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Characterisation of the interior structures and atmospheres of multiplanetary systems

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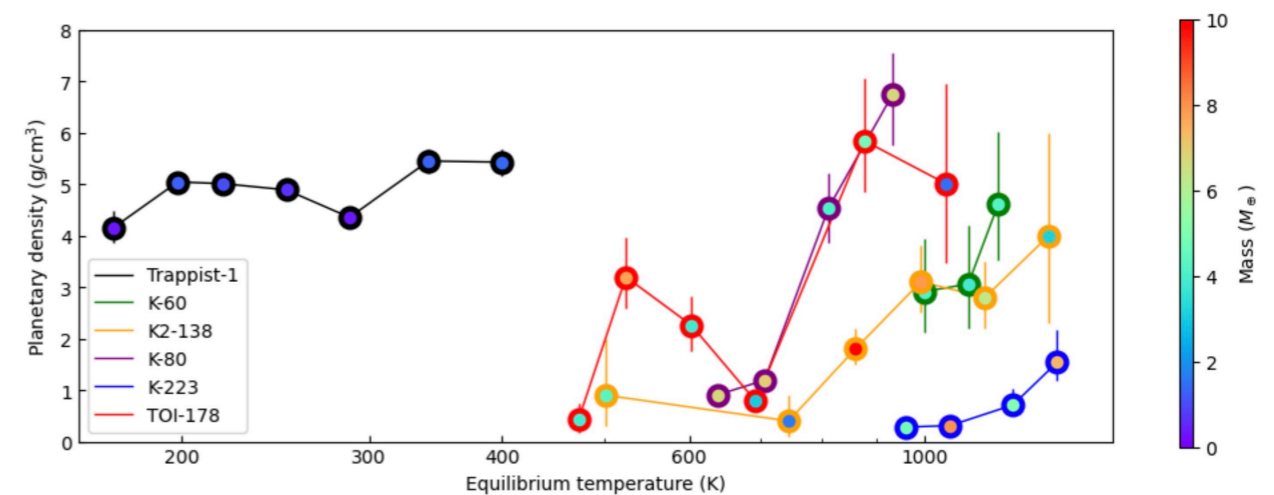
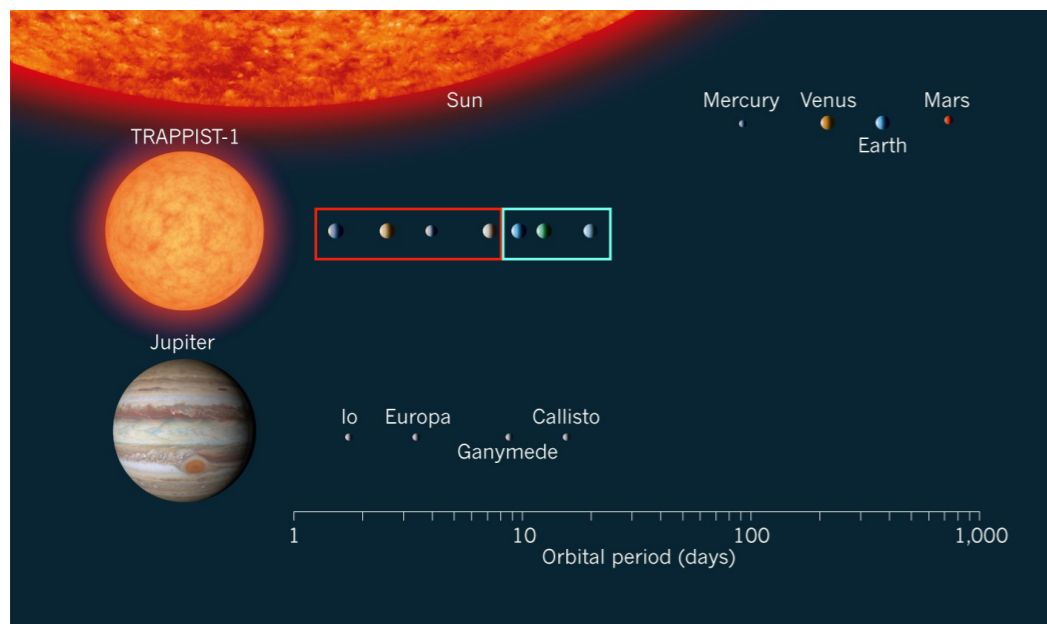
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PLATO conference 2021



Introduction

- TRAPPIST-1 (Acuña+ 21, Agol+ 20), TOI-178 (Leleu+ 21):



Leleu+ 21

- Multiplanetary systems are environments suitable to explore the compositional diversity of low-mass planets, their formation and evolution

Interior structure model

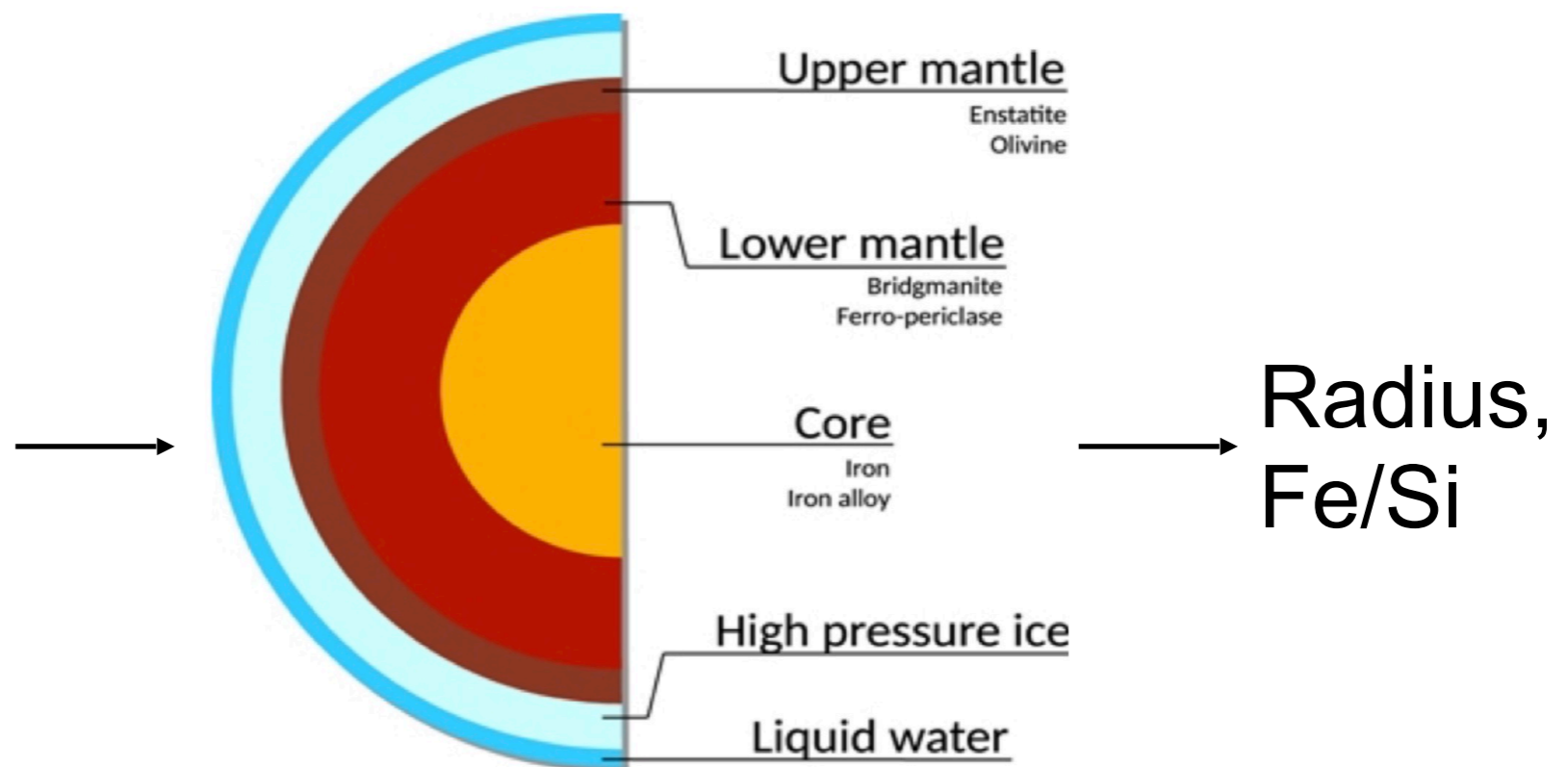
- Bruggen+ 16, 17:

Mass

Core Mass
Fraction (CMF)

Water Mass
Fraction (WMF)

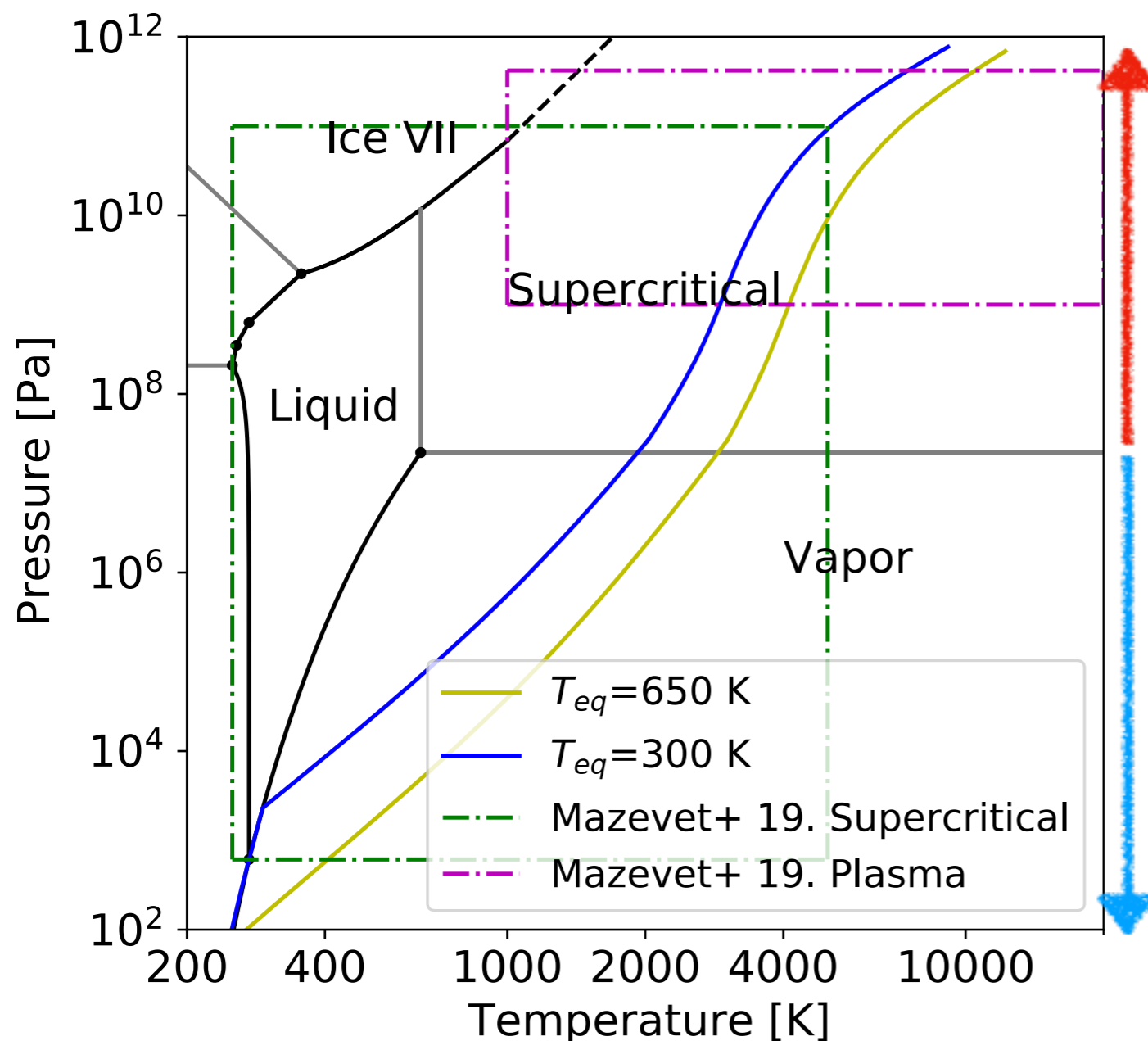
Surface
pressure and
temperature



Pressure $P(r)$
Gravity $g(r)$
Temperature $T(r)$
Density $\rho(r)$

Interior-atmosphere coupling

- Water phase diagram:



- Supercritical: Mousis+ 20. EOS from Mazevet+ 19
- Atmosphere model: Pluriel+19, Marcq+17
- Coupling algorithm: Acuña+ 21

Multiplanetary systems

- Low-mass planets ($M < 20 M_{\oplus}$)
- Systems with 5 or more planets

TRAPPIST-1

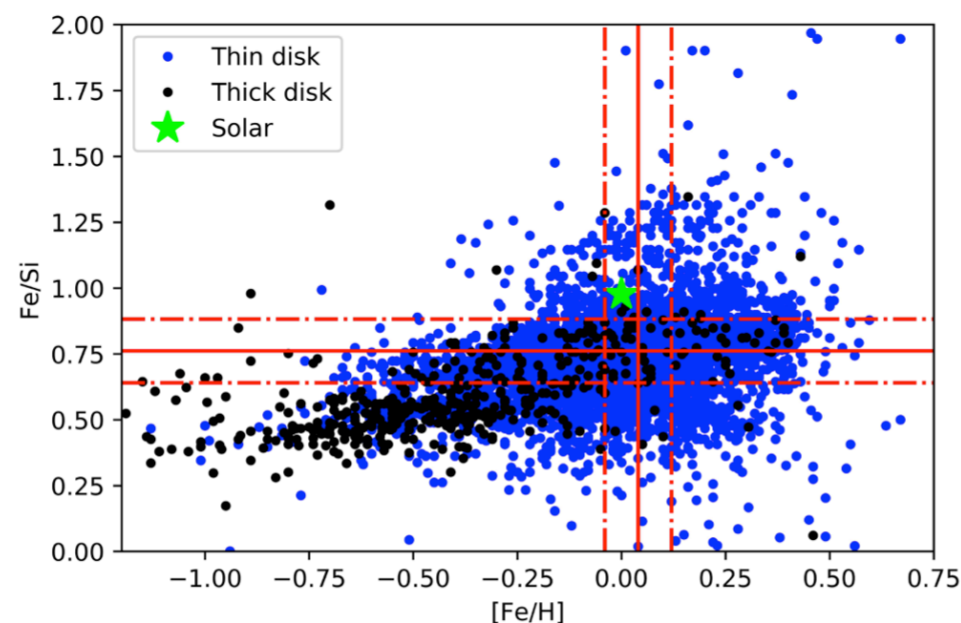
K2-138

TOI-178

Kepler-11

Kepler-102

Kepler-80



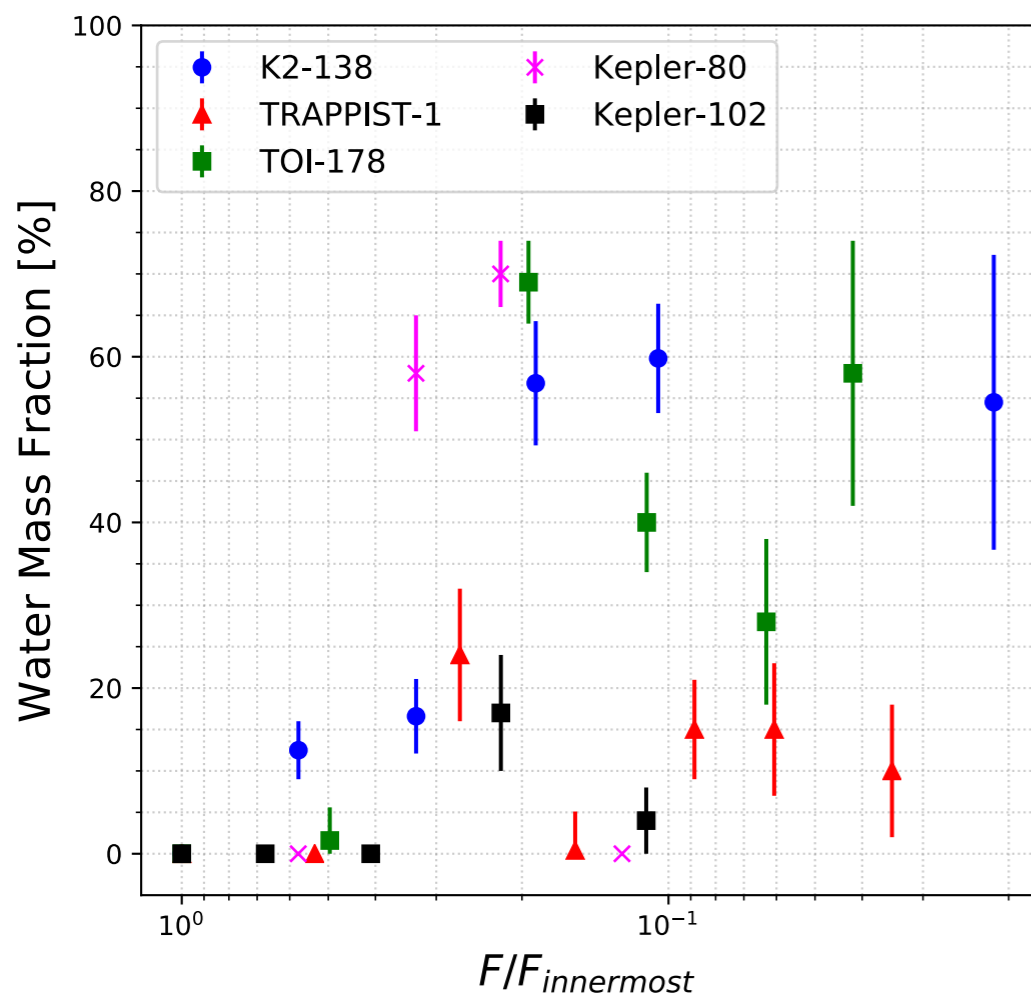
Masses, radii and stellar abundances



MCMC Bayesian algorithm
(Dorn+ 15, Acuña+ 21)

Results

WMF in multiplanetary systems



Gradient + plateau trend

System	Planet	CMF	WMF	Significance	$\Delta M_{H_2} [M_{\oplus}]$
TOI-178	b	0.21 ± 0.30	0	$< 1 \sigma$	0.83
	c	0.30 ± 0.02	$0.02^{+0.04}_{-0.02}$	$< 1 \sigma$	< 0.01
	d	0.10 ± 0.01	0.69 ± 0.05	1.3σ	0.16
	e	0.18 ± 0.02	0.40 ± 0.06	$< 1 \sigma$	< 0.01
	f	0.22 ± 0.03	0.28 ± 0.10	$< 1 \sigma$	< 0.01
	g	0.10 ± 0.01	0.58 ± 0.16	3.0σ	< 0.01
	Kepler-11	b	0.20 ± 0.04	0.27 ± 0.10	$< 1 \sigma$
c		0.18 ± 0.01	0.33 ± 0.04	1.7σ	< 0.01
d		0.10 ± 0.02	0.65 ± 0.05	2.4σ	< 0.01
e		0.12 ± 0.01	0.55 ± 0.04	4.4σ	< 0.01
f		0.14 ± 0.06	0.47 ± 0.10	1.9σ	0.56
Kepler-102		b	$0.91^{+0.09}_{-0.16}$	0	$< 1 \sigma$
	c	$0.95^{+0.05}_{-0.30}$	0	$< 1 \sigma$	0.10
	d	0.80 ± 0.14	0	$< 1 \sigma$	< 0.01
	e	0.22 ± 0.02	0.17 ± 0.07	$< 1 \sigma$	0.01
	f	0.27 ± 0.09	0.04 ± 0.04	$< 1 \sigma$	0.02
	Kepler-80	d	$0.97^{+0.03}_{-0.05}$	0	$< 1 \sigma$
e		0.43 ± 0.18	0	$< 1 \sigma$	< 0.01
b		0.13 ± 0.02	0.58 ± 0.07	$< 1 \sigma$	< 0.01
c		0.09 ± 0.01	0.70 ± 0.04	$< 1 \sigma$	< 0.01
g		0.31 ± 0.02	$< 1.5 \times 10^{-3}$	$< 1 \sigma$	140

Trend deviations case by case

Conclusion

- Our **interior structure model** can be applied to low-mass planets at a **wide range of irradiations**.
- We obtain a clear **increasing water content with distance from host star + a plateau** for several multiplanetary systems.
- These trend could be shaped by **atmospheric escape, migration type I and pebble accretion in the vicinity of the ice line**.
- We analyse case-by-case those planets that do not fit the trend. We are able to explain these cases with either **Jeans atmospheric escape, H/He envelopes or high-CMF forming processes**, such as mantle evaporation, collisions or formation in the vicinity of the rocklines.

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