Astronomy 596 NPA
Nuclear and Particle Astrophysics
Fall Semester 2009

Astronomy 134   MWF 2:00–2:50 pm

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Course web page URL

`http://courses.atlas.uiuc.edu/fall2009/astr/astr596npa/`

We will apply nuclear and particle physics to trace highlights in the history of cosmic matter from the big bang to the present. The course is targeted to beginning graduate students, with no nuclear or particle physics prerequisites. The emphasis will be on physical arguments and quantitative estimates to understand observations.

1 Course Requirements

Grading Scheme

Requirement	Weight
Preflights	30%
Problem Sets	60%
Final Exam	10%

2 Readings and Resources

Course Texts:

R. Boyd *Introduction to Nuclear Astrophysics*

University of Chicago Press (2008). *Recommended.*

This text is as up-to-date as one can hope for, particularly with respect to nuclear astrophysics. The essentials of both astrophysics and nuclear physics are briefly reviewed. Discussion of particle physics and of cosmology is mostly in the context of the nuclear connections to these topics.

E.W. Kolb and M.S. Turner *The Early Universe*

Redwood City: Addison-Wesley (1990). *Recommended.*

As the name suggests, extensive coverage of the early universe. Excellent discussion of basic physics; by now very dated with respect to the observations.

Other useful books include:

Arnett, *Supernovae and Nucleosynthesis*

Clayton, *Principles of Stellar Evolution and Nucleosynthesis*

Gaisser, *Cosmic Rays and Particle Physics*
Klapdor-Kleingrothaus and Zuber, *Particle Astrophysics*
Kolb and Turner, *The Early Universe: Reprints*
Pagel, *Nucleosynthesis and the Chemical Evolution of Galaxies*
Peacock, *Cosmological Physics*
Peebles, *Principles of Physical Cosmology*
Rolfs and Rodney, *Cauldrons in the Cosmos*

In addition to these texts, research and review articles will occasionally be assigned.

A large body useful material is available online, and will be useful for homework problems and for researching your report. See the `links` page on the course website.

3 Preflights

Class time is best spent when you have already read about the material, so that we can focus on the points that you found difficult and/or interesting. To encourage this reading, and to guide your thinking during the reading, "preflights" will be assigned on weeks when no problem set is due. These will be available online via the `preflights` link off of the course page. Each one will give the reading assignment for the upcoming week, and will include questions on the reading. These questions will be due, with a hard deadline. Your responses will be graded pass/fail: the point is not that you always understand fully all of the issues, but rather that you be prepared for class, and that I get an idea of what is difficult for you.

4 Problem Sets

I will assign about 6 problem sets throughout the course. The high frequency is intended to keep you up-to-date on the material. Problem sets are due in class; late homework will be deducted 25% for every calendar day late.

Science is a collaborative enterprise, and you are encouraged to discuss the class material and the problems with your classmates and the instructor. However, you are responsible for your own answers, which you should understand and write up in your own words.

5 Final Exam

The Final Exam will take the form of a final Problem Set, assigned on the last day of class. and will be due on or before the course exam date, **4:30pm, Friday December 11.** *Late exams will not be accepted!*

6 Fermilab Tour

We are very fortunate that the highest-energy particle accelerator in the world is a few hour's drive from us. We are even more fortunate that Prof. Kevin Pitts in the Physics department has offered to give us a guided tour on **Saturday October 10**. The tour is not required, but should be a lot of fun, and you are encouraged to attend. More details are posted on the course website.

Course Schedule

Lecture material may vary, but due dates are fixed. See course webpage for updates.

Date	Topic	Assignment Due
Aug 24	Introduction, Solar System Abundances	
Aug 26	Preliminaries: Nuclei and binding energy	
Aug 28	Preliminaries: Nuclear structure	
Aug 31	Preliminaries: Nuclear Reactions and Cross Sections	
Sept 2	Preliminaries: Thermonuclear Reaction Rates	
Sept 4	Preliminaries: Thermonuclear Reaction Rates	**PF 1**
Sept 7	*No class meeting: Labor Day*	
Sept 9	Preliminaries: Thermonuclear Reaction Rates	
Sept 11	Cosmology: FLRW Universe	**PS 1**
Sept 14	Cosmology: Thermodynamics	
Sept 16	Cosmology: Thermal History of the Universe	
Sept 18	Big bang nucleosynthesis: initial conditions	**PF 2**
Sept 21	Big bang nucleosynthesis: weak freezeout	
Sept 23	Big bang nucleosynthesis: Birth of the Light Elements	
Sept 25	Big bang nucleosynthesis: Observational strategy, ^{4}He	**PS 2**
Sept 28	Big bang nucleosynthesis: D, ^{7}Li	
Sept 30	Big bang nucleosynthesis: concordance and implications	
Oct 2	Big bang nucleosynthesis: neutrino counting	**PF 3**
Oct 5	Early Universe: freezeout physics, relic abundances	
Oct 7	Early Universe: WIMPS	
Oct 9	Early Universe: antimatter, baryogenesis ingredients	**PS 3**
Oct 12	Stellar Nucleosynthesis: stellar models	
Oct 14	Stellar Nucleosynthesis: H-burning	
Oct 16	Solar Neutrinos: solar model predictions, observed fluxes	**PF 4**
Oct 19	Solar Neutrinos: neutrino oscillations	
Oct 21	Supernovae: massive star evolution, explosion physics	
Oct 23	Supernovae: explosive nucleosynthesis, neutrino production and interactions	**PS 4**
Oct 26	Supernovae: SN 1987A, gamma-ray and neutrino signatures	
Oct 28	Supernovae: Thermonuclear (Type Ia) Explosions	
Oct 30	Supernovae: Type Ia Nucleosynthesis, Progenitors, Standarization	**PF 5**
Nov 2	Gamma-Ray Bursts	
Nov 4	Neutron capture nucleosynthesis: overview, basic equations	
Nov 6	Neutron capture nucleosynthesis: s-process physics, observations, site	**PS 5**
Nov 9	Neutron capture: r-process physics	
Nov 11	Neutron capture: r-process observations, sites	
Nov 13	Cosmic rays: spectrum, composition	**PF 6**
Nov 16	Cosmic rays: propagation, origin	
Nov 18	Cosmic rays: LiBeB production, observations	
Nov 20	Cosmic rays: gamma-ray production	**PS 6**
Nov 23–27	*No class meetings: Thanksgiving Break*	
Nov 30	Cosmic rays: atmospheric neutrinos	
Dec 2	Cosmic rays: cosmological production	
Dec 4	Chemical evolution: introduction	
Dec 7	Chemical evolution: simple model results	
Dec 9	Finale	**Final Problem Set**