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From *Star* to Surface: Tracing rocky exoplanet compositions

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Life exists in gradients, where it exploits disequilibrium to obtain the nutrients and energy required to thrive. For a planet to sustain life, it must be geochemically "alive". Its properties—temperature, size, stellar flux, chemistry, geodynamism—must allow for persistent planetary-scale cyclical processes that continuously transport fresh material to the planet's surface. The number of interdependent processes guiding the evolution of starstuff into life-sustaining worlds is nearly as astronomical as the number of planets in the universe, and it is not yet clear which variables significantly affect planetary evolution outcomes. I will discuss how we might trace a single life-essential element, phosphorus, from star to surface.

Techniques to calculate a bulk silicate planet composition (BSP) from the measured chemistry of its host star have, for the first time, enabled targeted geochemical investigations of "Earth-like" rocky exoplanets <2 Earth radii. Elemental ratios vary approximately by a factor of 2 for host stars, but such variability corresponds to only modest shifts from Earth's BSP. In an Si-Al-Fe-Mg-Ca-Na system, experiments revealed that tweaking bulk Mg/Si and Ca/Al ratios in primitive un-depleted Earth mantle shifts its mineralogy from olivine-dominated (olivine:orthopyroxene ~2:1, Earth-like) to orthopyroxene-dominated (~0.1:1) and depresses the dry solidus by ≤50 °C at 2 GPa [1]. These mineralogical changes further influence geodynamics as orthopyroxene and olivine viscosities have different dependencies on temperature and pressure, leading to divergent long-term thermal and volcanic histories. Our new experiments show that the addition of 0.02 wt% P_2O_5 and increase in Na_2O to 0.41 wt% to the same exomantle composition results in further depression of the solidus, altogether ≤100 °C compared to Earth. Our work explores planetary habitability amongst the vast tapestry of disciplines actively forging a shared vision of the irreducibly interdisciplinary nature of the questions now confronting us. Namely, how do variations in stellar properties affect mantle mineralogy, depth of melting, primary melt extraction, enrichment of life-essential elements in evolved magmas, volcanic eruption style, duration of planetary volcanism, granite production, mantle convection, atmospheric composition, and more? Interoperable, data-driven computational methodologies can provide the shared computational language capable of bridging these domains.

[1] Brugman et al. (2021) *JGR:Planets*