On the origin of extremely low-density exoplanets

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Kepler mission have discovered several exoplanets whose bulk densities are anomalously low. Those low-density exoplanets, called super-puffs, often show featureless transmission spectra at near-infrared wavelength, and their origins are under active debate. Recent studies proposed two promissing explanations for the anomalously low planetary density, namely, atmospheric aerosols and circumplanetary rings. In this study, we examine how each scenario affect the transit radius at different planetary properties. We first investigate aerosols formation in escaping atmospheres and its impacts on transit observations using a microphysical model. We find that aerosols formed at upper atmospheres, such as photochemical hazes, are necessary to enlarge the transit radius. With sufficiently high production rates, the outflowing hazes can explain both large transit radius and featureless transmission spectra of super-puffs. On the other hand, using an interior structure model, we find that the radius inflation by outflowing hazes can work only at relatively low planetary masses, say $< 5\ M_{Earth}$. The limitted mass range is owing to the small scale height to planetary radius ratio at massive exoplanets. To assess the another possibility by circumplanetary ring, we establish a new transmission spectrum model including ring opacity. We find that ring can also explain both large transit radius and featureless near-infrared spectrum, implying a possibility to complementary explain super-puffs with high planetary masses. We also reveal that the rings and aerosols produce noticeable differences at mid-infrared spectrum. Our results suggest that future observations by JWST and ARIEL will be able to distinguish whether ring or aerosols are the origin of super-puffs.

Keywords: Exoplanet, Atmosphere, Aerosol, Ring, Transmission spectroscopy

