Ph.D. Qualifications Exam

Combining Transit Timing And Radial Velocity Data To Constrain Dynamical Properties Of Exoplanetary Systems

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Abstract

TTVs have contributed significantly to constraining masses and orbital parameters of multi-planetary systems. So far, only 25 exoplanets have been detected using TTV among the thousands found through transits. Combining TTV with Radial Velocity we can further constrain the parameter space. This type of analysis is fundamentally necessary to measure the planet properties such as mass and radius with high precision, which can be used to understand the planet formation processes and planet interior structure. Along with the current large datasets, future space and ground based missions will provide more data to be analyzed.

For my thesis, I propose to write a pipeline to analyze these different dataset together to provide a self-consistent and easily reproducible analysis. The long-term goal is to do this kind of analysis for an ensemble of systems and draw statistical conclusions about the planet population. To tightly contrain the parameter space is non-trivial because of its highly complex nature. I plan to combine the TTVFast-like algorithm with a novel MCMC to provide the fastest possible level of analysis. The algorithms that I plan to use will be at least as fast as TTVFast but implemented in the open source `REBOUND` rather than custom libraries. This makes the code highly modular with a collection of integrators available, this allows for further optemizations for accuracy or computing time. The MCMC considered in the pipeline will make use of a Riemannian manifold on the log likelihood space.

As a first step I will reproduce the TTV masses for the Trappist 1 system. I will confirm the decrease in mass when more data is added as observed in [**1704.04290**]. I will try to understand if there are systematic effects favouring large masses. In the next step, I will try to simultaneously fit RV and TTV for one system of interest. The goal two-fold:

1. Obtain precise parameters for the transiting planets in emerging datasets.
2. Rigorously constrain the orbits of additional previously unseen planets with the hope of discovering new planets.

Project Summary

Overview

1. Provide a unified framework for fast MCMC techniques which uses both TTV and RV which is used to do bayesian inference on the parameters, this pipeline can then be used for future missions.
2. New and Hybrid MCMC will be investiged. Main focus on adding Langevin based MCMCs (This is novel, paper in works on Simple SMALA).
3. Analyze data from various exoplanet search projects to detect missed TTV (or refine RV?). The main dataset to be reanalysed will be Kepler but the total set of missions/projects which could provide data include: *RL*[**Red/color to highlight main dataset of interest?**]
   (a) Ground Based

i. HARPS
ii. HATNet Projects
iii. SuperWASP

(b) Space Missions

i. COROT
ii. Kepler/K2
iii. CHEOPS
iv. TESS
v. JWST

4. This is how we complete our objective: improve inferences on planet population detectable from TTV and RV This is useful for doing dynamic studies and provides insight or clues about potential planet formation mechanism for the target population.

5. I can then do an in-depth investigation on select systems which feature unusual transit or dynamical features.

6. Enhance the open exoplanet catalogue by providing MCMC dataset results, allowing others to perform desired Bayesian analysis with minimal computational cost. Especially good from a reproducibility perspective, hence scientific merit.

7. Additionally, these inferences on orbital elements give us a collection of posteriors which can be used to provide universal MCMC priors for this target population as we aim to process a considerable volume of systems.

Intellectual Merit

Expand on points 4 and 5. Apprx. 2 paragraphs.

Broader Impacts Of The Proposed Work

Expand on points 6 and 7. Apprx. 2 paragraphs.

Detailed Project Description

Proposed Study

Half a page of more on what we plan on doing and how it ties into dynamics and planet formation theory. Include a sample PhD. timeline (From Setptember 2017 to August 2021 *RL*[**Need to double check with Krystyna that this is when funding runs out.**]

Technical Details

Half a page detailing the technical details of the pipeline.

Supporting And Previous Work

Summary of paper and current works.