Exoplanetary Interiors from Stellar Exteriors

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Information about specific elemental abundances in protoplanetary (planet-forming) disks gives important insights into the planet formation process and critical constraints on the internal structure and composition of the planets. Protoplanetary disks with a short lifetime of only a few million years have long been dissipated around most of the known planets. Stellar atmospheres are thus the only possible observational sources for the relics of the protoplanetary disk chemistry.

Given their shared origin, the composition of planet-building materials is intricately linked to that of their parent stars, particularly for refractory elements. Notably, the relative abundances of refractory major rock-forming elements such as Fe, Mg, Si, obtained from stellar spectra, significantly enhance our ability to estimate the interiors of terrestrial planets. Moreover, stellar abundances of heat-producing radioelements are the only sources to estimate the radiogenic heat budget in rocky planets (K, Th, U, account for about 40% of Earth's present heat budget), which is critical to the assessment of their geological activity.

This project, under the UPFRONT initiative, leverages ultra-high-resolution spectra obtained by the ESPRESSO spectrograph to study solar-type stars hosting low-mass planets with precise mass and radius determinations. By employing state-of-the-art techniques for stellar composition analysis, the student will infer the interior composition and radiogenic heat budgets of these terrestrial planets. Such insights are invaluable in the context of large-scale spectroscopic and photometric planet search programs.

In addition to advancing our understanding of planetary interiors, this research has significant implications for astrobiology. By characterizing the composition and geological activity of terrestrial planets, it provides critical insights into their potential habitability and the search for life beyond our solar system.

Work plan

Tools

ARES - sousasag/ARES: ARES - Automatic Routine for line Equivalent widths in stellar Spectra (github.com)

MOOG - MOOG (utexas.edu)

References

From stars to planet building blocks:

Santos et al (2015) - Constraining planet structure from stellar chemistry: the cases of CoRoT-7, Kepler-10, and Kepler-93⋆⋆⋆ (aanda.org)

Santos et al (2017) - Constraining planet structure and composition from stellar chemistry: trends in different stellar populations | Astronomy & Astrophysics (A&A) (aanda.org)

Planetary compositions:

Dorn et al. (2015) - Can we constrain the interior structure of rocky exoplanets from mass and radius measurements? | Astronomy & Astrophysics (A&A) (aanda.org)

Star-planet:

Adibekyan e al. (2021) - A compositional link between rocky exoplanets and their host stars (science.org)

Plotnykov & Valencia (2020) - Chemical fingerprints of formation in rocky super-Earths' data | Monthly Notices of the Royal Astronomical Society | Oxford Academic (oup.com)