Constraining planet formation via atmospheric abundances

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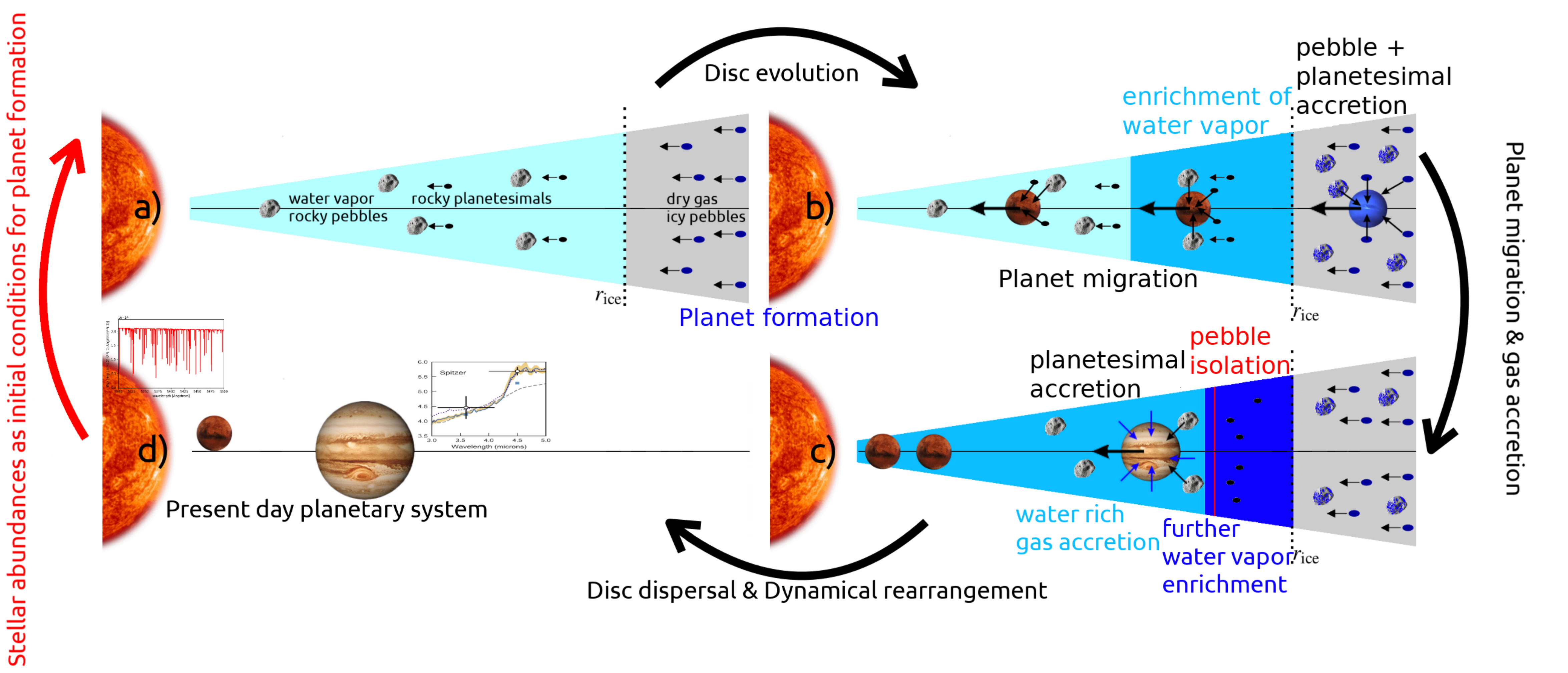
How do planetary systems grow?



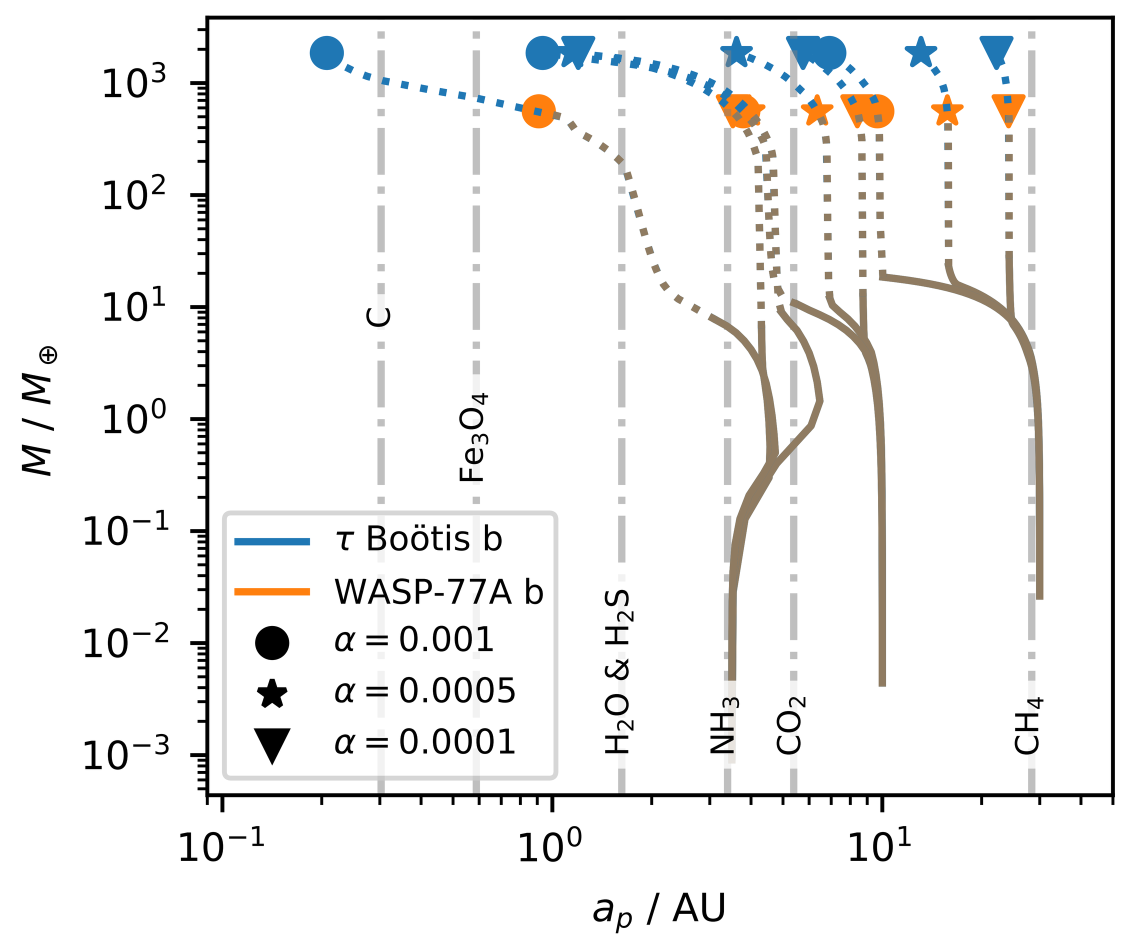
a) Planet formation starts in a disc of dust and pebbles that form planetesimals, while the disc evolves in time.

b) Pebbles **drift** inwards, **evaporate** and **enrich the disc with volatiles**. Planets form by the accretion of planetesimals and pebbles, while they migrate in type-I migration through the disc.

c) Once the planets become big enough, they accrete gas and migrate in type-II migration, while blocking the large pebbles exterior to their orbits.

d) After the gas disc dispersal, dynamical interactions shape the planetary system. Today, we observe the planetary systems, the stellar and planetary spectra.

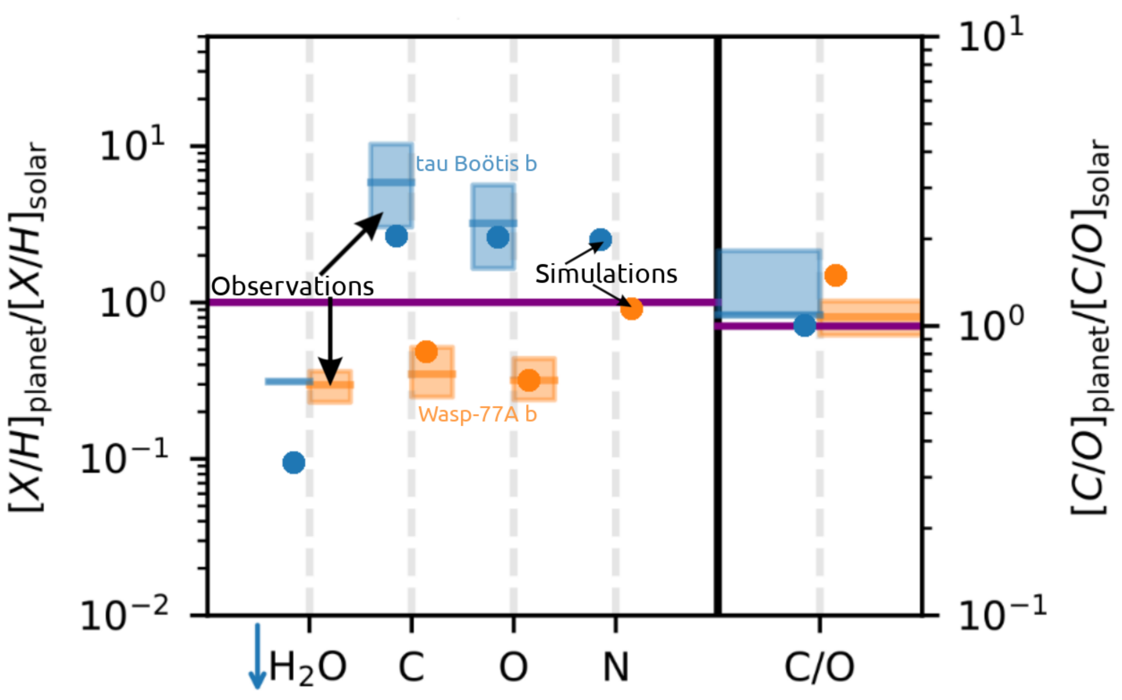
How do planets grow and migrate?



- Planets grow by pebble (solid lines) and gas accretion (dashed lines), while they migrate through the disc.
- Planet cross multiple evaporation fronts during their evolution, allowing them to accrete different materials in solid and gaseous form.

⇒ The planetary growth and migration history sets the planetary composition!

Where did the giants form?



- The pebble drift and evaporation model allows **super- and sub-solar** C/H and O/H in planetary atmospheres (Schneider & Bitsch, 2021a)!

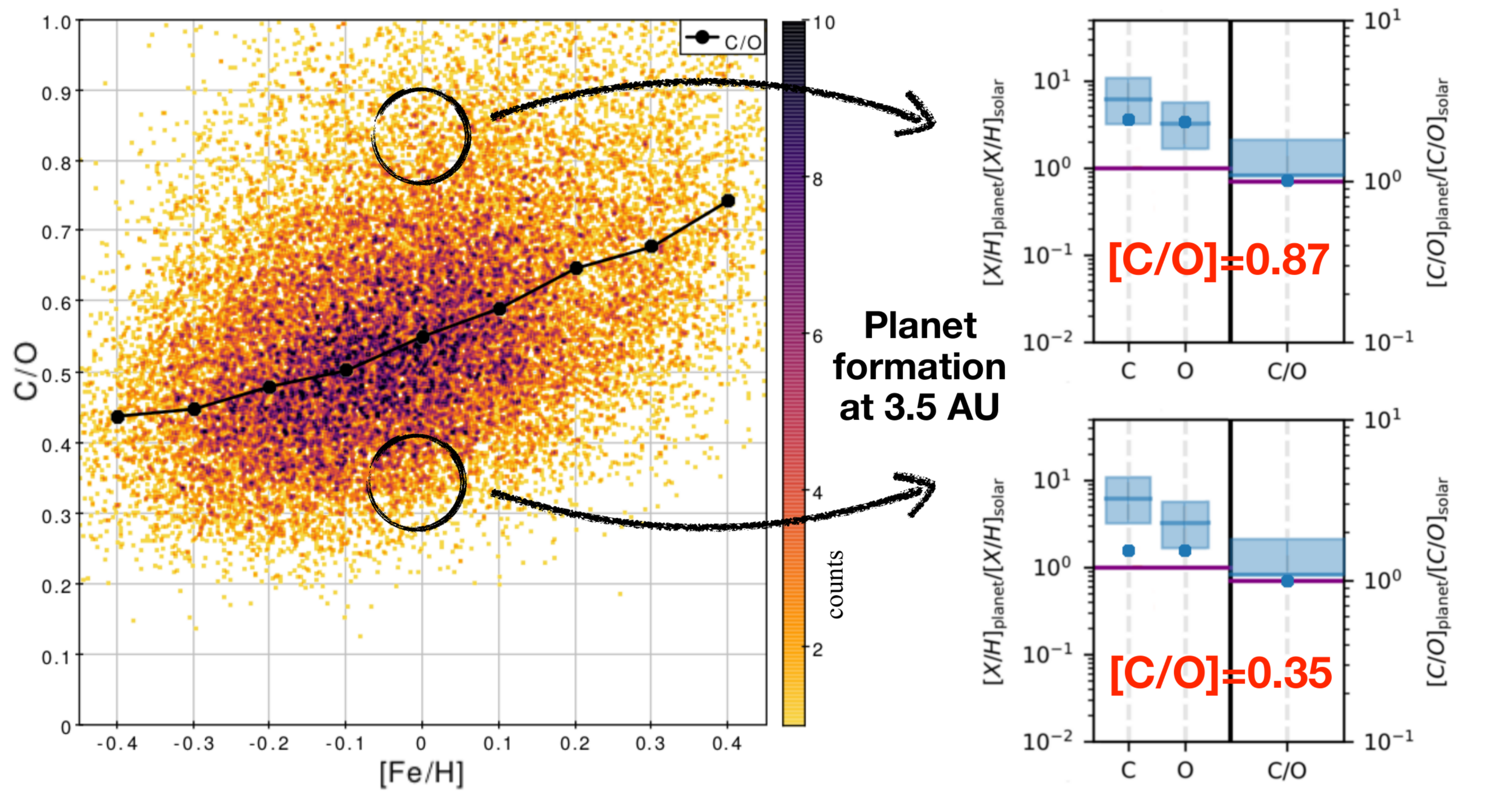
⇒ WASP-77A b formed beyond the CO_2 evaporation front (Bitsch et al., 2022).

⇒ τ Boötis b formed beyond the H_2O evaporation front (Bitsch et al., 2022).

⇒ The planetary C/O alone does not determine the planet's formation location!

⇒ No additional accretion of solids needed, as in classical models (e.g. Schneider & Bitsch 2021b)!

How do the stellar abundances shape the planet?



- Stellar abundances are used as initial conditions for planet formation. (e.g. Bitsch & Battistini 2020; Cabral et al. 2023)
- Stars with the same metallicity [Fe/H] can have significantly different C/O fractions!
- The stellar C/O ratio sets the chemical composition in the planet forming disc!

⇒ Planets forming in discs with different C/O ratio have different atmospheric composition!

⇒ Detailed stellar abundance measurements are essential if we want to constrain planetary formation histories via their atmospheric abundances!

Conclusions

- Pebble drift and evaporation enhances the disc with volatiles.
- The gaseous volatiles can be accreted via the gas by growing giant planets.

⇒ This process allows the formation of planets with super-solar abundances (Schneider & Bitsch, 2021a,b)!

⇒ We can constrain the formation location of giants via their atmospheric abundances (Bitsch et al., 2022).

⇒ Stellar abundances are essential to constrain the planet's formation history!

References

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