

# Advanced dynamics

PAP317, Advanced Dynamics in Astronomy, 5 op, Spring 2019

Time and place: Mondays at 10.15-12.00,

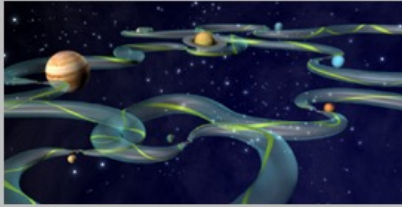
beginning 14.01.2019, D115, Physicum

Lecturers: Peter Johansson & Mikael Granvik

Course assistant: Antti Rantala & Lauri Siltala

<https://wiki.helsinki.fi/display/astjourn/Advanced+dynamics>

- The course aims at providing an in-depth view of both solar-system and galactic dynamics. The first half of the course covers dynamical phenomena in the solar system and the latter part describes important concepts in galactic dynamics.
- Course material: The following text books will be used: *Planetary dynamics* (Gladman and Burns) for the solar system part and *Galactic Dynamics* (Binney & Tremaine) for the galactic part.
- Lecture course: Problem sets, a course project and the final exam.



Information about the course:

## PAP317 Advanced dynamics (Dynamiikan jatkokurssi)

Lecturers: Prof. Peter Johansson (Room D332)  
Dr. Mikael Granvik (Room D312)

Course assistants: Dr. Pauli Pihajoki (Room D325)  
M.Sc. Lauri Siltala (Room D308)

**Lectures: Mondays 10.15-12.00 Room D115, Physicum**

**Problem sessions: Four times in total on Mondays 14.15-16.00 Room D115 Physicum on the following dates: 11.2 and 11.3 (period 3) and 1.4 and 29.4 (period 4)**

First lecture on 14.1.2019 and last lecture on 29.4.2019

- In total 14 lectures.
- The first 7 lectures will cover solar system dynamics and the final 7 lectures in the second part of the course will cover Galactic dynamics
- Problem sets with 20 problems (10 solar system dynamics and 10 galactic dynamics) will be handed out
- A course project on programming a numerical integrator will correspond to the equivalent of 10 problems.
- The minimum requirement for the problem sets and course project is 1/3 of the total points, surplus points will result in bonus points for the exam.

### Course material:

- The course material will consist of handouts closely following the material in the following text books:

1. B. Gladman & J. Burns: *Planetary Dynamics*, 2011 (draft of a book under preparation)
2. J. Binney & S. Tremaine: *Galactic Dynamics*, Second Edition, Princeton University Press, 2008

- Additional material can be found in the following books

1. J. M. A. Danby, *Fundamentals of Celestial Mechanics*, Second Edition, Willmann-Bell, Inc., 1992
2. G. Bertin: *Dynamics of Galaxies*, Cambridge Univ Press, 2000.

The [course project](#) is about the dynamics of dwarf planet Pluto with [these](#) initial conditions.

**Deadline: 30.04.2019. The maximum award is 30 exercise points.**

**Final exam:**

- **The final exam will be held on Wednesday 8.5.2019 at 10-14 in Room D115, Physicum**

**Course syllabus:**

**Lecture 1: 14.1.2019: "Introduction to solar system dynamics"**

- Structure and dynamical evolution of the solar system
- Short recap of the 2-body problem

**Lecture 2: 21.1.2019: "2-body problem and applications"**

- TBD

**Lecture 3: 28.1.2019: "Perturbation theory"**

- TBD

**Lecture 4: 4.2.2019: "N-body problem and numerical integration"**

- TBD

**Lecture 5: 11.2.2019: "3-body problem"**

- TBD

**Lecture 6: 18.2.2019: "Disturbing function and secular dynamics"**

- TBD

**Lecture 7: 25.2.2019: "Novel concepts in planetary-system dynamics"**

- Yarkovsky effect
- Planetary migration

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**Lecture 8: 11.3.2019: "Introduction to galactic dynamics and potential theory" Binney & Tremaine: pages: 1-5, 33-37, 55-77**

- Introduction to stellar systems
- Time scales: Relaxation timescale & Dynamical timescale
- Potential theory, Basic definitions and concepts
- Potentials of Spherical systems
- Potentials of Flattened systems

**Lecture 9: 18.3.2019: "N-body codes and orbit theory" Binney & Tremaine: pages: 122-137, 142-158**

- Direct summation
- Tree codes
- Particle-mesh codes
- Orbits in Spherical potentials

**Lecture 10: 25.3.2019: "Orbit theory continued and numerical orbit integration" Binney & Tremaine: pages: 159-170, 196-211**

- Orbits in axisymmetric potentials
- Symplectic integrators
- Leapfrog integrators
- Regularisation

**Lecture 11: 1.4.2019: "Equilibria and Stability of Collisionless Systems" Binney & Tremaine: pages: 274-283, 287-292, 338-347**

- The collisionless Boltzmann Equation
- Distribution functions for spherical systems
- Particle-based and orbit-based models

**Lecture 12: 8.4.2019: "The Jeans and virial equations and stellar kinematics as mass detector" Binney & Tremaine: pages: 347-372**

- The Jeans Equations
- The Tensor and Scalar Virial theorems
- Detecting black holes
- Extended mass distributions of elliptical galaxies

**Lecture 13: 15.4.2019: "Kinetic theory" Binney & Tremaine: pages: 554-573**

- Relaxation processes.
- General kinetic results.
- The thermodynamics of self-gravitating systems.

**Lecture 14: 29.4.2019: "Mergers of galaxies and galaxy formation" Binney & Tremaine: pages: 639-655, 674-678, 695-710**

- Dynamical friction and its application.
- Tidal radii and tidal forces.
- Galaxy mergers and the structure of merger remnants.
- Galaxy formation and galaxies in a cosmological setting.

**Problem sets:**

**3rd period:**

- [Problem set 1 - Solar System dynamics](#)
- [Problem set 2 - Solar System dynamics](#)

**4th period:**

- [Problem set 3 - Galactic Dynamics](#)
- [Problem set 4 - Galactic dynamics](#)

**Final results and course grading:**

- Results from the problem sets:
- Final grades: