Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.30523

The Effect of Composition Variation on Mantle Solidus and Thermal Evolution of Rocky Planets

CHANDAN KUMAR SAHU[1], BRADFORD FOLEY[2] AND AARON S WOLF[3]

[1]Pennsylvania State University
[2]The Pennsylvania State University
[3]SETI Institute

Understanding exoplanet interiors remains a challenge in the planetary science community due to the inherent difficulty of direct observation. While atmospheres of these planets are being observed using advanced telescopes like HST and JWST, interior modeling provides information about their interior structure, composition, and evolution relevant for interpreting atmospheric observations. Specifically, processes within a planet's deep interior, such as heat transport and magnetic field generation, as well as surface processes like outgassing, volcanism and tectonics can all shape atmosphere evolution and can be informed by interior models. Current models often assume an Earth-like interior mineral composition, however rocky exoplanets could come in a range of different compositions. Studies from the Hypatia catalog and other similar compilations of stellar compositions, show that stars can have a wide range of elemental abundances, leading to diverse mineral compositions in terrestrial planets, as they reflect the refractory materials present in the host star.

Our research investigates how variations in interior composition affect the mantle solidus and, consequently, the planet's thermal history. The solidus, marking the onset of melting, is crucial for determining cooling rates and melt production. On Earth, olivine and pyroxene are the primary minerals in the upper mantle. Variability in elemental abundances in stars suggests planets may have diverse olivine-pyroxene ratios. We use the MELTS model to determine how different mineralogies affect the mantle's solidus profile. Our results demonstrate that solidus temperatures decrease with a lower olivine-pyroxene ratio and increase with a higher olivine-pyroxene ratio. We then integrate the calculated solidii with the mantle adiabat and heat sources/sinks to simulate interactions between mantle composition, temperature, pressure, viscosity, and lid growth over geological timescales. This helps us understand heat transport, melt production, volatile outgassing, volcanism, and other dynamic processes during a rocky planet's evolution, aiding in predicting the thermal and geological history of exoplanets. Understanding these processes is essential for identifying planets that may support life, as the presence of tectonic activity and volcanism can create and sustain habitable conditions over long periods.