AST 403 / PHY 402 Stars and Star Formation

Spring 2011

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Textbooks

The Formation of Stars (Stahler and Palla)
An Introduction to Modern Stellar Astrophysics (Ostlie and Carroll)
These and other books are on reserve: see http://catalogue.princeton.edu
The books will be available in Lewis Library and in the Astrophysics reading room ("Grand Central"). Please do not remove the books from GC.

Now: there is a problem with the books. For a while, Ostlie and Carroll was out of print, and Labyrinth were unable to get any. They ordered "Stellar Structure and Evolution" by Kippenhahn and Weigert instead. I have just bought a couple of O&C and will put them in Grand Central when they get here.

The readings for the syllabus below are from Ostlie/Carrol and Stahler/Palla.

Additional Books

Radiative Processes in Astrophysics (Rybicki and Lightman)
Physics of Astrophysics I (Radiation) and II (Gas Dynamics) (Shu)
Principles of Astrophysical Fluid Dynamics (Clarke and Carswell)
Theoretical Astrophysics I. Astrophysical Processes (Padmanabhan)

*The Physics and Chemistry of the Interstellar Medium (Tielens)
*The Physics and Chemistry of the Interstellar Medium (Kwok)
*Physical Processes in the Interstellar Medium (Spitzer)
Physics of the Interstellar and Intergalactic Medium (Draine)
Interstellar Chemistry (Duley and Williams)
The Physics of the Interstellar Medium (Dyson and Williams)
The First Symposium on the Infrared Cirrus and Diffuse Interstellar Clouds (ed Cutri and Latter, ASP Conf Proc. 58)
The Evolution of the Interstellar Medium (ed. Blitz, ASP Conf Proc 12)

Massive Stars: Their Lives in the Interstellar Medium (ed. Casinelli and Churchwell, ASP Conf Proc #35)
Tetons 4: Galactic Structure, Stars and the Interstellar Medium (ed. Woodward, Bicay and Shull, ASP Conf Proc 231)

Stellar Spectral Classification (Gray and Corbally)
Structure and Evolution of the Stars (Schwarzschild)

Exotic Stars as Challenges to Evolution (ed. Tout and van Hamme, ASP Conf Proc 279)
Stellar Interiors (Hansen, Kawaler, Trimble)
Mass-Losing Pulsating Stars and their Circumstellar Matter (ed. Nakada et al., A&SSL)
Asymptotic Giant Branch Stars (ed. Habing and Olofsson)
Theoretical Astrophysics II Stars and Stellar Systems (Padmanabhan)

Books marked with * are on the shelves at Grand Central under AST 517.

Course Outline

The Universe consists of dark energy, dark matter and baryonic (normal) matter. The expansion and cooling of the early Universe left the baryonic matter in the form of gas composed almost entirely of hydrogen and helium. Subsequent gravitational collapse formed the galaxies and the stars within the galaxies, so that the baryonic material in a present-day galaxy is in the form of stars and interstellar gas. Stars (and their accompanying planetary systems) continue to form from the gas and, as they evolve, return material to the interstellar gas enriched by the processes of nucleosynthesis within the stars, thereby building up the chemical elements.

This course deals with the properties, nature and evolution of the stars and gas in a galaxy. We will derive the structure of stars and show how they steadily produce energy in their interiors by nuclear fusion reactions. We go on to discuss the formation of stars and their interaction with the interstellar gas, the physics and chemistry of the interstellar medium, and the evolution of stars and their end states. We will discuss and analyze the production and transfer of radiation in stars and the interstellar gas and the derivation of the structure, temperature and composition of stars and the interstellar gas. We'll describe the formation of stars from interstellar gas clouds and the surprisingly complex and delicate interaction between the stellar and interstellar components of a galaxy. We will also discuss major current and upcoming telescopes and space missions, including *Spitzer*, ALMA, *Herschel*, SOFIA, *Gaia*, and other projects to study the stars and gas in both nearby galaxies and at cosmic distances, and to study star and planet formation.

The course will have take-home mid-term and final exams, but emphasis will be placed on homework, which will consist both of short physics problem sets and of computer calculations on the evolution of stars, the structure of degenerate stars, and the interpretation of observations of forming stars.

1:30-2:50 pm, Rm 140 Peyton Hall, Tuesday/Thursday

Course web site: http://www.astro.princeton.edu/∼gk/A403. Homework problems and class notes will be available here, as well as computer manuals and links to useful web materials (and if you have any to add, please send me the links).

Draft Lecture Schedule

1. Introduction I. Interstellar Medium. Tuesday Feb 1

textbooks, requirements
topic of course
the ISM and star formation
stellar populations and the distribution of gas in galaxies
stellar timescales
Reading: SP ch 1.1; OC ch 10.1

2. Introduction II: Stars and Stellar Evolution. Thursday Feb 3

HR diagram
stellar types
stellar evolution
post main sequence evolution
a couple of basic equations and concepts:
black bodies, effective temperatures, Planck
function, Boltzmann equation
Reading: OC ch 8.2

3. Basic equations of stellar structure I. Tuesday Feb 8

hydrostatic equilibrium
equation of state
Reading: OC 10.1, 10.2

4. Basic equations of stellar structure II. Thursday Feb 10

radiation
convection
conduction
opacity
Reading: OC ch 10.4

5. Energy generation. Tuesday February 15

Reading: OC ch 10.3

6. The main sequence Thursday February 17

dynamical and thermal stability
the main sequence
stability on the main sequence
the Hayashi limit
Eddington model
high mass stars
mass-luminosity relation

the main sequence
Reading: OC ch 10.5, 10.6, 11, 13.1

7. Evolution Tuesday February 22

Evolution on the main sequence
Red Giants
Core-collapse Supernovae
Age-dating stallar clusters
Reading: OC ch 13, 15

8. Degeneracy Thursday February 24

zero-temperature condensed objects
low mass stars
the minimum-mass main sequence star
brown dwarfs
Reading: OC ch 16

9. Star Lore I: spectral types, spectroscopy. Tuesday March 1

Reading: OC ch 5

10. Star Lore II: observational conventions. Thursday March 3

Reading: OC ch 5
Takehome midterm exam handed out

11. Star Lore III: fundamental measurements. Tuesday March 8

Reading: OC ch 7

12. Stellar Atmospheres. Thursday March 10

LTE
the stellar spectral sequence
abundance determinations
Reading: OC ch 9
Takehome midterm exam due

————————Midterm Break————————

13. The ISM I. Tuesday March 22

phases
observational probes

magnetic field
Reading: OC ch 12.1, SP ch 2

14. The ISM II. Thursday March 24

energy density in ISM
begin radiative transfer:
specific intensity
Kirchoff's law and thermal equilibrium
Reading: SP ch 2,3

15. Photoionization. Tuesday March 29

ionization of hydrogen by UV and Xray
the pure H HII region
Stromgren sphere
Lyman-α luminosity of hot stars
ionization of helium
Reading: SP ch 15

16. Collisional excitation and ionization. Thursday March 31

CR ionization of ISM
heating and cooling of ISM
2- and 3-phase ISM

17. Bremmstrahlung and Synchrotron. Tuesday April 5

emergent broad-band SED

18. Interstellar dust. Thursday April 7

optical properties
heating, cooling and IR radiation
small grains and PAHs
propagation of light and extinction/reddening

19. Spectral line radiation. Tuesday April 12

Einstein coefficients
line formation
excitation temperature

20. The diffuse ISM Thursday April 14

21 cm line
HI clouds
the HI/H_2 interface

21. Chemistry Tuesday April 19

molecule formation
collisional excitation
cooling Reading: SP ch 7

22. Star formation. Thursday April 21

Molecular clouds
instability, collapse and star formation
pre-ms evolution
accretion and disks
planet formation
phenomenology
Reading: SP ch 11, 17

23. Winds and shocks. Tuesday April 26

outflows from young stars
post-MS evolution and winds from red giants
dust formation
planetary nebulae, white dwarfs and the Chandrasekhar limit
supernovae
blast waves
synchrotron emission
the 3-phase ISM and galactic fountains
cosmic ray production and propagation
Reading SP ch 18

24. Tying it all together. Thursday April 28

the star formation rate
feedback
nucleosynthesis and chemical enrichment
evolution of stars and ISM in the Galaxy
Reading: SP ch 19, 20