Proxima Centauri b –

Possible climates and Observability

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ESEP

6e Journée ESEP

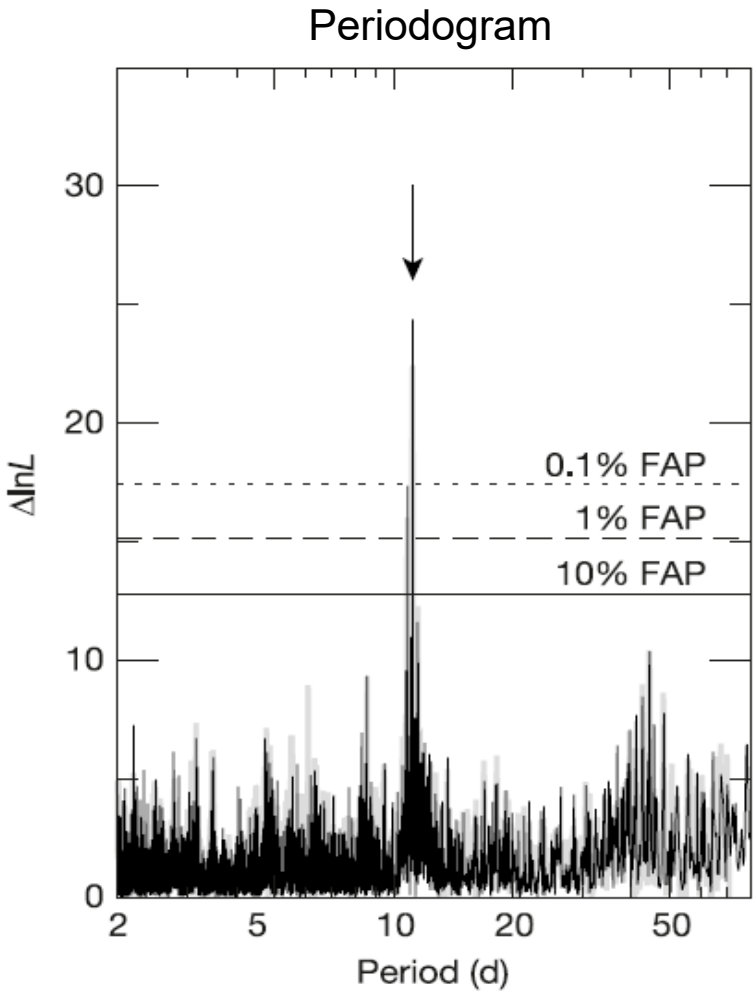
LMD

REMINDERS

- Detection of a planet around **Proxima Centauri** using Radial Velocity

- M sini = **1.3 M_{Earth}**

- P=11.2 days, d=0.05 AU, F~**65% F_{Earth}**

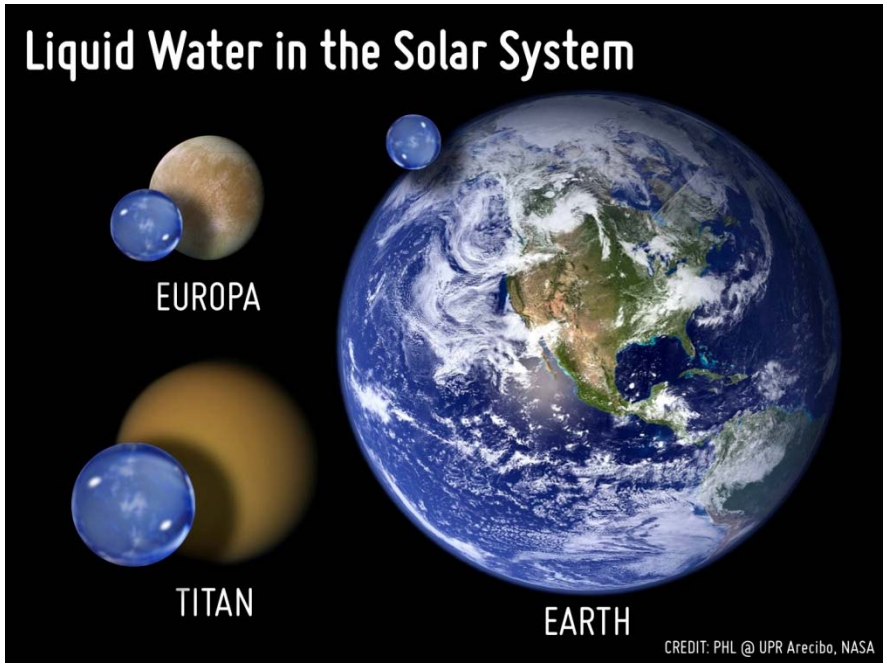


Anglada-Escudé et al. 2016, *Nature*

Evolution/Environment

1) Formation: Inside or Beyond the snow line ?
Water poor ? Water rich ?

Coleman et al. 2016, *MNRAS*

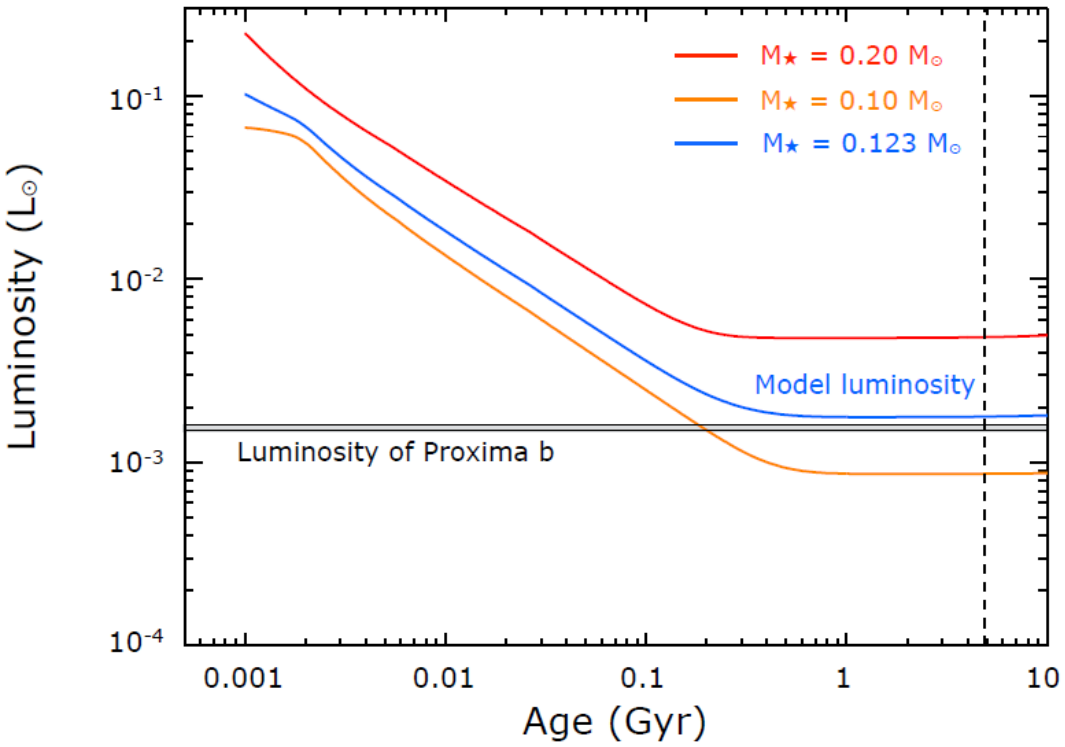


Evolution/Environment

1) Formation: Inside or Beyond the snow line ?
Water poor ? Water rich ?

2) Water loss:

- 100-200 My in runaway greenhouse



Ribas et al. 2016, *A&A*

Evolution/Environment

1) Formation: Inside or Beyond the snow line ?
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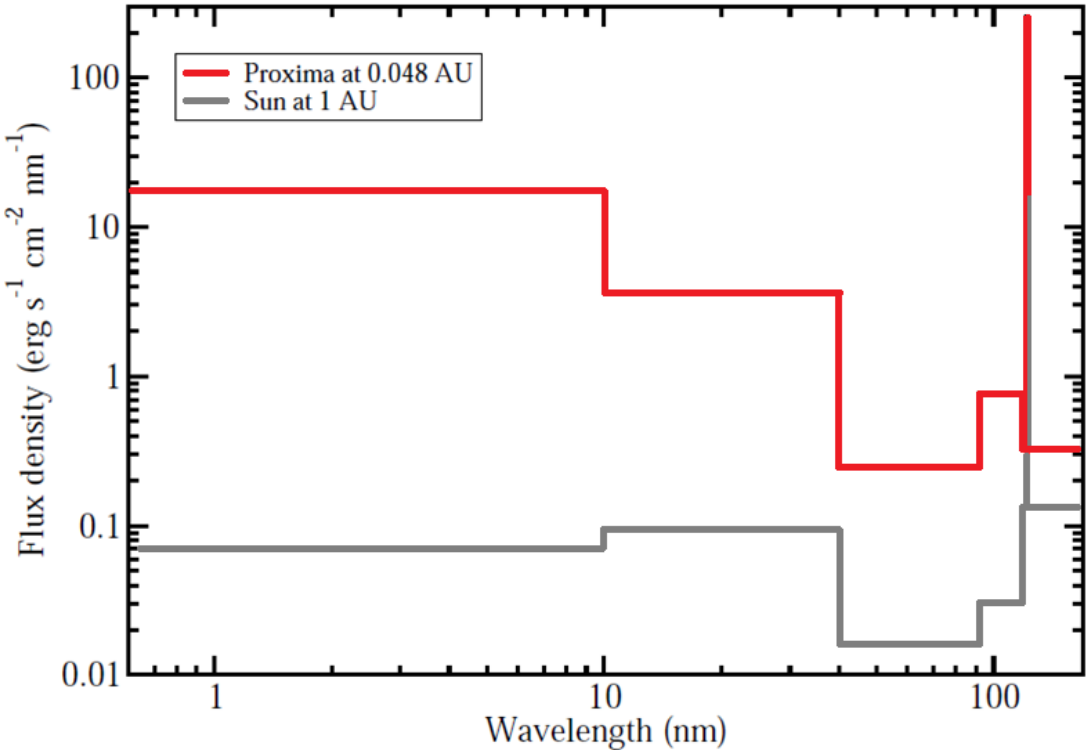
- 100-200 My in runaway greenhouse
- Very high XUV flux



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Evolution/Environment

1) Formation: Inside or Beyond the snow line ?
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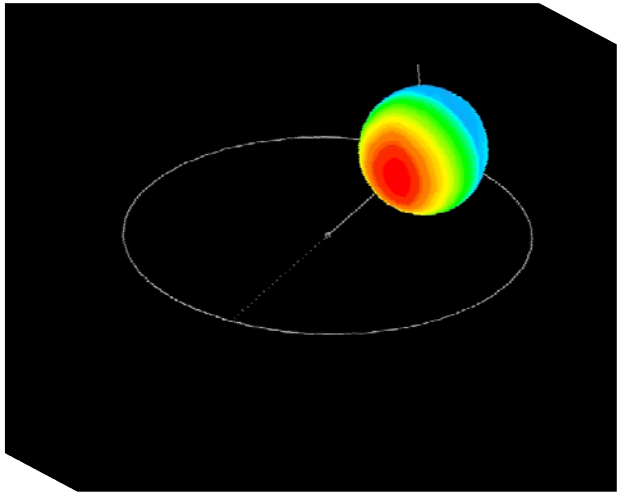
2) Water loss:

- 100-200 My in runaway greenhouse
- Very high XUV flux

3) Rotation mode: Slow rotation (synchronous, 3:2 resonance …)



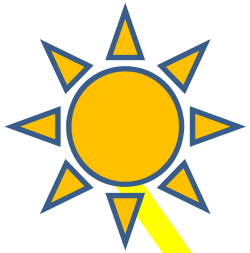
Ribas et al. 2016, *A&A*

Simulating the possibles climates on Proxima Centauri b

LMD Generic Model

1) Dynamical Core :

~universal

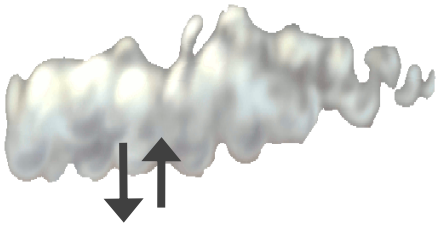


2) Radiative transfer through gas and aerosols

Correlated-k radiative transfer code.

5) Volatile condensation on the surface and in the atmosphere :

- Robust microphysics: Fixing mixing ratio of condensation nuclei
- Modified thermodynamics to handle condensation of major constituants (H_2O, CO_2)



3) Turbulence and convection in the boundary layer

⇨ Universal turbulent sheme

⇨ Robust convection scheme

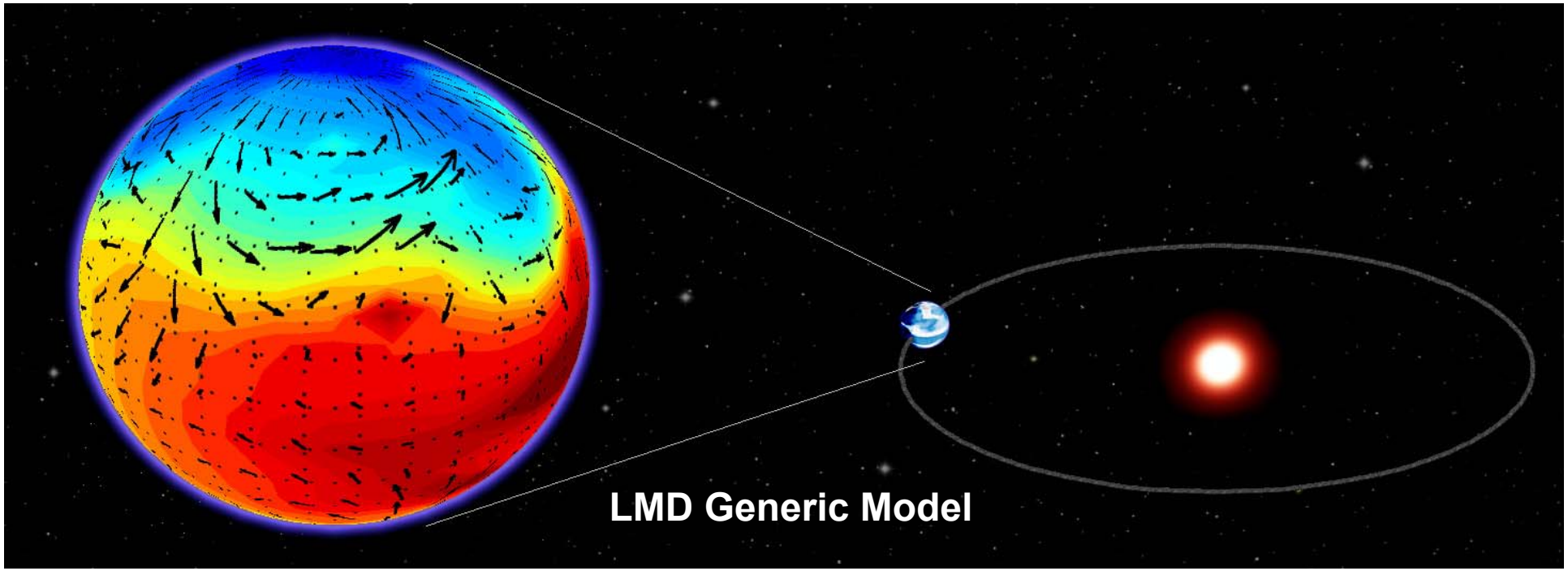
4) Surface and subsurface thermal balance

~universal

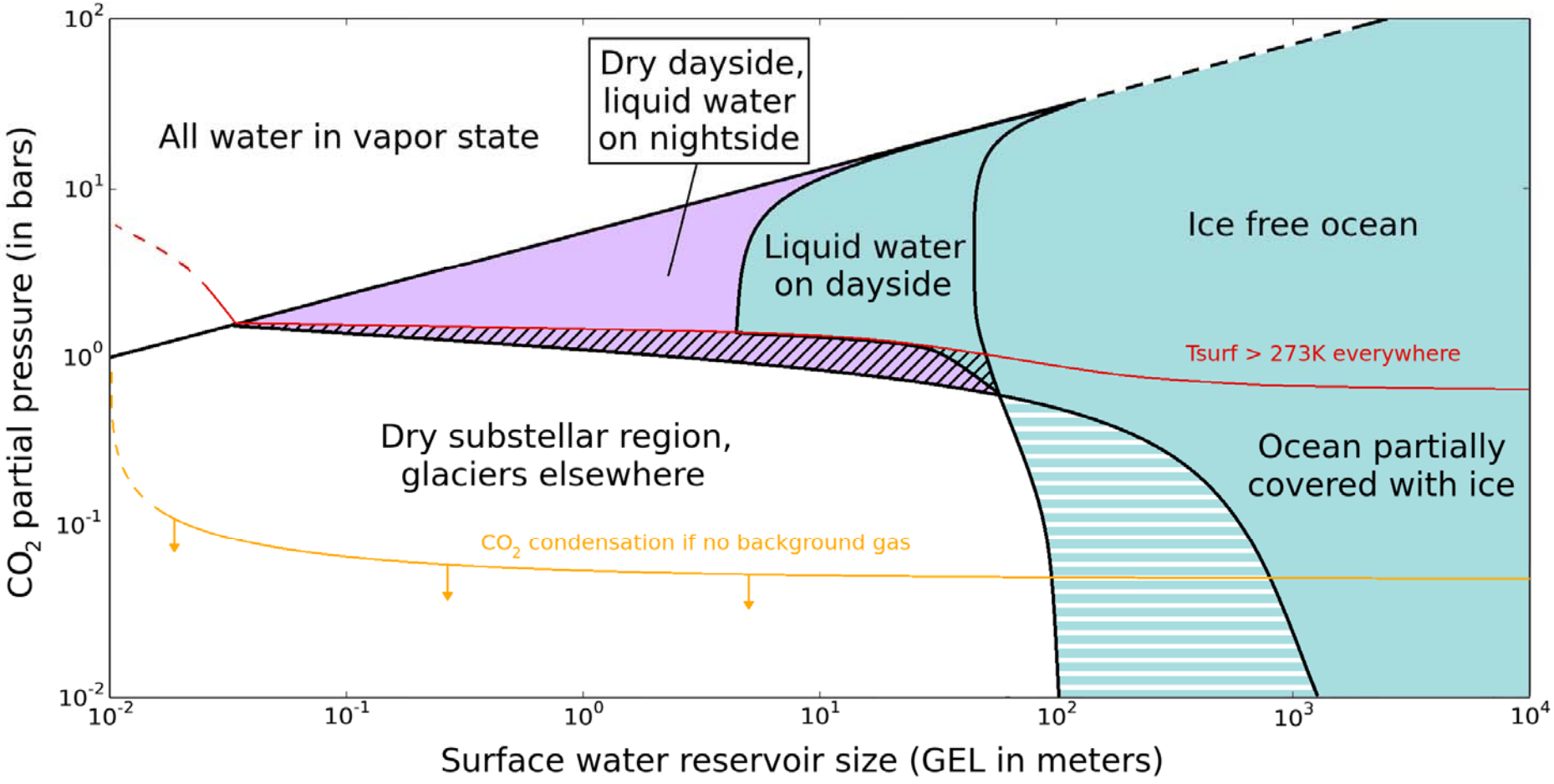
Simulating the possibles climates on Proxima Centauri b

Degree of confidence

- Flux = 65 % F_{earth}, Star spectrum
- Obliquity = 0°
- M = 1.4 M_{earth}
- 1:1 / 3:2 resonances
- Null excentricity
- Amount of volatiles
- Flat topography



Synchronous rotation: Possible climates



Turbet et al. 2016, *A&A*

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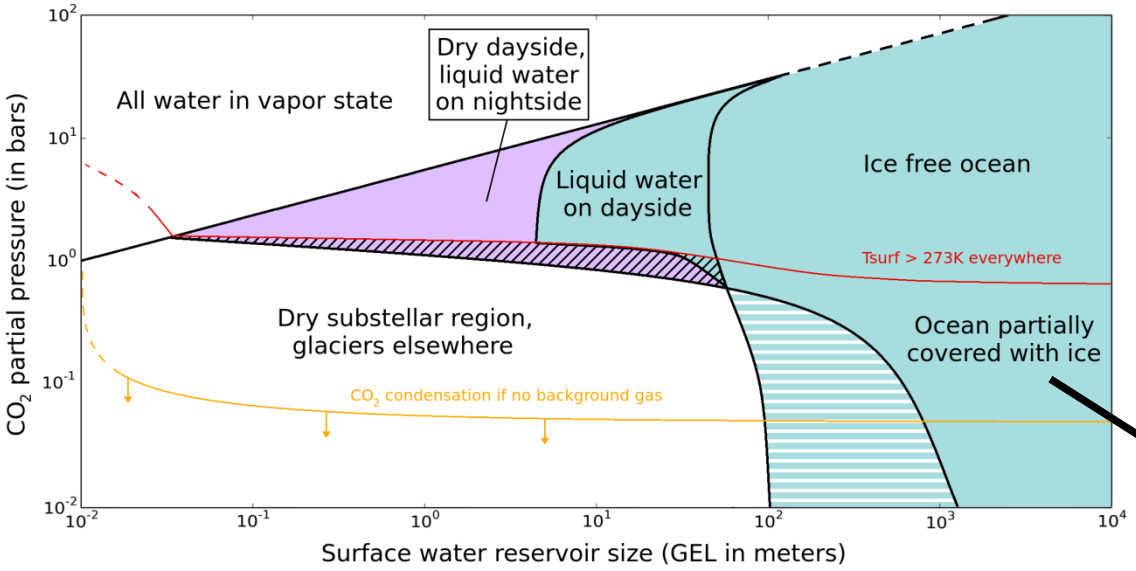
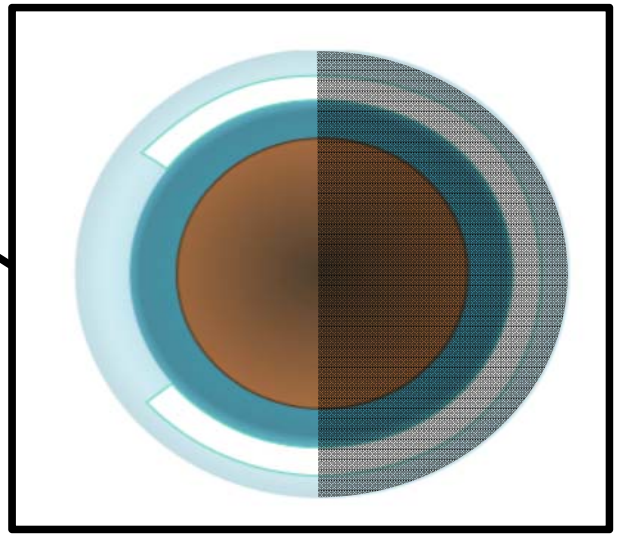
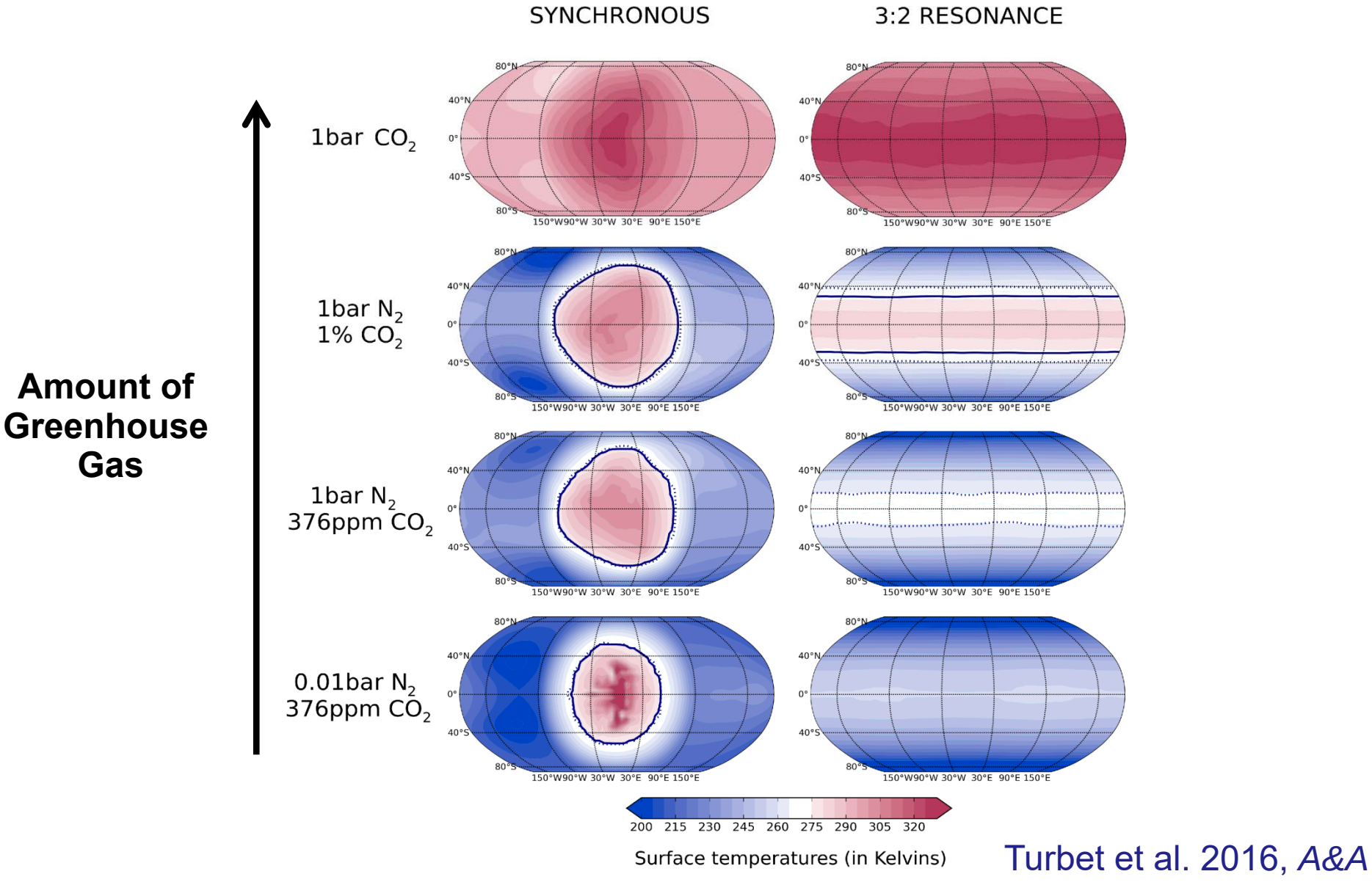


Eyeball planet



Turbet et al. 2016, *A&A*

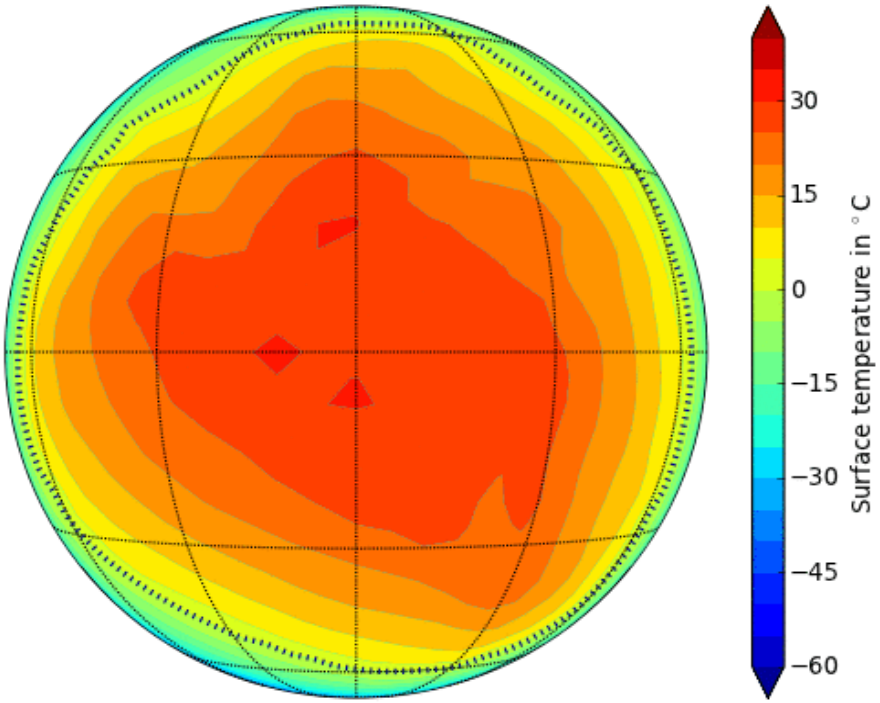
Influence of greenhouse gas content / rotation mode



Turbet et al. 2016, *A&A*

Proxima b with Earth-like oceans/atmosphere

Synchronous



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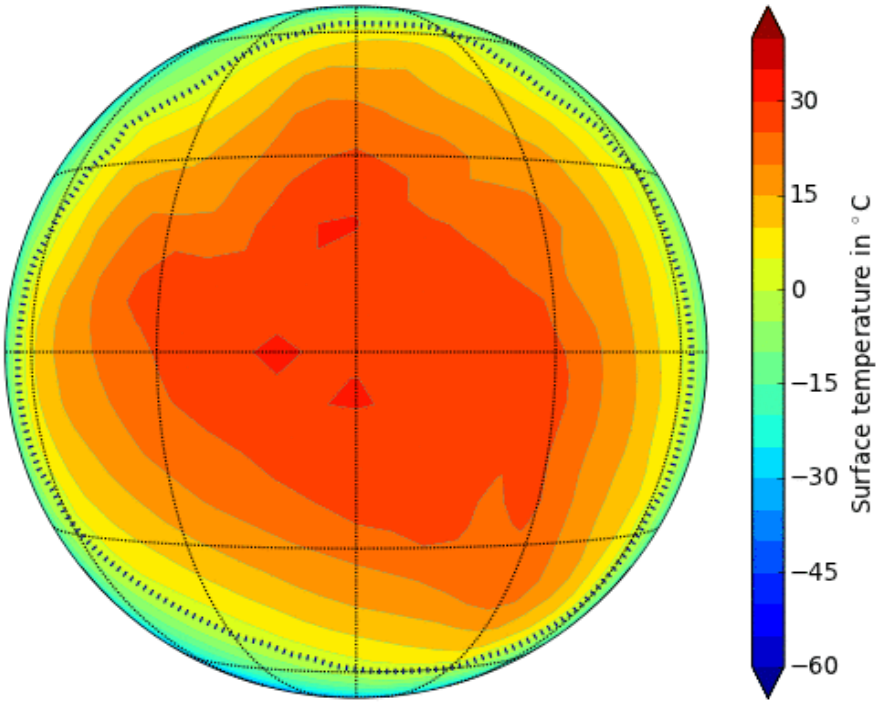
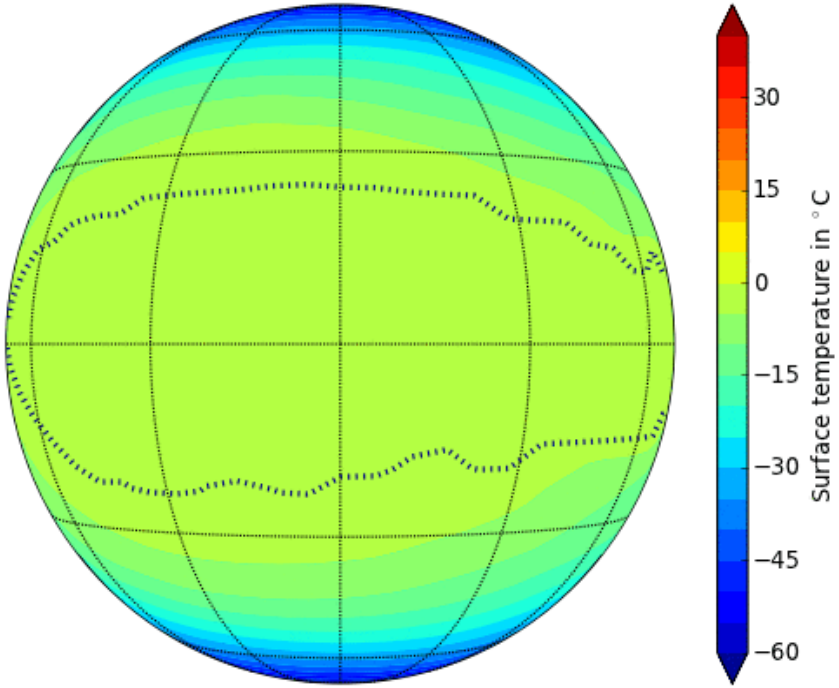
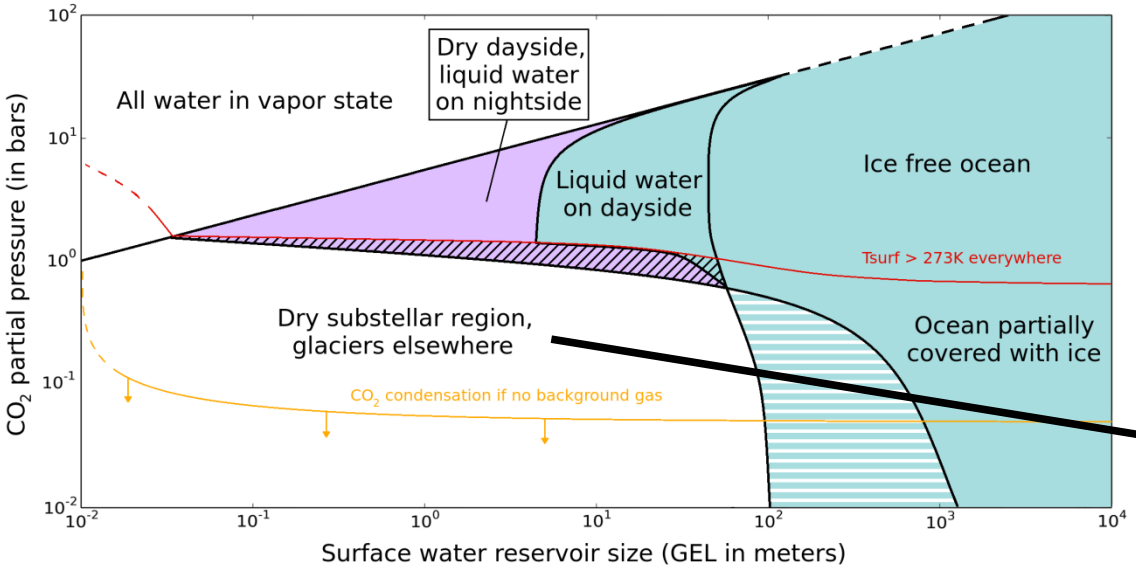


3:2 Resonance

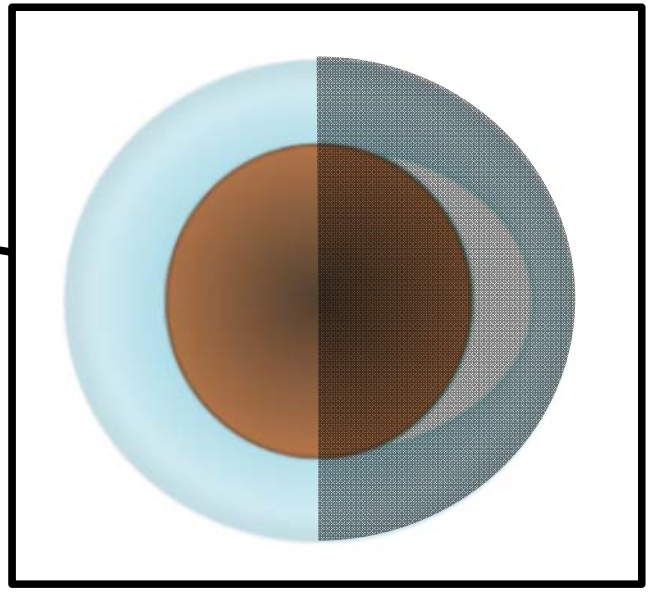


Turbet et al. 2016, *A&A*

Synchronous rotation: Possible climates

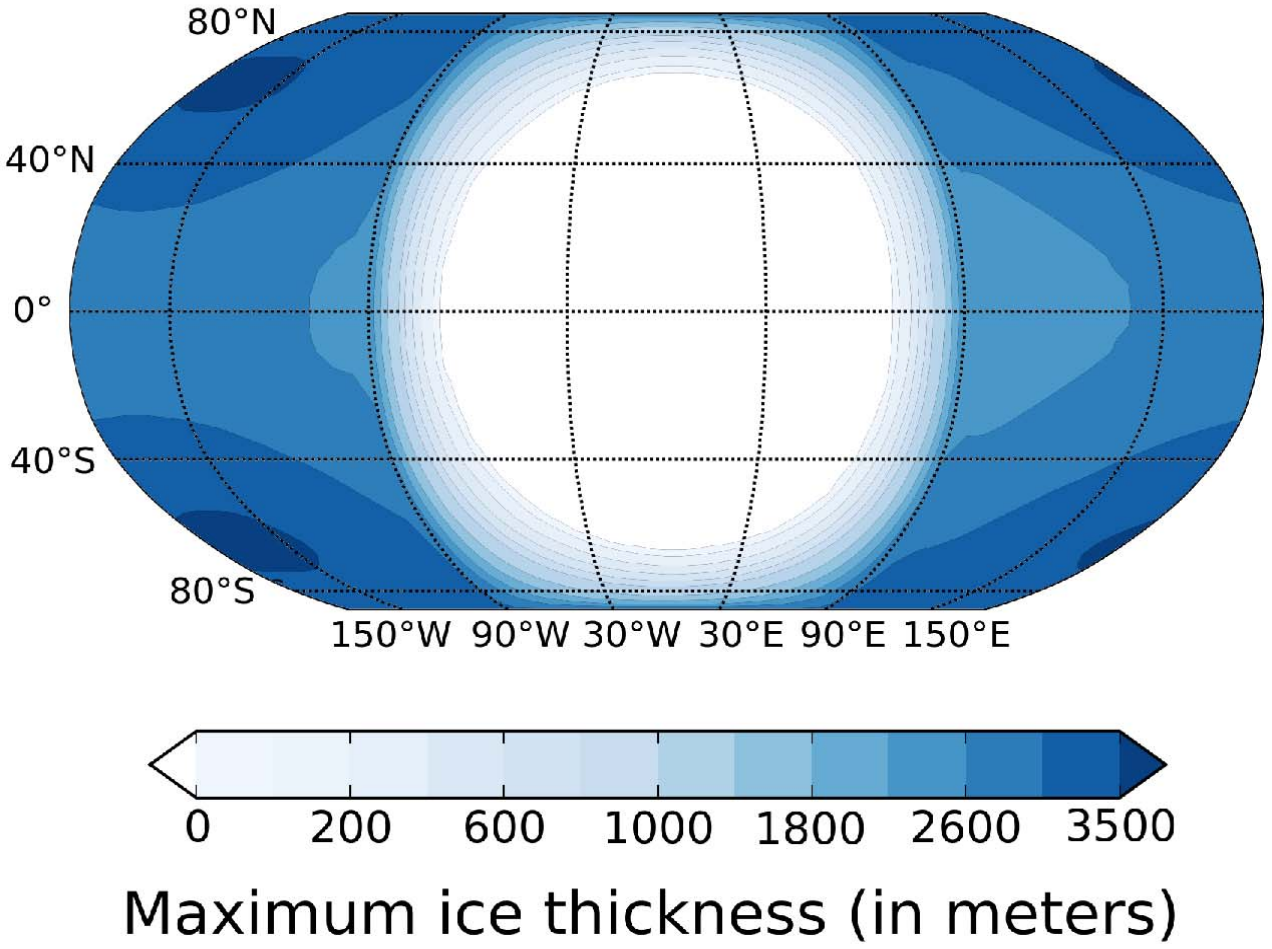


Glaciers in cold traps



Turbet et al. 2016, *A&A*

Maximum size of water ice glacier
(with Earth-like atmosphere)



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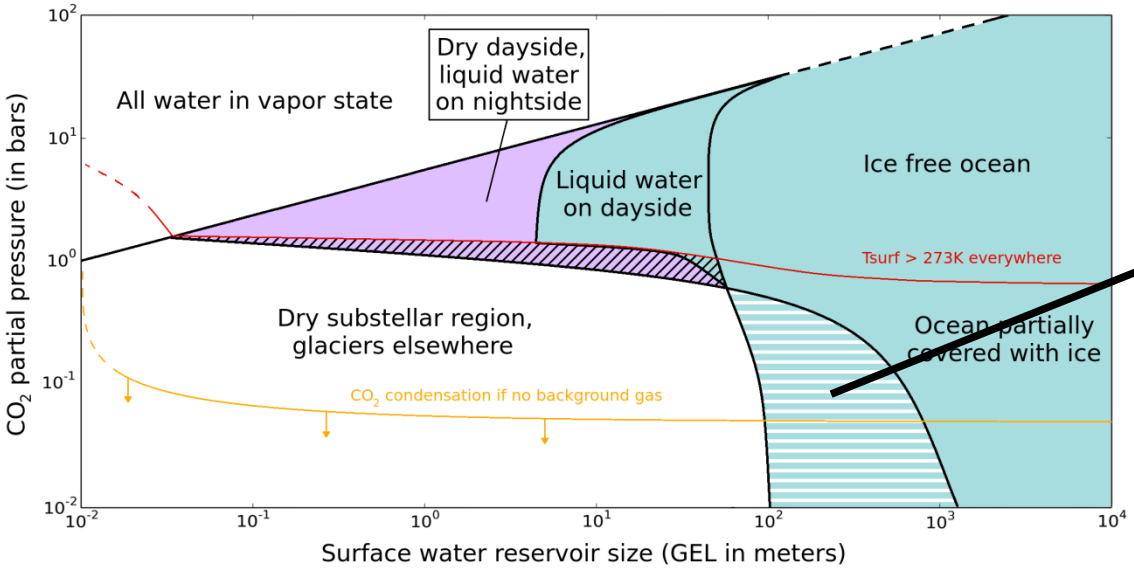
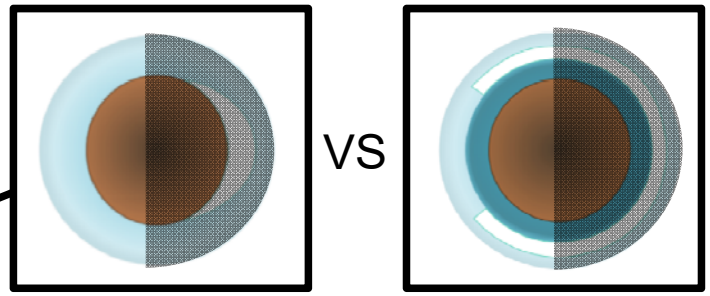
Synchronous rotation: Possible climates

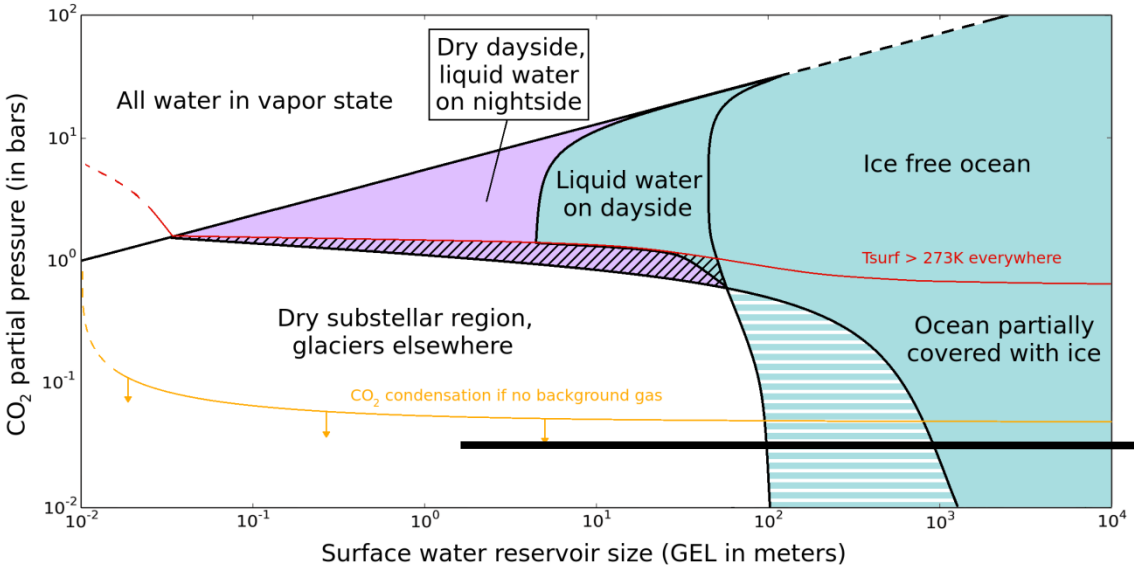


Climate bistability

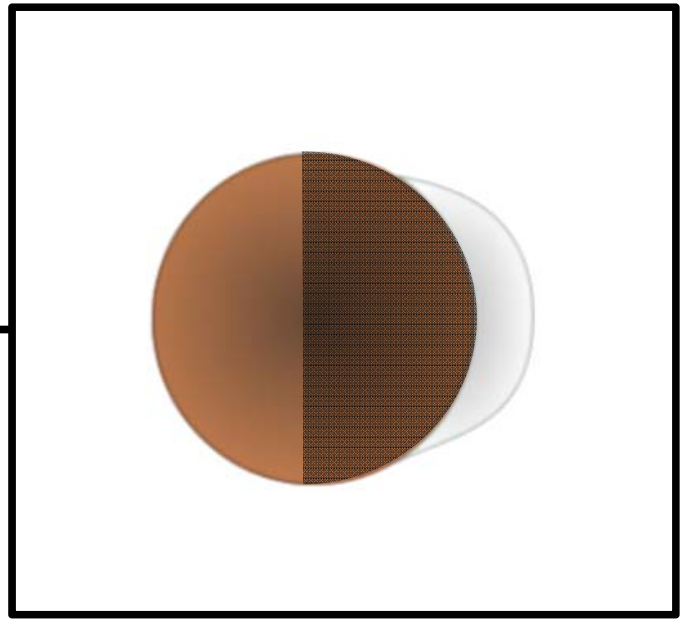


Turbet et al. 2016, *A&A*

Synchronous rotation: Possible climates

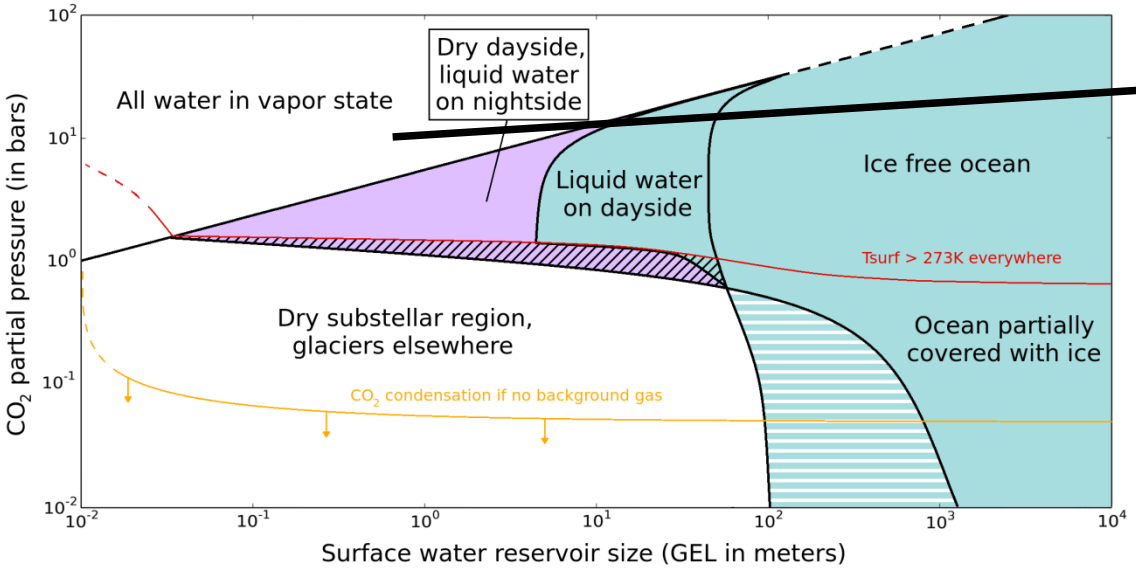


Atmospheric collapse

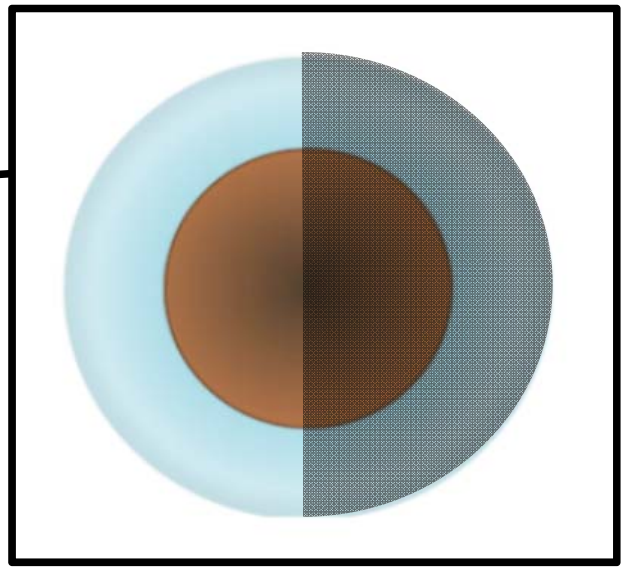


Turbet et al. 2016, *A&A*

Synchronous rotation: Possible climates



All water in vapor state



Turbet et al. 2016, *A&A*

What’s next ?

A transit of Proxima b ?

→ **No** conclusive transit using MOST photometry

Kipping et al. 2016, *ApJ*

→ Only **1.5%** chance for geometric reasons

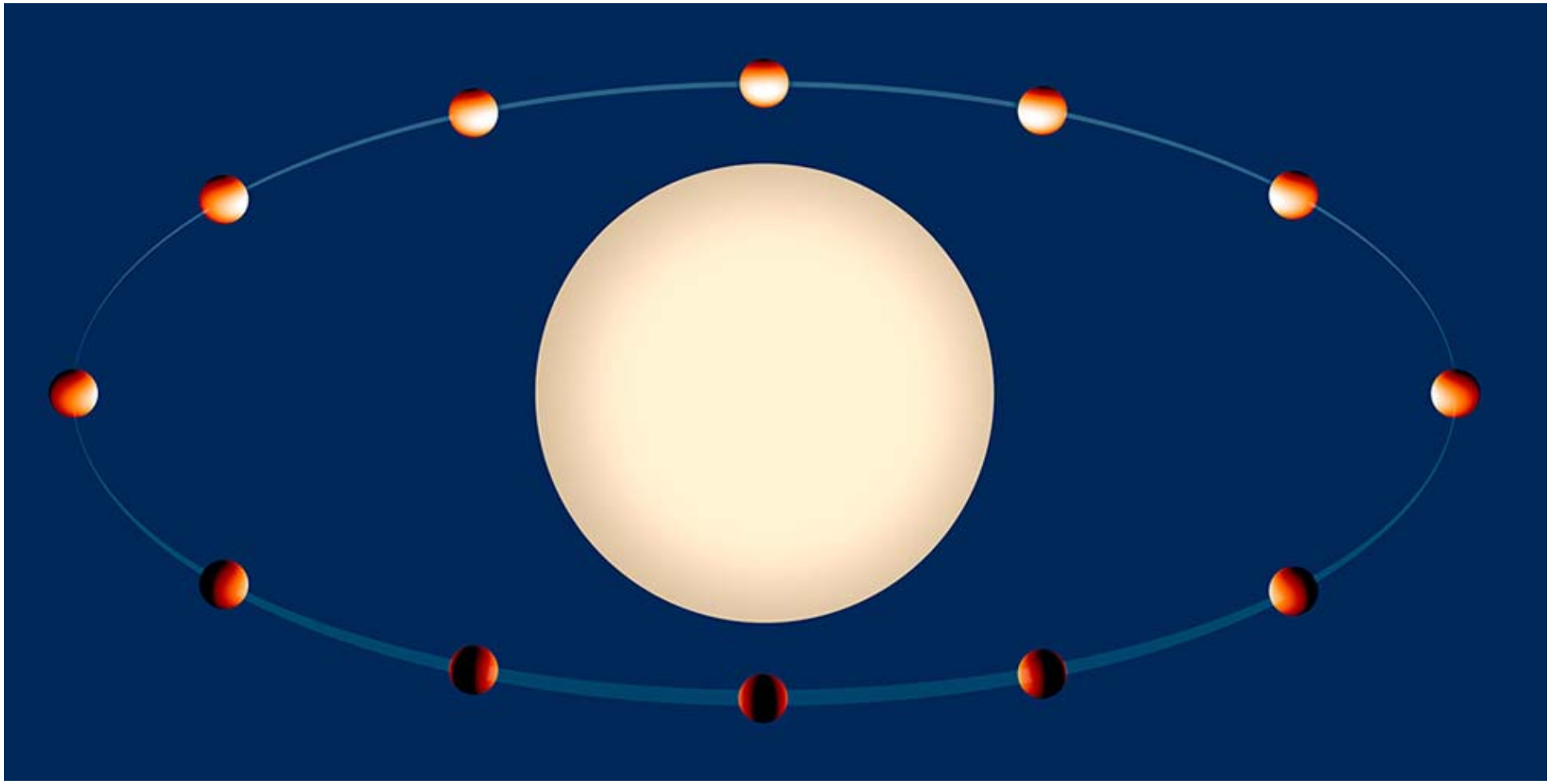
Radial velocity follow up ?

→ VLT-8m/**ESPRESSO** first light in 2017

→ Constrain **eccentricity** of Planet b ?
(and therefore its rotation mode ?)

→ Constrain the presence of **another planet ?**

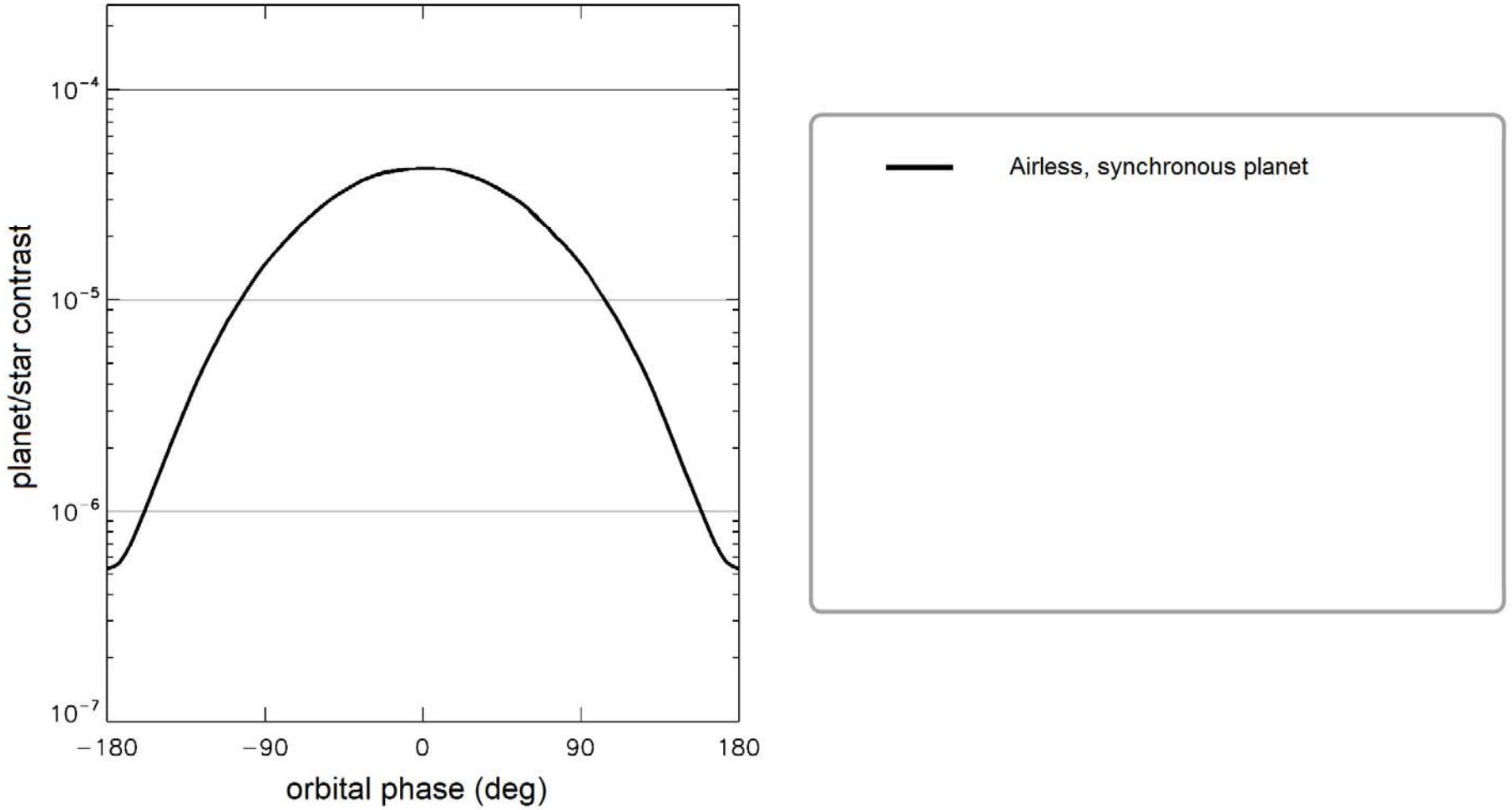
Phase curves with JWST in 2019



Credit: NASA/ESA

Thermal phase curves of Proxima b

at 11.2µm



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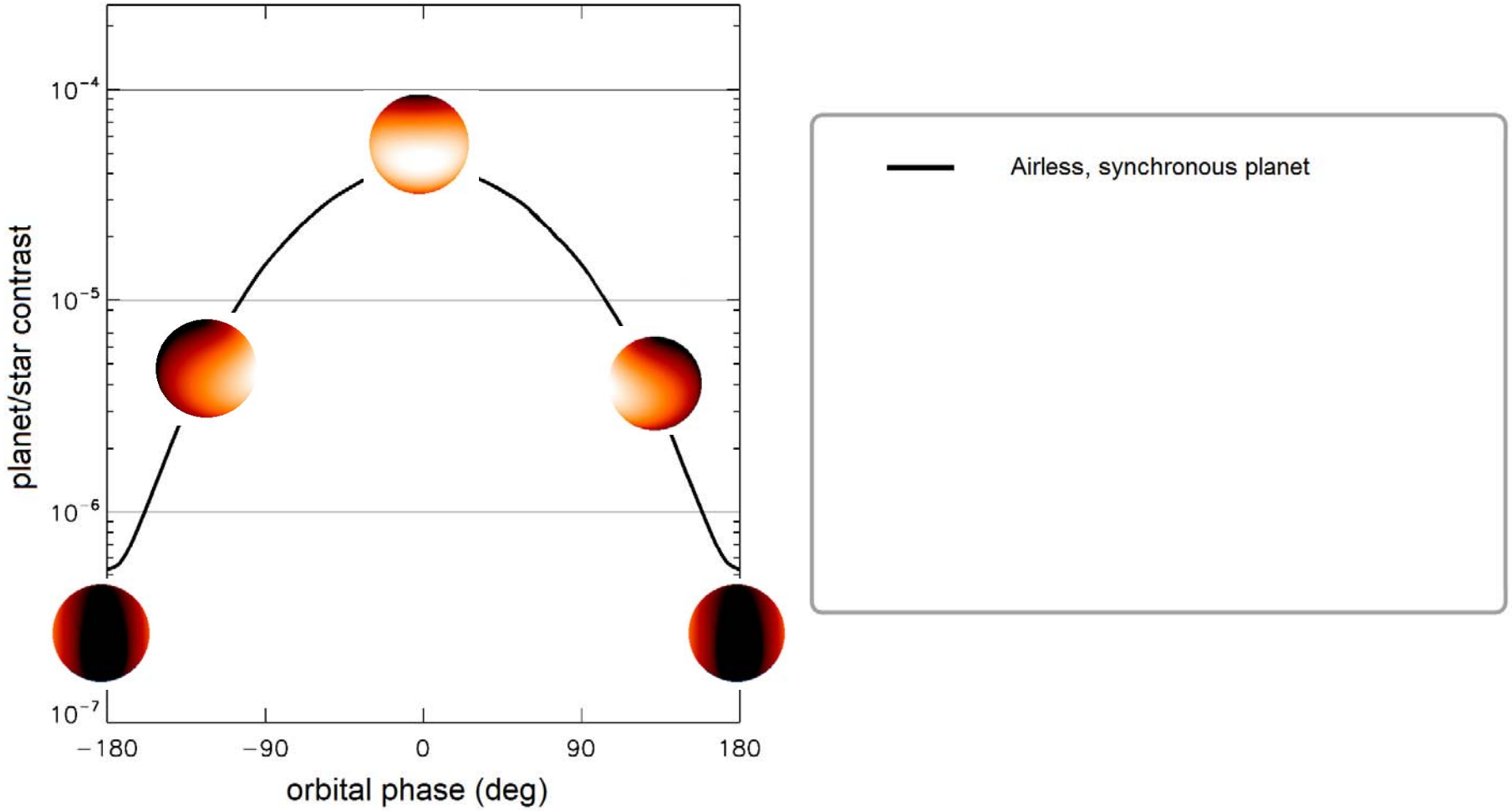

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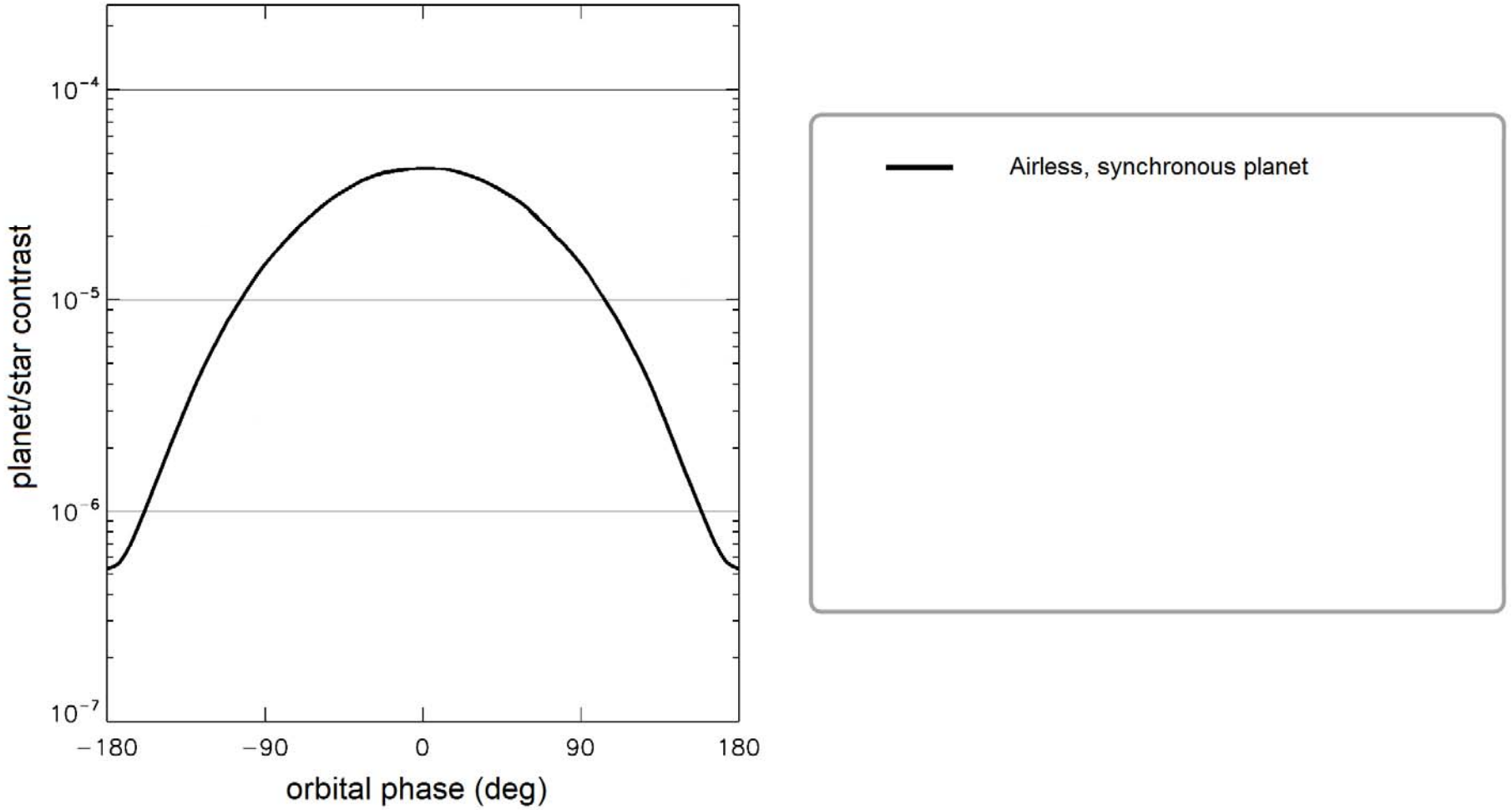

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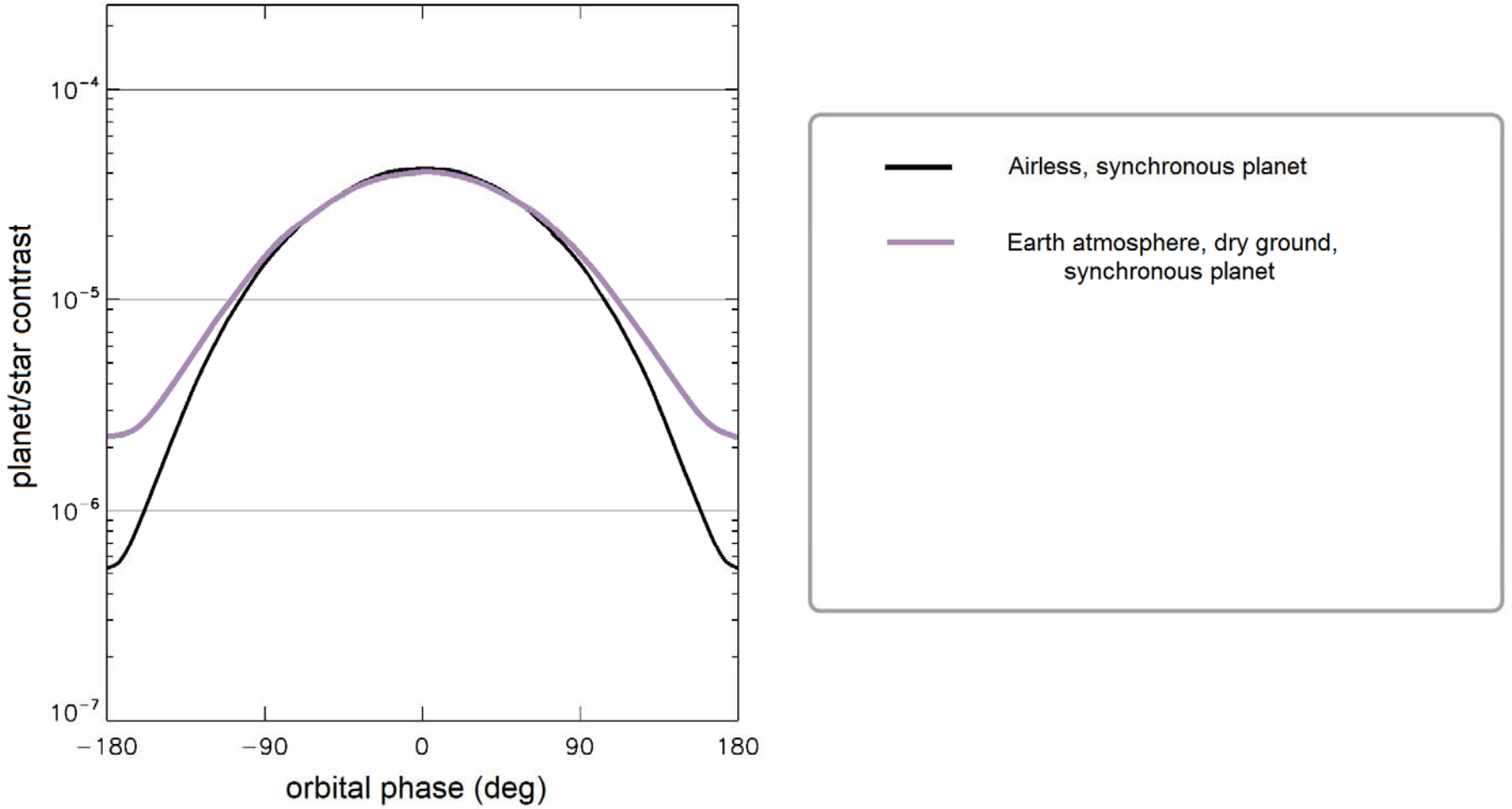

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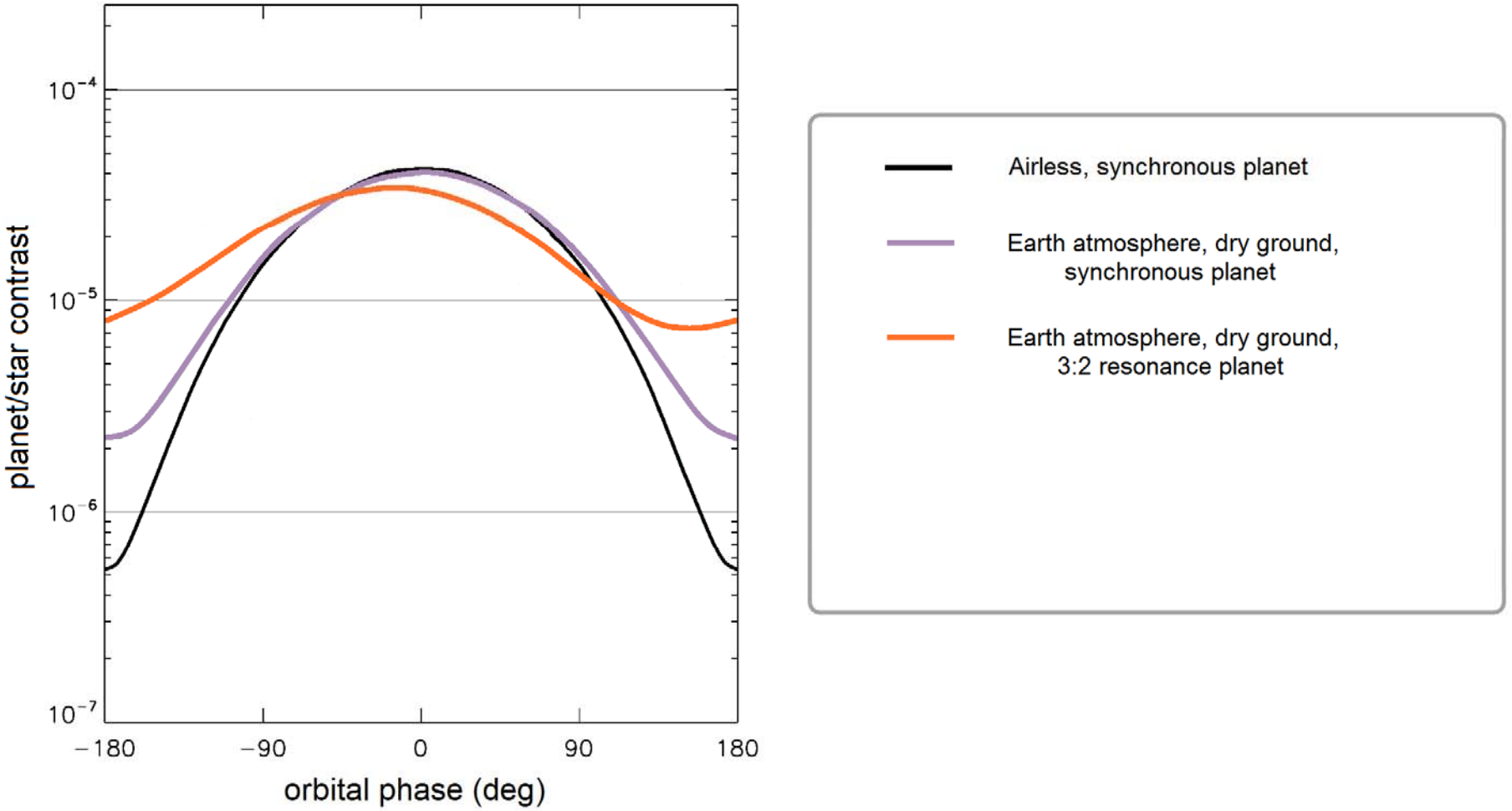

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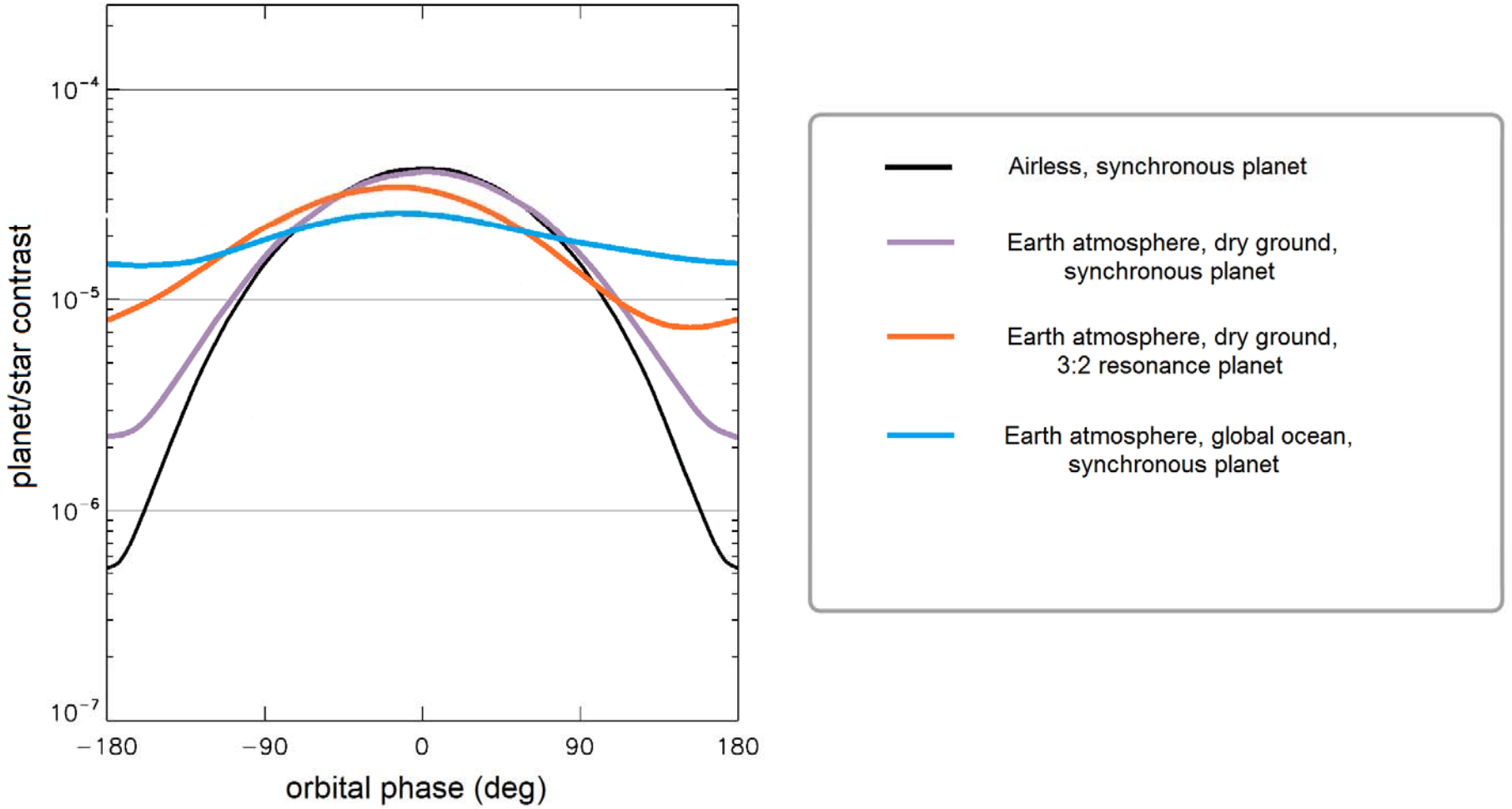

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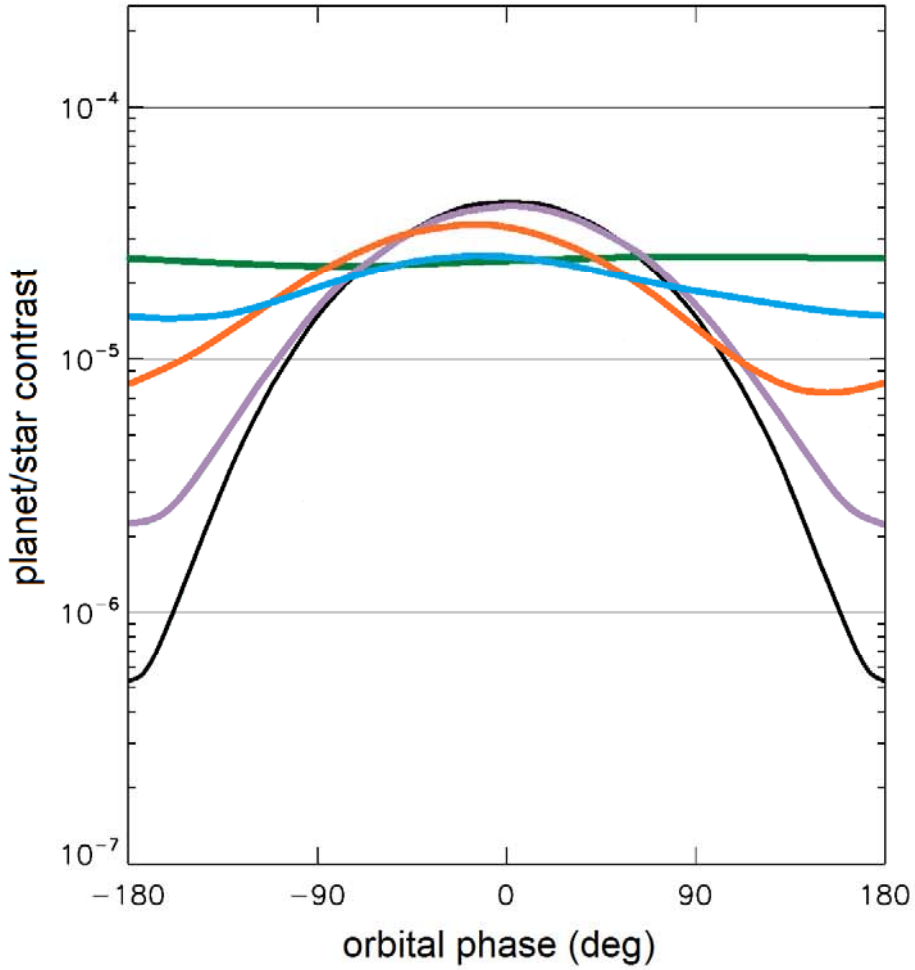
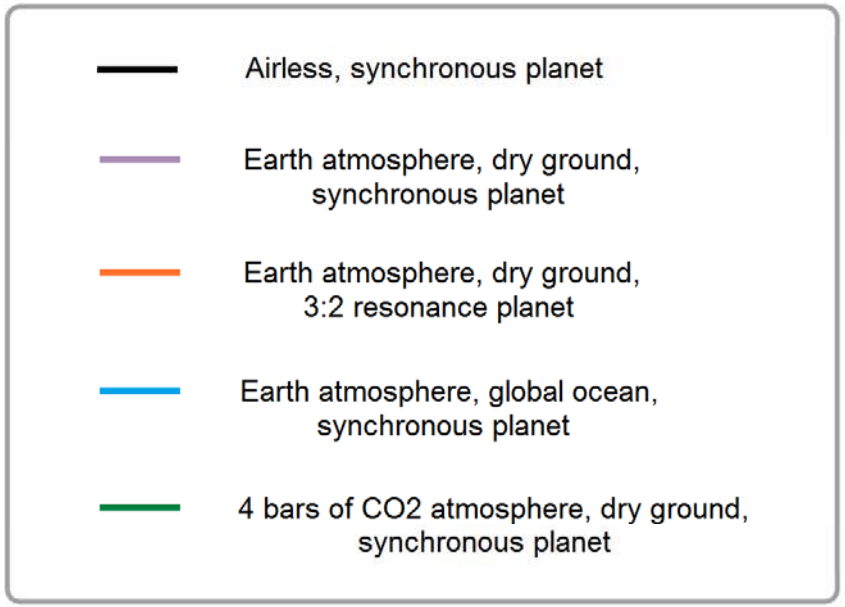
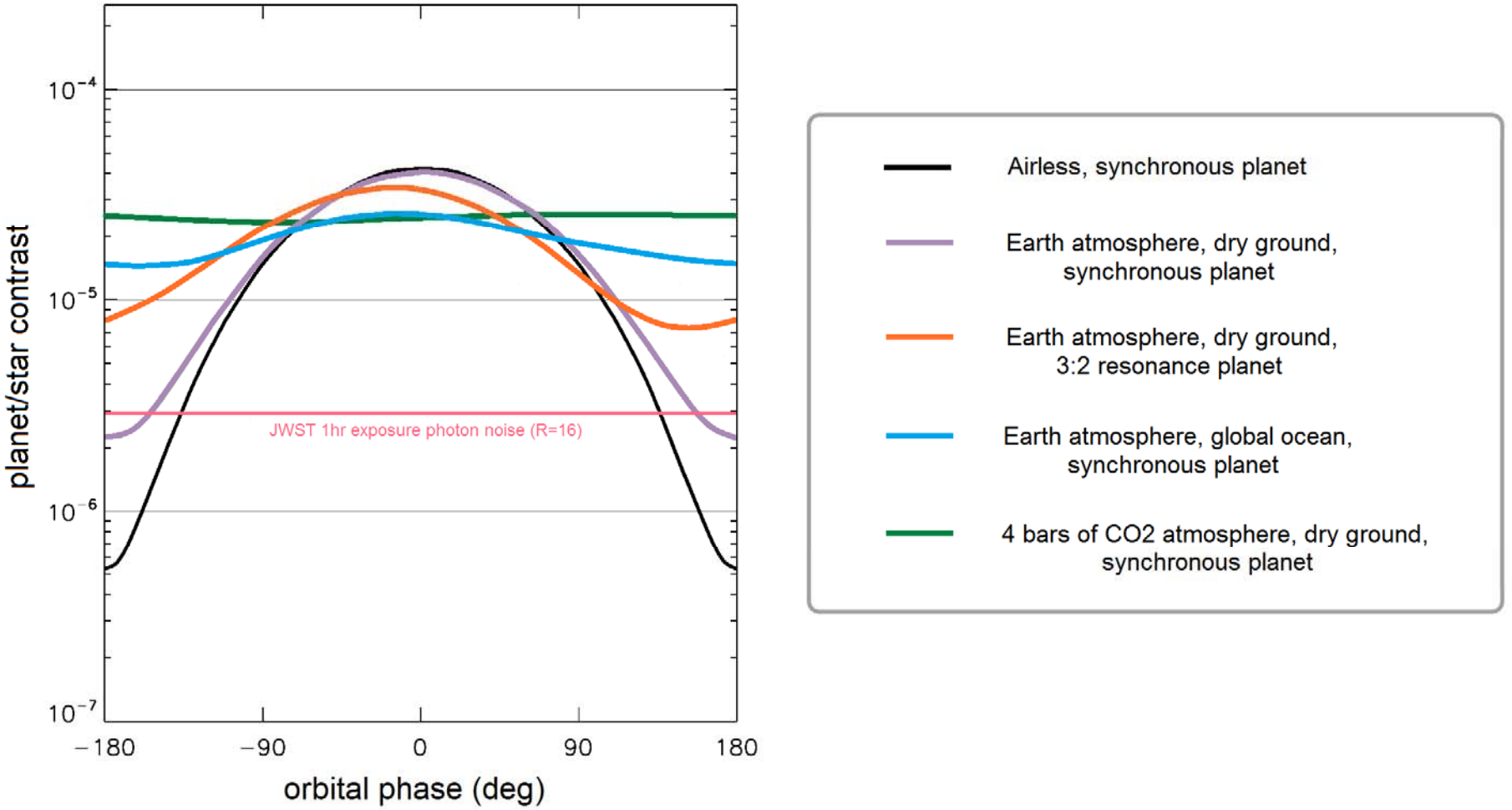




Turbet et al. 2016, *A&A*

Thermal phase curves of Proxima b

James Webb Space Telescope → First results mid-2019 !



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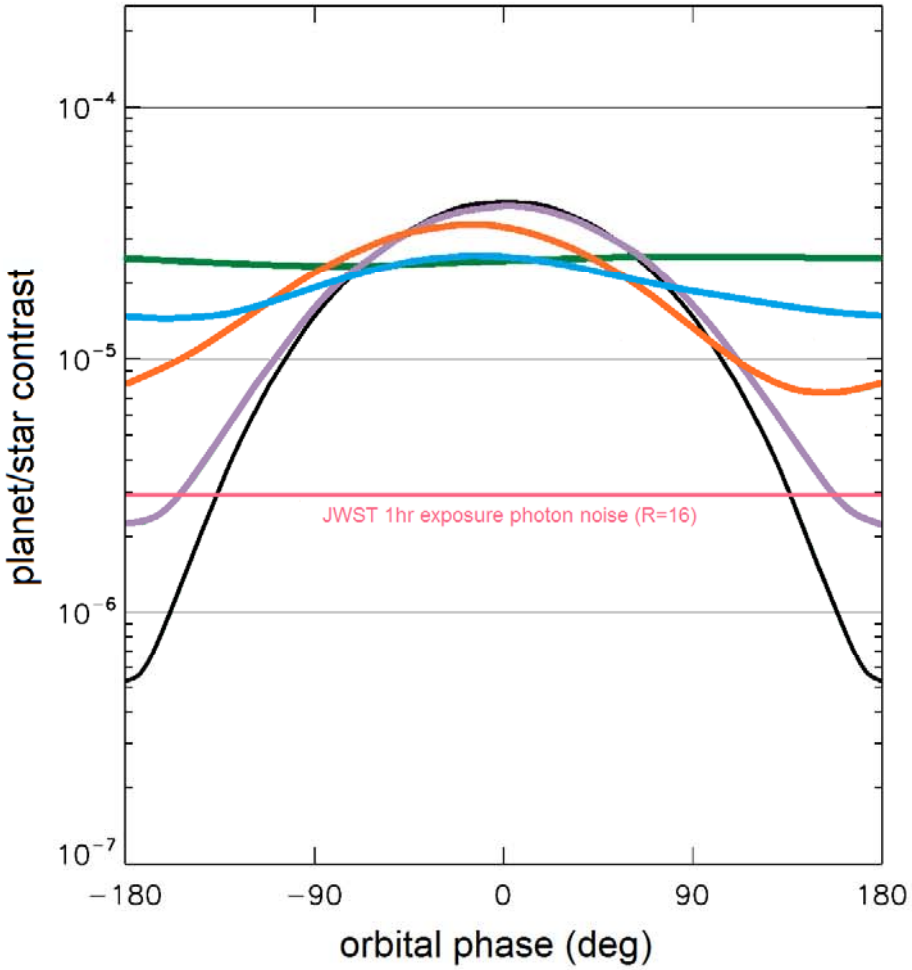


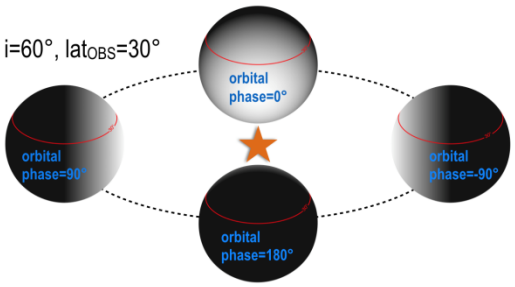
Main issues

1) **Is the noise photon-limited ?**

2) **Better understand/control variability of star luminosity**

Turbet et al. 2016, *A&A*

Direct imaging with E-ELT expected in 2025



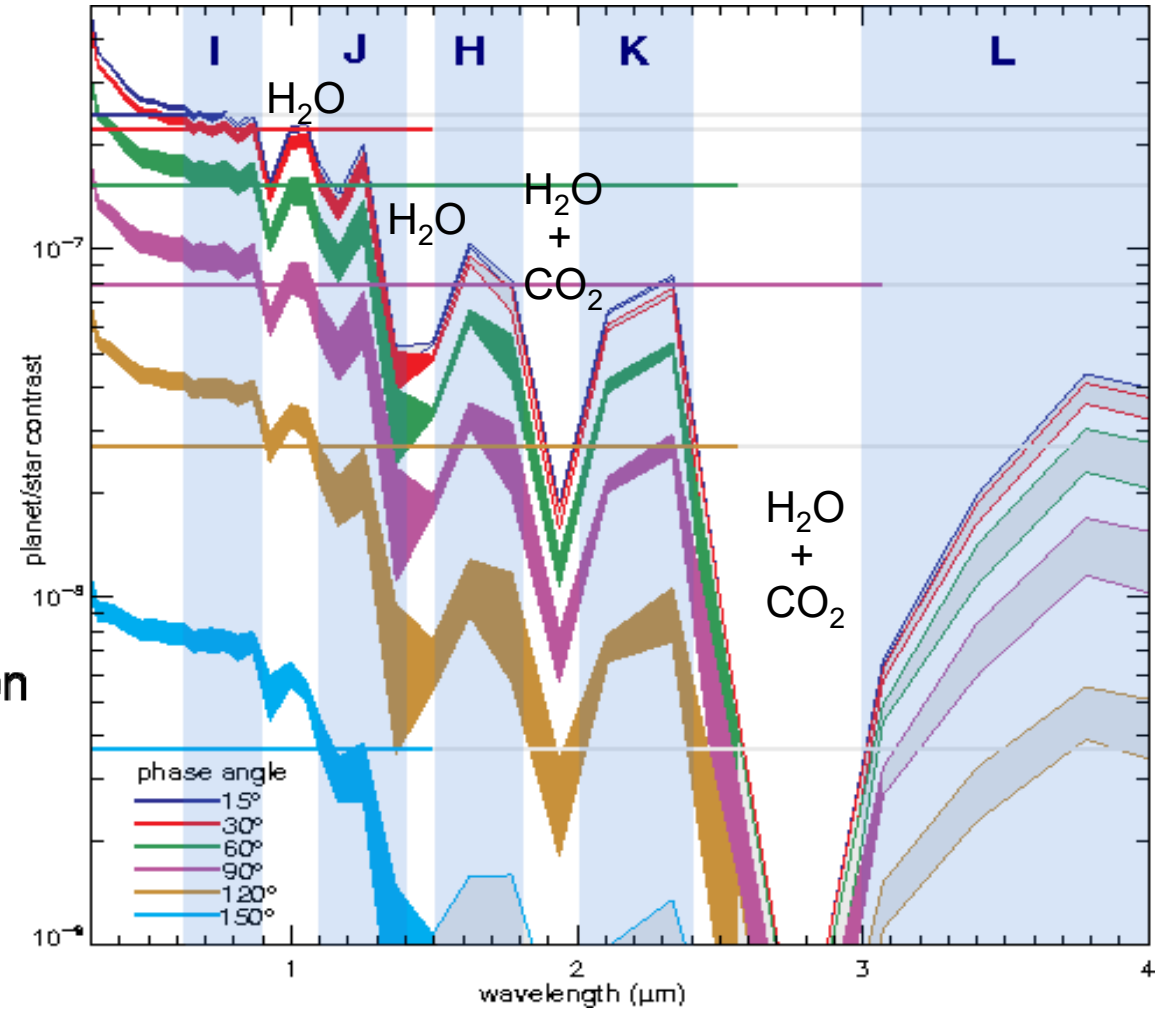
→ Angular separation between 0 and **38 mas**

→ **7** $\frac{\lambda}{D}$ **at 1 µm** with 39m ELT

→ **J band** seems the best option

→ **Aims:**
- high resolution spectroscopy
- reflexion phase curves
- …

Synchronous rotation mode :
Earth-like oceans/atmosphere



Turbet et al. 2016, *A&A*

CONCLUSIONS

- **On evolution:**

→ Early runaway phase, high atmospheric escape, slow rotation …

- **On possible climates:**

→ Various possibilities depending on amount of volatiles (H2O, greenhouse gas and background gas)

→ In particular, if Proxima b formed « beyond the snowline » and is now tidally locked, we predict that there should always be liquid water at the surface !!!

- **On observability:**

→ Proxima b is our best chance to observe directly a rocky planet in the Habitable Zone of its star.

→ Direct imaging with E-ELT from 2025 (maybe earlier with VLT/ESPRESSO using HCHR technique *[Sparks & Ford 2002, Snellen et al. 2015, Lovis et al. 2016]*)

→ Possibility to observe it from 2019 using IR thermal phase curves with JWST (atmosphere ? Heat redistribution ?)