Astronomy 301:
Cosmology and Gravitational Collapse
San Diego State University
Spring, 2006

Lecture times and location: Tuesday and Thursday 12:30 – 1:45 PM, Rm. PA 216 (Physics-Astronomy building)

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Office Hours: Tuesday & Thursday 2:00 – 4:00 PM (drop-in)
Thursday 4:00 – 5:00 PM (individual appointments only, scheduled in advance)
other times possible by prior arrangement

Website: http://sciences.sdsu.edu/∼leonard/astro301

Course references: *Voyages To the Stars and Galaxies* (Third Edition), by Andrew Fraknoi, David Morrison, & Sidney C. Wolff
The Extravagant Universe: Exploding Stars, Dark Energy, and the Accelerating Cosmos, by Robert P. Kirshner

Course Description

Astronomy 301. Cosmology and Gravitational Collapse

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). We shall trace the story of how the use of supernovae as extragalactic distance indicators has recently startled scientists with a disturbing answer to an age-old question: What will be the ultimate fate of our universe?

Course material is derived from two sources, the first a modern astronomy textbook, and the second a popular account of the "supernova discovery" by an eminent astronomer closely involved with the work. Through these works and class discussions we shall consider this scientific breakthrough with a particular emphasis on the human process by which such 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.

Course Syllabus

Week 1 (January 16 → January 20): *A Beginning*

Topics covered – Having eyes but refusing to see: The invisible supernova of 1054 and the entrenchment of Aristotelian thought; the nature of science; the construction of cosmologies: the finite speed of light and looking back in time; our place in the universe: the sun, planets, stars, Milky Way, other galaxies; introduction to curved space.

Readings: Selected writings of Hesiod, Lucretius, and Plato.

Week 2 (January 23 → January 27): *Struggling for Answers*

Topics covered – The world-views of Hesiod, Plato, and Lucretius; astronomy in ancient times; introduction to the night sky and the celestial sphere; the two-sphere cosmology; the spherical Earth; Ptolemy's *Almagest*, and the problem of the planets.

Readings: *Voyages* – Prologue; ch. 1.1, 1.2.1, 1.2.2, 1.2.5
Extravagant Universe – ch. 1

→ Homework assignment #1 due at the start of class, Tuesday, January 24.

Week 3 (January 30 → February 3): *A Monk Figures it Out*

Topics covered – A mathematical toolkit; Copernicus' *De Revolutionibus*: A Polish monk moves the Earth; Galileo's telescope. Tycho's island; Kepler's Laws; Newton's genius, and the occult force of gravity.

Readings: *Voyages* – ch. 2.1, 2.2, 2.3.1, 2.4.1, 2.4.2

Week 4 (February 6 → February 10): *Light – It's All We Have*

Topics covered – Nature of light; electromagnetic spectrum; radiation laws; spectroscopy I: Fraunhofer's mysterious dark lines and the fingerprints of the elements; Wien's Law; Stefan-Boltzmann Law; Kirchoff's Laws; the strange world of atoms; Doppler effect.

Readings: *Voyages* – ch. 4

Week 5 (February 13 → February 17): *Cecelia's Thesis*

Topics covered – Cecelia Payne-Gaposchkin deciphers the sun's composition; solar photosphere; how the sun shines, circa 1888; $E = mc^2$; nuclear fusion; elementary particles; the neutrino; hydrostatic equilibrium.

Readings: *Voyages* – ch. 6.1.1, 6.1.2, 7.1.1, 7.1.2, 7.2, 7.3.1, 7.3.2, 7.3.3, 7.4.2

→ Homework assignment #2 due at the start of class, Thursday, February 16.

Week 6 (February 20 → February 24): *Reading by Starlight*

Topics covered – Standard candles; magnitudes; color and temperature; spectroscopy II: A supernova spectrum.

Readings: *Voyages* – ch. 8.1, 8.2, 8.4

→ Midterm Exam #1 taken in class on Thursday, February 23.

Week 7 (February 27 → March 3): *The Lives of Stars*

Topics covered – The range of stellar masses; mass-luminosity relation; the Hertzsprung-Russell diagram; white dwarfs; evolution off the main-sequence; approaching death.

Readings: *Voyages* – ch. 9.2.3, 9.2.4, 9.4; 13.1, 13.2, 13.4, 13.5

Week 8 (March 6 → March 10): *Why Stars Explode*

Topics covered – Supernovae: The explosive demise of massive stars and low-mass stars in binary systems.

Readings: *Voyages* – ch. 14.1, 14.2, 14.4, 14.5

Week 9 (March 13 → March 17): *Matter at Rest.*

Topics covered – Sitting on the beach.

Readings: Subliminal message: astronomy makes excellent beach reading.

Week 10 (March 20 → March 24): *Black Holes: The End of Space and Time*

Topics covered – Principle of equivalence; spacetime and gravity; introduction to general relativity; black holes; finding black holes; voyages in space and time.

Readings: *Voyages* – ch. 15

→ **Homework assignment #3 due at the start of class, Thursday, March 23.**

Week 11 (March 27 → March 31): *Finding our Place in the Universe*

Topics covered – The realm of he nebulae; types of galaxies; the Milky Way; dark matter.

Readings: *Voyages* – ch. 16.3; 17.1, 17.2, 17.3

→ **Midterm Exam #2 taken in class on Thursday, March 30.**

Week 12 (April 3 → April 7): *It Started with a Bang*

Topics covered – Extragalactic distance scale; Type Ia supernovae as standard candles; redshift; expanding universe; the Big Bang; age of the universe; the expected deceleration.

Readings: *Voyages* – ch. 17.4, 17.5; 20.1.1, 20.1.2

Week 13 (April 10 → April 14): *The Big Surprise*

Topics covered – Robert Kirshner's personal account of the discovery begins; how to find supernovae; the meaning of statistics; metallicity; supernova light curves and spectra; details of the core-collapse process; SN 1987A.

Readings: *Voyages* – ch. 20.1.3, 20.1.4; 14.3
Extravagant Universe – ch. 2, 3

Week 14 (April 17 → April 21): *Einstein's Biggest Blunder?*

Topics covered – Birth of the cosmological constant (Λ); gravitational lensing; Henrietta Leavitt's Cepheid variable stars; cosmological redshift; redshift surveys; geometry of space according to general relativity; the long story of measuring H_0, and the Sandage-Freedman debate; the expanding photosphere method.

Readings: *Voyages* – ch. 10.3
Extravagant Universe – ch. 4, 5, 6

Week 15 (April 24 → April 28): *A Hot Day in Holmdale*

Topics covered – Cosmic microwave background; early universe; in the beginning: inflation and quantum uncertainty; hot dark matter; Occam's razor; cosmic dust.

Readings: *Voyages* – ch. 20.3, 20.4, 20.5, 20.6; 11.1, 11.3
Extravagant Universe – ch. 7, 8

Week 16 (May 1 → May 5): *Einstein's Blunder Returns*

Topics covered – Inhomogeneity of Type Ia supernovae; how science is done: a case study; Steinhart & Ostriker 1995: A prescient paper; hunting for high-redshift supernovae; time dilation of supernova light curves; the discovery of the accelerating universe: could it be wrong?

Readings: *Extravagant Universe* – ch. 9, 10

→ **Homework assignment #4 due at the start of class, Thursday, May 4.**

Week 17 (May 8 → May 12): *An Ending*

Topics covered – Going beyond $z = 1$; the Casimir effect; (brief) introduction to string theory; quintessence; energy budget of the universe; the beauty of science.

Readings: *Extravagant Universe* – ch. 11, epilogue

→ **Final Paper due by 5 PM Wednesday, May 10.**
→ **Final Exam: Tuesday, May 16, 1:00 PM – 3:00 PM, Rm. PA 216 (normal lecture room).**

Assignments and Course Grades

Course grades will be 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:

•*Homework assignments*: 10%. Nearly every week there will be one or two questions or problems assigned, which should be completed along with the weekly reading assignment. Keep your completed assignments together, as they will be collected together three times during the semester, roughly every five weeks (see syllabus for specific dates); note that the first homework assignment is due on the second day of class. All homeworks will be graded using a "check" system, which can be translated into percentages via: $\surd$+ (A, 95%); $\surd$ (B, 85%); $\surd$- (C, 75%). (A grade of $\surd$++ (A+, 100%) may also be awarded for truely exceptional work; a $\surd$- - (D, 65%) may also be given for extremely poor work.) Of your four homework marks, only the top 3 grades will count towards your final mark. All responses to homework questions must be typed; responses to mathematical problems may be handwritten.

•*Midterm Examinations and Final Paper*: 50%. There will be two midterm exams in this course, given in class on **Thursday, February 23** and **Thursday March 30**. A final paper is due on **Wednesday, May 10**. The nature of the exams and final paper will be discussed a few weeks into the course. Of the three grades received (two from the exams, one from the paper), only the top 2 will count towards your final mark (25% each, for a total contribution of 50%).

•*Final Examination*: 40%. The final examination will be given on Tuesday, May 16, 1:00 PM – 3:00 PM, Rm. PA 216 (normal lecture room).

Please note that no late assignments will be accepted, or make-up exams given. If you should miss an assignment or an exam, then that will simply be the grade that is dropped from your average for that component of the course. The final exam must be taken at the scheduled time. There will be no "extra credit" projects given. Finally, no form of cheating will be tolerated, and will result in automatic failure in the course and/or additional disciplinary action by the University.

Grade Calculator Worksheet

To compute your final grade in the course:
Step 1: Write down your 4 homework grades (percentage equivalents):

Step 2: Now, cross out the *lowest* homework grade. Add the remaining three grades together and divide by 3. 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 your 2 midterm exam percentages, and your final paper percentage here:

Step 5: Now, cross out the *lowest* grade written in Step 4. Add the remaining two numbers together and divide by 2. Write down that number here:

Step 6: Take the number obtained in step 5, and multiply it by 0.5. Write that number down here and put a box around it:

Step 7: Multiply your final exam percentage by 0.4, and write that number here, and put a box around it:

Step 8: Add the boxed numbers from Steps 3, 6, and 7 together and write it here:

Step 9: 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, 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, effort and dedication, and so forth. Note that I will never *lower* a grade that you have earned; your enthusiasm can only help you.