

AN INTERIOR MODEL TO BREAK THE COMPOSITION DEGENERACY FOR SUPER-EARTHS

Bastien BRUGGER

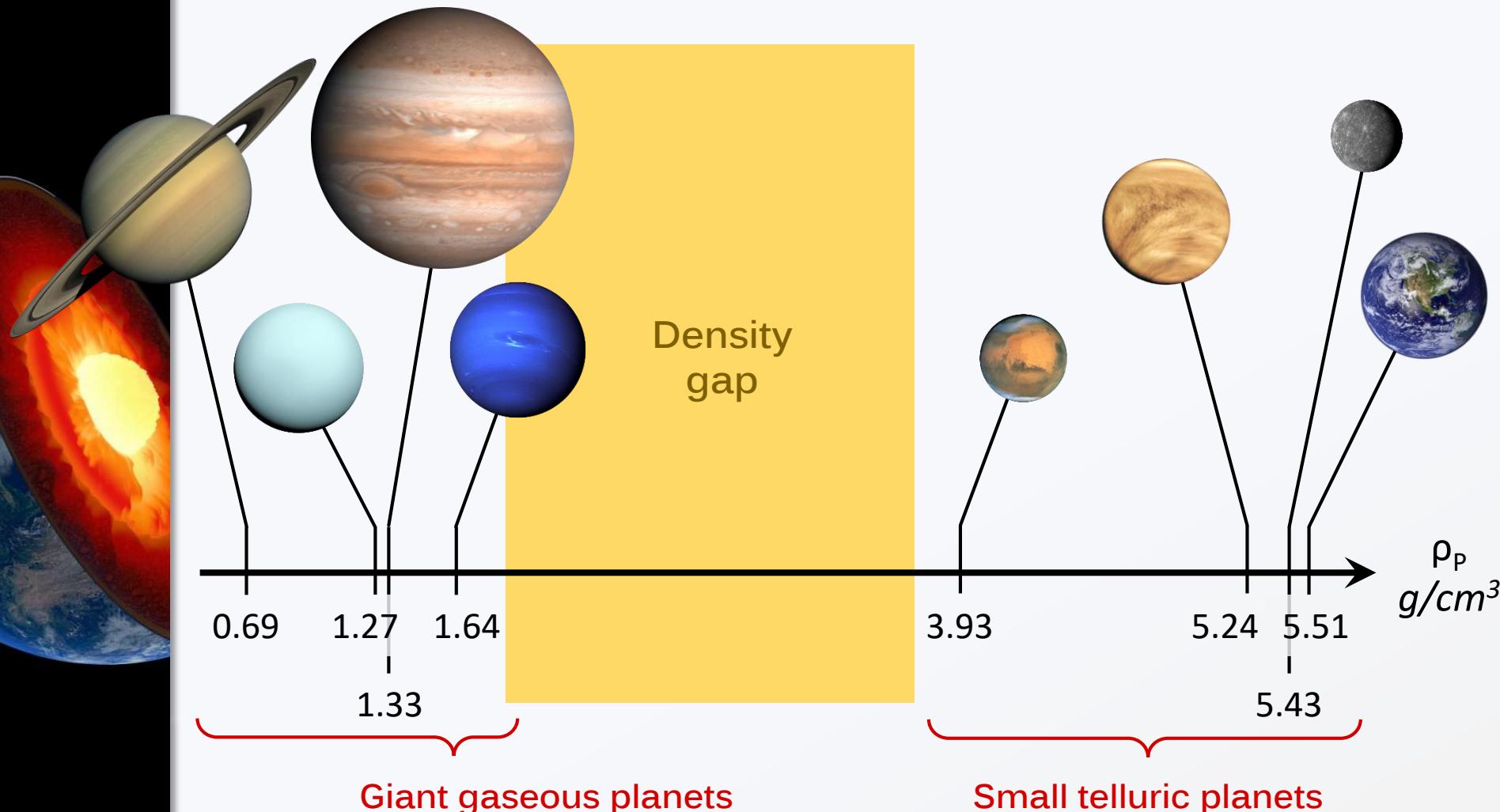
with Olivier MOUSIS

Magali DELEUIL

Frédéric DESCHAMPS

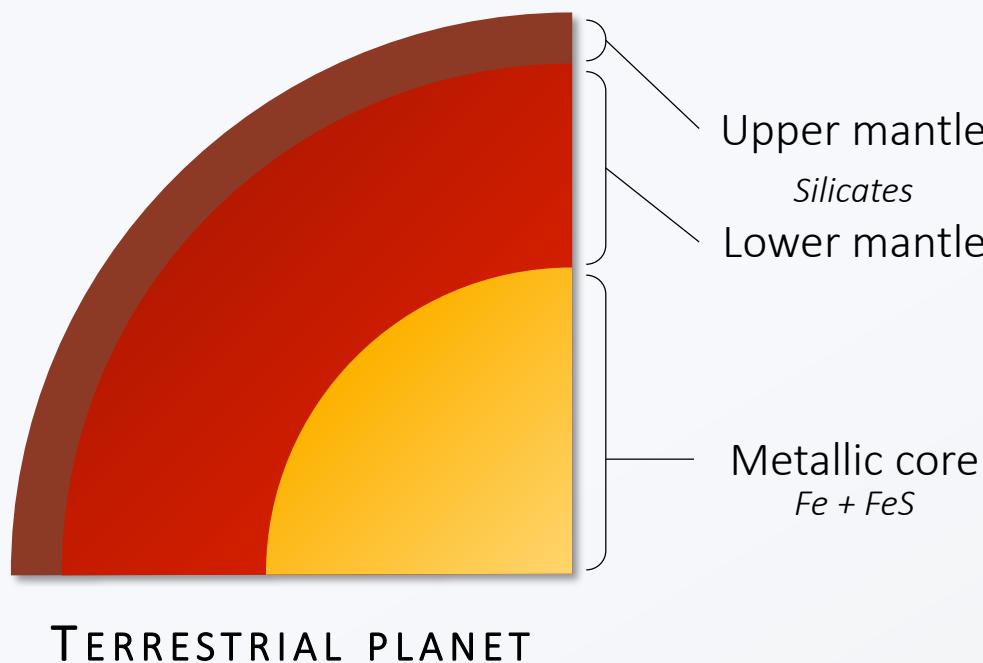
DETECTING EXOPLANETS

Planet composition from density



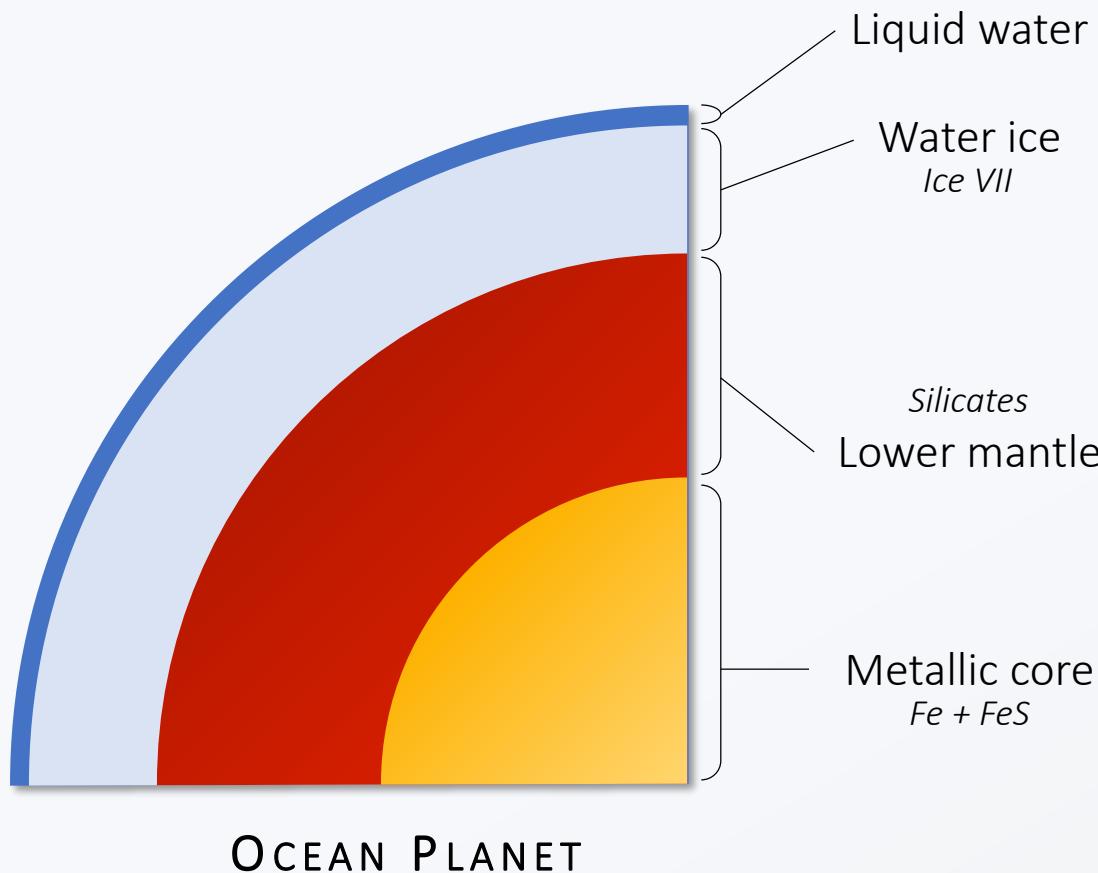
MODELLING PLANET INTERIORS

Earth as a reference model



MODELLING PLANET INTERIORS

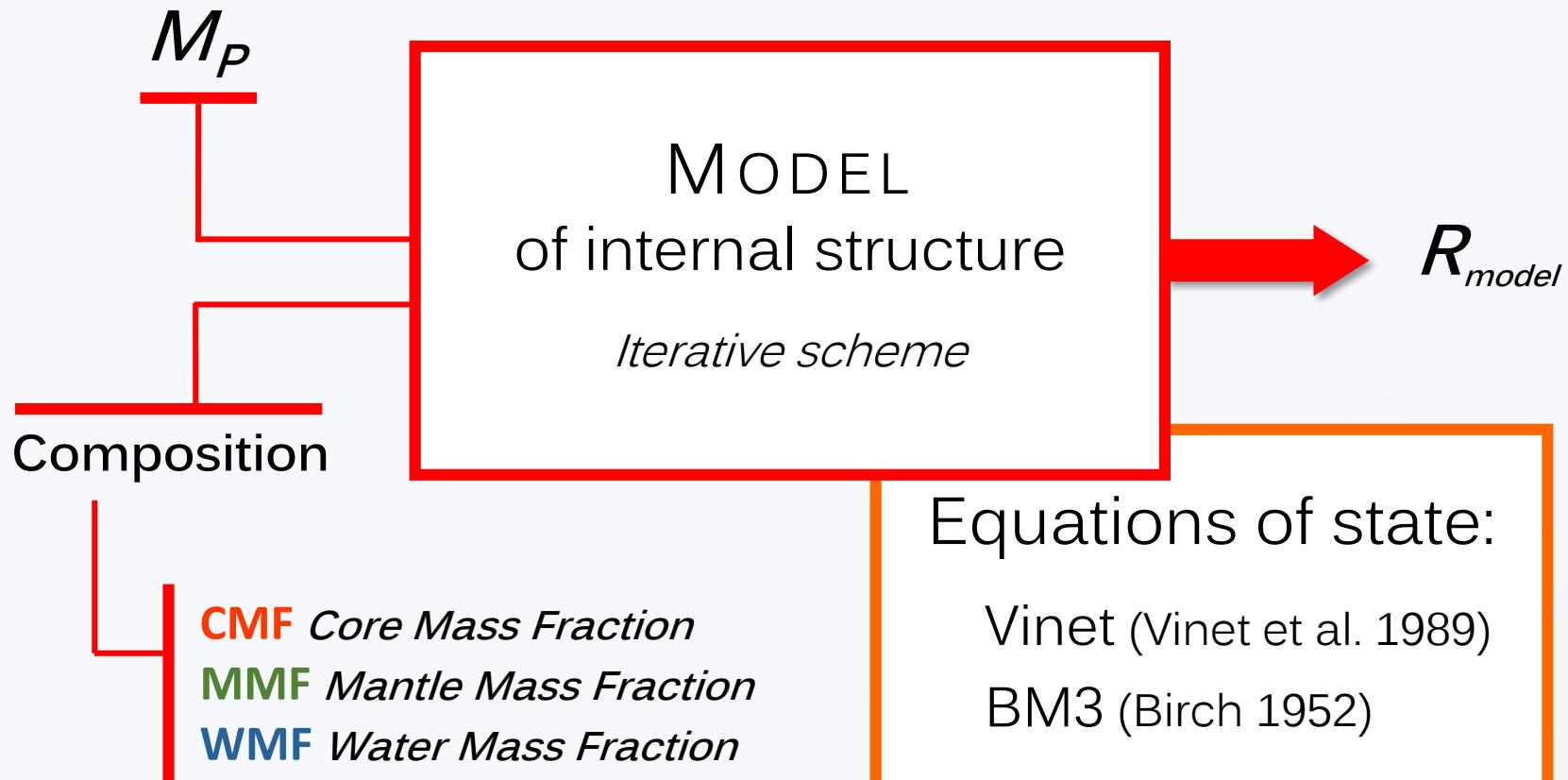
Earth as a reference model



MODELLING PLANET INTERIORS

Model inputs and scheme

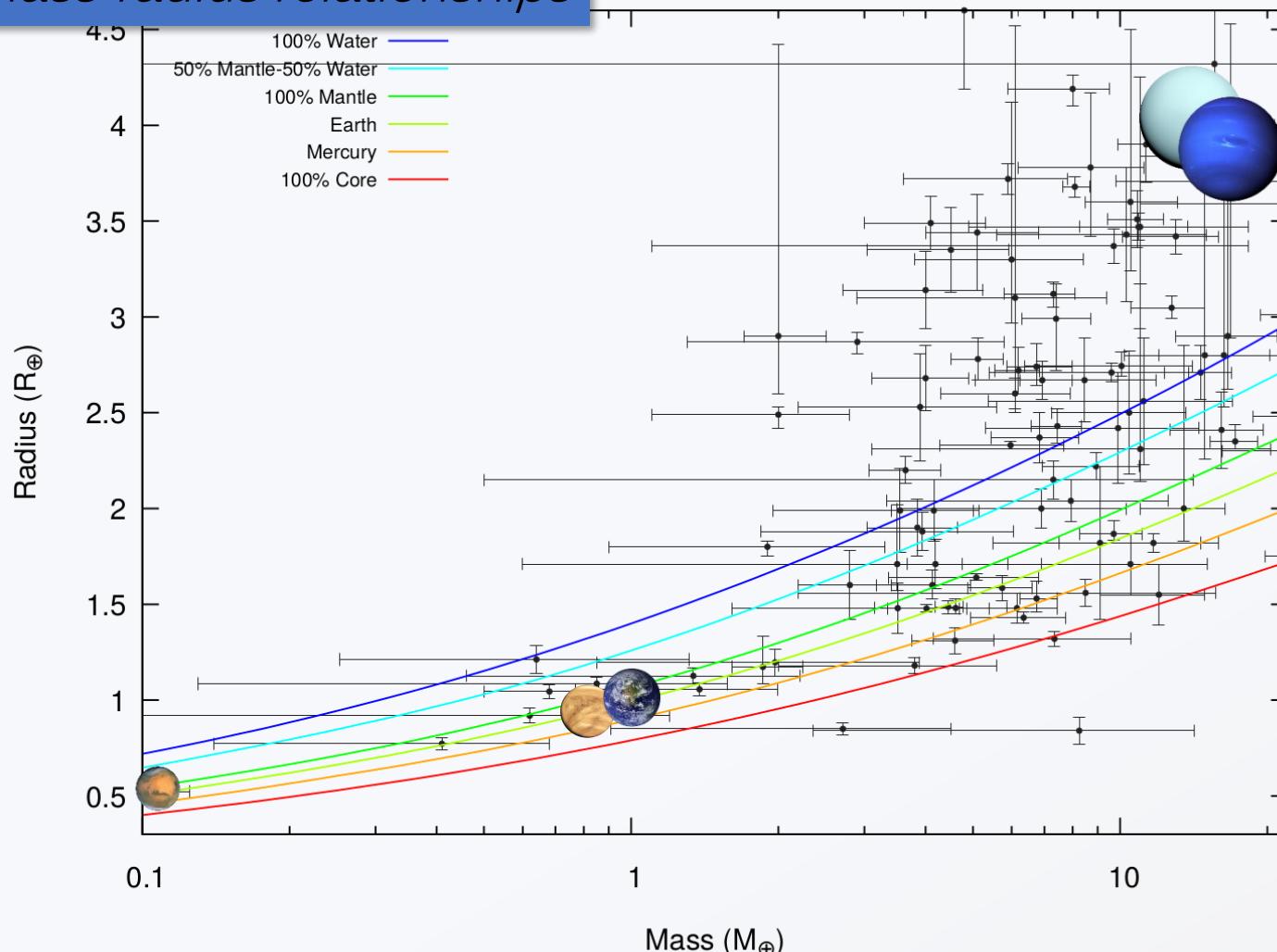
Based on Sotin et al. (2007)



MODELLING PLANET INTERIORS

Mass-radius relationships

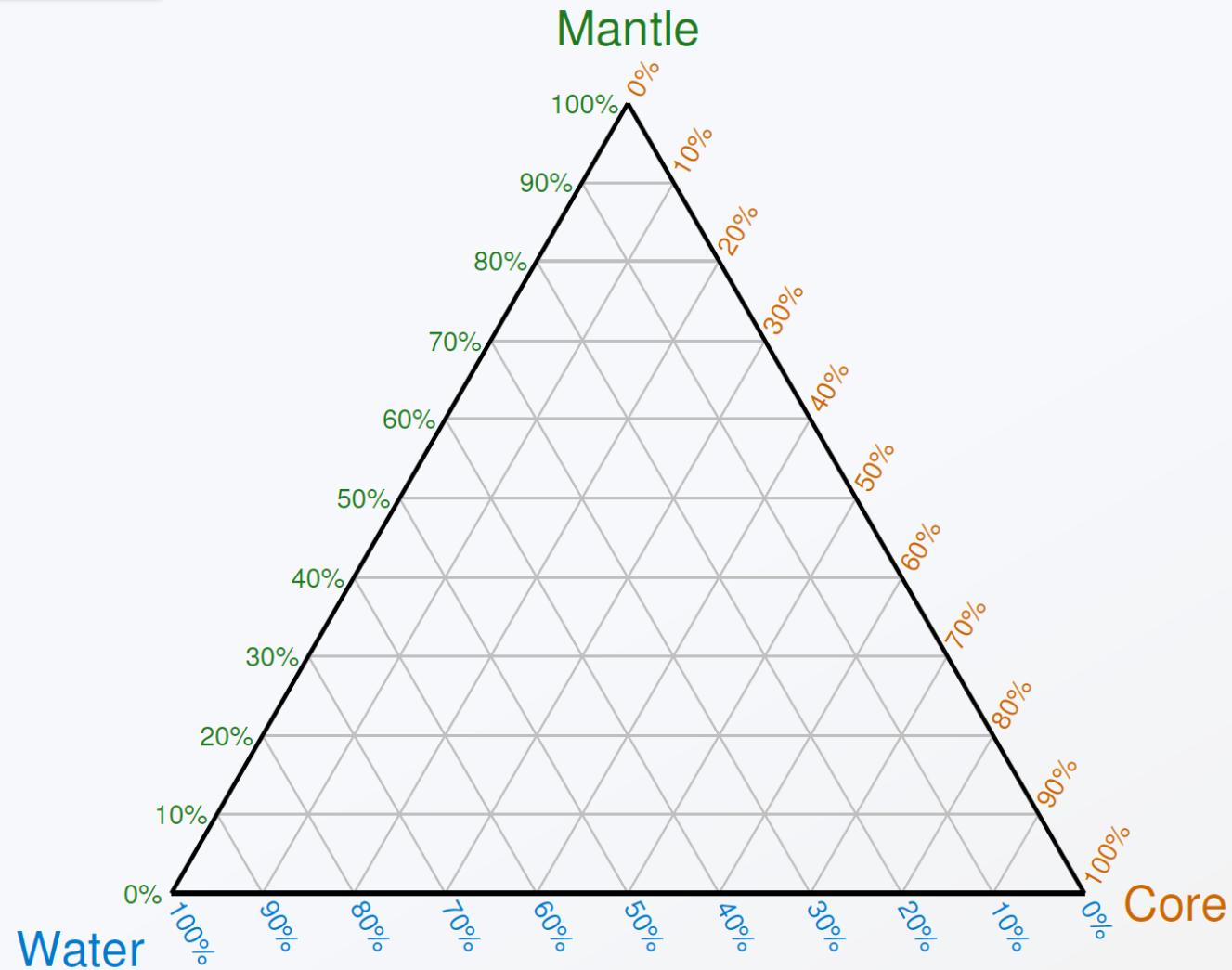
Brugger et al. (*submitted*)



more accurate curves compared to previous models

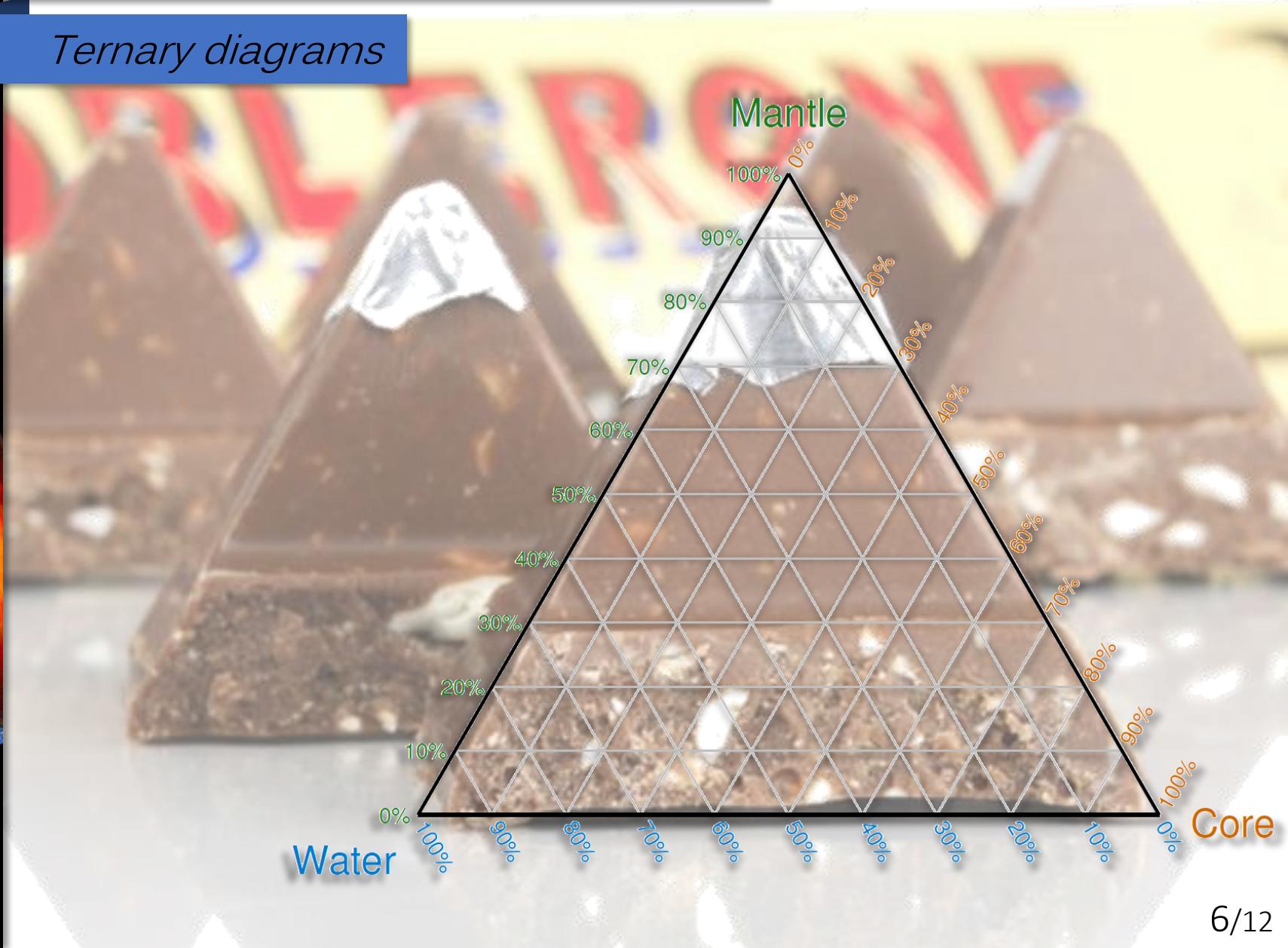
MODELLING PLANET INTERIORS

Ternary diagrams



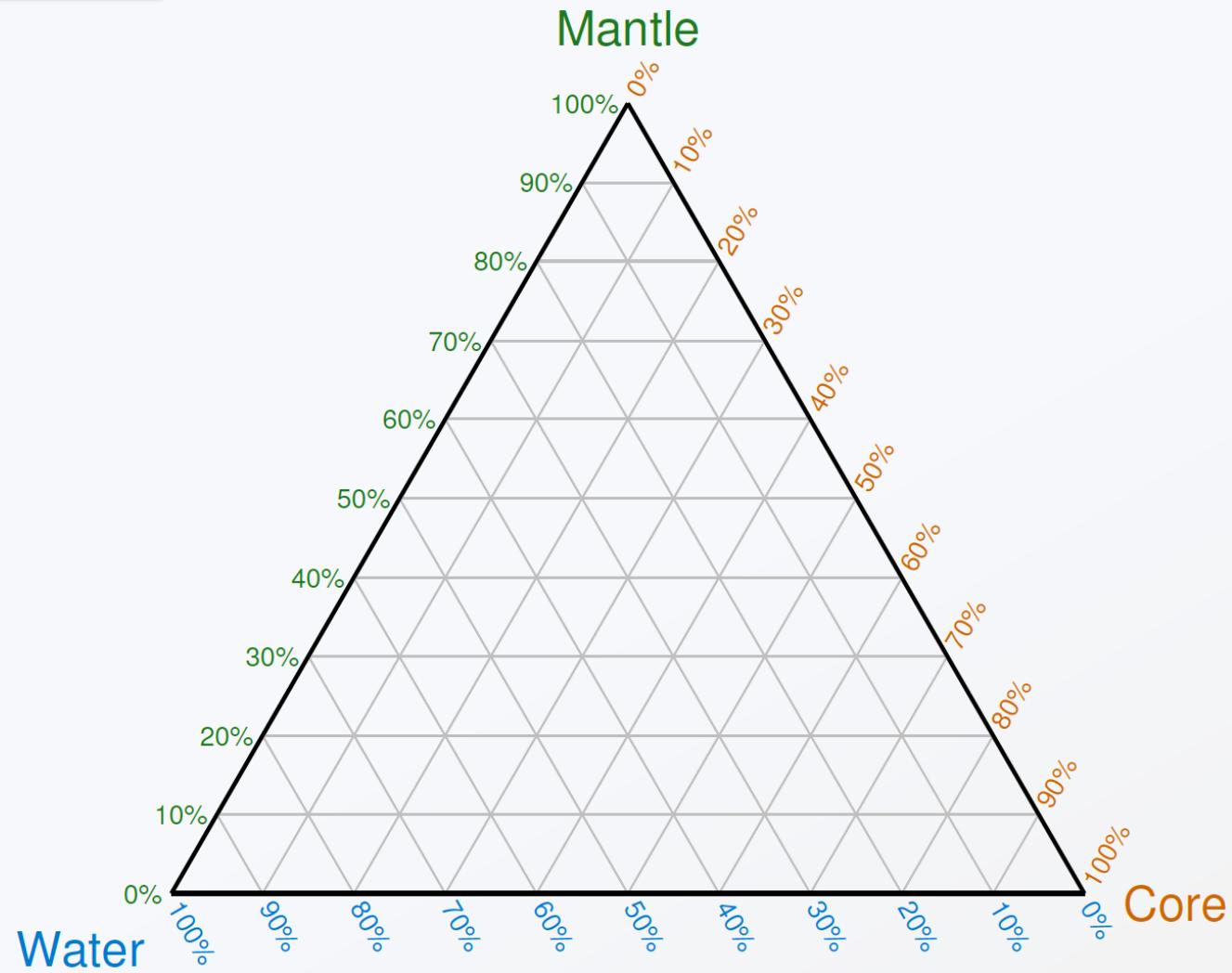
MODELLING PLANET INTERIORS

Ternary diagrams



MODELLING PLANET INTERIORS

Ternary diagrams



Valencia et al. (2007)

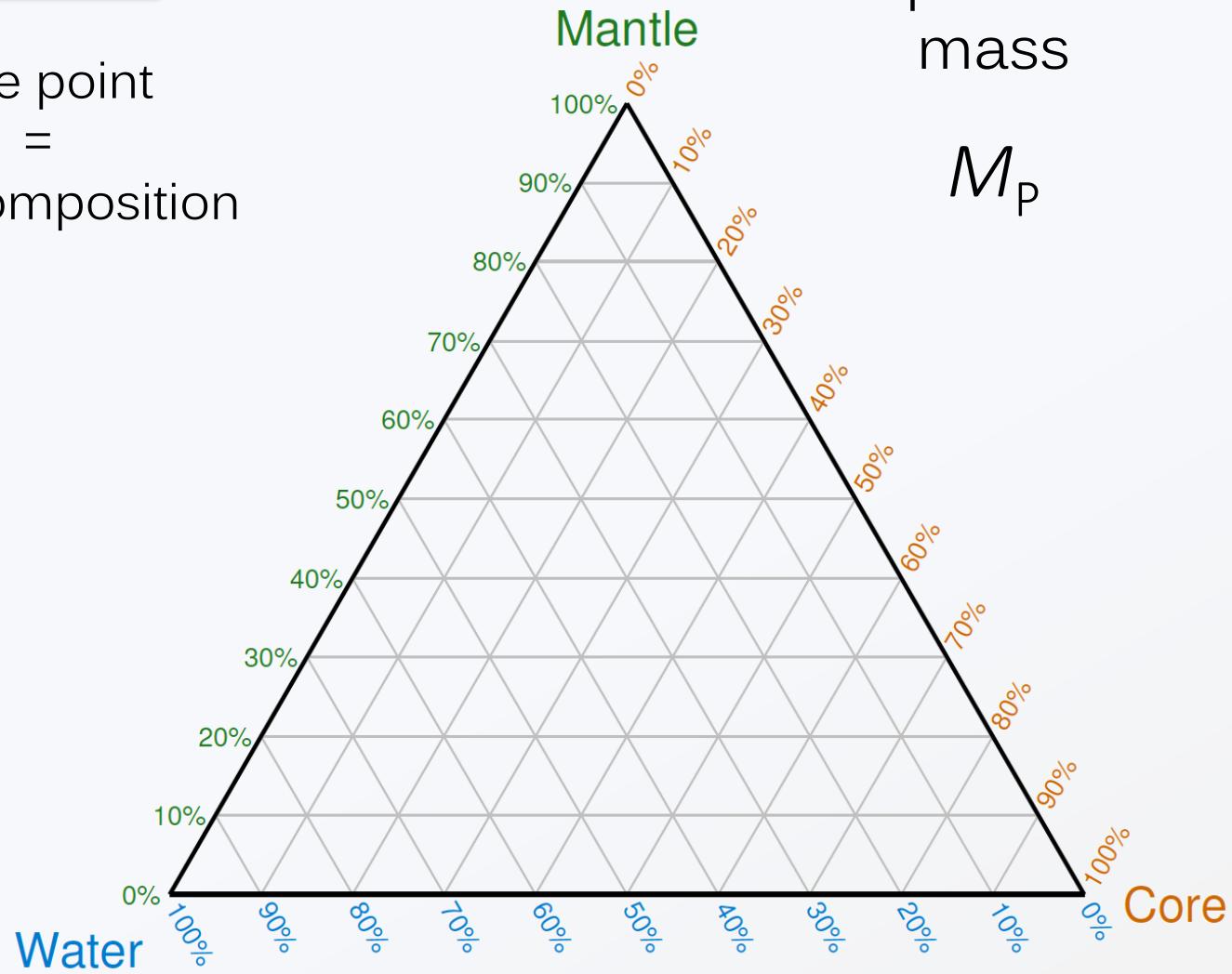
6/12

MODELLING PLANET INTERIORS

Ternary diagrams

One point
=
One composition

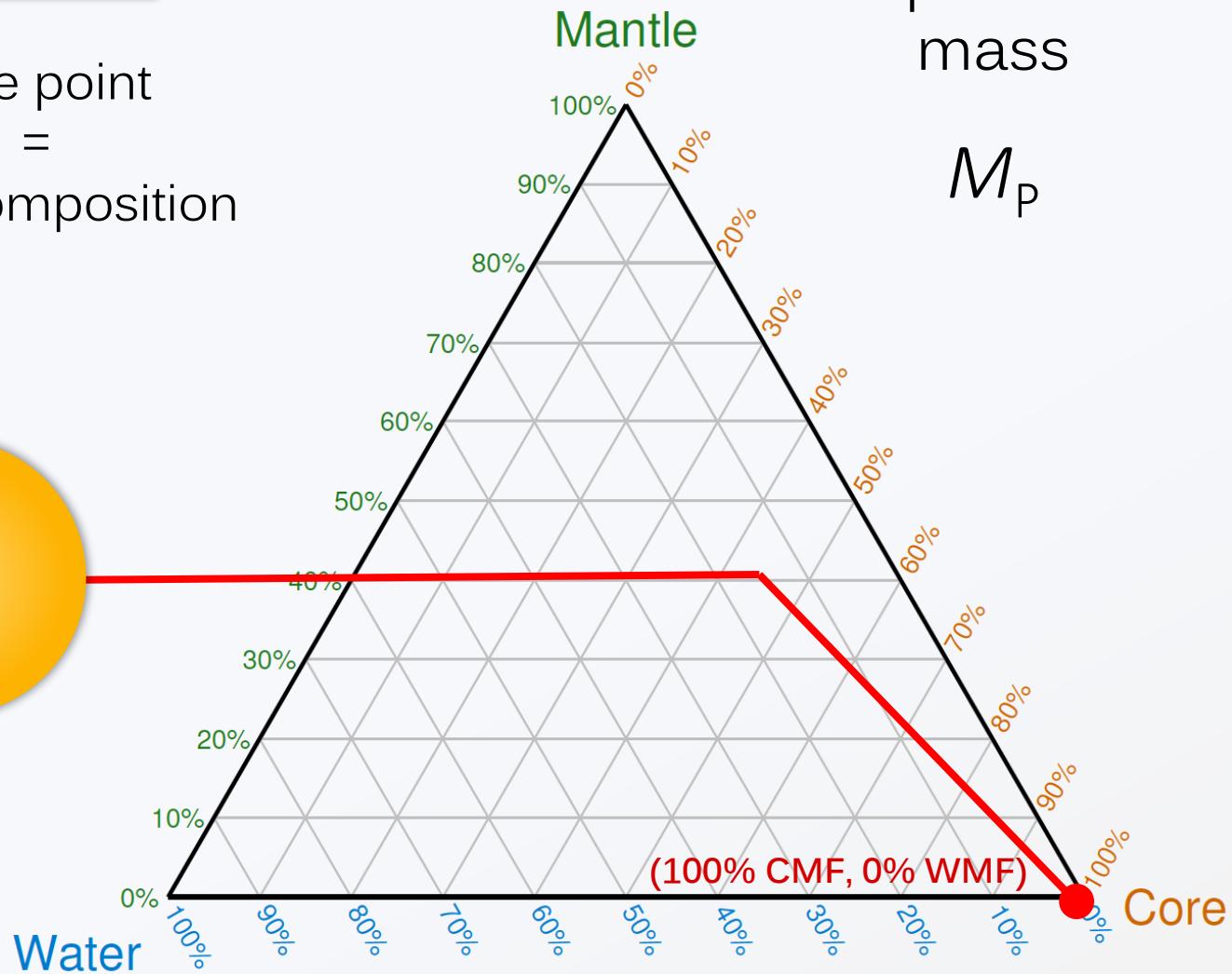
Fixed
planet
mass
 M_P



MODELLING PLANET INTERIORS

Ternary diagrams

One point
=
One composition



Fixed
planet
mass

M_P

MODELLING PLANET INTERIORS

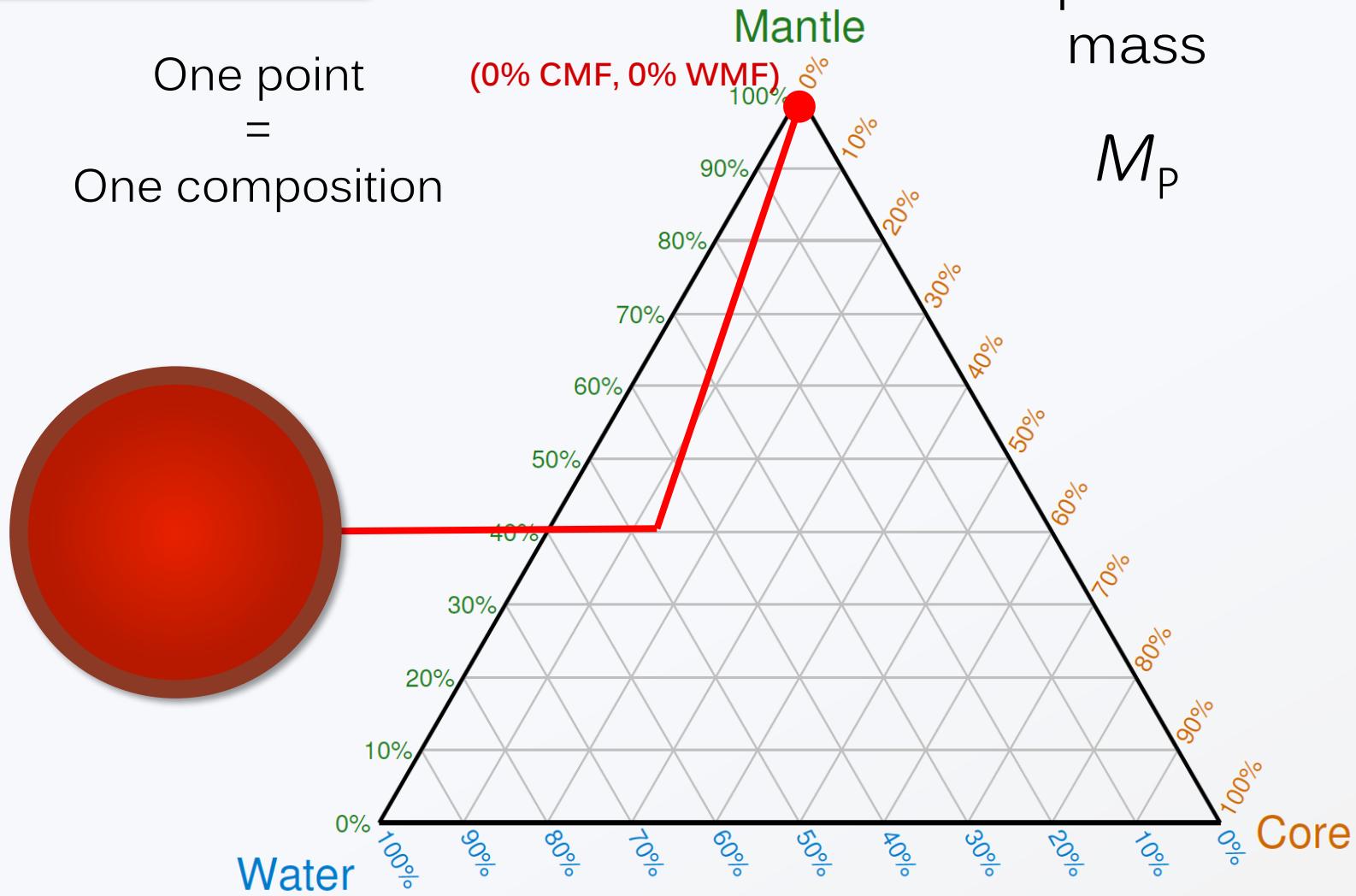
Ternary diagrams

One point
=
One composition

Mantle
(0% CMF, 0% WMF)

Fixed
planet
mass

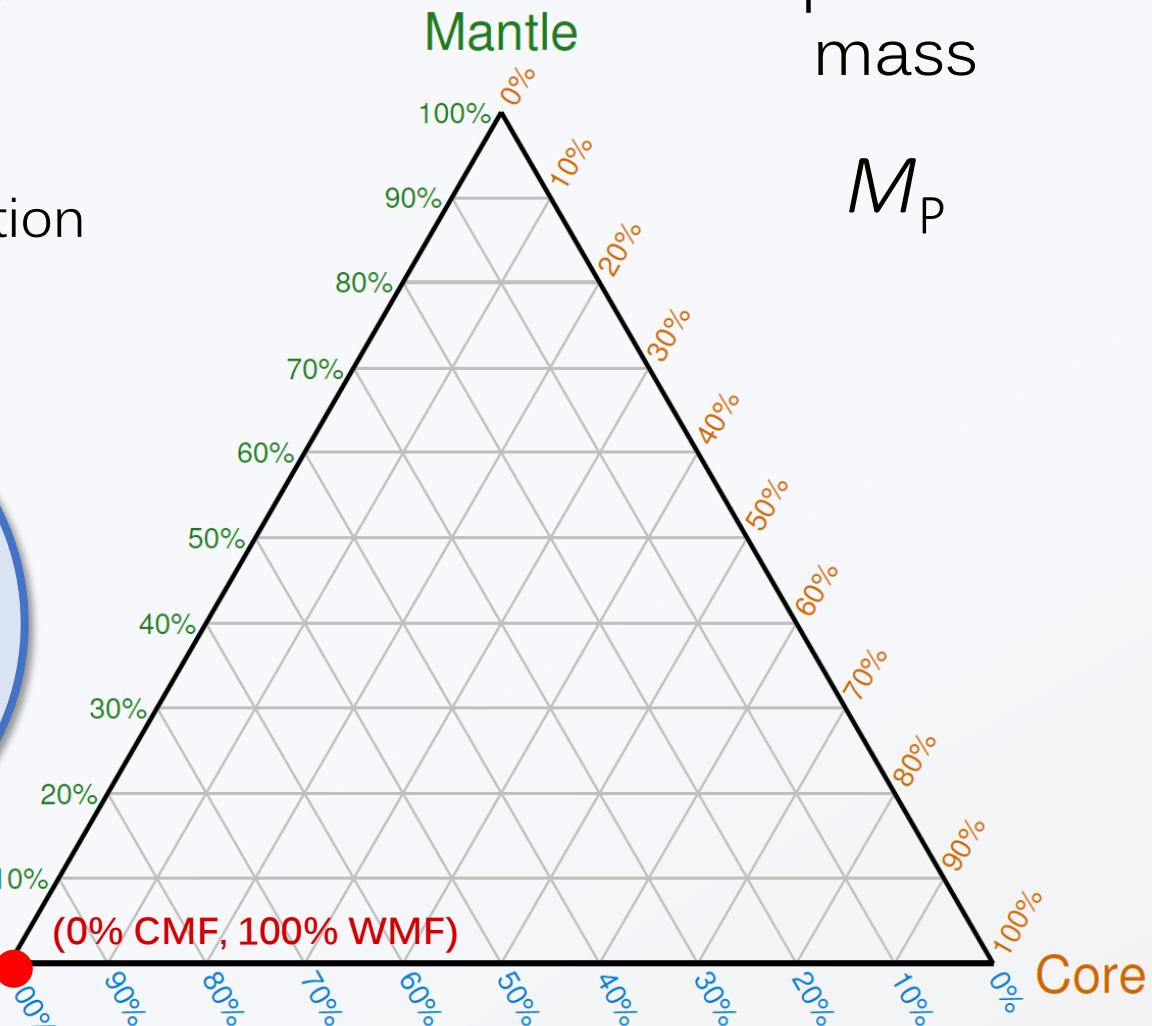
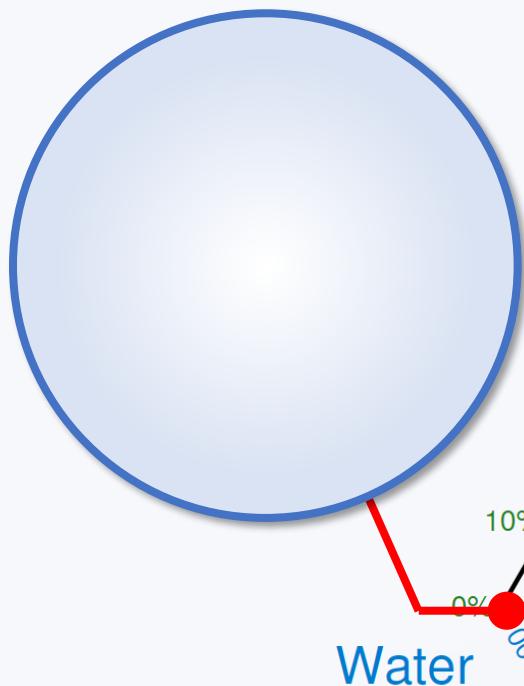
M_P



MODELLING PLANET INTERIORS

Ternary diagrams

One point
=
One composition

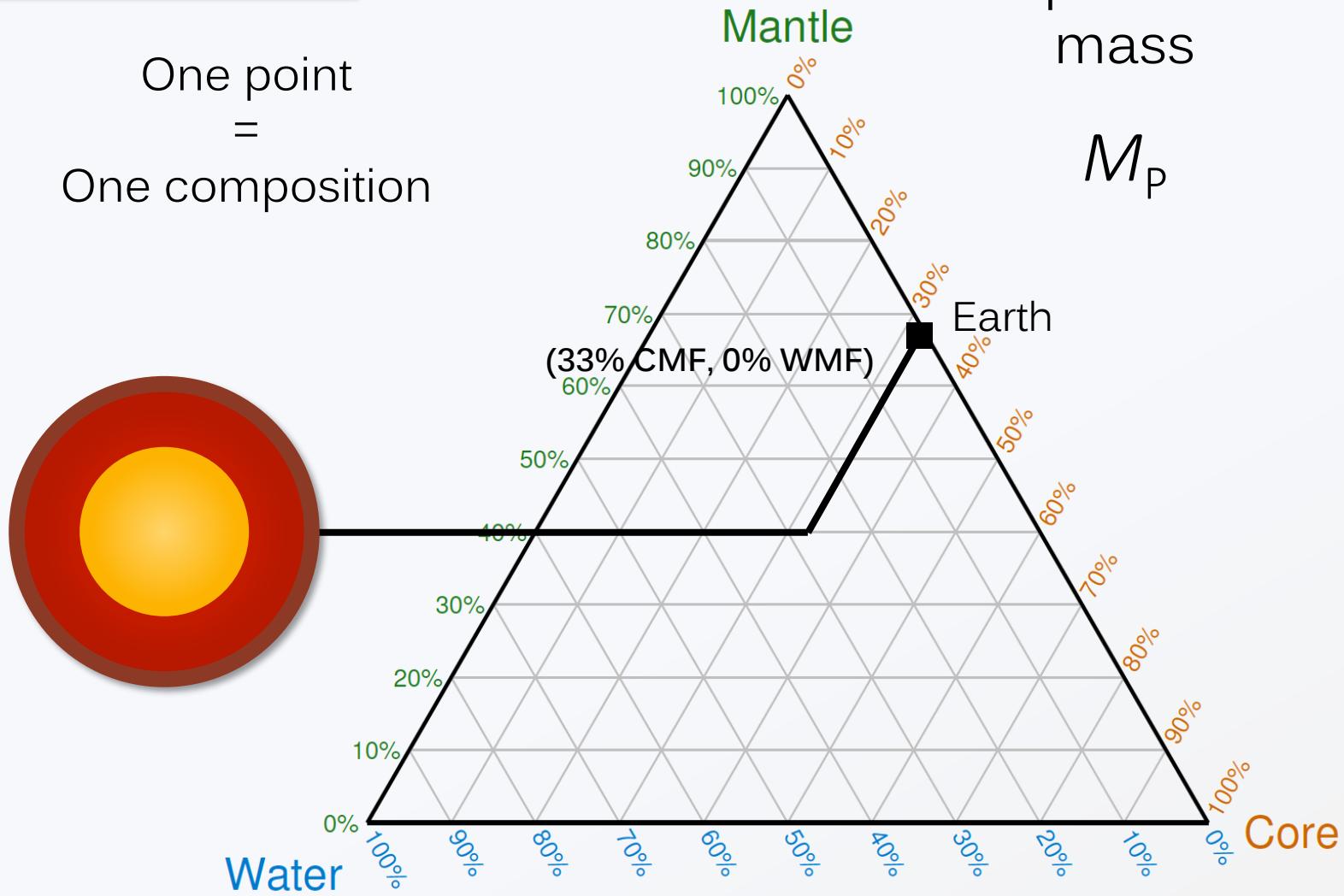


MODELLING PLANET INTERIORS

Ternary diagrams

One point
=

One composition



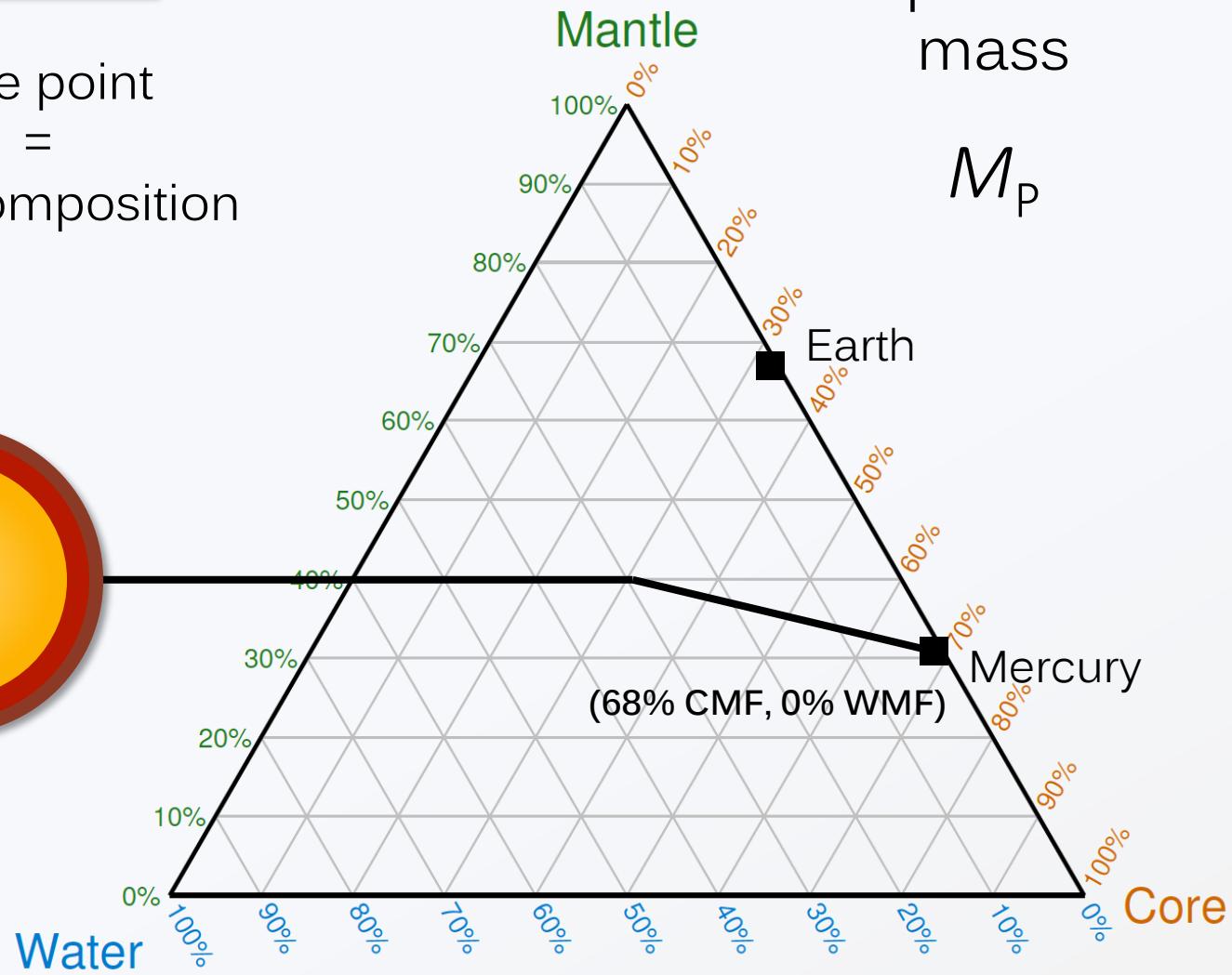
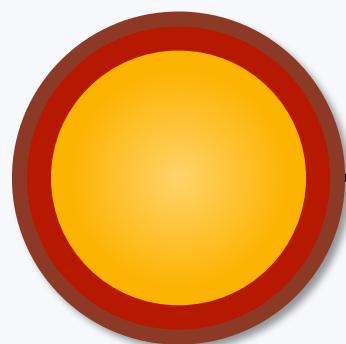
Fixed planet mass

M_P

MODELLING PLANET INTERIORS

Ternary diagrams

One point
=
One composition

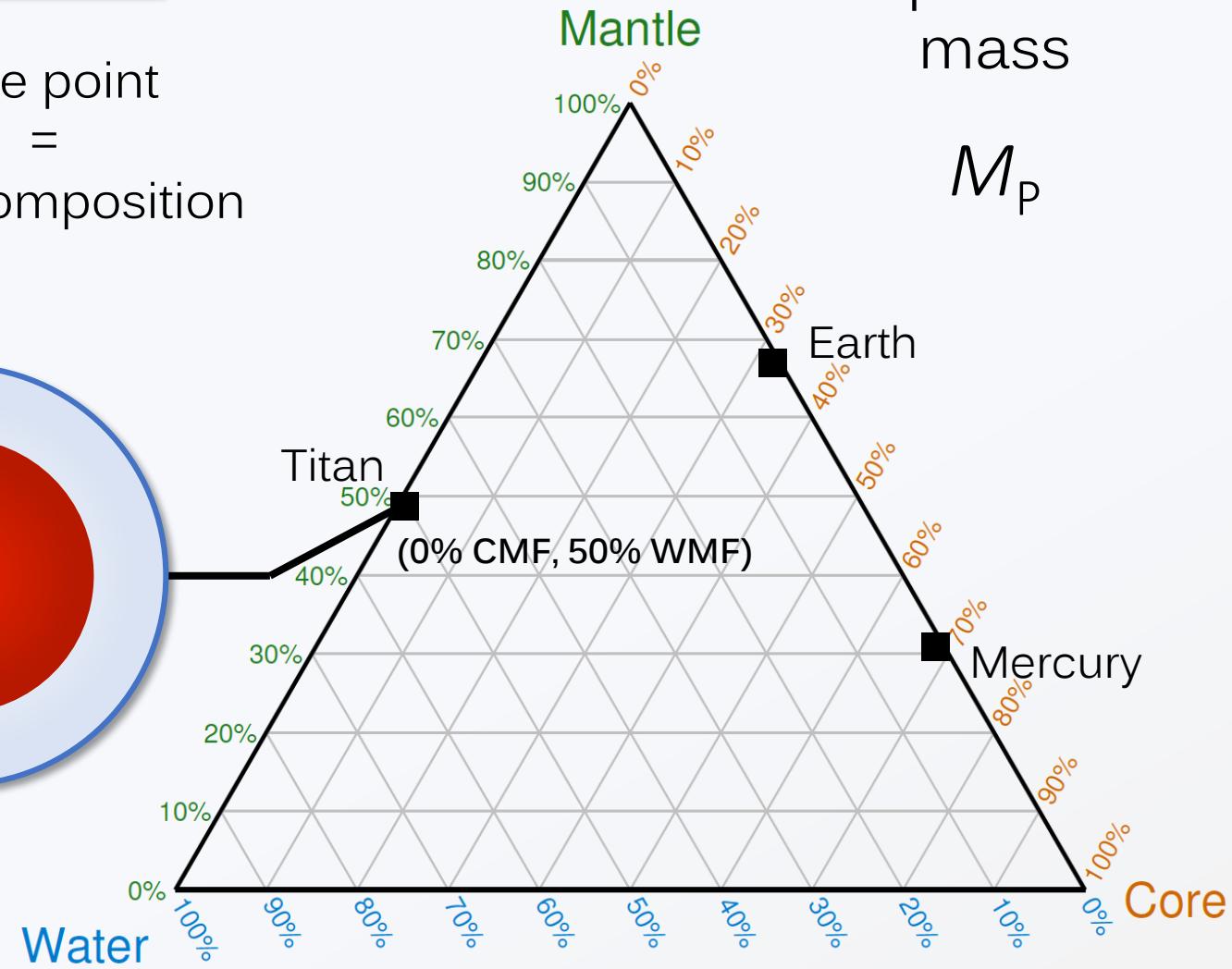


MODELLING PLANET INTERIORS

Ternary diagrams

One point
=

One composition

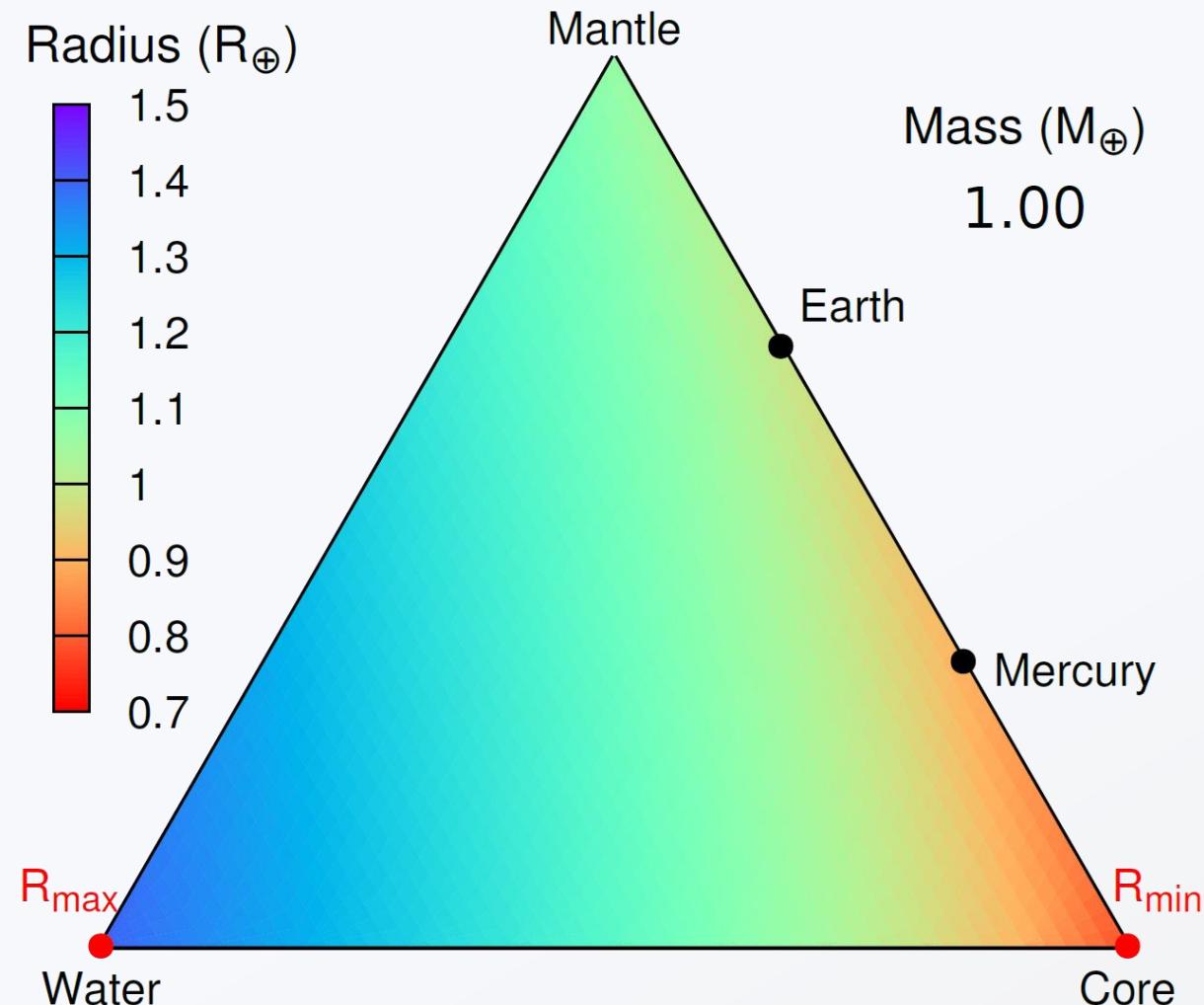


Fixed planet mass

M_P

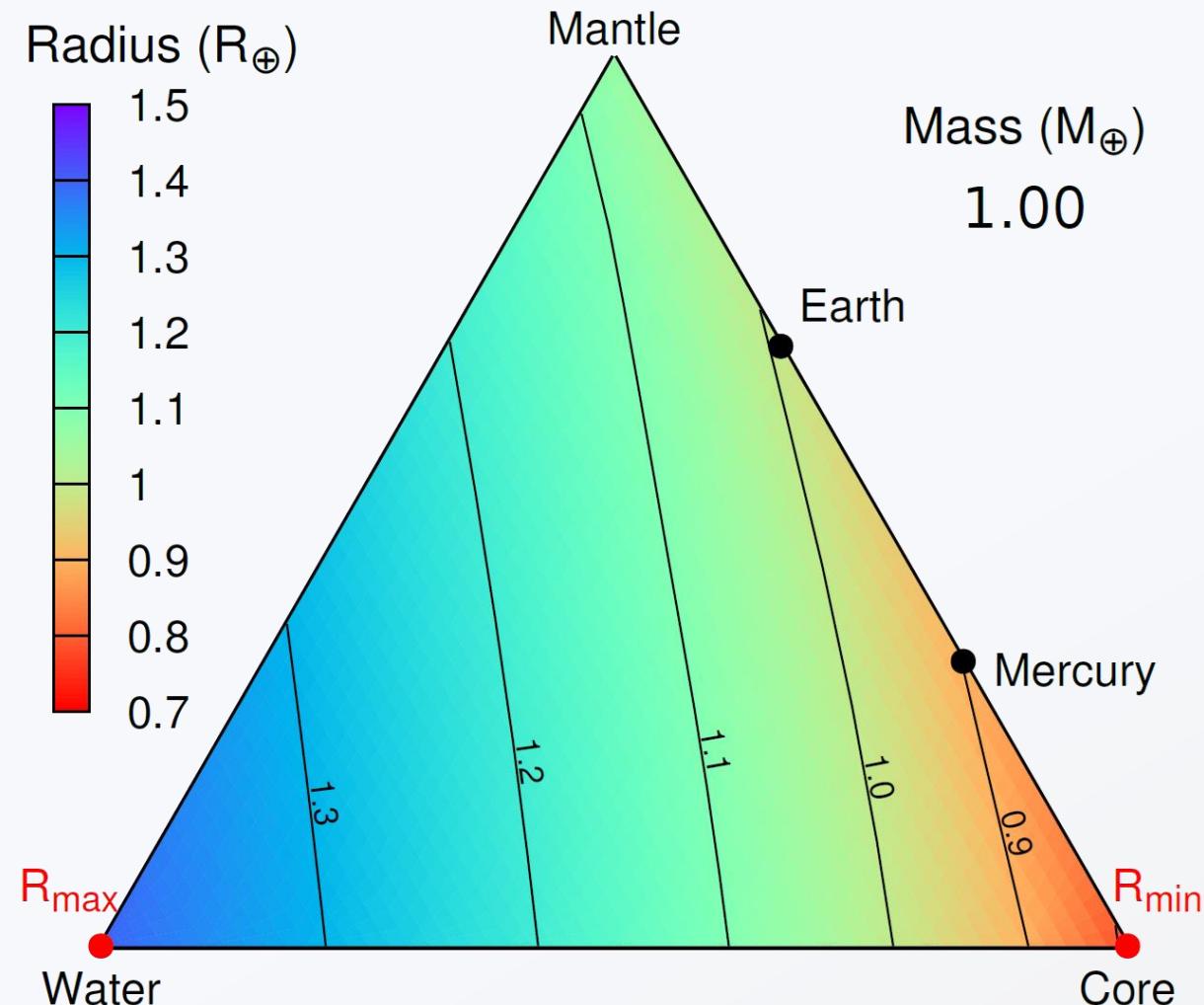
EXPLORING THE PARAMETER SPACE

Degeneracy on composition



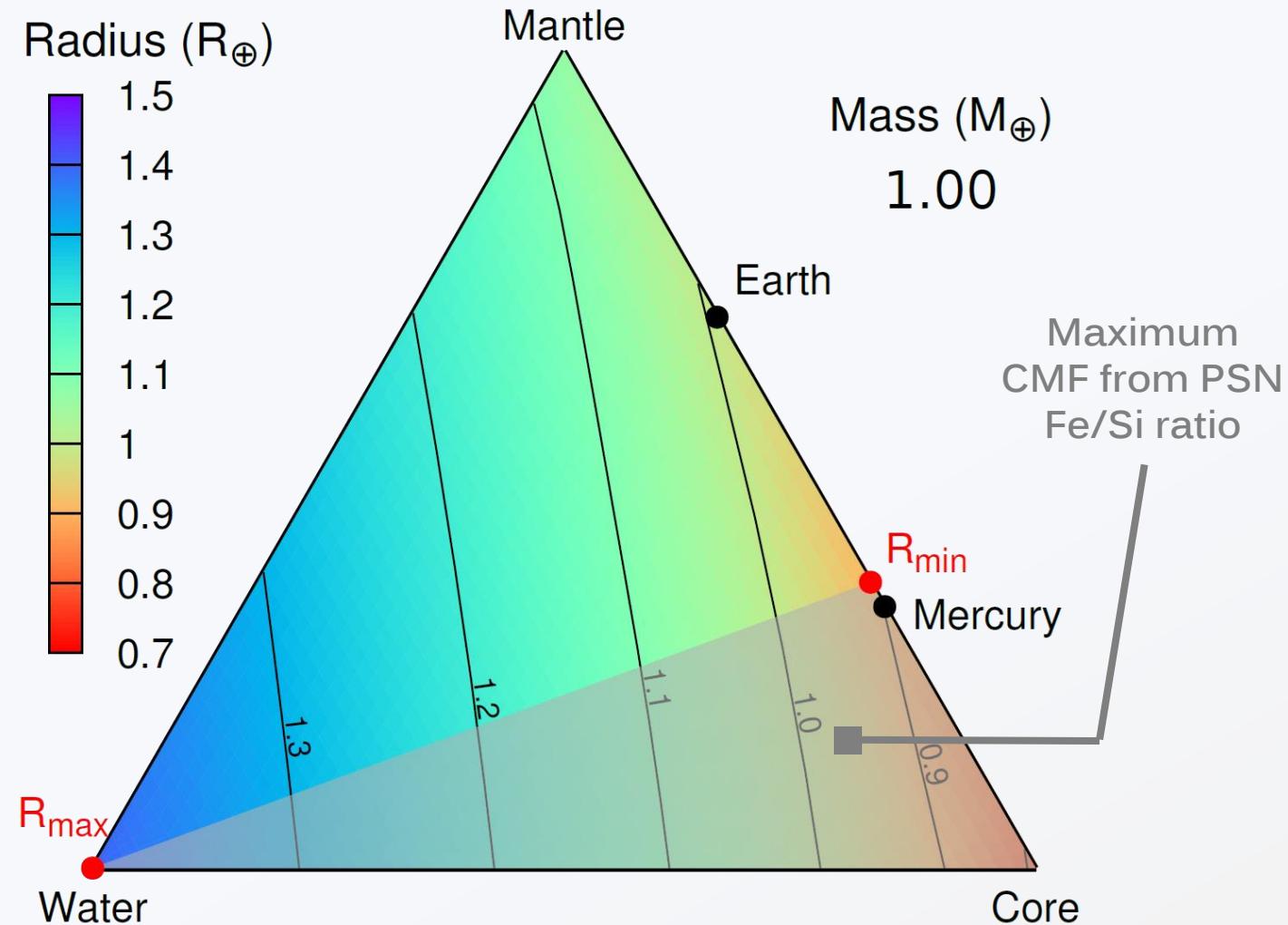
EXPLORING THE PARAMETER SPACE

Degeneracy on composition



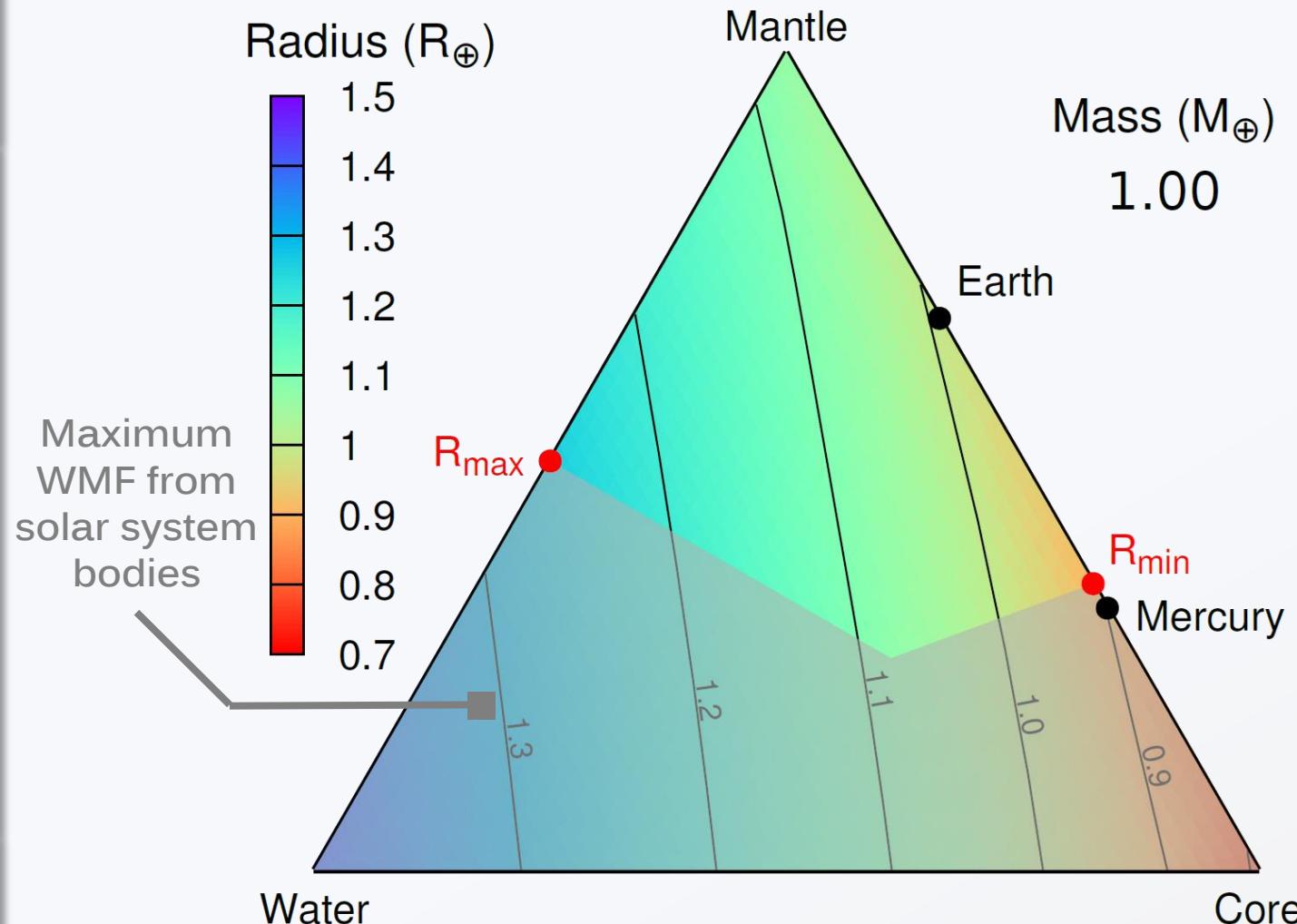
EXPLORING THE PARAMETER SPACE

Degeneracy on composition



EXPLORING THE PARAMETER SPACE

Degeneracy on composition



BREAKING THE DEGENERACY

Planet bulk Fe/Si ratio

Planets formation models (Thiabaud et al. 2015):

$$\left(\frac{Fe}{Si}\right)_P = \left(\frac{Fe}{Si}\right)_* \quad \left(\frac{Mg}{Si}\right)_P = \left(\frac{Mg}{Si}\right)_*$$

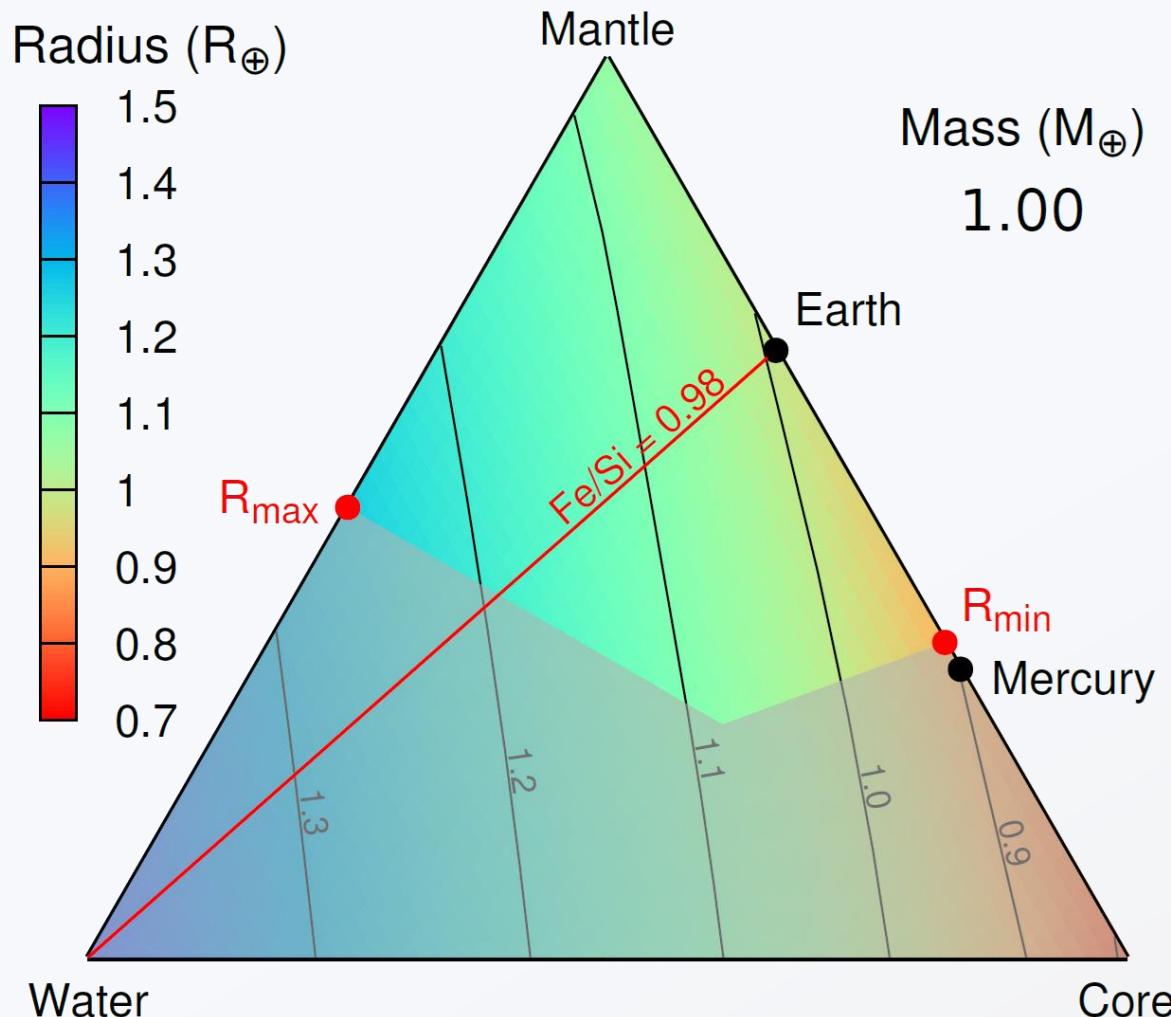
Internal structure:

- $\left(\frac{Fe}{Si}\right)_P \rightarrow$ linked to **CMF** & **MMF**
- \rightarrow independent of planet mass



BREAKING THE DEGENERACY

Planet bulk Fe/Si ratio



APPLYING THE MODEL

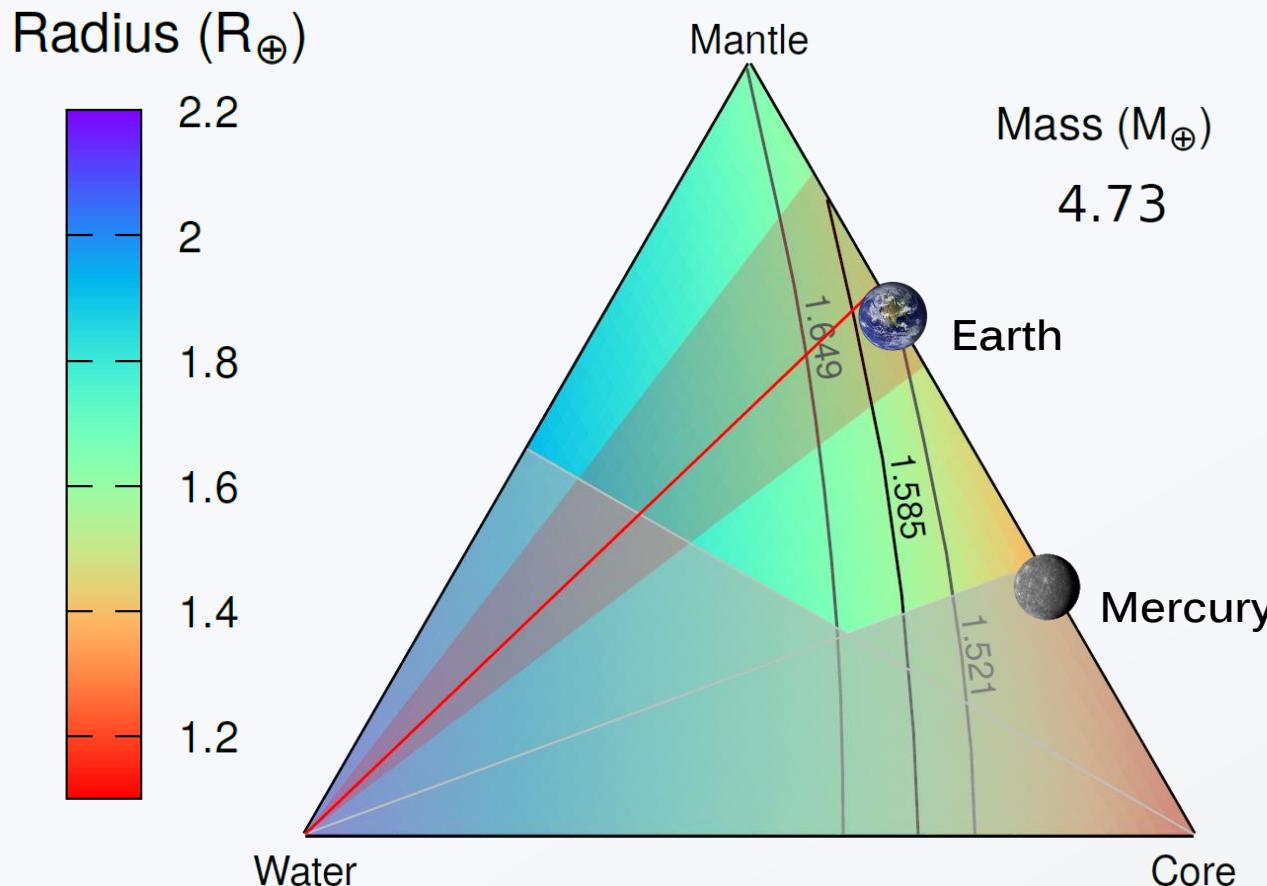
The Case of CoRoT-7b

$$M_P = 4.73 \pm 0.95 M_{\oplus}$$

Barros et al. 2014

$$R_P = 1.585 \pm 0.064 R_{\oplus}$$

Haywood et al. 2014



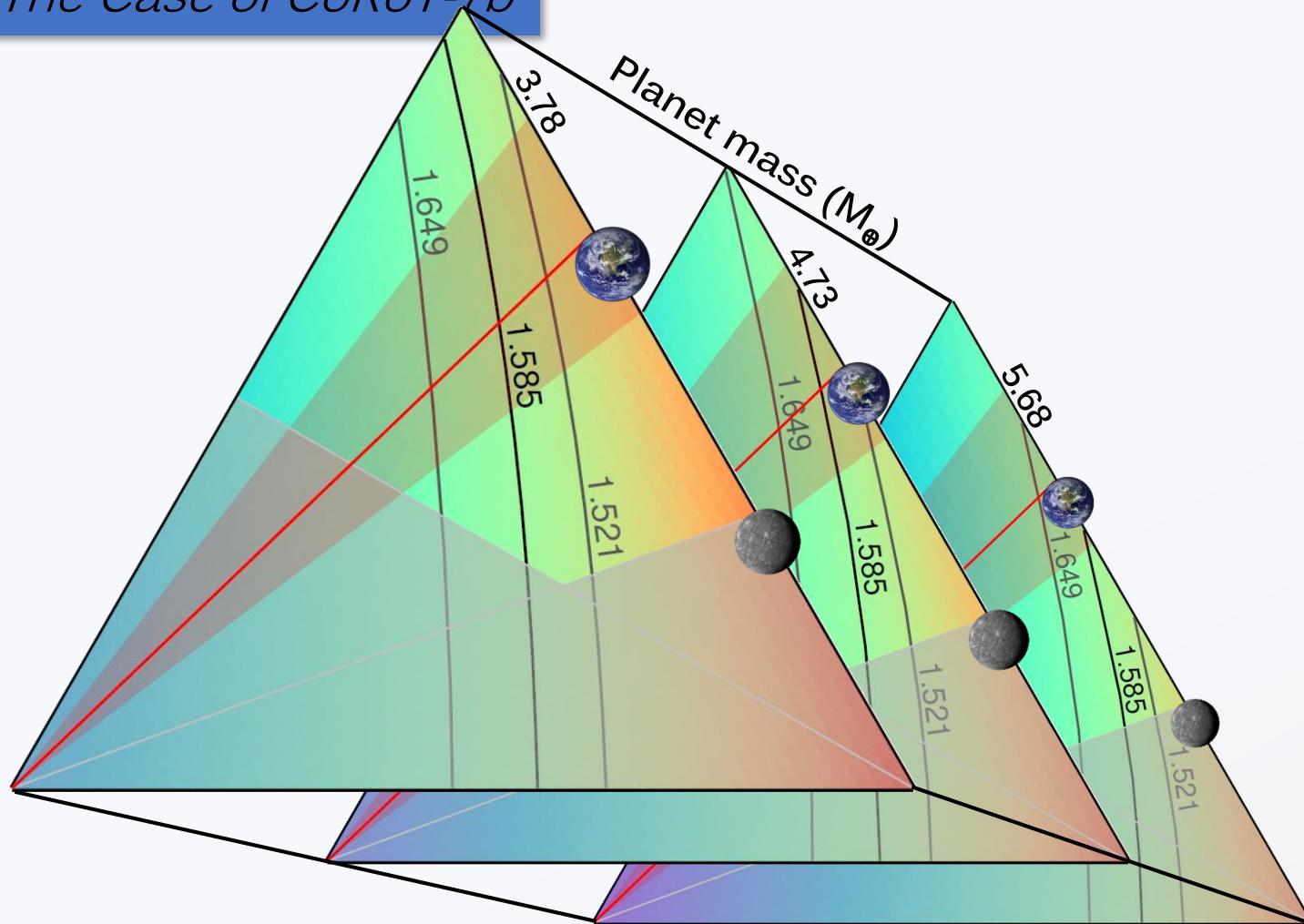
$$(Fe/Si)_P = 0.826 \pm 0.419$$

Brunett et al. 2010

Brugger et al. (submitted)

APPLYING THE MODEL

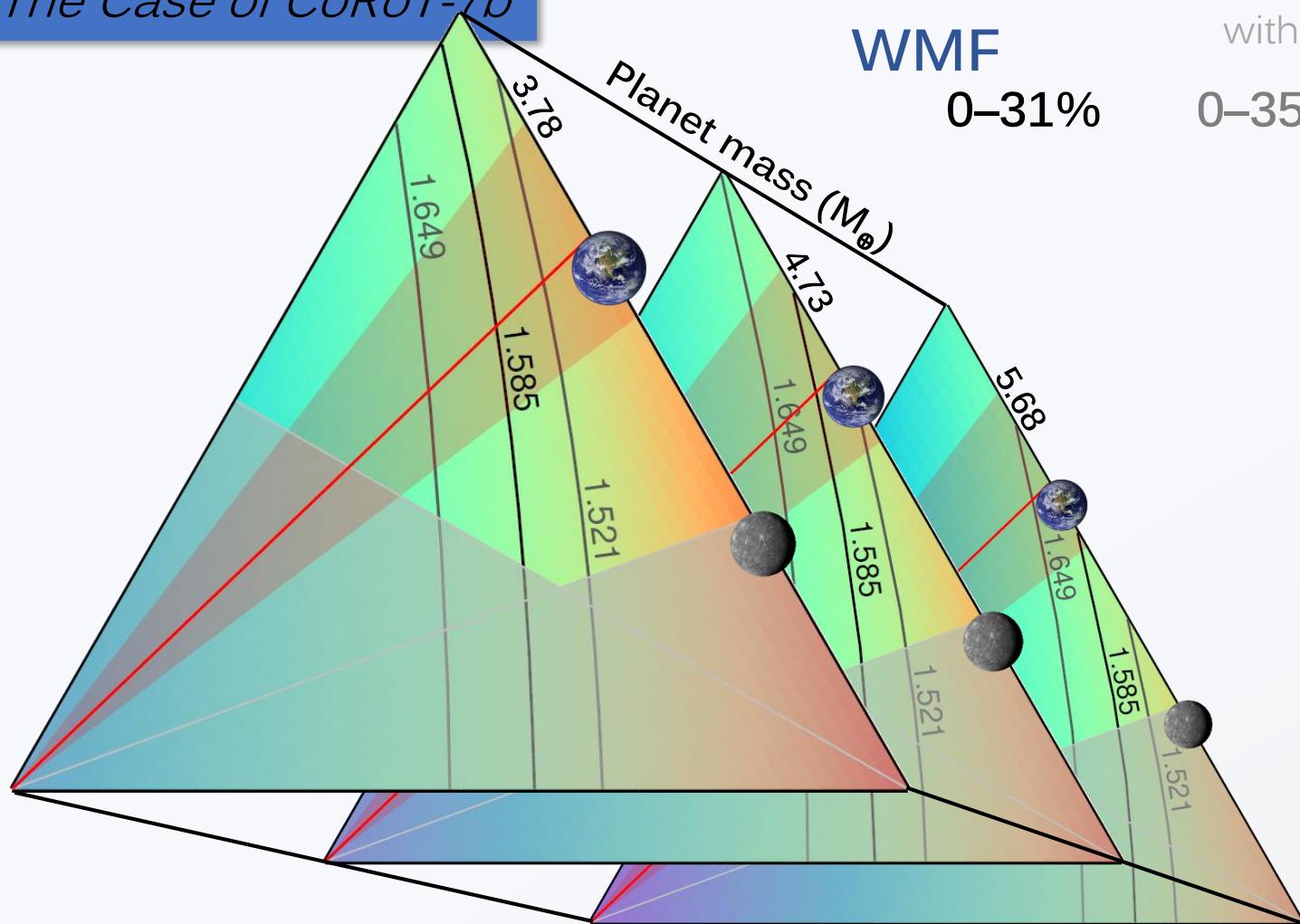
The Case of CoRoT-7b



Brugger et al. (*submitted*)

APPLYING THE MODEL

The Case of CoRoT-7b



CMF

10–37%

0–50%

without Fe/Si

WMF

0–31%

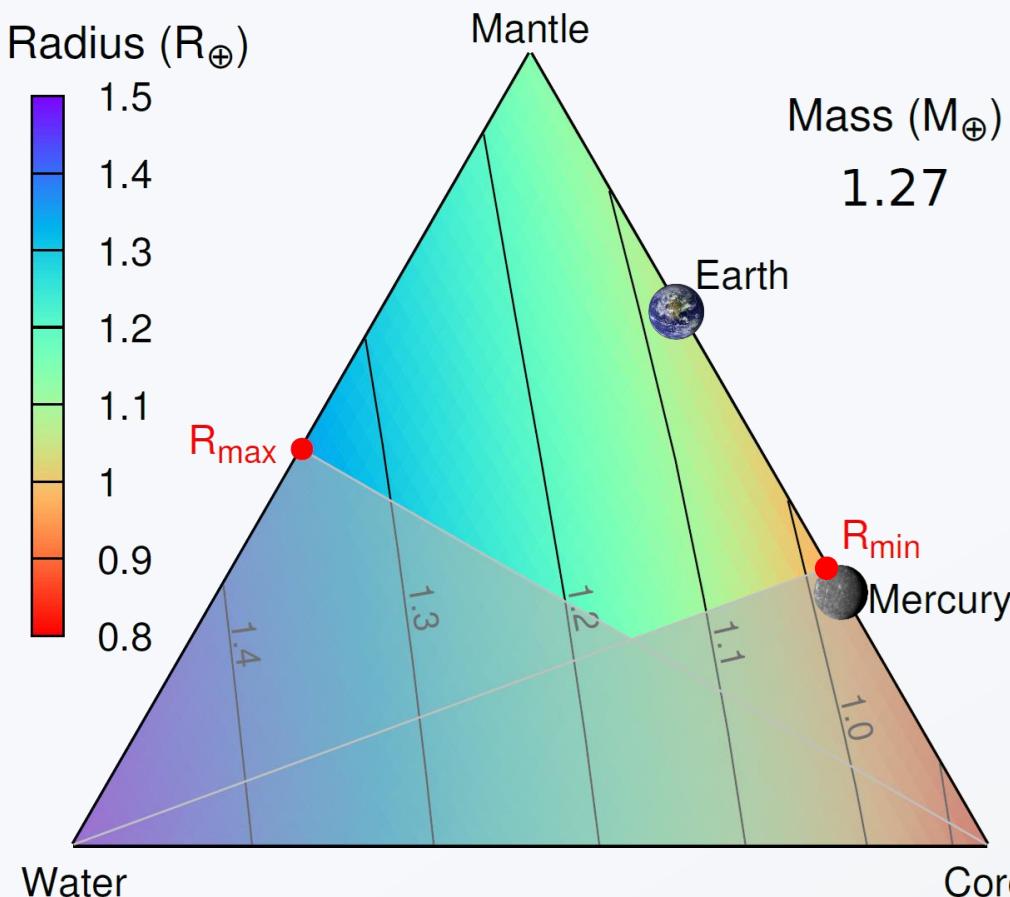
0–35%

APPLYING THE MODEL

The Case of Proxima b

$$M_p \sin i = 1.27 M_{\oplus}$$

Anglada-Escudé et al. 2016



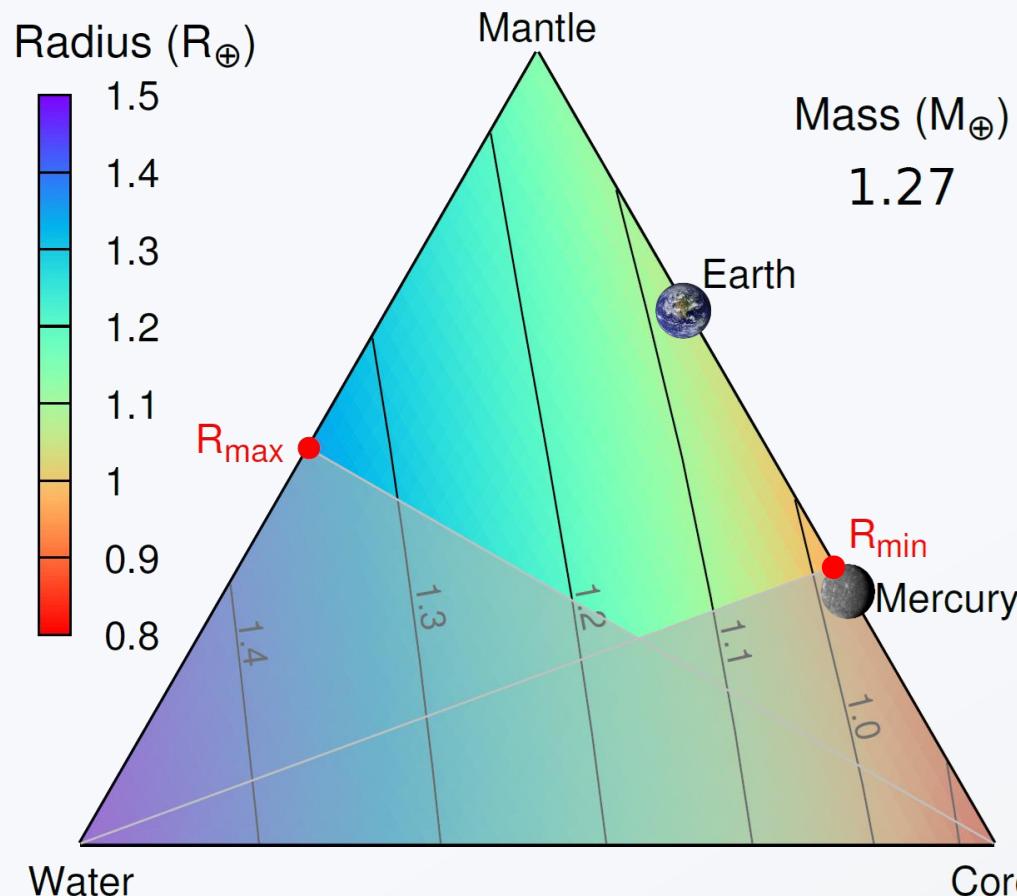
Brugger et al. (2016)

APPLYING THE MODEL

The Case of Proxima b

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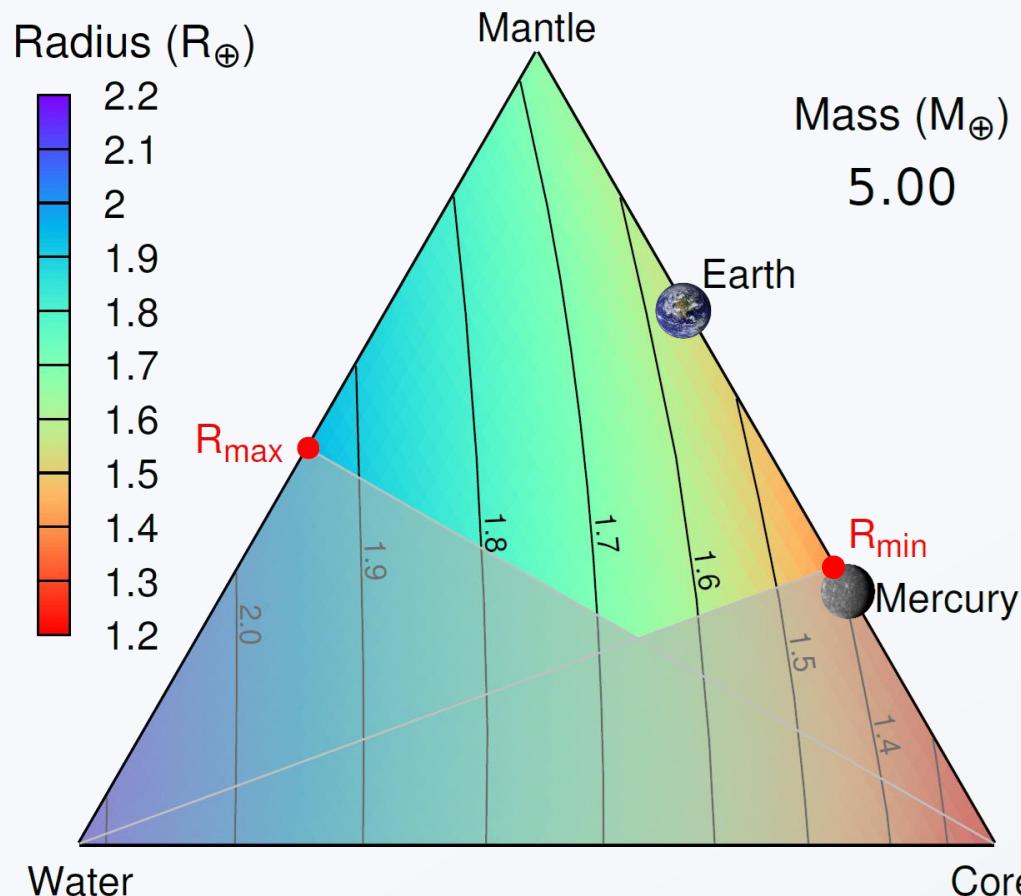


Radius range: $0.98\text{--}1.34 R_{\oplus}$
 $0.94\text{--}1.40 R_{\oplus}$

Brugger et al. (2016)

APPLYING THE MODEL

The Case of Proxima b



Radius range: $1.41\text{--}1.94 R_{\oplus}$

Brugger et al. (*submitted*)

CONCLUSIONS



Internal structure and composition of exoplanets **limited** by:

- precision on fundamental parameters
 - degeneracy on composition
- *reduced by Fe/Si ratio*

PLATO's important **contributions**:

- unrivalled precision on planet parameters
 - stellar abundances essential
- *bright stars*

Thank you!