

Astronomy 301:

Cosmology and Gravitational Collapse

San Diego State University

Fall 2011

Lecture time and location:

Section 1 (Schedule Number 20295): T/Th 11:00 AM — 12:15 PM, Rm. PA 216
(Physics-Astronomy building).

Instructor: Douglas Leonard

Office: Room 238, Physics building

Email: leonard@sciences.sdsu.edu [Note: "Plain-text" emails strongly preferred!]

Telephone: 619-594-2215

Office Hours: Friday 12:00 — 2:00 PM (no appointment needed, just drop by; other days/times available by appointment)

Website: <http://sciences.sdsu.edu/~leonard/astro301>

Required Course Material: Text: *Your Cosmic Context: An Introduction to Modern Cosmology*, first edition, by Todd Duncan & Craig Tyler.

Course Description

This course considers the universe on the grandest scales (cosmology) and during its most extreme moments (gravitational collapse of stars to form neutron stars and black holes through supernova explosions). Material is derived primarily from the course textbook (*Your Cosmic Context: An Introduction to Modern Cosmology*, by Todd Duncan & Craig Tyler). Through this work and class discussions we shall consider scientific breakthroughs with a particular emphasis on the interplay between the use of the "scientific method", and the (very) human process by which scientific discoveries are made. The class assumes no prior background in astronomy, although a general knowledge of science at the high-school level will be helpful. Mathematics will be limited to algebra and geometry.

Prerequisite: Completion of the General Education requirement in Foundations II. A.1. Physical Sciences.

Student Learning Objectives

Upon completing this course, you should be able to:

- Articulate the fundamental philosophical and physical differences between Isaac Newton's conception of gravity and Albert Einstein's Theory of General Relativity;
- Describe the physical location of the Earth with respect to the other constituents of the observable universe, and articulate the process by which humans attained this understanding;
- Convince a fellow student who has never taken an astronomy class that it is possible to determine the chemical constituents of a star without ever visiting it, through the careful analysis of its light;
- Explain the process by which stars, like our sun, produce energy;
- Construct an argument based on astronomical observations that the universe has evolved from a hot, dense state;
- Present the currently favored scientific theory for what the ultimate fate of our universe will be, and outline the astronomical observations upon which the theory is based;
- Read and comprehend articles concerning astronomy that appear in the popular press, and participate in discussions about them;
- Describe at least three major areas in which our astronomical knowledge is known to be incomplete.

Course Schedule¹

Week 1 (August 30 → September 5): *Starting Points*

Topics covered – The nature of science: scientific theories and falsifiability; reading graphs; introduction to cosmology.

Readings from text – Chapter 1.

- Online Reading Quiz #1 and Thought Question #1 due Sunday, September 4, 11:55 PM.

Week 2 (September 6 → September 12): *The Sky We See*

Topics covered – Looking into the sky: Stars vs. nebulae; galaxies; planets; light as a wave: wavelength, frequency, velocity; the electromagnetic spectrum; emission and absorption spectra; Doppler Effect; light as a time machine; parallax; proper motion.

Readings from text – Chapter 2.

- Online Reading Quiz #2 and Thought Question #2 due Sunday, September 11, 11:55 PM.

Week 3 (September 13 → September 19): *The Universe We Discover Through Heat and Light*

Topics covered – Atoms and quantum mechanics (brief introduction); light as a particle: Photons; temperature; standard candles in astronomy and the inverse square law of light propagation: Cepheid variable, the Tully-Fisher and Faber-Jackson relations, Type Ia supernovae; astronomical “distance ladder”; our place in the universe (brief overview).

Readings from text – Chapter 3.

- Online Reading Quiz #3 and Thought Question #3 due Sunday, September 18, 11:55 PM.
→ Optional planetarium show Friday, September 16, 12:00 – 1:00 PM.

Week 4 (September 20 → September 26): *The Universe We Discover Through Motion and Gravity*

Topics covered – Newton’s conception of gravity and his Universal Law; gravitational binding energy; kinetic energy; motion of stars in galaxies; galaxy structure: Galaxy bulges, disks, and spiral structure; discovery of dark matter’s existence, and speculations as to what it might be.

Readings from text – Chapter 4.

- Online Reading Quiz #4 and Thought Question #4 due Sunday, September 25, 11:55 PM.

Week 5 (September 27 → October 3): *Clues About the Cosmos*

Topics covered – Redshifts of galaxies; the Hubble Law; distribution of galaxies; cosmic microwave background (briefly); atoms and the periodic table of elements; the age of things in the universe; Olbers’s paradox.

Readings from text – Chapter 5.

- Online Reading Quiz #5 and Thought Question #5 due Sunday, October 2, 11:55 PM.
→ Optional “star party” Thursday, September 29, 6:30 PM.

¹All dates subject to changes announced in class. Please consult each week’s *Weekly Handout* for the specific readings assigned each week.

Week 6 (October 4 → October 10): *Putting the Clues Together, Part I*

Topics covered – Questions, summary, and review of material covered thus far.

→ **Midterm Exam #1 taken in class on Thursday, October 6.**

Week 7 (October 11 → October 17): *General Relativity and the Fabric of Spacetime*

Topics covered – Einstein’s General Theory of Relativity: Curved space and the equivalence principle; testing general relativity: Gravitational lensing and gravitational waves; black holes; quasars; Einstein’s legacy.

Readings from text – Chapter 6.

- Online Reading Quiz #6 and Thought Question #6 due Sunday, October 16, 11:55 PM.

Week 8 (October 18 → October 24): *An Expanding Universe*

Topics covered – Cosmological horizon; cosmic expansion; the Friedmann equation and the cosmic scale factor; introduction to “dark energy”; Hubble law revisited; cosmological redshift; the discovery of the decade (century?): The accelerating universe.

Readings from text – Chapter 7.

- Online Reading Quiz #7 and Thought Question #7 due Sunday, October 23, 11:55 PM.

Week 9 (October 25 → October 31): *Photons and Electrons*

Topics covered – Blackbody radiation; Bohr’s incorrect atomic model (and why we still use it); quantum mechanics and atomic structure; the quantum atom; electron scattering of photons; cosmic microwave background (CMB): anisotropies and polarization.

Readings from text – Chapter 8.

- Online Reading Quiz #8 and Thought Question #8 due Sunday, October 30, 11:55 PM.

Week 10 (November 1 → November 7): *The Nuclear Realm*

Topics covered – Energy; forms of energy; powering the stars with nuclear fusion; how stars live and die; gravitational collapse of stars and their explosions as supernovae; neutrinos; the search for weakly interacting massive particles (WIMPS); abundances of the elements.

Readings from text – Chapter 9.

- Online Reading Quiz #9 and Thought Question #9 due Sunday, November 6, 11:55 PM.

Week 11 (November 8 → November 14): *The Big Bang Theory*

Topics covered – Overview of the Big Bang Theory; cosmic expansion revisited; how the Big Bang explains it all; pie-chart of the universe’s constituents; evaluating the Big Bang “Theory”.

Readings from text – Chapter 10.

- Online Reading Quiz #10 and Thought Question #10 due Sunday, November 13, 11:55 PM.

Week 12 (November 15 → November 21): *Putting the Clues Together, Part II*

Topics covered – Questions, summary, and review of material covered thus far.

→ **Midterm Exam #2 taken in class on Thursday, November 17.**

Week 13 (November 22 → November 28): *History, Density, and Destiny*

Topics covered – Density of the universe; curvature of the universe; a brief history of time: baryogenesis, electroweak unification, annihilation, reionization; fate of the universe; dark energy possibilities.

Readings from text – Chapter 11.

- Online Reading Quiz #11 and Thought Question #11 due Sunday, November 27, 11:55 PM.
- Note: No class on Thursday, November 24 (Thanksgiving!).

Week 14 (November 29 → December 5): *The Story of Structure*

Topics covered – Reading the map of the CMB; precision cosmology; cold halos, galaxies, and the dark universe; cosmic inflation and the very, very, very early universe.

Readings from text – Chapter 12.

- Online Reading Quiz #12 and Thought Question #12 due Sunday, December 4, 11:55 PM.

Week 15 (December 6 → December 12): *An Ending*

Topics covered – What have we learned? Anthropic thoughts; multiverses; cosmic timeline; outstanding questions; Sisyphian nightmares and happiness.

Readings from text – Chapter 14.

→ Note: The last class is Thursday, December 8.

Week 16 (December 13 → December 19): *Final Paper*

→ Final paper due by 12:00 PM (noon), Thursday, December 15.

The Role of Astronomy 301 in San Diego State University's General Education Program: "Explorations of Human Experience"

Explorations Courses that fulfill the 9-unit requirement for Explorations in General Education take the goals and skills of GE Foundations courses to a more advanced level. Your three upper division courses in Explorations will provide greater interdisciplinary, more complex and in-depth theory, deeper investigation of local problems, and wider awareness of global challenges. More extensive reading, written analysis involving complex comparisons, well-developed arguments, considerable bibliography, and use of technology are appropriate in many Explorations courses.

This is an Explorations course in Natural Sciences. Completing this course will help you learn to do the following with greater depth: 1) explain basic concepts and theories of the natural sciences; 2) use logic and scientific methods to analyze the natural world and solve problems; 3) argue from multiple perspectives about issues in natural science that have personal and global relevance; 4) use technology in laboratory and field situations to connect concepts and theories with real-world phenomena.

Assignments and Course Grades

Course grades are based on the following scale:

Grade	Percentage
A	92.50 – 100%
A-	89.50 – 92.49%
B+	87.00 – 89.49%
B	82.50 – 86.99%
B-	79.50 – 82.49%
C+	77.00 – 79.49%
C	72.50 – 76.99%
C-	69.50 – 72.49%
D+	67.00 – 69.49%
D	62.50 – 66.99%
D-	59.50 – 62.49%
F	< 59.49%

Students taking the course using the credit/no credit option (“Cr/NC”) will receive a grade of “Credit” for achieving an equivalent letter grade of C or better. “No credit” will be given for equivalent letter grades of C- and below.

The final course grade will be determined based on your work in the following areas:

- *On-line homework assignments:* 15% of the course grade in total — 10% for the “Reading Quizzes” and 5% for completion of the “Thought Questions”. Nearly every week (see the “Course Schedule” for specific due dates) there will be two on-line assignments to be completed at the “CengageNOW!” web-site (<http://www.ilrn.com>). Details on these assignments, and how to access and complete them on-line, will be given at the start of the course. *Your lowest two “Reading Quiz” and “Thought Question” grades will be dropped when computing your final homework grade for the course.*
- *Midterm Examination #1:* 25% of the course grade. The first midterm exam will be given in class on **Thursday, October 6**, and is worth 25% of the course grade. The nature of this exam will be discussed in detail a few weeks into the course.
- *Midterm Examination #2:* 30% of the course grade. The second midterm exam will be given in class on **Thursday, November 17**, and is worth 30% of the course grade. The nature of this exam will be discussed in detail before the exam is given.
- *Final Paper:* 30% of the course grade. **There will be no final examination given in this course.** Rather, a final paper will be due at 12:00 PM (noon) on Thursday, December 15 (i.e., the nominal date of the final exam). Details on the nature and content of this final paper will be discussed mid-way through the course.

Please note that no late homework assignments will be accepted for any reason; should you miss a homework assignment, then that will simply be one of the homework grades that is dropped when computing your average for the “homework” component of the course. “Makeup exams” for the two midterms will be considered only for the most dire and verifiable circumstances beyond the control of the student.² Finally, there is no “extra credit” available in this course, and no form of cheating will be tolerated; if cheating is determined to have occurred, it will result in automatic failure in the course and additional disciplinary action by the University.

²To request an exam at a nonstandard time, please read and carefully follow all instructions on the form “Requesting an Exam at a Nonstandard Time”, available at the course web-site (click on “Course Handouts”, and then click on “Requesting an Exam at a Nonstandard Time”). Note that makeup exams will differ from the exams given in class, and may include (or consist entirely of) a one-on-one oral interview with the professor.

Grade Calculator Worksheet

To compute your final grade in the course:

Step 1: Write down all of your on-line Reading Quiz grades (percentage equivalents):

Step 2: Now, cross out the *lowest two* Reading Quiz grades. Add the remaining grades together and divide by the total number of graded Reading Quizzes (i.e., total number of Reading Quizzes given minus 2). Write down that number here:

Step 3: Take the number obtained in step 2, and multiply it by 0.1. Write that number down here, and put a box around it:

Step 4: Write down all of your on-line Thought Question grades (percentage equivalents):

Step 5: Now, cross out the *lowest two* Thought Question grades. Add the remaining grades together and divide by the total number of graded Thought Questions (i.e., total number of Thought Question given minus 2). Write down that number here:

Step 6: Take the number obtained in step 5, and multiply it by 0.05. Write that number down here, and put a box around it:

Step 7: Take your first midterm exam percentage and multiply it by 0.25. Write down that number here, and put a box around it:

Step 8: Take your second midterm exam percentage and multiply it by 0.3. Write down that number here, and put a box around it:

Step 9: Multiply your final paper percentage by 0.3, write that number here, and put a box around it:

Step 10: Add the boxed numbers from Steps 3, 6, 7, 8, and 9 together and write it here. This is your final percentage grade for the course.

Step 11: Use the grade scale given on the previous page to calculate your final letter grade, and write it down here:

In all likelihood, this is your final grade for the course. In *exceptional* cases, if your grade falls near a borderline (i.e., within about 1% or so of the next grade) I may *raise* your grade by up to one mark (e.g., C- to C; B+ to A-, etc.) based on such subjective criteria as my sense of your overall *enthusiasm* for the class and course material. This can be demonstrated in many ways, including “class participation” (note

that giving the sense that you are an engaged listener is considered to be just as important as actively contributing to the discussion), attendance, coming to office hours, evidence of effort and dedication, and so forth. Note that one particular way to demonstrate enthusiasm for the course material is to write very thoughtful responses to the weekly “Thought Questions”; although “any” response to the questions is awarded a 100% for grading purposes, I definitely consider the effort you put into these when deciding whether to “bump up” a student’s final grade. Finally, note of course that I will never *lower* a grade that you have earned; your enthusiasm can only help you.

Strategy

And now, some time-tested tips for success in this class:

- **Do the reading.** Each Tuesday you will be given a “Reading Guide” as part of the weekly handout, which includes the reading assignment for the week – typically, one chapter out of the course textbook. **Doing this reading is vital** to your success in the class. As discussed on the first day, I will *not* be lecturing on everything for which you are responsible – it is up to *you* to do the reading and ask me questions about it! The textbook contains the bulk of the material for which you are responsible in this course.
- **Come to lecture.** This is designed to be a highly interactive class, and so coming to the lectures is an integral part of the learning experience. “Lectures” will come in two varieties: (1) A broad introduction to the material to be read in the textbook (generally, on Thursdays of each week); and (2) A free-ranging question-and-answer session, driven by *your* questions and interests (generally, on Tuesdays of each week, after the reading has been completed). It will be extremely beneficial to attend both classes each week!
- **Use the weekly on-line reading quizzes to test your understanding of the material.** As discussed in class, the best way to “take” the weekly reading quizzes is to *study* the material thoroughly before looking at the quiz; then, print out the quiz and take it off-line as though it is a test. After you’ve done this, *then* look up any answers that you are unsure about before submitting your quiz online. Use of this self-correcting technique will enable you to gauge how well you are mastering the material *before* facing it on an exam, and force you to engage in the material at a high level each week.
- **Get help.** Come to my office hours. Go to TA Help Room hours.³ There are lots of opportunities to get individual assistance with the course material – use them!
- **Study.** Material is covered at a very rapid pace in class, and must be reviewed at home for complete comprehension. **It is expected that you spend at least 6 hours per week studying the material outside of class each week!** Don’t wait until the last minute to prepare for an examination. This course presents a large amount of information, and it can really “catch up to you” if you do not stay current with the readings.
- **Visit the course website, <http://sciences.sdsu.edu/~leonard/astro301>,** when needed. There you will find all of the class handouts and assignments, in case you missed anything. All Powerpoint slides from any lectures are also posted there, usually within a day after the lecture is given.

³The TA Help Room is located in the Physics-Astronomy Building, Rm. PA-215. Hours to be announced.

Other Things

- **Contacting the professor.** Ordered from the *best* way to get in touch with me to absolute *worst* way to get in touch with me:
 1. **Best way:** *Come to office hours.* This is absolutely the best way to get help from me in a one-on-one (or small group) setting. My office hours are a low-pressure environment, and you don't even need to come with specific questions in mind – if you just want to talk about the material in general or have me review some concepts with you that is fine. Office hours are Fridays, from 12:00 — 2:00 PM, in the physics building, Rm. 238, and I strongly encourage you to use them; no appointment is needed. If these hours don't fit your schedule and you must meet with me, let me know and we may be able to work out another time to meet.
 2. **Good way:** *Send me email.* This is an effective way to contact me directly. I am very responsive to emails, often responding within minutes and almost always within 24 hours. When sending me email please, if at all possible, send it to me in “plain text” format. It is difficult for my ancient emailer to read “rich-text” or “HTML-formatted” emails. Usually, you can change the format of your outgoing email by changing the “settings”.
 3. **OK way:** *Catch me right after class.* If you have a very quick question (or need to let me know something) that can be dealt with in under a minute or so, catching me right after class can be effective. Since another class needs to get into the room right after ours, please wait outside PA-216 for me to get everything together – once I'm out of the room, you will have my undivided attention. If your question turns out to be more complicated, I may ask you to come back to my office to discuss.
 4. **Poor way:** *Call my office.* This is not such a great way to get hold of me, as I am frequently out of the office, or, if I am meeting with other students at the time, I may not even answer the phone. Send email, and you'll likely get a better response.
 5. **TERRIBLE way:** *Come up right before class.* Please do not try to talk with me immediately before class, either at my office or in the lecture room. This is absolutely the worst time to attempt to communicate with me. Before lecture I am likely busy getting the lecture material ready/Powerpoint working/etc. If it's a quick question, or you need to let me know something, speak with me right after class or, even better, during office hours or through email.
- **Class videos.** If you get to class a little early, on many days you will find a video playing, usually having something to do with the material to be presented in that day's lecture. *Getting to class early to watch these videos is completely optional*; they will never contain required material that is not also presented during the formal lecture and/or by the textbook. The official class will never begin before class time (i.e., 11:00 AM). That said, many students in the past have found the videos to be a relaxing way to get introduced to the topics being discussed in the course, before class actually begins.
- **Asking questions.** Asking questions is an essential part of this course – do it!
- **Your professor's three “pet peeves”.** Here are three things that *really* annoy me, so please do your best to not do them!
 1. **Requesting an assignment extension.** Solutions to the weekly reading quizzes are posted on-line immediately after each quiz is due. It is therefore not possible to grant any assignment extensions for the reading quizzes. Furthermore, this course has built-in safeguards to prevent personal, unforeseen or “emergency” circumstances from adversely affecting your overall performance on these quizzes for the semester. Specifically, the lowest two reading quiz and thought question scores (which may include an assignment on which you scored 0% – e.g., you were unable to take it) are not counted when computing your final course grade. Thus, you can completely miss up to two homework assignments (for any reason) and it won't hurt your grade. So please, do not ask for an extension to any assignment.

2. **Emailing questions about the course that are answered in the Course Syllabus or Weekly Handouts.** I try very hard to have *all* relevant course information (e.g., assignment due dates, exam dates, etc.) contained in the Course Syllabus or, if it is of a late-breaking variety, in the updated Weekly Handouts that are given out every Tuesday in class and available at the course website. It almost never happens that I *say* something in class about the course that is not also contained in the Syllabus and/or Weekly assignments. So please — especially if you miss a class — before emailing me a question, check to see that it is not already answered in the Syllabus or Weekly Handouts! (Note that emailed questions about astronomy are always welcome!)
 3. **Leaving class before it is over.** I will lecture right up until the official end of our class period (12:15 PM). I will never end class late, and will almost never end it early. It is a *huge* distraction when students begin leaving with a few minutes to go; the shuffling and noise make it difficult for others to hear and see the final parts of the lecture. Thus, I request that you not get up to leave the lecture until it is over. If you are unable to stay for the entire lecture, then please exit the room more than ten minutes before the end (i.e., by 12:05 PM).
- **Classroom safety.** For all information concerning safety in the classroom, please read the information contained at San Diego State University’s “Emergency Preparedness” website: <http://bfa.sdsu.edu/emergency/>.

Summary of Course Policies

To ensure that there is no confusion (or surprises at course’s end) I explicitly state three of the more important course rules here.

- **There is no “extra credit” given in this course.** Focus all of your efforts on the “for credit” parts of the class (i.e., homework assignments, exams, and the paper)!
- **There are no assignment extensions, and “make-up” exams will be considered under only the most extraordinary (or otherwise unavoidable) and verifiable circumstances.**
- **No course grades of “Incomplete” (I) will be given.** See p. 462 of the SDSU General Catalog for official University policy on Incomplete grades. If your performance in Astronomy 301 is less than satisfactory to you as the semester draws to a close, then your only options are:
 1. *Course Forgiveness.* At SDSU, you are permitted to retake one upper division course for which a grade of C- or lower has been achieved, and have only the most recent grade counted towards your GPA. You can thus choose Course Forgiveness for Astronomy 301 if you do poorly the first time through, and retake it (once) in a future semester (either with me, or with a different professor) and hopefully improve your final grade. Please see p. 463 of the current SDSU General Catalog for all of the details on repeating a course.
 2. *Course Withdraw.* If you feel that you have a compelling case, you can petition to get a “late” (i.e., it’s after the 10-class day drop period) withdraw from Astronomy 301. Please see p. 462 of the current SDSU General Catalog for details on the process. Note that all of the paperwork (this includes obtaining my signature, getting the approval of the dean of the college of your major, and filing the forms with the Registrar) must be completed by the last day of classes (Friday, December 9, 2011). In general, I am sympathetic to allowing you to withdraw from the class if you have a solid, documented reason (i.e., I will give you my signature; convincing your dean and the Registrar is up to you!). Note, though, that the last time that I am available to sign a course withdraw form is Friday, December 2, at 2:00 PM.
 3. *Complete withdraw from the entire semester.* If your performance in all (or most) of your classes has been severely impacted by a cause beyond your control, you can consider a complete

“retroactive withdraw” from the University for the semester. Details on this process are on p. 469 of the current SDSU General Catalog. Note that this is your only option if it is after Friday, December 9!

→ Note that the best way to avoid having to chose among any of the above actions is to do well in the class!



(Mileva Maric and Albert Einstein, c. 1902.)