ASTR 300

Galaxies

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HCG59 NASA/HST

About the course

This course is about galaxies. The emphasis will be on understanding the nature and content of galaxies and clusters of galaxies, and the physical processes that shape them.

Topics we will cover include:

- Properties of normal galaxies
- Elements of stellar dynamics
- Galactic structure, dynamics and evolution
- Groups and clusters of galaxies
- The interstellar and intergalactic medium
- Active galaxies and quasars
- Large scale structure

Assumed background

The course is intended primarily for physics and astronomy majors and honours students. You are expected to have taken second-year physics and math courses, and an introductory astronomy course.

Familiarity with Newtonian mechanics, introductory E & M and quantum physics, and vector algebra is assumed. We will use multivariate and vector calculus and solve simple differential equations.

Some computing skills, including programming, may also be useful.

Prerequisites:
ASTR 200 or 205 and one of PHYS 210, EOSC 211, CPCS 302 or 303

Corequisites:
One of MATH 217, 227 or 317.

Learning goals

Naturally, your goal should be to learn as much about the subject as possible!

After taking this course you should be able to:

- Describe the various types of galaxies, their content and physical structure.
- Discuss the orbital motion of stars and gas in galaxies, and the nature of spiral structure.
- Explain how galaxies formed and how they evolve
- Discuss the evidence for dark matter and dark energy, and the possible forms that these may take.
- Formulate and solve problems involving all aspects of galactic astrophysics.

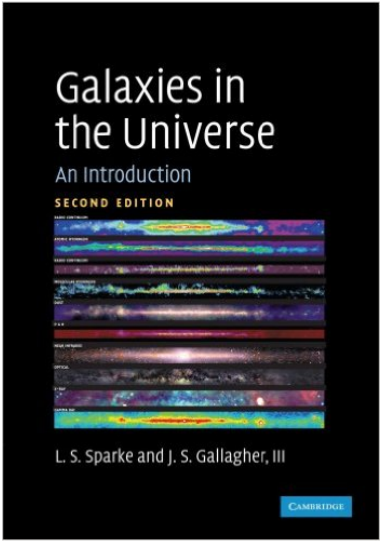
Resources

Instructor	Prof. Jeremy Heyl HENN 417 Office hours W 1200-1300 or email me heyl@phas.ubc.ca
Course website	wiki.ubc.ca/Course:ASTR300
Course notes	The viewgraphs (thanks to Paul Hickson) are on the website now.
Internet	There are many astronomy-related websites (eg. NASA, ESA, HST, ESO...) which have information on facilities, discoveries, etc.

Text book

The required text book is *Galaxies in the Universe* (second edition) by Linda S. Sparke and John S. Gallagher, III, Second Edition, Cambridge University Press 2007.

Soft-cover copies are available at amazon.ca for $114.95 (new, less for used) and at the UBC bookstore.



Course evaluation

Assignments	40%
Midterm exam	10%
Final exam	50%

Homework will be assigned each week, and is due by 5 pm on the Wednesday of the following week. You may work together but you must submit your own written answers. The lowest grade will be dropped when computing the final average.

Late homework assignments will not be accepted.

The midterm exam will be held on October 25.

The final exam will be scheduled in December.

Examination policy

Exams will be *open book*. You can consult the text book and your notes, but not your neighbours, or the internet.

If you miss the midterm exam, please come and see me without delay.

If you miss the final exam, you will need to ask your faculty advising office to grant you permission to write a deferred exam. You will need to demonstrate that you completed all other components of the course.

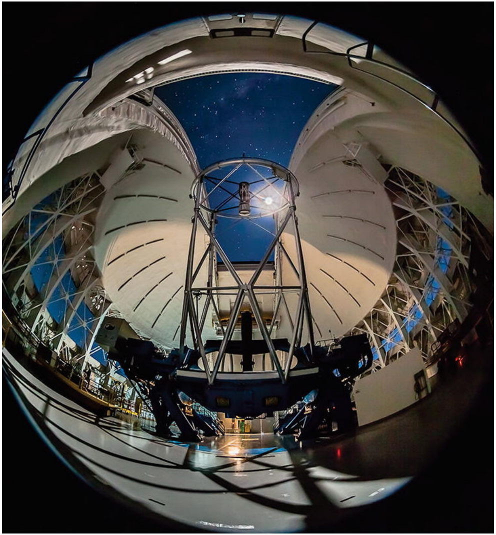
Important dates

Sep 6	Start of classes
Sep 19	Last day for dropping the course without a "W"
Oct 13	Last day to withdraw from the course, with a "W"
Oct 25	Midterm exam
Dec 1	Last day of classes
Dec 5 – 20	Exam period

Course outline

Chapter 1. Introduction

- Astronomical measurements
- The stars
- Our Milky Way
- Other galaxies
- Galaxies in the expanding Universe
- The pregalactic era: a brief history of matter



Gemini Observatory

Course outline

Chapter 2. Mapping our Milky Way

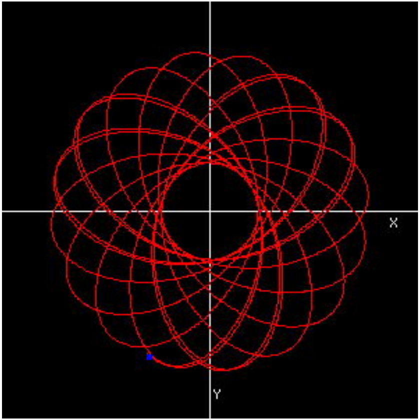
- The solar neighbourhood
- The stars in the Galaxy
- Galactic rotation
- Milky Way meteorology: the interstellar gas

Wikimedia

Course outline

Chapter 3. The orbits of the stars

- Motion under gravity: weighing the Galaxy
- Why the Galaxy isn't bumpy: two-body relaxation
- Orbits of disk stars: epicycles
- The collisionless Boltzmann equation

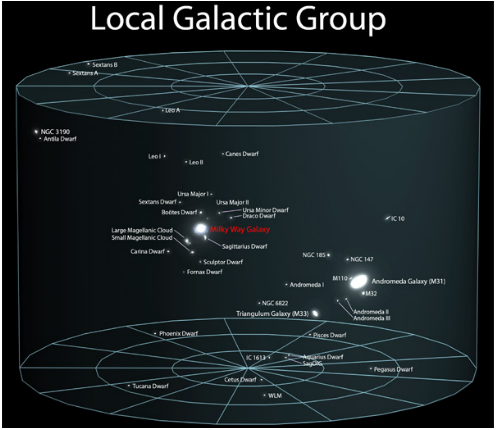


astr.cwru.edu

Course outline

Chapter 4. Our backyard: the Local Group

- Satellites of the Milky Way
- Spirals of the Local Group
- How did the Local Group galaxies form?
- Dwarf galaxies in the Local Group
- The past and future of the Local Group

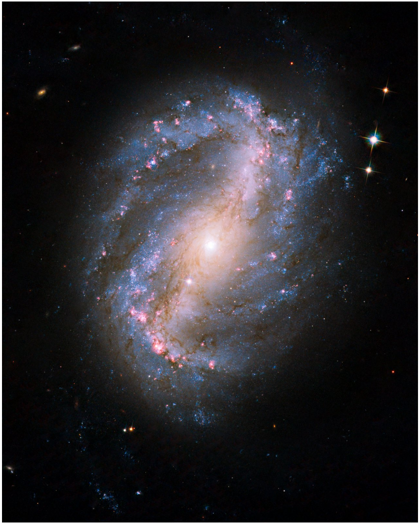


Richard Powell, Atlas of the Universe

Course outline

Chapter 5. Spiral and S0 galaxies

- The distribution of starlight
- Observing the gas
- Gas motions and the masses of disk galaxies
- Interlude: the sequence of disk galaxies
- Spiral arms and galactic bars
- Bulges and centres of disk galaxies



NGC 6217 NASA/ESA/HST

Course outline

Chapter 6. Elliptical galaxies

- Photometry
- Motions of the stars
- Stellar populations and gas
- Dark matter and black holes

NGC 5128 CFHT

Course outline

Chapter 7. Galaxy groups and clusters

- Groups: the homes of disk galaxies
- Rich clusters: the domain of S0 and elliptical galaxies
- Galaxy formation: nature, nurture, or merger?
- Intergalactic dark matter gravitational lensing

Seyfert's Sextet NASA/ESA/HST

Course outline

Chapter 8. Large scale distribution of galaxies

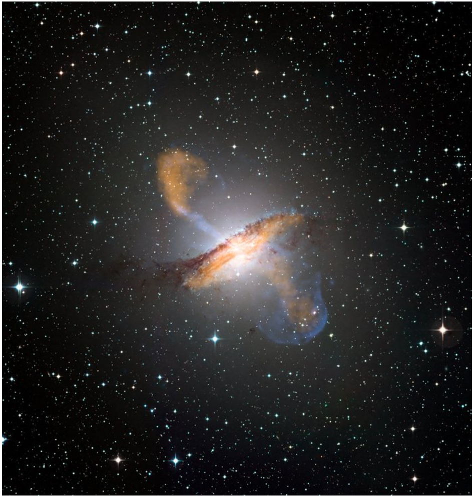
- Large-scale structure today
- Expansion of a homogeneous Universe
- Observing the earliest galaxies
- Growth of structure: from small beginnings
- Growth of structure: clusters, walls, and voids

Abell 2151, the Hercules Cluster, Bob Franke

Course outline

Chapter 9. Active galactic nuclei and the early history of galaxies

- Active galactic nuclei
- Fast jets in active nuclei, microquasars, and γ-ray bursts
- Intergalactic gas
- The first galaxies



Centaurus A, x-ray+visible+radio, ESO

Units

Astronomers employ a wide variety of special units, driven primarily by the need to describe quantities that are far from the metres kilograms and seconds of human experience.

Although the Système International (SI) system remains the primary standard, we shall employ astronomical units whenever it is convenient.

In addition, one should be aware that the "cgs" system of units is widely employed by the astronomical community.

Common astronomical units

Julian year	yr	3.156×10^7 s
Astronomical unit	AU	1.496×10^{11} m
Light year	ly	9.461×10^{15} m
Parsec	pc	3.086×10^{16} m
Angstrom	Å	10^{-10} m
Arcsec	arcsec	4.848×10^{-6} rad
Jansky	Jy	10^{-26} W m^{-2} Hz^{-1}
Electron volt	ev	1.602×10^{-19} J
Solar radius	$R_\odot$	6.955×10^8 m
Solar mass	$M_\odot$	1.989×10^{30} kg
Solar luminosity (bolometric)	$L_\odot$	3.839×10^{26} W
Earth radius (mean)	$R_\oplus$	6.371×10^6 m
Earth mass	$M_\oplus$	5.974×10^{24} kg

Common physical constants

Planck's constant	h	6.626×10^{-34} J s
Newton's constant	G	6.674×10^{-11} N m^2 kg^{-2}
Boltzmann's constant	k	1.381×10^{-23} J K^{-1}
Speed of light	c	2.998×10^{8} m s^{-1}
Electron charge	e	1.602×10^{-19} C
Electron mass	m_e	9.109×10^{-31} kg
Hydrogen atom mass	m_{H}	1.674×10^{-27} kg
Stefan-Boltzmann constant	σ_{SB}	5.670×10^{-8} W m^{-2} K^{-4}
Fine structure constant	$\alpha = e^2/\hbar c$	$1/137.036$

Natural units

It is common for theorists to use “natural units” in which the speed of light is equal to 1. In this system length and time have the same units (m or s).

Since $E = mc^2$, energy and mass then have the same units.

One can take this further and set the reduced Planck constant $\hbar = h/2\pi = 1$. Since $E = \hbar\omega$, energy and mass have units of inverse time.

Coulomb’s law, Maxwell’s equations, etc. take the same form as in SI units, but with $\varepsilon_0 = \mu_0 = 1$.

Finally, one can set Boltzmann’s constant $k = 1$, in which case temperature and energy have the same units.

Equations are simpler in natural units. If needed, one can convert them to SI units by inserting factors of c, $\hbar$ and k by dimensional analysis.