The Astronomical Detection of Biosignatures on Extrasolar Terrestrial Planets: The Virtual Planetary Laboratory

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NASA and ESA are designing space-based observatories to detect and characterize extrasolar terrestrial planets. Because these systems will initially resolve planets only as point sources, we must learn to distinguish habitable worlds and to discriminate between planets with and without life based entirely on the interpretation of remote sensing observations of disk-averaged spectra. The Virtual Planetary Laboratory (VPL) is being developed to assess the information content of such observations and to optimize the designs and search strategies for future missions.

The VPL is a suite of computer models that simulates environmental processes that contribute to a planet’s spectrum. Its core consists of coupled radiative transfer, climate, and atmospheric chemistry models that have been validated in studies of the Earth and our neighboring planets. Geologic, biospheric, and exogenic modules are being added to simulate a broad range of environments on planets in orbit around stars with different luminosities and stellar types. A self-consistent description of these physical, chemical, and biological processes is essential for assessing the detectability of spectral biosignatures because these processes can conspire to exaggerate or mask discriminating spectral features.

Given initial conditions (stellar type, orbit characteristics, mass, radius, rotation rate, surface and atmospheric bulk composition, surface type, volatile inventory, etc.), the VPL marches forward in time to generate an equilibrium environment. It then produces a disk-averaged spectrum for a specified viewing geometry, processes this spectrum with an instrument simulator model, and analyzes it to assess the detectability of biosignatures with instruments like those being considered for NASA’s Terrestrial Planet Finder and ESA’s Darwin missions. Here, we review the objectives, scope, and architecture of the VPL, and summarize some preliminary results.

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