CoRoT 101186644: A transiting low-mass dense M-dwarf on an eccentric 20.7-day period orbit around a late F-star

L. Tal-Or, T. Mazeh, R. Alonso, F. Bouchy, J. Cabrera, H. J. Deeg, M. Deleuil, S. Faigler, M. Fridlund, G. Hebrard, C. Moutou, A. Santerne, and B. Tingley

arXiv:1302.5830

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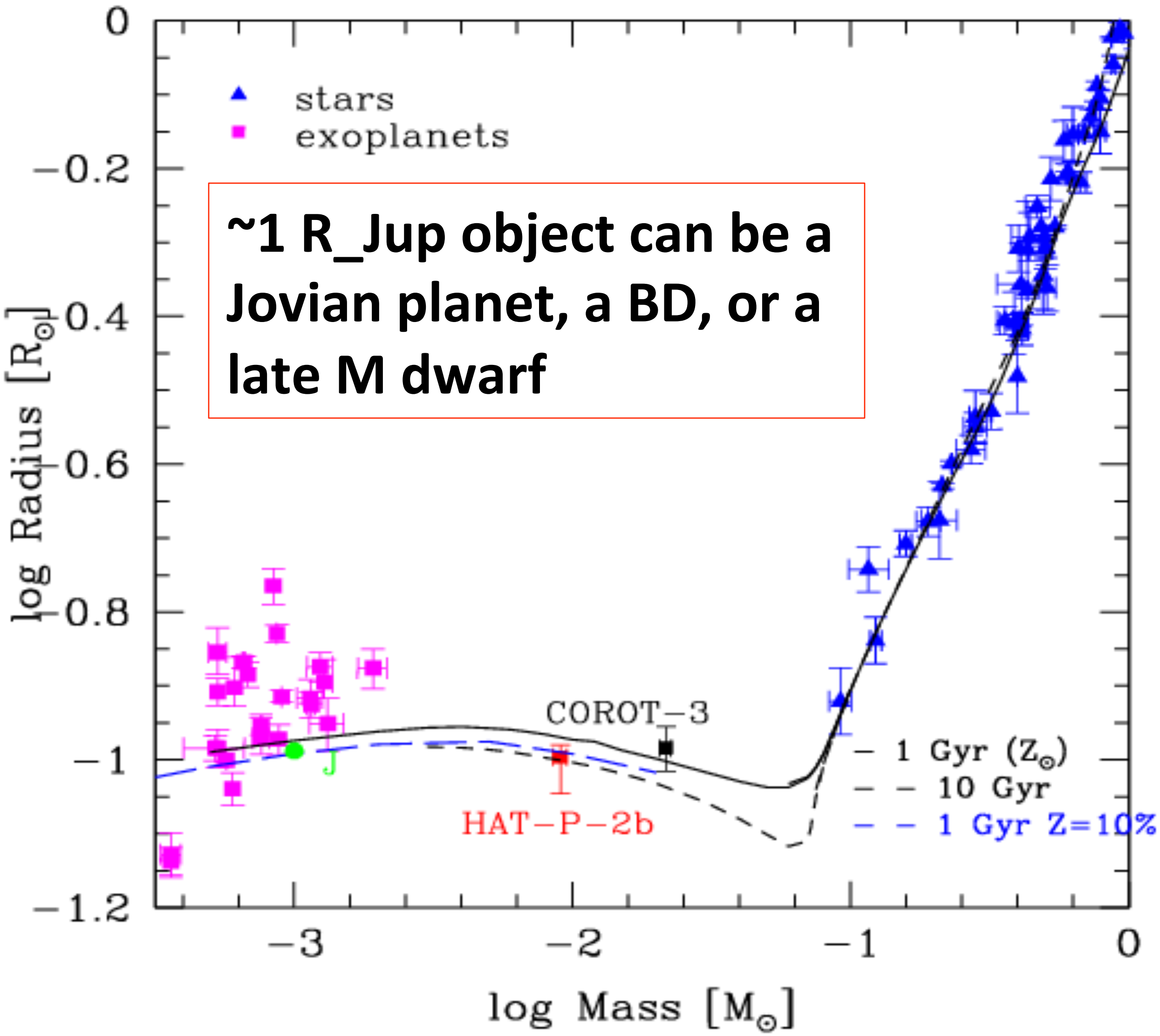
CoRoT 101186644: Context



N (Jovian planets with derived mass and radius)

>

N (BDs or late M dwarfs with derived mass and radius)

Image credit: Chabrier, G. et al. AIP Conf.Proc. 1094 (2009) 102-111 arXiv:0810.5085

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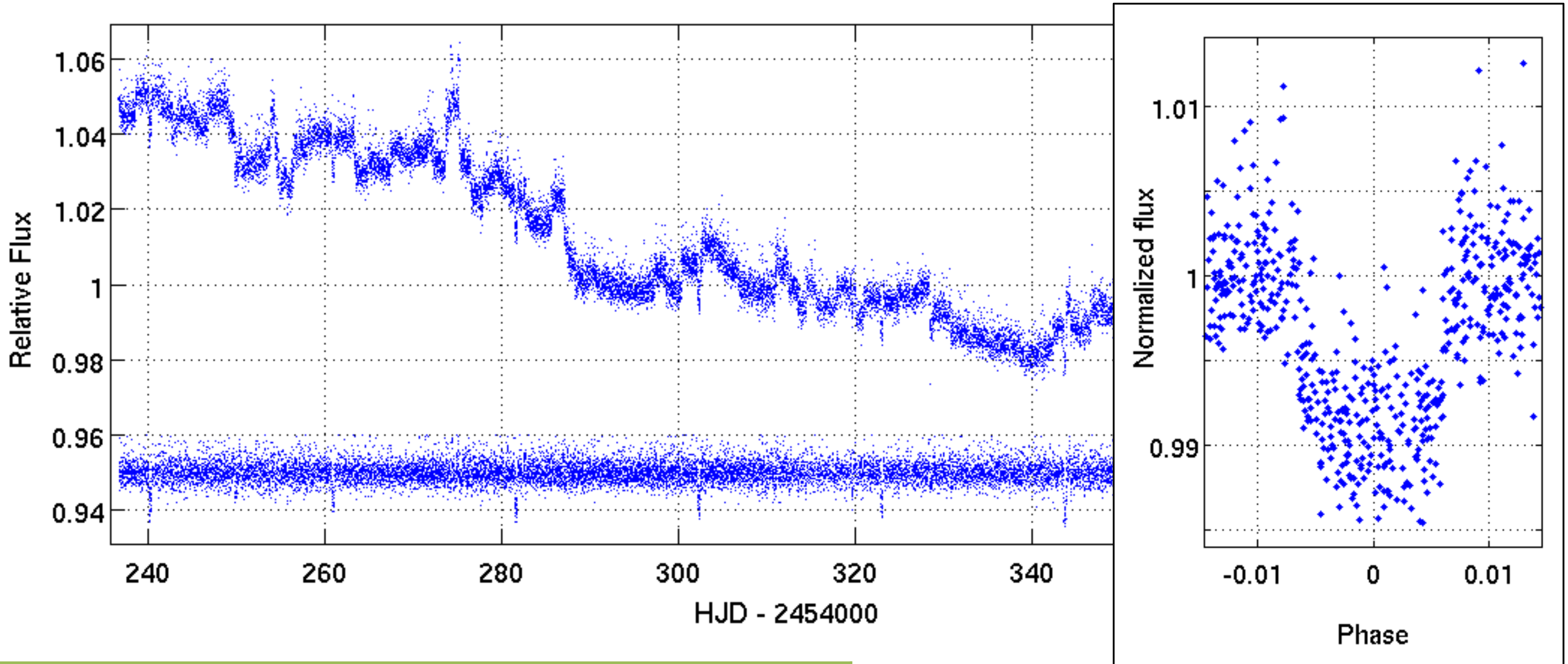
CoRoT 101186644: The candidate



Parameter	Value	Ref.
Period (day)	20.68369 (11)	Phot FU
Duration (h.)	7.6	Roi's plot
Depth (%)	0.96	Roi's plot

CoRoT 101186644 =
LRc01_E1_4780 = C4780

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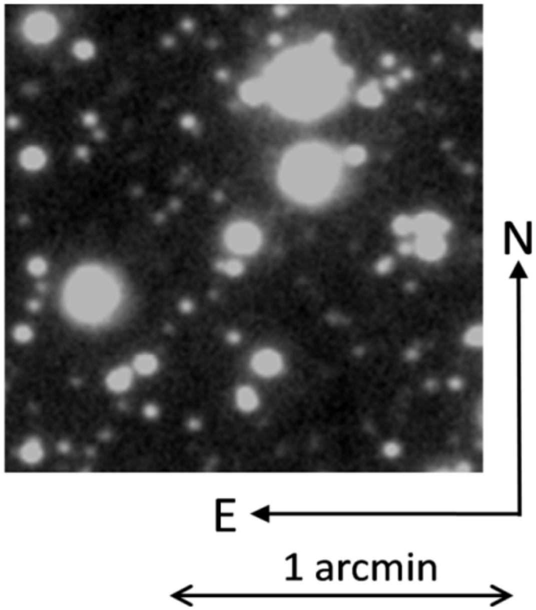
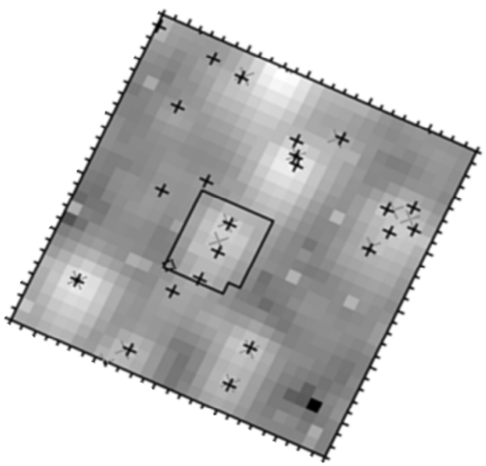
CoRoT 101186644: The star





Parameter	Value	Ref.
RA (J2000)	19*h*26*m*59*s*.08	*ExoDat*
Dec (J2000)	+00°29'06".4	*ExoDat*
V (mag)	16.05 $\pm$ 0.07	*ExoDat*

Contamination level - about 10 %

Photometric follow-up:
on target

Top: Image from the Wise Observatory
Bottom: Image from CoRoT with the photometric mask

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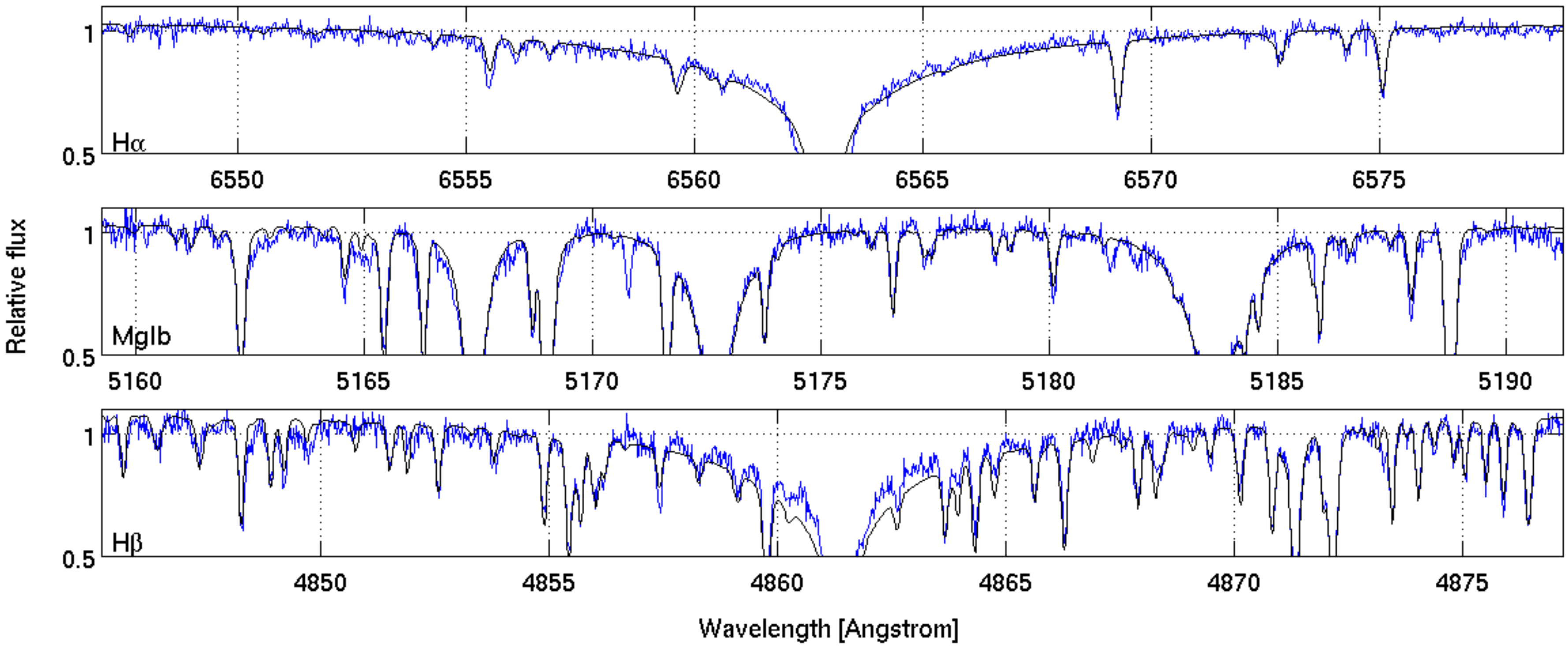
CoRoT 101186644: HARPS spectra and RVs



Atmospheric parameters	Value	Method
Effective temperature (K)	6090 ± 200	SME
logg (cgs)	4.4 ± 0.2	SME
Metallicity (dex)	+0.2 ± 0.2	SME

Top image: Nine HARPS spectra co-added (blue) + model (black)

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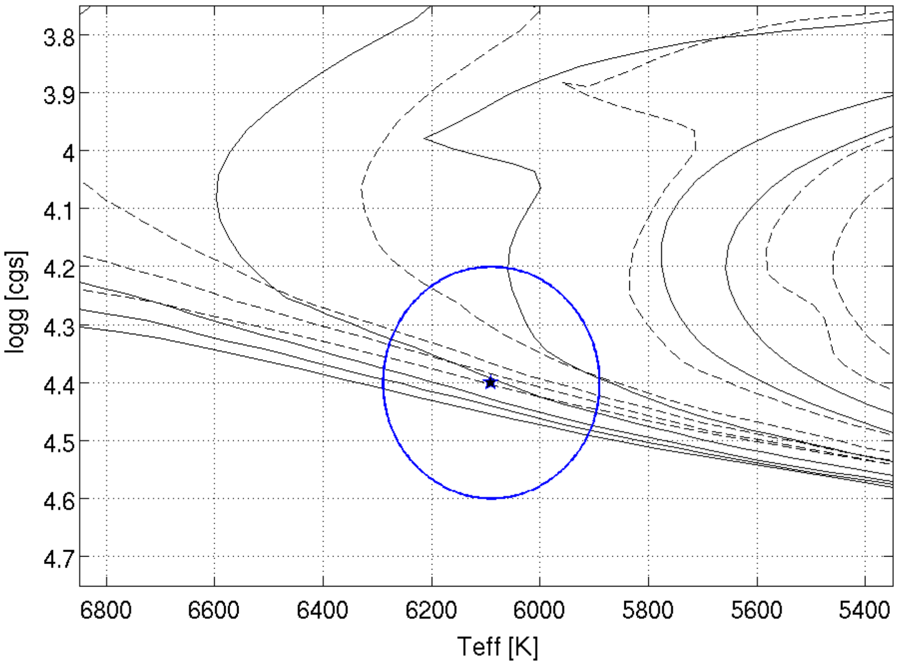
CoRoT 101186644: Primary modeling



Filter	Magnitude	Source
B	17.09 ± 0.15	*ExoDat*[a]
V	16.05 ± 0.07	*ExoDat*
r'	15.67 ± 0.14	*ExoDat*
i'	14.93 ± 0.03	*ExoDat*
J	14.03 ± 0.03	2MASS[b]
H	13.63 ± 0.02	2MASS
Ks	13.56 ± 0.03	2MASS

Primary parameters	Value	Method
Mass (M_Sun)	1.2 ± 0.2	Atmospheric parameters + YY isochrones
Age (Gyr, 2σ)	< 7	Atmospheric parameters + YY isochrones
Distance (pc)	1100 +300 / -150	Broad-band photometry + YY isochrones
Extinction (A_V, mag)	1.1 +0.2 / -0.4	Broad-band photometry + YY isochrones

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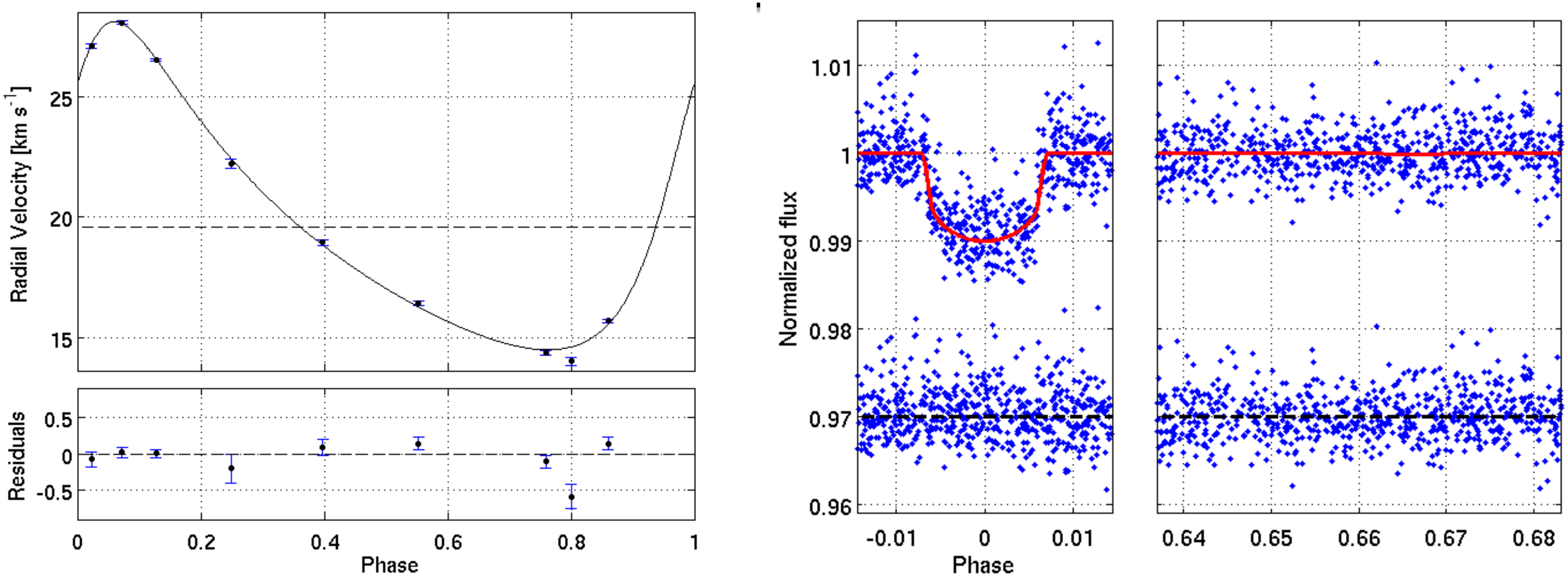
CoRoT 101186644: MCMC analysis



<u>MCMC features:</u>

1. **Simultaneous lightcurve and RVs modeling** $(\chi^2 = \chi^2_{lightcurve} + \chi^2_{RV})$
2. **12 free parameters:** $P, T_0, e\cdot cos\omega, e\cdot sin\omega, J_s, r_t, k, L_3, x, u_p, K, \gamma$
3. **Metropolis-Hastings sampling**
4. **1,000,000 accepted steps**
5. **Lightcurve model: EBOP** (Popper & Etzel 1981)

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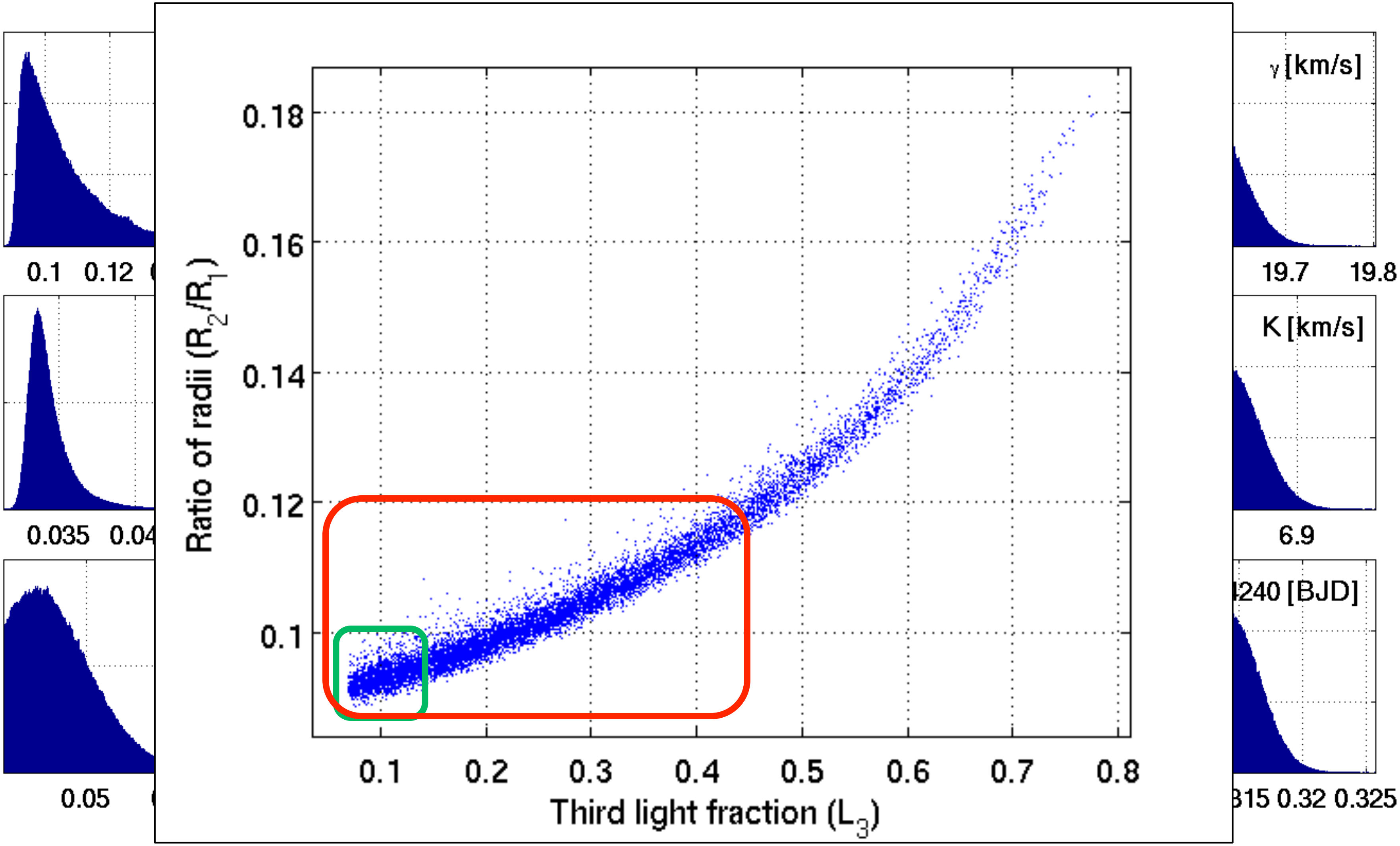

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CoRoT 101186644: MCMC analysis

Symbol	Parameter name	Value	Units
	Orbital parameters		
P	Orbital period	20.6841 ± 0.0006	day
$e\cos\omega$	Eccentricity × cosine longitude of periastron	$0.251_{-0.007}^{+0.002}$	–
$e\sin\omega$	Eccentricity × sine longitude of periastron	-0.314 ± 0.006	–
K	RV semiamplitude	6.816 ± 0.039	$\mathrm{km\,s^{-1}}$
γ	Center-of-mass RV	19.608 ± 0.038	$\mathrm{km\,s^{-1}}$
T	Time of periastron*	$2454234.31_{-0.09}^{+0.04}$	BJD
f	Mass function*	0.000522 ± 0.000010	$M_\odot$
	Photometric parameters		
T_0	Time of center of primary transit	2454240.3144 ± 0.0023	BJD
J_s	Surface-brightness ratio	$0.02_{-0.02}^{+0.04}$	–
r_t	Fractional sum of radii** (= $(R_1+R_2)/a$)	$0.0336_{-0.0004}^{+0.0019}$	–
k	Ratio of radii** (= R_2/R_1)	$0.095_{-0.001}^{+0.026}$	–
x	Impact parameter** (= $\cos i \cdot (1-e^2) \cdot r_t^{-1} \cdot (1+e\sin\omega)^{-1}$)	0.0 ± 0.2	–
L_3	Third-light (blending) fraction***	$0.10_{-0.03}^{+0.35}$	–
u_p	Limb-darkening coefficient of primary***	$0.57_{-0.01}^{+0.06}$	–
i	inclination*	90.0 ± 0.4	degree
	Parameters estimated assuming $M_1 = 1.2 \pm 0.2\,M_\odot$		
q	Mass ratio* (M_2/M_1)	0.080 ± 0.005	–
a	Semi-major axis*	0.16 ± 0.01	AU
M_2	Mass of secondary*	0.096 ± 0.011	$M_\odot$
R_1	Radius of primary*	1.07 ± 0.07	$R_\odot$
R_2	Radius of secondary*	$0.104_{-0.006}^{+0.026}$	$R_\odot$
$\log g_1$	Surface gravity of primary*	$4.47_{-0.06}^{+0.03}$	cgs

$$(M_1 f^{-1} \sin^3 i) q^3 - q^2 - 2q - 1 = 0.$$

$$R_1^3 = \frac{GP^2(M_1+M_2)}{4\pi^2}\,\frac{r_t^3}{(1+k)^3}$$

* derived analytically from the fitted parameters

** see Tamuz et al. (2006) and Mazeh et al. (2006) for the reasoning behind this definition

*** lower limit was determined by the chosen prior

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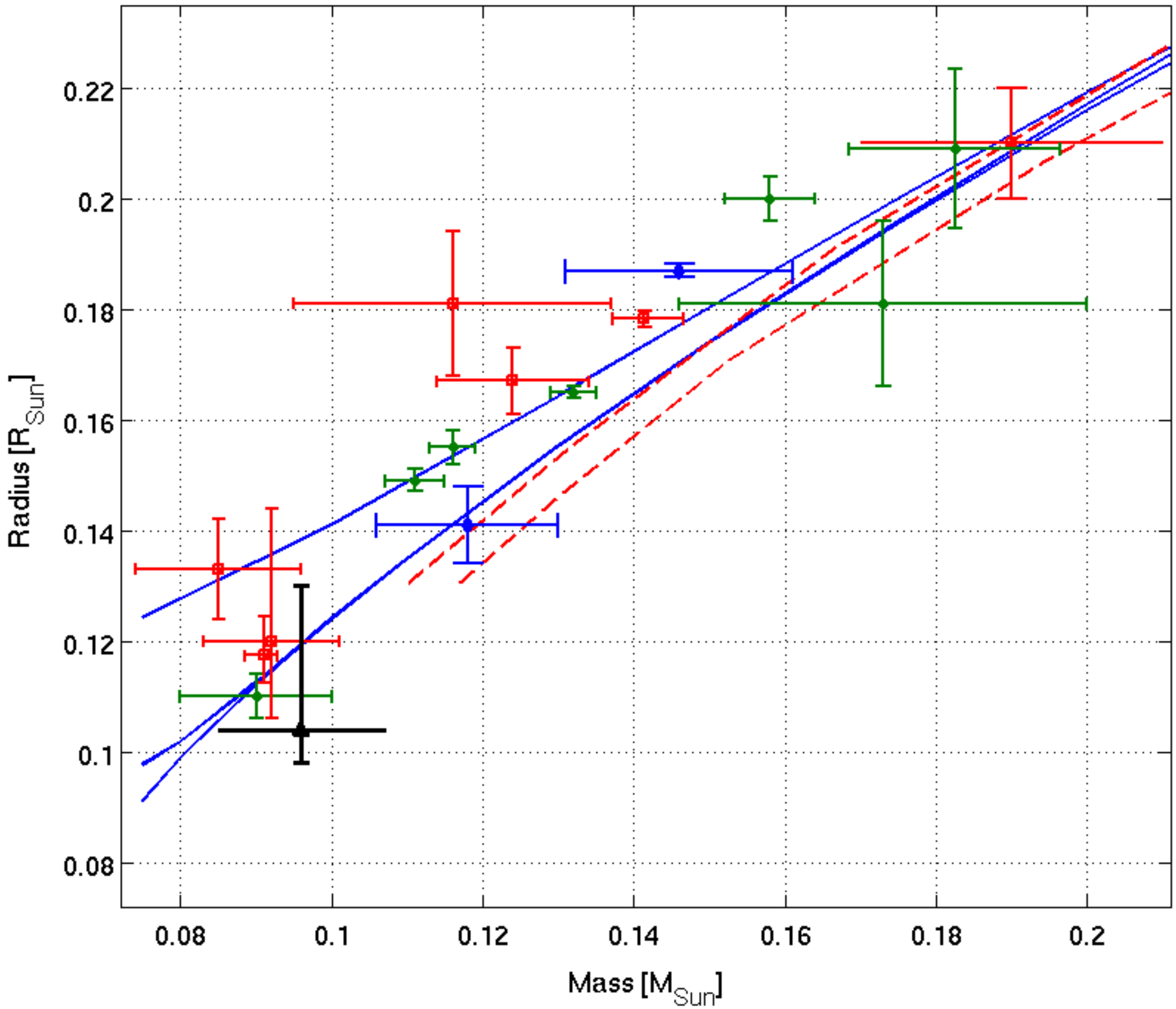
M-R relation of very low mass stars (VLMS)



Star name (by mass)
OGLE-TR 123 B
SDSS 0857+03 B
J1219-39 B
OGLE-TR 122 B
C4780 B
NN Ser B
GK Vir B
OGLE-TR 106 B
GJ 551
HAT-TR-205-013 B
SDSS 0138-00 B
KIC 1571511 B
GJ 699
SDSS 1210+33 B
SDSS 1548+40 B
RR Cae B
2MASS 0446+19 B

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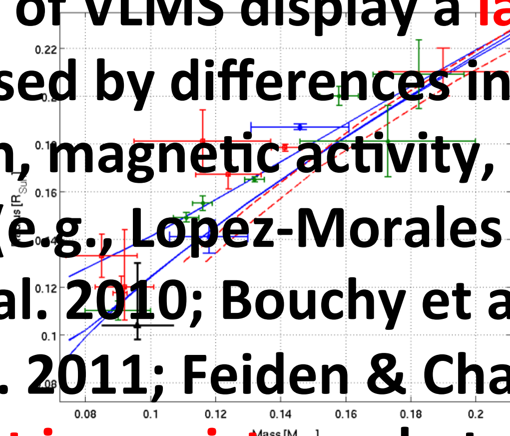
Conclusions

1. **C4780 B might be the smallest main sequence star ever detected.**
2. **Further investigation of the blending fraction (L_3) might reduce the uncertainties on its radius.**
3. **The models of VLMS display a large theoretical spread, caused by differences in age, metallicity, fast rotation, magnetic activity, strong irradiation, and clouds (e.g., Lopez-Morales 2007; Chabrier et al. 2007; Morales et al. 2010; Bouchy et al. 2011; Burrows et al. 2011; Knigge et al. 2011; Feiden & Chaboyer 2012).**



4. **No apparent inconsistency between the observed systems and the available theory can be deduced.**
5. **Complete and homogeneous analysis of low mass M dwarfs that were detected by CoRoT and *Kepler* might help understanding the astrophysics close to the low end of the main sequence.**

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4. No apparent inconsistency between the observed systems and the available theory can be deduced.
5. Complete and homogeneous analysis of low mass M dwarfs that were detected by CoRoT and *Kepler* might enhance our understanding of the astrophysics close to the low end of the main sequence.

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