Detecting Storms on Extrasolar Giant Planets with Extremely Large Telescopes

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Abstract

Extremely large telescope (ELT) instruments with adaptive optics, high-contrast imaging, and high-resolution spectroscopy will enable the exploration of directly-imaged exoplanet atmospheric dynamics and chemistry. The European Southern Observatory's Mid-infrared ELT Imager and Spectrograph (ELT/METIS) and the Thirty Meter Telescope's Multi-Objective Diffraction-limited High-resolution Infrared Spectrograph (TMT/MODHIS) offer the spectral resolution and signal-to-noise (S/N) necessary to Doppler image planetary atmospheres based on temporal spectral variations due to surface inhomogeneities. Using our publicly-available code, Imber, developed and validated in Plummer & Wang (2022), we evaluate these instruments' abilities to identify and study dynamic and enduring atmospheric features on extrasolar giant planets in the Beta Pic and HR 8799 systems. We find both ELT/METIS and TMT/MODHIS are suitable for Doppler imaging Beta Pic b over a single rotation. The HR 8799 planets require multiple-integrated rotations to constrain spot parameters. We compare the spectroscopic technique against photometry-exclusive inference and find that combining spectroscopic and photometric observations leads to improved Bayesian inference of surface inhomogeneities and offers insight into whether planetary atmospheres are dominated by spotted or banded features.

Keywords: Direct Imaging, Exoplanets, Exoplanetary Atmospheres, Extremely Large Telescopes, Infrared, High Contrast Imaging, Adaptive Optics

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