Cool Space Stuff

by

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A thesis submitted in conformity with the requirements
for the degree of Doctor of Philosophy

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Doctor of Philosophy
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2023

Abstract

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Dedications go here.

Acknowledgements

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Chapter 1

Introduction

"This, recruits, is a 20 kilo ferous slug. Feel the weight! Every five seconds, the main gun of an Everest-class dreadnought accelerates one, to one-point-three percent of lightspeed. It impacts with the force a 38 kiloton bomb. That is three times the yield of the city buster dropped on Hiroshima back on Earth. That means, Sir Isacc Newton is the deadliest son-of-a-b***h in space! Now! Serviceman Burnside, what is Newton's First Law?"
"Sir! An object in motion stays in motion, sir!"
"No credit for partial answers maggot!"
"Sir! Unless acted on by an outside force, sir!"
– Mass Effect 2, BioWare

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The splendour of the cosmos also has an incredible capacity to ignite the imagination. This perhaps shines brightest when it comes to works of science fiction, however. One of the earliest works of science fiction was written by none other than Johannes Kepler himself in his post-humous work Somnium (Kepler and Kepler, 1634), which uses a narrative about demons on the moon as

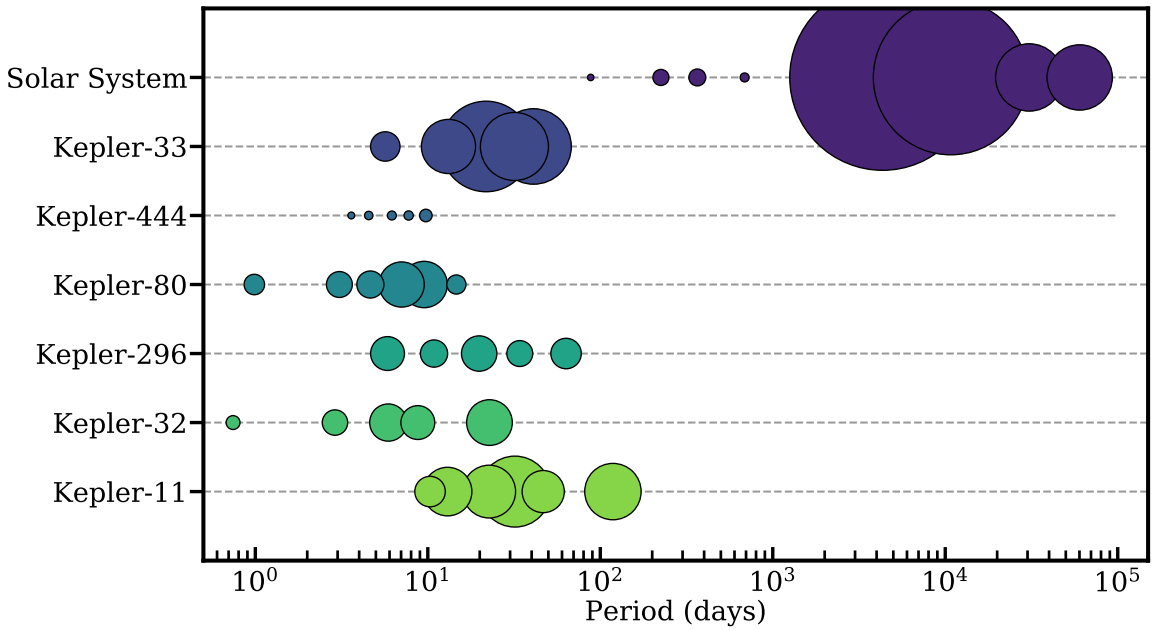


Figure 1.1: Comparison of the Solar System and several compact, multi-planet systems detected with the transit method. Each circle represents a planet, with its horizontal placement according to its orbital period and size linearly scaled according to its radius. Periods and radii are from (NASA Exoplanet Archive, 2019).

a means to envision astronomical observations as viewed from the Moon. I have conducted such work myself[1], linking astronomical research and science fiction to study the dynamical stability of the numerous multi-planet systems found in BioWare's Mass Effect series (Obertas and Paradise, 2021).

To set the stage for my work in this dissertation about Cool Space Stuff, I first review some relevant background material. I present a brief overview of what it means to be cool in Sec. 1.1. In Sec. 1.2, I give a summary of space. Sec. 1.3 provides a primer of stuff. Finally, Sec. 1.4 gives an overview of the remaining chapters of this dissertation.

1.1 Cool

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[1] Hopefully mine won't lead to my mum being arrested on suspicion of witchcraft.

Table 1.1: Counts of exoplanets in multi-planet systems discovered and detected (i.e. characterised) with different methods. These exoplanets are in SPACE. As of 7 April 2023, 2221 exoplanets have been discovered in 884 multi-planet systems. Values from NASA Exoplanet Archive (2023).

	Transit	Transit Variations	Radial Velocity	Other
Discovered	1645	24	506	46
Detected	1663	304	766	48

Fig. 1.1 shows several cool planetary systems. Each circle represents a planet, with its horizontal placement according to its orbital period and size linearly scaled according to its radius. Periods and radii are from (NASA Exoplanet Archive, 2019). Cool planetary systems (most of which have been detected with Kepler) have many interesting features (as reviewed in e.g. Zhu and Dong, 2021; Weiss et al., 2022).

1.2 Space

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Table 1.1 shows counts for exoplanets in multi-planet systems discovered and detected in SPACE according to the NASA Exoplanet Archive's list of Confirmed Planets (NASA Exoplanet Archive, 2023).

1.3 Stuff

I provide an overview of some related topic in Sec. 1.3.1.

1.3.1 Stuff Subsection That's Really Long and Would Extend to Multiple Lines in the Table of Contents So You Should Probably Use a Short Title

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A straight line can be described by,

$$y = mx + b. \tag{1.1}$$

In eq. 1.1, m is the slope of the line and b is the y-intercept.

For more details, see **Stuff Subsubsection** in Sec. 1.3.1.

For more details, see 1.3.1.

Stuff Subsubsection

There are ways to change the numbering of subsubsections and whether or not they appear in the table of contents, but you'll have to look that up. I've just left the default style/formatting.

1.4 Thesis Overview

The remainder of this dissertation describes my work towards on new Cool Space Stuff.

In Chapter 2, I describe my project on Cool Space Stuff that is focused on something idk (published as Obertas et al., 2017).

In Chapter 3, I describe my project on some different Cool Space Stuff. (publication accepted; preprint posted as Obertas et al., 2023).

Finally, I summarise the findings and conclusions of these two projects in Chapter 4 and discuss my results within the broader context of the field of Cool Space Stuff. I finish by describing exciting new prospects for gaining new and critical insight into Cool Space Stuff.

Chapter 2

Some Cool Space Stuff

"I am the very model of a scientist salarian, I've studied species Turian, Asari and Batarian. I'm quite good at genetics as a subset of biology because I am an expert which I know is a tautology! My xenoscience studies range from urban to agrarian, I am the very model of a scientist salarian!" — Mordin Solus, Mass Effect 2, BioWare

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A version of the following chapter was originally published in the September 2017 issue of Icarus, Volume 293 as Obertas et al. (2017). The co-authors were Christa van Laerhoven (who was my supervisor for the project, overseen by Norm Murray) and Daniel Tamayo. In this chapter, I explore how the dynamical spacing between orbits in evenly-spaced five-planet systems affects the system's instability timescale. In particular, I explore how a set of systems with a high-density distribution in spacing reveals additional structure on top of the instability-spacing relationship. This leads to the hypothesis that interacting mean motion resonances of multiple pairs of planets are responsible for the dynamics of such systems, and ultimately driving the instability.

Abstract

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2.1 Introduction

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Acknowledgements

thx

Chapter 3

More Cool Space Stuff

"Had to be me. Someone else might have gotten it wrong." — Mordin Solus, Mass Effect 3, BioWare

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A version of the following chapter has been accepted for publication in Monthly Notices of the Royal Astronomical Society and a preprint version of the article is posted on the arxiv as Obertas et al. (2023). The co-authors were Daniel Tamayo and Norm Murray. In this chapter, I re-visit the dynamical packing of the Kepler multi-planet systems, with an order-of-magnitude more planets in multi-planet systems available compared to previous studies. In particular, I use `SPOCK` *to examine the stability of over 9 million different orbital configurations after an additional planet has been inserted between an observed adjacent pair and reduce this data down to two different summary metrics corresponding to two different frameworks of planet formation. I find that dynamical packing increases with a system's observed planet multiplicity, which is consistent with dynamical sculpting throughout system evolution or with lower multiplicity systems having a higher likelihood of unseen planets.*

Abstract

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3.1 Introduction

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Acknowledgements

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Data Availability

MNRAS papers require a data availability statement and I opted to retain it.

Appendix - Chapter 3

3.A Appendix Name

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Chapter 4

Conclusions

"I should go." — Commander Shepard, Mass Effect Series, BioWare

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Stuff in space is cool.

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