THE ELEMENTAL DEVOLATILIZATION PATTERN OF A HABITABLE PLANET Haiyang Wang[1] and Charles H. Lineweaver[1], [1]Planetary Science Institute, Research School of Astronomy and Astrophysics and Research School of Earth Sciences, The Australian National University, Australia, haiyang.wang@anu.edu.au, charley.lineweaver@anu.edu.au

To estimate the bulk chemical composition of a habitable planet one needs to quantify the chemical relationship between the planet and its host star. Using the best available bulk chemical compositions of the Earth and Sun, we quantified the levels of volatile depletion of the Earth.

In Fig. 1 we plot the relative bulk elemental abundances of the Earth normalized to aluminium and the Sun, as a function of 50% condensation temperatures [1]. The relative abundances of refractory elements 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. We further describe the Earth as a devolatilized piece of the Sun on the basis of [2].

This devolatilization pattern can be used as a first-order generic devolatilization pattern for habitable planets around Sun-like stars. Thus, the bulk chemical composition of a habitable planet can be approximately derived using this pattern from the observable elemental abundances of its host star.

The transition between depleted and non-depleted elements occurs at a critical condensation temperature: $\mathbf{Tc_{critical} = 1400 \pm 30}$ **K**. We interpret this as the highest temperature in the solar nebula experienced by the material in the feeding zone of the Earth, before the material became gravitationally bound to the Earth.

The elemental abundances of Sun-normalized CI carbonaceous chondrites (~3AU) show that only very highly volatile elements with $Tc_{critical} < 300$ K are devolatilized (Fig. 1). Devolatilization is a universal process largely caused by photoevaporation and is correlated with the distances (or effective temperatures) of objects from their host star. On this basis, compared with the depletion of volatile elements of the Earth, those of Mars are expected to be less depleted and its $Tc_{critical}$ should shift to a range lower than 1400 K. Conversely, Venus should have more depleted volatiles and a higher $Tc_{critical}$. A semimajor axis- and host-star-luminosity-dependent devolatilization pattern is expected for exoplanets around Sun-like stars [3].

References: [1] Lodders K. (2003) *ApJ*, 691: 1220-1247. [2] Lineweaver C.H. et al. (2010) *AbSciCon., Abstract #5221*. [3] Wang H.-Y. & Lineweaver C.H. (2015, *in prep*). [4] Lodders K. (2009) *in Landolt-Börnstein, New Series, Vol. VI/4B, Chap. 4.4, 560-630. J.E. Trümper (ed.): Springer-Verlag.* [5] Asplund M. et al. (2009) *A&A, 47*:481-522. [6] Scott P. et al. (2015). *A&A*, 573: A25 (19). [7] Scott P. et al. (2015). *A&A*, 573: A26 (33). [8] Grevesse N. et al. (2015). *A&A*, *573:* A27 (23). [9] Palme H. et al. (2014) *Treatise on Geochem., 2nd Ed, Chap. 2.2, 15-36.*

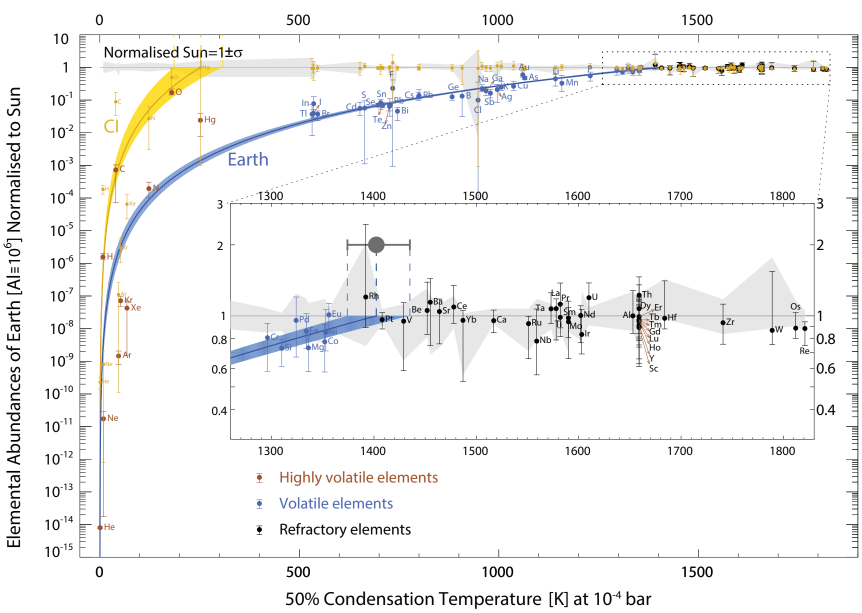

Figure 1
Elemental devolatilization pattern (blue) of the Earth to the Sun, compared with CI carbonaceous chondrites' devolatilization pattern (yellow).

Data sources for elemental abundances – Earth: based on the compositions of earth crust, mantle, and core [3]; Sun: weighted average of the solar abundances [4-8]; CI: based on [9]