Course Evaluation

1. Prepare a research survey paper focusing on a topic related to stellar structure and evolution. You should pick a question and then explain how stellar structure and evolution calculations relate to this question. Then discuss the current state of understanding on the topic and describe particular areas where progress appears possible giving reasons to support your evaluation. This paper will be worth 35% of the grade.

   Possible topics include:

   (a) Observational diagnostics of theories of star formation.

   (b) Theories of type Ia supernovae.

   (c) Isotope abundances in stellar winds.

   (d) The formation of multiple star systems.

   (e) Stellar cycles of magnetic activity and their relationship to the solar eleven-year cycle.

   (f) The nature of Wolf-Rayet stars.

   (g) Stellar pulsations of all types.

   (h) The formation and evolution of the most luminous stars in the galaxy.

   (i) The formation of heavy elements in red giants and supernovae.

   (j) The evolution of Lithium in young stars.

   (k) The theory of disks in star formation.

2. A final exam on the lecture material. This will be worth 65% of the grade.

Course Outline

1. Summary of the basic data on stellar structure and evolution. (3 lectures 1/10, 1/12, 1/17)
   (a) The conversion between observational and theoretical Hertzsprung-Russell diagrams (color-magnitude diagrams).
      i. Photometry systems.
      ii. Effective Temperature
      iii. Bolometric Correction
      iv. Spectral classification
   (b) Brief Summary of Key Points in Stellar Evolution.
      i. Low Stellar Mass Cases
      ii. High Stellar Mass Cases
      iii. Shell Sources and depleted cores
      iv. Summary of End Points
   (c) Mass-Luminosity relationship
   (d) Nuclear Abundances
   (e) The case of the sun – neutrinos, oscillations, and other special constraints.
2. Stellar Structure equations (2 lectures 1/19, 1/24)
   (a) The four structure equations – hydrostatic equilibrium, mass accounting, energy transport, energy conservation.
   (b) The auxillary physical relations – equation of state, opacity, nuclear reaction rates, abundance transformations.
   (c) The time dependent quantities – thermal cooling and gravitational contraction, nuclear abundances.
   (d) Virial Theorem and its consequences.

Course Outline (continued)

3. Simplified Models (3 lectures 1/26, 1/31, 2/2)
   (a) Polytropes
   (b) Isothermal Spheres and Stellar Stability/Collapse
   (c) White Dwarfs
4. Equation of State (1.5 lectures 2/7, 2/9)
   (a) Perfect gas law.
   (b) Degeneracy and partial degeneracy
   (c) Relativistic degeneracy - neutron star equation of state.
   (d) Coulomb interactions - Brown dwarf limit.
5. Opacity (1.5 lecture 2/9, 2/14)
   (a) The basic processes – bf, ff, bb, electron scattering, (conduction)
   (b) The Kramers law.
   (c) Modern calculations.
6. Nuclear transformations (2 lectures 2/16, 2/21)
   (a) Formulation of nuclear reaction rates.
   (b) Nuclear burning networks.
   (c) The principal nuclear burning stages.
   (d) The end-points of stellar evolution.
   (e) The role of neutrinos in stellar evolution.

Course Outline (continued)

7. Late stages of evolution (1 lecture 2/23)
   (a) High mass stars.
   (b) Low mass stars – globular clusters
   (c) Mass loss, stellar winds
   (d) Supernova theory
8. Star Formation (2 lectures 2/28, 3/2)
   (a) Conditions for collapse, angular momentum, magnetic field.
   (b) When do stars first become visible.
   (c) Accretion disks.
   (d) Binary stars
9. The Sun (4 lectures 3/7, 3/9, 3/14, 3/16)
   (a) Solar models
   (b) The solar neutrino problem
   (c) Helioseismology
   (d) Magnetic activity cycles.

Some Useful Books

1. Schwarzschild, M. 1958, "Structure and Evolution of the Stars", Princeton University Press.
2. Clayton, D. D. 1968, "Principles of Stellar Evolution and Nucleosynthesis", Mc Graw-Hill.
3. Novotony, E. 1973, "Introduction to Stellar Atmospheres and Interiors", Oxford University Press
4. Chiu, H.-Y. 1968, "Stellar Physics", Blaisdell Publishing.
5. Kippenhahn, R. and Weigert, A. 1991, "Stellar Structure and Evolution", Springer-Verlag
6. Bahcall, J.N. 1989, "Neutrino Astrophysics", Cambridge Univ. Press
7. Padmanabhan, T. 2001, "Theoretical Astrophysics, Volume II: Stars and Stellar Systems", Cambridge Univ. Press (Alternate text for the course)
8. Hansen, C. J. and Kawaler, S. D. 1994, "Stellare Interiors – Physical Principles, Structure, and Evolution", Springer-Verlag (Required text)

References for Properties of Stars

1. IAU Symposium 111, "Calibration of Fundamental Stellar Quantities", Hayes et al eds., 1984, Reidel:Dordrecht

   This volume contains the following useful chapters:

   (a) H. A. McAlister, "The Calibration of Interferometrically Determined Properties of Binary Stars", p. 97

   (b) R. Hanbury Brown, "Measuring Stars with High Angular Resolution: Results from Narrabri Observatory", p. 185

   (c) J. Davis, "Measuring Stars with High Angular Resolution: Current Status and Future Prospects", p. 193

   (d) P. C. Keenan, "The MK Classification and its Calibration", p. 121

2. IAU Symposium 189, "Fundamental Stellar Properties: The Interaction between Observation and Theory", Bedding, Booth and Davis, 1997, Kluwer, Boston

   This volume contains numerous chapters which are updates of the above volume. Many of the fundamental measurements are not superceded. The UV fluxes however have been a matter of considerable discussion.

3. R. Hanbury Brown, 1974, "The Intensity Interferometer", (Taylor and Francis: London).

4. Code, A. D., Davis, J., Bless, R. C., and Hanbury Brown, R. 1976, Ap. J., **203**, 417.

5. Popper, D. M. 1980, Ann. Rev. Astron. and Astroph., **18**, 115.

6. Blackwell, D. E. and Lynas-Gray, A. E. 1994, Astron. and Astroph., **282**, 889.