Spring 2-1-2019

ASTR 353.01: Galactic Astrophysics

Nathan T. McCrady
University of Montana - Missoula, nate.mccrady@umontana.edu

Astronomy 353: Galactic Astrophysics

University of Montana
Spring 2019
MWF 10:00 – 10:50 am
CHCB 231
Course Number 34483

Professor Nate McCrady
e-mail: nate.mccrady@umontana.edu
Office: 122 CH Clapp Building
Office Hours: MW 11a-12p, F 1-2p and by appointment

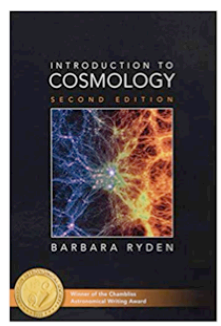
Course Description
Galaxies are gravitationally bound systems typically containing billions of stars. In this course, you will investigate the structure, contents, and dynamics of our Milky Way galaxy. You will study the morphology, distribution, formation history, dark matter content, and evolution of other galaxies. While galaxies are inherently interesting objects of study, on cosmological scales they represent mere markers that trace the distribution of matter and demonstrate the expansion of the Universe. You will learn about the large scale structure of the Universe, nucleosynthesis in the hot, dense Big Bang, the cosmic micromave background radiation, and dark energy, and apply concepts from General Relativity to decipher the expansion history and future of the Universe.

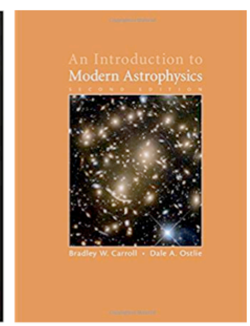
Course Objectives
My goals in this course are to…

1. Introduce the contents, structure and evolution of galaxies.
2. Apply General Relativity to the expansion history and future of the Universe.
3. Introduce the fundamental experiments that constrain cosmological theories.

Text Materials
Introduction to Cosmology, 2nd Ed.
by Barbara Ryden (required)

An Introduction to Modern Astrophysics, 2nd Ed.
by Carroll and Ostlie
(recommended, required in Astr 363 & Astr 365)





Expectations of the Professor
This upper-division course is intended for physics majors with a concentration in astrophysics. I expect that you will have completed the designated pre-requisite courses: Astronomy 132 or 142 (introductory astronomy) and Physics 217/218 (physics with calculus). It is advantageous if you have also taken Physics 343 (modern physics), but we will study the necessary relativity, and atomic and nuclear physics within this course. You should also be comfortable working with logarithms, scientific notation and the Greek alphabet! Time in the classroom is an essential part of this course, and it will be to your benefit to attend class meetings. Exams and homework will

be based primarily on material presented in class. This syllabus includes assigned readings. *I expect students to read the material in advance of the class on a topic, and to be prepared to discuss the material in class.*

This course is a collaborative effort – please ask questions, offer your ideas and be prepared to participate in the discussion. Written work submitted in this course must be expressed in your own words. I specifically encourage students to work together, but each student must write up their own response to problems. This step is essential to your learning – writing up the answer to a question requires you to understand the conclusion of your group, whereas transcription of the work of another does not. When in doubt, please ask me what is acceptable.

And of course, while in class, please silence your phones and other electronic gadgets. Laptops are acceptable for note-taking, if you so desire.

Pedagogical Philosophy of the Professor

My primary goal in teaching upper-division majors is to help you develop physical intuition and apply principles of fundamental physics learned in introductory coursework. This class in particular is an advanced course in astrophysics, a field of applied physics. As with any applied field, there is a significant amount of vocabulary specific to the discipline. This course will help develop your fluency in the language of galactic astrophysics and cosmology.

Research in how people learn indicates that the knowledge of an expert in a topic is organized around core concepts. In order to help you develop expertise in galactic astrophysics, I have organized this course around several core concepts. These are outlined on the class schedule in this syllabus. Each concept is associated with a number of specific learning goals, a complete list of which I will provide you for use as a study aid. Each learning goal is stated from the student's perspective. If you can achieve these specific goals, you will succeed in this course – and be well on your way towards expertise in galactic astrophysics!

Grading Policy

This course will be graded on the University's traditional letter grade system. Your grade will be based on three midterm exams (15% each), a cumulative final exam (25%), and weekly homework sets (30% total). I have not determined in advance how many As, Bs, etc will be assigned – I'm happy to give every student an A if they demonstrate mastery of the material. Along the way I will provide regular updates regarding your grade in the course via Moodle.

Midterm exams take place during regular class time on the scheduled days unless a longer evening time is selected by agreement of the class. If you cannot be present, tell me *before* the exam and we can discuss arrangements. For *well-documented* compulsory absences, we will arrange a time for you to take the exam *early*.

Homework must be turned in <u>by 5pm on the due date</u> (generally Fridays). Late homework will be penalized by 10% per workday to a minimum of 50%. Homework must be legible! If your first attempt is messy, use it as a draft to rewrite a final version for submission. If I can't read it easily, you'll get no credit!

Course Schedule & Reading Assignments

			Readings
		OUR GALAXY	
F	Jan 11	Milky Way overview, review of stellar physics	CO 3.2, Table 8.1
M	Jan 14	Mapping the Milky Way	CO 24.1
W	Jan 16	Milky Way components, stellar kinematics	CO 24.2
F	Jan 18	Galactic rotation	CO 24.3
M	Jan 21	*Martin Luther King, Jr. Holiday*	
W	Jan 23	Galactic center and the supermassive black hole	CO 24.4
F	Jan 25	The Local Group	CO pp 1058-61
		OTHER GALAXIES	
M	Jan 28	Disk galaxies	CO 25.1, 25.2
W	Jan 30	Elliptical galaxies	CO 25.4
F	Feb 1	Galaxy collisions and mergers, starbursts	CO 26.1
M	Feb 4	Active galactic nuclei	CO 28.1, 28.2
W	Feb 6	Groups and clustering, galaxy distribution	CO 27.3
F	Feb 8	Galaxy evolution	CO 26.2
M	Feb 11	**Midterm 1**	
		COSMOLOGY: OBSERVATIONS	
W	Feb 13	Olbers paradox and Hubble law	R Ch. 1
F	Feb 15	Expansion, particles and the CMB	R Ch. 2
M	Feb 18	*Washington-Lincoln Holiday*	
		RELATIVISTIC COSMOLOGY	
W	Feb 20	Gravity: Newton vs Einstein	R 3.1, 3.2, 3.3
F	Feb 22	Curvature, Robertson-Walker metric	R 3.4, 3.5, 3.6
M	Feb 25	Cosmic dynamics: Einstein & Friedmann eqns	R 4.1, 4.2
W	Feb 27	Fluid eq, equation of state, Λ	R 4.3, 4.4, 4.5
F	Mar 1	Model universes: empty universes	R 5.1, 5.2
M	Mar 4	Model universes: single-component universes	R 5.3
W	Mar 6	Model universes: multiple-component universes	R 5.4
F	Mar 8	Model universes: benchmark model	R 5.5
M	Mar 11	**Midterm 2**	
		PRECISION COSMOLOGY	
W	Mar 13	H_0, q_0, luminosity distance	R 6.1, 6.2
F	Mar 15	Angular diameter, Cepheids and H_0	R 6.3, 6.4
M	Mar 18	Type Ia supernovae, accleration, dark energy	R 6.5
		DARK MATTER	
W	Mar 20	Visible and dark matter in galaxies & clusters	R 7.1, 7.2, 7.3
F	Mar 22	Gravitational lensing, dark matter candidates	R 7.4, 7.5

		THE EARLY UNIVERSE	
M	Apr 1	CMB: observations	R 8.1, 8.2
W	Apr 3	CMB: epoch of recombination, fluctuations	R 8.3, 8.4, 8.5
F	Apr 5	The first three minutes	R 9.1, 9.2
M	Apr 8	Big Bang nucleosynthesis	R 9.3, 9.4
W	Apr 10	Deuterium abundance, matter/antimatter	R 9.5
F	Apr 12	**Midterm 3**	
		LARGE SCALE STRUCTURE	
M	Apr 15	Structure formation, Jeans length	R 11.1, 11.2
W	Apr 17	Evolution of density fluctuations	R 11.3, 11.4
F	Apr 19	ΛCDM model	R 11.5, 11.6
M	Apr 22	Structure formation: baryons & photons	R 12.1, 12.2, 12.3
W	Apr 24	Making stars and galaxies	R 12.4, 12.5
F	Apr 26	Review	
W	May 1	**Final Exam, 10:10am – 12:10pm**	

CO: Carroll & Ostlie *R: Ryden*

Additional Reading

There are many excellent texts on the subjects of galactic astrophysics and cosmology, many of which were used to prepare course material. The texts marked with stars are classics in the field.

Galaxies in the Universe, 2nd Ed., L. Sparke & J. Gallagher, 2007

Galactic Astronomy, J. Binney & M. Merrifield, 1998 ★

Active Galactic Nuclei, J. Krolik, 1998

Galaxy Formation, M. Longair, 2000

Principles of Physical Cosmology, J. Peebles, 1993 ★

Gravity: An Introduction to Einstein’s General Relativity, J.B. Hartle, 2003

A General Relativity Workbook, T. Moore, 2013

Structure Formation in the Universe, T. Padmanabhan, 1993 ★

A Brief History of Time, S. Hawking, 1998