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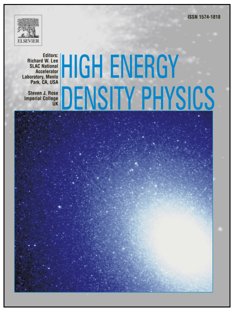

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Collisional Radiative Average Atom Code Based on a Relativistic Screened Hydrogenic Model

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A steady-state and time-dependent collisional-radiative ''average-atom'' (AA) model (ATMED CR) is presented for the calculation of atomic and radiative properties of plasmas for a wide range of laboratory and theoretical conditions: coronal, local thermodynamic equilibrium or nonlocal thermodynamic equilibrium, optically thin or thick plasmas and photoionized plasmas. The radiative and collisional rates are a set of analytical approximations that compare well with more sophisticated quantum treatment of atomic rates that yield fast calculations. The atomic model is based on a new Relativistic Screened Hydrogenic Model (NRSHM) with a set of universal screening constants including nlj-splitting that has been obtained by fitting to a large database of ionization potentials and excitation energies compiled from the National Institute of Standards and Technology (NIST) database and the Flexible Atomic Code (FAC). The model NRSHM has been validated by comparing the results with ionization energies, transition energies and wave functions computed using sophisticated self-consistent codes and experimental data. All the calculations presented in this work were performed using ATMED CR code.

Keywords:
Screened hydrogenic model; Average atom model; Collisional Radiative Code; Opacity; Rosseland and Planck mean opacities; Plasmas in NLTE and LTE regimes

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I. INTRODUCTION

Accurate calculations of atomic populations of plasmas at different temperature and density conditions are required for the determination of the radiative properties for hydrodynamic simulations and spectroscopic diagnostics. These calculations are required for many research areas such as astrophysics, X-Ray lasers, Z-Pinches, other pulsed power machines, inertial and magnetic confinement fusion.

In a previous work [1], an average-atom model for plasmas in Local Thermodynamic Equilibrium (LTE), has been developed under the name of ATMED, which is a code for fast computation of radiative properties and equations of state of warm dense matter and LTE dense plasma mixtures for inertial confinement fusion design [1,2]. This code has its range of application for plasma conditions where it is feasible to assume that the electronic temperature is equal to the radiation temperature, but nevertheless, in real experiments [3,4], it has been observed that, for a wide range of applications, this LTE assumption is not valid, and it is necessary to treat these situations in the regime of Non-Local Thermodynamic Equilibrium (NLTE). Thus, the aforementioned code ATMED only covers a finite part of the time history of the thermodynamic evolution. This is the main reason for having extended the code to calculate plasma population kinetics under NLTE conditions for which the electron and radiation temperatures are different and vary in time.

In this paper we present a collisional-radiative model (ATMED CR) developed in the Average Atom framework using a Relativistic Screened Hydrogenic Model (RSHM). This code has been conceived to compute the population distribution of relativistic atomic levels (nlj), the average ionization as well as the atomic and radiative properties of steady-state and temporal plasmas of pure elements and mixtures of atomic species in the average atom formalism.