ETH zürich

Rocky exoplanet compositions

and its effects on long-term planetary evolution

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This presentation participates in OSPP

EGU

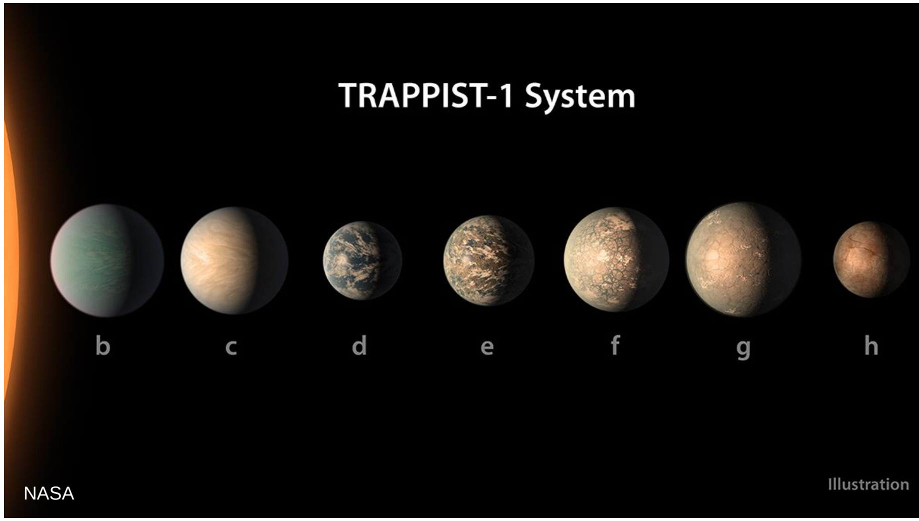
Outstanding Student & PhD candidate Presentation contest

Terrestrial exoplanet compositions

- Terrestrial exoplanets differ from Earth
- Large diversity, even within a system like TRAPPIST-1
- Diversity in terms of interior composition is currently under-explored
- Composition affects structure (core size), physical properties (mantle mineralogy), melting behaviour/volcanism

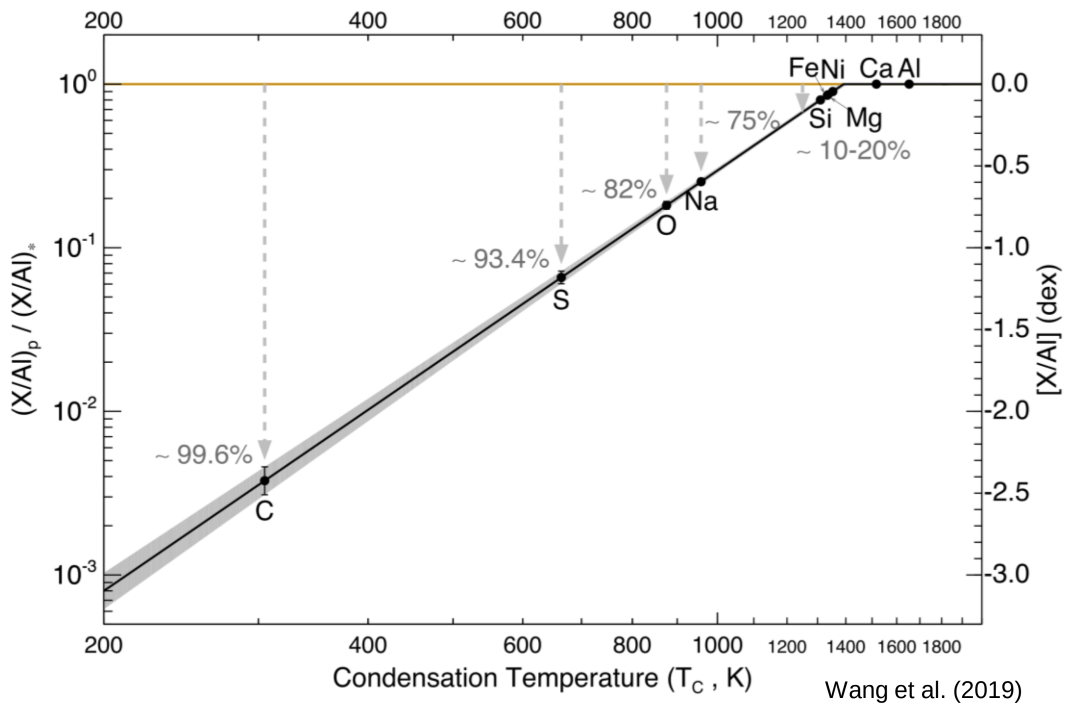
- Observations limited: Usually Mass and Radius; cannot observe composition
- Resolve by using Star-Planet compositional link
- Planet, star form from same material

- Goal: Use stellar composition measurements to constrain what compositions terrestrial planets can have



Terrestrial exoplanet compositions

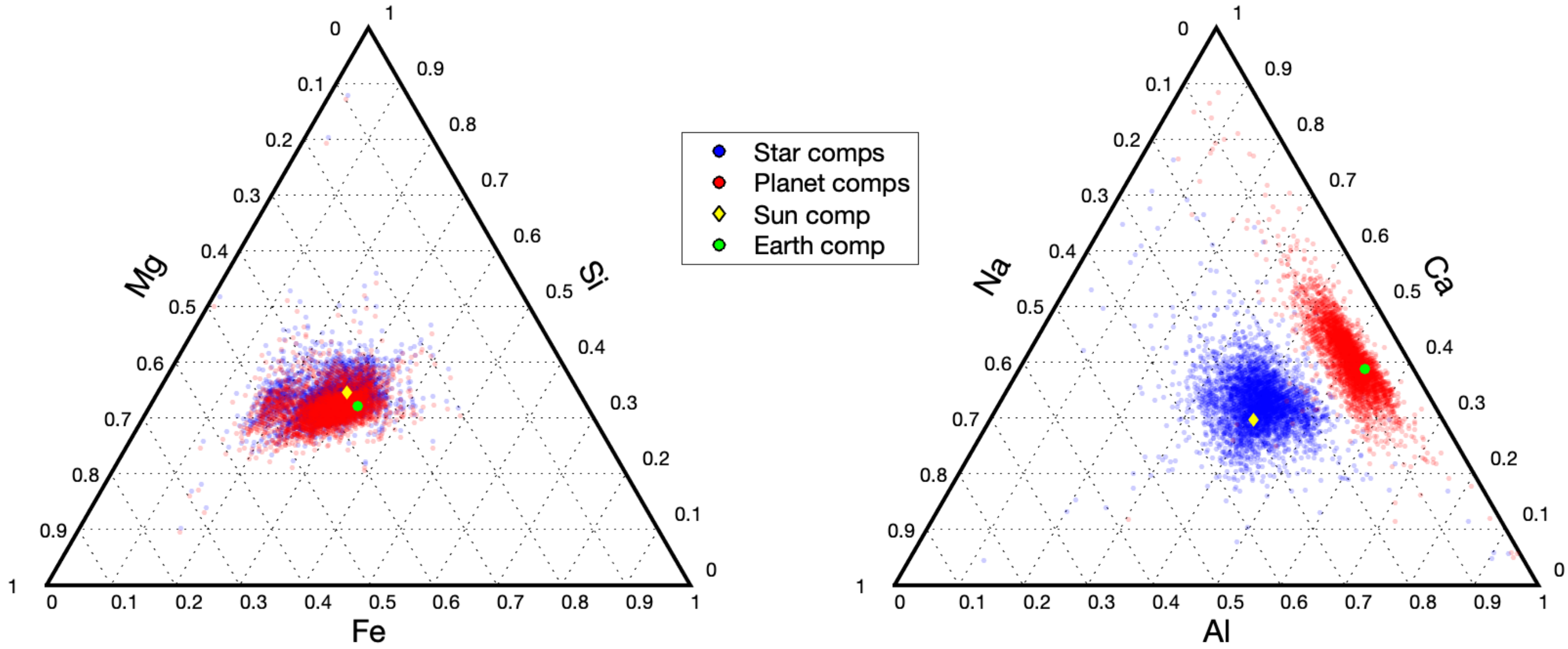
- Haiyang Wang's work (presentation in same session): compare composition of Earth and Sun -> clear and simple relation
- Function of 50% condensation temperature of elements in the planet-forming disk
- Earth and Sun identical for elements of high Tc; Earth progressively more depleted in volatile elements (low Tc)
- Earth ≈ Sun - volatiles
- Approach exoplanets as devolatized star by applying depletion factors (percentages in figure)
- Important elements: Ca, Al, Mg, Fe, Si, Ni, Na, K, S, O



Wang et al. (2019)

Exoplanet compositions

- Apply devolatilization to stellar abundances, found in Hypatia catalogue
- Stars: F, G, K types; Solar neighbourhood (within 200 pc)
- Effect small for similar Fe, Mg, Si; large for volatile Na vs non-volatile Ca, Al

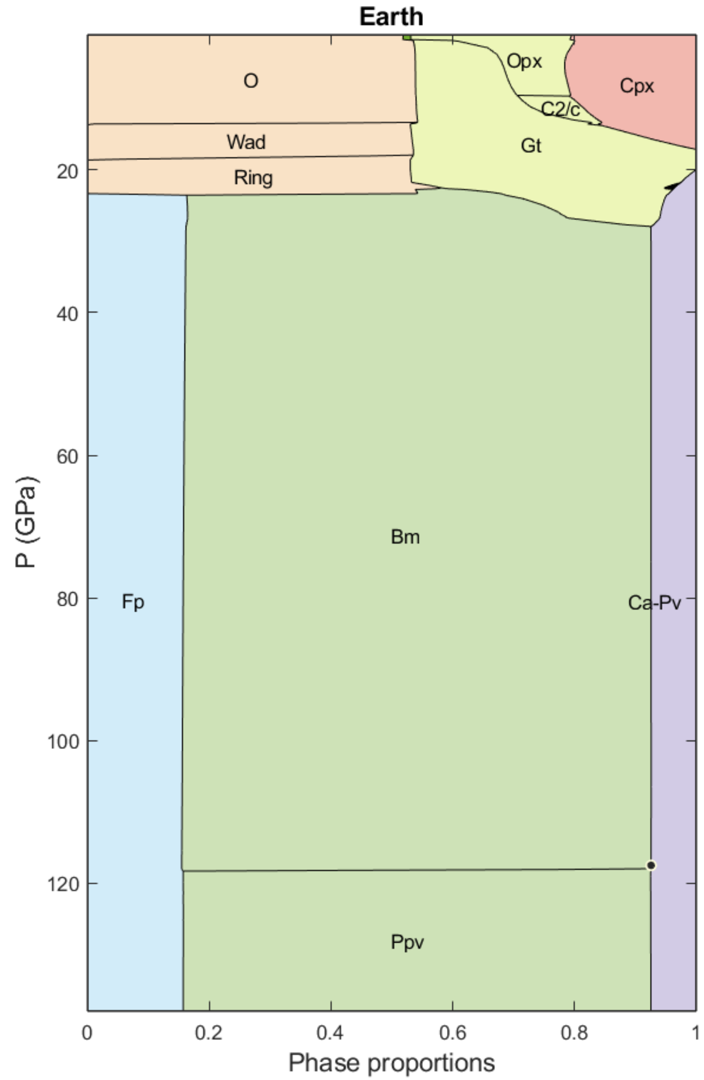


Exoplanet mineralogy

- From composition to physical properties: need mantle mineralogy
- For Earth: Figure to the right

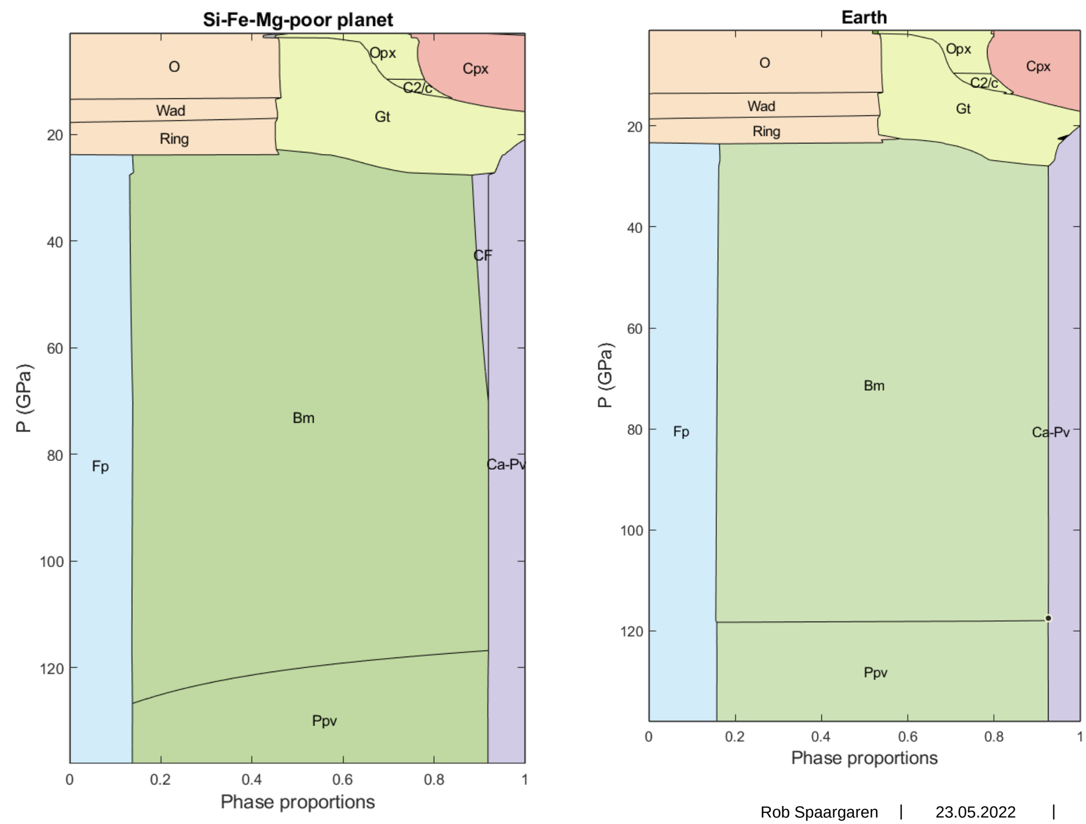
- Compare to end-member compositions based on population of planets, see previous slide

- Calculate mantle mineralogy with Perple_X, Gibbs energy minimization algorithm



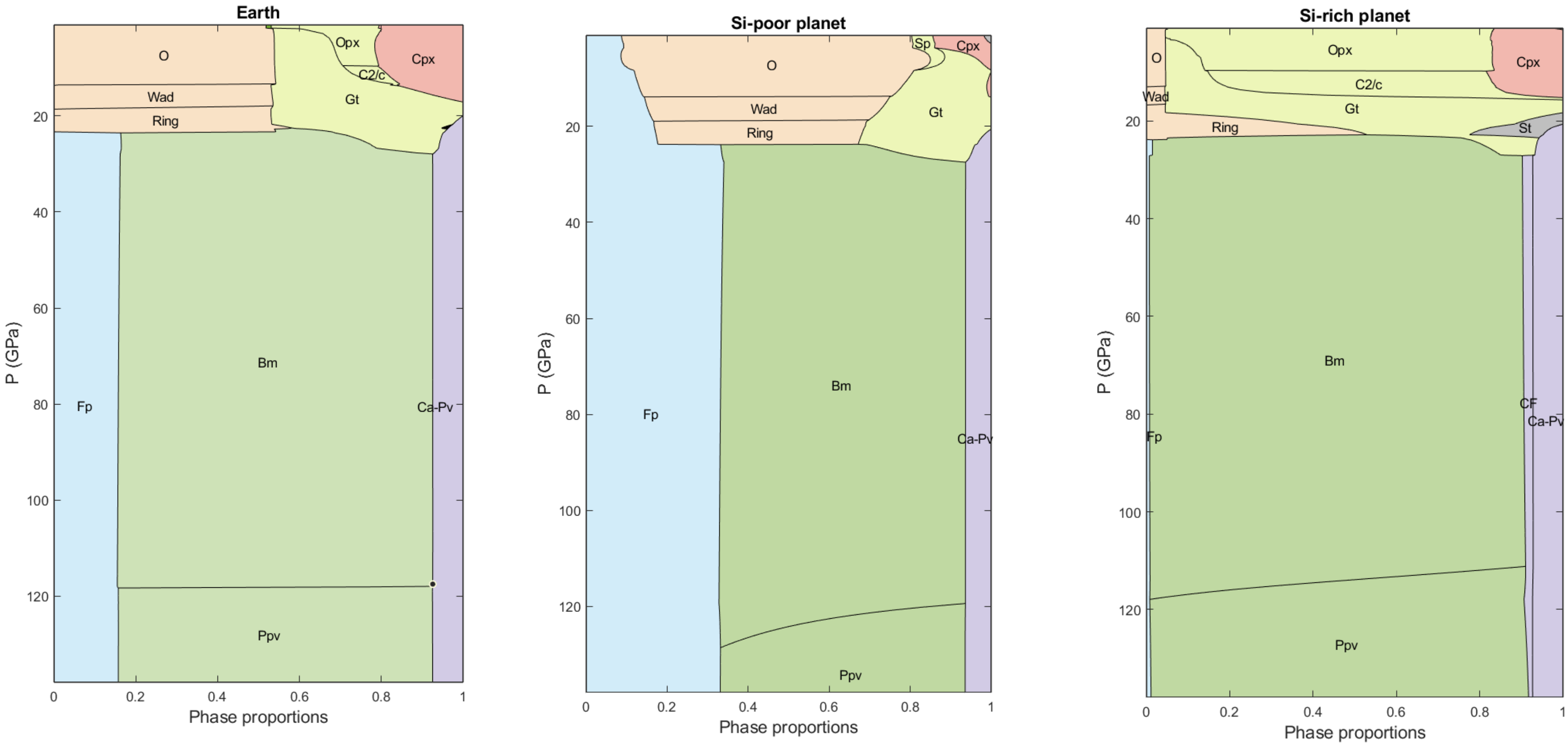
Exoplanet mineralogy

- Planet with most Si+Fe+Mg-poor mantle: Still similar to Earth
- More Cpx (red), Ca-pv (purple); some CF, but still mainly Mg/Fe-silicates (orange, yellow, green, blue)
- Stars are rich in Fe, Mg, Si compared to Ca, Al, Na
- Exotic compositions (different minerals than Earth) are rare



Exoplanet mineralogy

- Relative abundances Fe/Mg silicates vary a lot
- Some have Fp (blue) in upper mantle, some have very little Fp and O (orange)
- No quartz planets found



Implications

- Terrestrial exoplanets will have similar mineralogy to Earth; few exotic minerals
- Relative abundances of minerals vary a lot, will affect interior dynamics
- Largest effect: ferro-periclase is weak, bridgmanite is strong, Fp/bm varies a lot

- Will composition affect dynamic regime (i.e., plate tectonics or stagnant lid like behaviour)?
- Needs investigation with geodynamic models
- I will investigate my end-member compositions in more detail with a geodynamical model, StagYY, so stay tuned!

Take-home messages

- Constrain **terrestrial exoplanet compositions** using observed stellar abundances
- **Exotic compositions** are rare; **Fe/Mg-silicates** common
- **Relative mineral abundances** vary; far-reaching effects on planet evolution
- Use for modelling terrestrial exoplanet interiors, with **composition-dependent properties**