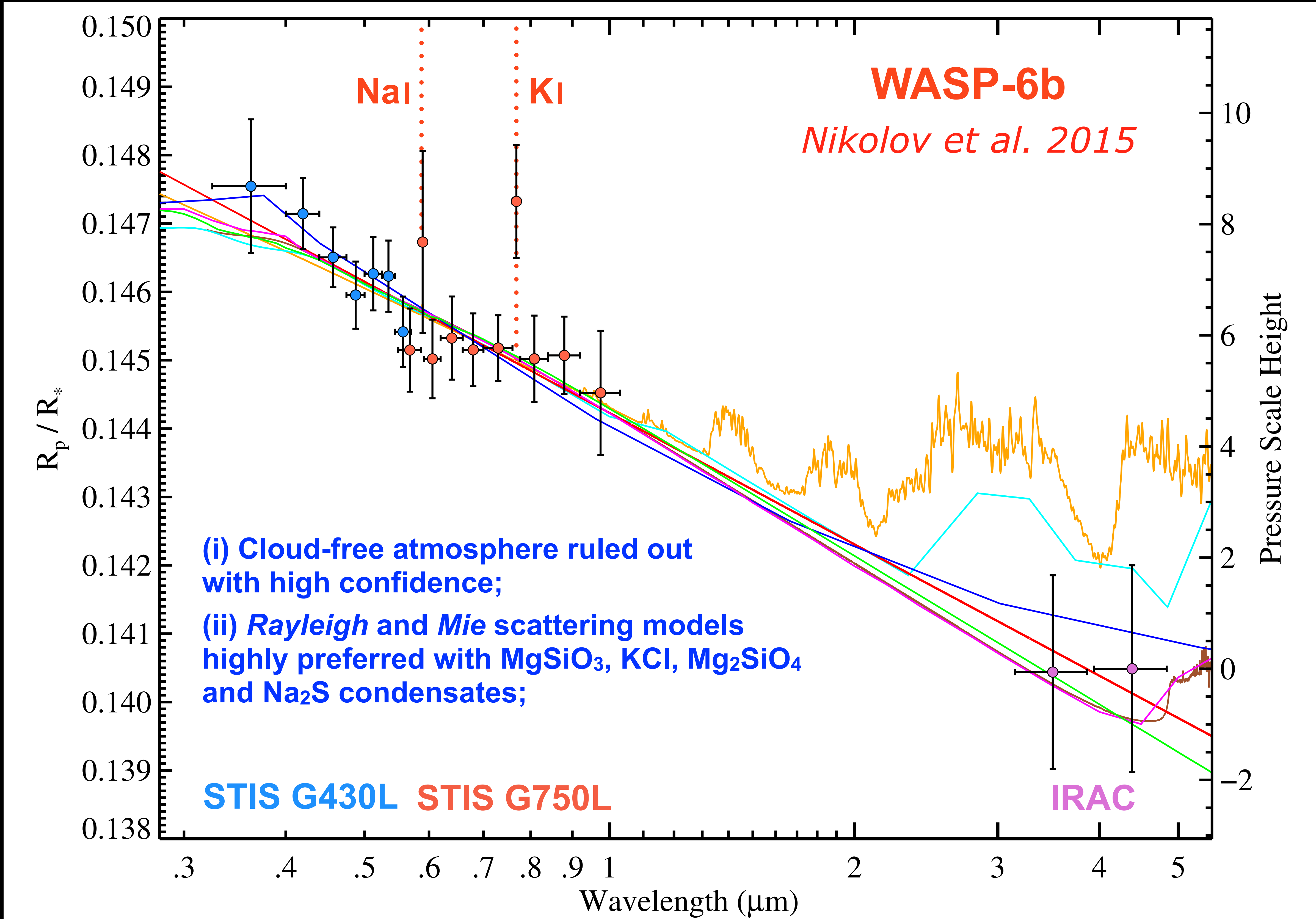
WASP-6b
Nikolov et al. 2015
NaI
KI
(i) Cloud-free atmosphere ruled out with high confidence;
(ii) Rayleigh and Mie scattering models highly preferred with MgSiO3, KCl, Mg2SiO4 and Na2S condensates;
STIS G430L
STIS G750L
IRAC
Rp / R*
Pressure Scale Height
Wavelength (μm)
0.150
0.149
0.148
0.147
0.146
0.145
0.144
0.143
0.142
0.141
0.140
0.139
0.138
10
8
6
4
2
0
−2
.3
.4
.5
.6
.7
.8
.9
1
2
3
4
5

WASP-6b

Nikolov et al. (2015)

H_2O H_2O H_2O CO

WASP-17b

Ballester et al. (in prep.)

Conclusions:

(1) WASP-17b, -31b and -6b show evidence for cloud-free, cloudy and hazy atmosphere, i.e. an emerging diversity of exoplanet atmospheres;

(2) We find a significant variation in both the Na and K frequency and the Na/K abundance ratio across the targets;

(3) Cloudy and hazy atmospheres can provide important atmospheric constraints, i.g. particle sizes, temperatures, etc.;

(4) More planets must be studied in transmission to establish correlations between atmospheric and planetary physical properties, e.g. atmospheric type and planet evolutionary history.