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The next generation planetary population synthesis - Stellar mass influence

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Abstract

We present a new set of planetary population syntheses with the updated *Bern* model. In particular, changes to the collisonal treatment, stellar evolution and disk photoevaporation can shape the resulting population. The influence of the stellar mass is studied and the distribution of resulting planets presented. A comparison with key systems – such as the solar system or the TRAPPIST-1 system – is possible thanks to the multiple stellar masses.

1 Introduction

The planetary population synthesis framework helps understanding the interactions between the mechanisms at play during planet formation and allows for comparison with the observed population of planets [4, 5].

The extension of this model to lower mass stars is a natural choice given the same shift in observational work. Ground based radial velocity surveys such as *NIRPS* [8] or *CARMENES* [9] focus on M-stars and also the space-borne *TESS* is more sensitive to M-dwarfs than its predecessor *Kepler*. Additionally, more discoveries can be expected from the upcoming SAINT-EX [10] project, the follow-up of TRAPPIST, which was responsible for the discovery of the TRAPPIST-1 system [11].

2 Model

In the past years the models of Alibert, 2013 [1] – taking into account the N-body interactions between multiple growing embryos – and Mordasini, 2012 [2, 3] – calculating the long-term evolution of the planets – were merged and now mechanisms were added. Amongst the improvements to the model (often called the *Bern* model) are: a new N-body integrator (*Mercury*) allowing for up to 100 growing embryos per disk, an evolving star [6], a more realistic collision detection and the subsequent handling of the collisional energy, and a new disk model with a state of the art internal X-ray photo-evaporation model [7].

To account for the drift of small bodies, we use a power-law slope for the initial planetesimal disk of -1.5, which is steeper than the typical slope for the gas disk of -0.9. The previous arbitrary Monte Carlo variable called M_{wind} is replaced by the observed X-ray luminosity of young stars L_X [12]. All the initial conditions have to be adapted to the lower stellar mass. For the disk's mass [13] and radius [14] sub-millimeter thermal emission helps to constrain possible scaling laws, even though the uncertainty increases with decreasing stellar mass.

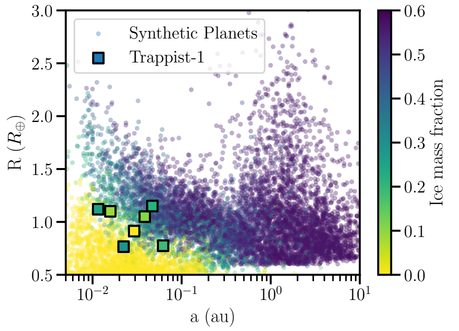

Figure 1: Semi-major axis vs radius diagram of a preliminary population of synthetic planets around a 0.1 $M_\odot$ star. The color code represents the mass fraction of ice and the observational data for the TRAPPIST-1 system is taken from [15] and [16].

3 Results and Discussion

For very low mass stars with a mass of 0.1 $M_\odot$, planets with masses above 1 $M_\oplus$ are rare. Planets tend to form in resonant chains, preventing migration to the inner edge of the disk (which is abundant in single-embryo simulations). For 0.5 $M_\odot$ stars, the picture is similar, but the typical mass is shifted to super-earth masses.

Giant planets are getting less abundant when going from stellar mass to lower mass stars. This results in different dynamical configurations.

The individual planets of the TRAPPIST-1 system lie in the bulk of synthetic planets in terms of semi-major axis and mass or radius (see Fig. 1). However, reproducing an analogue system remains challenging.

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