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Attempting rapid exoplanets' classification with neural networks

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Abstract

Despite the number of confirmed exoplanets currently exceeds 3500, for only few hundreds of them both mass and radius have been determined (e.g., https://exoplanetarchive.ipac.caltech.edu). For these objects the mean density can be calculated to obtain a first handle on the interior structure. However, inferring the interior structure from just mass and radius is a highly non-unique problem (e.g., [1]). The forthcoming space-based telescopes TESS, CHEOPS, and PLATO will provide accurate determination of the radii of thousands of exoplanets (e.g., [2]). These improved instrumental capabilities along with the increasing temporal baseline of exoplanetary orbits' observations may also allow the inference of the fluid Love number k_2 (e.g., [3]), a parameter that depends on the concentration of matter in the interior and is akin to the moment of inertia (e.g., [4]). Exoplanetary masses will be determined through follow-up campaigns using ground-based telescopes. In the best case scenario, three constraints–mass, radius, and k_2–will be available to investigate the interior structure of exoplanets.

The goal of this work is to understand whether from the determination of the radius and k_2 only, it will possible to classify an exoplanet–e.g., earth-like versus neptune-like–and if any bounds on its mass can be placed in advance of follow-up campaigns that will determine its mass from radial velocity. We test this hypothesis using a neural network approach. We build a large (in excess of 10^5) set of interior structure models in the mass range between 1 and 20 earth masses, where the super-Earth and mini-Neptune classes overlap. The parameters entering the model (i.e., total mass, core mass fraction, silicate reference densities, water/ice mass fraction, etc.) represent the inputs for the forward model, while the resulting radius and k_2 represent the outputs. Since the forward problem is only mildly non-linear, we will use neural network architectures with one or two hidden layers with three to five neurons each. We will adopt the common training, validation, and test split of the data (in proportion 80:10:10).

If this approach at planets' classification proves successful, it will be possible to rapidly draw preliminary inferences on an exoplanet's interior in advance of mass determinations from follow-up radial velocity campaigns.

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References

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