A Matter of Time: The Coupled Role of Stellar Abundances, Exoplanet Radiogenic Heat Budgets and Climatic Evolution

A planet's heat budget is a combination of the retained heat of formation, the energy released due to the gravitational segregation of a Fe core and decay of the long-lived radionuclides U, Th and ^{40}K. While secular cooling and the energy of core segregation are dependent on the formation history and magma ocean evolution, the amount of radiogenic heat a planet contains is solely a function of a planet's total amount of these elements. As refractory elements, U and Th are likely to exist in the same proportions relative to rock building elements in the planet as in the host-star. ^{40}K is moderately volatile, and a planet's abundance is dependent on the degree of processing during planet formation. Recent observations of Solar twins show a range of stellar Th abundances between 60 and 250% of the Sun's (Unterborn et al., 2015), with similar ranges expected for U and bulk K. If this range of radionuclide compositions is indicative of the range of exoplanet radiogenic heat budgets, the thermal and chemical evolution of these planets may be quite different from the Earth.

In this talk I will discuss the results of recent coupled climate and convection models for 1-6 Earth mass stagnant lid planet with probabilistically determined radiogenic heat budgets constrained by observationally-determined abundances of U, Th and K. These models allow us to estimate the rates of surface volcanism, CO_2 degassing from the interior and surface weathering processes. These models allow us to more realistically examine the short-, medium- and long-term climatic effects of varying radionuclide abundance given the different half-lives of the individual elements. An important output of our models is the lifetime of degassing across our parameter space. Using these degassing lifetimes, I will show that the habitable zone planets TRAPPIST-1 f and g are likely too old to be actively degassing today without additional tidal heating as an additional source of heat or the planets undergoing plate tectonics. Additionally, I will present a sample of observed rocky exoplanets both young and massive enough to be likely degassing today, making them prime targets in our search for planets with temperate climates. These results show the importance of estimating the age of a planetary system when assessing its likelihood to harbor Earth-like planets.