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Prospects for detecting decreasing exoplanet frequency with main-sequence age using PLATO

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Abstract

The space mission PLATO will usher in a new era of exoplanetary science by expanding our current inventory of transiting systems and constraining host star ages, which are currently highly uncertain. This capability might allow PLATO to detect changes in planetary system architecture with time, particularly because planetary scattering due to Lagrange instability may be triggered long after the system was formed. Here, we utilize previously published instability time-scale prescriptions to determine PLATO's capability to detect a trend of decreasing planet frequency with age for systems with equal-mass planets. For two-planet systems, our results demonstrate that PLATO may detect a trend for planet masses which are at least as massive as super-Earths. For systems with three or more planets, we link in [2] their initial compactness to potentially detectable frequency trends in order to aid future investigations when these populations will be better characterized.

1. Introduction

Nearly all exoplanets orbit stars whose ages are poorly constrained. This situation is unfortunate because the potential to learn about the dynamical evolution of planetary systems through the host star's evolution has yet to be realized. Accurate stellar ages may provide key constraints and insights on the formation and fate of planets.

The PLATO space mission [1], due for launch in 2024, will help provide tight age constraints. One of the main aims of PLATO is to achieve 10 per cent precision in the age of 20 000 main-sequence stars of spectral types F5-K7. In order to achieve this goal, PLATO will produce internal stellar mass distributions for different stars by combining radius measurements derived from Gaia data with the oscillation frequencies observed in the PLATO light curves.

Other techniques which will be used to derive stellar ages, such as gyrochronology, will be assessed and calibrated from this 'primary' sample and then applied to the hundreds of thousands of main-sequence stars that PLATO will observe during the course of its 6 yr mission (albeit at a lower age precision). Moreover, PLATO will, for the primary sample, allow for direct testing of stellar evolution tracks.

Such a large sample will enable us to detect trends in exoplanetary science that remain currently hidden in the noise. One of these trends is frequency of planets versus main-sequence age. Not all systems with multiple planets will remain stable over their main-sequence lifetimes. Overall, the frequency of planets might decrease with time. In [1], we combine stability prescriptions from previous investigations with the detection capabilities of the PLATO mission.

2. Figures

We consider both two-planet systems and three-planet systems which are "packed", such that no additional planets could fit between them in a stable manner.

Figure 1 illustrates the minimum planet masses for which PLATO will be able to detect a trend of decreasing planet frequency with main-sequence age, provided that PLATO can discover enough planets at these given masses to build up a large-enough sample.

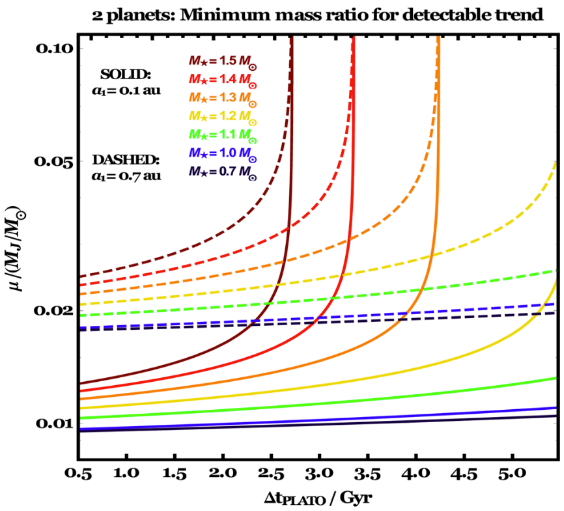

Figure 1: The minimum planet–star mass ratio μ for which PLATO can detect a decreasing trend of planet frequency versus time for packed, Hill-stable two-planet systems. The *x*-axis refers to the (variable) magnitude of the stellar age constraints PLATO may provide.

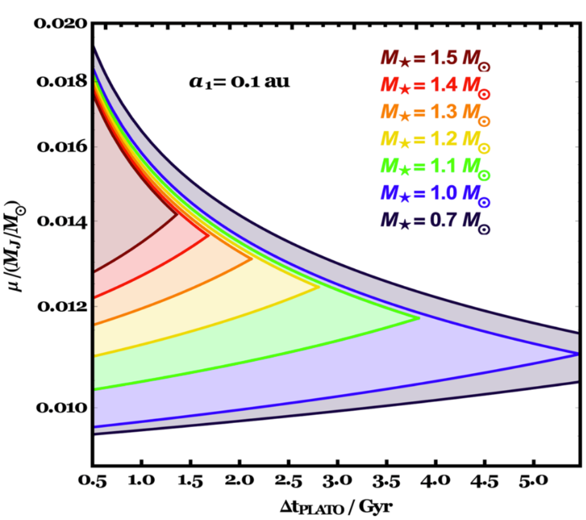

Figure 2: Same as Figure 1, but with the important first time bin excluded. If ages are constrained to within 1 Gyr, then a trend should be detectable for planets at least as massive as 10^{-2} Jupiter masses.

3. Conclusions

Compared to previous experiments, the PLATO space mission will significantly improve robust stellar age estimates by developing separate internal mass distributions for thousands of individual stars. Consequently, PLATO will unveil currently undetectable trends in planetary systems. In this work, we demonstrated one such potential trend: decreasing planetary frequency with main-sequence age for marginally unstable equal-mass multiplanet systems. For two- planet systems, this trend could be most secure for planetary masses which are of the order of 10 Earth masses, well within PLATO's planet detection capabilities. Detection of this trend could also help constrain formation mechanisms and test the theory that tightly packed inner planets were more prevalent in the initial stages of the lifetime of planetary systems.

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References

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