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Exploring the transition between Ice and Gas giant exoplanets from TESS

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Abstract

The transitions between ice-giant and gas-giant exoplanets; between volatile-rich and volatile-poor high-mass planets, is not well understood. Many of the known exoplanets that fall within this parameter space either have no measured mass (most Kepler discoveries) or no measured radii (most RV survey discoveries). The Transiting Exoplanet Survey Satellite (TESS) mission will change this landscape completely. TESS has since September 2018 successfully delivered more than 500 exoplanet candidates around bright stars, of which ~ 50 are intermediate sized.

We are targeting exoplanets ranging from Neptune- to Saturn like radii ($4 - 10\ \mathrm{R_{earth}}$) with the the high resolution spectrograph CORALIE on the Swiss telescope in La Silla Observatory, Chile. These measurements are used to calculate the bulk density and internal structure of these rare objects, allowing us to asses the formation processes. We are furthermore providing prime targets for atmospheric characterisation, which will constrain the composition even further.

Introduction

The known population of giant exoplanets ($R > 4\ \mathrm{R_{earth}}$) is diverse in bulk density, which is a reflection of formation and evolution history. Both ice and gas giants are thought to form through some flavor of core-accretion [2], where gas, pebbles and/or planetesimals accrete onto an icy or rocky core. The resulting bulk density will be dictated by the final composition and core-mass-fraction - which in turn depends on the formation location, incident stellar flux, disk environment, and other factors. Thus, determining a giant planet's preset-day composition through precise radius and mass characterisation [1] allows us to assess its formation process. Evolutionary effects such as photo-evaporation and migration after formation should also be taken into account, as the host star can strip the planet of its atmosphere, or inflate it.

Despite being key to understanding exoplanet formation, only a few ice and low-mass gas giants have precise mass measurements. From K2 and Kepler, mainly Super-Earths and sub-Neptunes which are the most abundant planets, have been mass-characterised. To this date a mere 23 planets with $R = 4 - 10\ \mathrm{R_{earth}}$ have masses determined to a precision of 20% or better with radial velocities (RVs), as show in in Figure 1.

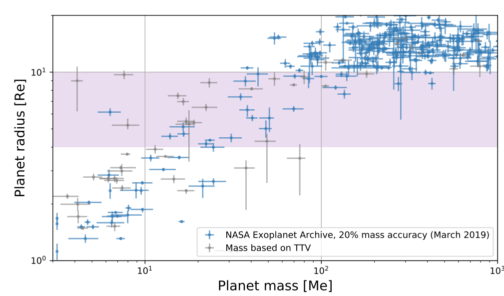

Figure 1: Radius-mass diagram for exoplanets that have massed determined to 20 % accuracy or better from the NASA Exoplanet Archive as per March 2019. The parameter space of intermediate sized giant planets with radii between 4 and 10 $\mathrm{R_{earth}}$ targeted in this proposal is highlighted in purple. It is evident that this population is poorly constrained in terms of density.

TESS and RV followup

The primary goal of the TESS mission is to measuring the massed and radii of 50 planets with $R < 4\ \mathrm{R_{earth}}$, but we are also finding a multitude of giant planets. In sectors 1 through 7, more than 100 Neptune- and Saturn-like planet candidates around relatively bright stars have been identified. We aim to derive precise masses for at least 10 planets with radii $4 - 10\ \mathrm{R_{earth}}$ during the first year of the TESS mission, and more in coming semesters. This will increase the number of well-characterised planets in this parameter-range by $\sim 50\%$ and thus enabling population studies to constrain and test formation scenarios.

We will probe the low-mass portion of the ice- and gas- giants found by TESS with HARPS on the ESO 3.6 m telescope in La Silla observatory. In parallel we will perform mass-determination of the more massive TESS candidates using the high resolution spectrograph CORALIE on the Swiss 1.2 m Euler telescope in La Silla. Combining the results from both instruments, will provide a global view of the transition between ice and gas giants.

The Neptune desert and atmospheric characterisation

The Neptune desert described by citeMazeh puts upper and lower limits on how close Neptunian planets are observed to be to their host stars. The parameter space we propose to probe will help constrain the upper boundary of the Neptune desert. This is believed to be linked to planet migration: either giant planets migrating in can cross a line beyond which the planets cannot exist, or the disk is truncated inwards, exerting less drag on the planets close in and effectively stopping migration. Neptune- and Saturn-like transiting planets with periods longer than 10 days are rare, and will therefore also be of special interest to us.

Many the targets in our sample will be prime targets for atmospheric characterization by the next generation of instruments, including ESPRESSO, NIRPS, JWST and subsequently the E-ELT. Having precise planetary masses is imperative for successful modelling of exoplanet atmospheres and subsequent extraction of transmission- and emission spectra [5], [6]. Providing suitable targets for atmospheric characterisation with well-constrained masses is imperative in order to constrain bulk and atmospheric compositions. These quantities are also linked to solving the puzzle of planet formation scenarios, as gas giants have primordial atmospheres.

References

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