ASTR620 *Galaxies* Fall 2021 [3 credits]

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Office Hours: By appointment
Lectures: Tuesday & Thursday 2:00-3:15 pm
(in person unless announced otherwise!)

*In that case, make sure to have “ASTR620” in the “Subject” or your email may be missed!

Objectives:

- Review the physical properties of the Milky Way and external galaxies.
- Introduce some theoretical tools to help you understand the kinematics, dynamics, and other physical properties of galaxies.
- Get you to the point where you can appreciate why current papers in the literature are being written.

Course Material:

Here's a quick summary of the material that we will cover in this course:

- Introduction: overview, structure, classification, evolution, environment, review on stars;
- Milky Way: basic data, distribution of stars, gas, dust, metals, and relativistic particles, large-scale structure and rotation, dynamical components;
- Disk galaxies: scaling relations and patterns, kinematics, stellar dynamics and stability, density waves, bars;
- Elliptical galaxies: scaling relations and patterns, kinematics, stellar dynamics, mass profiles;
- Galactic nuclei: our Milky Way, dormant black holes, AGN, starburst galaxies, issues of feedback; galaxy - CGM - IGM ecosystems
- Galaxy evolution: chemistry, cannibalism, interactions, environment, dependence on look-back time, implications on models of galaxy formation.

For more details, see the schedule of lectures at the end of this syllabus.

Books:

- Optional: *Introduction to Galaxy Formation and Evolution: From Primordial Gas to Present-Day Galaxies* by Cimatti, Fraternali, & Nipoti, Cambridge U. Press, 2019
- Optional: *Galaxy Formation and Evolution* by Mo, van den Bosch, & White, Cambridge U. Press, 2010
- Optional: *Galactic Dynamics, 2nd Edition* by Binney & Tremaine, Princeton U. Press, 2008
- Optional: *Galaxies in the Universe, An Introduction, 2nd Edition* by Sparke & Gallagher, Cambridge U. Press, 2007

This is a fast-moving field of research; some of these books are quickly becoming outdated. So, we will rely heavily on more recent scientific articles, as well as literature reviews in ARAA and A&A.

Grading:

I will grade on a point scale with the different components of this course weighted as shown in the following table:

ASSIGNMENT	Homeworks	Discussions	Term Paper	Midterm Exam	Final Exam	Participation	Total
PERCENTAGE	20%	20%	20%	15%	20%	5%	100%

Homeworks:

There will be 4 homeworks during the semester. A mixture of types: practical (web search), dull & routine (stuff skipped in class), and more challenging thought problems. You can talk between yourselves about a problem, but the write-up should be your own. All homeworks are due in class at 2:00 pm (i.e., at the beginning of the lecture).

Discussions:

During the last ~15-20 minutes of each lecture, starting in the second week of the semester, we will discuss a relevant paper recently published or posted on the archives (arXiv). You will be asked to lead the class discussion on two of these papers during the semester. There will be a running list of papers to pick from. Much like the "hot papers" series, these discussions will not simply be monologues by the discussion leaders - class participation will also be expected.

Term Paper:

Write *in your own words* a paper of no more than 15 single-spaced pages (11 or 12 pt. fonts) including text, figures, and references on an extragalactic topic of your choice (avoid cosmology topics covered in ASTR622!). The term paper is meant to be a short literature review on a specific narrow topic. As a source of inspiration, you may look at the most recent (< 3 years) issues of the *Annual Review of Astronomy and Astrophysics* THAT WE HAVE NOT DISCUSSED IN CLASS. Your topic will be narrower and more focused. To avoid any bad surprise, tell me your proposed topic *before* you start working on it. This term paper is due on the last day of classes (December 9).

Mid-Term and Final Exams:

The format of these exams (closed- *vs* open-book, in-class *vs* take-home) has not yet been decided. The mid-term exam will take place sometime in late October (exact date TBD) regardless of the exact format. If in-class, the final exam would be on Saturday, December 18 at 10:30 am - 12:30 pm, according to University rules, but let's discuss this in class.

Participation:

To make the lectures and discussions livelier, I expect you to be inquisitive, ask questions, and participate actively in the discussions. I will also ask you questions to trigger discussions. Your participation in class will count for 5% of your grade - easy-peasy!

COVID-19 Health & Safety Policy:

We will follow the latest University policy regarding masks, as posted here.

Academic Integrity:

A simple reminder that you should …

Never

- Copy from another student.
- Directly quote any published article unless you also give full credit to that article.
- Allow other students to copy from you.

Always

- Write the honor pledge on each assignment, per campus policy.
- Present your own thoughts in your own words.
- Cite any references that you use.
- Ask me, in case of doubt!

ASTR620 LECTURES

(29 - 1 [midterm] - 1 [overflow for discussions] = 27 lectures)
CFN = Cimatti, Fraternali, & Nipoti; MBW = Mo, van den Bosch & White (2010); BT = Binney & Tremaine (2008); SG = Sparke & Gallagher (2007)

Major Theme	Topics	Additional Reading	Slides + Material
Introduction & review (~2 lectures)	General outlook on galaxies and their ecosystems Basic properties: number density, colors, luminosities, masses Galactic structure, morphological classification Evolution: some key physical processes and their time scales Environment: galaxy groups and clusters, large-scale structure (take-home review of stars and stellar evolution)	MBW 1, 2.1-2.5, 10.2-10.3; BT 1; SG 1	#1 - #2 SG 1.1
Our Galaxy & its satellites (~6 lectures)	Distribution: stars, gas, dust, metals, relativistic particles Kinematics: solar motion, differential rotation, random motion Dynamics: potential energy, component decomposition Implications on formation history	Bland-Hawthorn+Gerhard 16; BT 2, 8.4	#3 - #8 Disk heating Rotation Dynamics
Disk galaxies (~5 lectures)	Observational summary, scaling relations Stellar orbits in disk potentials Spiral structure & density wave theory Stability of disks Stellar bars	Kennicutt+Evans 12 MBW 2.3.3, 9.5, 11 BT 3.1, 3.2, 6 SG 3, 5	#9 - #13 Stellar orbits in disk potentials Spiral Structure
Elliptical galaxies (~4 lectures)	Observational summary, scaling relations Stellar relaxation Boltzmann, Vlasov, and Jeans equations Applications: mass profiles, intrisic shapes, and rotation	Cappellari 16 MBW 2.3.2, 13.1, 13.4, 13.5 BT 1.2, 4 SG 3.4, 6	#14 - #17 Dynamics of elliptical galaxies
Galactic nuclei & beyond (~5 lectures)	SMBH in our Galaxy Dormant SMBH in nearby galaxies Active galactic nuclei Starburst galaxies Galaxy - CGM - IGM ecosystems		#18 - #19 #20 - #22
Galaxy evolution (~5 lectures)	Chemical evolution: closed- and open-box models Dynamical friction, cannibalism, ram-pressure stripping Tidal interaction, merger, galaxy harassment, strangulation Dependence on look-back time Implications on models of galaxy formation		#23 - #27