Surface properties of the day and night sides of K2-141 b

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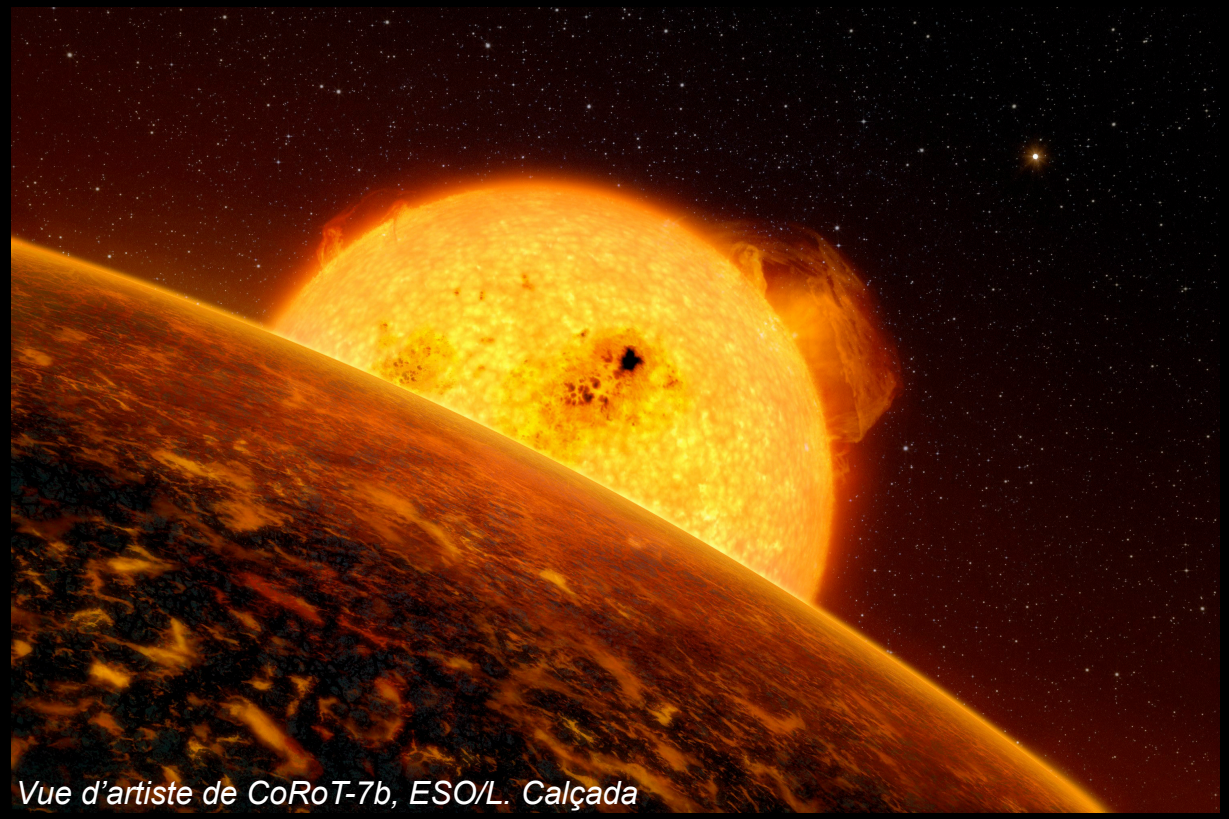
K2 141 b: A « Lava Planet »



Vue d'artiste de CoRoT-7b, ESO/L. Calçada

Parameter	K2-141b
P [day]	0.2803244 ± 0.0000015
T_0 [day][a]	7744.07160 ± 0.00022
$a/R_\star$	$2.292^{+0.053}_{-0.060}$
$R_p/R_\star$	0.02037 ± 0.00046
i [degree]	$86.3^{+2.7}_{-3.6}(>82.6)$
R_p [$R_\oplus$]	1.51 ± 0.05
K [m s^{-1}][b]	6.25 ± 0.48
e[d]	0
ω [deg][d]	90
$\mathcal{M}_0$ [deg][b,e]	182.2 ± 0.6
M_p [$M_\oplus$][b]	5.08 ± 0.41
ρ [$\rho_\oplus$]	1.48 ± 0.20
ρ [g cm^{-3}]	8.2 ± 1.1

Table from Malavolta et al. 2018

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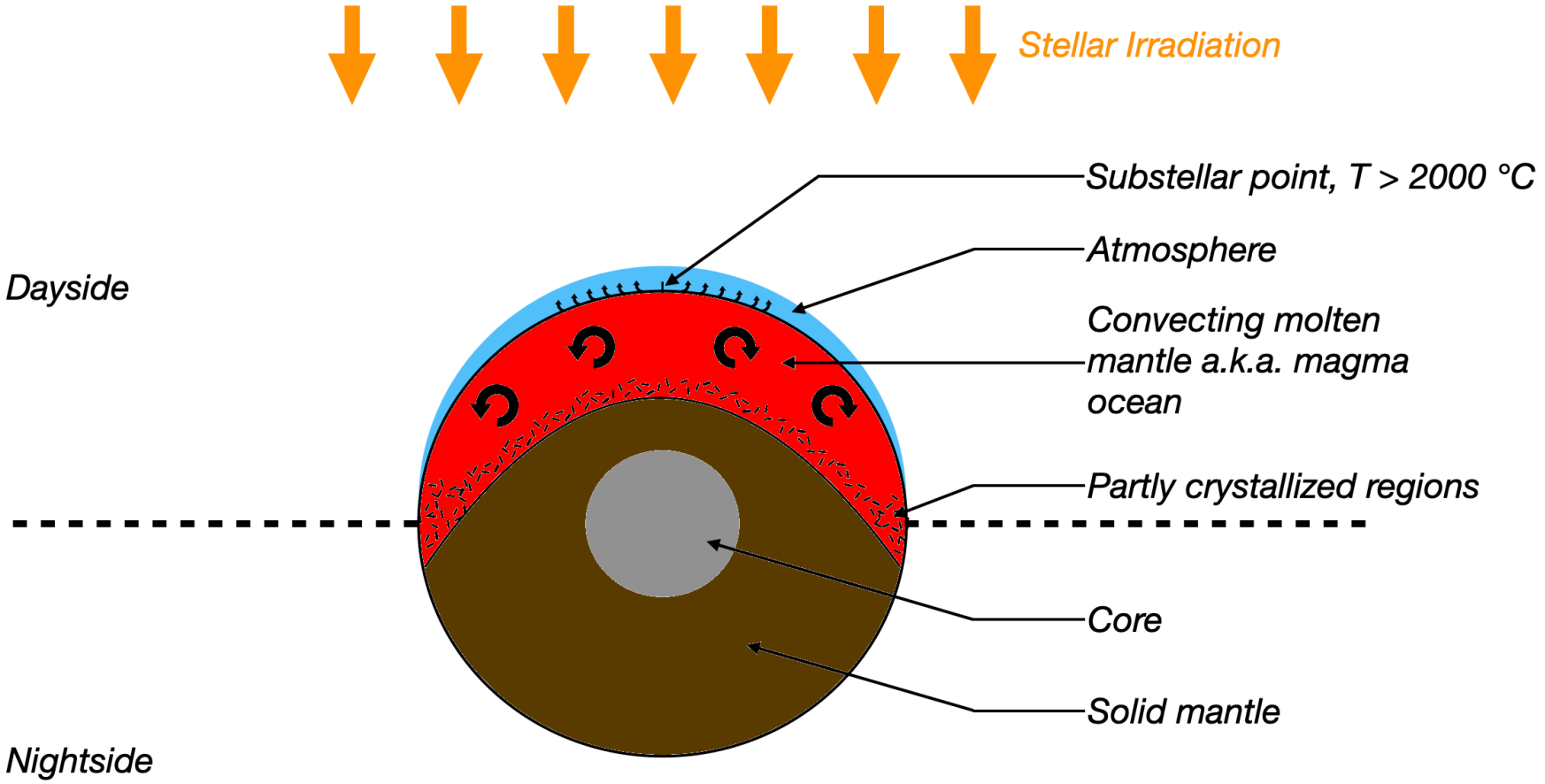

Molten dayside?

Solid nightside?

Surface temperatures?

Atmosphere?

Project anchor

- Composition are basically unknown and could deviate largely from terrestrial ones
  - e.g. C-rich (Madhusudhan et al. 2014) or refractory (Léger et al. 2011)
- What could be the importance of very different magma compositions on M.O. convection, outgassing and final mantle structure/planet surface?

Project anchor

- Composition are basically unknown and could deviate largely from terrestrial ones
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- What could be the importance of very different magma compositions on M.O. convection, outgassing and final mantle structure/planet surface?

=> need generalist models of magma properties.

=> focus on the most important properties.

Modeling magma ocean properties at surface

gpvisc for silicate melt viscosity

+

Equations for the effects of the crystals (Costa et al. 2009)

+

Transition for the rheology of a solid mantle (Scott and Kohlstedt, 2006)

+

Dayside temperature calculations of a closely-irradiated planet using Carter code (DOI: 10.5281/zenodo.10534584)

+

FactSAGE phase calculations for three compositional scenarios

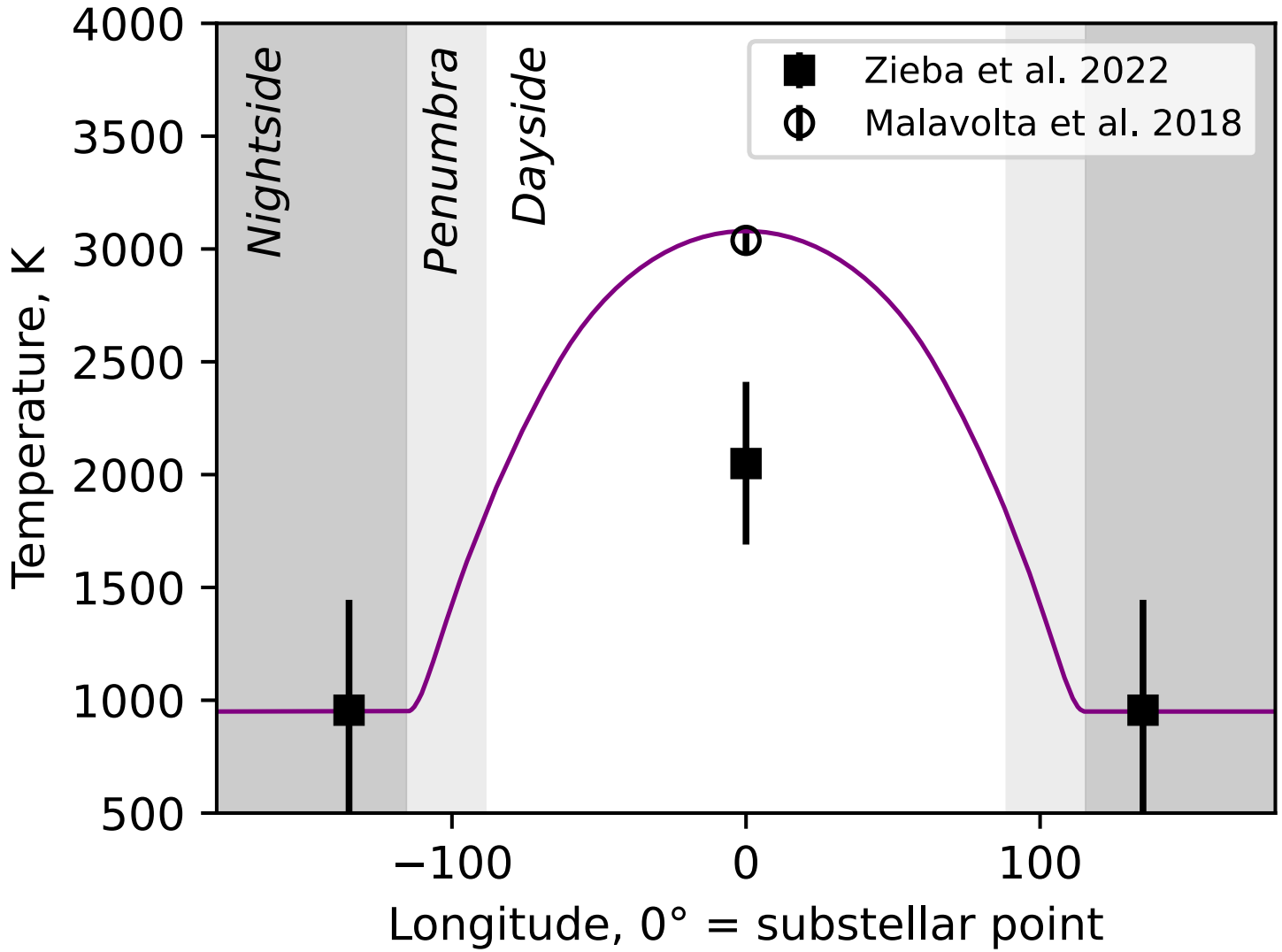
Work published in:
Le Losq, Ferraina, Sossi, Boukaré, 2025, EPSL 656
Code available online:
github.com/charlesll/gpvisc

Code

Paper

Surface temperature

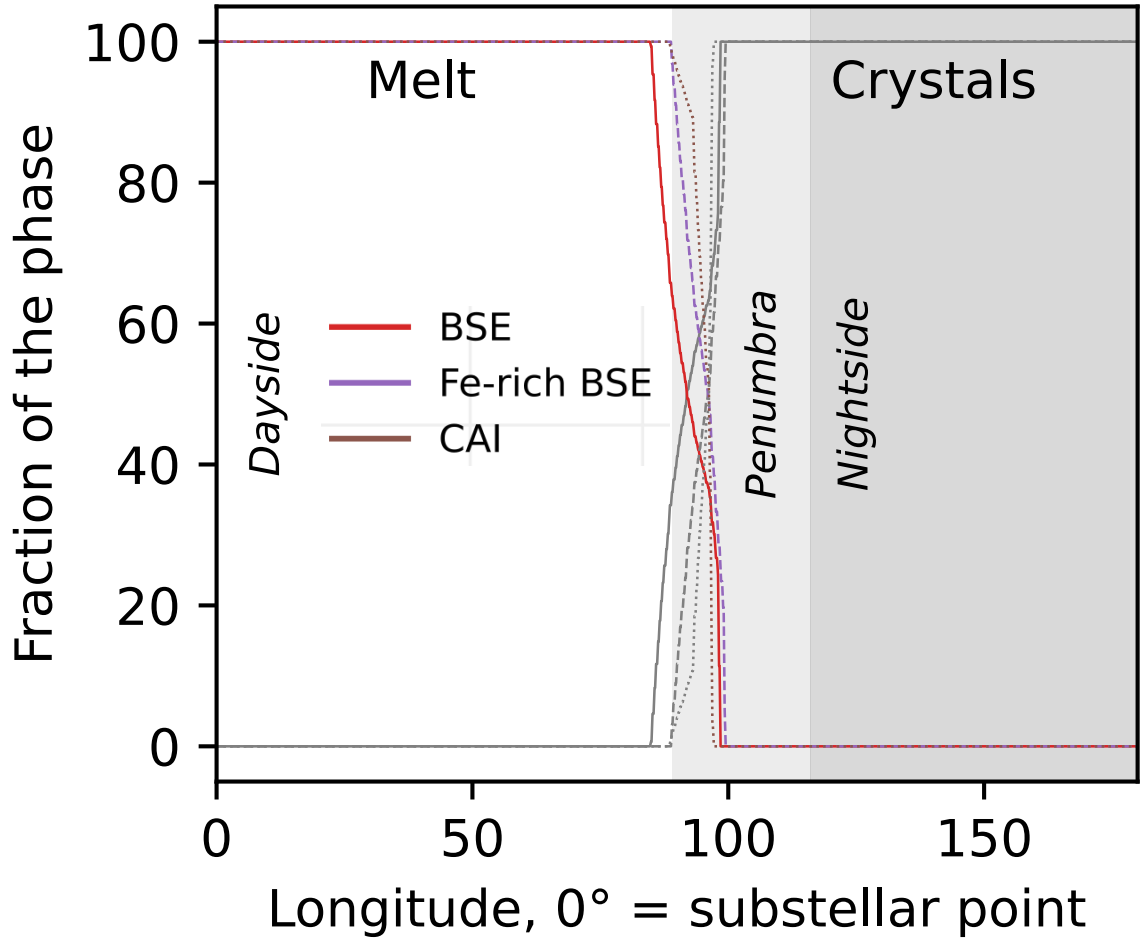
Hypothesis:
no steam
atmosphere



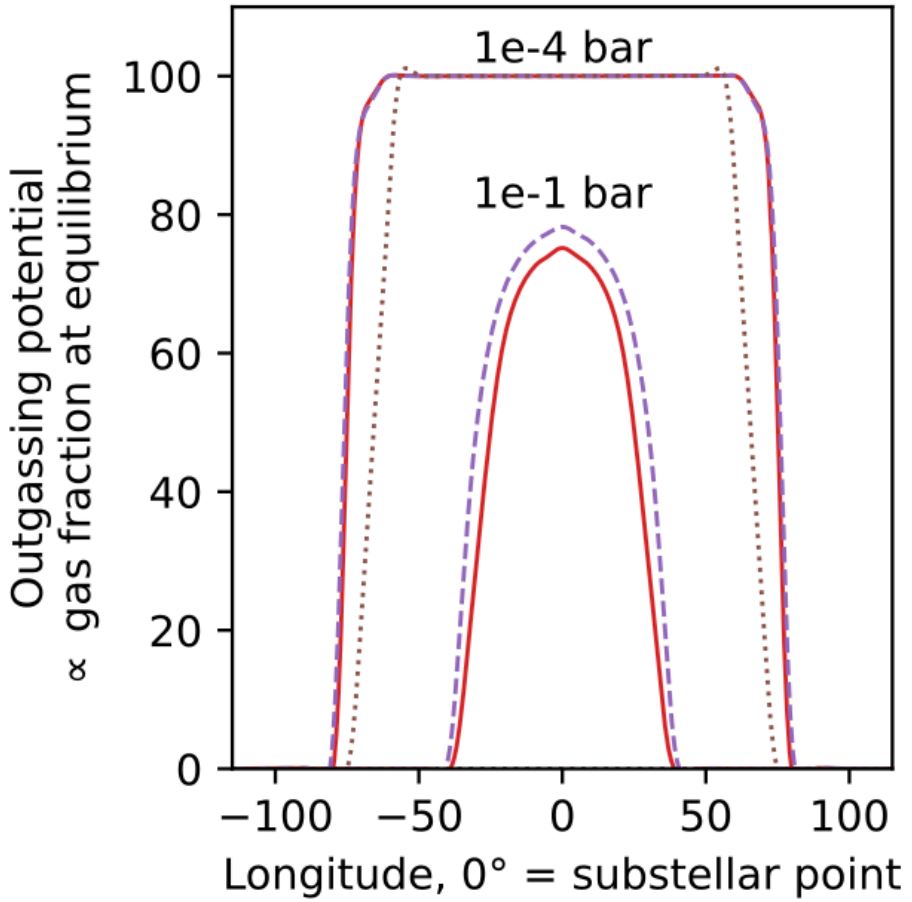
Le Losq et al. 2025

Dayside surface properties

Fully molten

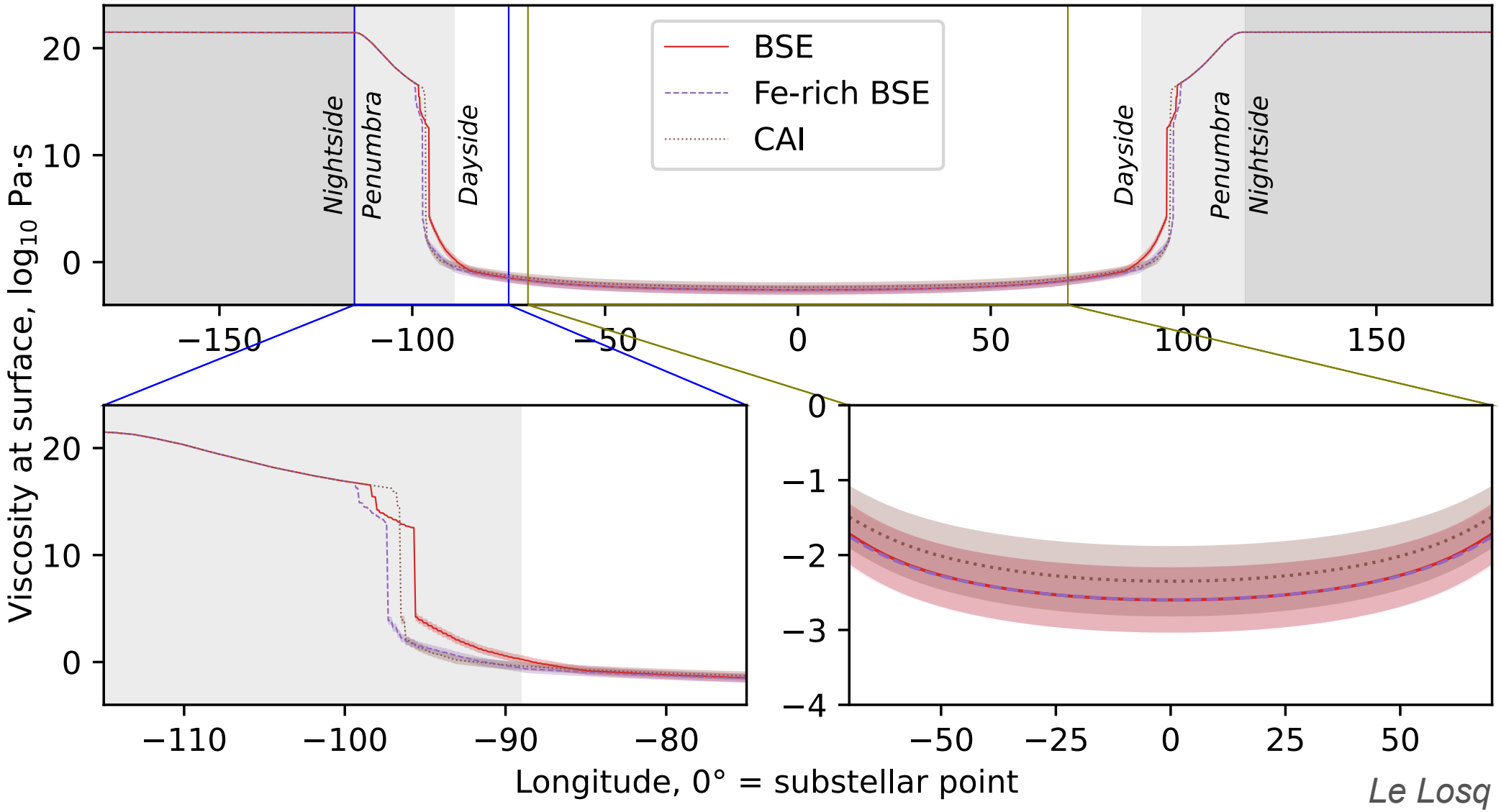


Thin rocky atmosphere, in agreement with Zieba et al. (2022)



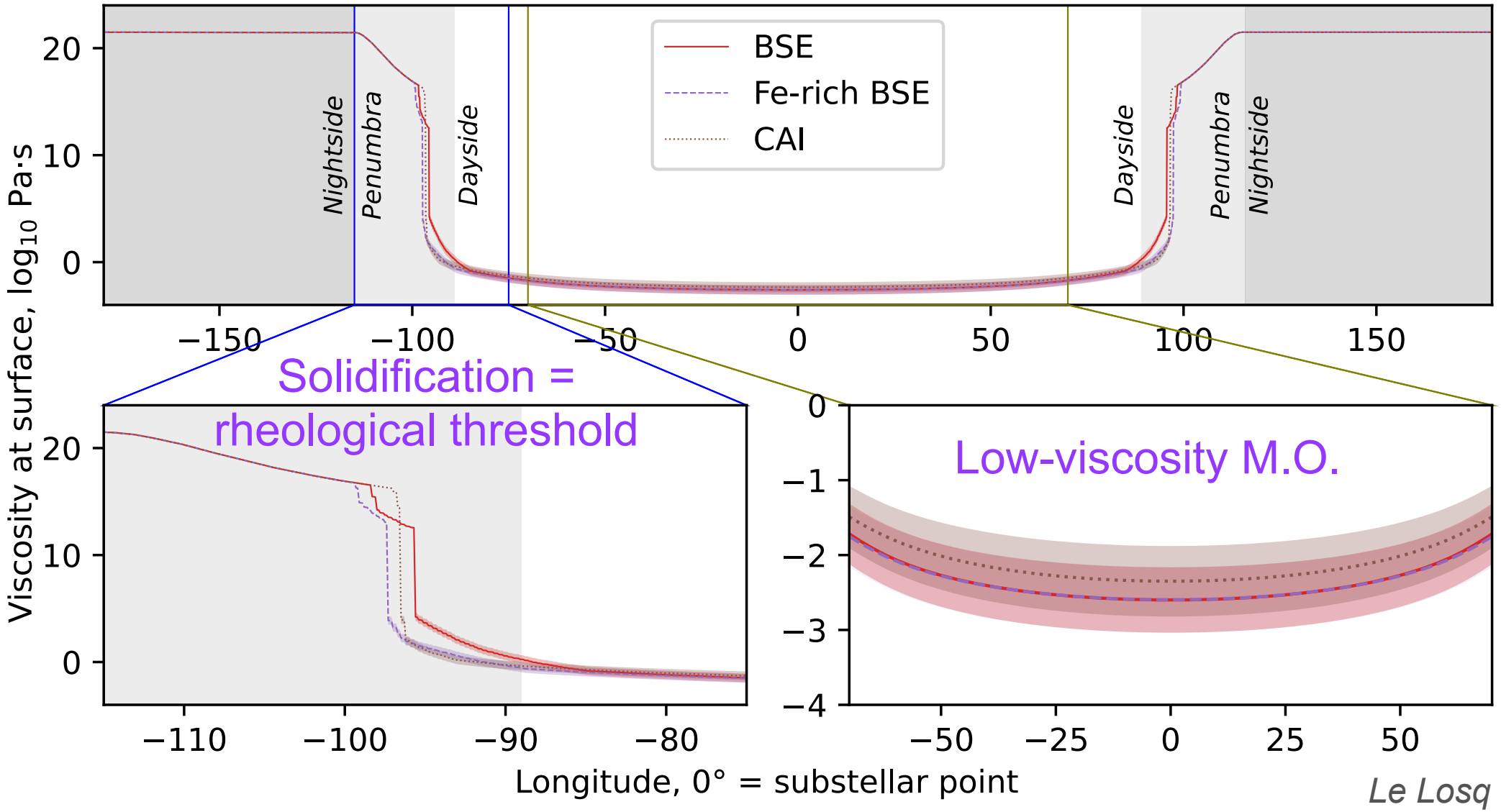
Le Losq et al. 2025

Viscosity at surface



Le Losq et al. 2025

Viscosity at surface



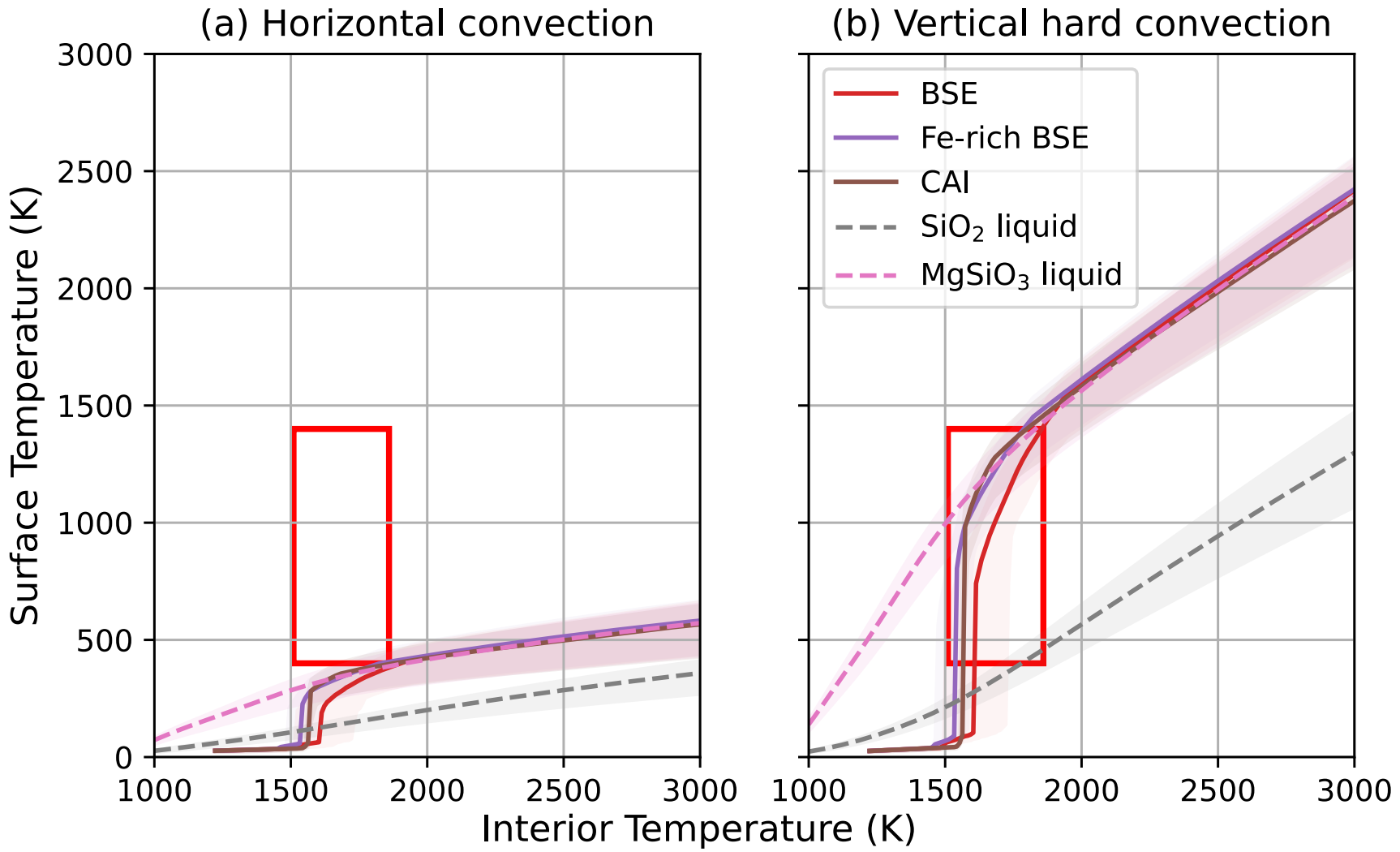
Le Losq et al. 2025

Nightside surface properties

No steam atmosphere
T ≈ 400−1445 K
(Zieba et al. 2022)

Future estimations incoming with JWST (Lisa Dang's proposal and work)

Geothermal flux likely sustained by convection of a partially molten mantle.



Le Losq et al. 2025

Conclusion

Lava planet research: generalist models of melt properties are much needed

- test different scenarios, different conditions…
- machine learning is helping building the next generation of models
- state of the art viscosity model: *gpvisc*

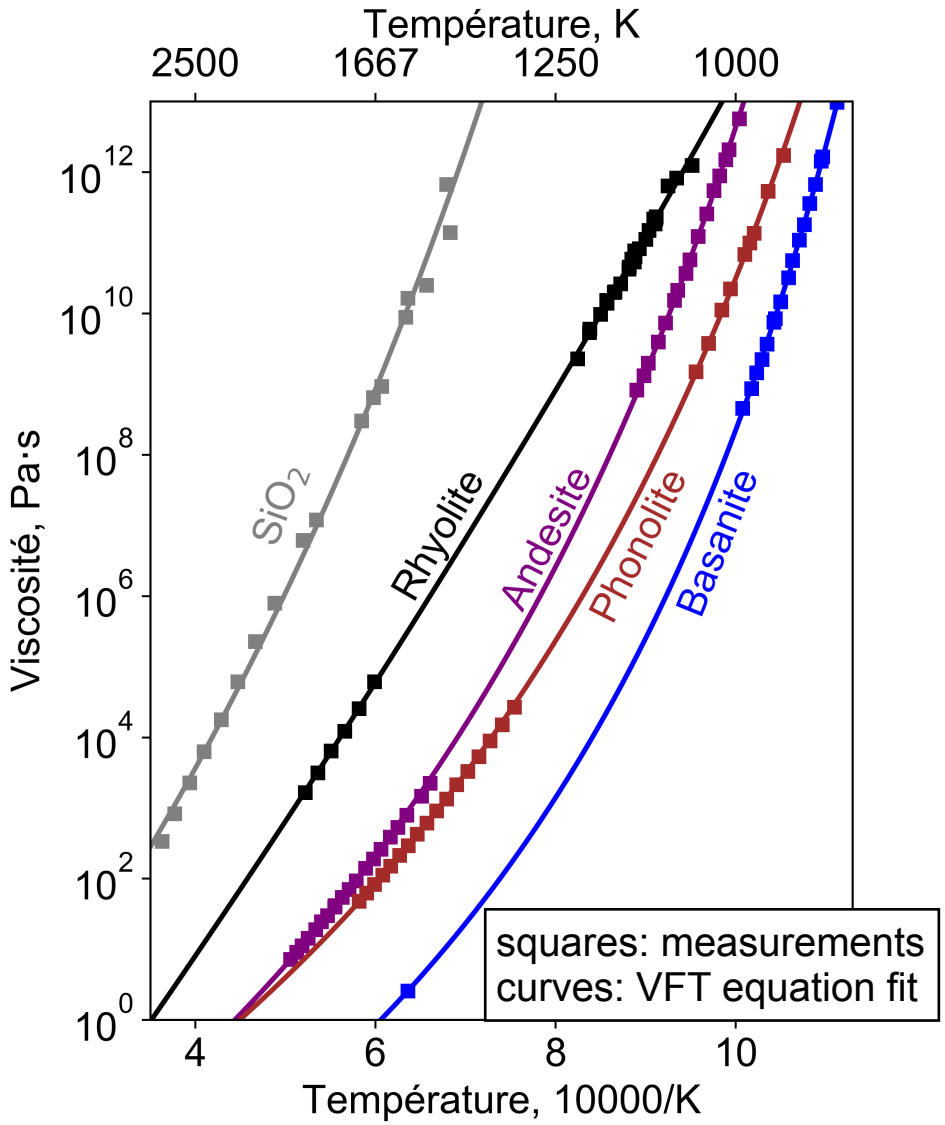
Possible expectations for K2 141 b:

- **dayside**
  - temperature between ≈ 1900 K (lon = 90°) and 3100 K (lon = 0°)
  - very low viscosity silicate melt; melt composition has a limited effect.
  - outgassing within ≈ 40° of the substellar point, condensation at higher longitudes

- **penumbral region**
  - between ≈ 90° and ≈ 115°
  - solidification => rapid increase in magma viscosity, solid surface near 100°

- **nightside**
  - geothermal flux sustained by the convection of a partially-molten mantle

One key property: magma viscosity



Varies by orders of magnitude with:
- temperature
- chemical composition
- disolved volatile elements (H, C…)
- crystal and bubble fractions

Figure data from Hetherington 1964, Urbain 1982, Le Losq and Neuville 2013, Le Losq et al. 2015, Whittington et al. 2000, Villeneuve et al. 2008

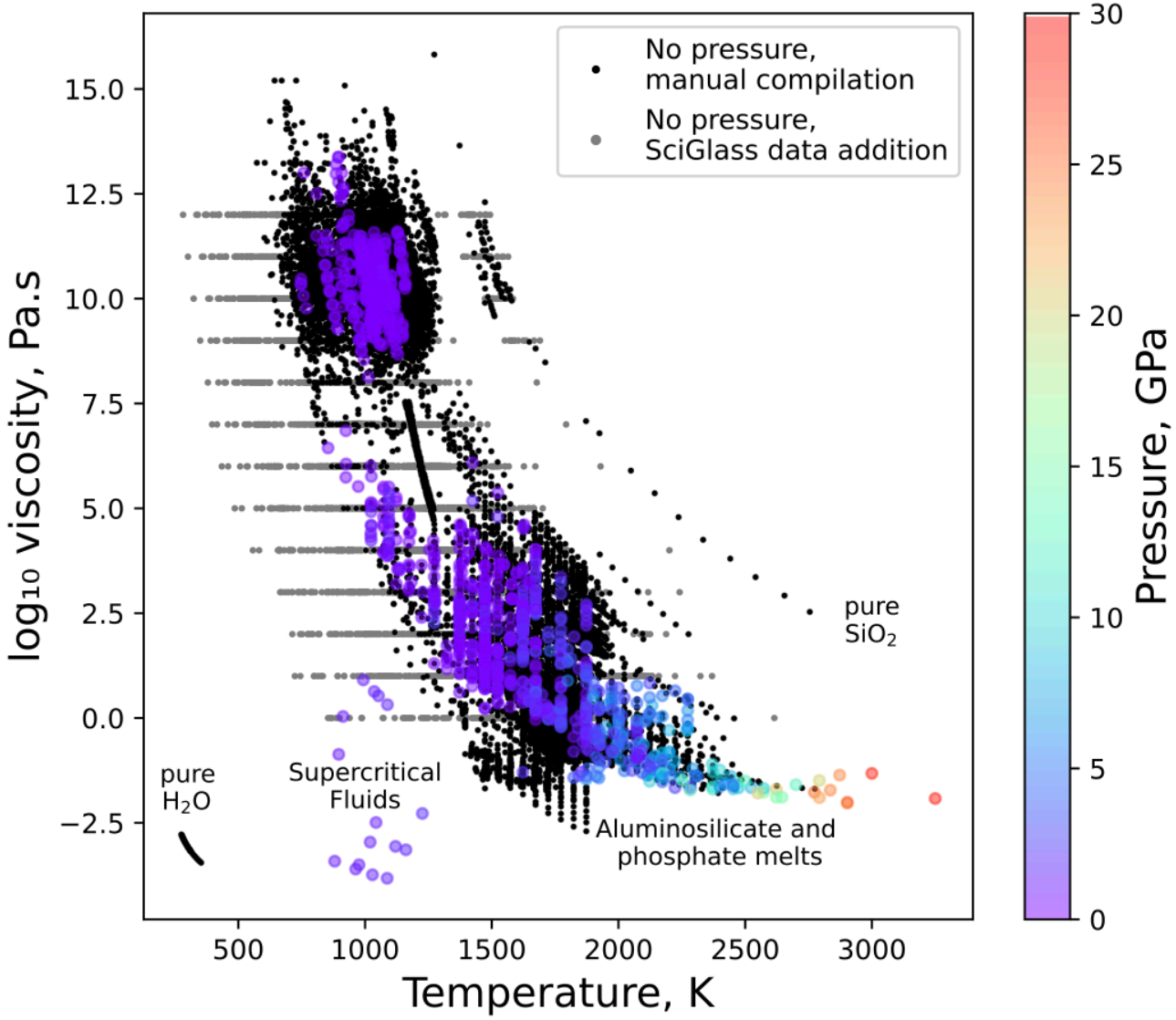
One key property: magma viscosity

New database

SiO_2-TiO_2-Al_2O_3-FeO-Fe_2O_3-MnO-Na_2O-K_2O-MgO-CaO-P_2O_5-H_2O

27 418 data points from 7553 different melt compositions

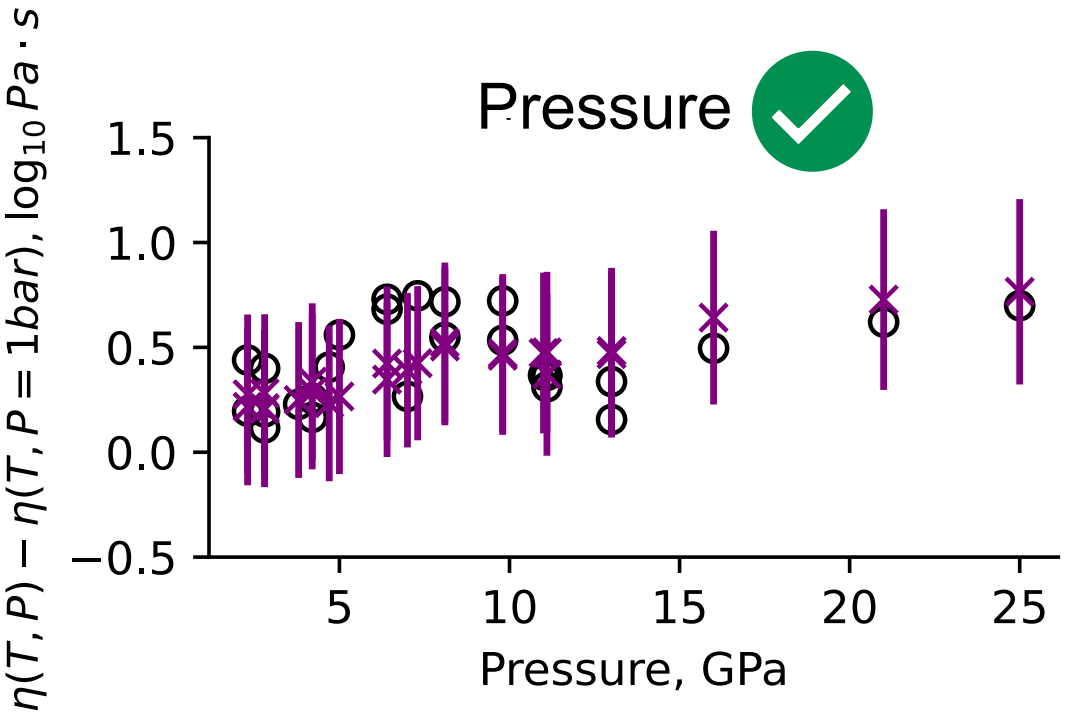
Includes simple melts, such as SiO_2, P_2O_5, H_2O, and complex magmatic and industrial melts

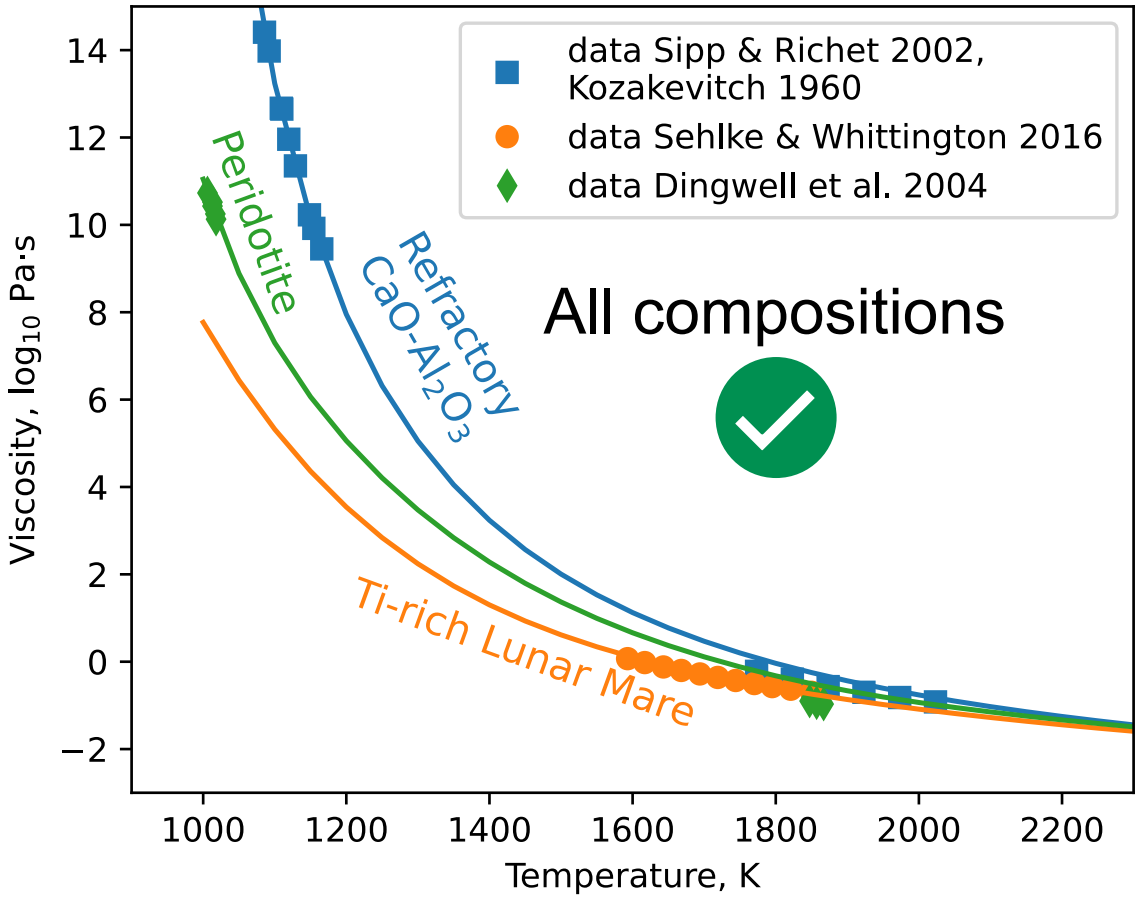


One key property: magma viscosity

New viscosity model: *gpvisc*

State of the art performance, with uncertainties lower than 0.45 log Pa s





Predictions in microseconds (on GPU) to tens of microseconds (on CPU)