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Transmission spectrum models of low-mass exoplanet atmospheres with haze: Application to GJ 3470b

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Since the first exoplanet was discovered in 1995, detection of more than 1000 exoplanets has been reported. Recently, transit observations of an exoplanet have been done at multiple wavelengths. From a decline in apparent stellar brightness due to a planetary transit, we can measure the plantary radius. In addition, observed dependence of the planetary radius on wavelength (which is often called the transimission spectrum) provides the information of absorption and scattering by molecules and small particles such as haze and clouds in the planetary atmosphere. Thus, the composition of the planetary atmosphere can be constrained by comparison between the observational and theoretical transmission spectra. The constraint on atmospheric composition gives an important clue to the origin of the planet.

Our observational group has recently observed transits of two low-mass exoplanets, GJ 3470b and GJ 1214b, at multiple wavelengths. For both planets, the observed transit radii in the optical wavelength region are greater than those in the near-infrared region, inferring the existence of haze in the atmosphere. While the observed transmission spectrum was already analysed theoretically in detail as for GJ 1214b, there are few researches discussing the theoretical spectrum models incorporating the effect of haze systematically for GJ 3470b. In this study, we have modeled theoretical transmission spectra of low-mass exoplanets orbiting close to their host stars. Then, applying the calculated spectrum models to GJ 3470b and GJ 1214b, we discuss the property of the atmospheres of both planets.

In calculating theoretical spectrum models, we have taken into account the vertical distribution of molecular abundances from the chemical equilibrium calculations, in addition to absorption and scattering of the incident radiation from the host star by molecules and haze particles in the planetary atmosphere. We explore the dependences of the atmosphere's metallicity, C/O ratio and water vapor abundances on the transmission spectrum. We also probe the dependences of haze's height, particle sizes and number density. In comparing the observed and theoretical transmission spectra, we have performed the chi-squared analysis to quantify the validity of each atmospheric model.

Keywords: exoplanets, transits, transmission spectrum models, atmospheric composition, haze