Galaxies and Cosmology – AST 222H1-S (LEC0101)

PROFESSOR JEREMY WEBB

MWF 12:10-1:00 PM, ROSEBRUGH BUILDING - RS 208

Course Description

This survey course offers a description of the Universe ranging in scale from our own Galaxy to the entire Universe in time and space, with emphasis on the application of basic concepts of modern physics. Topics covered include: the structure and contents of the Milky Way, properties of external disk and elliptical galaxies, clusters of galaxies, active galaxies and quasars, the high-redshift Universe, large scale structure and cosmology, the early Universe, and the formation of structure in the Universe. AST 221 is a prerequisite.

Instructor

Prof. Jeremy Webb
Office: Astronomy Building (AB), Room 214, 50 St. George Street
Contact: jeremy.webb@utoronto.ca
Office hours: Monday 1:00-2:00pm (or by appointment)

TAs:
Ariel Amaral (amaral@astro.utoronto.ca)
Jessica Campbell (campbell@astro.utoronto.ca)
Ryan Mckinven (mckinven@astro.utoronto.ca)

Email policy: Email should be used for urgent matters. Questions for which the answer is in this syllabus or questions about the assignments should be posed during office hours (preferred), after class, or on the QUERCUS discussion board. I will typically respond to email within two business days. When emailing, please include the class code (AST222) in the subject heading.

Course Rationale

After learning about the Sun and the solar system that formed around it in AST 221, this course will establish where that system fits into the grand scheme of the Universe. We will "Tour the Universe", moving outwards in space and backwards in time from our current location. When combined, AST 221 and AST 222 are meant to leave you with a general sense of what the Universe is and how it all works.

TA Help Sessions

Time and place to be determined, check Quercus for announcement

Every week the TAs will host a two-hour help session where you can ask questions related to the course and the assignments. This is also a good opportunity to work together with your classmates on the assignments, with the TAs on hand to answer questions as they come up. You are encouraged to work together on the assignments, but each student needs to provide their own write-up without copying from other students.

Learning Objectives

The learning objectives of this course are as follows:

- Know and recognize the key properties (size, shape, mass, density, profiles) of different types of galaxies.
- Be able to explain how galaxies form and evolve over time.
- Understand why dark matter is believed to exist, how it affects galaxies, and how we can study it both directly and indirectly.
- Develop a working understanding of how the early Universe behaved for a given cosmological model and what present-day observations can be used to study the early Universe.

Required Materials

The required textbook for this class is

"An Introduction to Modern Astrophysics", by B. Carroll & D. Ostlie, 2nd Edition

Another good textbook to consult is

"Extragalactic Astronomy and Cosmology", by P. Schneider, 2nd Edition

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

(If this link doesn't work, try searching for the book at http://link.springer.com/search; on the book page, you should see a link to download the PDF near the top of the page).

Quercus

We will be making use of Quercus, the online course management system. **You are responsible for monitoring the course Quercus page and your @utoronto.ca email address for announcements, assignments, etc. on a daily basis.** Please check immediately that you can login and seek help if you cannot.

Grading Scheme

Grading for this course will be based on 5 problem sets, a midterm, and a final exam. You are encouraged to work together on the assignments, but each student needs to provide their own write-up without copying from other students.

Problem Sets	**45%**
Midterm	**20%**
Final exam	**35%**
Pop Talk Bonus (see below)	**1%**

Pop Talks

For those interested, there is also an opportunity to earn a 1% bonus by doing a 1-minute pop-talk at the beginning of class (although your final mark cannot exceed 100%). The goal of the pop-talk will be to discuss a topic from the readings, without the use of jargon. A sign-up sheet will be provided.

Computational Physics

A significant part of scientific research is centered around using computers to analyse data and perform simulations. Astronomy is no exception, whether you are analyzing large datasets from an observational survey or simulations of how galaxies form and evolve. A ***minor*** goal of this course is to expose student's to some basic computer programming through the problem sets.

In this course, we will introduce and use the PYTHON programming language to help solve problems in astronomy. The Jupyter Notebook interface will be used to help introduce students to the world of programming.

Late Work

Assignments are due at the start of the lecture during which they are due, indicated in the Course Outline below. **Late work will not be accepted.**

Exceptions to this policy will be made only upon receipt of medical documentation on the University's standard form, available at

http://www.illnessverification.utoronto.ca/

Exceptions due to a non-medical emergency require a note from your college's registrar.

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.

(Continued on next page)

Course Outline

Week	Lectures	Topic	Work Due on Wed / Notes	Reading C&O*
#1	Jan. 6/8/10	Practicalities & Intro; Fundamentals: Theory & Observations		
#2	Jan. 13/15/17	Milky Way structure, Milky Way kinematics	Fri tutorial	24.1,24.2, 24.3
Learning Goals:		The Milky Way: • The properties (size, shape, mass, density profiles) of its main components (stellar disk, gas disk, bulge, stellar halo, dark-matter halo) • How the components fit together The phenomenology of spiral structure: • Number of arms, pitch angle, well-defined vs. flocculent, that spiral arms are trailing • Basics physics of spiral arm dynamics (winding problem, anti-spiral theorem, density waves)		
#3	Jan. 20/22/24	Milky Way kinematics; Hubble sequence; spirals	Problem Set 1 Fri tutorial	24.3, 25.1 25.2, 25.3
Learning Goals:		Milky Way Kinematics: • The solar-neighbourhood description in terms of the Oort constants and epicycles • The rotation of interstellar gas • The Sun's motion in the Milky Way The Hubble Sequence		
#4	Jan. 27/29/31	Elliptical galaxies, scaling relations; Groups & clusters of galaxies		25.4 PS 3.4 27.3
Learning Goals:		Elliptical Galaxies • Shape (oblate, prolate, triaxial; what does EX mean?), • Types (normal, cD, dwarf ellipticals, …) • Brightness profile • Internal dynamics (collisional relaxation, pressure support vs. rotational support) Galaxy scaling relations: • Tully-Fisher, Faber-Jackson, fundamental plane, etc.): • What are they and which types of galaxies do they apply to		

		• Why are they important • How can they be used to obtain distances to distant galaxies? Groups and clusters of galaxies: • Basic properties (size, mass, contents) • Techniques for measuring their mass (dynamics, lensing) • The Local Group: main galaxies, mass		
#5	Feb. 3/5/7	Gravitational lensing	Problem Set 2 Fri tutorial	PS 2.5, 3.11
Learning Goals:		• Lensing equation and lensing by a point source • Einstein rings and magnification • Microlensing • Weak and strong lensing		
#6	Feb. 10/12/14	Dark matter	Midterm on Fri. (**in class**)	
Learning Goals:		• Rotation curves and how they show the presence of dark matter • Amount of dark matter in large and small galaxies • Candidates for dark matter (MACHOs, WIMPs, axions)		
		-----READING WEEK-----		
		-----NO CLASS-----		
#7	Feb. 24/26/28	Galaxy formation and evolution	Fri tutorial	PS 10.1/2/4
Learning Goals:		• The importance of gas cooling in setting the size of galaxies • When do large and small galaxies form? • The Eggen-Lynden-Bell-Sandage (ELS) picture of galaxy formation, • The Searle & Zinn picture • Current hierarchical structure formation model • Dynamical friction		
#8	Mar. 2/4/6	Active galaxies and quasars; central black holes	Problem Set 3	28.1,28.2, 28.3, PS 3.8
Learning Goals:		Active galaxies and galactic nuclei (AGN and quasars): • What is an AGN? • Basic structure of an AGN (black hole, accretion disk, torus, broad-line region, narrow-line region, jet) • Size of the accretion region Central supermassive black holes: • The Milky Way's central black hole (mass, region of influence) • Scaling relations for black holes and galaxy properties		

#9	Mar. 9/11/13	Distance scale; Universe’s expansion	Fri tutorial	27.1,27.2
Learning Goals:	• Parallax • Photometric distances • Variable stars • Type Ia supernovae distances.			
#10	Mar. 16/18/20	Newtonian cosmology	Problem Set 4 Fri tutorial Last drop Mar. 15	29.1
Learning Goals:	Basics of observational cosmology: • Hubble law for the expansion of the Local Universe and how this is determined • The basic properties of the cosmic web • The scale on which the Universe becomes homogeneous • Homogeneity and isotropy • Olber’s paradox Simple cosmological models: • Scale factor and comoving distances • Simple pressure-less dust Universe • Friedmann equations (expansion and acceleration) for the scale factor • Evolution of components with pressure (radiation, dark energy, general case of an equation of state) • Expansion of a multi-component Universe			
#11	Mar. 23/25/27	The early Universe; inflation; the growth of structure	Problem Set 5 **(due on Fri)**	29.2, 30.1, 30.2
Learning Goals:	• Matter-radiation equality • The formation of He • The basics of the CMB • The flatness and horizon problems • Basic picture of inflation			
#12	Mar. 30 Apr. 1/3	Simulations & Review	Fri tutorial	

* PS = Peter Schneider “Extragalactic Astronomy and Cosmology”

Keys to Success

- Have an open mind:
  - The Universe is a rather abstract concept, and we often don't have any natural intuition for understanding some of its properties and its components. Do not worry if certain concepts seem "out of this world". Embrace the craziness! Be curious! Be patient! As more and more pieces fall into place we will develop our own astronomy-based intuition together. You will be surprised at how much of the Universe can be understood using Earth-bound physics.
- Reading:
  - To be successful in this course and achieve the learning goals discussed above, student's need to look no further than the Course Outline. In the Course Outline each week's topic and the sections of the textbook that corresponding to the topic are listed. I highly recommend reading the textbook BEFORE class, so you have a general understanding of each topic before we discuss the finer details. Furthermore, reading the text also offers a different approach to introducing you to course material.
- Understand the Assignments:
  - This one may seem like a no-brainer, as assignments are worth 45% of your final mark, but the keyword here is UNDERSTAND. Assignments are where you learn by doing, which for many of us is the most effective method of learning anything. So don't just work to get an answer that looks right. Don't just "do the math". Make sure, from an astronomy and physics perspective, that you really know what's going on. If you do not, see the next key to success.
- Utilize your resources:
  - This class has a professor who wants every single student to come away from this course with a newfound passion and interest for all things astronomy. This professor also has office hours and doesn't mind sticking around after class to answer questions. USE YOUR PROFESSOR! If anything from class is not clear to you, then chances are it's your professor's fault. So come ask me about it, and let's work things out together.
  - This class also has multiple teaching assistants who will be running tutorials and help session. Attend both! Ask the TA's questions, even if they aren't necessary assignment questions. They want to help too!
  - This class has a large number of students. Use each other! Studies have shown that students learn best from their own classmates. So talk after class, in tutorials, post questions on QUERCUS. Chances are at least one fellow student has the same question as you and another student has an explanation that will help things "click".