

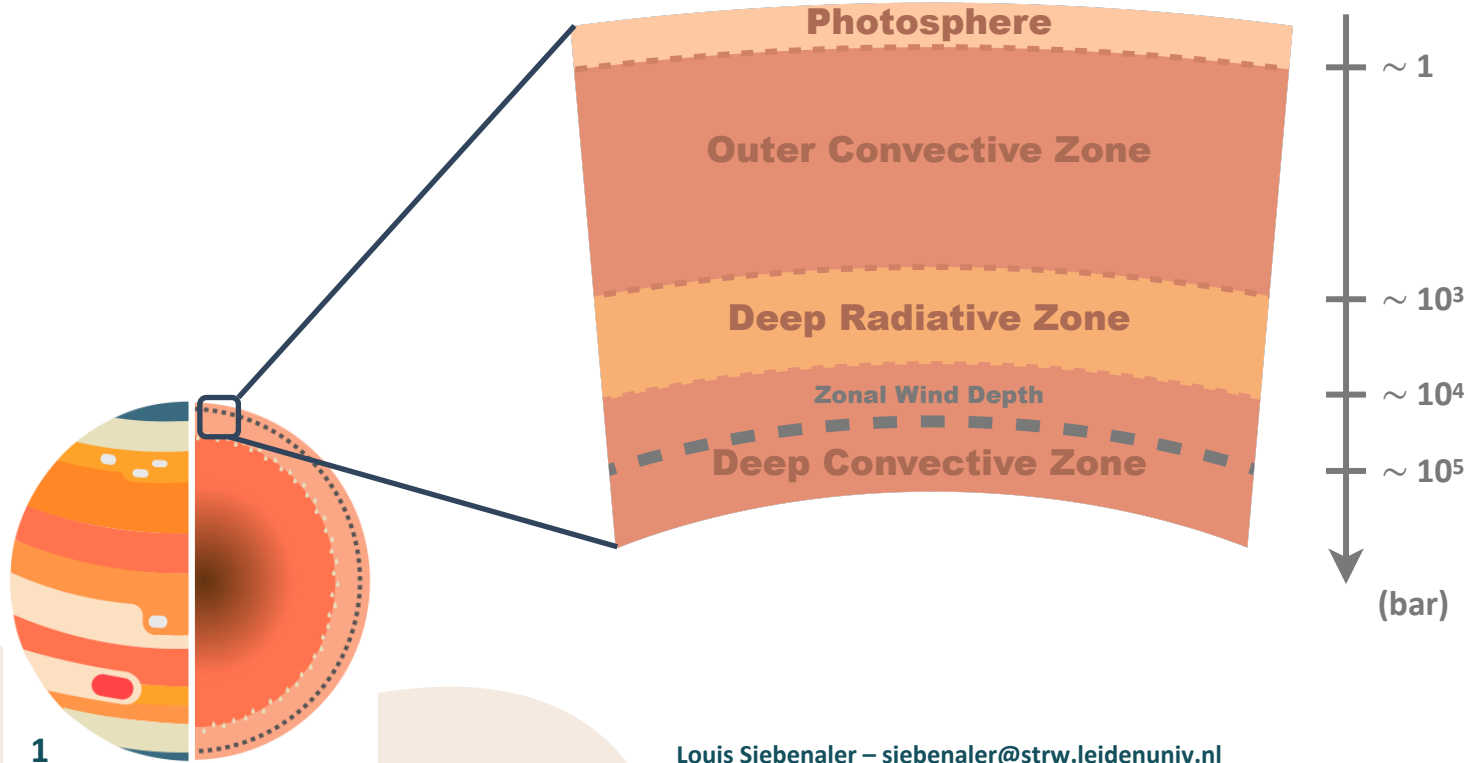


Mean-Opacity Tables for Probing Stable Stratification in Giant Planets

Louis Siebenaler¹, Yamila Miguel^{1,2}, Sam de Regt¹, Tristan Guillot³

1: Leiden University, 2: SRON Netherlands Institute for Space Research, 3: Observatoire de la Côte d'Azur

H₂-Envelope (with Stable Layer)



ARGUMENTS FOR STABLE LAYER

Outer envelope
density predicted
by interior models
is too low

(Howard et al. 2023; Müller &
Helled 2024)

Observed deep
water abundance
and tropospheric
CO abundance

(Cavalié et al. 2023)

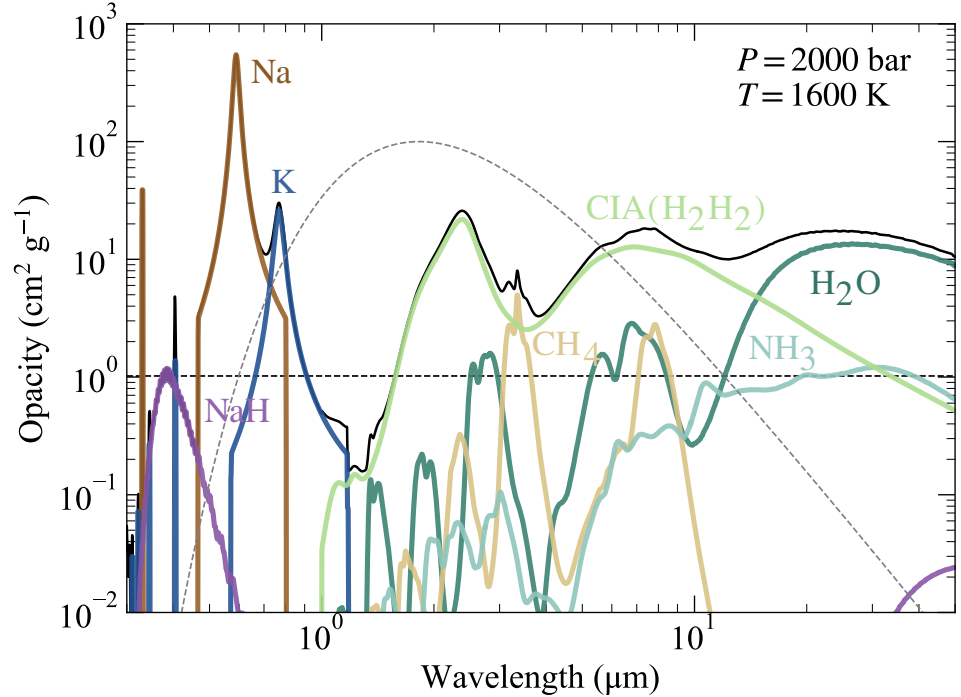
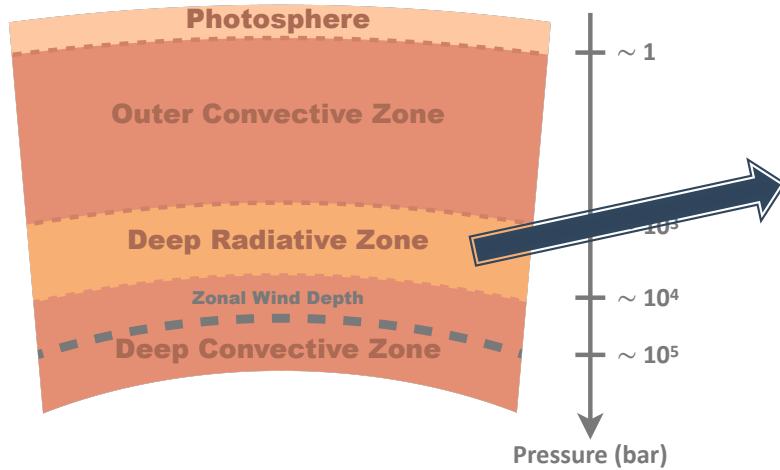
Zonal Wind decay
profile

(Christensen & Wulff 2024)

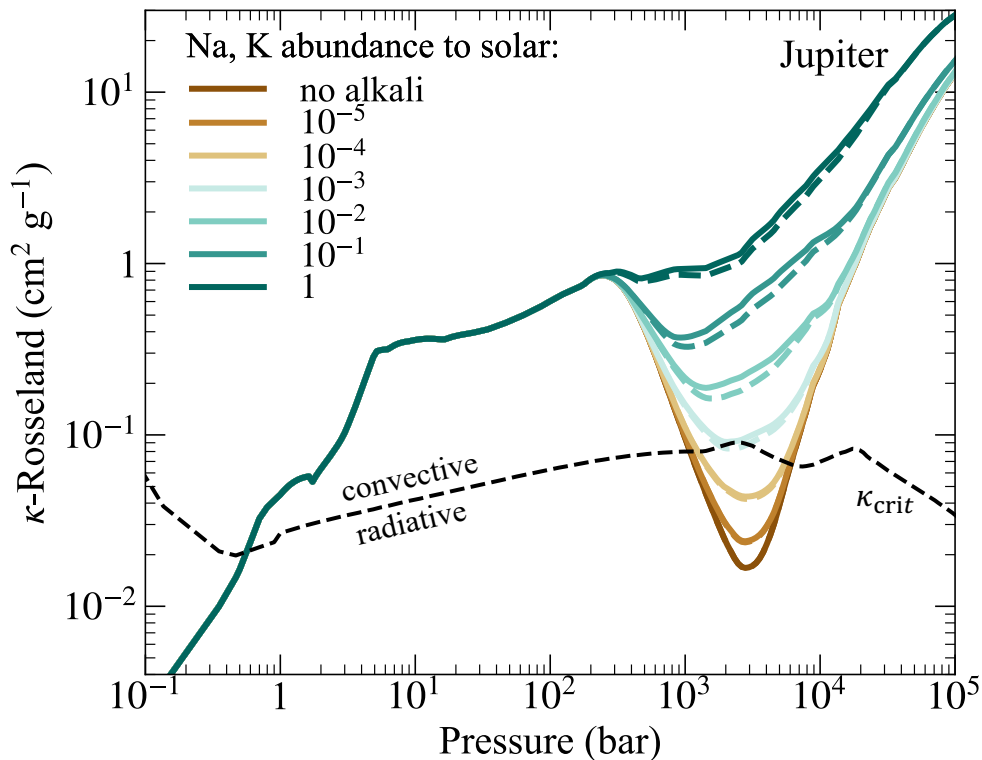
Opacities – $1000 < P < 10000$ bar

1000 - 10000 bar:

K, Na, NaH are the only significant sources of opacities for $\lambda < 1\mu\text{m}$



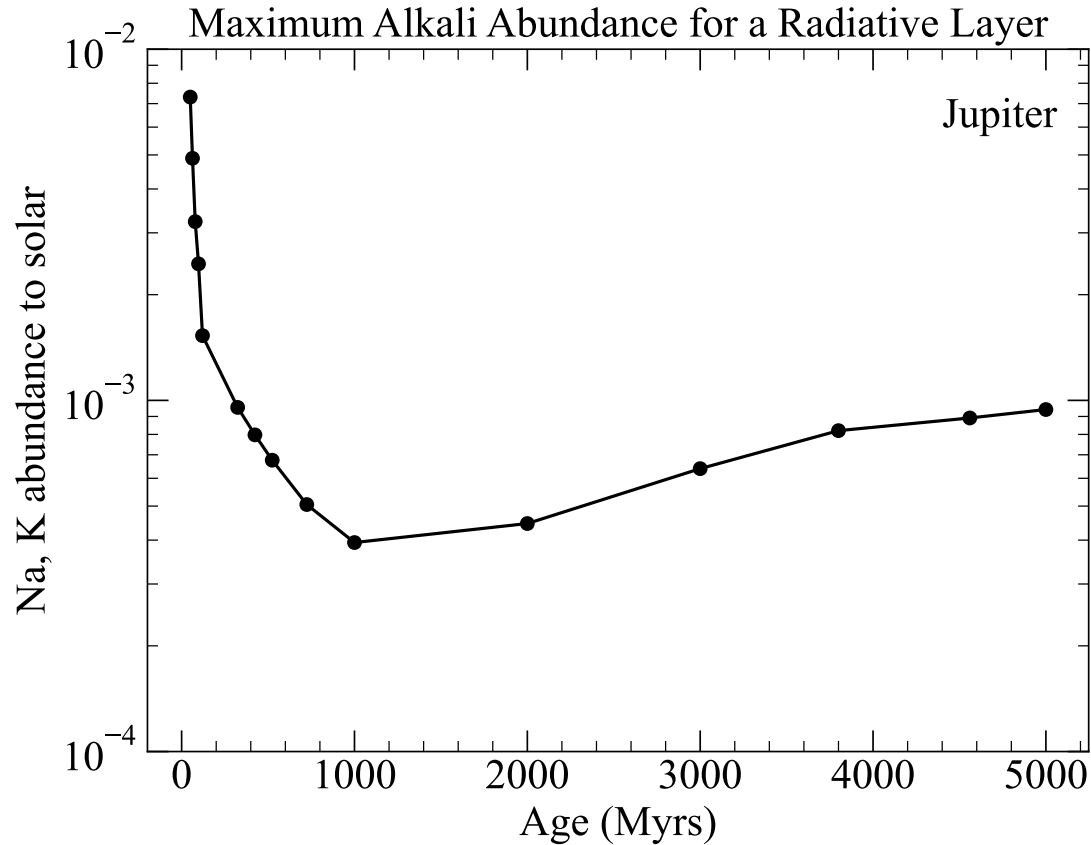
K, Na, NaH Impact



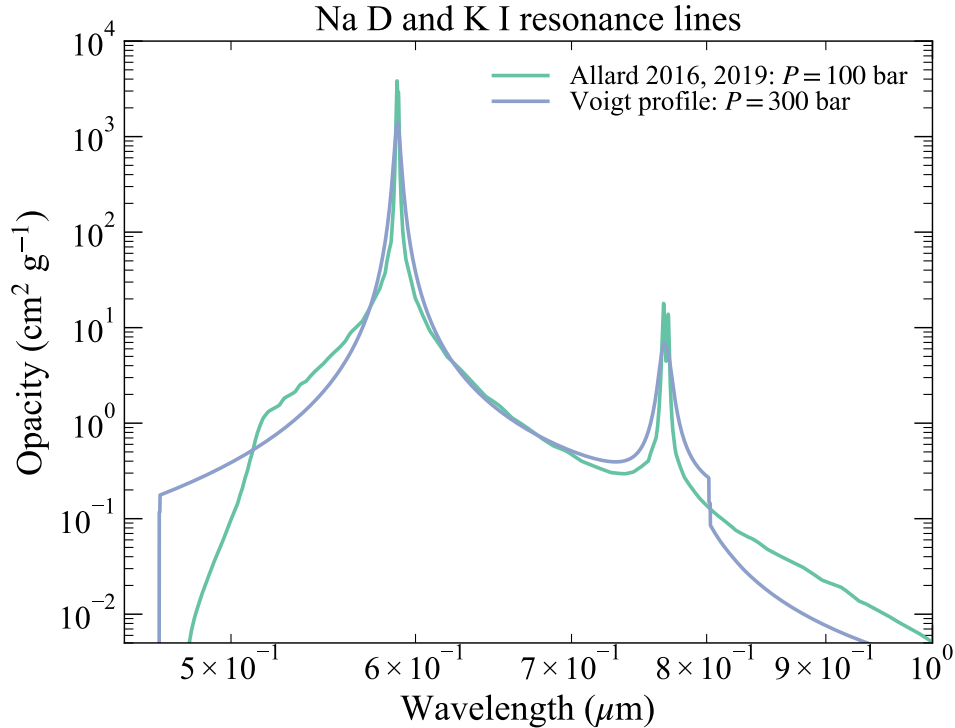
Conditions for a radiative zone:
[Na/H] and [K/H] < -3

constraints [Na/H] and [K/H]:
[-5, -1] (Bhattacharya et al. 2023,
Aglyamov et al. 2025)

Jupiter Evolution



Na, K resonance lines

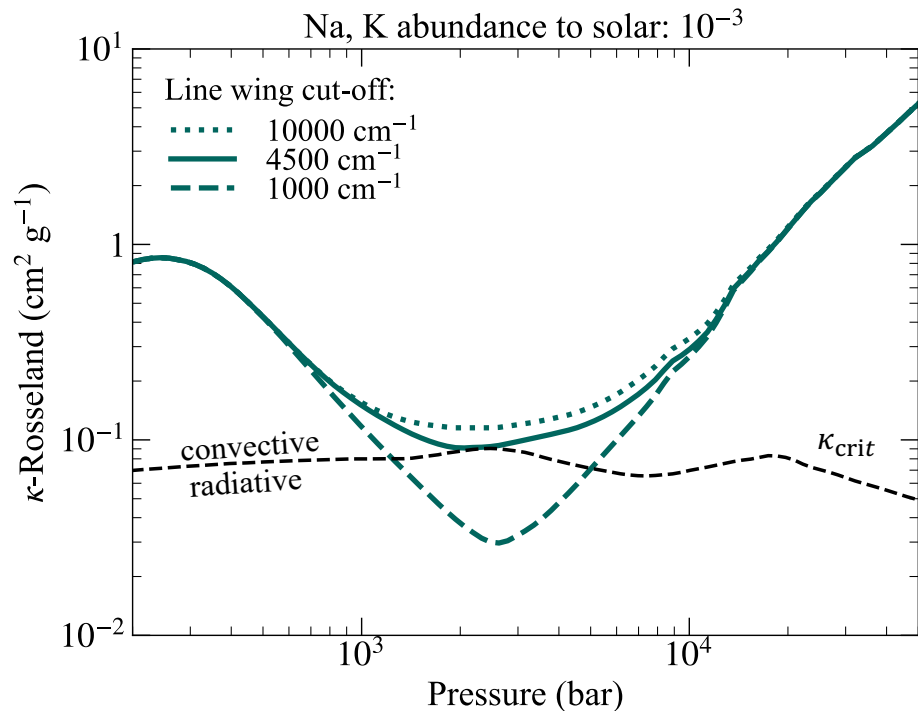


Allard calculations only valid for $n_{\text{H}_2} < 10^{21} \text{ cm}^{-3}$ ($P \lesssim 100$ bar).

For $n_{\text{H}_2} > 10^{21} \text{ cm}^{-3}$ we use a **Voigt profile** with a line wing cut-off of 4500 cm^{-1} .*

* cut-off value suggested by Baudino et al. (2017)

Na, K resonance lines

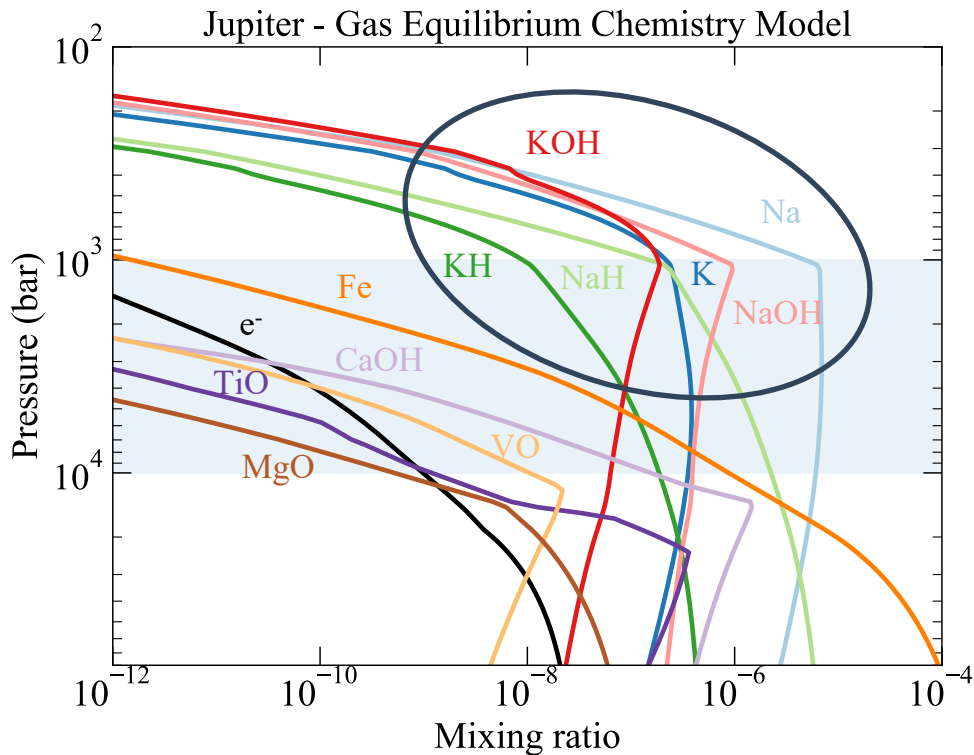


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Missing Opacity



(Important?) missing data:

NaOH: $\lambda_{\min} = 1.11\mu\text{m}$

KOH: $\lambda_{\min} = 1.67\mu\text{m}$

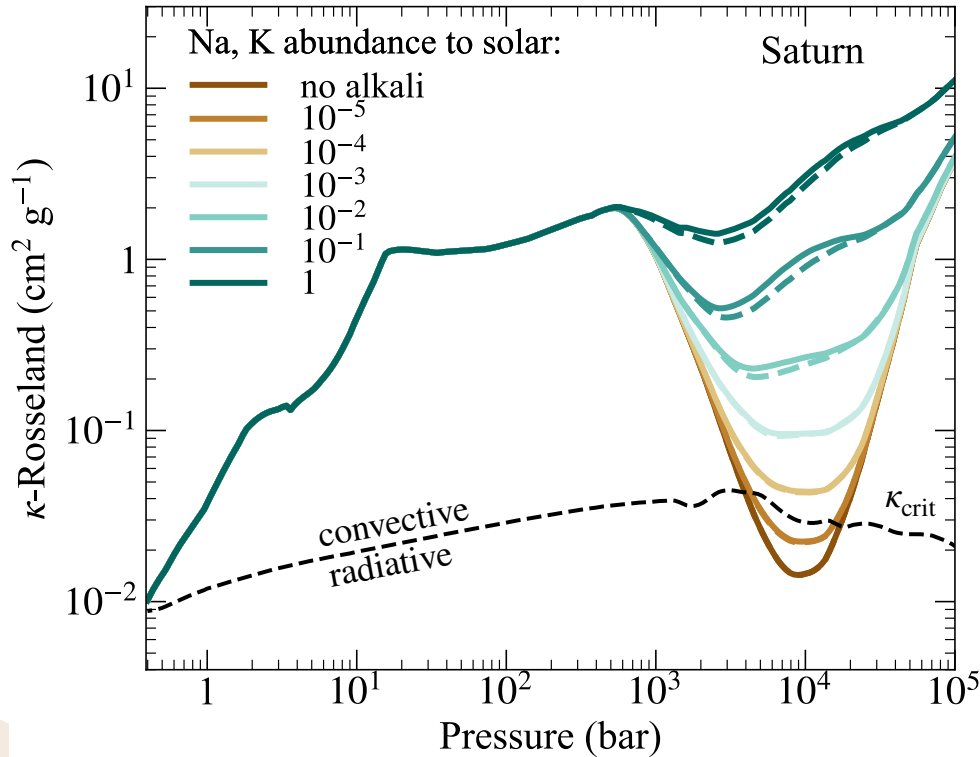
KH: no line list



SUMMARY

- Alkali metals (K, Na, NaH) control the presence of a stable layer in the outer envelope
- $[\text{Na}/\text{H}], [\text{K}/\text{H}] < -3$ is needed to develop a stable layer in Jupiter
- Important to improve the theoretical calculations of the Na D and K I resonance lines

Saturn



Conditions for a radiative zone:
[Na/H] and [K/H] < -4

(Less Na, K abundance is needed to ensure
convection on Saturn)