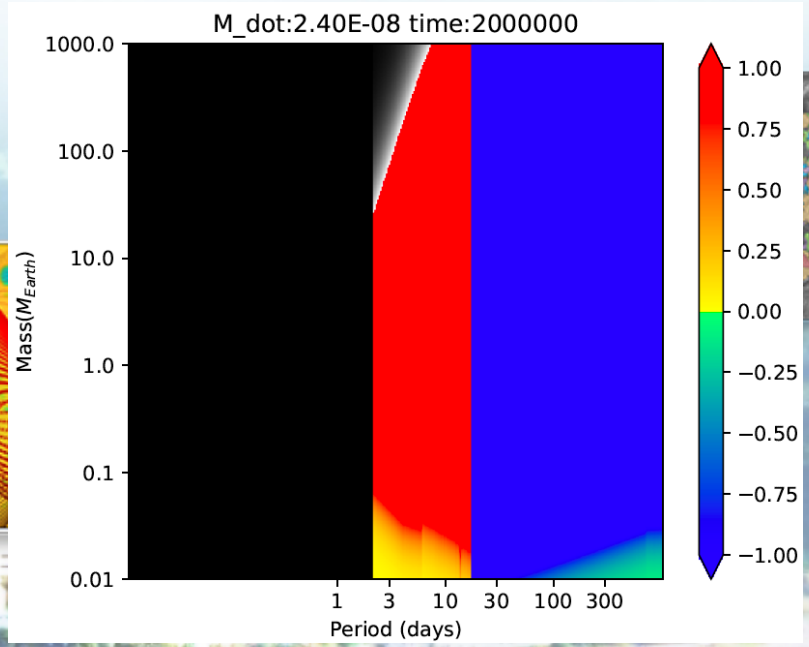
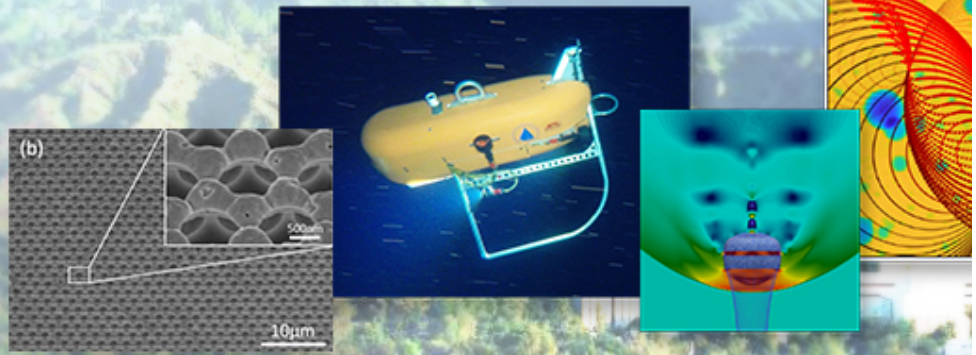
RPC 2020





Virtual Research Presentation Conference

Building a New Planet Formation Model for Characterizing Habitable Rocky Planets

Principal Investigator: Yasuhiro Hasegawa (3262)
Co-Is: Brad Hansen (UCLA), Tze Yeung (Mathew) Yu (UCLA)
Program: SURP

Assigned Presentation #: RPC-017

Jet Propulsion Laboratory
California Institute of Technology

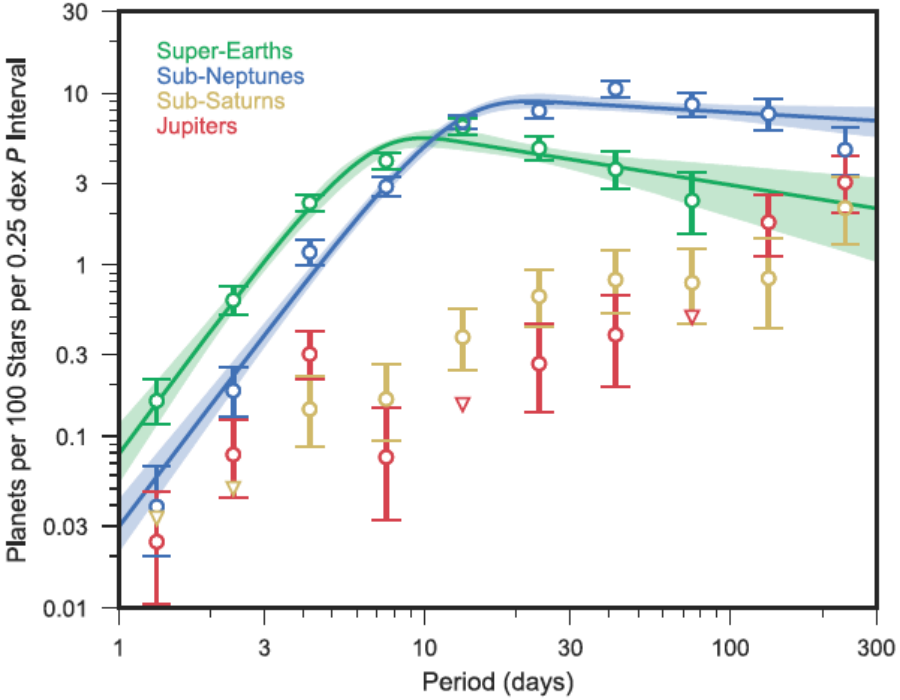
Tutorial Introduction

Abstract

Ever since the first discovery of an exoplanet around a sun-like star in 1995, more than 4000 exoplanets have been detected so far

NASA Kepler mission revealed that close-in super-Earths and sub-Neptunes are dominant in the observed exoplanet population. These two populations show intriguing occurrence rate distributions

The formation and orbital evolution mechanisms of these planets are imperfectly understood because there is no such an analogue in the solar system



Petigura et al 2018

Problem Description

Context:

Understanding the origin of close-in super-Earths and sub-Neptune is fundamental in astrophysics and planetary science today

SOA (Comparison or advancement over current state-of-the-art):

Previous studies attempted to reproduce the population by artificially imposing truncation of disks at their inner edge due to stellar magnetic fields and by trapping planets that undergo planetary migration.

However, the artificial treatment of disk truncation should be examined by a more detailed model.

We developed such a more realistic model, by incorporating the radial diffusion of stellar magnetic fields into protoplanetary disks and directly taking into account its effect on disk properties

Relevance to NASA and JPL (Impact on current or future programs):

This work provided novel insights about the formation of close-in super-Earths and sub-Neptunes by tightly constraining the role of stellar magnetic fields. This finding is useful for developing new interpretations on upcoming observations done by TESS, JWST, and WFIRST. These efforts therefore act as an inevitable stepping stone for systematically characterizing small-sized exoplanets and eventually identifying habitable planets. Thus, our efforts are fully relevant to NASA and JPL

Methodology

Formulation, theory or experiment description:

Combine the **N-body code**, Mercury (Chambers 1999), with the **torque formula** (Paardekooper et al. 2011) and **a new disk model**

In the new disk model, stellar magnetic fields, viscous heating, and stellar irradiations are all taken into account

Disk properties (the surface density and disk temperature) are self-consistently computed

Innovation, advancement:

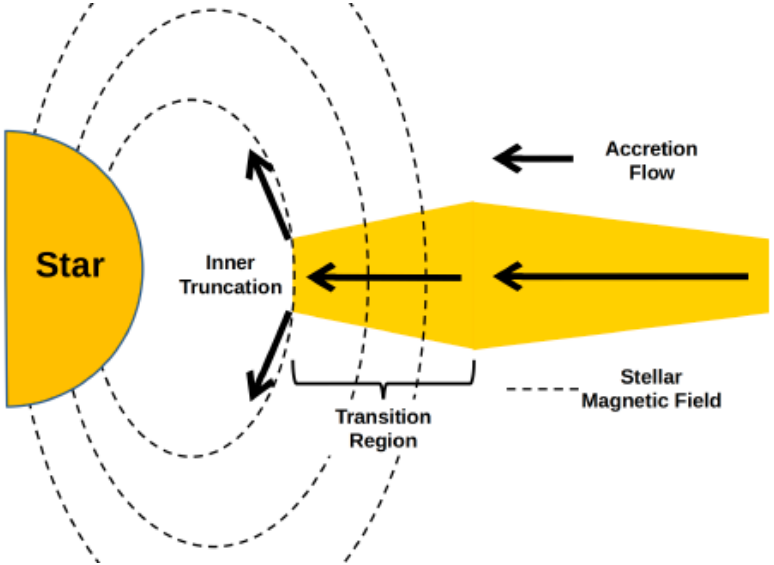
The disk inner edge region is divided into three components;

Inner truncation: determined by the balance between the magnetic pressure and the ram pressure of the accreted disk gas

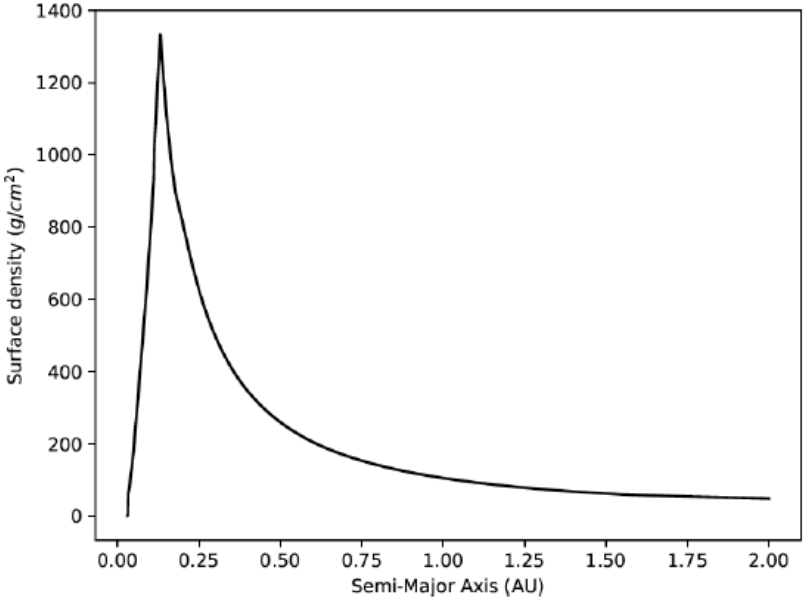
Transition zone: stellar magnetic fields determine disk properties

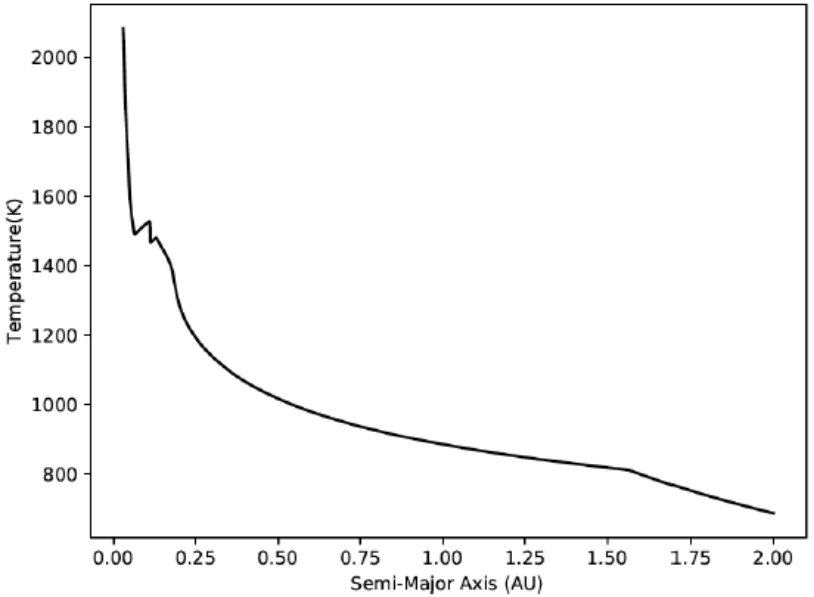
Outer disk: similar to the standard disk model

The properties of the transition zone determine the orbital distribution of close-in super-Earths and sub-Neptunes



Results: Disk properties

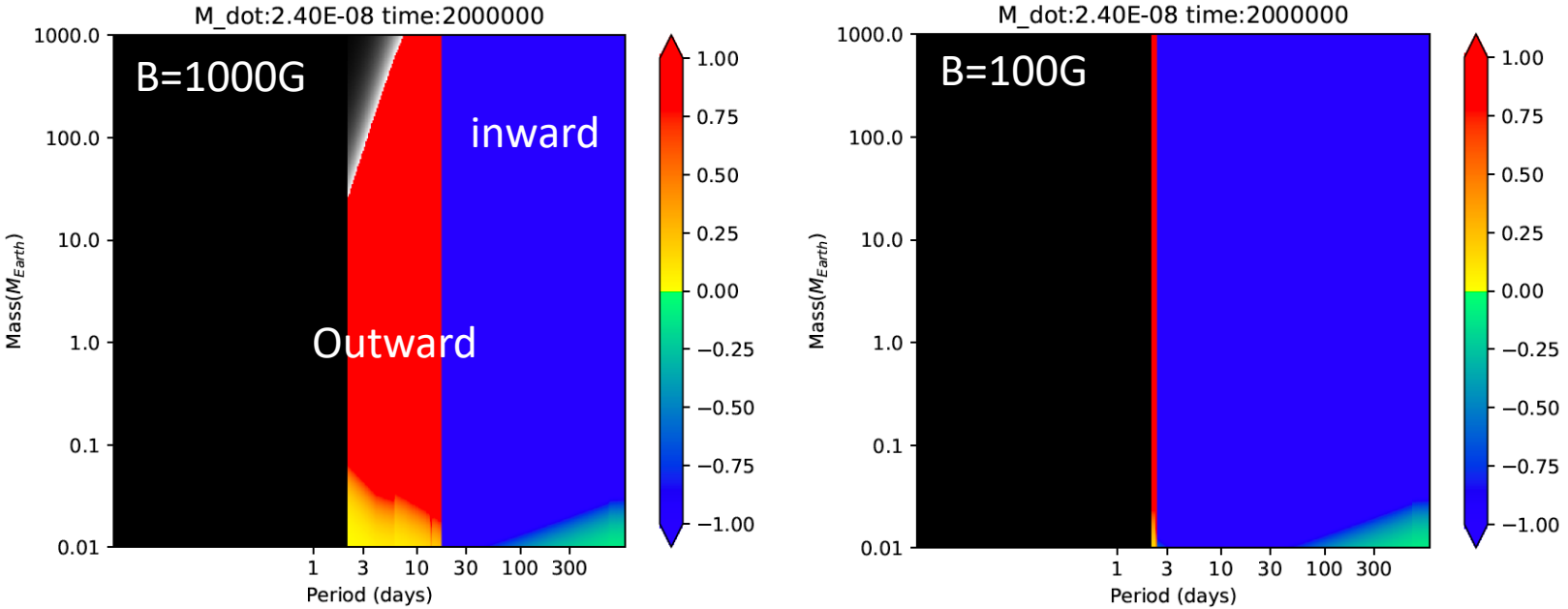




The stellar dipole field produces the positive radial gradient in the surface density (corresponding to the transition zone), which act as trapping of planetary migration (the next slide)

The spiky temperature structure is generated by the opacity transition

Results: Migration map



Migrating planets are stopped at the interface between the red (outward migration) and the blue (inward one) regions

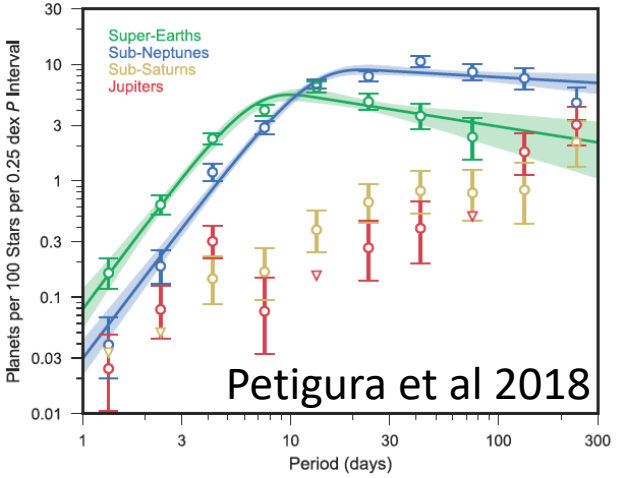
The variation of stellar magnetic fields may be an origin of diversity in the observed population of close-in low-mass planets

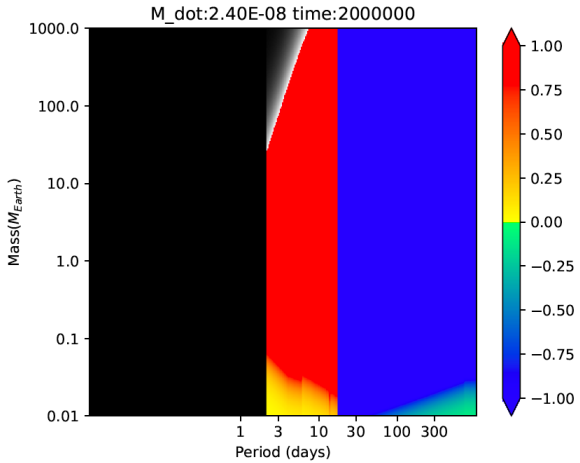
Significance & Next Steps

We investigated the role of stellar magnetic fields on the spatial distribution of close-in super-Earths and determined the condition to reproduce the Kepler observations:

Stellar dipole fields of 100-1000 G are optimal to better understand the observed occurrence rate distributions of close-in super-Earths and sub-Neptunes.

We are currently confirming this finding and exploring the effect of multiplicity. In particular, we are running N-body simulations and modeling reversal of migration which may lead to dynamical instability





Publications and References

Conference presentation:

Tze Yeung Mathew, Yu, “Modeling Super Earth migration in Magnetospherically Truncated Protoplanetary Disks,” *ExSoCal 2020,* Riverside, CA, USA (Sept 14-15, 2020; virtual meeting)

References:

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S., Paardekooper, C. Baruteau, and W. Kley, (2011) “A torque formula for non-isothermal Type I planetary migration - II. Effects of diffusion,” *Monthly Notices of the Royal Astronomical Society,* 410, pp293-303