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1. Introduction

Proposed sections in the introduction:

1. Exoplanet detection – Dominant detection methods = Transit, RV. Basic statistics of exoplanets discovered by Kepler Space Telescope.
2. Planet Formation – MMSN, Core accretion/GI models, Planetesimal Formation, Nice Model.
3. Planet Dynamics – Migration, Mean Motion Resonance, Stability.
4. Numerical Integration – Hamiltonian Dynamics, Close Encounters, etc.

Below I am going to elaborate on planet dynamics.

2. Planet Dynamics

2.1. Migration

2.2. Mean Motion Resonance (MMR)

Planets can be in MMR when the orbital period of one planet is an integer ratio of another. Like other types of resonance that occur in nature, MMR results in the amplitude growth of various quantities characterizing the system, like eccentricity, semi-major axis and the longitude of pericentre (Murray & Dermott 1999). As a result, the presence of MMR can strongly affect the formation, evolution and longterm stability of planetary systems in a diversity of ways. For example, Kirkwood gaps are unstable regions in the asteroid belt carved by MMR with Jupiter, while Pluto and Neptune are protected from colliding due to MMR, even though their orbits overlap.

There are two resonant angles related to every $p:q$ MMR (where p and q are integers):

$$\phi_1 = p\lambda_1 - q\lambda_2 + \omega_1$$

$$\phi_2 = p\lambda_1 - q\lambda_2 + \omega_2$$

where λ is the mean longitude and ω is the longitude of periapse. For planets to be in MMR at least one resonant angle is librating.

Of particular interest are the planetary systems discovered by *Kepler*. Figure 1 shows the distribution of *Kepler* period ratios, along with the locations of first and second order MMR. As can be seen, statistical excesses of planets exist just wide of the 2:1 and 3:2 MMR (Lissauer et al. 2011; Fabrycky et al. 2014; Steffen & Hwang 2015). If planets are to get captured in MMR it is expected that they would be captured in these since MMR strength is proportional to e^{p-q} AS[**need citation**] . The most popular dissipative mechanisms to explain these observed near-resonant systems are tidal (Lithwick & Wu 2012; Batygin & Morbidelli 2013; Delisle et al. 2014), protoplanetary (Rein 2012; Baruteau & Papaloizou 2013; Goldreich & Schlichting 2014), and planetesimal (Moore et al. 2013; Chatterjee & Ford 2015). The formation implications for each mechanism are different, and no clear consensus has yet emerged.

1. Excess of Kepler planets near MMR (plot), but most planets are far from MMR.

2. Theory dictates that a) planets embedded in a protoplanetary disk tend to migrate and b) migrating planets should be captured in MMR. First order resonances are dominant modes of capture, as the strength of the resonance goes as e^{p-q}. Evidence is mounting that this picture is far more complicated than originally believed (e.g. Jeff's paper says planets don't migrate).

3. If planets are trapped in MMR after the dispersal of the protoplanetary disk, there

are only a few mechanisms able to transport planets from MMR – tides, planet-planet scattering, and planetesimals.

2.3. Secular Resonance

2.4. Stability

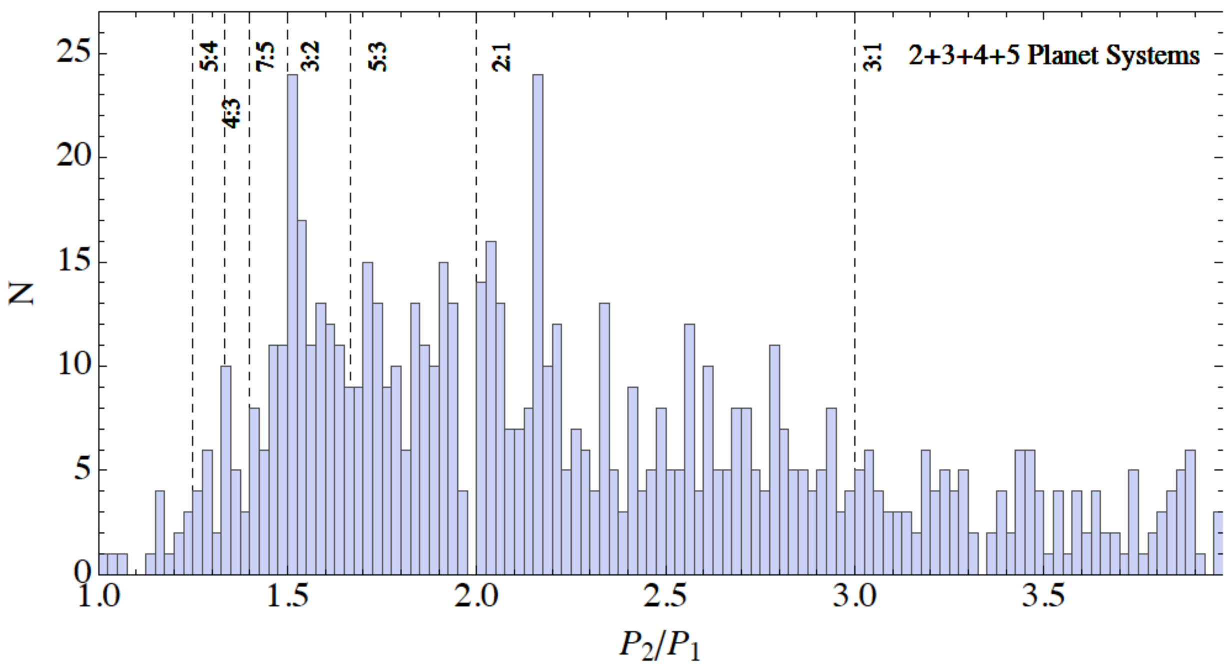

Fig. 1.— Period ratios of Kepler planets, image from Goldreich & Schlichting (2014).

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