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Unveiling the Nature of Close-In Neptune Planets: Insights from a Homogeneous Planetary Sample

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Using a homogeneous analysis approach, we present a comprehensive study of close-in Neptune-sized planets. We compile a well-defined sample of TESS-observed planets, ranked based on their orbital period, radius, and the visual magnitude of their host stars. To ensure precise radial velocity measurements, we incorporate archival and new HARPS data, resulting in a final sample of 64 targets—46 confirmed planets and 18 with no significant radial velocity signals. Our analysis explores key planetary and stellar properties, including the mass-radius distribution, planetary density, host star metallicity, and the presence of stellar and planetary companions. Notably, we find that 26% of our sample belongs to multi-planet systems, primarily located near the lower boundary of the Neptunian desert. Focusing on a subset of 33 confirmed planets with radii between $2R_{\oplus}$ and $10R_{\oplus}$, we calculate envelope mass fractions (EMFs) using the GAS gianT modeL for Interiors (GASTLI). Our results reveal a striking division in EMFs based on equilibrium temperature: planets with temperatures above 1300 K (or orbital periods shorter than ˜3.5 days) exhibit near-zero EMFs, while those beyond this threshold typically have EMFs between 20% and 40%, scaling linearly with planetary mass. Intriguingly, this orbital period boundary aligns with the transition from the Neptunian desert to the recently identified Neptunian ridge, suggesting distinct formation or evolutionary processes at play. These findings provide new insights into the nature of close-in Neptune-sized planets and their atmospheric evolution, offering a fresh perspective on the underlying mechanisms shaping their distribution.

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