Stellar atmospheres

Questions for the final exam on Friday, December 20, 2019

The exam will consist of two **large** questions requiring a detailed answer, and a few questions requiring a one-two sentence answer. Large questions will cover the second part of the course (starting from question 17 from the list below) , whereas small questions will cover the entire syllabus. Some questions from the list below can be combined, separated, or rephrased.

Questions:

1. Definition of a Stellar atmosphere. Spectral Types, Luminosity Classes, Magnitudes, Bolometric Flux and Bolometric Correction.
2. Specific and mean intensity, Flux & luminosity, Black body radiation, Effective temperature (Stefan-Boltzmann law), Brightness and Color temperatures. Radiation density and pressure.
3. Describe what is meant by Local Thermodynamic Equilibrium (LTE). List the relevant microscopic physical processes obeyed by the gas and the radiation field in an LTE environment. State, with a brief explanation, for which types of stellar atmosphere LTE is a good or a poor approximation
4. Definitions and units of absorption coefficient, cross-section, optical depth, emission coefficient, source function. Source function in thermodynamic equilibrium (TE) and in the local thermodynamic equilibrium (LTE). What is the intensity of radiation in TE and LTE?
5. A simple form of the (parallel-ray) radiative transfer equation and its formal solution. Optically thin and optically thick cases. Origin of absorption and emission lines. Relation to the temperature gradient.
6. Radiative transfer equation in plane-parallel atmosphere. A formal solution. A case of source function as a linear function of optical depth, emergent intensity and flux. The Eddington-Barbier relation.
7. Explanation of Limb darkening. How limb darkening observations can be used to obtain the optical depth dependence of the temperature of a stellar photosphere?
8. A concept of the radiative equilibrium. Radiative equilibrium (radiative balance) in the grey atmosphere. Temperature profile of the grey atmosphere in the Eddington approximation, the surface temperature.
9. LTE. Maxwellian distribution, Boltzmann formulae, Saha formula.
10. The structure of a hydrogen atom. Ionization potentials from different energy levels. Definition of bound-bound, bound-free (free-bound) and free-free transitions. Sources of opacity.

11. Continuous absorption coefficient of a hydrogen-like atom. Dependence on n, λ, and Z. Absorption coefficient per hydrogen atom (cross-section) at Lyman limit. Impossibility of observing distant objects at $\lambda < 912$Å. Make a sketch of dependence of the hydrogen continuous absorption coefficient on photon wavelength (or frequency) for different temperatures. Explain using Boltzmann formula.
12. The Saha equation. Ionization of hydrogen and characteristic temperature of ionization. Negative ion of hydrogen, its ionization potential (in eV and Å). Explain qualitatively why H^- absorption is more important than absorption by neutral hydrogen at temperatures T $\sim$ 4500 – 8000 K. What is the difference relative to the earlier class stars?
13. The Thomson cross-section and the role of electron scattering.
14. Effect of non-greyness of the absorption coefficient on the emergent stellar radiation. Explain qualitatively using the Eddington-Barbier relation. Determining temperature (or density) from the Balmer jump.
15. The Rosseland mean absorption coefficient. Its physical interpretation. Temperature profile of the atmosphere.
16. The equation of hydrostatic equilibrium. The scale-height of an (isothermal) atmosphere. Definition of radiation pressure. Correction to gravity due to radiation pressure. The Eddington limit. Explain why it is difficult to form very massive stars.
17. The line absorption coefficient. Dumping profile, natural width. Thermal motions and the Doppler profile. The Voigt profile.
18. The line equivalent width, W_λ. W_λ for optically thin lines in LTE. Optically thick lines. The line intensity in the center of deep lines. Schuster-Schwarzschild atmosphere model. The curve of growth. Explain qualitatively its general behaviour.
19. Scattering in lines. Transfer Equation including lines. The Milne-Eddington model. Residual flux of the line. Absorption and scattering lines. Schuster Mechanism for Line Emission
20. Non-LTE. Statistical equilibrium equations. Radiative and collisional rates. Relation between Einstein coefficient. Relation between excitation and de-excitation collisional coefficients. When non-LTE effects are important?
21. Spectral type sequence.
22. Direct measurement of radii. Determining T_{eff} and surface gravity, Model-independent methods, Model-dependent methods, Atmospheric models, Photometric methods, Spectroscopic methods.