AST1420: Galactic structure and dynamics

Fall 2017

(last updated: September 1, 2017; rev. f34da91)

Course description

This graduate-level course provides an introduction to galaxies and their properties. The focus of the course is on the physical understanding of the fundamental processes that shape galaxies and their constituents and much attention will go to various manifestations of the gravitational force, arguably the most important force shaping galaxies. We will also focus on learning the basic theoretical tools and observational data sets used in the study of galaxies.

Logistics

- **Meeting time / place:** Fridays, 11am–1pm, Room: TBD.
- **Instructor:** Jo Bovy, AB 229.
- **Email:** jo.bovy@utoronto.ca
- **Office hours:** Stop by my office or by appointment.
- **Course website:** `https://github.com/jobovy/AST1420`.

Learning objectives

After this course you should understand

- the different constituents of galaxies, their typical properties (density, morphology, kinematics, etc.), and their relation to one another.
- the basic dynamical properties of mass distributions: dynamical time, relaxation time, circular velocity, escape speed, and the important differences between spherical, axisymmetric, and triaxial mass distributions.
- the basic properties of orbits for spherical, axisymmetric, and non-axisymmetric mass distributions; the importance of conservation laws and integrals of the motion in characterizing orbits.
- the properties of close-to-circular orbits (epicycle approximation) and the dynamics of the solar neighborhood.
- rotation curves and the distribution of dark matter in galaxies.
- equilibrium states of spherical and axisymmetric stellar systems and how to use these to observationally measure the mass and orbital distributions of galaxies.
- N-body modeling.
- basic galactic chemical evolution (single-zone, open-box models).
- how and why bars and spiral structure forms; how galaxies form and grow through violent relaxation, phase-mixing, gas accretion, mergers, and dynamical friction.

Reading

A set of lecture notes will be posted on the course website throughout the semester. For additional reading, we will mostly be using

- Binney & Tremaine, *Galactic Dynamics, 2nd Edition*, 2008, Princeton University Press. Errata can be found here.
- Binney & Merrifield, *Galactic Astronomy*, 1998, Princeton University Press. Errata can be found here.

Another useful textbook on galaxies is

- Schneider, *Extragalactic Astronomy and Cosmology*, 2015, Springer. You can access this book online on the UofT wireless network by going to: `http://link.springer.com/book/10.1007%2F978-3-642-54083-7`

Grading scheme

- **Assignments:** 30 % over three assignments; see course website for due dates.
- **Participation:** 20 %
- **Presentations:** 20 %
- **Take-home final + oral exam:** 30 %

  You are allowed to (and are encouraged to!) work together with classmates on the assignments, but each student must hand in an independent write-up of their solutions. The take-home final should be your own work. Solutions must be written up in a detailed enough manner to demonstrate that you understand each step. The oral exam will consist of a discussion of the take-home final and questions from the General Qualifying Exam.

Academic integrity

From Appendix D of the Academic Integrity Handbook:

> Academic integrity is one of the cornerstones of the University of Toronto. It is critically important both to maintain our community which honours the values of honesty, trust, respect, fairness, and responsibility and to protect you, the students within this community, and the value of the degree towards which you are all working so diligently.
>
> According to Section B of the University of Toronto's Code of Behaviour on Academic Matter (`http://www.governingcouncil.utoronto.ca/policies/behaveac.htm`) which all students are expected to read and by which they are expected to abide, it is an offence for students to:
>
> - Use someone else's ideas or words in their own work without acknowledging explicitly that those ideas/words are not their own with a citation and quotation marks, i.e. to commit plagiarism.
> - Include false, misleading, or concocted citations in their work.
> - Obtain unauthorized assistance on any assignment.
> - Provide unauthorized assistance to another students. This includes showing another student your own work.

- Submit their own work for credit in more than one course without the permission of the instructors.

There are other offenses covered under the Code, but these are the most common. You are instructed to respect these rules and the values that they protect.

Schedule

- **Week 1:** Introduction to galactic structure; coordinate systems; galaxies as collisionless sytems.
- **Week 2:** General properties of gravitational potentials; properties and examples of spherical mass distribution; orbits in spherical potentials.
- **Week 3:** Equilibrium configurations of spherical systems; virial theorem; collisionless Boltzmann equation; spherical Jeans equations; spherical distribution functions.
- **Week 4:** ; Mass determinations of spherical systems: Milky Way halo, dwarf spheroidal galaxies, ultra-diffuse galaxies; The Local Group; the Hubble sequence.
- **Week 5:** Properties of disky mass distributions; orbits in axisymmetric potentials.
- **Week 6:** Rotation curves; gas kinematics in the Milky Way; the Milky Way's rotation curve; Oort constants.
- **Week 7:** Equilibrium configurations of disks; axisymmetric Jeans equations; disk distribution functions; the dynamics of the Solar neighborhood.
- **Week 8:** Triaxial mass distributions; Schwarzschild modeling; the internal structure of elliptical galaxies.
- **Week 9:** N-body modeling; chemical evolution of galaxies; age–abundance relations in the solar neighborhood; stellar population synthesis.
- **Week 10:** Dynamical instabilities; bars; spiral arms; mergers and dynamical friction; violent relaxation; phase-mixing.
- **Week 11:** Student presentations.
- **Week 12:** Tides; high-speed encounters; dispersal of open clusters; adiabatic contraction. Scattering of stars in disk.