Possible origin of diverse transmission spectra of warm transiting exoplanets: Growth and settling of atmospheric haze produced via UV irradiation

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Since the first exoplanet was discovered in 1995, detection of more than 3000 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 planetary radius. In addition, observed dependence of the planetary radius on wavelength (which is often called the transmission 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.

Some of the recent observations, detected steep Rayleigh slope features in the visible and/or featureless spectra in the near-infrared, inferring the existence of haze in the atmospheres, which prevents us from probing the atmospheric molecular composition. Also, the transmission spectra are somewhat diverse: Some contain the Rayleigh slope features in the visible, some show molecular and atomic features. While a few studies addressed theoretical modeling of transmission spectra of hydrogen/helium-dominated atmospheres with the effect of hydrocarbon haze, they did not necessarily use physically-based values of the haze layer parameters (namely, the size and number density of haze particles and the altitude and thickness of the haze layer).

In this study, to derive the physically-based distribution of haze particles, we develop a theoretical model for the creation, growth, and settling of hydrocarbon haze particles in hydrogen/helium-dominated atmospheres of close-in warm (< 1000 K) exoplanets. Also, with obtained properties of haze, we model transmission spectra of the atmospheres to explore whether the recently-observed diversity of transmission spectra can be explained by the variation in the production rate of haze monomers. We find that the haze tends to spread in a wider region than previously thought and consists of particles of various sizes. We also find that the observed diversity of transmission spectra can be explained by the difference in the production rate of haze monomers, which may relate to the strength of UV irradiation from the host stars.

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