Water oceans on dense exoplanets from outgassing and interior-atmosphere feedback processes

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Technische Universität Berlin
DLR
exoplanet diversity
SPP 1992

The search for habitable planets

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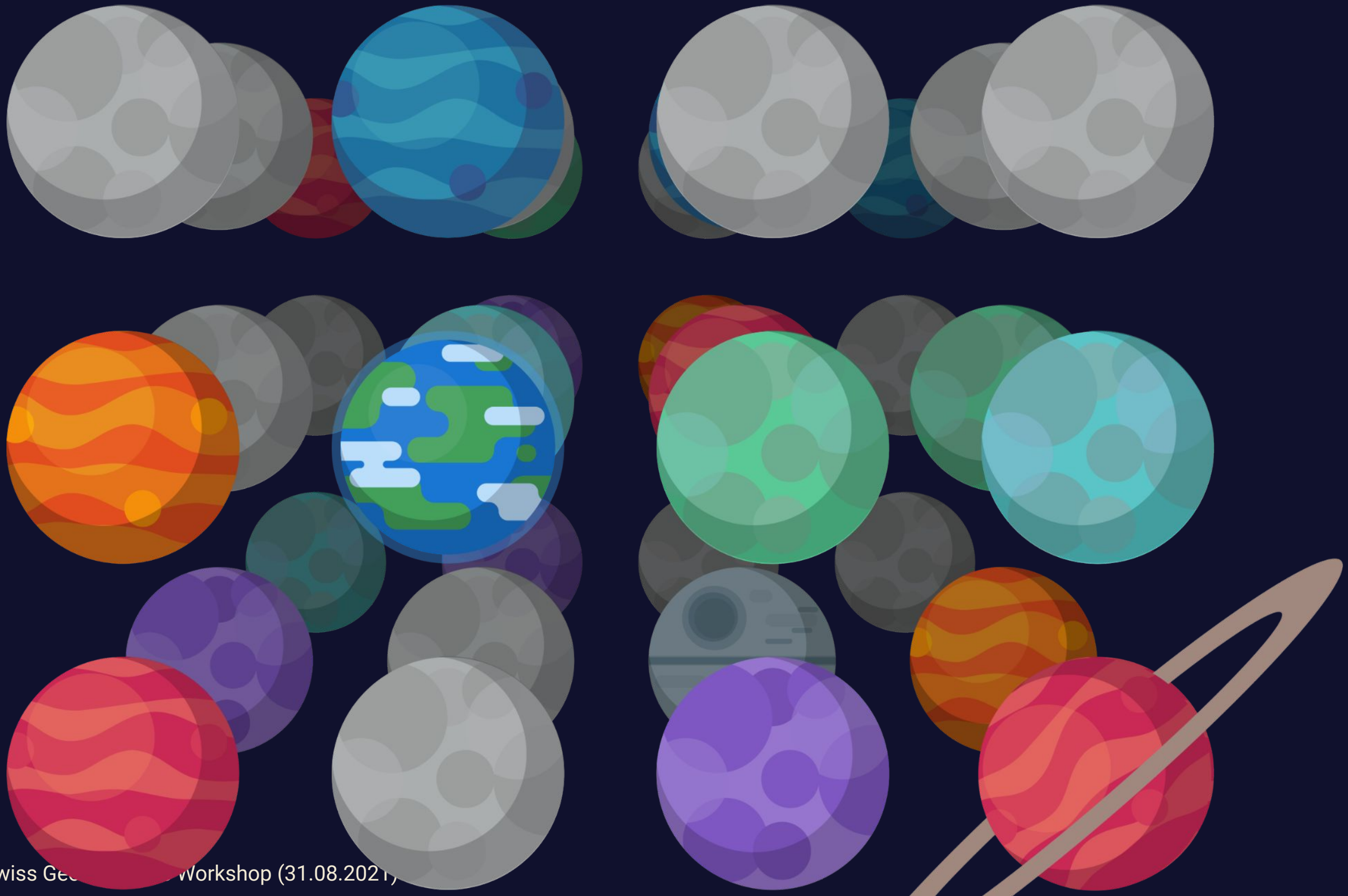
Atmosphere measurements can only give indirect evidence

Direct detection of an ocean is extremely challenging

Which planets *can* have oceans?



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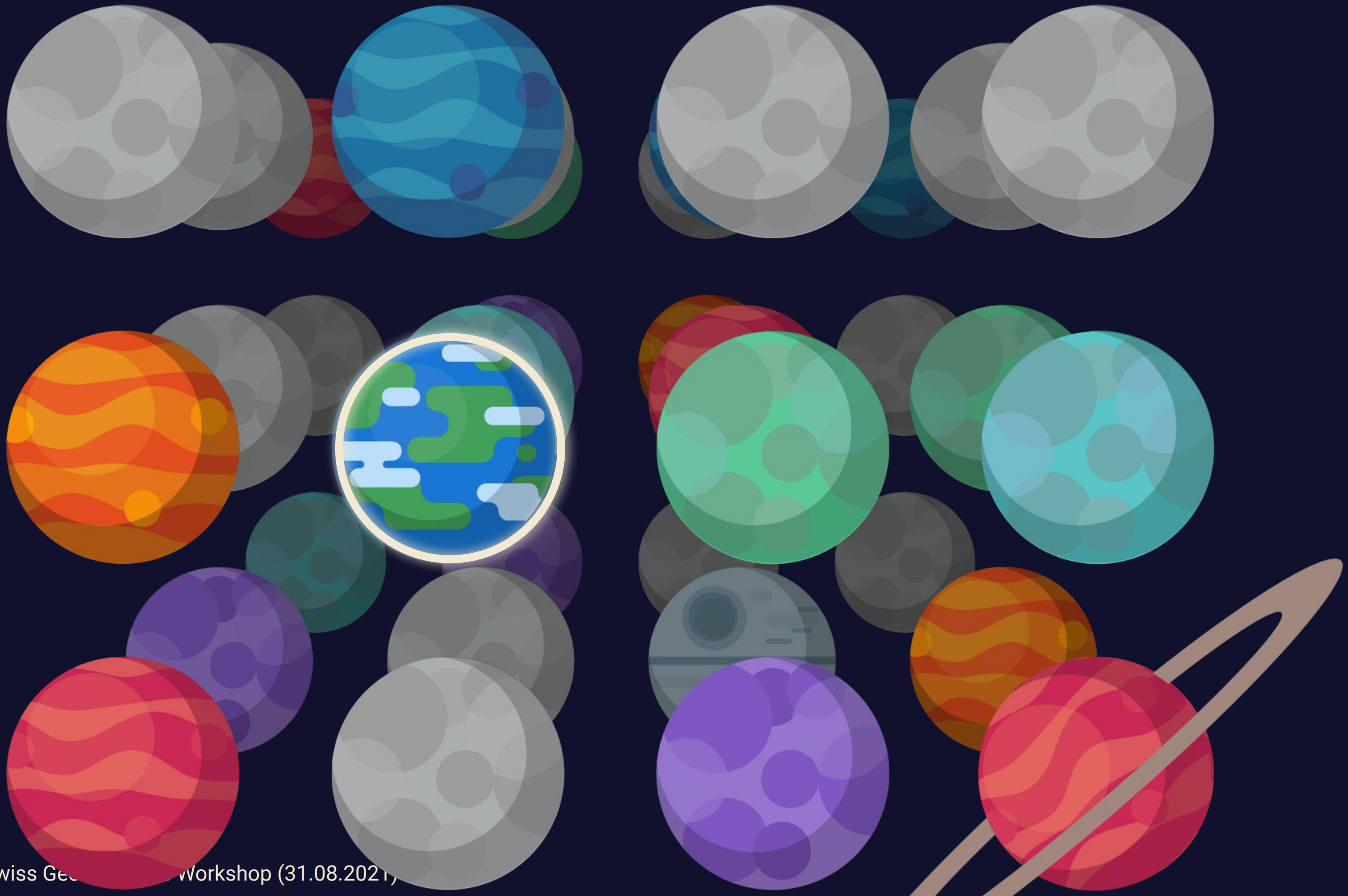
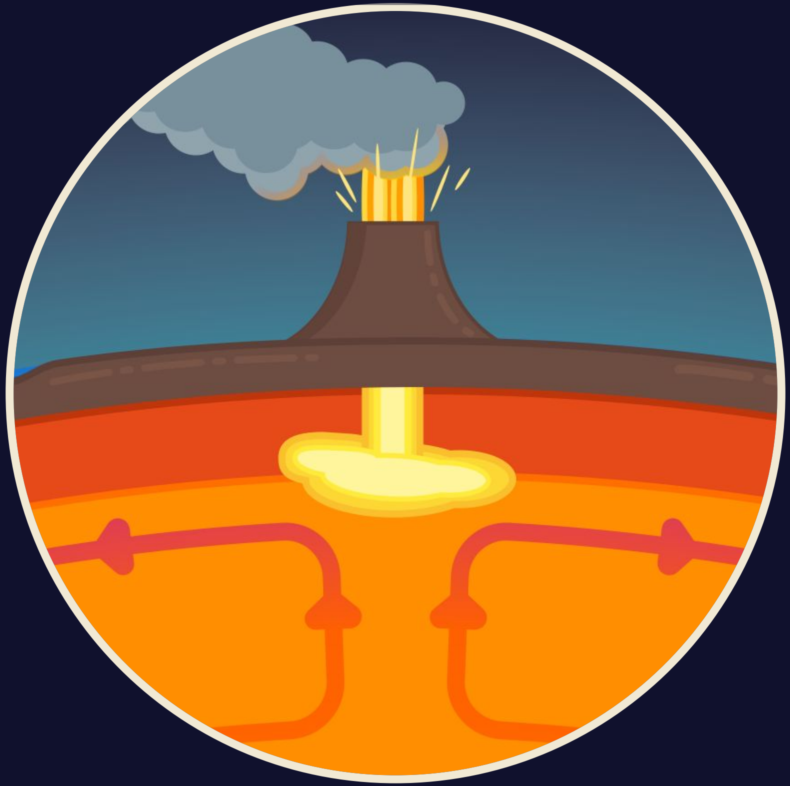


The planet interior is a major source of water



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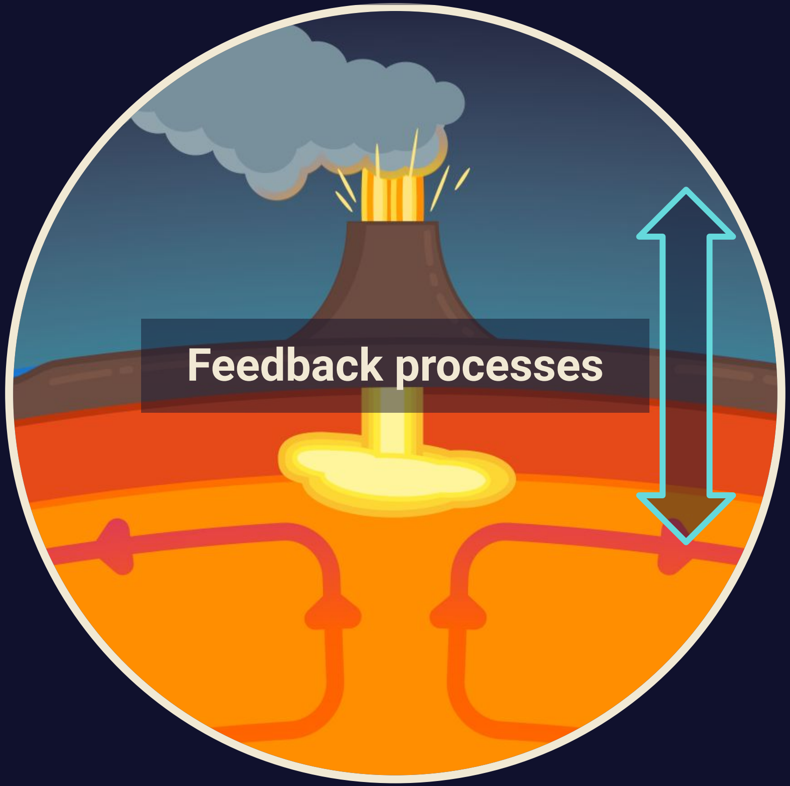
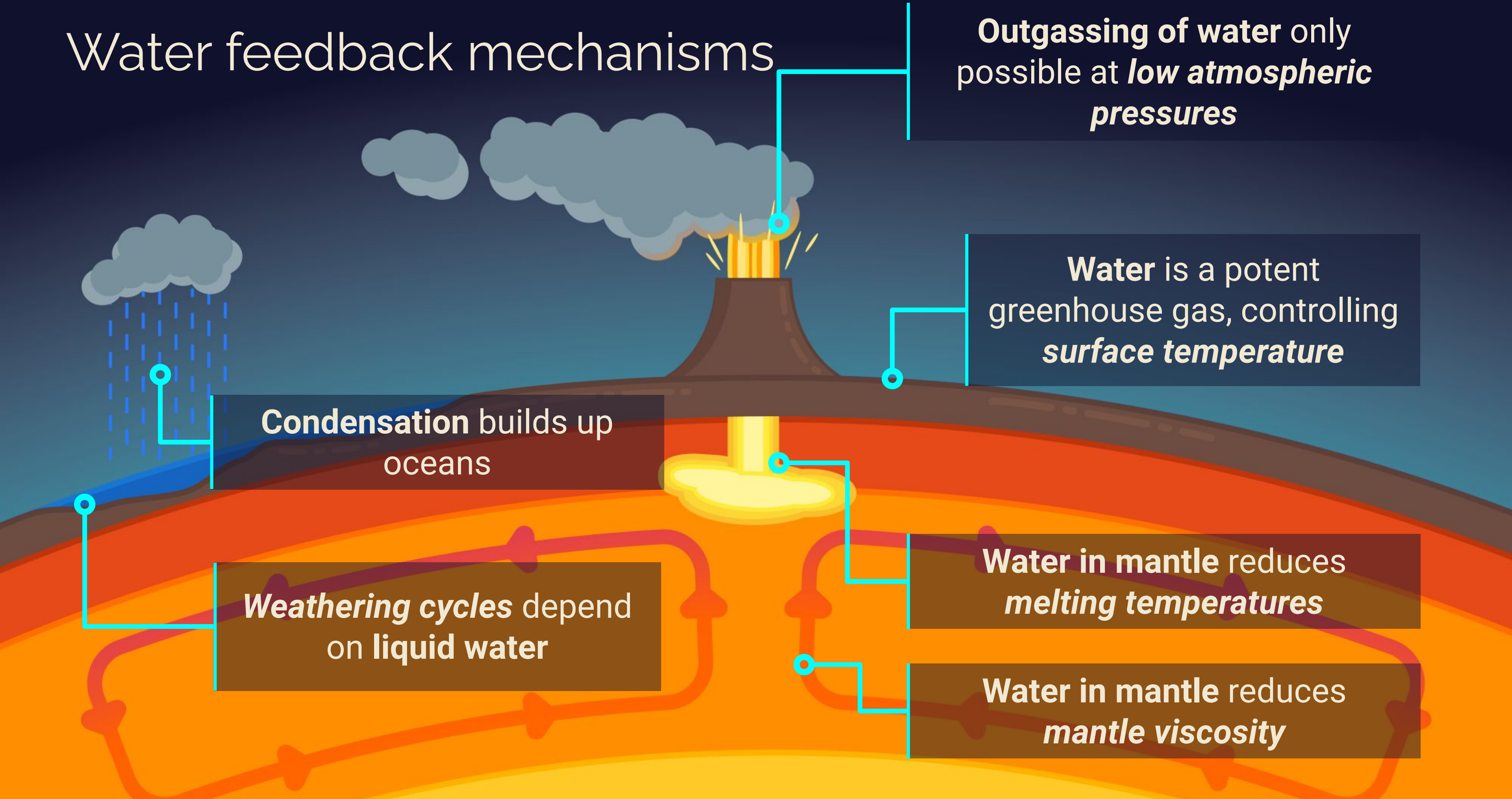
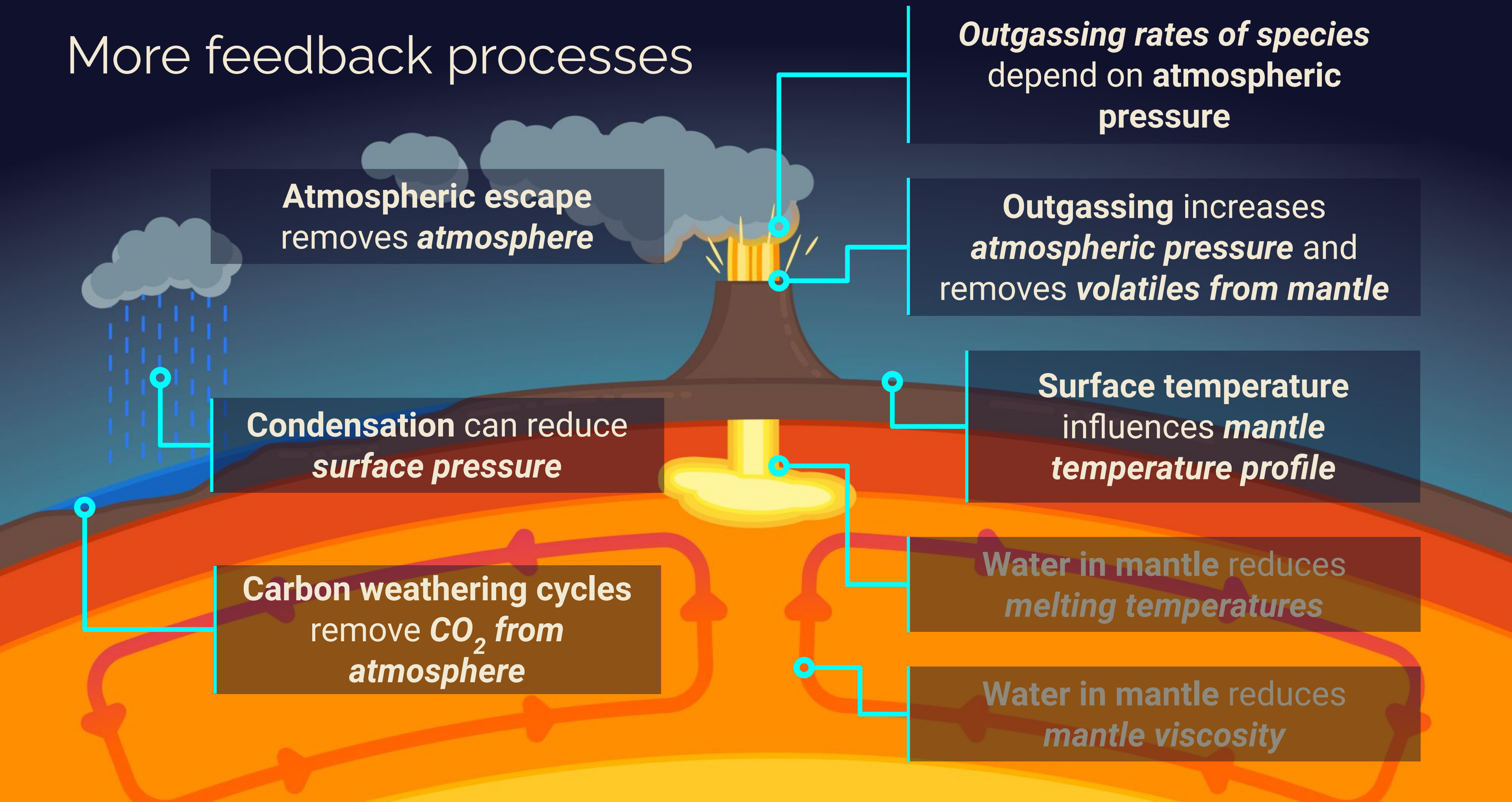


Water feedback mechanisms



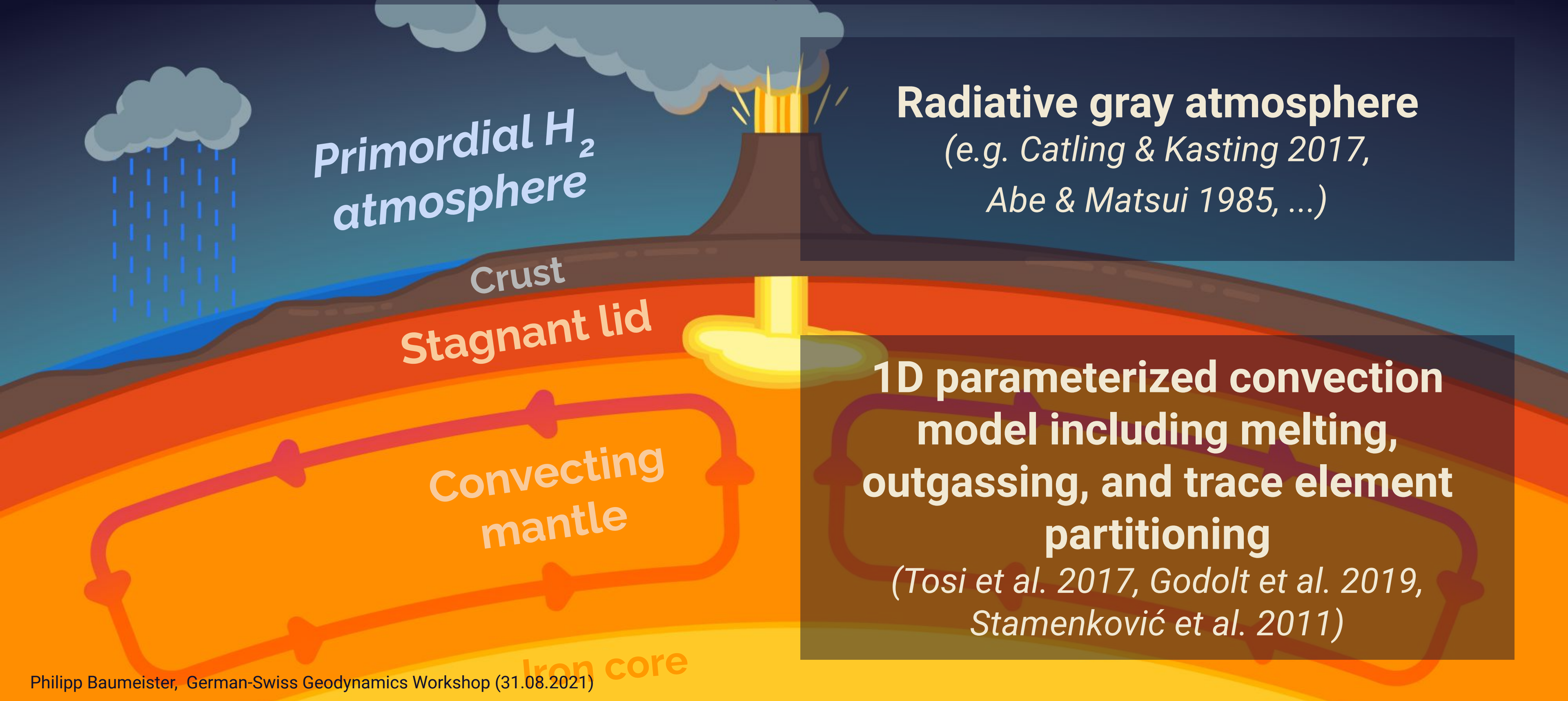
More feedback processes



Philipp Baumeister, German-Swiss Geodynamics Workshop (31.08.2021)

Our modeling approach:

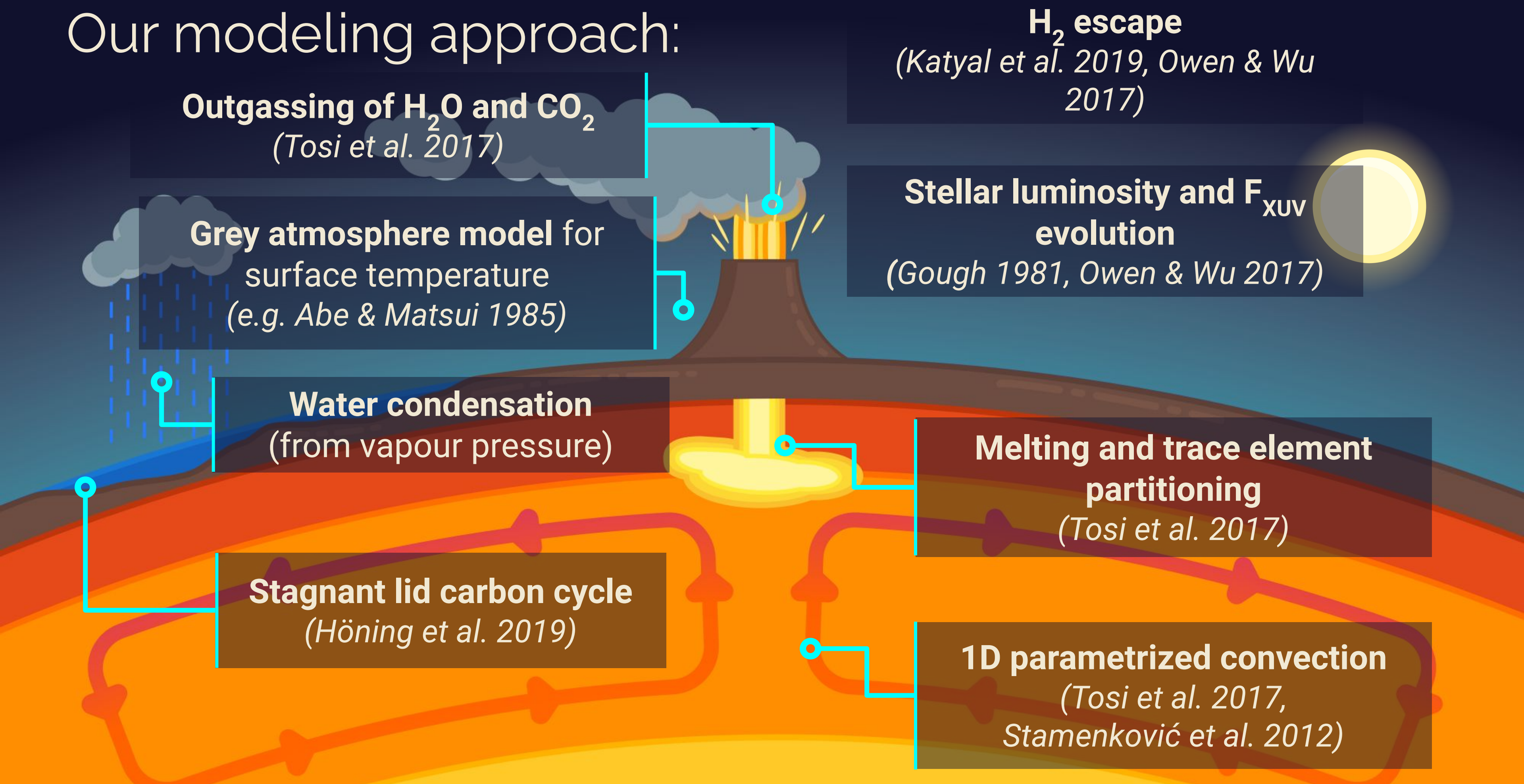
Run > 30.000 planet evolutions for varying initial conditions



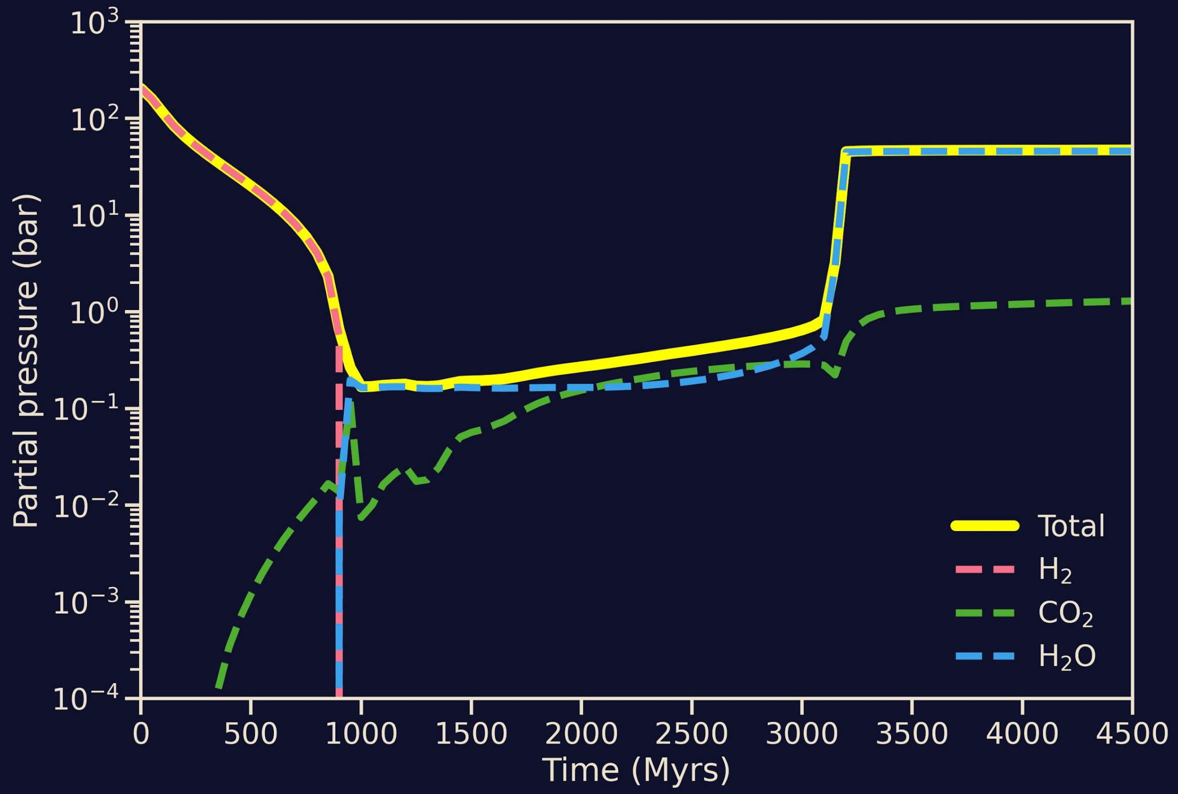
Radiative gray atmosphere
(e.g. Catling & Kasting 2017, Abe & Matsui 1985, ...)

1D parameterized convection model including melting, outgassing, and trace element partitioning
(Tosi et al. 2017, Godolt et al. 2019, Stamenković et al. 2011)

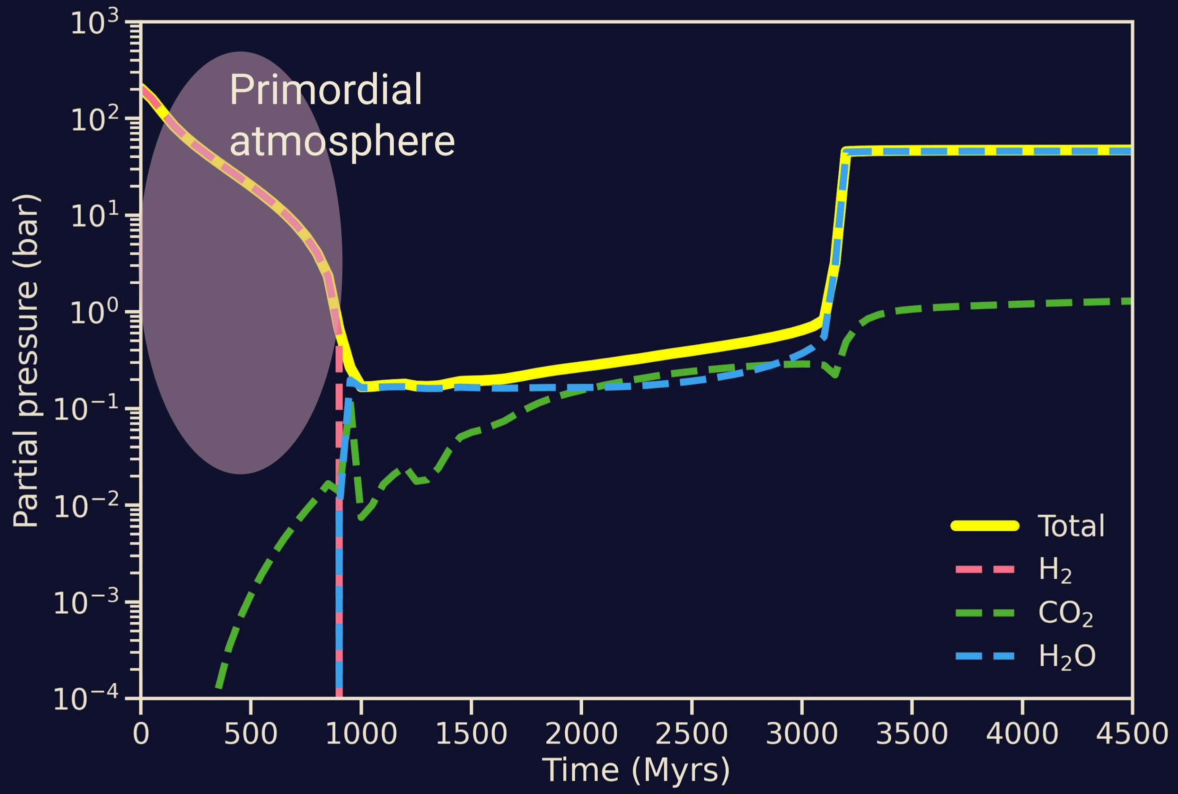
Our modeling approach:



Characteristic outgassing evolution



Characteristic outgassing evolution



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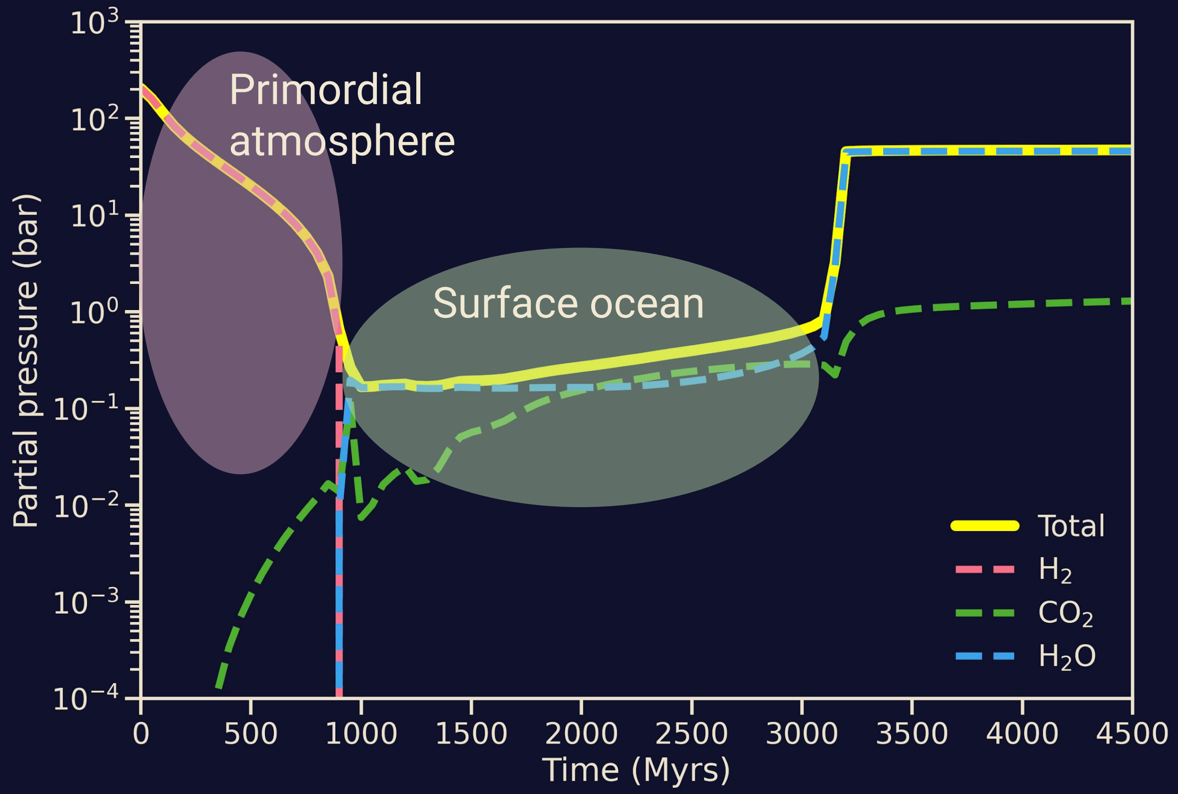
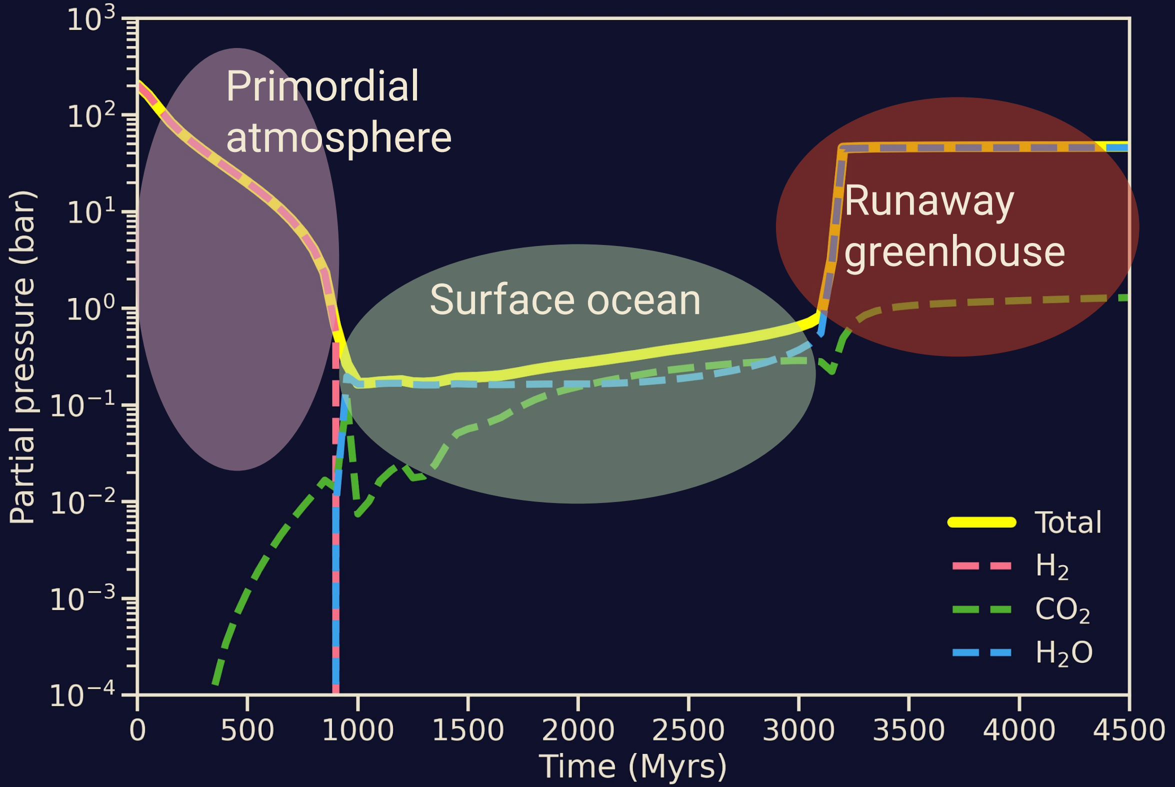
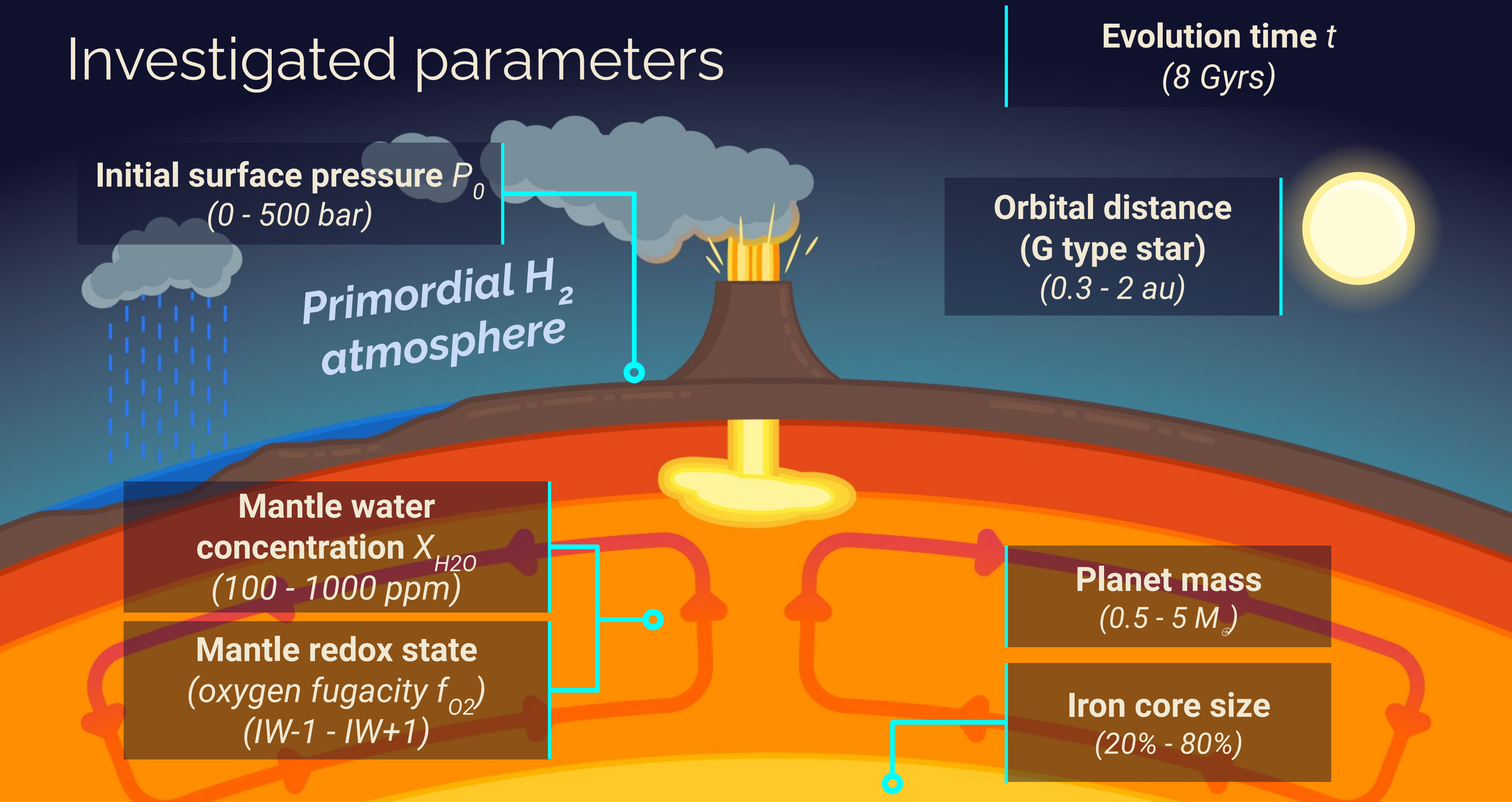


Characteristic outgassing evolution



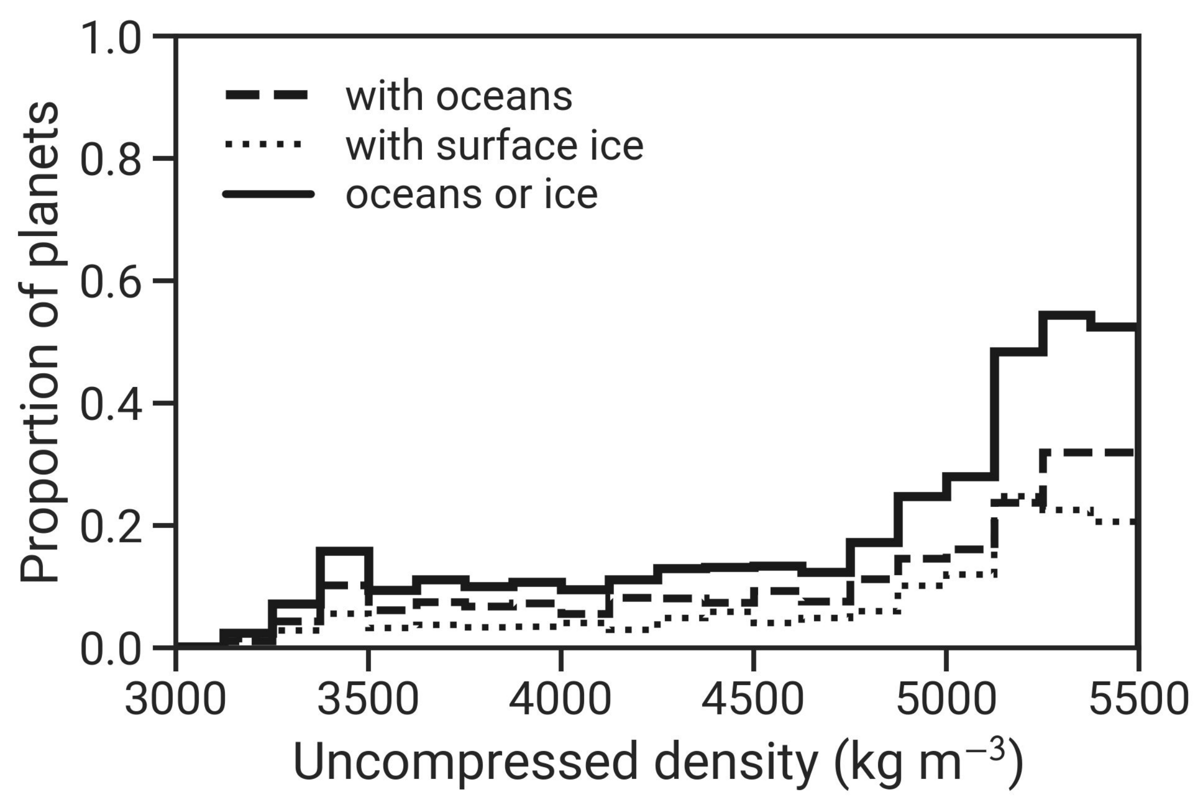
Investigated parameters



We ran 30.000 planet evolutions for randomly chosen parameters, then selected snapshots at random ages

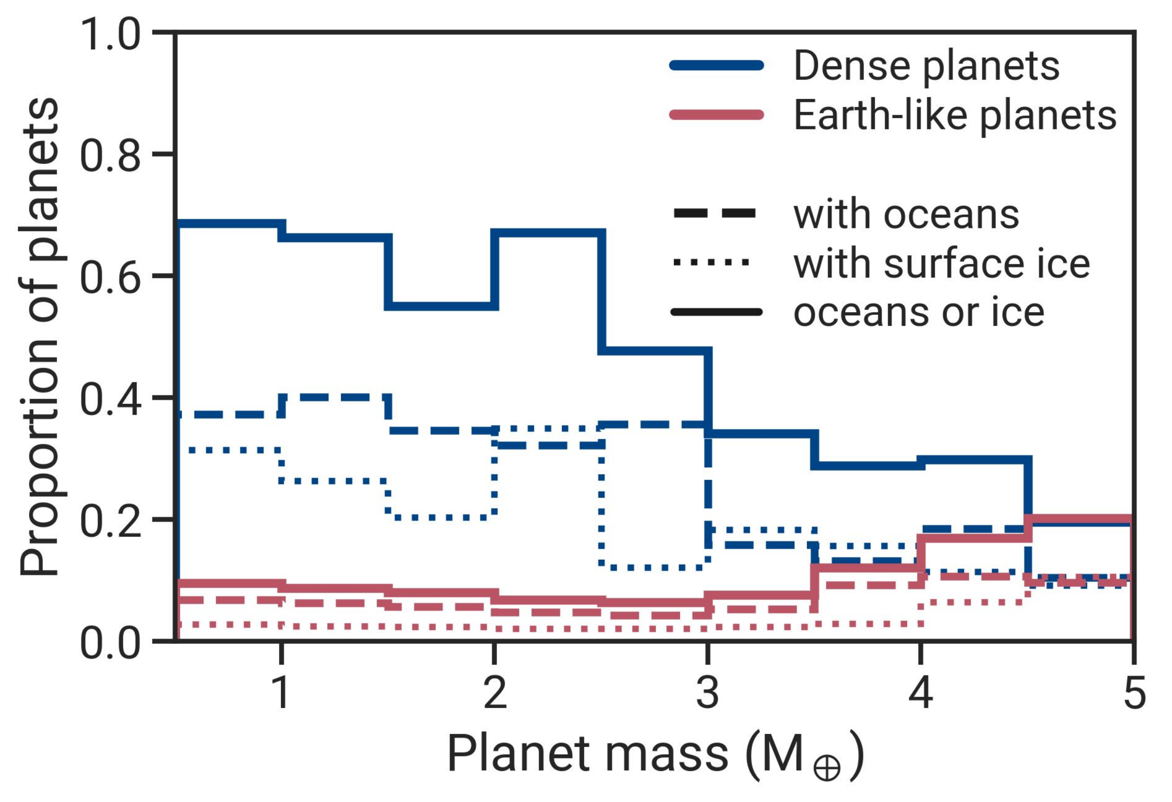
Most dense planets have oceans ...

Baumeister et al. 2021, under review.



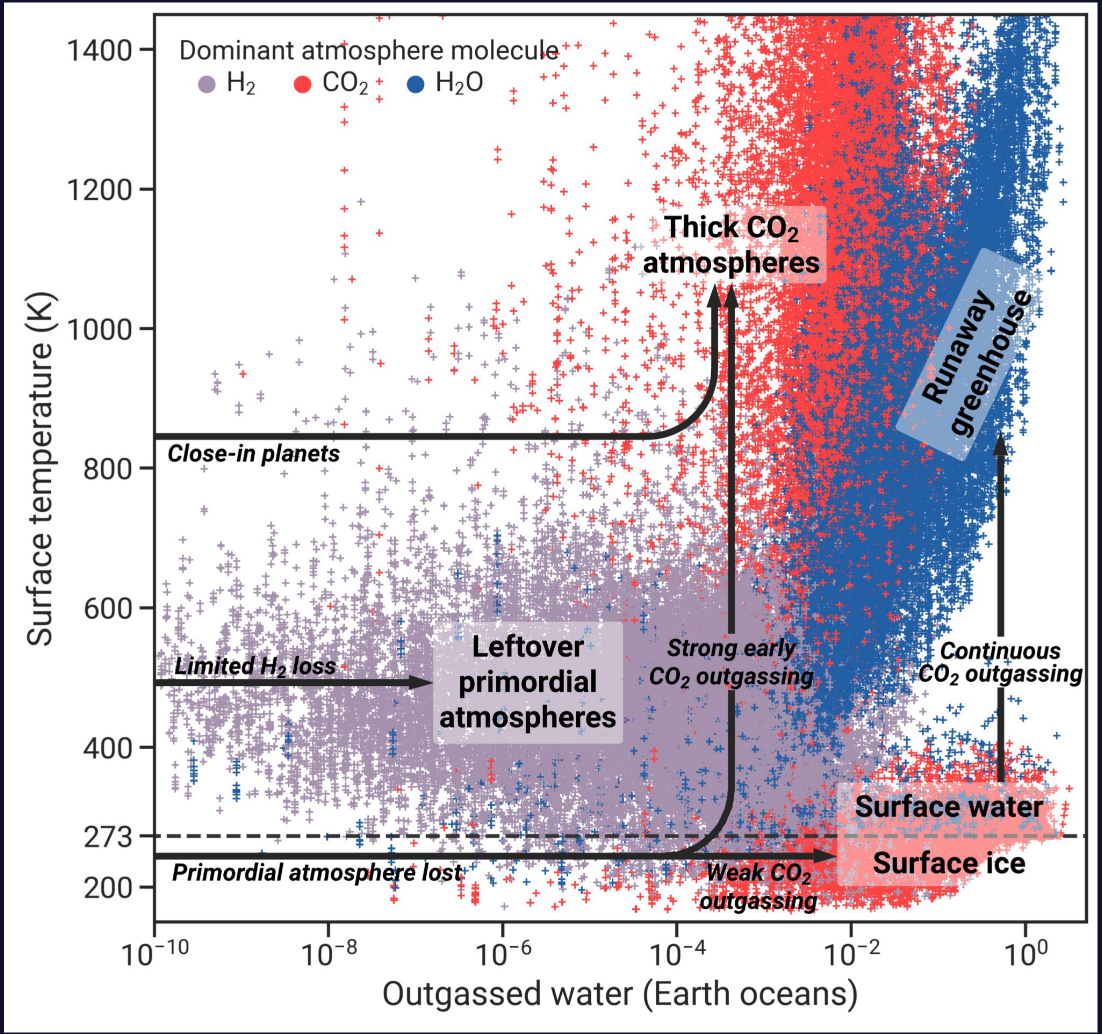
…especially at low masses

Baumeister et al. 2021, under review.



CO_2 outgassing rate determines ocean evolution

- Stagnant-lid planets lack efficient process for long-term CO_2 removal
- For water outgassing, surface pressure needs to be low
- For surface water, CO_2 outgassing needs to be low
- Otherwise: Runaway greenhouse



Baumeister et al. 2021, under review.

- Less volcanic activity due to large pressure gradients *(see also e.g. Noack et al. 2017)*
- Faster mantle cooling
- **Water outgassing is favoured**

- Long-lived, stronger volcanic activity
- **CO_2 outgassing is favoured**

Dense planets planets may offer a better chance at detecting an ocean than Earth-like planets

Conclusions

- A majority of high-density planets have water oceans/surface water
- Rate of CO_2 outgassing drives the coupled interior-atmosphere evolution
- Water outgassing is favored on planets with large cores
- Planets with small cores tend to transition into a runaway greenhouse regime

Thank you for your attention!

Dense planets planets may offer a better chance at detecting an ocean than Earth-like planets