The Warm gIaNts with tEss collaboration

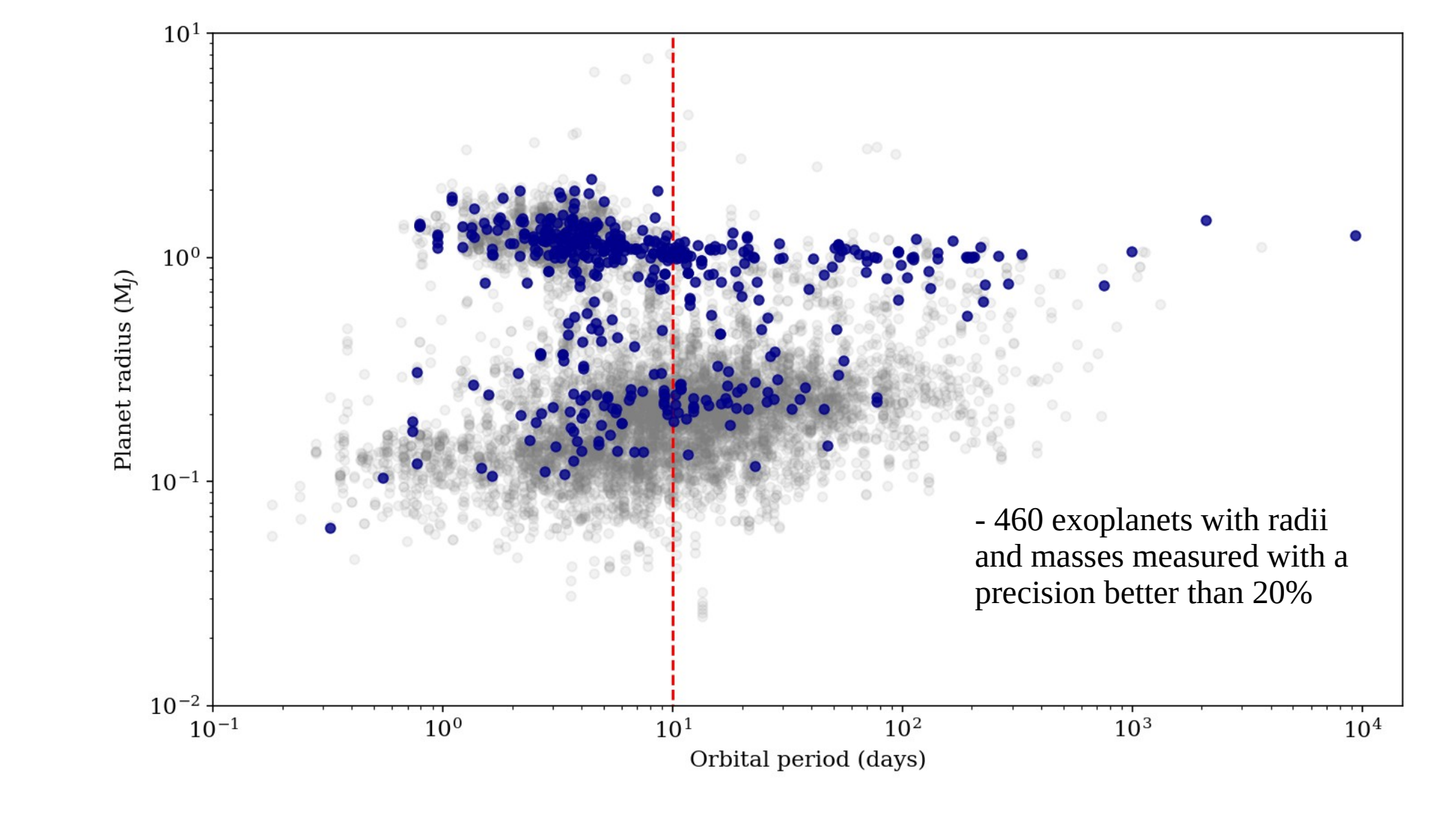
Marcelo Tala Pinto - UAI
on behalf of the WINE collaboration

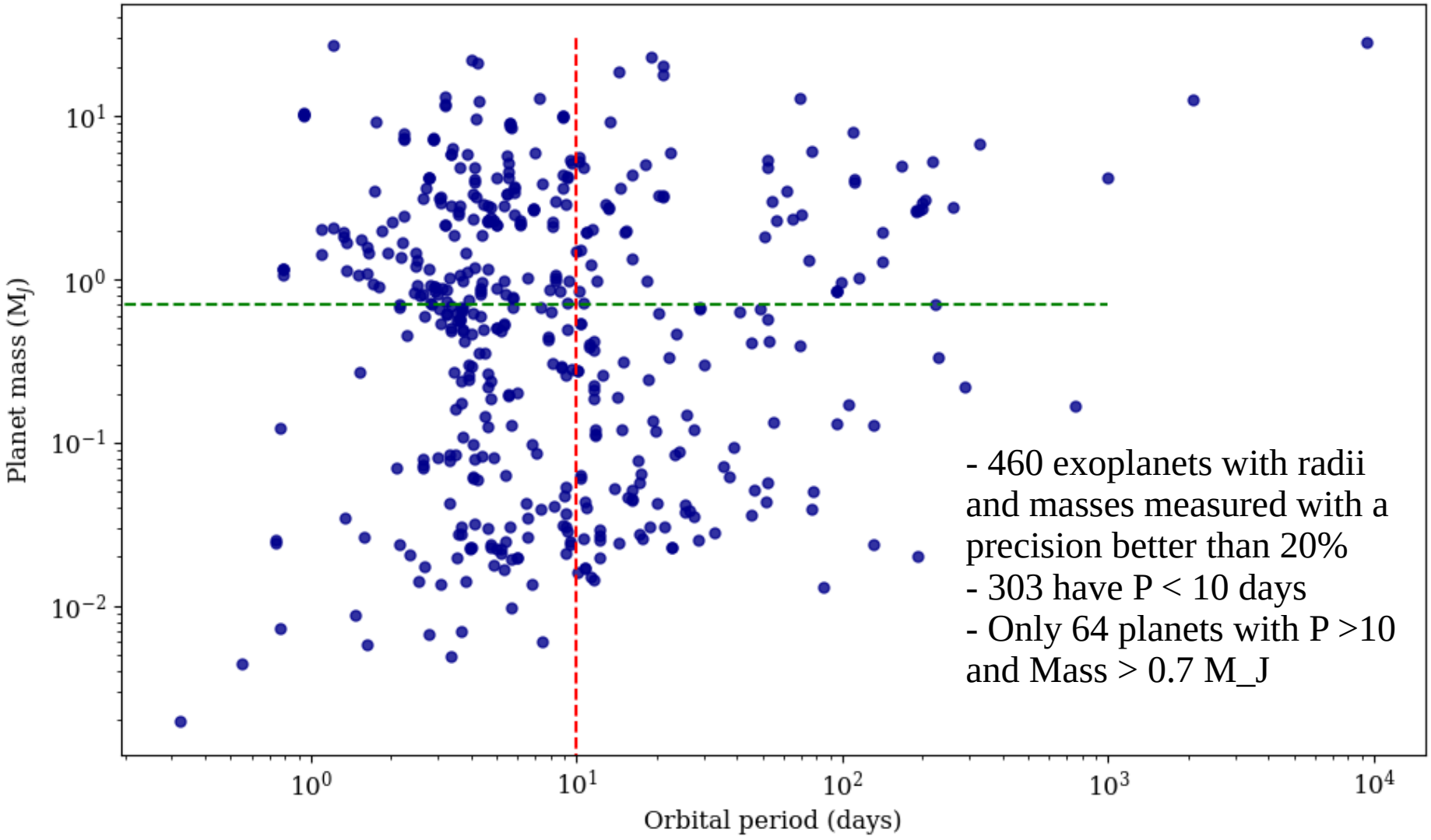
The WINE collaboration

- Hot Jupiters population suggest that they may have formed in places where core accretion or disk instabilities are more likely and then migrated inwards to their current locations
- Warm giants – planets with about P>10 d – are ideal labs to test formation and migration mechanisms
  → they are not so affected by their host-star
- **Main goal**: to provide observational constraints to planet formation and migration theories
- Members:

Rafael Brahm (PI, U. Adolfo Ibañez, Chile),
Andrés Jordán (U. Adolfo Ibañez, Chile),
Thomas Henning (MPIA, Germany),
Trifon Trifonov (MPIA/LSW, Germany),
Matías Jones (ESO, Chile),
Yared Reinarz (MPIA, Germany),
Lorena Acuña (MPIA, Germany)

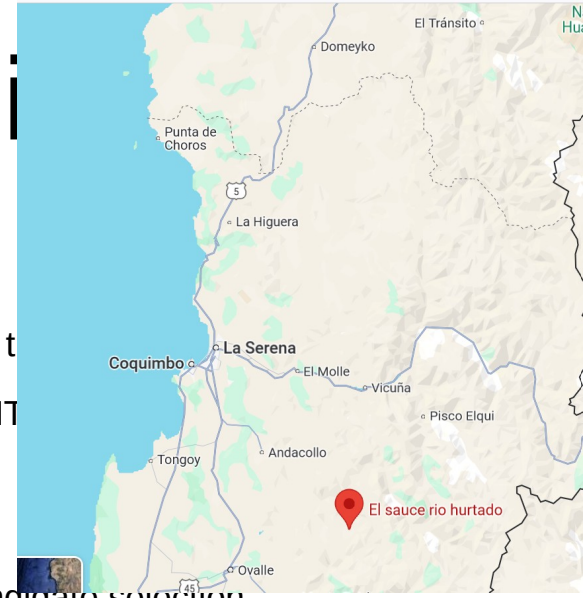
Jan Eberhardt (MPIA, Germany),
Nestor Espinoza (STSci, USA),
Diana Kossakowski (MPIA, Germany),
Martin Schleker (U. Arizona, USA),
Melissa Hobson (U. Geneva, Switzerland),
Michaela Vítková (Ondrejov Observatory, Czechia),
Felipe Rojas (PUC, Chile),
Marcelo Tala Pinto (U. Adolfo Ibañez, Chile)


Planet radius (M_J)
10^1
10^0
10^{-1}
10^{-2}
10^{-1}
10^0
10^1
10^2
10^3
10^4
Orbital period (days)
- 460 exoplanets with radii and masses measured with a precision better than 20%


Planet mass (M_J)
10^1
10^0
10^{-1}
10^{-2}
10^0
10^1
10^2
10^3
10^4
Orbital period (days)
- 460 exoplanets with radii and masses measured with a precision better than 20%
- 303 have P < 10 days
- Only 64 planets with P >10 and Mass > 0.7 M_J

How do we do it?

- TESS transits
- Follow-up facilities
  - Photometry: **Observatoire Moana CDK600 and RiDK500**, LCOGT access through CNTAC, CHAT (RIP), exofop
  - Spectroscopy: HARPS (ESO), FEROS (MPIA and CNTAC), CHIRON (CNTAC), CORALIE (CNTAC), PFS (CNTAC)
  - Hi-resolution imaging through **exofop**
- CHERCAN → candidates database: we reject false positives and perform a candidate selection
- Tesseract (Rojas+24) → TESS full frame images lightcurve analysis
- ceres (Brahm+16) → spectra reduction
- Zaspe (Brahm+16) → stellar atmospheric parameters
- Juliet (Espinoza+18) and ExoStriker (Trifonov+19) → Joint analysis of transits and RVs
- MESA (Jones+24) and GASTLI (Acuña+24) → Interior modeling



- MESA (Jones+24) and GASTLI (Acu

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CHERCAN

Add systems | Upload Spec | Upload LC | TESSERACT | Become a Robot! | lc

There are 0 juliet fits runing at the moment:

System ID	Start time	Time running	CPU usage

plain text list

Filter

NAME	RA	DEC	Vmag	NAMES	Periods [d]	T. dur. [d]	General priority	Nosb RV	TODO
TIC257467784	0.084679783653	5.04438770958	13.766	TOI-6841, UCAC4476-000009,	13.93	0.17	0	0	PHFU, FEROS:2
TIC152070435	0.247827271777	-23.4434076818	9.633	TYC6412-00076-1, UCAC4333-000013,	ST	0.3	0	0	FEROS:2, PHFU
TIC327917279	1.99379020399	-68.2266434218	12.107	TOI-6819, UCAC4109-000116,	8.55	0.16	0	0	PHFU, FEROS:2
				TOI-6893,					

TIC75650448 (a.k.a. UCAC4274-075783,)

Exofop Link

Status	General priority	RA	DEC	Vmag	TODO	Update
Confirmed Planet	0	225.83705	-35.230579	12.9	FEROS:3	

Transiting candidates

Add new candidate

Name	Period [d]	T0 [BJD]	Duration [d]	Action
TIC75650448.01	18.184347	2458602.7208	0.185	Transits

Spectroscopic observations (21)

Photometric observations (8)

Rad-Vel Fits: New fit
1 planets, 1 instruments
1 planets, 2 instruments

How do we do it?

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- Follow-up facilities
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  - Spectroscopy: HARPS (ESO), FEROS (MPIA and CNTAC), CHIRON (CNTAC), CORALIE (CNTAC), PFS (CNTAC)
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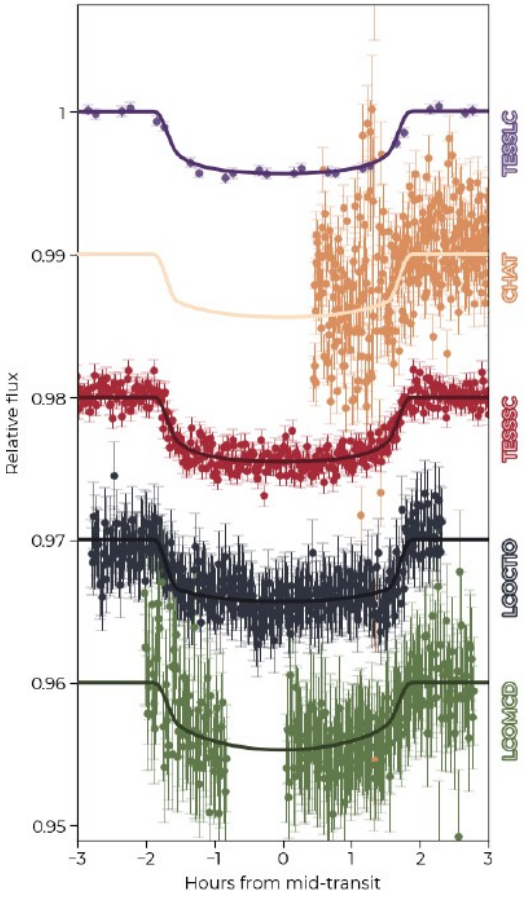
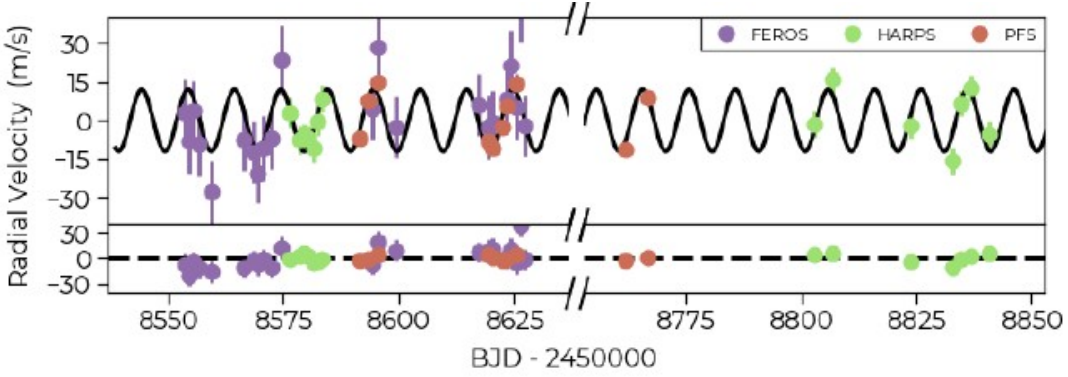
TOI-833 b (Rojas+2024)



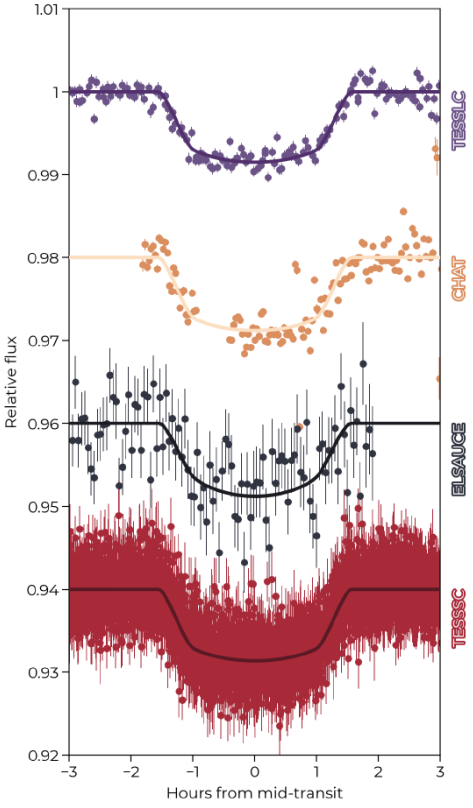


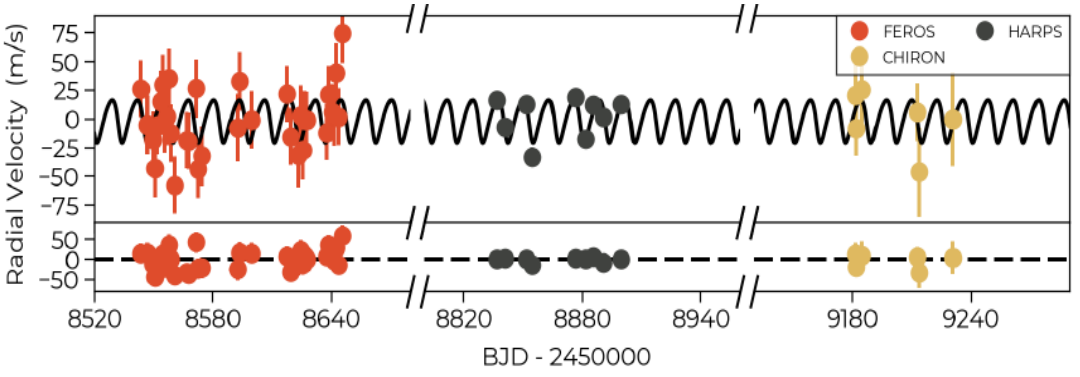
$T_{\rm eff}$ (K)	5697 ± 80
Spectral Type	G
[Fe/H] (dex)	0.02 ± 0.04
$\log g_*$ (cgs)	4.429 ± 0.022
$v \sin(i_*)$ (km/s)	2.53 ± 0.30
M_* ($M_\odot$)	$0.956^{+0.054}_{-0.051}$
R_* ($R_\odot$)	$0.988^{+0.012}_{-0.012}$
L_* ($L_\odot$)	$0.934^{+0.043}_{-0.031}$
A_v (mag)	$0.08^{+0.06}_{-0.05}$
Age (Gyr)	$6.5^{+2.0}_{-2.1}$
ρ_* (g cm^{-3})	$1.40^{+0.15}_{-0.14}$

P_b	$10.05772^{+0.00002}_{-0.00002}$
$t_{0,b}$	$2458466.4730^{+0.0012}_{-0.0013}$
$r_{1,b}$	$0.657^{+0.023}_{-0.024}$
$r_{2,b}$	$0.063^{+0.001}_{-0.001}$
K_b	$11.926^{+0.961}_{-0.945}$
e_b	0 (fixed)
ω	90 (fixed)

M_P (M_J)	0.123 ± 0.012
R_P (R_J)	0.604 ± 0.028
a (AU)	0.0898 ± 0.0023
$T_{\rm eq}$ (K)	1086 ± 19

TOI-899 b (Rojas+2024)

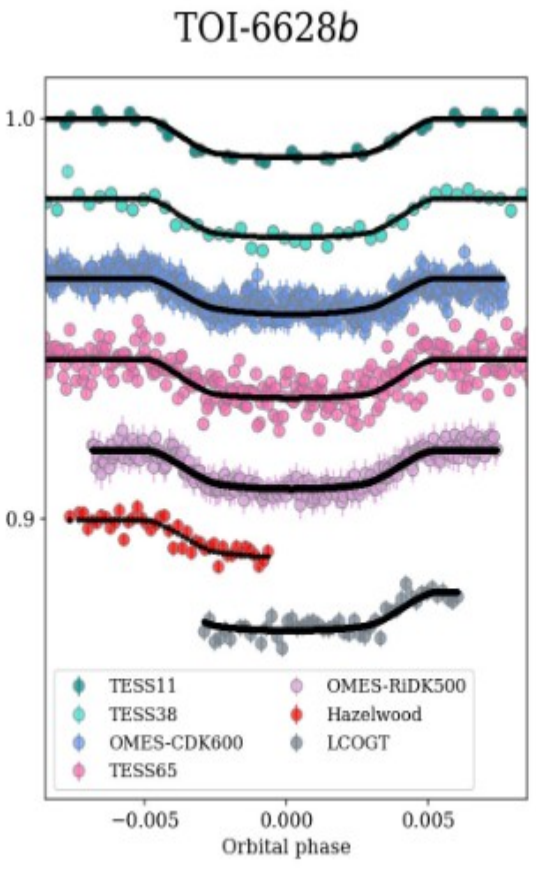


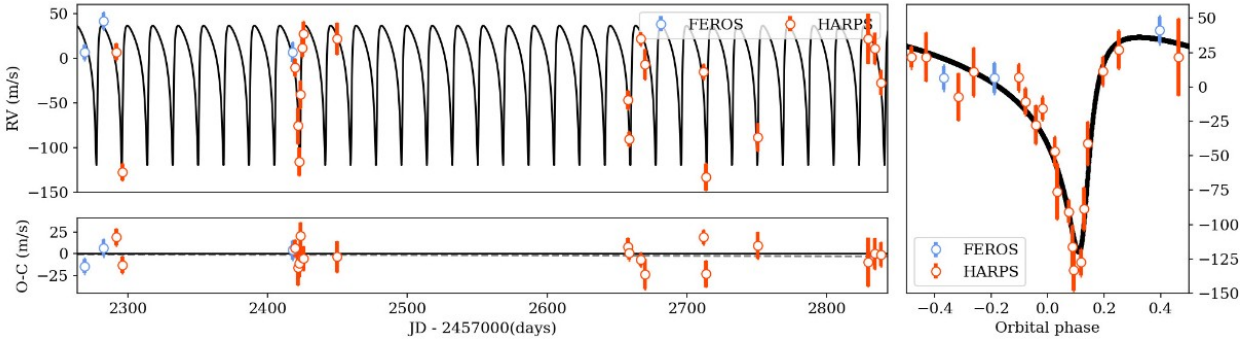


$T_{\rm eff}$ (K)	5696 ± 80
Spectral Type	G
[Fe/H] (dex)	0.10 ± 0.04
$\log g_*$ (cgs)	4.355 ± 0.022
$v \sin(i_*)$ (km/s)	3.65 ± 0.30
M_* ($M_\odot$)	$0.972^{+0.054}_{-0.053}$
R_* ($R_\odot$)	$1.086^{+0.013}_{-0.012}$
L_* ($L_\odot$)	$1.113^{+0.054}_{-0.052}$
A_v (mag)	$0.18^{+0.069}_{-0.072}$
Age (Gyr)	$8.4^{+2.0}_{-2.0}$
ρ_* (g cm^{-3})	$1.07^{+0.11}$

P_b	$12.846185^{+0.000008}_{-0.000008}$
$t_{0,b}$	$2458313.637577^{+0.000434}_{-0.000441}$
$r_{1,b}$	1110^{+80}_{-86}
$r_{2,b}$	$0.8277^{+0.0206}_{-0.0229}$
K_b	$0.0937^{+0.0012}_{-0.0015}$
e_b	$18.685^{+2.020}_{-1.990}$
ω	$0.218^{+0.054}_{-0.057}$

M_P (M_J)	0.213 ± 0.024
R_P (R_J)	0.991 ± 0.044
a (AU)	0.1063 ± 0.0026
$T_{\rm eq}$ (K)	1040 ± 19



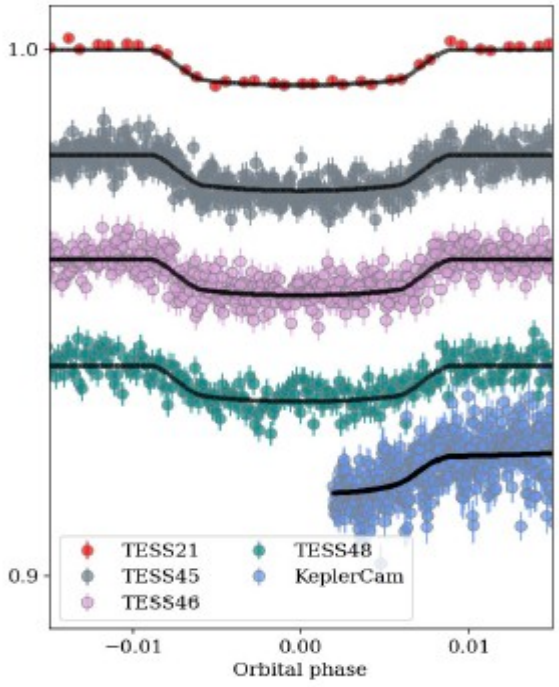


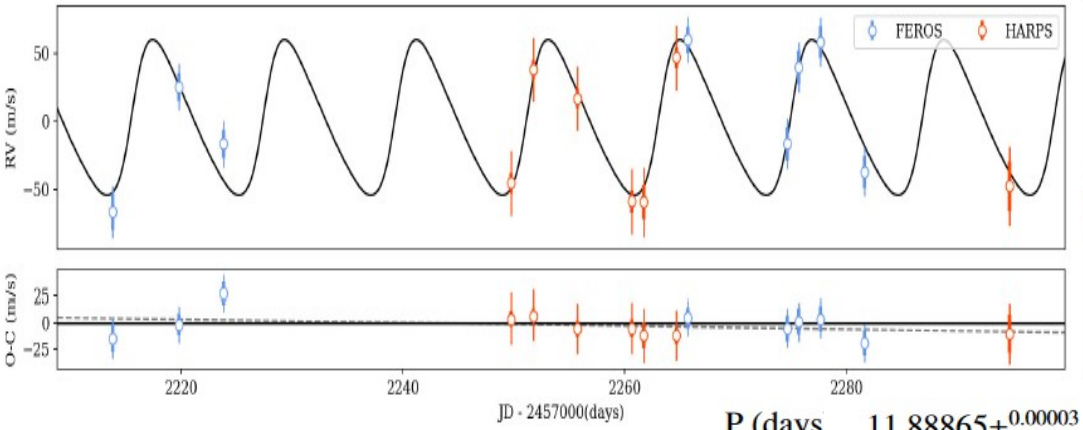
Distance (pc)[5]	315.2±8.3
Luminosity ($L_\odot$)[5]	$0.817^{+0.046}_{-0.044}$
Mass ($M_\odot$)[5]	$0.97^{+0.06}_{-0.06}$
Radius ($R_\odot$)[5]	$1.01^{+0.06}_{-0.05}$
ρ_* (g/cm^3)[5]	$1.323\pm^{0.225}_{0.187}$
$T_{\rm eff}$ (K)[5]	5463^{+143}_{-142}
Age (Gyr)[5]	$7.5^{+2.4}_{-2.5}$
log g (cm s^{-2})[5]	$4.416^{+0.024}_{-0.025}$
A_v (mag)	$0.313^{+0.083}_{-0.084}$
[Fe/H] (dex)[5]	0.36±0.02
$v \sin i$ (km s^{-1})[5]	3.13±0.20

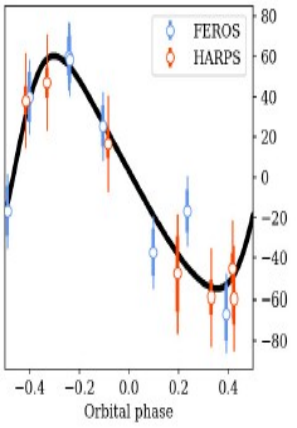
P (days)	$18.18424\pm^{0.00001}_{0.00001}$
t0 (days)	$2458602.7209\pm^{0.0009}_{0.0009}$
b	$0.814\pm^{0.016}_{0.017}$
p	$0.100\pm^{0.001}_{0.001}$
e	$0.667\pm^{0.016}_{0.016}$
ω (deg)	$215.4\pm^{2.4}_{2.3}$
ρ_* (kg/m^3)	$1299.3\pm^{89.3}_{95.0}$
K (m/s)	$78.90\pm^{3.10}_{3.12}$

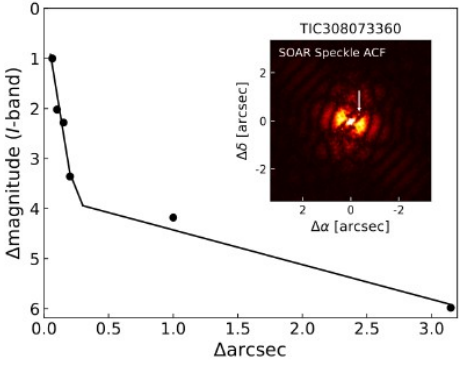
i (deg)	88.17 ± 0.13
m_p (m_J)	$0.75\pm^{0.06}_{0.06}$
a (AU)	$0.133\pm^{0.007}_{0.007}$
R_p (R_J)	$0.98\pm^{0.05}_{0.05}$
ρ_p (g/cm^3)	$0.97\pm^{0.16}_{0.16}$
T_{eq} (K)	$836\pm^{22}_{23}$

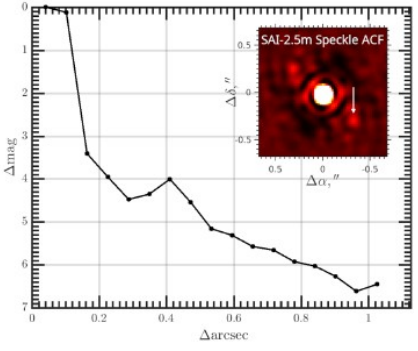
TOI-3837*b*





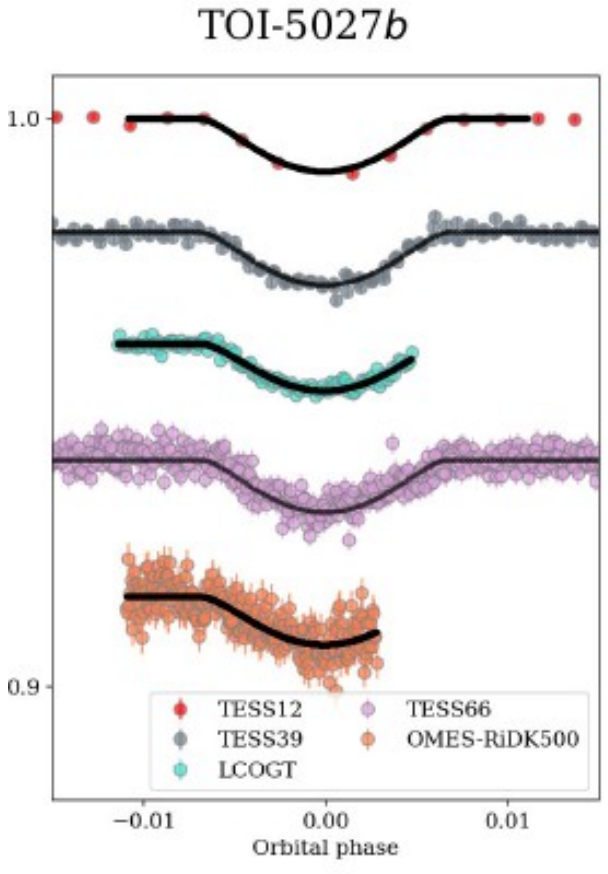


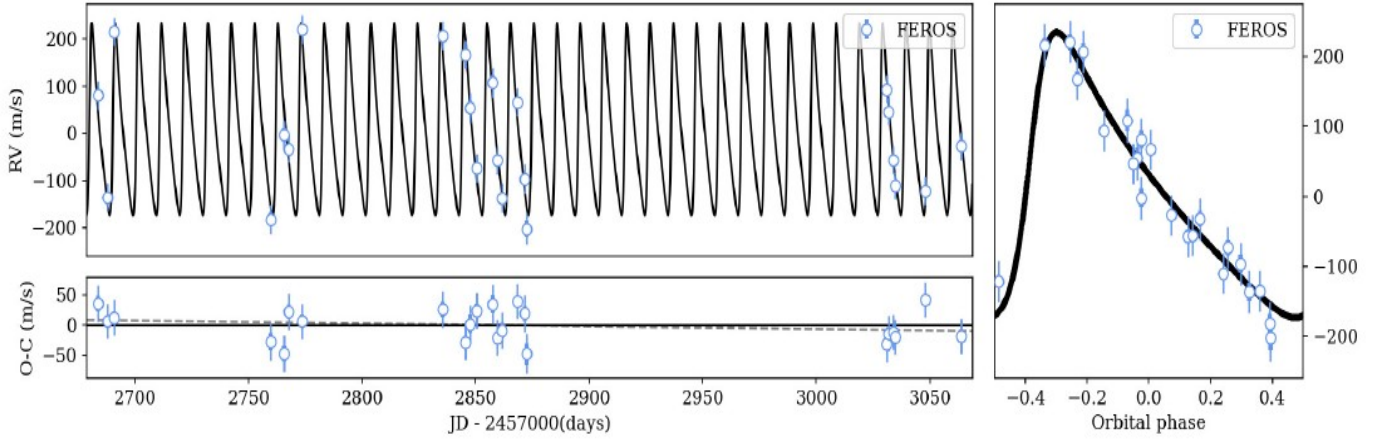




Distance (pc)[5]	306.7±5.8
Luminosity ($L_\odot$)[5]	$1.571^{+0.085}_{-0.076}$
Mass ($M_\odot$)[5]	$0.89^{+0.05}_{-0.05}$
Radius ($R_\odot$)[5]	$1.20^{+0.05}_{-0.05}$
ρ_* (g/cm^3)[5]	$0.725^{+0.118}_{-0.098}$
$T_{\rm eff}$ (K)[5]	5905^{+157}_{-155}
Age (Gyr)[5]	$11.2^{+2.5}_{-2.6}$
log g (cm s^{-2})[5]	$4.229^{+0.018}_{-0.019}$
A_v (mag)	$0.228^{+0.072}_{-0.068}$
[Fe/H] (dex)[5]	-0.26±0.05
$v \sin i$ (km s^{-1})[5]	3.47±0.26

P (days	$11.88865\pm^{0.00003}_{0.00003}$		
t0 (days	$2459530.1610\pm^{0.0007}_{0.0008}$		
b	$0.728\pm^{0.032}_{0.051}$	i (deg)	87.98±0.17
p	$0.082\pm^{0.002}_{0.002}$	m_p (M_J)	$0.59\pm^{0.06}_{0.06}$
e	$0.198\pm^{0.046}_{0.058}$	a (AU)	$0.098\pm^{0.005}_{0.005}$
ω (deg)	$285.3\pm^{12.4}_{11.7}$	R_p (R_J)	$0.96\pm^{0.05}_{0.05}$
ρ_* (kg/m	$723.6\pm^{37.3}_{38.4}$	ρ_p (g/cm^3)	$0.85\pm^{0.16}_{0.16}$
K (m/s)	$58.39\pm^{3.97}_{3.98}$	T_{eq} (K)	$1182\pm^{30}_{31}$

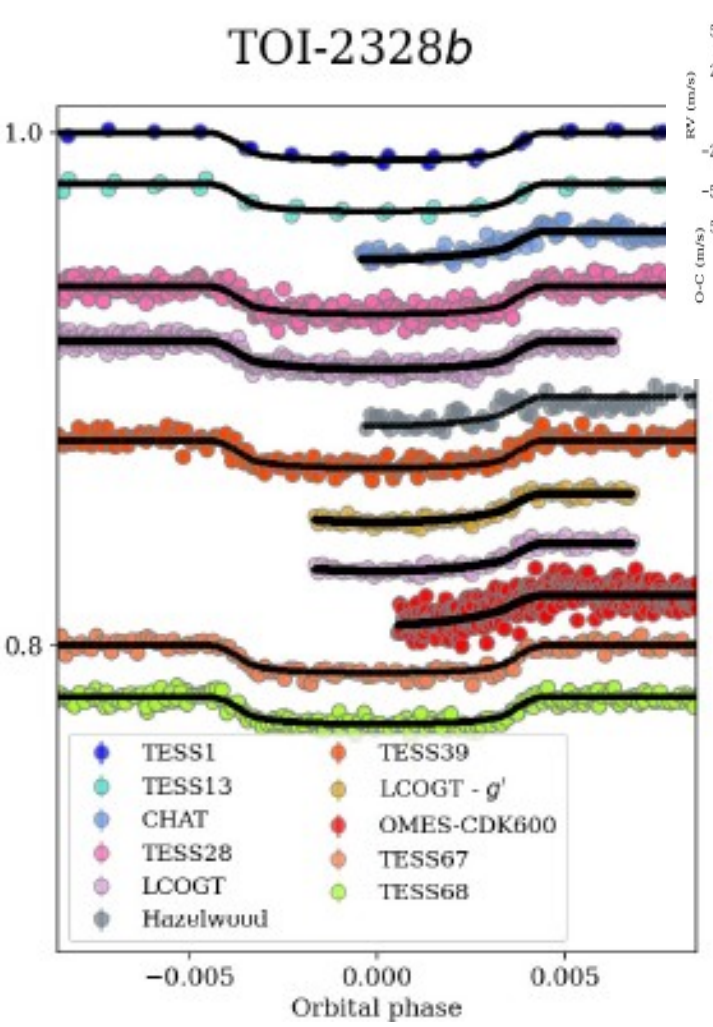


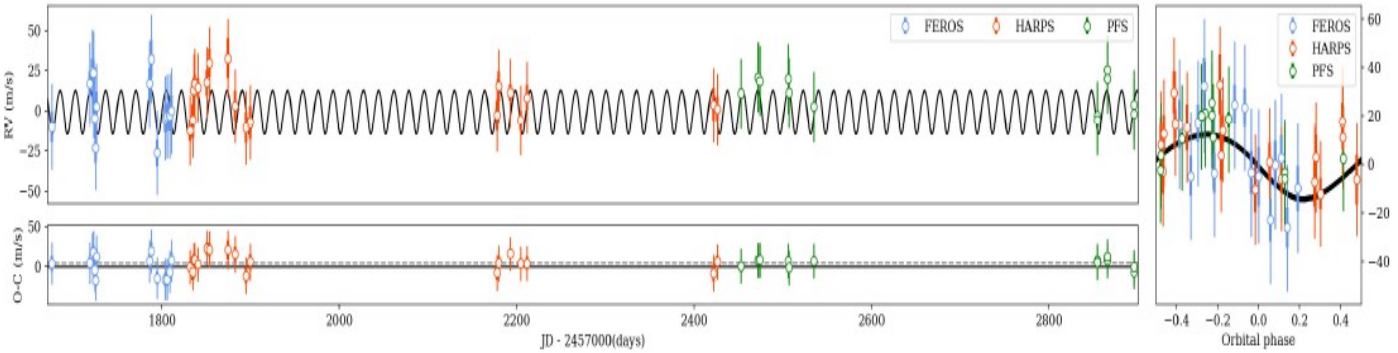


Distance (pc)[5]	202.2±1.5
Luminosity ($L_\odot$)[5]	$0.932^{+0.034}_{-0.033}$
Mass ($M_\odot$)[5]	$1.02^{+0.05}_{-0.05}$
Radius ($R_\odot$)[5]	$0.92^{+0.04}_{-0.04}$
ρ_* (g/cm^3)[5]	$1.831^{+0.038}_{-0.044}$
$T_{\rm eff}$ (K)[5]	5909^{+145}_{-144}
Age (Gyr)[5]	$0.4^{+0.6}_{-0.3}$
log g (cm s^{-2})[5]	$4.517^{+0.006}_{-0.008}$
A_v (mag)	$0.100^{+0.041}_{-0.041}$
[Fe/H] (dex)[5]	-0.15±0.03
$v \sin i$ (km s^{-1})[5]	4.52±0.13

P (days)	$10.24368^{+0.00001}_{-0.00001}$
t0 (days)	$2458649.4580^{+0.0010}_{-0.0009}$
b	$0.926^{+0.026}_{-0.017}$
p	$0.109^{+0.013}_{-0.006}$
e	$0.395^{+0.032}_{-0.029}$
ω (deg)	$288.6^{+3.4}_{-3.4}$
ρ_* (kg/m^3)	$1833.3^{+38.8}_{-37.5}$
K (m/s)	$201.77^{+4.00}_{-4.23}$

i (deg)	$88.18^{+0.13}_{-0.10}$
m_p (m_J)	$2.01^{+0.13}_{-0.13}$
a (AU)	$0.093^{+0.004}_{-0.004}$
R_p (R_J)	$0.99^{+0.07}_{-0.12}$
ρ_p (g/cm^3)	$2.77^{+0.90}_{-0.90}$
T_{eq} (K)	1056^{+23}_{-24}



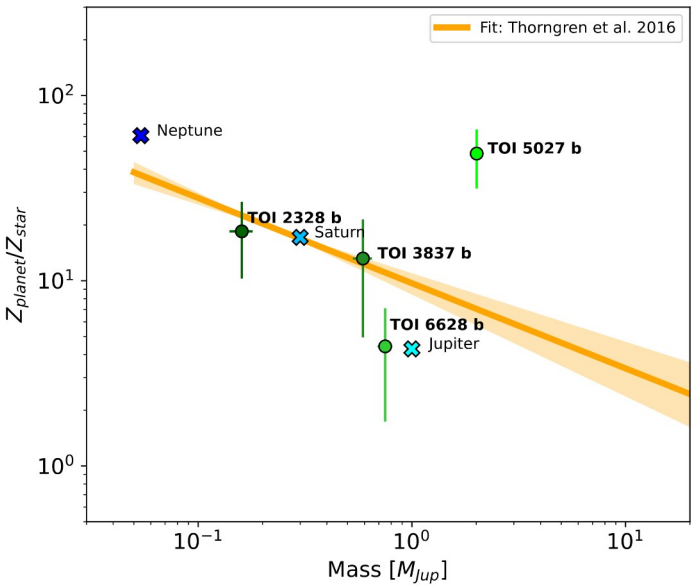


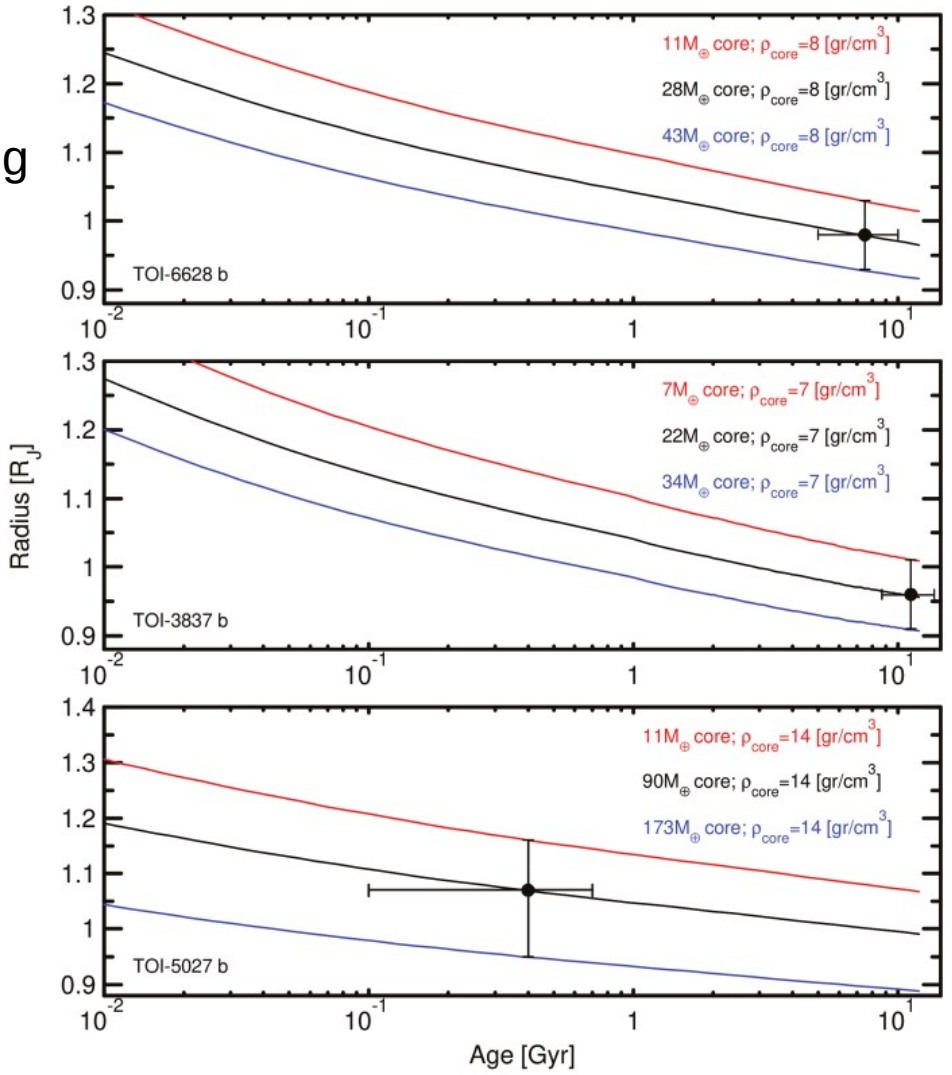
Distance (pc)[5]	228.9±1.5
Luminosity ($L_\odot$)[5]	$0.676^{+0.031}_{-0.031}$
Mass ($M_\odot$)[5]	$0.95^{+0.06}_{-0.06}$
Radius ($R_\odot$)[5]	$0.90^{+0.06}_{-0.06}$
ρ_* (g/cm^3)[5]	$1.828\pm^{0.289}_{0.245}$
$T_{\rm eff}$ (K)[5]	5525^{+147}_{-144}
Age (Gyr)[5]	$4.0^{+2.3}_{-2.7}$
log g (cm s^{-2})[5]	$4.505^{+0.021}_{-0.020}$
A_v (mag)	$0.262^{+0.063}_{-0.060}$
[Fe/H] (dex)[5]	0.09±0.03
$v \sin i$ (km s^{-1})[5]	2.61±0.25

P (days)	$17.10197\pm^{0.00000}_{0.00001}$
t0 (days)	$2458330.4894\pm^{0.0004}_{0.0003}$
b	$0.688\pm^{0.022}_{0.018}$
p	$0.102\pm^{0.000}_{0.000}$
e	$0.057\pm^{0.046}_{0.029}$
ω (deg)	$148.7\pm^{14.1}_{9.3}$
ρ_* (kg/m^3)	$1806.1\pm^{42.1}_{35.4}$
K (m/s)	$13.29\pm^{1.57}_{1.53}$

i (deg)	88.18±0.10
m_p (m_J)	$2.01\pm^{0.13}_{0.13}$
a (AU)	$0.093\pm^{0.004}_{0.004}$
R_p (R_J)	$0.99\pm^{0.07}_{0.12}$
ρ_p (g/cm^3)	$2.77\pm^{0.90}_{0.90}$
T_{eq} (K)	$1056\pm^{23}_{24}$

Interior modeling of Giant Planets using MESA and GASTLI





TOI-4504 – a system with a 4 days TTV! (Vitková+2024)

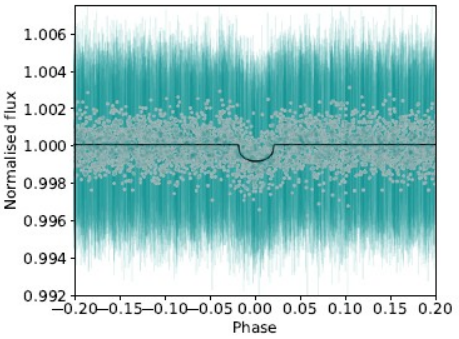


Figure 3. Phase plot for TOI-4504 b transit. Light curve was binned into one-hour bins.

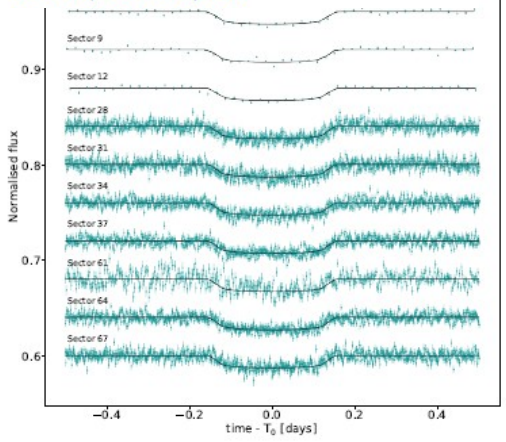
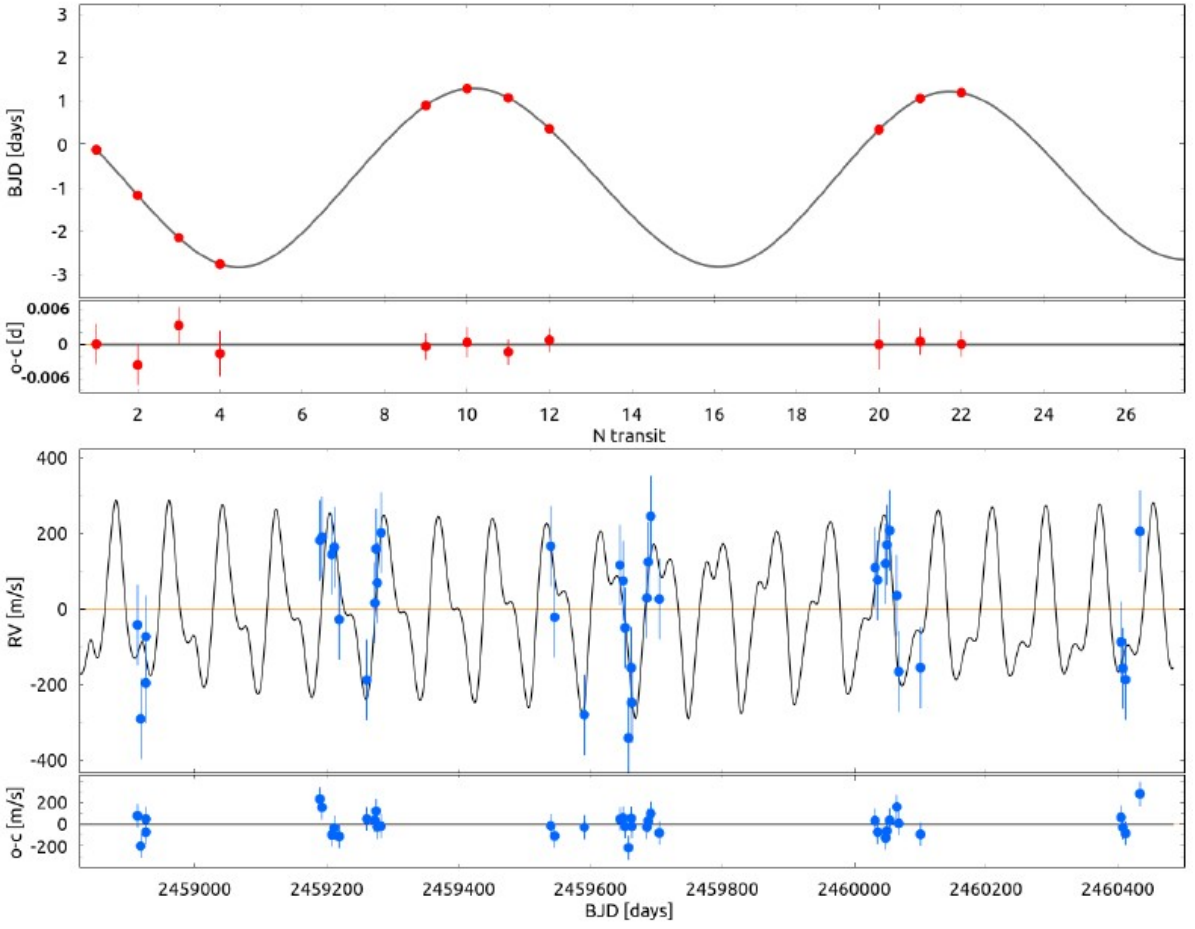


Figure 4. Transits of TOI-4504 c with a model from Juliet shifted to have mid-transit at 0 and plotted with vertical offsets.

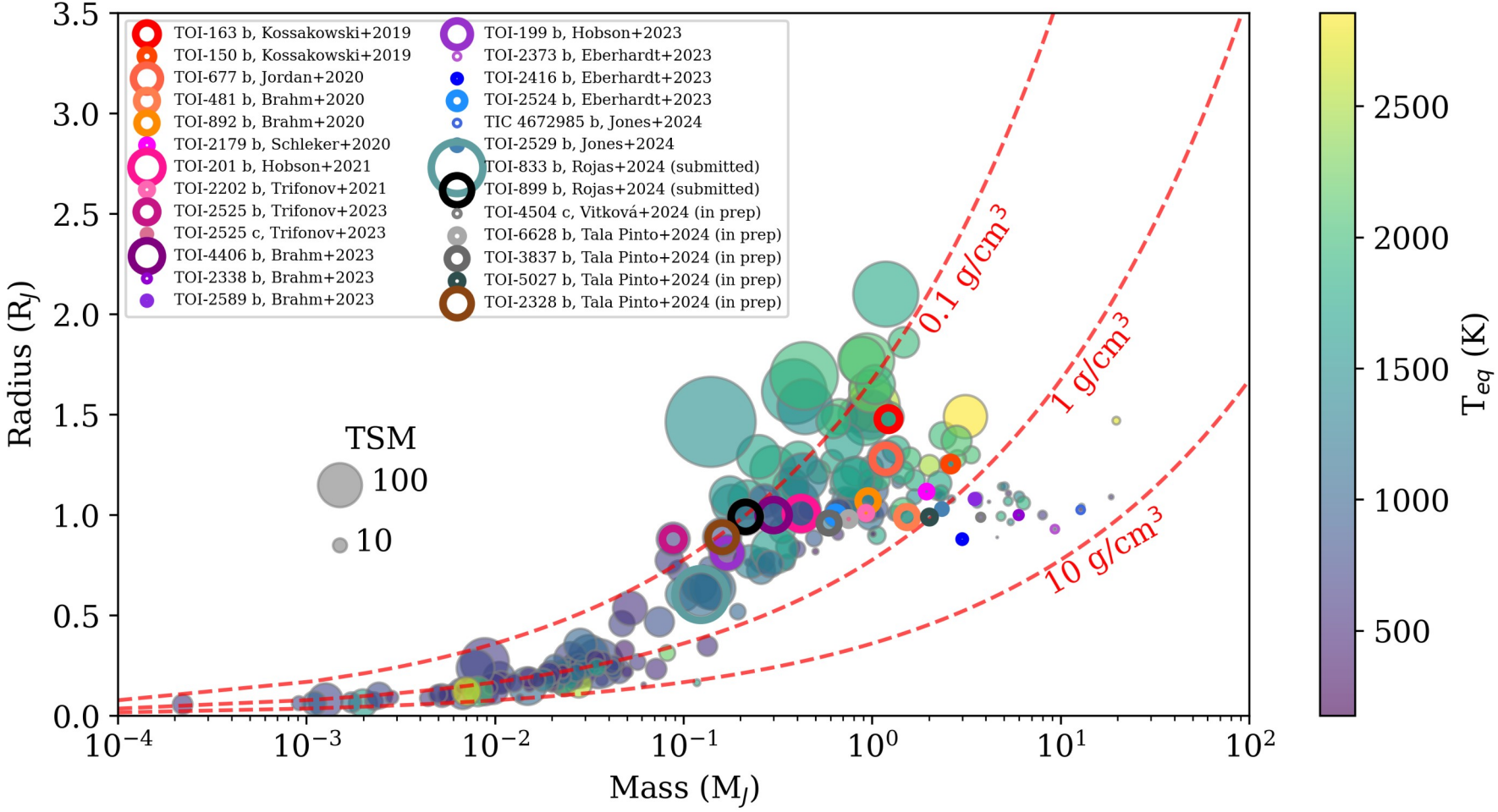


TOI-4504 – a system with a 4 days TTV! (Vitková+2024)

Parameter	Prior	Posterior
P [days]	$\mathcal{N}$ (2.4,0.5)	$2.42614^{+0.00014}_{-0.00013}$
t_0 [BJD]	$\mathcal{N}$ (2459038.46,0.2)	$2459038.458^{+0.022}_{-0.021}$
b	$\mathcal{U}$ (0.0,1.0)	$0.396^{+0.134}_{-0.197}$
R_p/R_*	$\mathcal{U}$ (0.0,1.0)	$0.0268^{+0.0019}_{-0.0019}$
q_1	$\mathcal{U}$ (0.0,1.0)	$0.527^{+0.320}_{-0.308}$
q_2	$\mathcal{U}$ (0.0,1.0)	$0.496^{+0.323}_{-0.316}$
e	fixed 0.0	–
ω [°]	fixed 90.0	–
ρ_* [kg cm^{-3}]	$\mathcal{N}$ (1600,100)	1601^{+100}_{-97}
$m_{\rm dilution}$	fixed, 1.0	–
$m_{\rm flux}$	$\mathcal{N}$ (0.0,0.1)	$-0.000046^{+0.000014}_{-0.000014}$
σ_w [ppm]	$\mathcal{J}$ (0.1,1000.0)	$2.16^{+17.11}_{-1.90}$
a [au]	–	0.03392 ± 0.00068
R_p [$R_\oplus$]	–	2.689 ± 0.191
i [°]	–	$87.4^{+0.9}_{-1.3}$

NOTE—a is calculated using Kepler's third law and derived period P

	Median and 1σ	Ma
Parameter	Planet d	Planet c
K [m s^{-1}]	$90.8366^{+1.8812}_{-2.5466}$	$190.8921^{+4.7269}_{-6.2119}$
P [days]	$40.5634^{+0.0363}_{-0.0368}$	$82.5438^{+0.0150}_{-0.0176}$
$e\sin(\omega)$	$0.0439^{+0.0010}_{-0.0011}$	$-0.0320^{+0.0014}_{-0.0016}$
$e\cos(\omega)$	$-0.0064^{+0.0039}_{-0.0047}$	$0.0005^{+0.0011}_{-0.0013}$
λ [deg]	$9.89^{+3.45}_{-2.43}$	$83.97^{+0.12}_{-0.15}$
i [deg]	$85.00^{+0.28}_{-0.30}$	$89.69^{+0.03}_{-0.03}$
Ω [deg]	0.0	$0.0^{+0.9}_{-1.0}$
RV$_{\rm off.}$ FEROS [m s^{-1}]	$2067.0517^{+14.2161}_{-14.8783}$	...
RV$_{\rm jit.}$ FEROS [m s^{-1}]	$103.3721^{+13.8367}_{-7.0042}$	...
e	$0.0445^{+0.0010}_{-0.0009}$	$0.0320^{+0.0016}_{-0.0014}$
ω [deg]	$98.3^{+6.1}_{-5.1}$	$270.9^{+2.0}_{-2.2}$
$M0$ [deg]	$271.6^{+7.3}_{-7.5}$	$173.1^{+2.1}_{-1.9}$
Δi [deg]	$4.7^{+0.3}_{-0.3}$	...
m_p [M$_{\rm Jup.}$]	$1.4166^{+0.0651}_{-0.0647}$	$3.7672^{+0.1810}_{-0.1822}$
a_p [au]	$0.2219^{+0.0041}_{-0.0043}$	$0.3569^{+0.0066}_{-0.0069}$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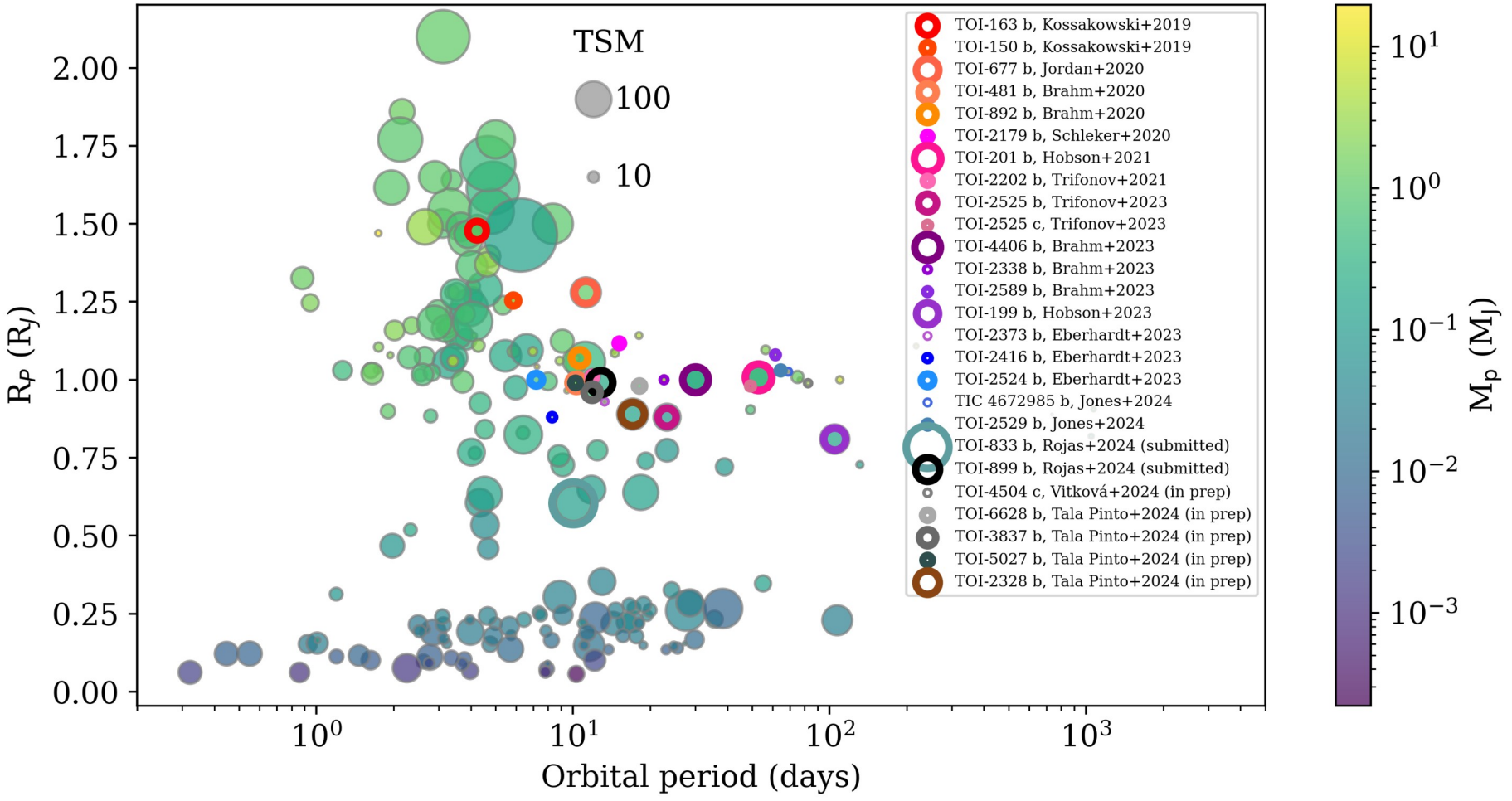
TOI-150 b, Kossakowski+2019
TOI-677 b, Jordan+2020
TOI-481 b, Brahm+2020
TOI-892 b, Brahm+2020
TOI-2179 b, Schleker+2020
TOI-201 b, Hobson+2021
TOI-2202 b, Trifonov+2021
TOI-2525 b, Trifonov+2023
TOI-2525 c, Trifonov+2023
TOI-4406 b, Brahm+2023
TOI-2338 b, Brahm+2023
TOI-2589 b, Brahm+2023
TOI-199 b, Hobson+2023
TOI-2373 b, Eberhardt+2023
TOI-2416 b, Eberhardt+2023
TOI-2524 b, Eberhardt+2023
TIC 4672985 b, Jones+2024
TOI-2529 b, Jones+2024
TOI-833 b, Rojas+2024 (submitted)
TOI-899 b, Rojas+2024 (submitted)
TOI-4504 c, Vitková+2024 (in prep)
TOI-6628 b, Tala Pinto+2024 (in prep)
TOI-3837 b, Tala Pinto+2024 (in prep)
TOI-5027 b, Tala Pinto+2024 (in prep)
TOI-2328 b, Tala Pinto+2024 (in prep)
TSM
100
10
0.1 g/cm³
1 g/cm³
10 g/cm³
Radius (R_J)
Mass (M_J)
T_eq (K)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
10^−4
10^−3
10^−2
10^−1
10^0
10^1
10^2
2500
2000
1500
1000
500


TSM
100
10
TOI-163 b, Kossakowski+2019
TOI-150 b, Kossakowski+2019
TOI-677 b, Jordan+2020
TOI-481 b, Brahm+2020
TOI-892 b, Brahm+2020
TOI-2179 b, Schleker+2020
TOI-201 b, Hobson+2021
TOI-2202 b, Trifonov+2021
TOI-2525 b, Trifonov+2023
TOI-2525 c, Trifonov+2023
TOI-4406 b, Brahm+2023
TOI-2338 b, Brahm+2023
TOI-2589 b, Brahm+2023
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TOI-2416 b, Eberhardt+2023
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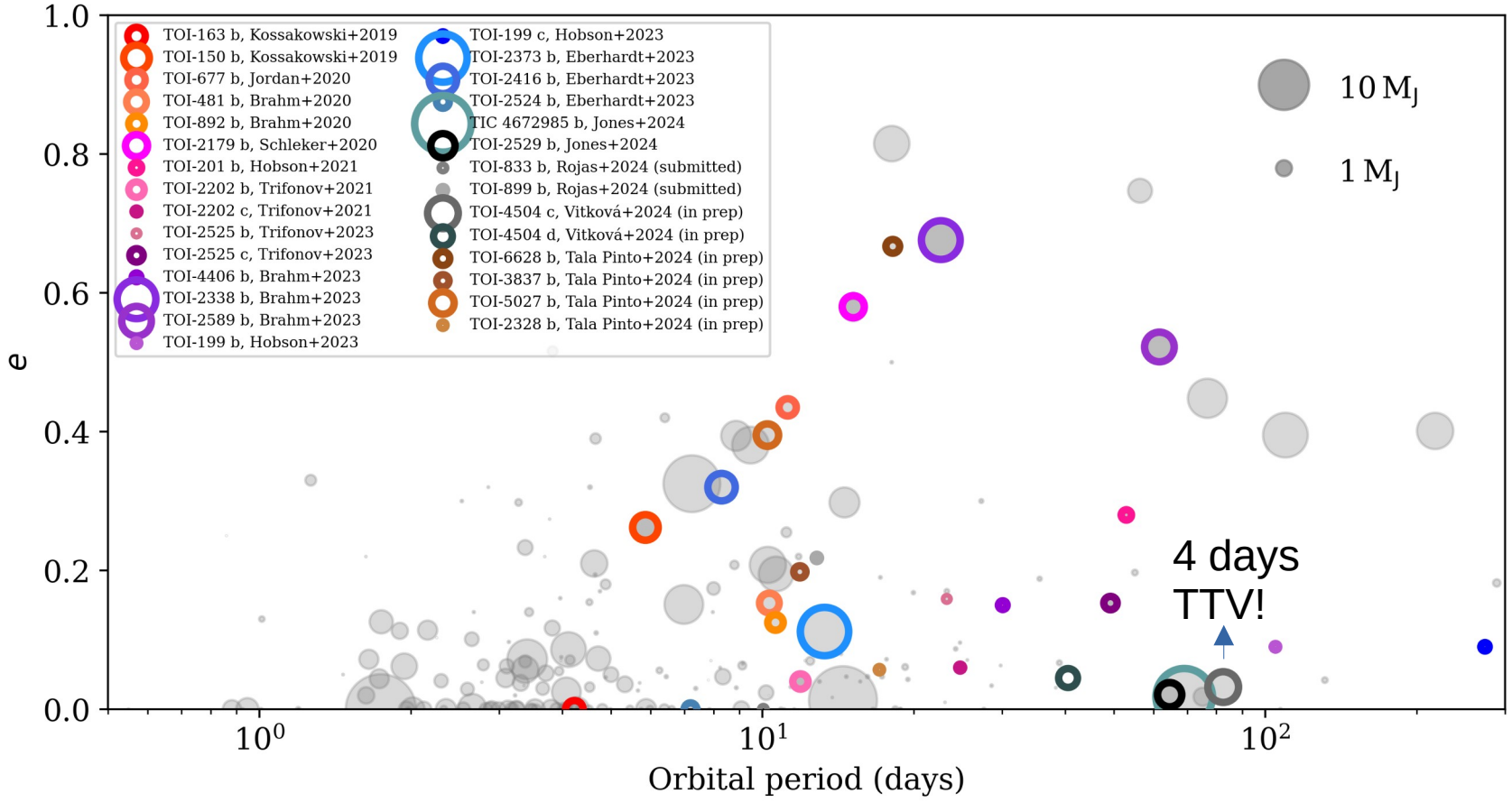
TOI-3837 b, Tala Pinto+2024 (in prep)
TOI-5027 b, Tala Pinto+2024 (in prep)
TOI-2328 b, Tala Pinto+2024 (in prep)
R_P (R_J)
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
10^0
10^1
10^2
10^3
Orbital period (days)
M_p (M_J)
10^1
10^0
10^{-1}
10^{-2}
10^{-3}


TOI-163 b, Kossakowski+2019
TOI-150 b, Kossakowski+2019
TOI-677 b, Jordan+2020
TOI-481 b, Brahm+2020
TOI-892 b, Brahm+2020
TOI-2179 b, Schleker+2020
TOI-201 b, Hobson+2021
TOI-2202 b, Trifonov+2021
TOI-2202 c, Trifonov+2021
TOI-2525 b, Trifonov+2023
TOI-2525 c, Trifonov+2023
TOI-4406 b, Brahm+2023
TOI-2338 b, Brahm+2023
TOI-2589 b, Brahm+2023
TOI-199 b, Hobson+2023
TOI-199 c, Hobson+2023
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TOI-2416 b, Eberhardt+2023
TOI-2524 b, Eberhardt+2023
TIC 4672985 b, Jones+2024
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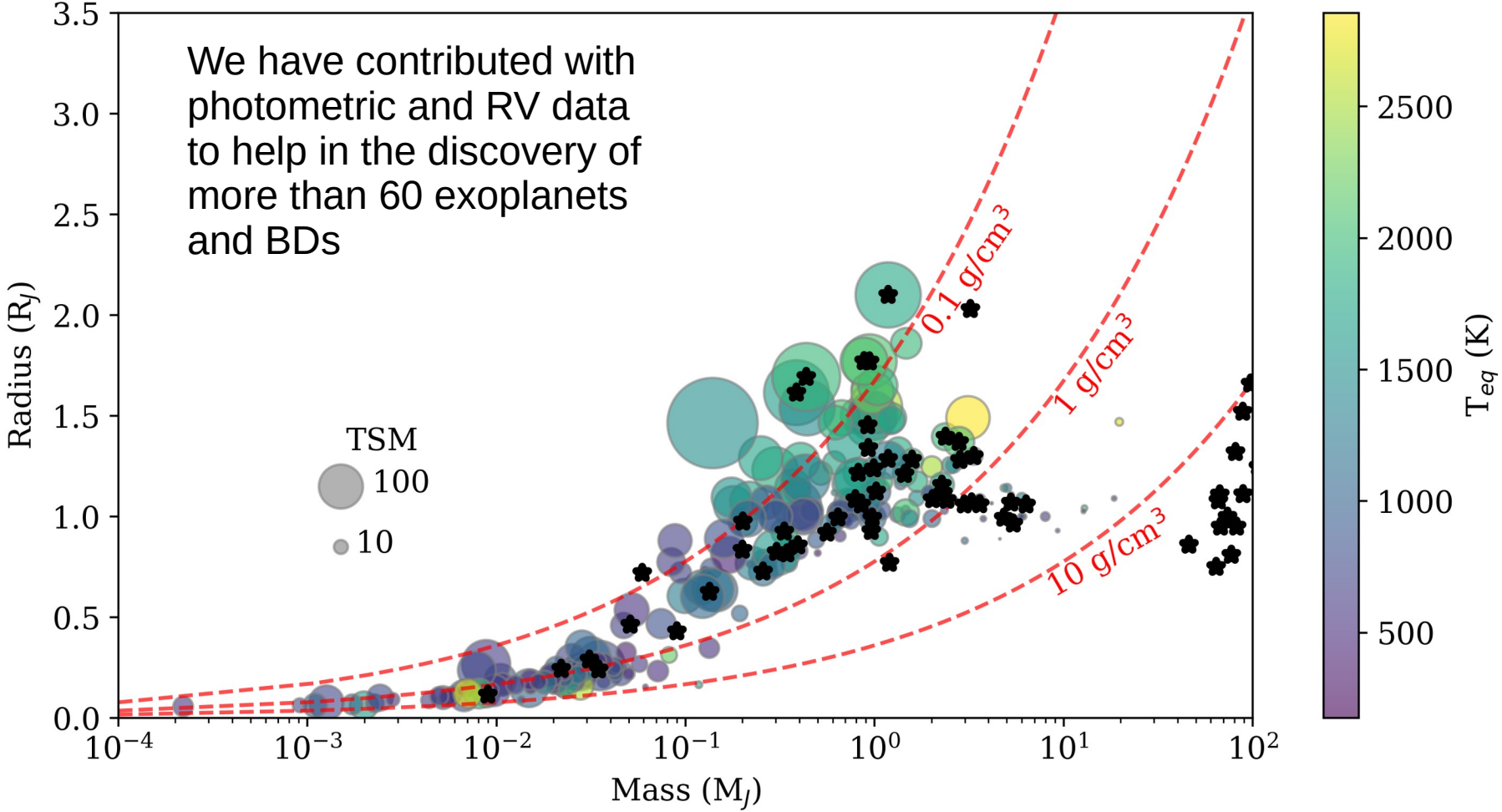
TOI-833 b, Rojas+2024 (submitted)
TOI-899 b, Rojas+2024 (submitted)
TOI-4504 c, Vitková+2024 (in prep)
TOI-4504 d, Vitková+2024 (in prep)
TOI-6628 b, Tala Pinto+2024 (in prep)
TOI-3837 b, Tala Pinto+2024 (in prep)
TOI-5027 b, Tala Pinto+2024 (in prep)
TOI-2328 b, Tala Pinto+2024 (in prep)
10 M_J
1 M_J
4 days
TTV!
e
Orbital period (days)
1.0
0.8
0.6
0.4
0.2
0.0
10^0
10^1
10^2


We have contributed with photometric and RV data to help in the discovery of more than 60 exoplanets and BDs
TSM
100
10
0.1 g/cm³
1 g/cm³
10 g/cm³
Radius (R_J)
Mass (M_J)
T_eq (K)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
10^−4
10^−3
10^−2
10^−1
10^0
10^1
10^2
2500
2000
1500
1000
500

Where to now...

- TTVs and planetary dynamics is hard! But necessary
- Systematic characterization of planetary orbits and interior models of a sample of 50+ Wjs
  - Build up sample
  - Study correlations of orbital parameters with metal enhancement
- 3D orbits by measuring the obliquity using the R-M effect (J. I. Espinoza (PUC), R. Brahm (UAI))

Thanks for your attention!