PHYS771c Syllabus, Spring 2013
Physics Department, University of Nevada, Reno

PHYS771c: theory, modeling and data analysis in plasma spectroscopy with emphasis on high-energy-density plasma applications, 3 credits.

Instructor: Roberto C. Mancini, rcman@unr.edu

Recommended pre-requisites: graduate level electricity and magnetism, and quantum and statistical mechanics.

Schedule: two lectures per week, each one an hour and fifteen minutes long.

Objectives: the goal of this graduate level course is to provide an introduction to plasma spectroscopy of high-energy-density plasmas with emphasis on the physics of x-ray spectra formation and its application to the diagnosis of plasma conditions. Course material includes a discussion of the atomic processes and level population kinetics relevant to line emission and absorption in plasmas, plasma broadened line shapes, radiation transport, and the solution of inversion problems associated with spectroscopic data analysis.

Topics

1. Atomic processes in plasmas: electron collisional excitation and de-excitation, electron collisional ionization and recombination, resonant electron capture and autoionization, spontaneous radiative decay, stimulated emission and photo-excitation, and photo-ionization and radiative recombination. The principle of detailed balance. Cross sections and rates. Plasma atomic kinetics: corona model and LTE approximations, photoionized plasmas, collisional-radiative model. Single- and multi-element atomic kinetics. Steady-state and time-dependent cases. Continuum lowering and pressure ionization. Magnetic sublevel atomic kinetics, plasma anisotropy, and line polarization. Population inversion and x-ray lasers. Examples and applications.

2. Line shapes: natural and Doppler broadening effects. Stark-broadened line shapes, the standard Stark-broadening theory approximation. Plasma microfield distribution function; the Tighe-Hooper approximation, the APEX model, field mixing effects and forbidden line transitions. Electron broadening, the impact approximation, semi-classical theory, and second-order quantum-mechanical approximation. Line shifts, ion-dynamics, two-temperature line shapes, field-gradient effect. Examples and applications.

3. Radiation transport: the radiative transfer equation, radiation transport broadening and emergent line intensity distribution. Self-consistent level populations and radiation field. Opacity effects on atomic kinetics. The two level atom and the equivalent two level atom approximations. Escape probabilities, escape factors and escape factor functionals. The complete linearization and Lambda operator methods. Line radiation transport and line overlapping effects. Synthetic spectra calculations. Examples and applications.

4. Spectroscopic data analysis and plasma diagnostics: data analysis and inversion problems in plasma spectroscopy. Exhaustive search in parameter space, examples and limitations. Algorithmic search and optimization driven by genetic algorithms. Uniqueness of the solution. Single- and multi-objective spectroscopic data analysis, Pareto domination, and Pareto optimal solution. Space-integrated and space-resolved data analysis. Extraction of temperature and density spatial profiles. Examples and applications.

Bibliography

Lectures will be based on material from journal papers, instructor's notes, and the following books:

1. "Principles of Plasma Spectroscopy" H. R. Griem, Cambridge Monographs on Plasma Physics, ISBN 0 521 45504 9, Cambridge University Press, 1997.

2. "Quantum Mechanics of One- and Two-Electron Systems" H. A. Bethe and E. E. Salpeter, ISBN 0 306 20022 8, Plenum Publishing, 1977.

3. "The Theory of Atomic Structure and Spectra" R. D. Cowan, Los Alamos Series in Basic and Applied Sciences, ISBN 0 520 03821 5, University of California Press, 1981.

4. "Excitation of Atoms and Broadening of Spectral Lines" I. I. Sobelman, L. A. Vainshtein and E. A. Yukov, Second Edition, Springer Series on Atoms and Plasmas, ISBN 0 540 58686 5, Springer-Verlag Publishers, 1995.

5. "Stellar Atmospheres" D. Mihalas, Second Edition, ISBN 0 7167 0359 9, W. H. Freeman and Co., 1978.

6. "Data Reduction and Error Analysis for the Physical Sciences" P. R. Bevington and D. K. Robinson, Second Edition, ISBN 0 07 911243 9, McGraw Hill, 1992.

7. "Genetic Algorithms in Search, Optimization and Machine Learning" D. E. Goldberg, ISBN 0-201-15767-5, Addison-Wesley Publishing, 1989.