Ground-based transmission spectroscopy of TRAPPIST-1g

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Measuring the compositions of planetary atmospheres is important for understanding planetary formation, evolution, and habitability. The TRAPPIST-1 system, which has seven Earth-sized planets orbiting an M-dwarf, provides an exceptional opportunity for the atmospheric characterization of temperate Earth-sized exoplanets (Gillon et al. 2017). Based on previous studies using the Hubble Space Telescope (de Wit et al. 2018), most of the TRAPPIST-1 planets seem not to have clear H2/He-dominated atmospheres. However for TRAPPIST-1g, the largest planet in the system, the result was not conclusive in the observed wavelengths (1.1-1.7um). In addition, the effect of stellar surface inhomogeneity on the transmission spectra has recently begun to be considered (Rackham et al. 2017). With this effect, the planetary transmission spectra can be considerably distorted, especially in the optical wavelength range. To study the atmosphere of TRAPPIST-1g, we observed a TRAPPIST-1g transit event on the night of UT 2017 September 2 simultaneously with the Gemini Telescope / Gemini Multi-Object Spectrographs (GMOS) at 600nm and the Subaru Telescope / Multi-object infrared camera and spectrograph (MOIRCS) at 1300-2300nm. The observed wavelength range is useful to constrain the planet's atmosphere because it covers strong methane absorption lines around 2300nm and signatures of Rayleigh scattering in the optical wavelength range.

We jointly model the light curve as the combination of a transit and a Gaussian Process. We fit the 14 light curves in each wavelength bin simultaneously and estimate the model parameters using Markov Chain Monte Carlo. The resultant transit depths are consistent with the results of other telescopes, although the derived transit depths have uncertainties that are too large to distinguish between different atmospheric models. However, our results are important to constrain the stellar surface model of TRAPPIST-1. We compare the validity of several stellar surface models obtained from previous studies and three different atmospheric models. The derived relatively flat transmission spectrum can rule out the existence of large hot spots on the surface of TRAPPIST-1. We find that it is important to observe transmission spectra simultaneously in a wide wavelength range to constrain stellar models prior to conducting intensive planetary atmosphere studies using next-generation large telescopes.

Keywords: TRAPPIST-1, Atmosphere, Spectroscopy, Observation, Habitable Planets