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

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:**