While thousands of transiting exoplanets have been discovered to date, relatively little is known about their atmospheric properties and compositions. The main limitation in characterizing a planet's atmosphere lies in the extreme difference in brightness between the planet and its host star, typically preventing direct atmospheric emission from being resolved. However, recent progress in the field has made use of transmission spectroscopy during transits, when the light from the host star passes through the exoplanet's atmosphere and allows for the detection of any atomic or molecular species present. This technique was first used by Charbonneau et al. [1] to provide evidence for atmospheric sodium, marking the first detection of an atmosphere around a planet outside our solar system. Notable contributions since this initial discovery include detections of other chemical elements, as well as organic molecules, water vapour, and atmospheric hazes (e.g. [11], [9], [10], [7]). Despite a great deal of progress in the study of exoplanetary atmospheres, however, transmission spectroscopy has to date almost exclusively targeted high-mass "hot Jupiters"—Jupiter-mass planets with orbital periods shorter than 10 days—at low spectral resolution.

In this research project, we will use transmission spectroscopy and other innovative methods to probe the atmosphere of HAT-P-12b, a sub-Saturn mass transiting exoplanet first discovered in 2009 [3]. As a candidate for atmospheric research and characterization, HAT-P-12b is of particular interest. It is representative of an unexplored region of parameter-space, with a mass and temperature (~ 0.2 M_J and ~ 950 K respectively; [3]) lower than those of almost all exoplanets that have had their transmission spectra observed at high spectral resolution. Furthermore, the planet is considerably inflated, with a large atmospheric scale-height that will result in extremely high variations in the transit depth [5], greatly increasing our ability to make an atmospheric detection. HAT-P-12b is thus the ideal candidate for extending transmission spectroscopy techniques to lower-mass planets, and the high-resolution data we have obtained from the High Dispersion Spectrograph [6] on the *Subaru Telescope*—higher resolution than any previous observations of this planet—are undoubtedly rife with undiscovered atmospheric properties and features.

Various low-resolution efforts to study the atmosphere of HAT-P-12b have resulted in discoveries that will guide our analysis. For example, Line et al. [4] used low-resolution data from the *Hubble Space Telescope* to show a lack of expected water absorption features in the planet's atmosphere, and Sing et al. [7] used similar data to find evidence of atmospheric potassium. Our high-resolution optical observations will allow for an unparalleled look at the atmosphere of HAT-P-12b, revealing atmospheric features that have to date remained undiscovered or unconfirmed due to the lack of sufficiently-detailed spectra. The primary objective of this project will be to confirm the presence of potassium and sodium in the planet's atmosphere, which will provide information on the temperature structure of the planet's atmosphere as well as determine the pressure level of any clouds or hazes present. This will be accomplished by integrating the atmospheric flux over wavelengths of interest as in Snellen et al. [8] and developing novel techniques for removing intervening signal from the Earth's atmosphere. We will then use an advanced Doppler cross-correlation technique explored in Snellen et al. [9] and Esteves et al. [2] to search for atmospheric water vapour. In addition to confirming the detections made by Line et al. [4], Sing et al. [7], and others, we also hope to uncover previously-unresolved properties of the exoplanetary atmosphere.

This work will also serve as an important stepping-stone between constraining atmospheric properties of giant planets and in-depth, detailed analyses of Earth-like atmospheres on planets similar to our own. The techniques developed during this project to target the atmosphere of HAT-P-12b will have a direct application in the study of Earth-mass exoplanets, as smaller planets result in weaker signals and thus require much higher-resolution observations for atmospheric features to be detected. The process of analyzing the transmission spectra of HAT-P-12b—smaller than any other hot Jupiter for which ground-based transmission spectroscopy has been used—demands for innovative techniques that can be applied to even smaller Earth-mass planets in the future. Where only 15 years ago astronomers were just detecting an extrasolar atmosphere for the first time, we are now poised to observe, in great detail, exoplanetary atmospheres similar to our own—and this work provides one of the first steps in making such discoveries a reality.

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