Planetary Dynamics
Mini-Courses 1, 2, & 3

Winter 2021

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Time & Place: TBD

Description: Introductory Mini-Courses for Astronomy Graduate Students

Since ancient times, humans have observed the night sky. One of the most striking feature easily observable with the naked eye are planets, the wandering stars. For centuries astronomers have recorded and predicted their motion. This course introduces graduate students to three topics in the wide field of Planetary Dynamics.

Note that students can opt to take only one or two out of the three mini-courses being offered. But note that each mini-course builds on the knowledge developed during the previous mini-course(s).

Main Topics:

- Historical observations of planetary motion by ancient civilizations
- Keplerian orbits, orbital elements
- Analytic solutions to planetary motion including secular theory
- Approximate numerical solutions to Kepler's equation
- Symplectic integration methods for planetary dynamics
- Methods to solve collisional systems such as planetesimal formation and planetary rings

Textbooks:

- Astrophysics of Planet Formation by Philip J Armitage
- Solar System Dynamics by Carl D. Murray
- Modern Celestial Mechanics: Dynamics in the Solar System by Alessandro Morbidelli

Short Numerical Projects:

Students will have a choice in the nature of a short numerical project. All students will use the research-grade general purpose REBOUND integrator and will be given access to computing resources to run their projects. The instructor will offer a list of potential numerical projects inspired by the various astrophysical topics discussed in class.

Grading (applies to each mini-course):

- One Assignment (concept questions + problems): 20%
- Numerical Project: 40% (10% for design, 15% for execution, 15% for final presentation)
- Final one-to-one oral exam on understanding a research article of relevance: 40%

Tentative Schedule:

<u>Mini-Course 1: Celestial Mechanics</u>

- Lecture 1: Written records of planetary motion by ancient civilizations and how such observations still serve as valuable datapoints today
- Lecture 2: Keplerian orbits, orbital elements
- Lecture 3: Introduction to secular theory
- Lecture 4: Long term evolution of the Solar System

<u>Mini-Course 2: N-body simulations</u>

- Lecture 5: High order non-symplectic integration methods
- Lecture 6: Introduction to symplectic integration methods
- Lecture 7: Taking it to the extreme: construction of high order symplectic methods using concepts from Group Theory
- Lecture 8: Time regularization and variational equations

Mini-Course 3: Collisional systems

- Lecture 9: Collisional evolution of dust during planetesimal formation, streaming instability
- Lecture 10: Introduction to the rich dynamics of Saturn's rings
- Lecture 11: Numerical simulations of planetary rings using tree codes
- Lecture 12: Recent developments in our understanding of the formation of Saturn's rings