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Using Protoplanetary Disks To Weigh The Youngest Stars And Constrain The Earliest Stages Of Stellar Evolution

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Meeting Abstracts

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resonances in exoplanet pairs

Mean-motion resonances (MMRs) are typically stable configurations for pairs of planets. Given that planets should migrate relative to one another in their natal disk, one might expect to have found most planets locked in such MMRs. The fact that most Kepler planets are *not* observed in MMRs therefore requires an explanation. Goldreich and Schlichting (2014) recently argued that, in fact, due to interactions with the protoplanetary disk, planets below a threshold mass should break out of the strongest MMRs, i.e., the MMRs become *overstable*.

While follow-up work has studied the robustness of this result to varying orbital architectures, we focus on the specific numerical implementation of the disk effects, which translates into differing physical interpretations of the planet-disk interactions. We will present how these physical choices affect the parameter space in which overstability sets in, and how certain choices can generate spurious results. We will then extend our results to general cases of broad applicability, and summarize the merits and pitfalls of these different numerical implementations of perturbations from the protoplanetary disk, particularly in tightly packed systems.

We have packaged these numerical implementations into REBOUNDx, an open-source C and Python package for incorporating planet-disk interactions, as well as additional effects (like post-newtonian corrections), into N-body simulations using REBOUND. We will give a brief demo that highlights its ease of installation and use, as well as its synergy with Python's powerful plotting and scientific analysis libraries.

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105.03 – Constraints on Exoplanet System Architectures from Debris Disks

Debris disks are dusty disks around main sequence stars. Terrestrial planets may be forming in young debris disks with ages <100 Myr. Planets in debris disks dynamically sculpt the dust in these systems. Thus, the spatial structure of debris disks could be an indicator of where planets have formed. We present an analysis of several members of the Scorpius-Centaurus OB Association (Sco Cen) that host both debris disks and planets, including HD 95086, HD 106906, and HD 133803. These objects are about 15-17 Myr old. The thermal emission from the debris disks constrains the locations of the dust. The dust is typically interior to the directly imaged planets in the systems. If additional planets reside in these systems, their locations are constrained by the positions of the dust belts. Many debris disk systems in Sco Cen appear to be two-belt systems. The gap between the belts in each system is a likely location for additional planets. The detection of planets in debris disk systems provide clues about the planet formation process, giving insights into where, when and how planets form.

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105.04 – The survival of gas giant planets on wide orbits

It is not known whether gas giant planets on wide orbits form the same way as Jupiter or by fragmentation of gravitationally unstable discs. It has been suggested that giant planets that form on wide orbits in gravitationally unstable discs quickly migrate towards the central star. We simulate the migration of such planets including the effects of gas accretion onto the planet and radiative feedback from the planet, both of which have been ignored in previous studies. We show that a giant planet, which has formed in the outer regions of a protostellar disc, initially migrates towards the central star while accreting gas from the disc. However, the planet eventually opens up a gap in the disc and the migration is essentially halted. At the same time, accretion-powered radiative feedback from the planet, significantly limits its mass growth, keeping it within the planetary mass regime (i.e. below the deuterium burning limit). Giant planets are therefore able to survive as planets (not higher-mass objects, i.e. brown dwarfs) on wide orbits, shaping the environment in which terrestrial planets that may harbour life form.

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105.05 – Constraint of a planet mass from the depth and width of an observed gap on a protoplanetary disk

In a protoplanetary disk, a large planet is able to create the so-called disk gap, which is a low gas density region along the planet's orbit, due to the gravitational interaction between the disc and the planet. The gap formation induced by the giant planet is a possible mechanism to explain the formation of the so-called pre-transition disks with a ring gap structure. If the gap is created by the planet, the gap shape, i.e., the depth and width, would represent the mass and location of the planet. At the present stage, many pre-transition disks have been observed by e.g., ALMA and Subaru telescopes. It is important for us to examine what properties of the planet are constrained from the observed gap if the planet is in the gap.
We derived the relation between the depth of the observed gap and the planet mass in the gap based on the analytical model (Kanagawa et al. 2015a). This relation is a powerful tool to estimate the planet mass from the direct imaging of gaps in protoplanetary disks. We also applied this relation to the image of HL Tau' disk given by a part of the 2014 ALMA long baseline camphene and estimate the planet masses (Kanagawa et al 2015b).
We also performed the numerical hydrodynamic simulation with the FARGO which is well-known code for the rotation disk, and found that the gap width becomes wider with a square root of the planet mass. Using this empirical relation for the gap width, we can also constrain the planet mass from the gap width.
I'll talk about the relation between the gap depth, width and the planet, and the method for estimating the planet mass from the observed image of the disks.

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105.06 – Using Protoplanetary Disks to Weigh the Youngest Stars and Constrain The Earliest Stages of Stellar Evolution

Mass is the fundamental property that determines the fate of a star. In particular, the masses of young stars are of great relevance to many astrophysical problems, including star and planet formation. We have developed a novel approach that combines spatially resolved sub-millimeter spectral line imaging and optical/near-infrared high resolution spectroscopy to derive the fundamental properties of a young star: mass, temperature, and radius. By applying our technique to a sample of pre-main sequence stars, we are mapping out a dynamically-calibrated Hertzsprung-Russell diagram for the express purpose of evaluating pre-main sequence evolutionary models. Looking forward, ALMA is poised to deliver precise stellar masses in statistically large quantities, enabling a meaningful survey of the fundamental properties of young stars.

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105.07 – Caught in the act: The quest for forming giant planets still embedded in their parent disk