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Mass-loss rate constraints on the observed distribution of exoplanets

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Abstract

Atmospheric escape is a key factor shaping the known exoplanet population, determining their composition and size, among other properties. Here, we present a uniform analysis of the atmospheric escape rate of Neptune-like planets with known radius and mass. For each planet we characterize their mass-loss rate by computing the Jeans escape parameter (Λ), for a hydrogen atom evaluated at the planetary mass, radius, and equilibrium temperature. Values of $\Lambda \lesssim 20$ suggest extremely high mass-loss rates. For a sample of 170 Neptunes, we select the planets with high escape rates to further estimate their mass-loss rates ($L_{\rm hy}$) with tailored atmospheric hydrodynamic models.

We find that nearly 15% of the planets exhibit extremely high mass-loss rates ($L_{\rm hy} > 0.1\,M_{\oplus}{\rm Gyr}^{-1}$), which defy evolution and composition models of their atmospheres. On one hand, these mass-loss rates should deplete the planetary atmospheres from their hydrogen content within the first Gyr. On the other hand, the observed mass and radius lead to low densities, requiring a significant hydrogen envelope fraction.

To solve this contradiction, we hypothesize that these planets are not truly under such high mass-loss rates. Instead, either hydrodynamic models overestimate the mass-loss rates, transit-timing-variation measurements underestimate the planetary masses, optical transit observations overestimate the planetary radii (due to high-altitude clouds), or Neptunes have consistently higher albedos than Jupiter planets. We conclude that at least one of these established estimations/techniques is consistently producing biased values for Neptune planets. Such an important fraction of exoplanets with misinterpreted parameters can significantly bias our view of populations studies.