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System-level fractionation of carbon from disk and planetesimal processing

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Finding and characterizing extrasolar Earth analogs will rely on interpretation of the planetary system's environmental context. The total budget and fractionation between C–H–O species sensitively affect the climatic and geodynamic state of terrestrial worlds, but their main delivery channels are poorly constrained. We connect numerical models of volatile chemistry and pebble coagulation in the circumstellar disk with the internal compositional evolution of planetesimals during the primary accretion phase. Our simulations demonstrate that disk chemistry and degassing from planetesimals operate on comparable timescales and can fractionate the relative abundances of major water and carbon carriers by orders of magnitude. As a result, individual planetary systems with significant planetesimal processing display increased correlation in the volatile budget of planetary building blocks relative to no internal heating. Planetesimal processing in a subset of systems increases the variance of volatile contents across planetary systems. Our simulations thus suggest that exoplanetary atmospheric compositions may provide constraints on *when* a specific planet formed.