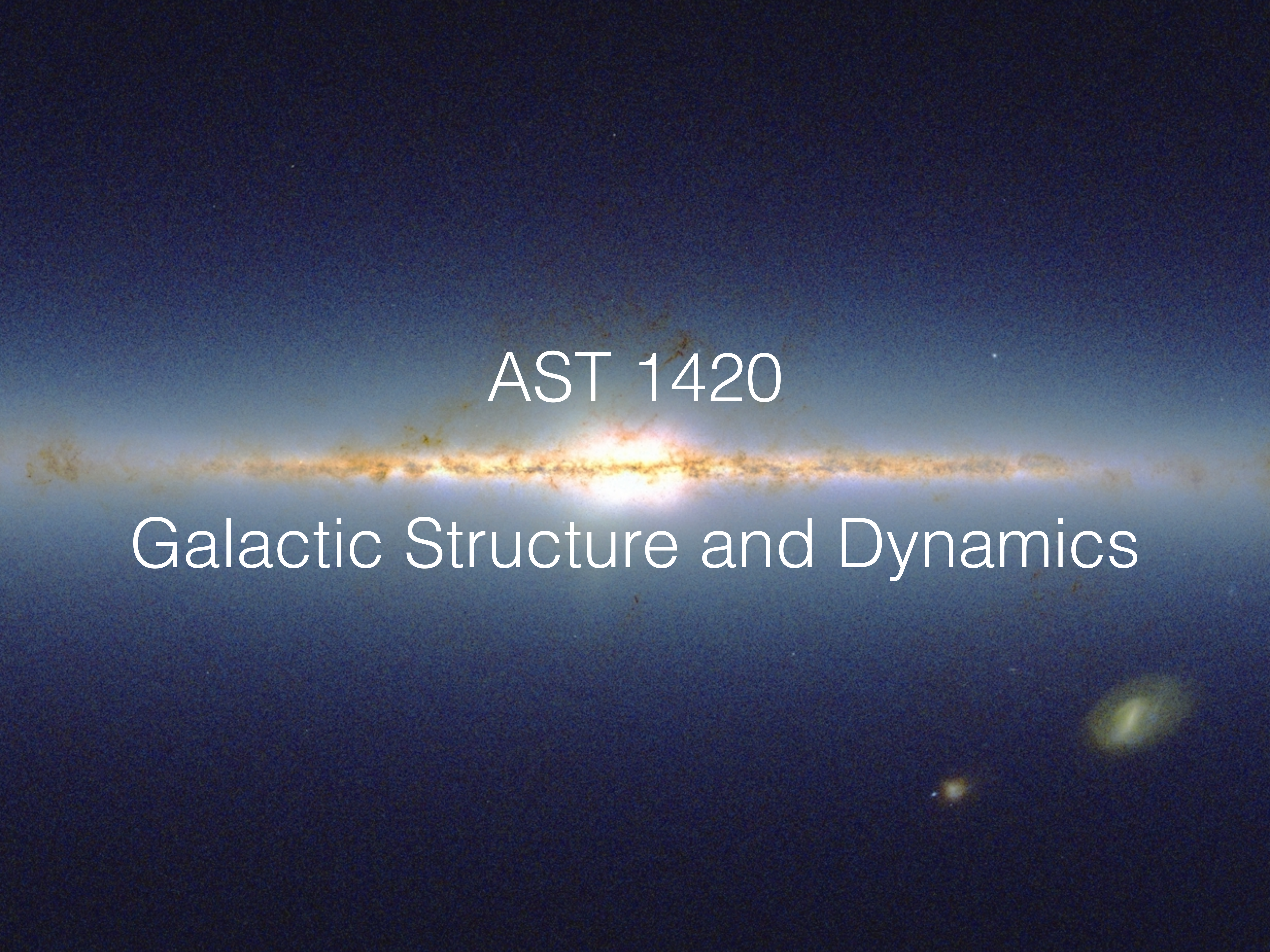


AST 1420

Galactic Structure and Dynamics

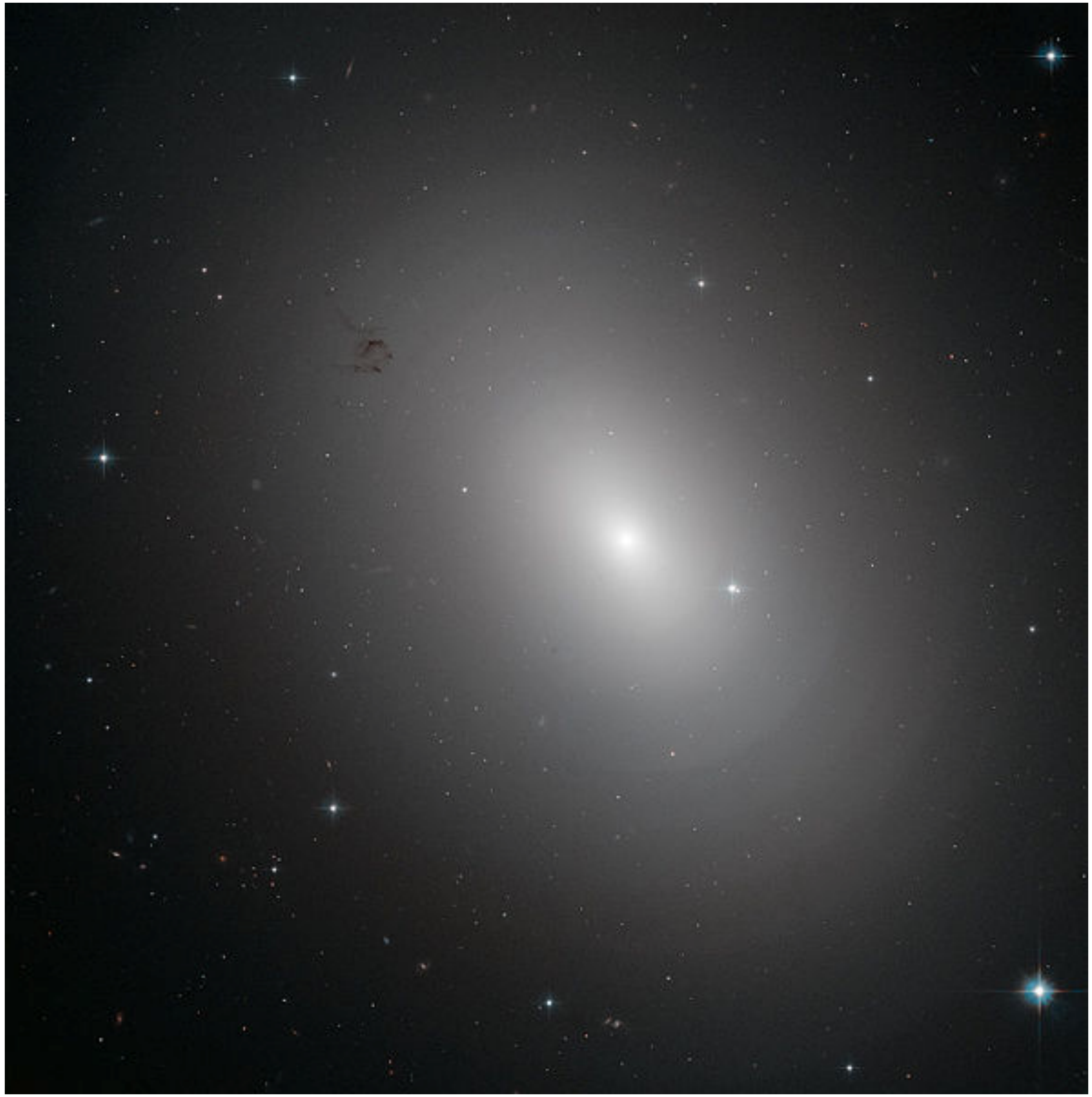
M51

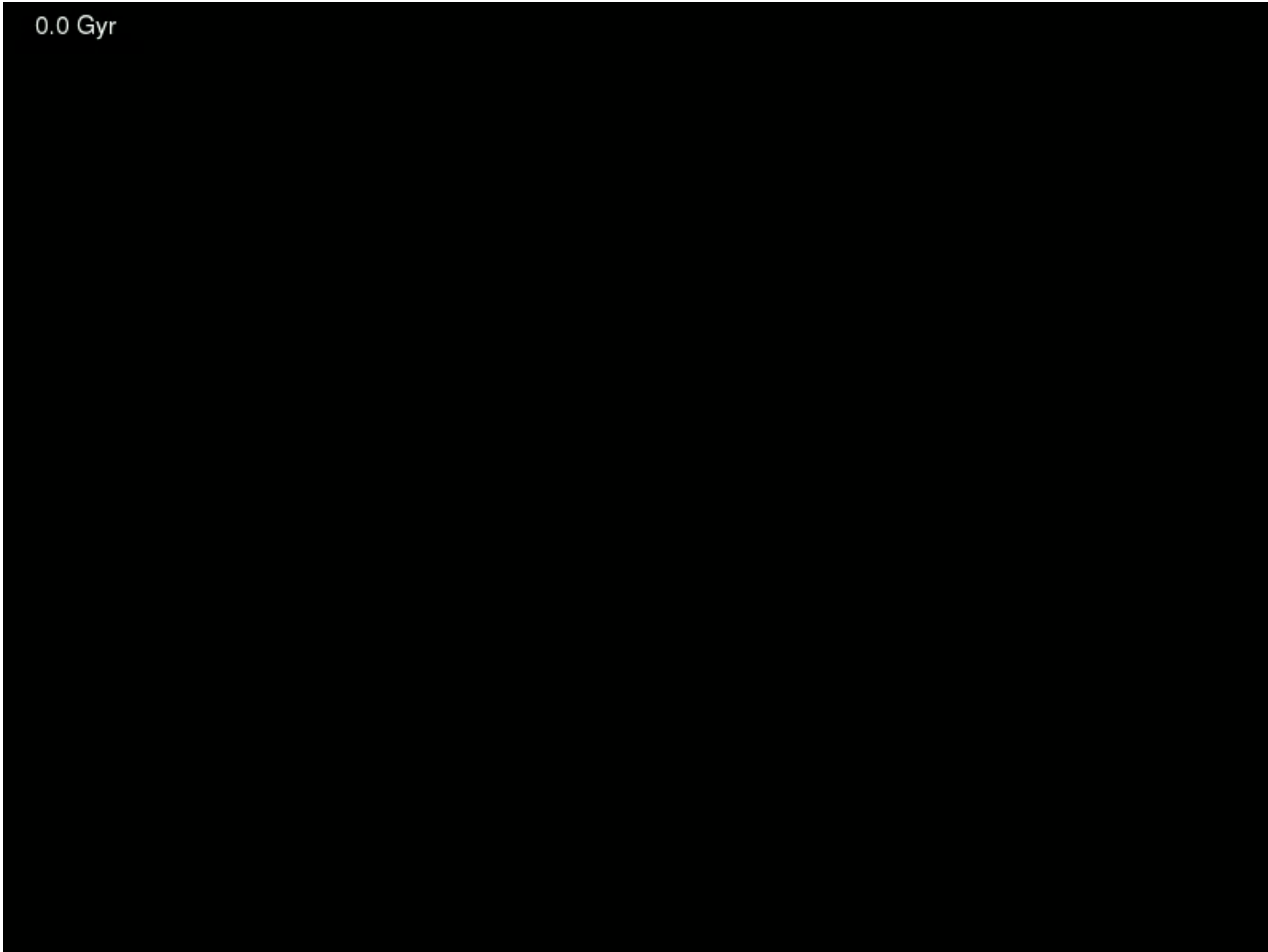
Cen A

NGC 1300

M81

NGC 3923





Credit: Greg Stinson, MUGS (http://mugs.mcmaster.ca/)

Why study galaxies?

- Fascinating cosmic objects!
- Great application of fundamental physics: GR: galaxy formation in expanding Universe; Newtonian gravity dominating the evolution of bound galaxies; radiation, hydrodynamics, magnetic fields,…
- Our own cosmic genesis: how did the Milky Way that contain our solar system form? Where did the solar system travel over the lifetime of the Sun?
- Cosmic laboratories for investigating *dark matter*

Why study Galactic Structure and Dynamics?

- Gravity is the dominant force in galaxies: most of the mass *only** feels gravity (stars and dark matter)

- Could just run large simulations but:

    - Running large, gravity-only simulations still *very* expensive, don't always lead to a very good *understanding* of gravitational effects

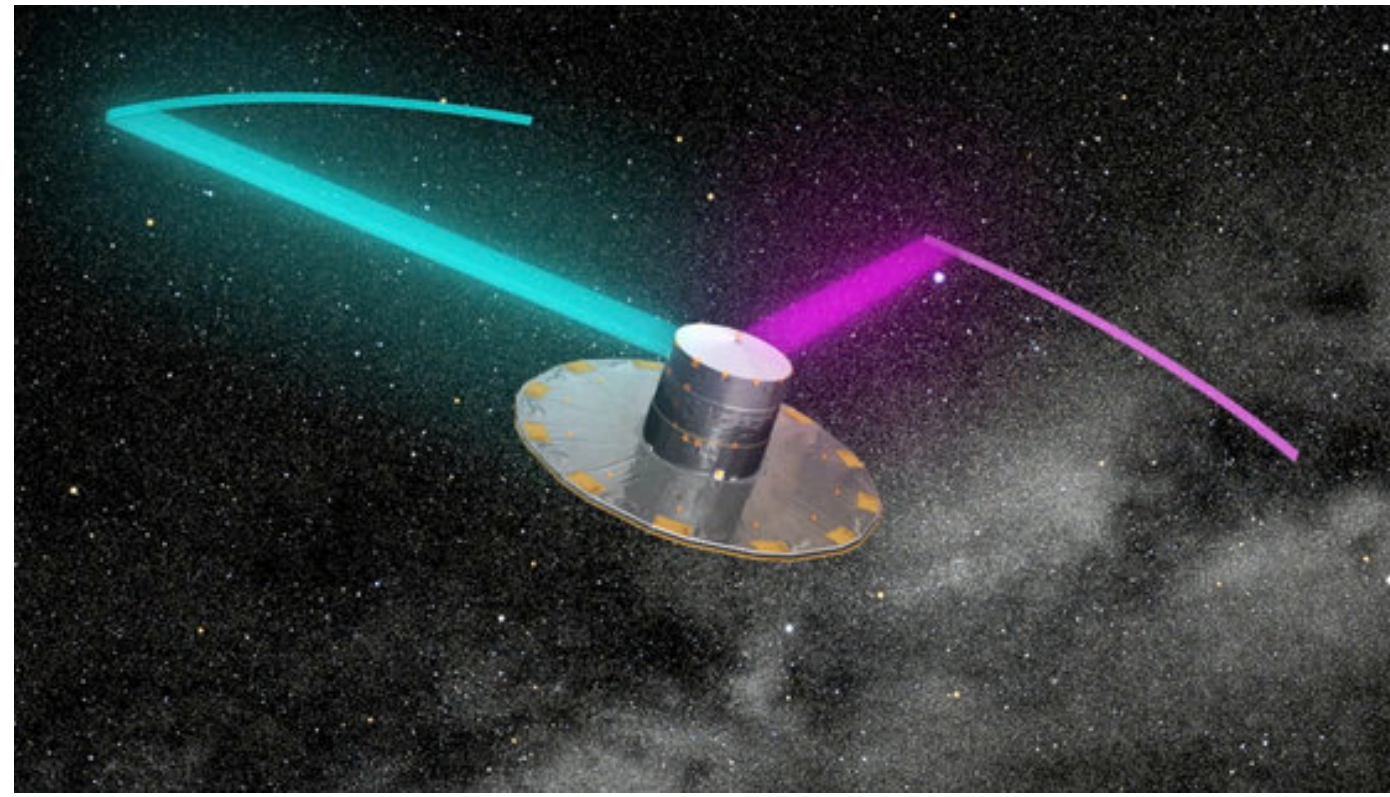
    - Additional physics ("baryonic physics") of star-formation, feedback from stellar winds, supernovae, active galactic nuclei very uncertain *and* difficult to simulate

- Newtonian gravity + dark matter: simple framework to understand complex phenomenology of galaxies

- Only well-understood physical systems can lead to *big discoveries*: e.g., dark matter, dark energy

Golden age of galactic dynamics

- *Gaia* satellite is scanning the sky and making high-precision measurements of stellar positions over five years —> measure stellar distances, motions, and stellar properties for >1 billion stars!



- First major data release in April 2018, next one on Dec. 3 2020!

- Is providing an incredibly detailed view of all aspects of galactic dynamics: detailed kinematics in the disk, most precise measurement of structure of dark matter halo of *any* galaxy, internal kinematics of clusters, star-forming regions, globular clusters, orbits of all satellite galaxies, …

Objectives of this course

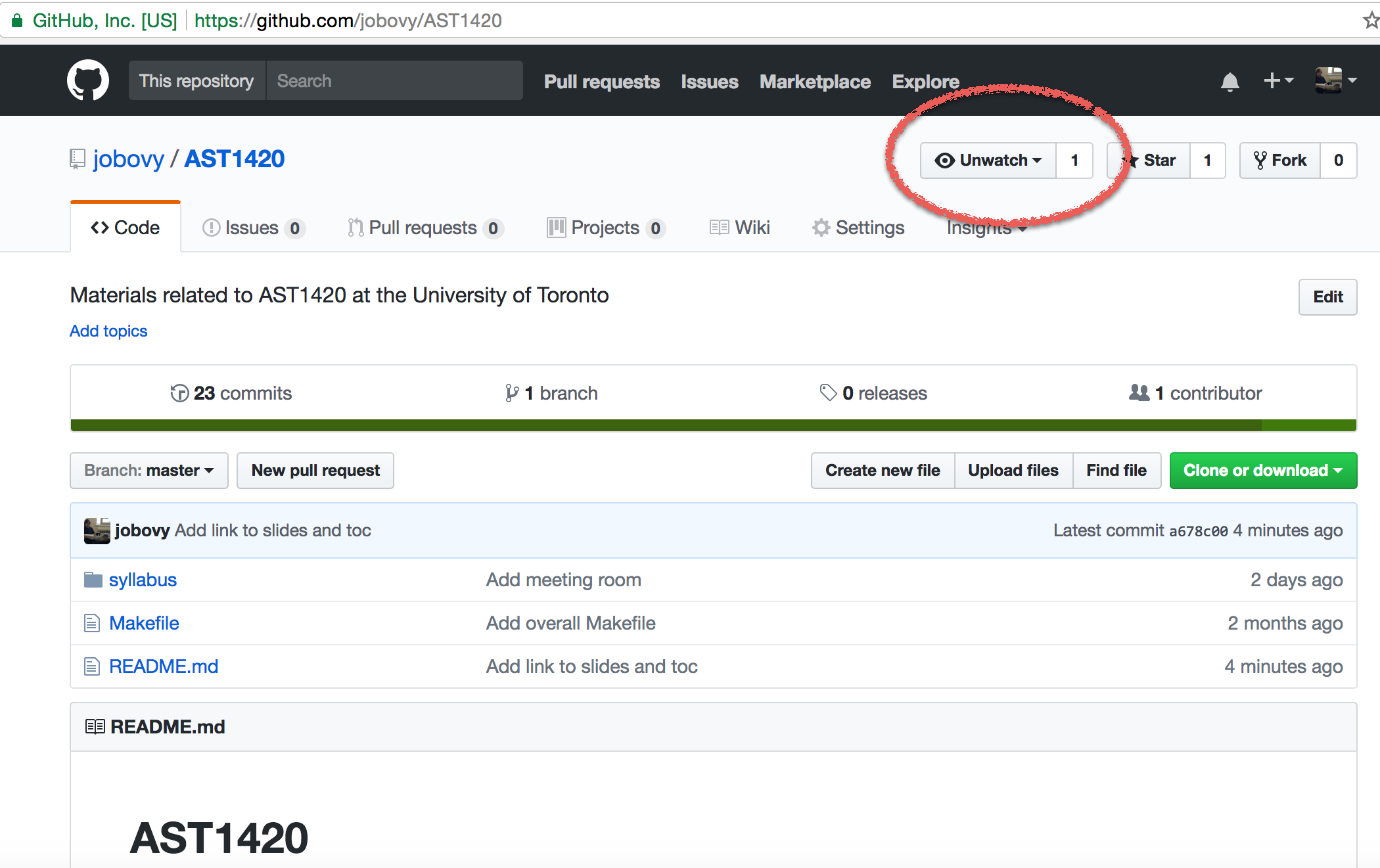
- To know and understand the basic physical properties of galaxies: constituents of galaxies, their dynamics, and relation to each other

- Overview of types of tools available for studying galaxy formation and evolution

- Hone astrophysical problem solving skills: combination of analytical thinking, numerical approaches, simulations, and data analysis

Course details

- Full details on the website: https://github.com/jobovy/AST1420
- Lectures:
  - Asynchronous, posted on MS Stream, linked on the course website
  - Weekly Q&A session: **Thu at 12:10 pm** (to 1 or 1:30 pm)
- Email: jo.bovy@utoronto.ca
- Getting help:
  - Slack channel #ast1420-fall2020 (you may want to set up a channel on the GASA slack, make sure to invite non-astro students)
  - Email to set up a Zoom appointment



GitHub, Inc. [US] https://github.com/jobovy/AST1420
This repository
Search
Pull requests
Issues
Marketplace
Explore
jobovy / AST1420
Unwatch 1
Star 1
Fork 0
Code
Issues 0
Pull requests 0
Projects 0
Wiki
Settings
Insights
Materials related to AST1420 at the University of Toronto
Edit
Add topics
23 commits
1 branch
0 releases
1 contributor
Branch: master
New pull request
Create new file
Upload files
Find file
Clone or download
jobovy Add link to slides and toc
Latest commit a678c00 4 minutes ago
syllabus
Add meeting room
2 days ago
Makefile
Add overall Makefile
2 months ago
README.md
Add link to slides and toc
4 minutes ago
README.md
AST1420

Lecture notes

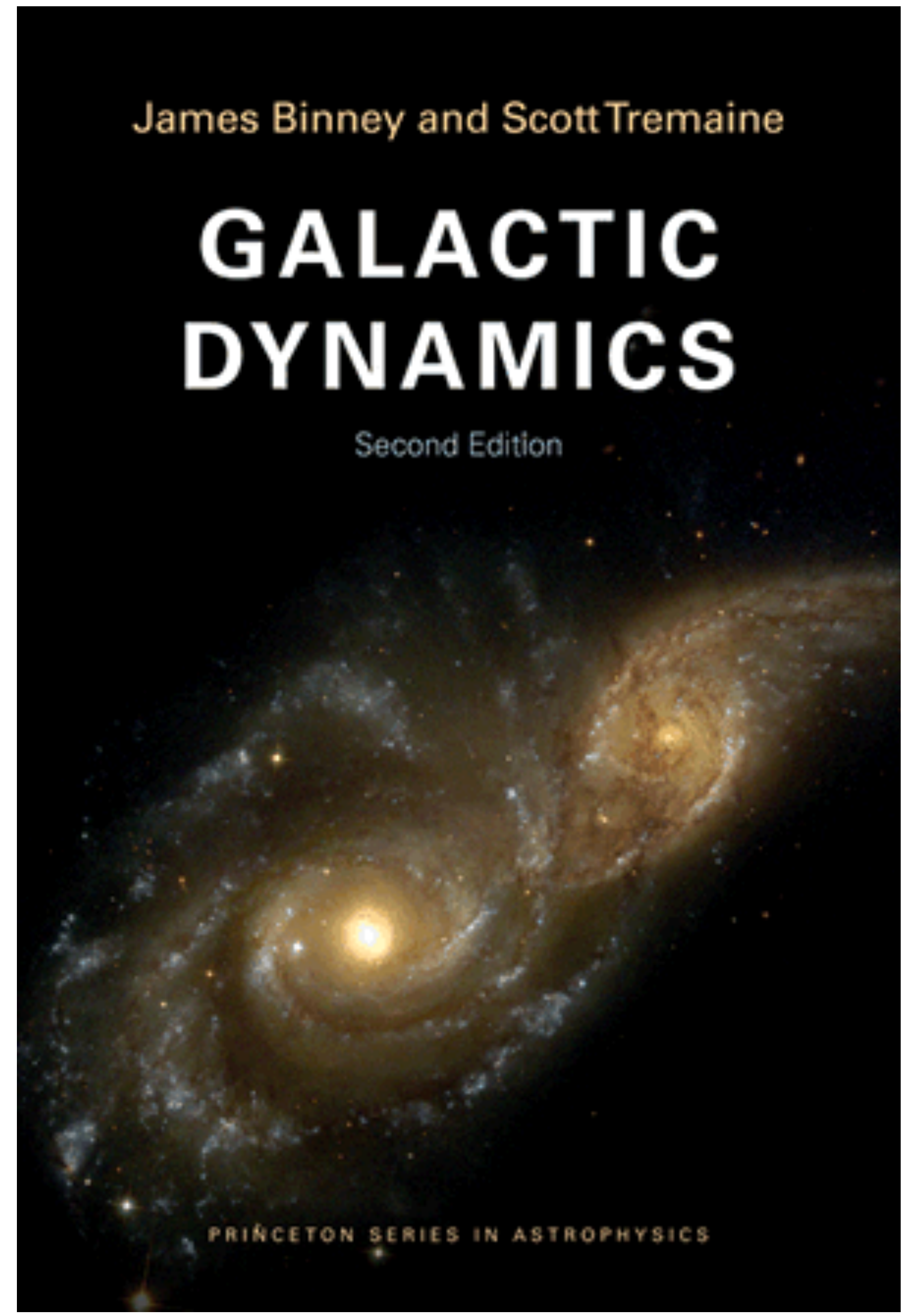
- Linked to from course webpage
- New notes will be posted at least one week ahead of class (but most already there; may get slightly updated though)
- Some webpages have lots of content / math-to-typeset; you might want to keep these pages open in different tabs
- Should work in Chrome, may have issues in other browsers
- Please send me an email pointing out any typos, broken links, or other mistakes in the notes

Additional reading

- Essential reference book: Binney & Tremaine, *Galactic Dynamics, 2nd Edition*, 2008, Princeton University Press

- Goes into more detail on some topics than the notes will + advanced material

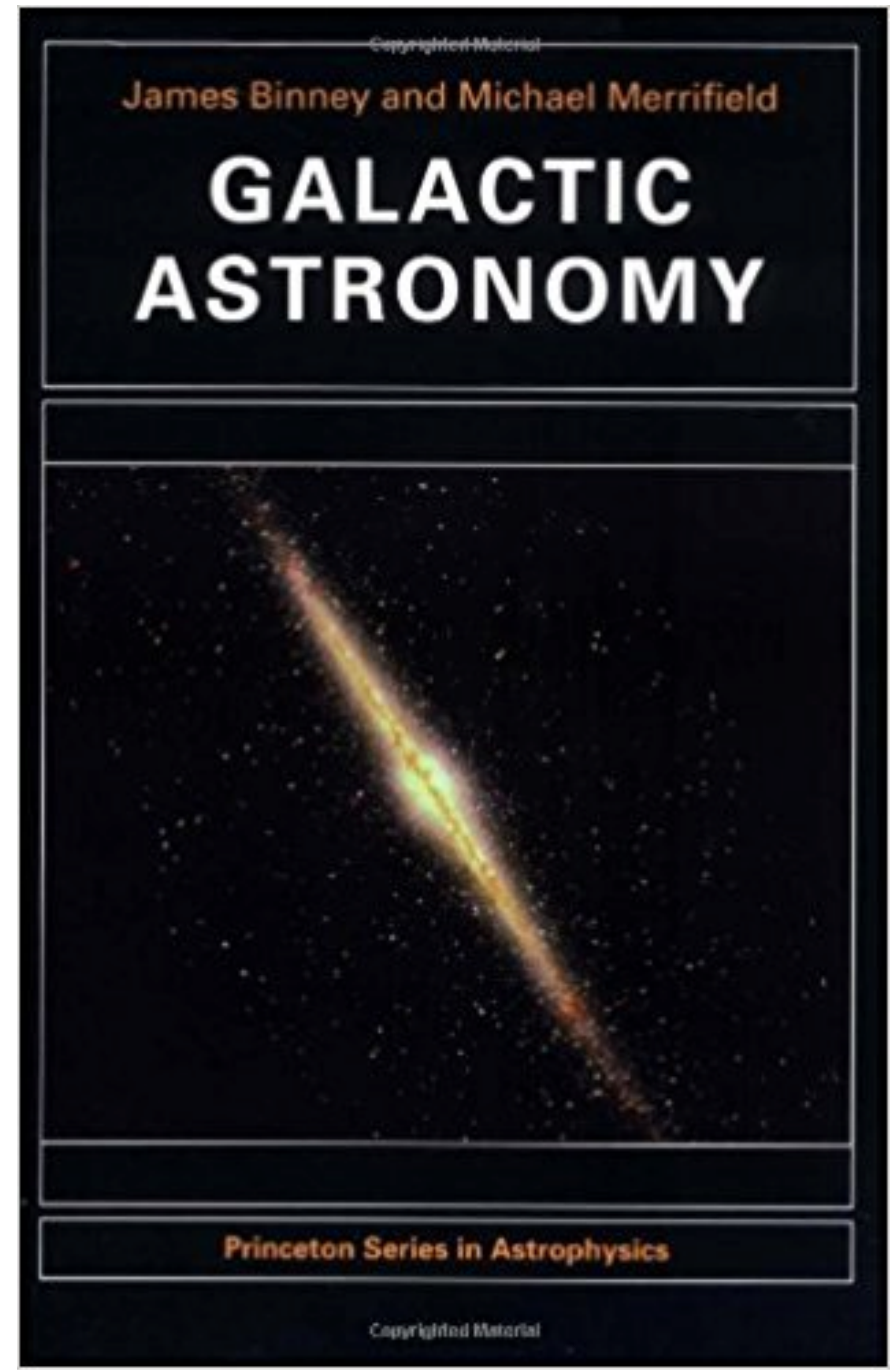
- Must-have for the galactic dynamicist!



Additional reading

- Binney & Merrifield, *Galactic Astronomy*, 1998, Princeton University Press

- Will use for galaxy phenomenology and topics related to galaxy evolution / formation

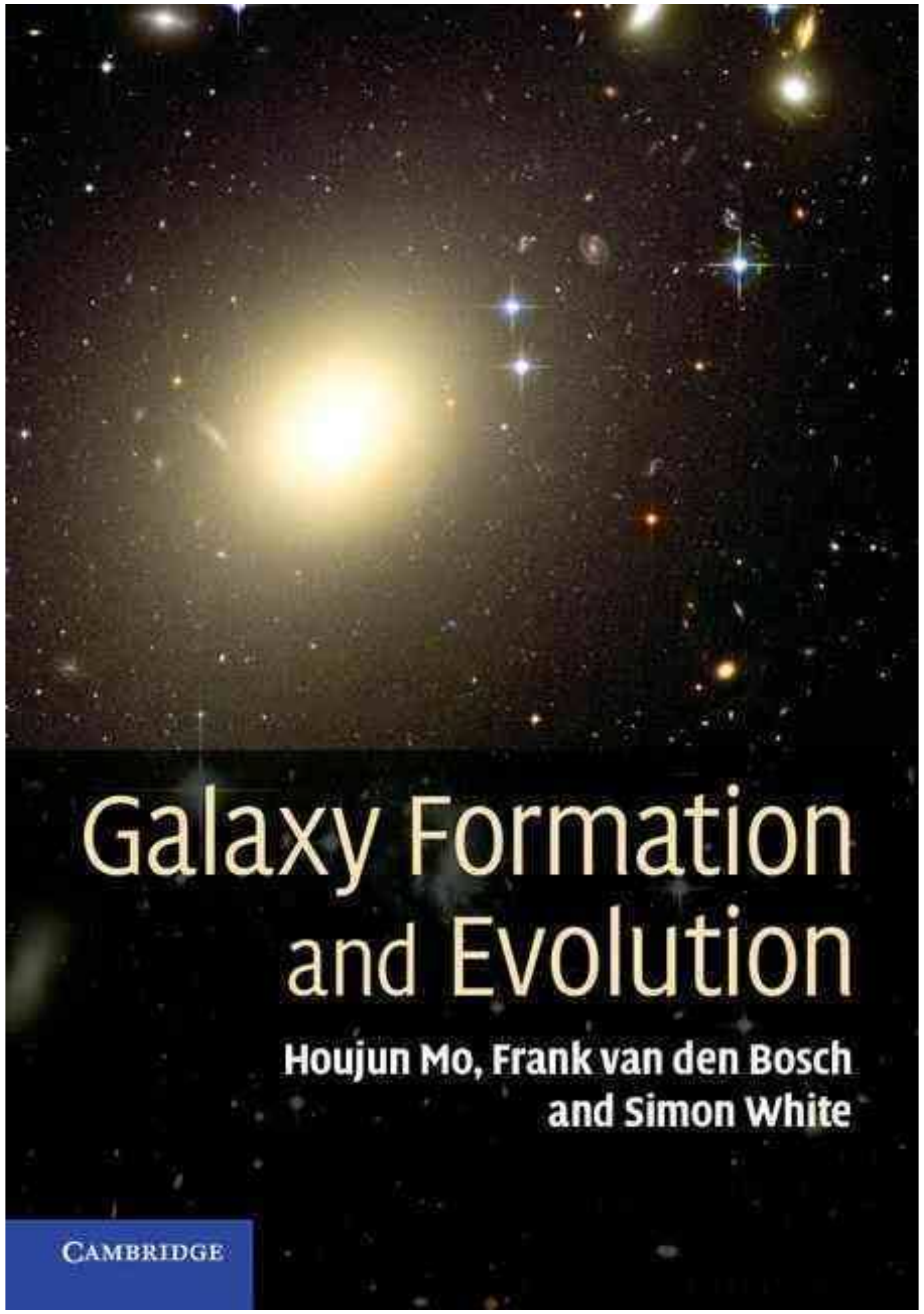


Additional reading

- Mo, van den Bosch, & White, *Galaxy Formation and Evolution*, 2010, Cambridge University Press

- Will use for formation of dark-matter halos and topics related to galaxy evolution / formation

- Additional readings indicated on the course website



Code

- Lecture notes contain code examples in Python
- Assignments + final will require some coding as well, preferably done in Python (e.g., jupyter notebook)
- Please try installing all of the pre-requisites ASAP, don’t wait until the first assignment

Code

- Require:

```
name: galdyncourse
channels:
  - conda-forge
dependencies:
  - python=3.8
  - ipython
  - jupyter
  - numpy
  - scipy
  - matplotlib
  - pyqt
  - pandas
  - pip
  - conda-forge::astropy>=2
  - conda-forge::galpy
  - pip:
    - astroquery
```

- See the Notes' Preface for an **`environment.yml`** file that easily allow you to setup a **`conda`** environment for this course that contains everything you need

- (note that because some of the code required in the notes is in active development, for some code examples you will need to download galpy's development version)

- The course notes have live code

Marking scheme

- Assignments: 3 assignments throughout the semester —> total 30%
- Participation —> 20%:
  - Each student needs to send at least one question by the end of the work day the day before the Q&A session
- Presentation: Each student gives a short presentation in week 10 (Nov. 23-27, exact date/time TBD) on a topic in “Galactic Structure and Dynamics”; we’ll discuss possible topics later —> 20% of total
- Take-home final + oral —> 30%

Assignments

- **Assignment 1**: TBP on Oct. 1, due Oct 15 at the start of class
- **Assignment 2**: TBP on Oct. 22, due Nov. 5 at the start of class
- **Assignment 3**: TBP on Nov. 5, due Nov. 19 at the start of class

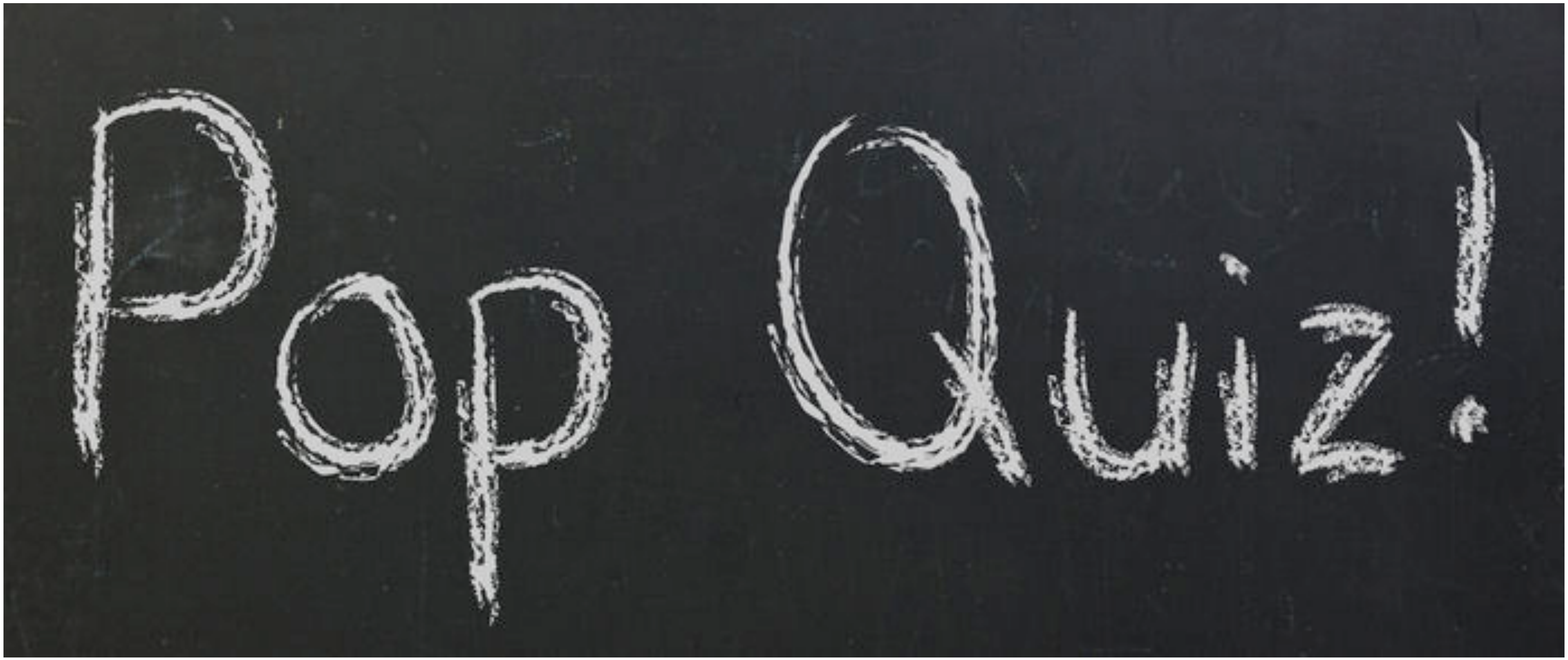
(preliminary) Schedule

Schedule

- **Week 1:** Class logistics; Introduction to galactic structure; overview of background knowledge.
- **Week 2:** General properties of gravitational potentials; properties and examples of spherical mass distributions; basics of classical mechanics; orbits in spherical potentials.
- **Week 3:** Galaxies as collisionless sytems; equilibrium configurations of spherical systems; virial theorem; collisionless Boltzmann equation; spherical Jeans equations; spherical distribution functions; applications: masses of spherical systems.
- **Week 4:** Properties of disky mass distributions; orbits in axisymmetric potentials; dark matter; rotation curves; gas kinematics in the Milky Way.
- **Week 5:** Asymmetric drift; the dynamics of the solar neighborhood; Spheroidal and triaxial mass distributions; orbits in these mass distributions; surfaces of section; chaos; Schwarzschild modeling.
- **Week 6:** Numerical methods; N-body modeling.
- **Week 7:** Formation and evolution of dark matter halos; violent relaxation; phase-mixing.
- **Week 8:** Chemical evolution of galaxies; age–abundance relations in the solar neighborhood; stellar population synthesis.
- **Week 9:** Internal structure of elliptical galaxies; supermassive central black holes; stability of stellar systems; bars; spiral arms.
- **Week 10:** Student presentations.
- **Week 11:** Mergers and dynamical friction; tides.
- **Week 12:** Review.

What's going on this week? What's due?

Week	Dates	Topic	Due on Thu?
1	Sep 14 – Sep 18	Introduction to galactic structure	
2	Sep 21 – Sep 25	Gravitation, classical mechanics, spherical orbits	
3	Sep 28 – Oct 02	Dynamical equilibria, masses of spherical systems	
4	Oct 05 – Oct 09	Galactic disks, galactic rotation	
5	Oct 12 – Oct 16	Disk equilibria, spheroidal mass distributions	Assignment 1
6	Oct 19 – Oct 23	Numerical methods	Presentation topic
7	Oct 26 – Oct 30	Dark matter halos	
8	Nov 02 – Nov 06	Chemical evolution	Assignment 2
	Nov 09 – Nov 13	**Reading week, no class**	
9	Nov 16 – Nov 20	Elliptical galaxies, stability	Assignment 3
10	Nov 23 – Nov 27	**Presentations**	
11	Nov 20 – Dec 04	Mergers and dynamical friction	
12	Dec 07 – Dec 11	Review	


Pop Quiz!

What is the diameter of the Milky Way disk?

A. 3 kpc

B. 10 kpc

C. 30 kpc

D. 100 kpc

What is the diameter of the Milky Way disk?

A. 3 kpc

B. 10 kpc

C. 30 kpc

D. 100 kpc

How thick is the Milky Way disk?

A. 100 pc

B. 600 pc

C. 2 kpc

D. 20 kpc

How thick is the Milky Way disk?

A. 100 pc

B. 600 pc

C. 2 kpc

D. 20 kpc

How many stars does the Milky Way contain?

A. 10^5

B. 10^7

C. 10^{11}

D. 10^{13}

How many stars does the Milky Way contain?

A. 10^5

B. 10^7

C. 10^{11}

D. 10^{13}

What is the ratio of (dark matter) / (stellar matter) in total in the Milky Way?

A. 0.3

B. 1

C. 3

D. 15

What is the ratio of (dark matter) / (stellar matter) in total in the Milky Way?

A. 0.3

B. 1

C. 3

D. 15

What is the orbital period of the Sun around the Galactic center?

A. 1 Gyr

B. 100 Myr

C. 50 Myr

D. 250 Myr

What is the orbital period of the Sun around the Galactic center?

A. 1 Gyr

B. 100 Myr

C. 50 Myr

D. 250 Myr