Thermochemical evolution of exoplanets: linking stellar chemistry, interior Composition, and volatile release

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The elemental composition of exoplanets is intimately linked to that of their host stars, yet the extent to which stellar abundances predict planetary bulk composition remains an open question. While refractory elements such as Mg, Si, and Fe are expected to be preserved during planet formation, volatile elements, particularly carbon, may undergo significant redistribution in protoplanetary disks, leading to deviations from stellar composition. I will discuss the link between interior and atmospheric composition of small exoplanets ($R < 2 R_\oplus$ and $M < 10 M_\oplus$), and particularly investigate the relationship between stellar abundances and the composition of rocky and volatile-rich exoplanets, focusing on the influence of stellar metallicity, Mg/Si, and C/O ratios. Using high-precision spectroscopic data from the APOGEE and Hypatia catalogs, we analyze elemental abundance trends across a broad range of metallicities, placing particular emphasis on GKM-type stars, which are key targets for small exoplanet characterization. We derive atomic ratios (e.g., C/O, Mg/Si, Fe/Mg) and explore their implications for planetary interiors. By applying simple thermochemical models to carbon-rich silicate planets, we assess the fate of primordial organic matter and its role in shaping planetary outgassing. Our results suggest that planets forming beyond the soot line may retain substantial refractory organics, leading to methane- and nitrogen-rich atmospheres upon thermal evolution. Titan, an organic-rich moon with a subsurface ocean and a thick N_2–CH_4 atmosphere, serves as an analog for such exoplanets. Understanding the link between stellar composition, planetary interiors, and atmospheric evolution is crucial for identifying and characterizing carbon-rich exoplanets in the era of exoplanetology.