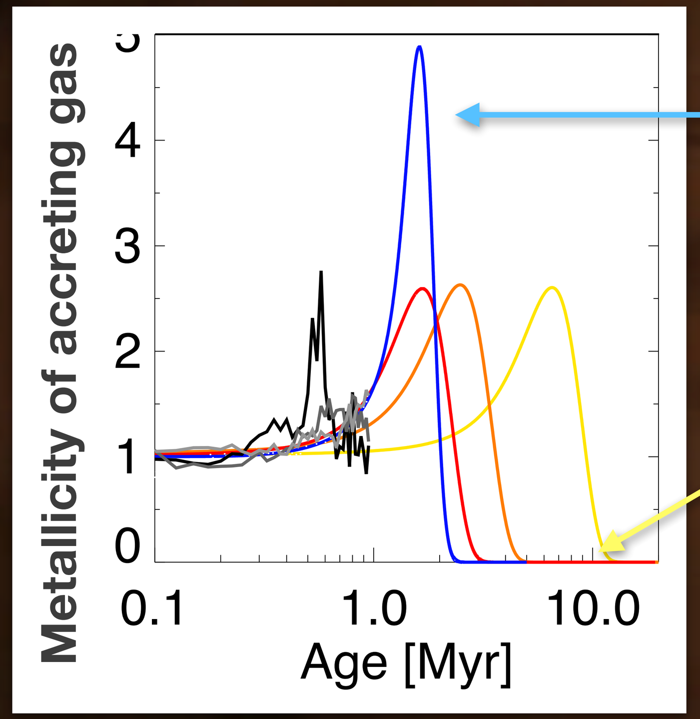
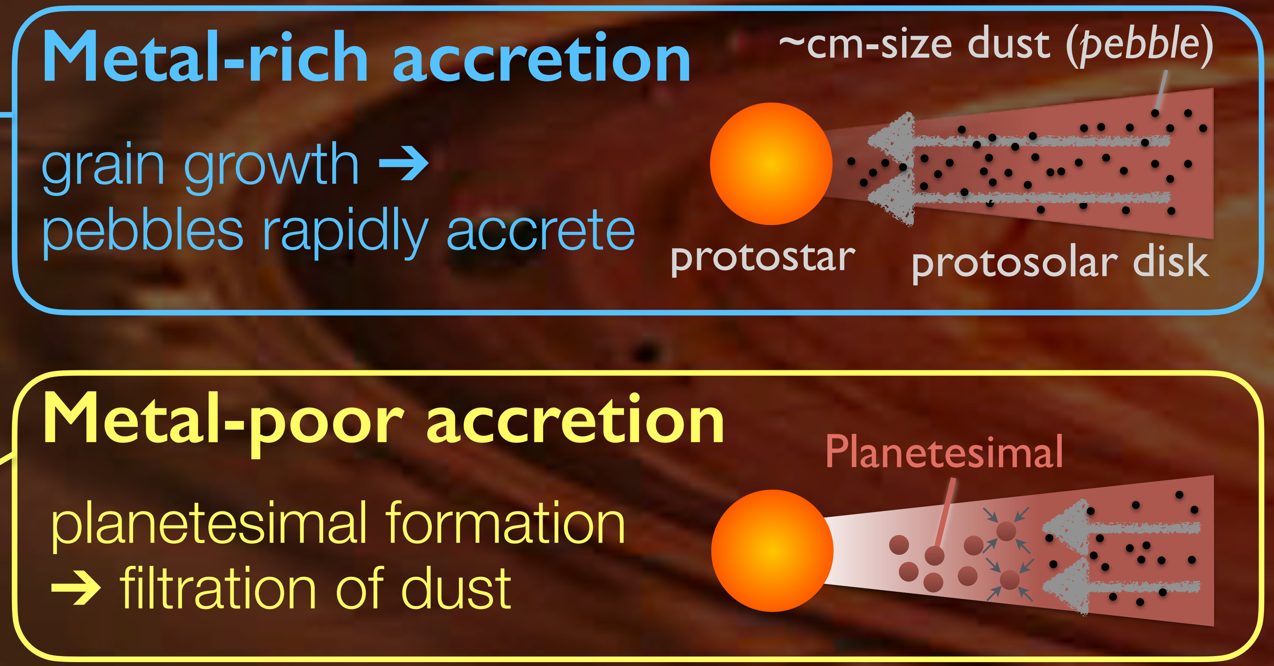
Consequences of planet formation on the stellar composition

Masanobu Kunitomo (Kurume U.) & Tristan Guillot (OCA) Email: kunitomo.masanobu@gmail.com

"Pebble wave" & planet formation



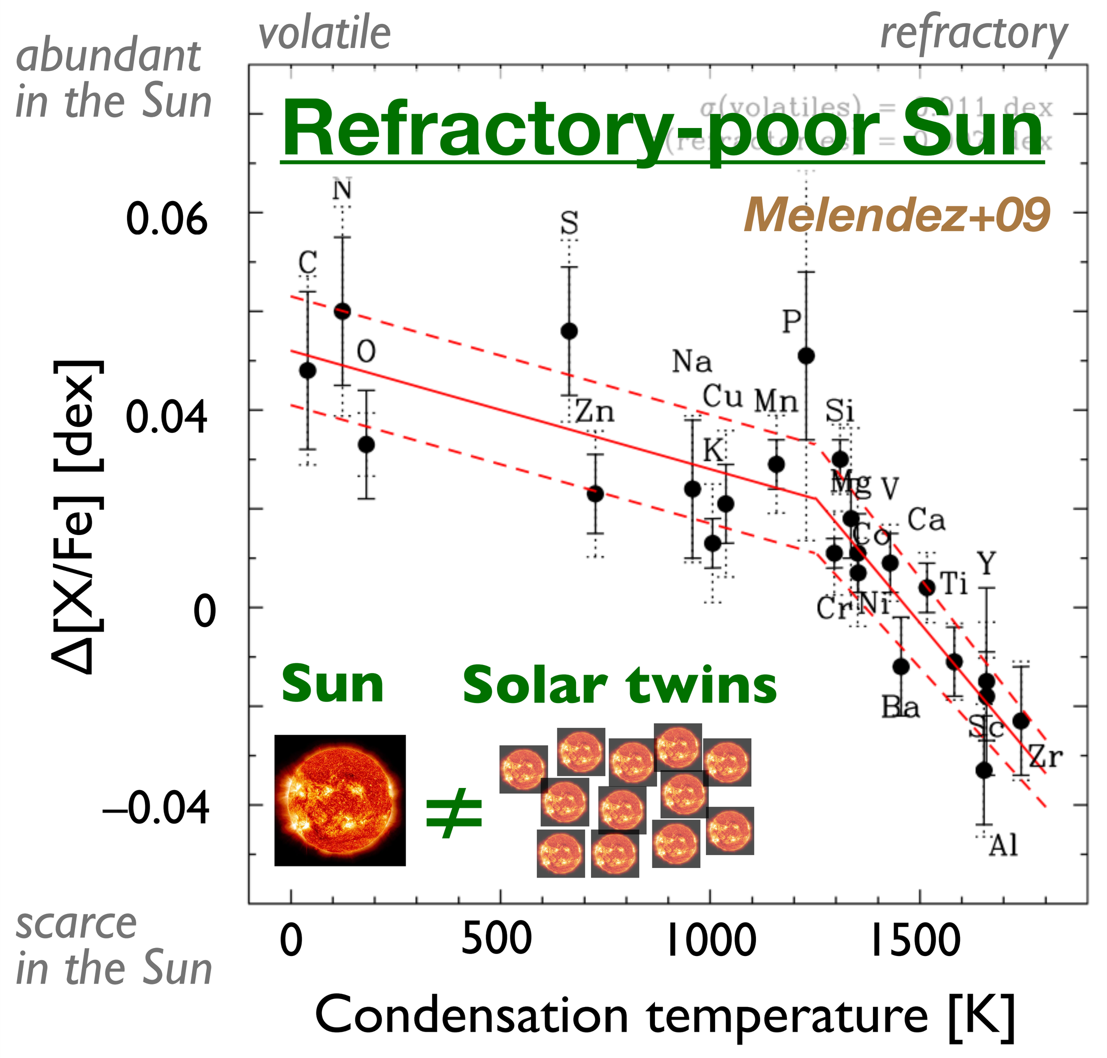


Garaud+2007, Guillot+2014, Applegren+2020, Elbakyan+2020

Does this variable disk composition affect the solar composition?

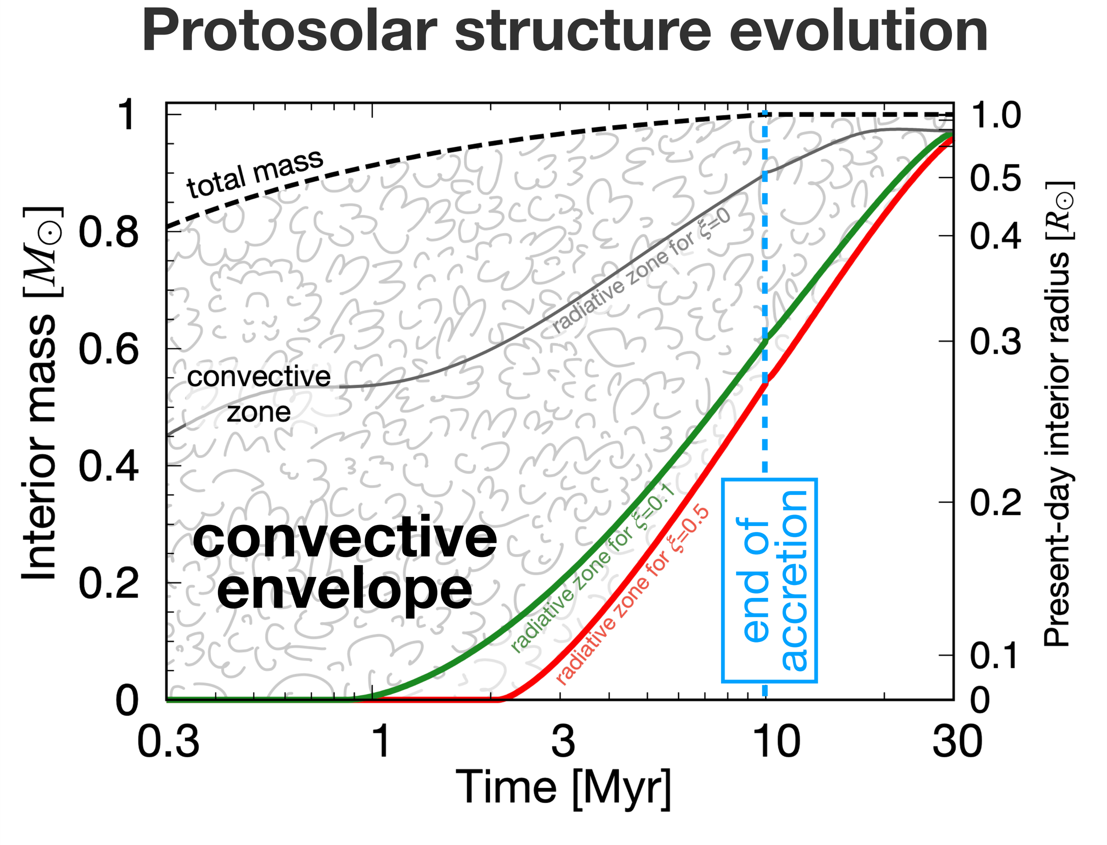
In this poster, we discuss two implications

(1) Solar surface composition *Kunitomo+2018*



- The Sun is refractory compared to solar twins. Is this a signature of planet formation?
- Chambers (2010) suggested that **4 $M_\oplus$ rocky planet formation** in the Solar System can fill this difference with the present-day solar structure
- However, **stellar structure is crucial** in this scenario: Accreted gas is mixed in the surface convective zone.
- We revisited this scenario with a realistic pre-amin-sequence evolution models simulated with a code MESA (Paxton+2011)

see also Booth+Owen 2020; Adibekyan+2014; Ramirez+2009

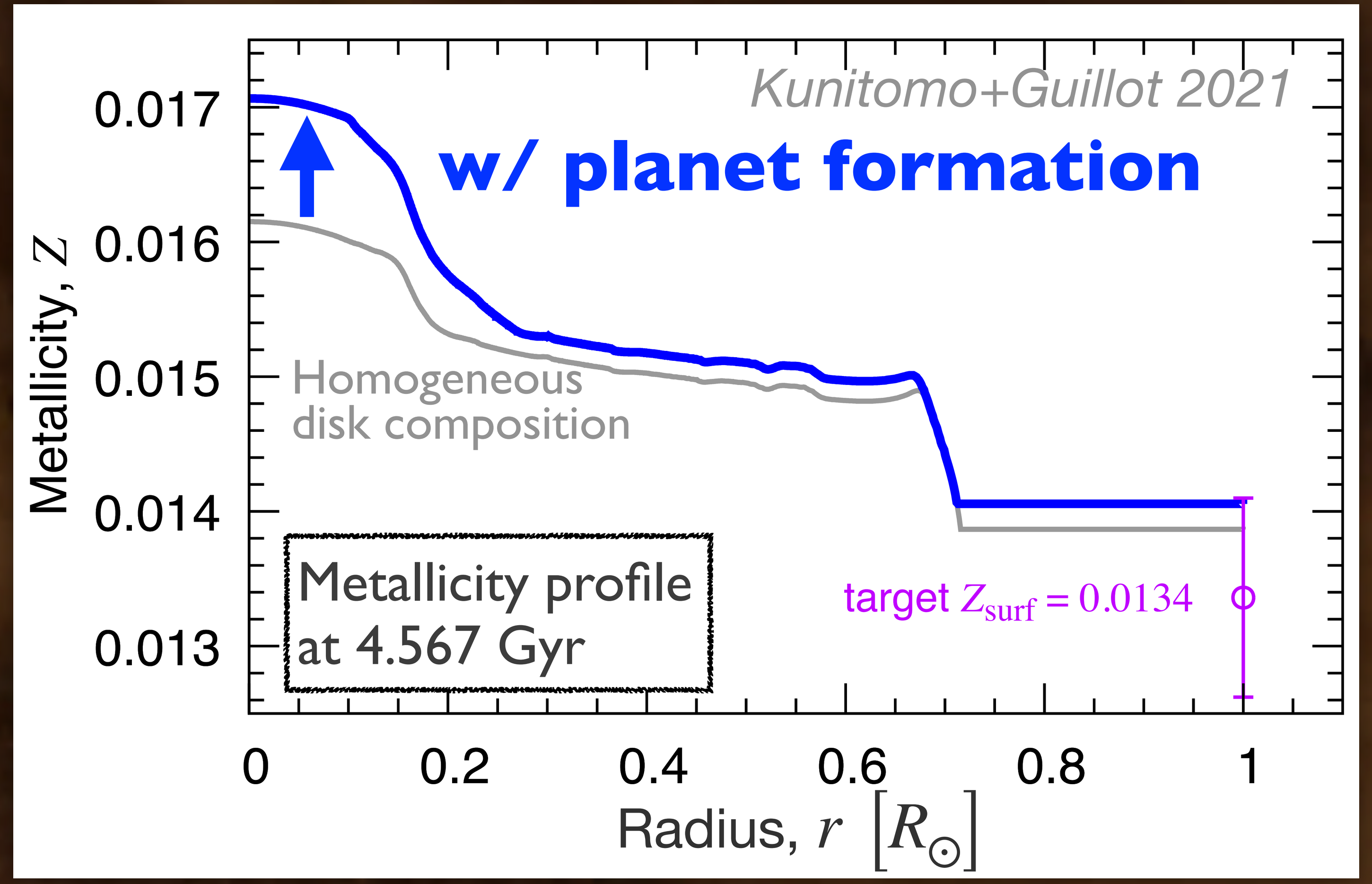


- The proto-Sun has a large convective zone **~0.6–0.7 $M_\odot$** (with a weak dependence on the accretion process; see different lines)
- In the Solar System, ~150 $M_\oplus$ solids were used to form planets. To reproduce the refractory-poor solar surface, **~100 $M_\oplus$ rocky planet formation** is needed (instead of 4 $M_\oplus$) and **the ice-to-rock ratio of the solids to be ≲0.4**. This should be tested by future exploration.

Other implications

- λ Boo stars • Different [F/e/H] of binary stars
- [Fe/H] trend in clusters *(see Kunitomo+2018)*

(2) Solar internal composition *Kunitomo+Guillot 2021*



- We have detailed constraints on the solar interior from helioseismic and neutrino observations, but there still remain mismatches between models and observations
- Due to the variable disk composition, the present-day solar interior can have a composition gradient in the deep interior. **The central metallicity can be enhanced by up to 5%**
  - This is in agreement with recent **neutrino** observations (Orebi-Gann+2021)
- To fill the gap between models and helioseismic observations (so-called ***solar abundance problem***), we found that a **12–18% opacity increase** is needed, which was indeed suggested by recent experiments by Bailey+2015

SELECTED REFERENCES

Kunitomo & Guillot, 2021, A&A, in press. (arXiv:2109.06492)
Kunitomo, Guillot, Ida, & Takeuchi, 2018, A&A, 618, A132
Kunitomo, Guillot, Takeuchi, & Ida, 2017, A&A, 599, A49
Meléndez, Asplund, Gustafsson, & Yong, 2009, ApJ, 704, L66
Asplund, Grevesse,, Sauval, & Scott, 2009, ARA&A, 47, 481
Orebi Gann, Zuber, Bemmerer, et al., 2021, ARNPS, 71, 491