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The Elemental Devolatilization Pattern of a Habitable Planet

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INTRODUCTION Planet Bulk Composition is Related to Host Star Bulk Composition

- Bulk chemical compositions of a rocky planet are crucial for assessing habitability, but they are not directly measurable.
- To estimate the bulk chemical composition of a planet one needs to quantify the planet's chemical relationship with its host star.
- Using the best available chemical compositions of the Sun, carbonaceous chondrites (type I, CI) and Earth, we quantified the levels of elemental depletion in the Earth and CIs.

DATA ANALYSIS Elemental Abundances

- We compiled the most complete and up-to-date elemental abundances for the Sun, Earth, and CIs.
- We use aluminum (Al), not silicon (Si), to normalize because Al is more refractory than Si.
- This compilation and normalization allows us to make a precise comparison of the bulk elemental compositions of the Sun, CIs and the Earth to help understand the devolatilization processes of rocky materials in the solar system.

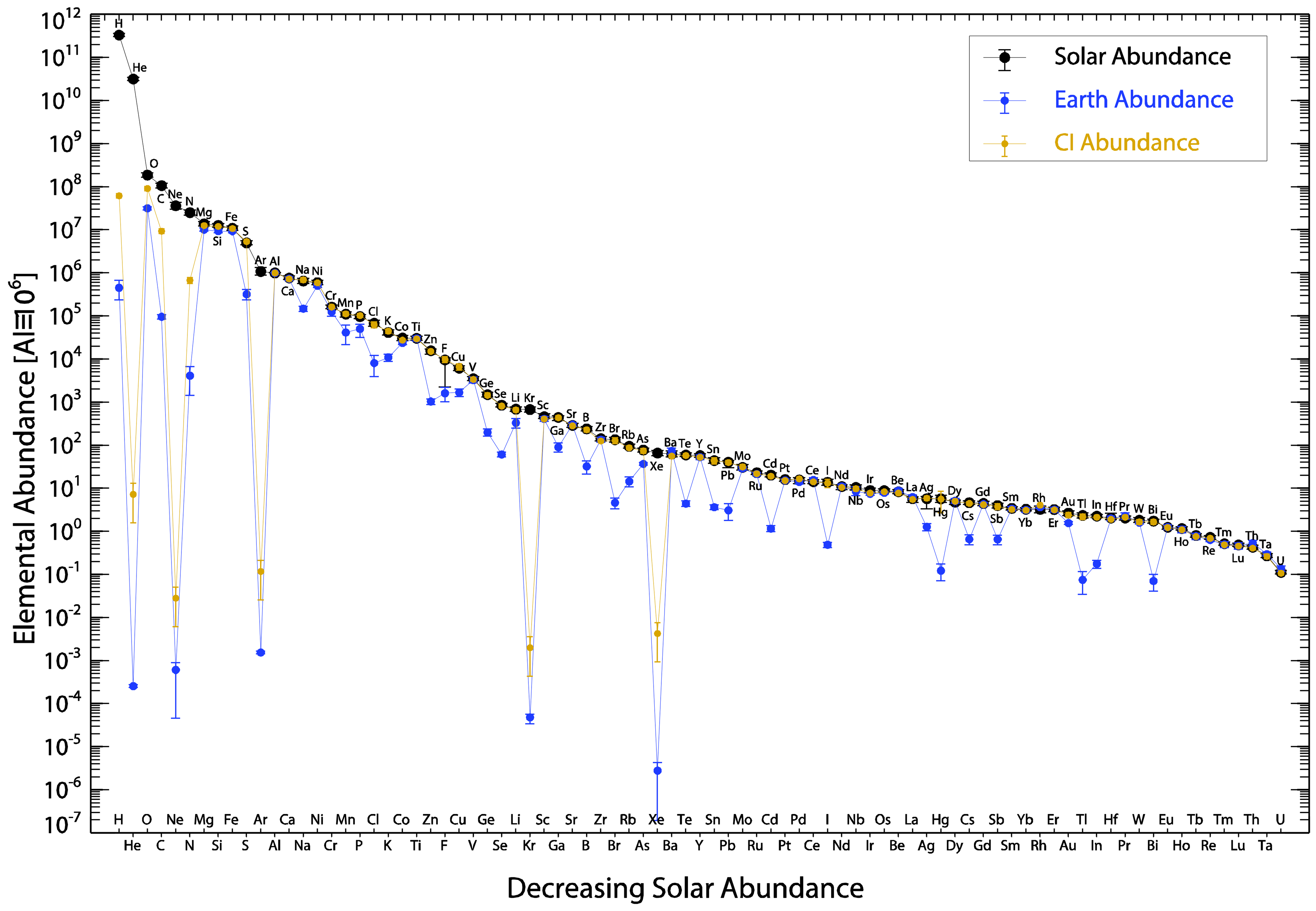

Fig.1 Comparison of Elemental Abundances (Al≡10^6) of Sun[1-5], CI[5] and Earth[6-17].

RESULTS Elemental Devolatilization Pattern

- The relative abundances of refractory elements in CIs and in the Earth are identical to those in the Sun. Moderately volatile elements show intermediate levels of depletion, while the most volatile elements are depleted in the Earth by many orders of magnitude compared with the Sun (Fig.2.).
- The magnitudes of volatile elemental depletion for Earth and CIs are different. This is probably due to the different thermal and photoevaporation histories of ~ 1 AU and ~ 3 AU material.
- For the Earth, the transition between depleted and non-depleted elements occurs at a condensation temperature: $T_{transition}$(Earth) = 1400 ± 30 K. We interpret this as the highest temperature in the solar nebula experienced by the material in the feeding zone of the Earth.
- The elemental abundances of Sun-normalized CI carbonaceous chondrites (~3 AU) show the devolatilization of only very highly volatile elements with condensation temperature less than $T_{transtition}$ (CI) ~ 300 K.
- The further material is from the Sun, the weaker the depletion of volatile elements and the lower the transition temperature.

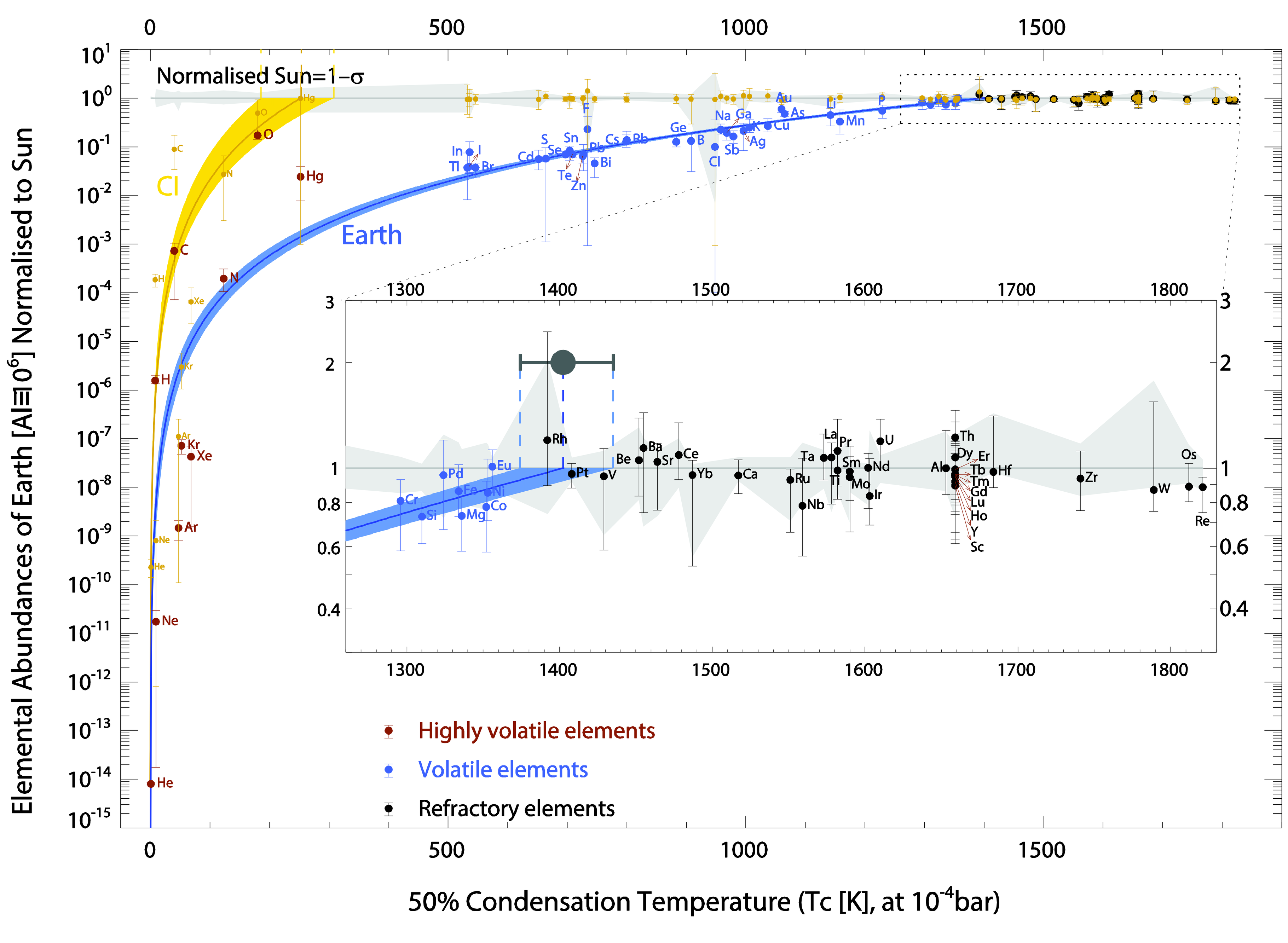

Fig.2 Comparison of Sun-normalized elemental abundances of Earth and CIs plotted as a function of 50% Condensation Temperature[18] – showing the elemental devolatilization patterns for Earth (blue) and CIs (yellow).

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FUTURE WORK A General Devolatilization Model

- Compared with the elemental depletions in the Earth and CIs, those of Mars are expected to be less depleted than Earth (more than CI) and $T_{transition}$ (Mars) should be lower than 1400 K. Conversely, Venus should have fewer volatiles and a higher $T_{transition.}$
- We expect a general semimajor axis- and host-star-luminosity-dependent devolatilization pattern for exoplanets.