Constraints on the existence of low-mass planets with supercritical hydrospheres

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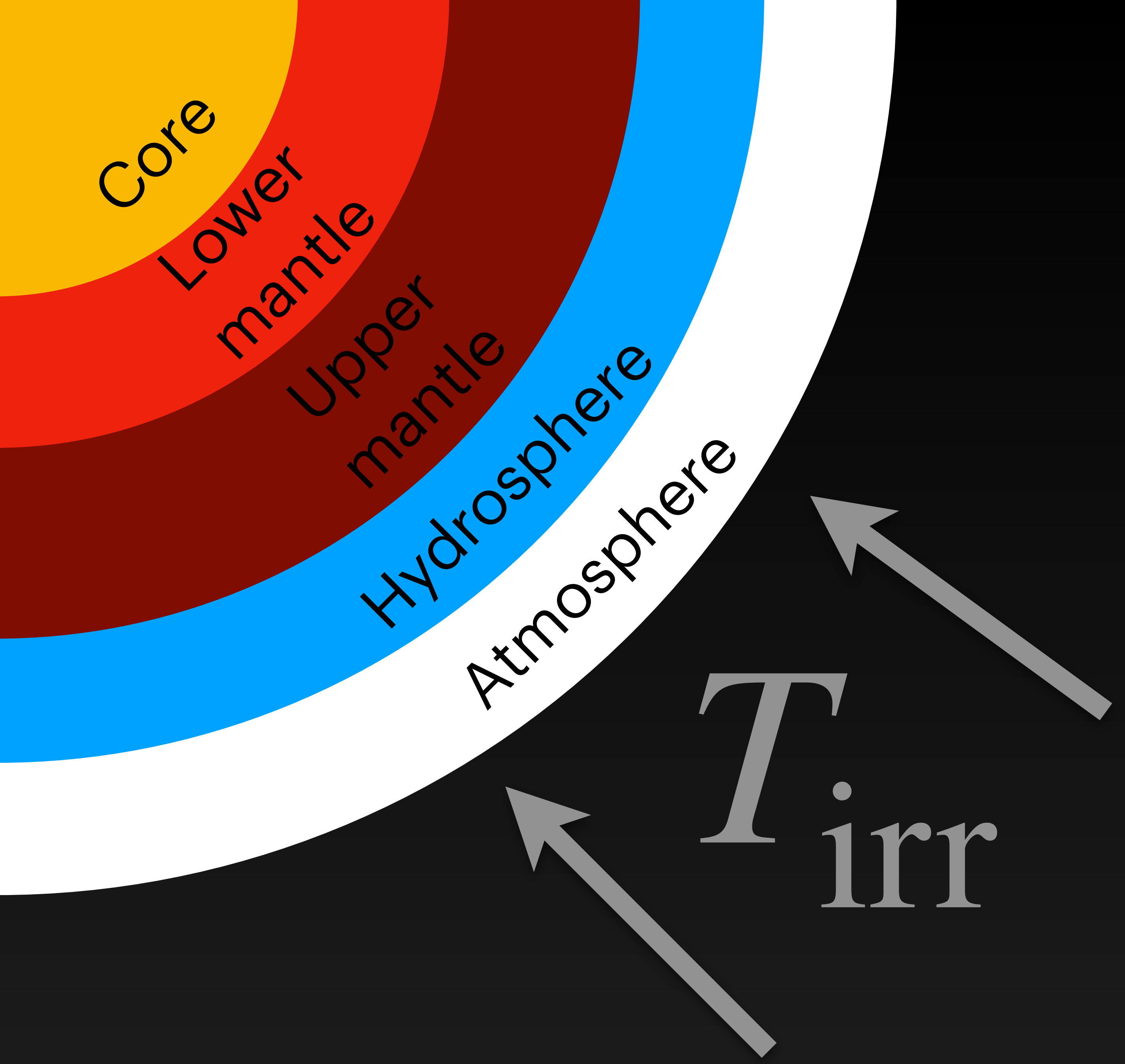
Context & goals

Existence of Earth-like ocean worlds

- Earth-like mass planets are the epitome of exoplanet detection
- Léger et al. 2004: theoretical existence of water worlds
- Water rich planets could explain the gap between super-Earth and sub-Neptune

- Possible existence of water rich $0.2 - 1M_{\oplus}$ planets
  - Atmosphere stability
  - Core compression

Turbet et al. 2019, Mousis et al. 2020



Model

Methods and parameters

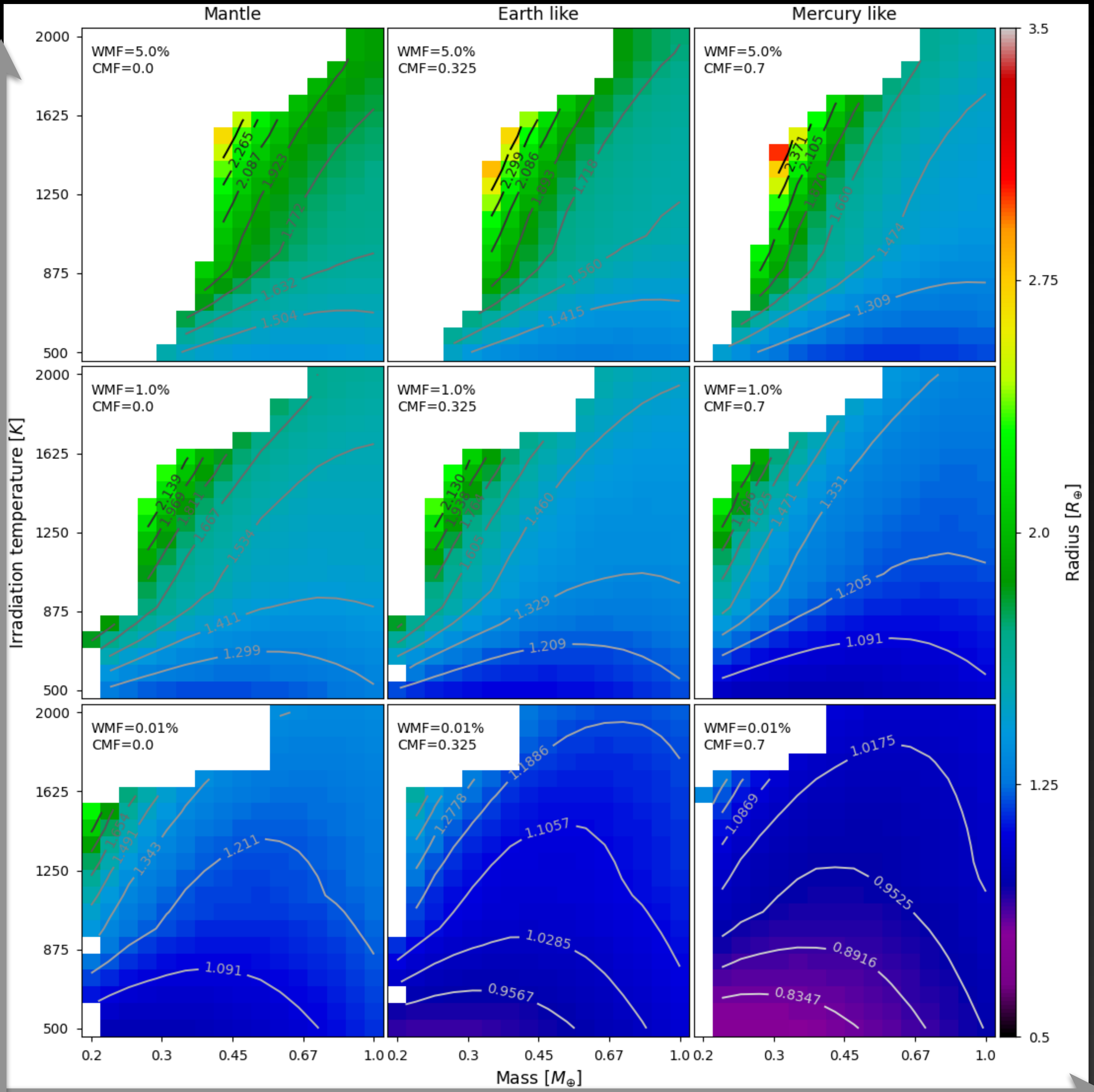
- Self consistent interior and atmosphere model
  - Implementation of an upgraded convergence scheme
  - The atmosphere grid has been extended to surface gravity as low as $1 m . s^{-2}$
  - Hydrostatic stability is assessed for each planet

Explored composition:

- CMF: 0, 0.325, 0.7
- WMF: 0.01%, 1%, 5%
- M_P: $0.2 - 1 M_\oplus$
- T_{irr}: $500 - 2000 K$

Brugger et al. 2017, Marcq et al. 2017, 2019, Mousis et al. 2020, Aguichine et al. 2021

Increasing WMF



Increasing CMF

Radius inflation

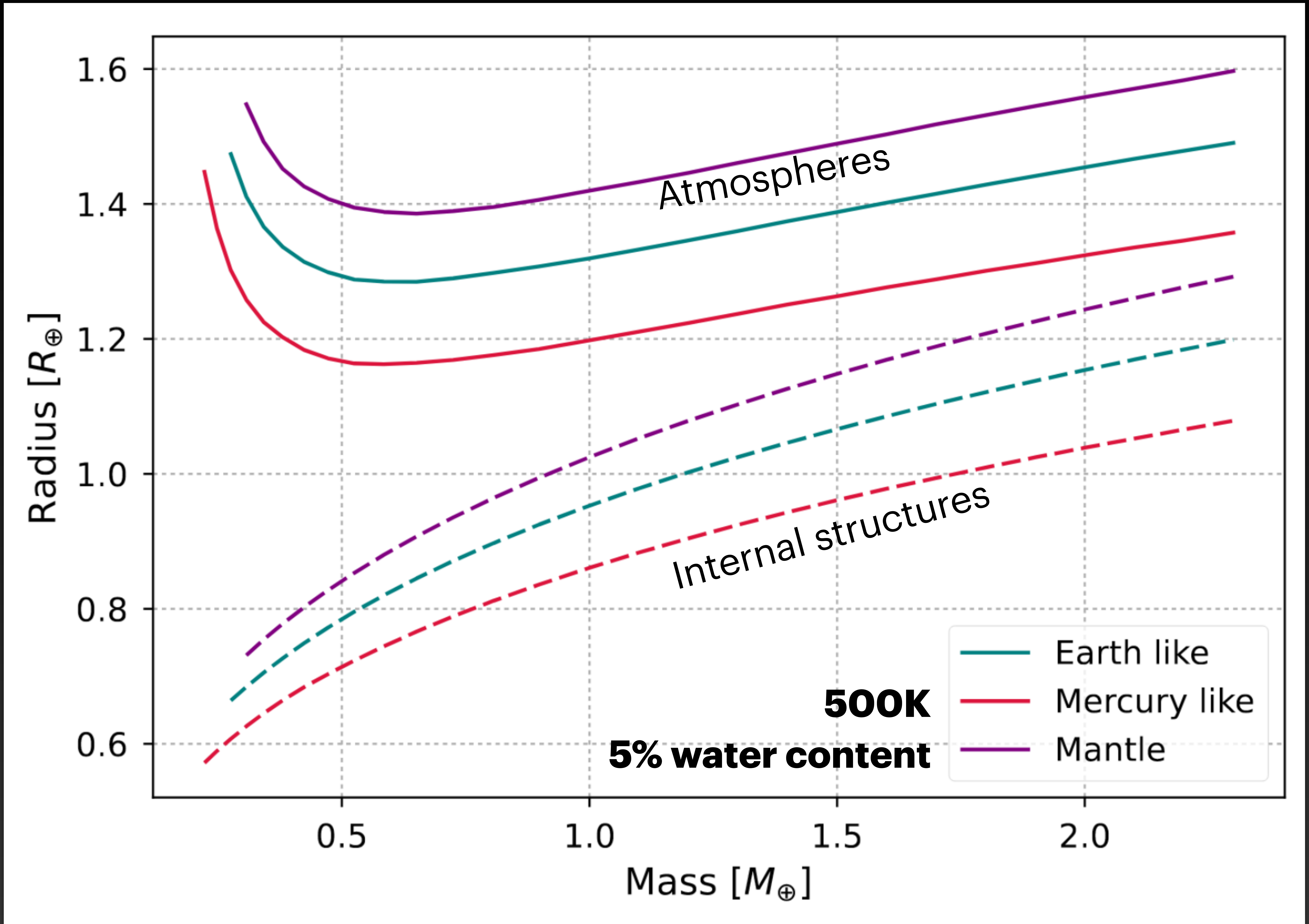
- The atmosphere boundary is defined at 20mbar
- White areas → unstable atmosphere

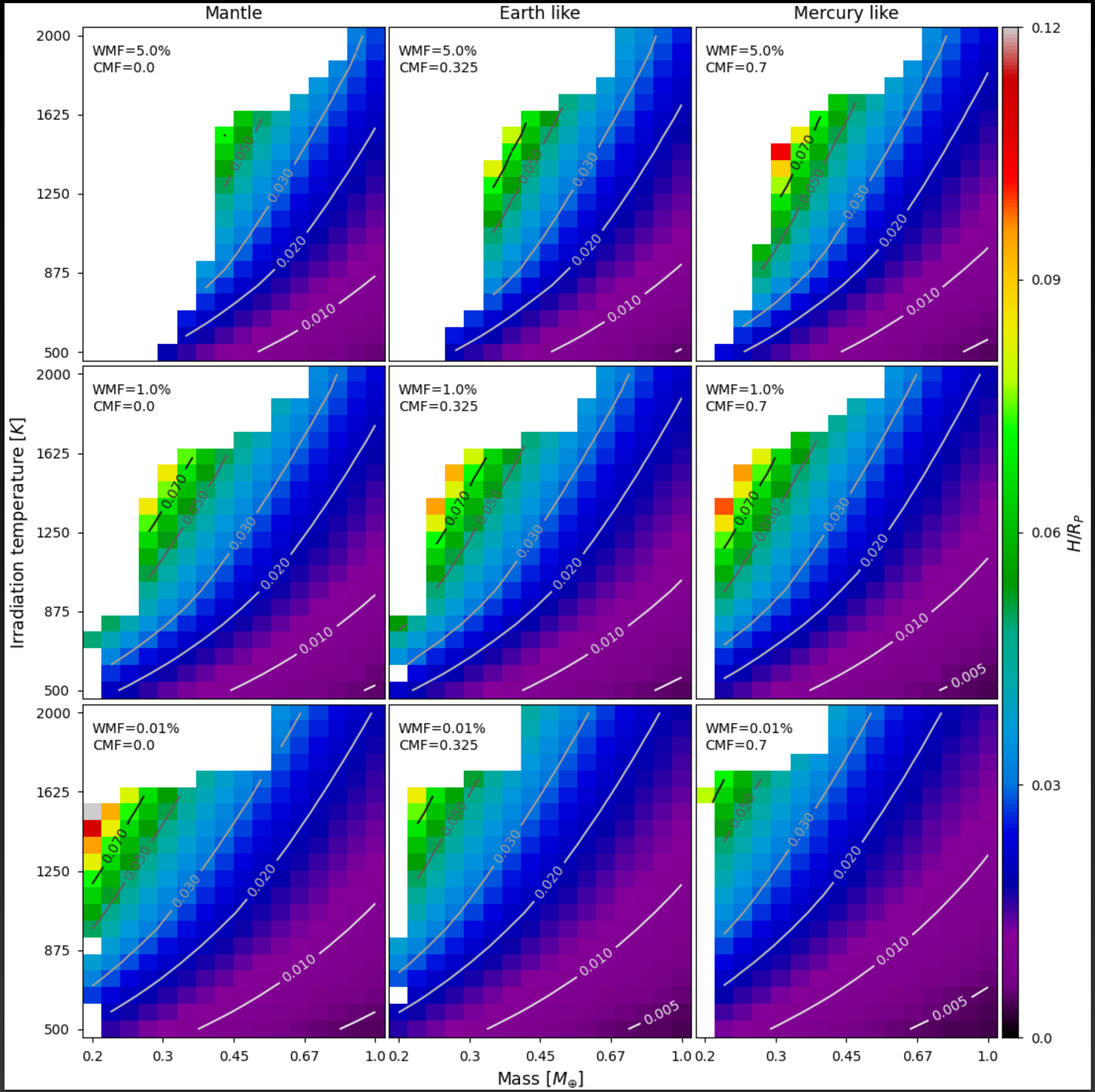
→ Atmosphere inflation for low mass and irradiation

Impact of the CMF

→ Radius inflation at low masses

→ Influence of the CMF on the inflation





Stability criterion

$$H = \frac{k_B T_{\mathrm{irr}} R_P^2}{G M_P m_{\mathrm{H_2O}}} \Rightarrow H > \eta R_P$$

→ Atmosphere is lost quickly when η is greater than ~ 0.1

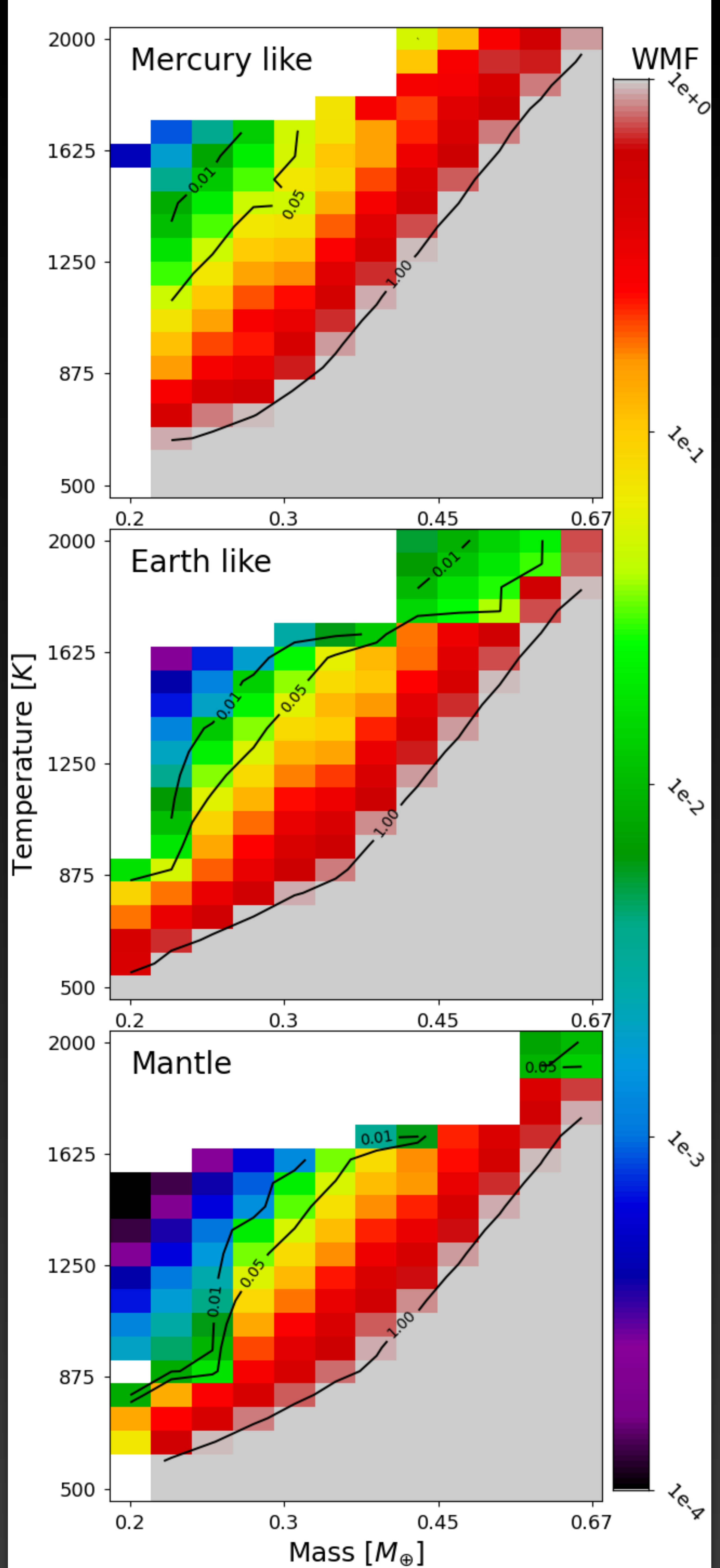
Similar to $\Lambda = R_P/H$ and R_P/R_B for H/He rich planets

Fossati et al. 2017, Owen & Wu 2016

Theoretical maximum WMF

- For each M_P and T_{irr} we fit R_P as a function of the WMF
- We find the radius for which $\eta = 0.1$

→ Sharp transition between 100% water sustainable and complete evaporation



Keys points

→ Model is fully self-consistent, unlike previous studies

→ Irradiated low-mass planets can sustain a steam atmosphere under certain conditions

→ Internal structure compression plays an important role even at low WMF

→ Internal structure is itself noticeably impacted even at low WMF

→ Transition of water content sustainability regime is sharp

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Appendix 1: Comparison with another model

→ Models are compatible

→ Internal structure compression has an impact even at low WMF