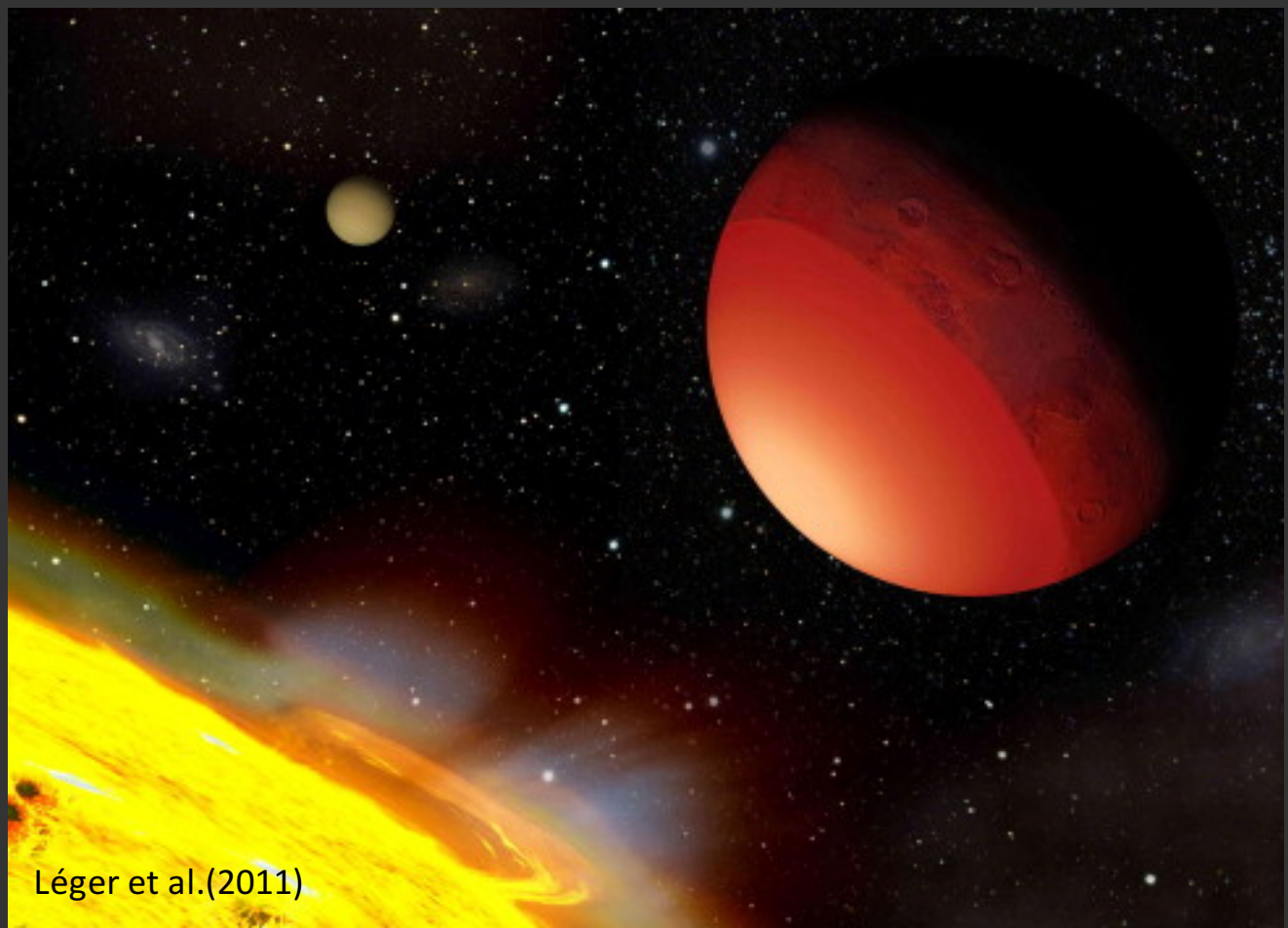
Atmospheres of Hot Rocky Exoplanets

Yuichi Ito[1]

Collaborators: Quentin, C.[1], Giovanna, T.[1], Masahiro, I.[2] & Kazuhito, O.[2]

([1]UCL, [2]Tokyo Univ.)



Léger et al.(2011)

Objectives of our study

Investigating:

- **Rocky vapor atmospheres of close-in terrestrial planets**

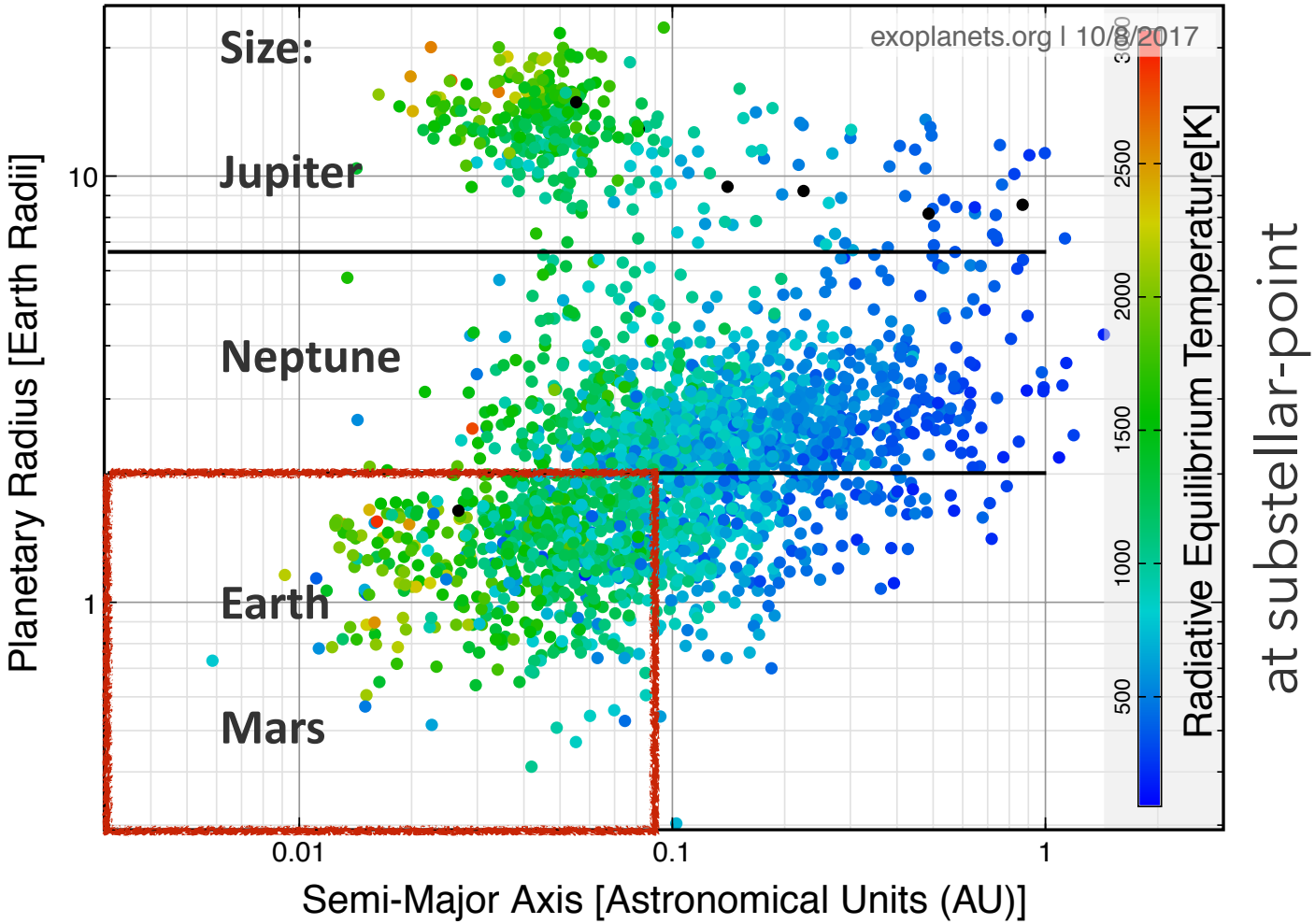
  - Atmospheric composition, structure, emission spectra -

- **The impact of Alkali metals on the atmospheres**

  - Alkali metals: Potential tracer for the evolution of the planets -

- **Detectability of rocky vapor & volatile-rich atmospheres with Ariel**

Size and Temperature (orbit) of Exoplanet



~500 close-in & small planets

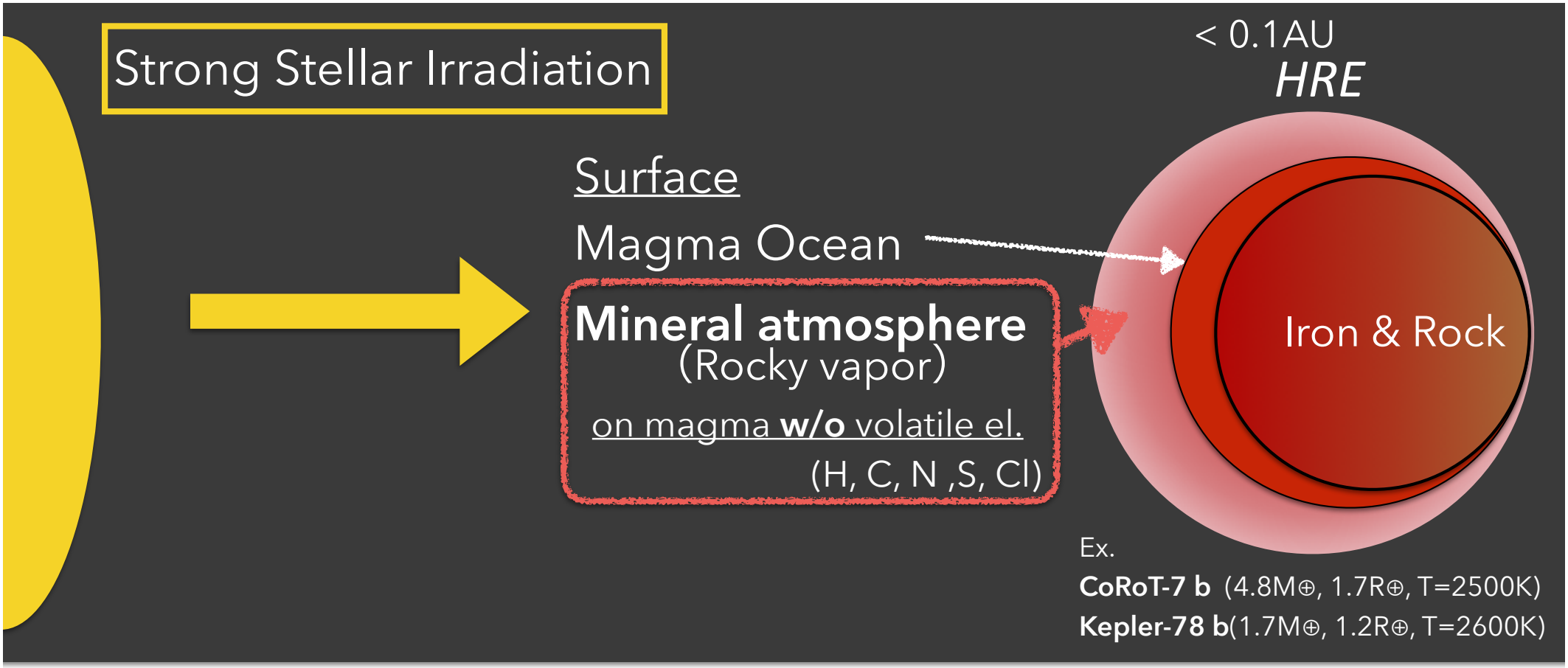
Radiative Equilibrium Temperature > Melting Temperature of Rock (~1500K)

HRE: Hot Rocky Exoplanet

Schaefer & Fegley (2009): Gas-melt equilibrium calculation

If rocky and dry, HREs have **mineral atmospheres** (rocky vapor)

Na, SiO, O_2 etc.

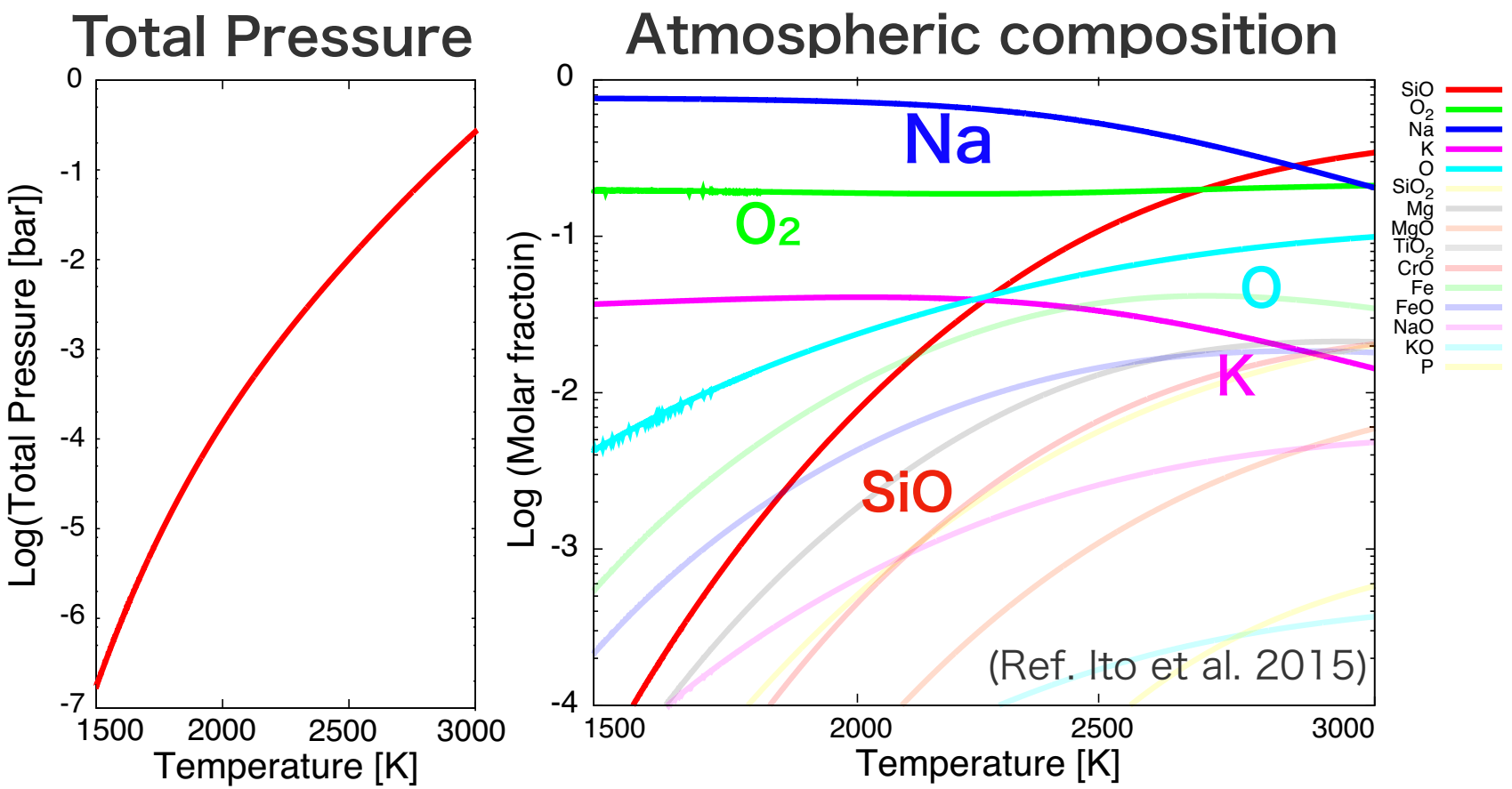


Radiative Equilibrium Temperature > Melting Temperature of Rock (~1500K)
High density (i.e., mass & radius) like that of rocky planet

Mineral atmosphere: Composition & Pressure

H, C, N, S, Cl

Gas in equilibrium with volatile-free magma(Schaefer & Fegley 2009 , Ito et al., 2015)



Composition：**Na(main)**, O_2, O, K, SiO etc.

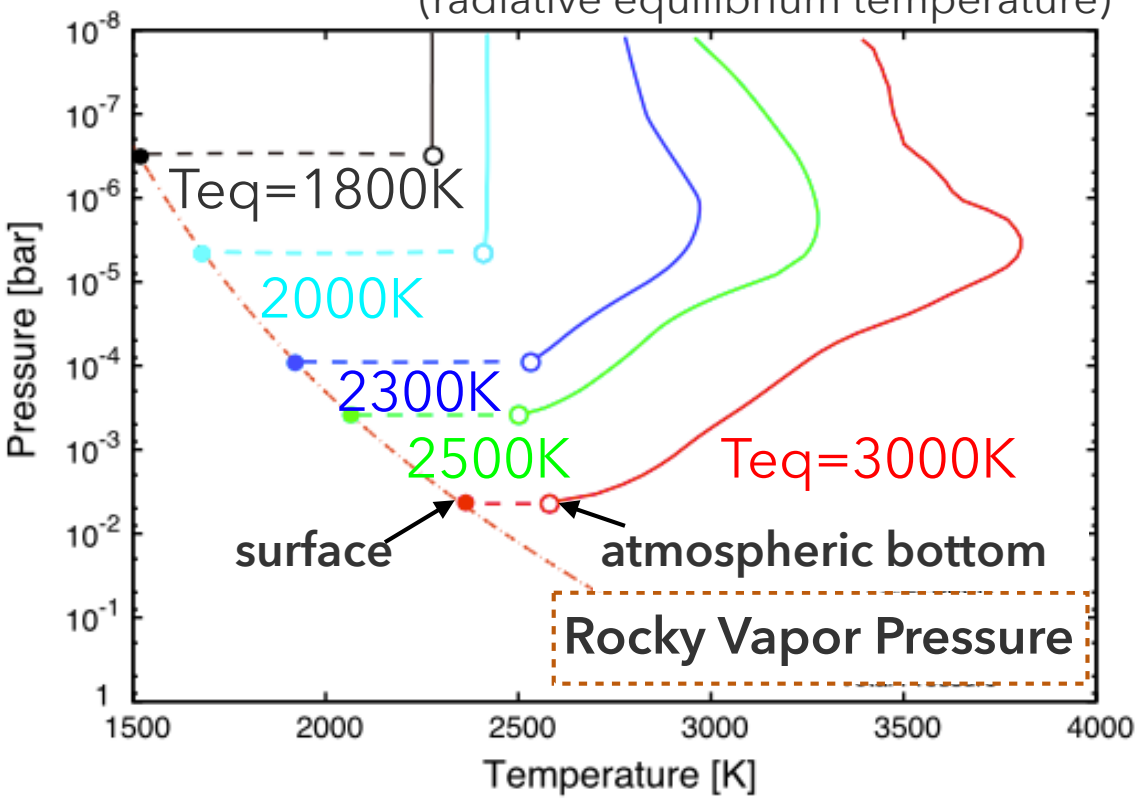
Total pressure：10^{-7} - 10^{-1} bar (1500-3000K)

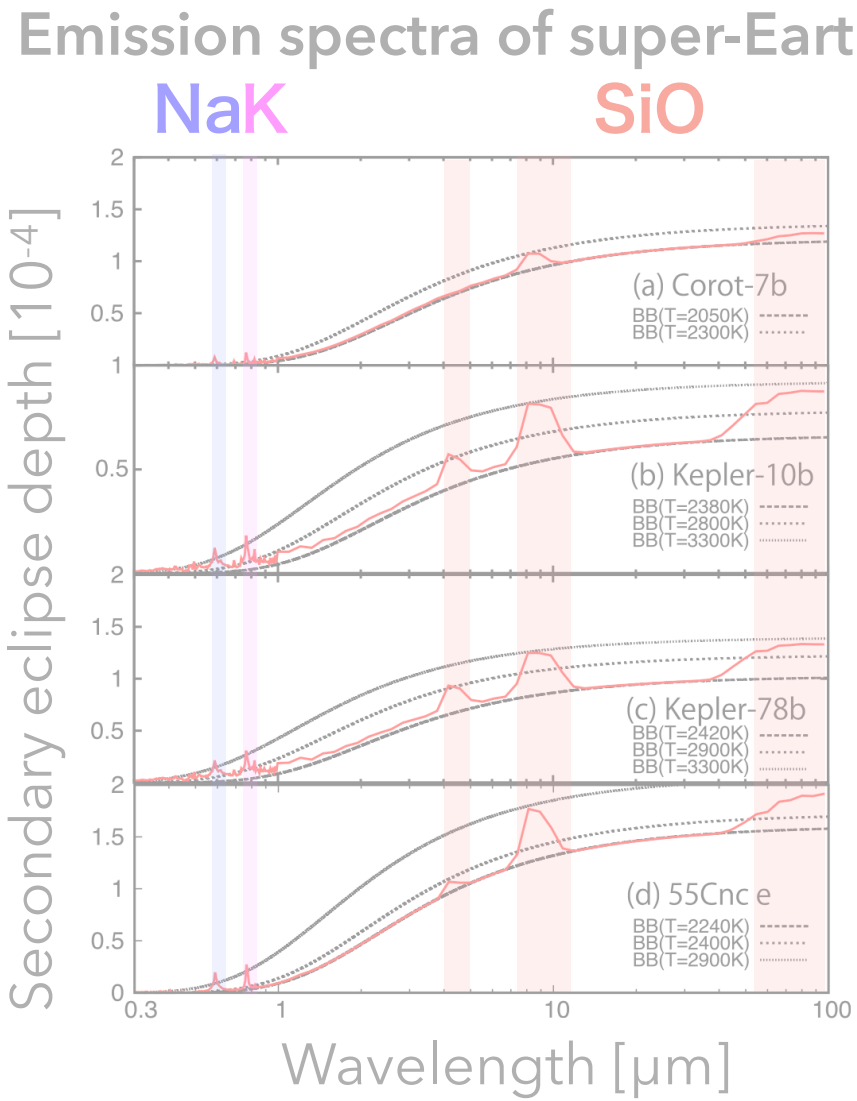
Mineral atmosphere: Structure & Spectral feature

Hydrostatic/radiative/chemical equilibrium atmospheric model (Ito et al., 2015)

T-P structure: $T_{eq} = T^* \sqrt{R_*/a}$

(radiative equilibrium temperature)





Thermal inversion is caused: Teq>2300K

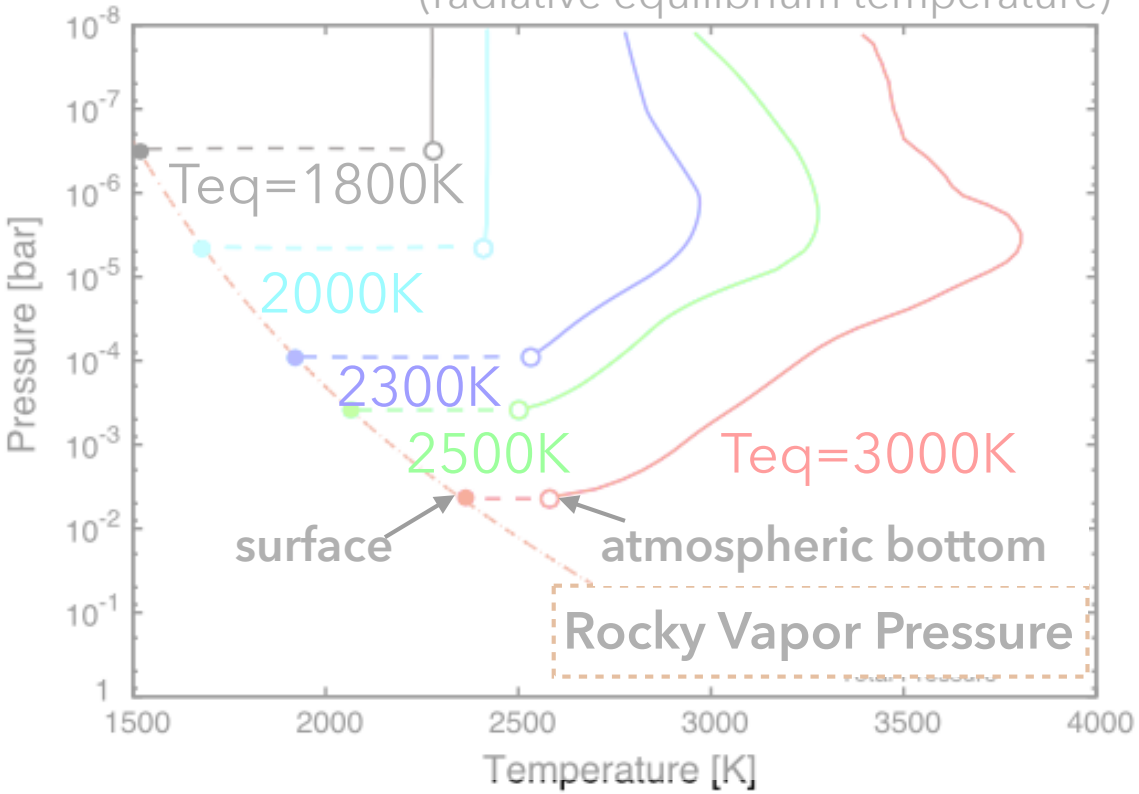
Mineral atmospheres have characteristic spectra: Na, K and SiO

(detectable by space-telescopes such as JWST)

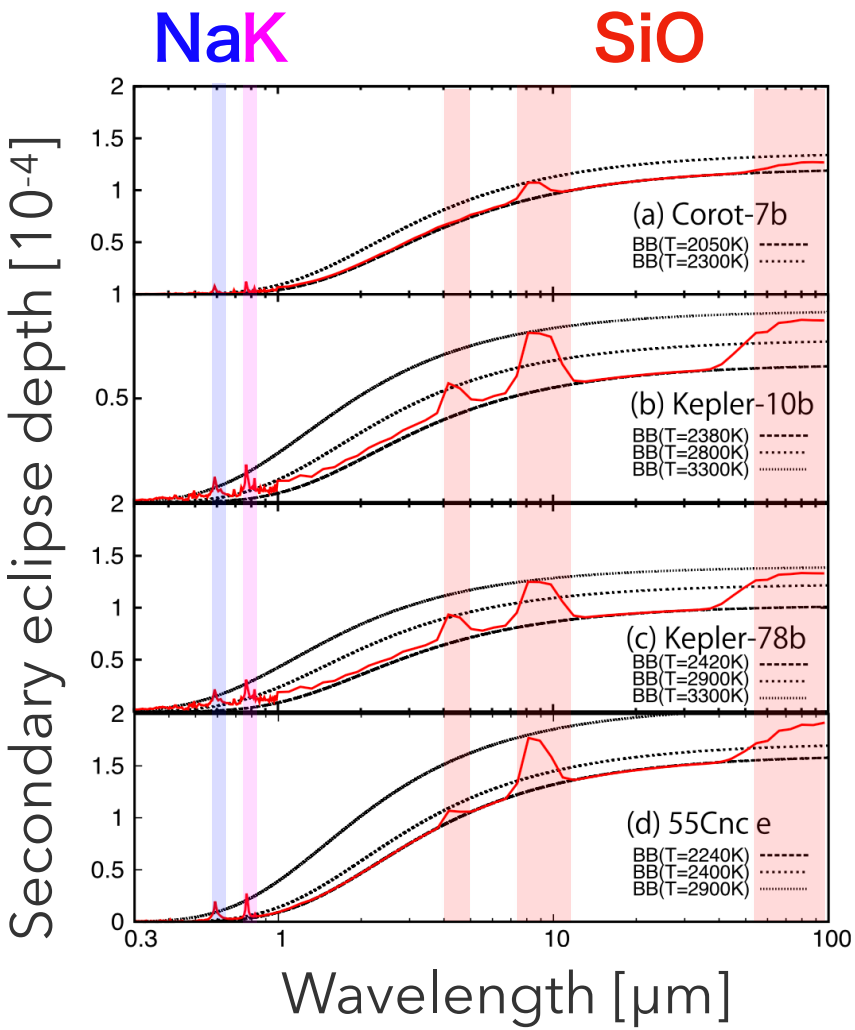
Mineral atmosphere: Structure & Spectral feature

Hydrostatic/radiative/chemical equilibrium atmospheric model (Ito et al., 2015)

T-P structure: $T_{eq} = T^* \sqrt{R_*/a}$
(radiative equilibrium temperature)



Emission spectra of super-Earths

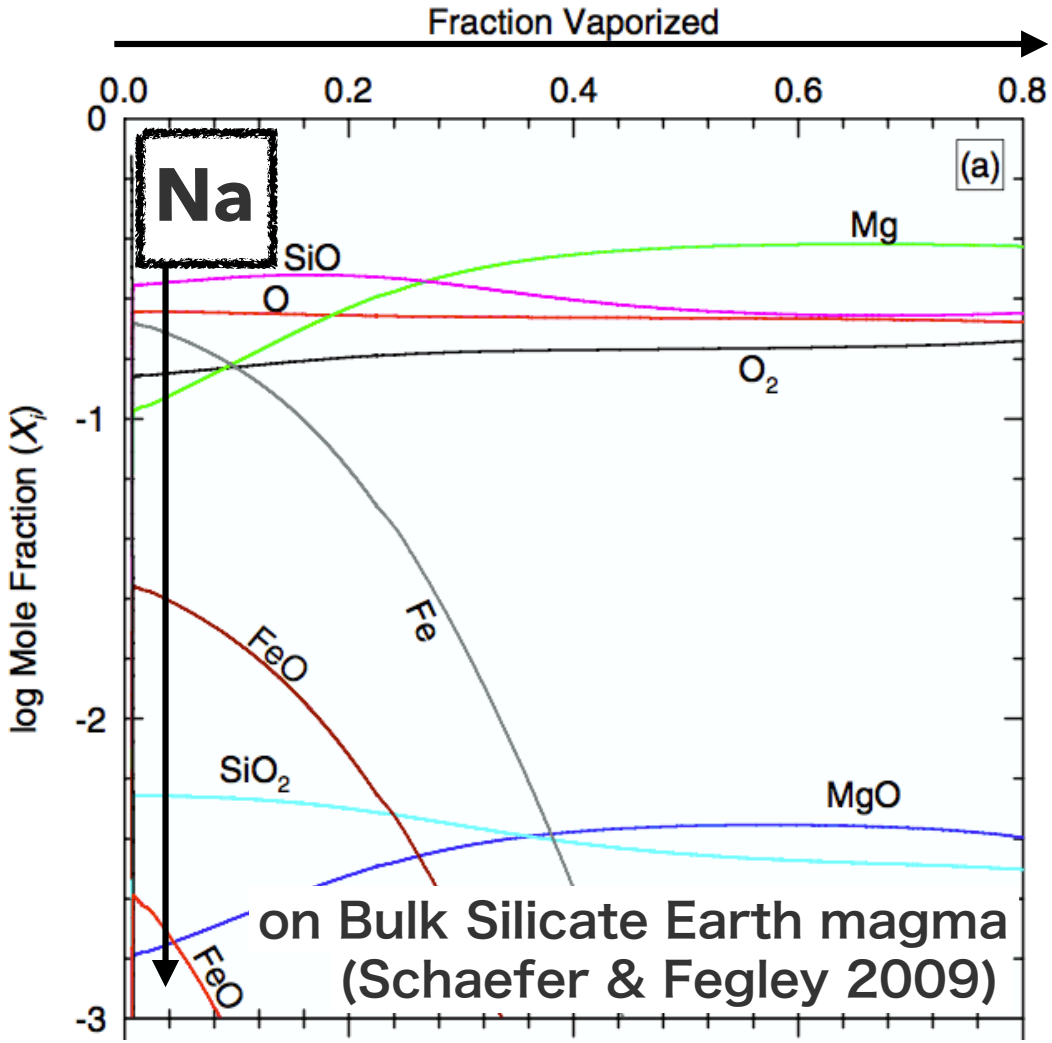


Thermal inversion is caused: Teq>2300K

Mineral atmospheres have characteristic spectra: Na, K and SiO
(detectable with space-telescopes such as JWST)

Selective remove of Alkali metal from atmosphere

Composition during fractional vaporization



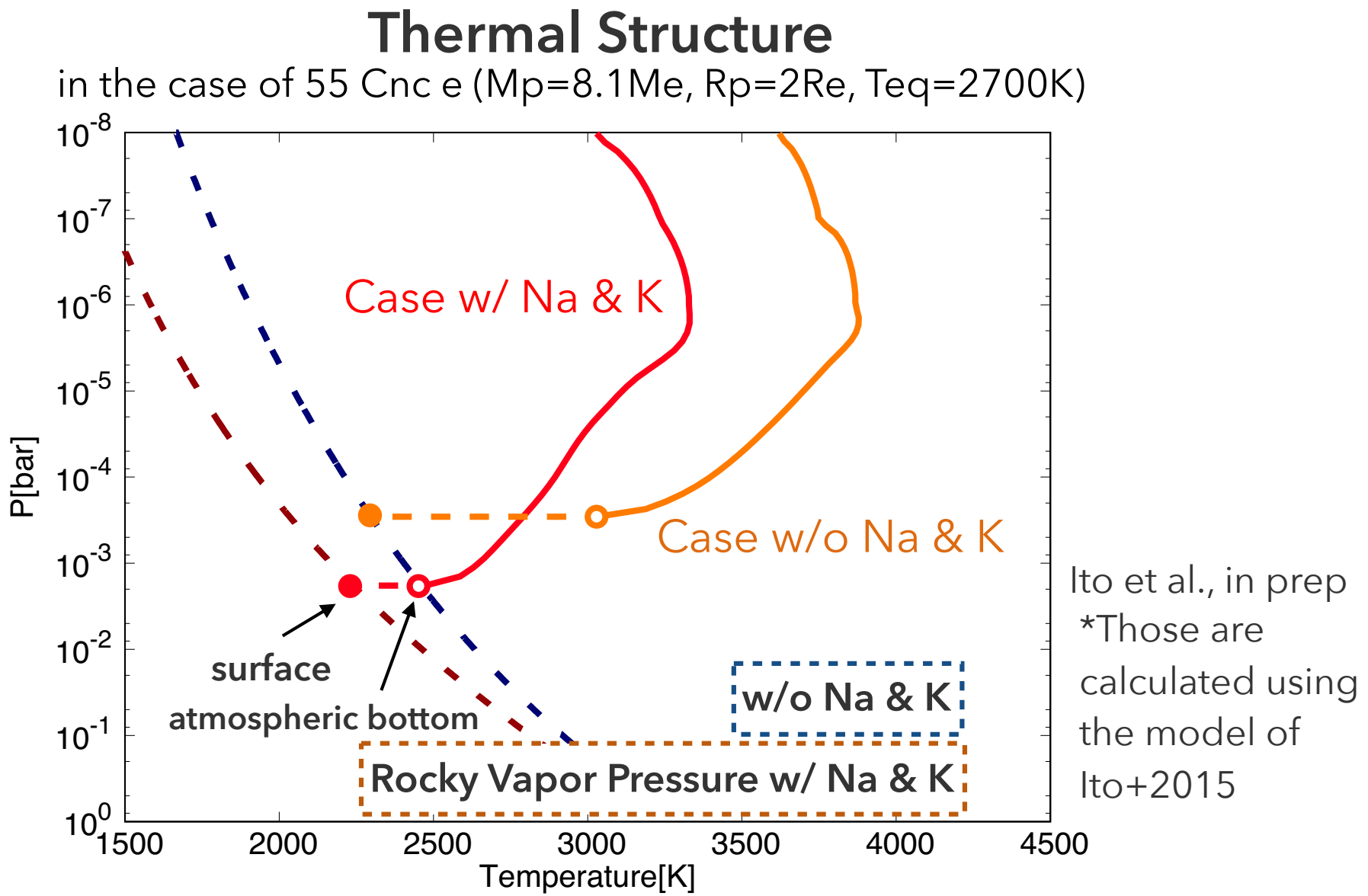
Gas remove process in mineral atmosphere

Photo-evaporation
of highly-UV-irradiated mineral atmosphere (Ito & Ikoma, in prep)

Alkali metals (minor elements in rock) would be selectively removed

If the most abundant species Na is lost, the atmospheres are detectable?
(and also K)

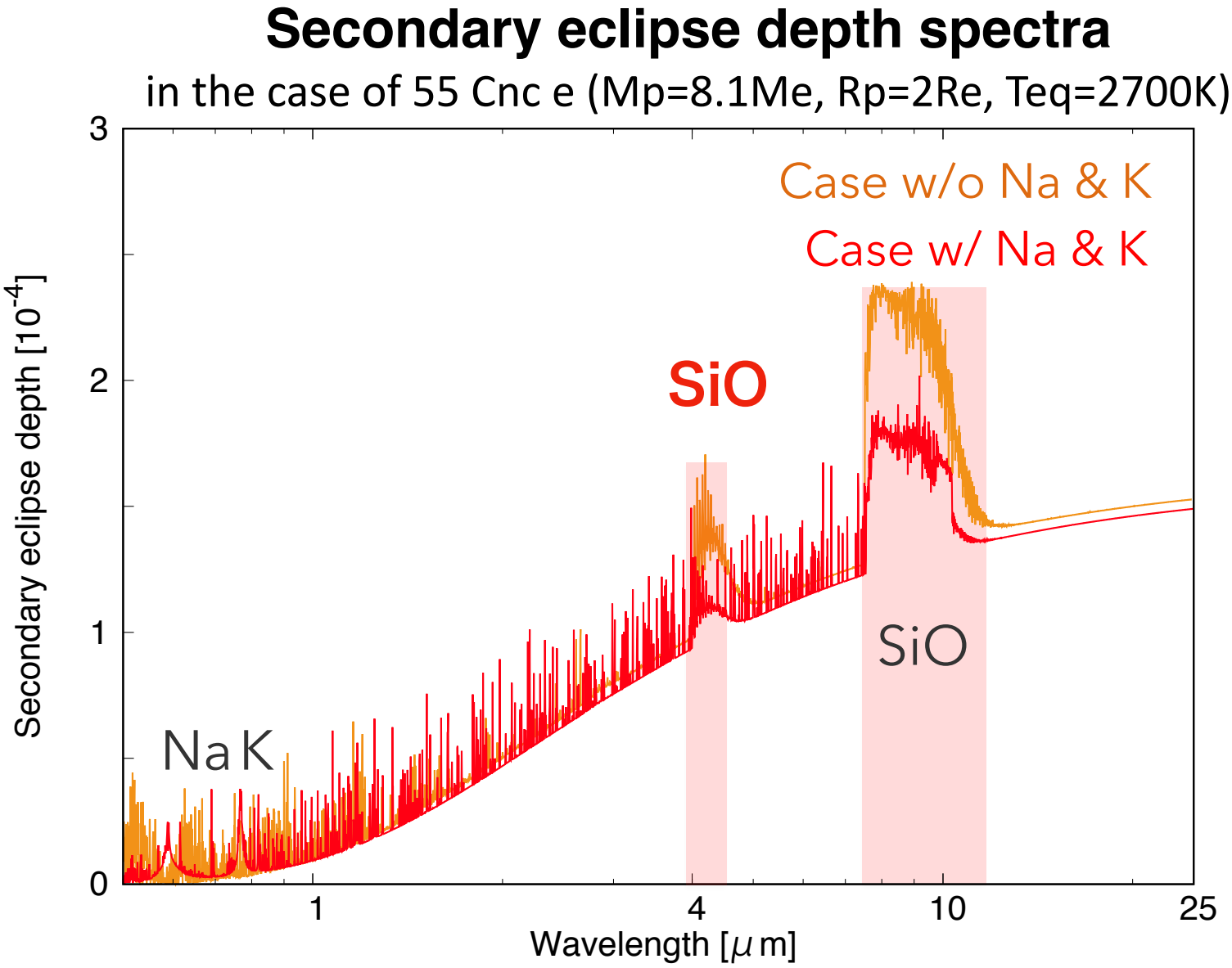
Impact of Na & K lack on thermal structure



Ito et al., in prep
*Those are calculated using the model of Ito+2015

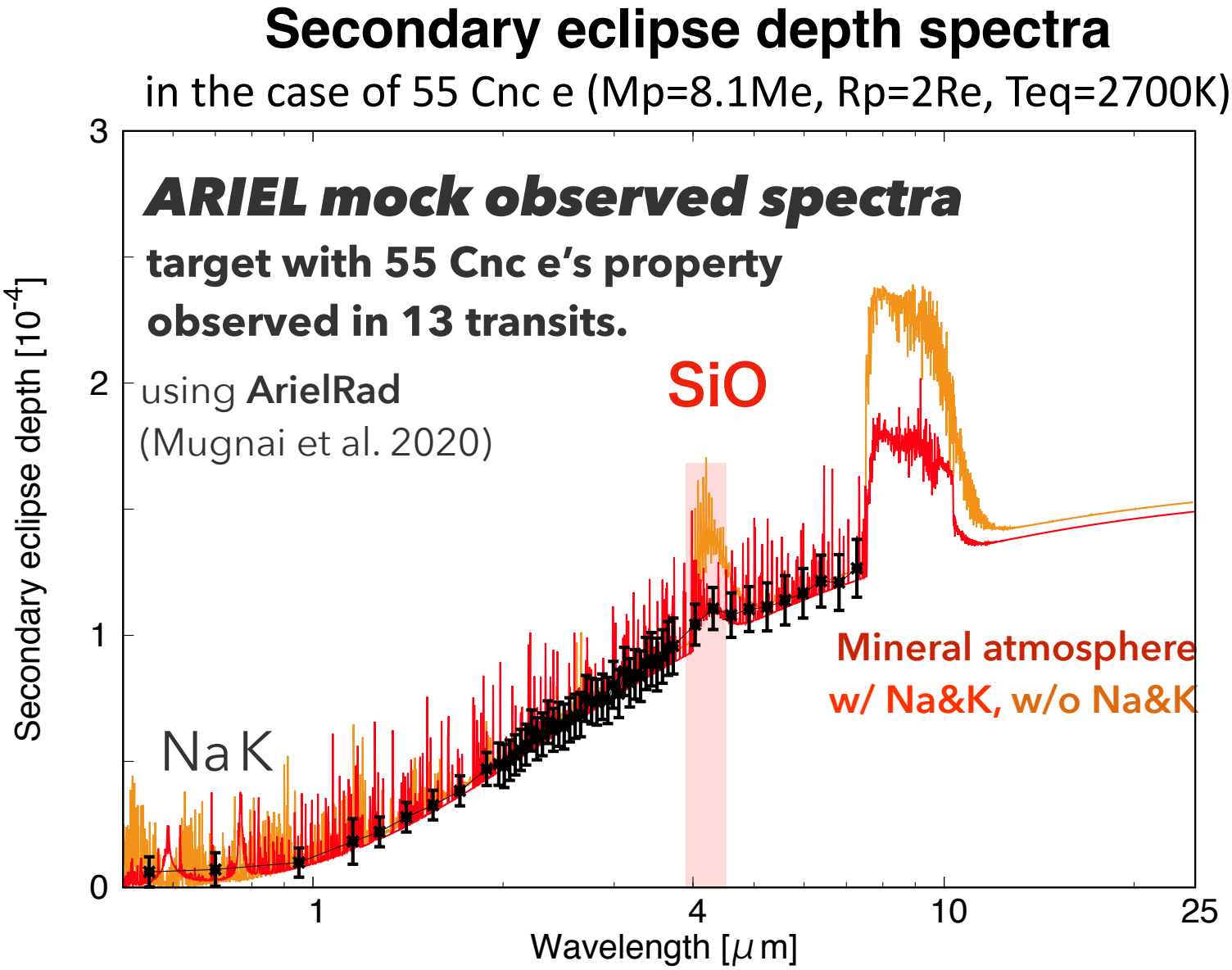
Lack of Na & K makes the atmosphere hot,
due to causing by the emissivity of the atmosphere at visible low.

Impact of Na & K lack on emission spectra



Case w/o Na & K: stronger SiO feature & non-Na/K line feature

Detectability with ARIEL

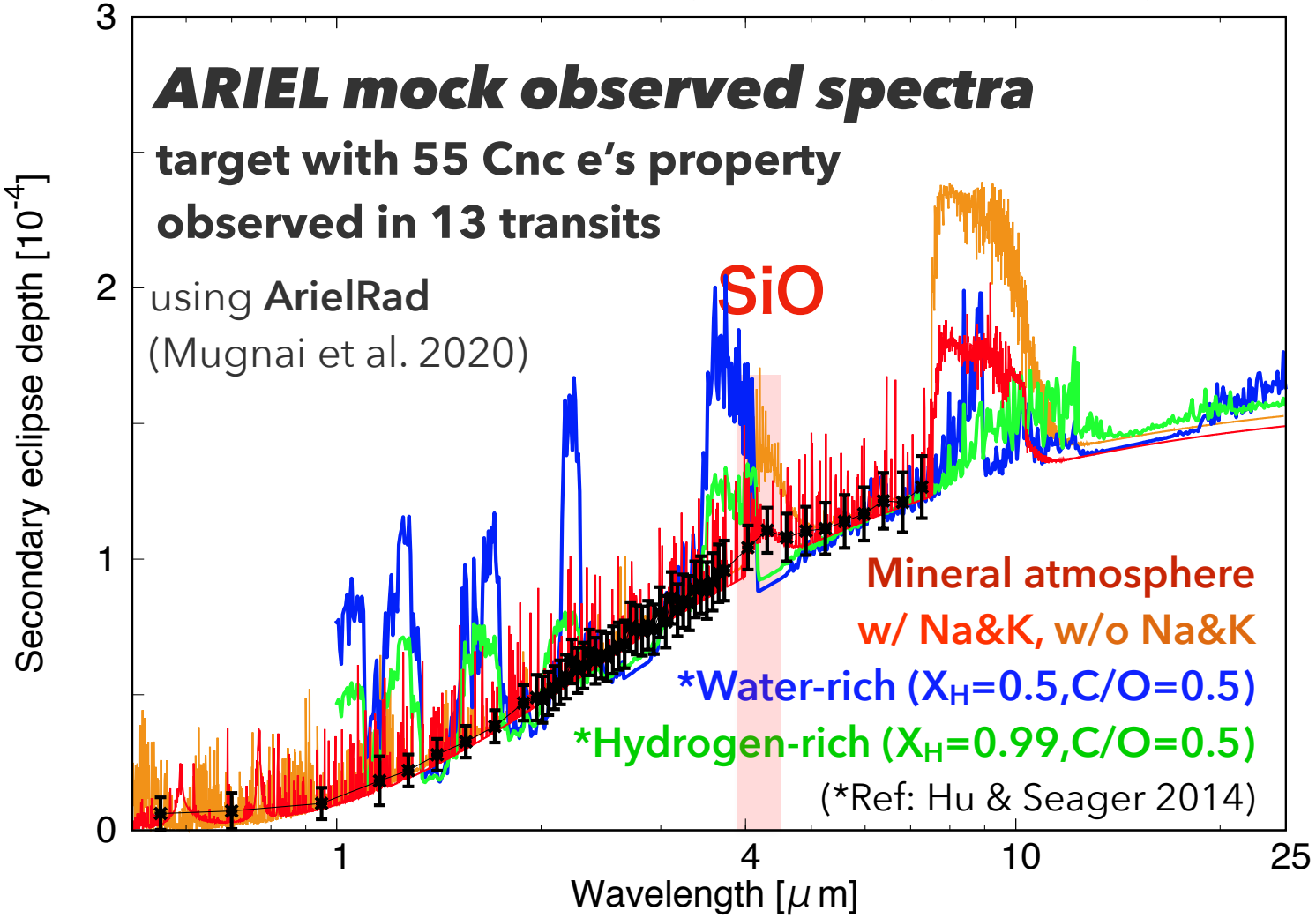


SiO feature at 4 μm is detectable with Ariel(marginally for w/ Na&K)

Detectability with ARIEL

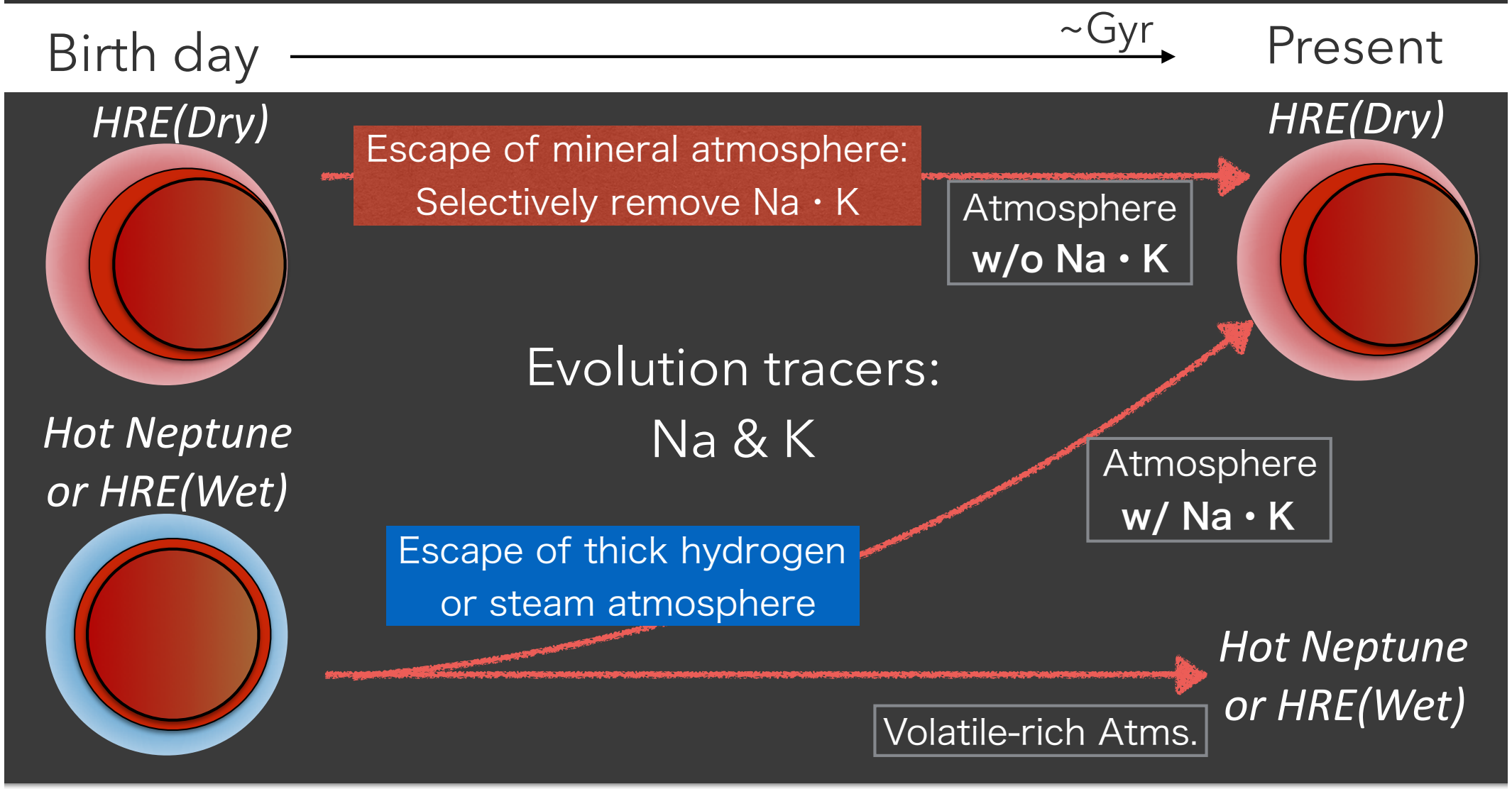
Secondary eclipse depth spectra

in the case of 55 Cnc e (Mp=8.1Me, Rp=2Re, Teq=2700K)



ARIEL can distinguish mineral atmosphere from volatile-rich ones (i.e., absence/presence of volatile element such as H_2O in magma)

Disc.: Evolution of hot rocky exoplanets (HREs)



Keys for Evol.: Atmospheric escape & Internal mixing

Task for Obs.: Detection of Species(Na, SiO)・Brightness Temp.

Summary

Understanding:

Rocky vapor atmospheres of close-in terrestrial planets
- **Mineral atmospheres have characteristic spectra: Na, K and SiO** -

The impact of Alkali metals on mineral atmospheres
- **Na/K lack increases the atmospheric temperature & SiO emission** -

Detectability of rocky vapor & volatile-rich atmospheres with Ariel

The magma composition

such as Na/K, non-Na/K

and absence/presence of volatile components in magma,

would be detectable with Ariel

Future tasks to know the evolution tracks of hot small exoplanets
Modeling: Atmospheric escape & Internal mixing
Task for Obs.: Detection of Species(Na, SiO)・Brightness Temp.