Astronomy 631
Stellar Atmospheres and Radiative Transfer

Rolf Kudritzki – spring semester 2013 TTh 11am

This is an introduction into the physics of stellar atmospheres and the formation of stellar spectra. The goal of this course is to provide the basic knowledge of the physical processes which determine the structure of stellar atmospheres (density and temperature stratification) and which allow to determine fundamental stellar properties (effective temperature, gravity, luminosity, chemical composition) from observed spectra and energy distributions through the technique of spectral diagnostics. Knowledge of this field is crucial for understanding stellar evolution (from birth to death), the structure and evolution of galaxies (through the spectral diagnostics of their stellar populations either by analysis of individual stars or by population synthesis techniques) and the ionization of the interstellar medium in galaxies of the local and the high red-shift universe (through UV photons emerging from the atmospheres of massive stars).

The physics of stellar atmospheres and radiative transfer are complex and combine elements of atomic physics, plasma physics, hydrodynamics, thermodynamics and statistics with transport theory. The ambition of this course is to keep things simple and to understand the basic principles, but simultaneously to appreciate the complexity of modern stellar atmosphere modeling. The course is accompanied by homework.

A detailed manuscript of the course will be provided in advance of each lecture and can be downloaded from the instructor’s website.

Content

Basic assumptions for stellar atmospheres:
- geometry, stationarity,
- conservation of momentum, mass, energy
- Local Thermodynamic Equilibrium (LTE)

Transport of energy: radiation
- specific intensity, radiative flux, radiation pressure
- absorption and emission coefficients
- optical depth
- equation of transfer, source function
- exact formal solution, integral operators, approximate solutions
- atmospheric temperature stratification
- grey atmospheres, mean opacities
- limb darkening and empirical temperature stratification

Transport of energy: convection
- convection in stars, solar granulation
- Schwarzschild-criterion
- mixing-length theory
- numerical simulation of convection
Atomic radiation processes:
  bound-bound transitions, Einstein coefficients, oscillator strengths
  line broadening processes and profiles
  continuous absorption and scattering

Stellar spectra:
  excitation and ionization, Saha equation
  stellar spectral classification
  stellar opacities

Non-LTE – basic concept:
  LTE versus non-LTE
  occupation numbers
  rate equations
  transition probabilities
  examples: hot stars, A supergiants, M supergiants

Spectral line formation:
  two level atom, Milne-Eddington model
  curve of growth

Stellar winds:
  observed stellar wind signatures across the HRD
  effects on stellar evolution and stellar atmospheres

Line formation in expanding atmospheres:
  effects of velocity fields on absorption coefficients,
  optical depth and radiative transfer, escape probabilities,
  interaction regions, Sobolev-approximation, P-Cygni profiles

X-ray, IR- and radio excess and stellar wind diagnostics:
  mass-loss rates and IR/radio- excess
  X-rays and stellar wind shocks

Hydrodynamic theory of stellar winds:
  hydrodynamic equations of stellar winds
  radiation pressure
  line driven winds
  theory and observation
  very massive stars and stellar winds in the early universe