Probing the Cores of Puffy Planets Using their Orbital Periods

Tim Hallatt is a PhD student working with Prof. Eve J. Lee, a William Dawson Scholar and Assistant Professor in the Department of Physics.

At its most basic level, a planet can be described as a solid rock enveloped by a gaseous atmosphere. The size of a planet is determined by how thick its atmosphere is, which in turn is determined by how massive the planet's rocky core is. The core mass plays a key role in whether the planet emerges as a small gas-poor planet or a large gas-rich planet. However, the core mass is not directly measurable.

A new study led by PhD student Tim Hallatt and Prof. Eve Lee proposes a novel solution to the problem of measuring the core mass using orbital periods. Lee and Hallatt leveraged the distribution of planets' orbital periods to infer the overall core masses of a particular exoplanet population called Sub-Saturns. Sub-Saturns, planets that are about 4-8 Earth radii, are the failed Jupiters whose solid and gas masses are about equal. This makes them ideal targets for probing the origin of the boundary between gas-poor and gas-rich planets.

Lee and Hallatt demonstrate that the decrease in the prevalence of Sub-Saturns towards smaller orbital periods is a result of rapid atmospheric erosion, which shrinks their radii and transforms them into smaller worlds more efficiently at shorter orbital periods. Massive planets are able to hold on to their envelopes more tightly. Therefore, the relative rarity of Sub-Saturns at shorter periods can be translated directly into the likely distribution of core masses these planets inherited from planet formation, giving us an insight into the required conditions for the creation of gas-rich planets.

Additionally, the new study proposes that several super-puffs (a rare type of planets so "puffy" that their densities are equivalent to that of cotton candy) in our Galaxy are presently undergoing rapid mass loss. This prospect opens avenues for further theoretical and observational tests.

Citation: "Sculpting the Sub-Saturn Occurrence Rate via Atmospheric Mass Loss", Hallatt, T. & Lee, E.J. (2022) ApJ, Vol 924, Issue 1, 15 pp.

Left: Artistic conception of a hot Jupiter with an evaporating atmosphere (credit: NASA / Ames /

Why is this important?

Planetary core masses are a key parameter that determines whether a planet becomes gas-poor or gas-rich, but they cannot be measured directly. This study offers a simple yet novel way to infer the core masses of Sub-Saturns from their orbital periods, revealing the origin of these unique types of planets that had the potential to become gas giants but failed to do so.