

Development of a New Retrieval Framework for Characterizing Magma Oceans on Sub-Neptunes

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With the advent of high-precision atmospheric spectroscopy using large telescopes such as JWST, we have entered a new era of detailed characterization of sub-Neptunes and close-in rocky planets. These observations are placing strong constraints on the atmospheric compositions of such planets. Beyond JWST, the upcoming space telescope Ariel: Atmospheric Remote-Sensing Infrared Exoplanet Large-Survey (ESA M4 Mission), scheduled for launch in 2029, will conduct a comprehensive survey of exoplanetary atmospheres across a wide wavelength range, covering planets from Jupiter-like gas giants to Earth-like terrestrial planets. This is expected to significantly advance our understanding of exoplanetary atmospheres. Furthermore, the observed atmospheric compositions are now being used to constrain planetary bulk compositions, which cannot be determined from mass and radius alone for sub-Neptunes, and to constrain the volatile content within potential rocky interior (e.g., Madhusudhan et al. 2023, Shorttle et al. 2024). Such investigations, extending beyond atmospheric studies to interior composition, will provide insights into planetary building materials and the diversity of sub-Neptunes. However, while retrieval methods currently allow for the quantitative constraint of atmospheric compositions by directly incorporating observational spectra, no established method yet exists for constraining interior compositions in a similar manner from atmospheric spectra.

In this study, we focus on sub-Neptunes with magma oceans on their surfaces and develop a retrieval framework that directly constrains the oxidation state and volatile content of the magma from atmospheric spectra. To achieve this, we construct a magma-atmosphere model that accounts for chemical equilibrium between the magma and atmosphere, as well as the solubility of volatile elements (H, C, O, N) in the magma. This model is then integrated with the publicly available retrieval code TauREx3 (Al-Refaie et al. 2019). In this presentation, we introduce the model framework of our retrieval method and present the results of performance tests.

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