The optical properties of Hydrogen plasma described in the frame of the fully quantum method based on a cut-off Coulomb model potential

Nenad M. Sakan[1]*, Zoran J. Simić[2], and Momchil Dechev[3]

[1] *Institute of Physics, Belgrade University, Pregrevica 118, 11080 Zemun, Belgrade, Serbia*

[2] *Astronomical Observatory, Volgina 7, 11060 Belgrade, Serbia*

[3] *Institute of Astronomy and National Astronomical Observatory, Bulgarian Academy of Sciences, 72, Tsarigradsko chaussee Blvd. Sofia, Bulgaria*

nsakan@ipb.ac.rs

The goal - as much processes as possible

Up untill now it is work in progress:

- Transport properties - to be included
- Optical properties
  - Free-free transitions (inverse Bremsstrahlung) - included
  - Bond-free transitions (Photoionization) - included
  - Bond-bond transitions - partially included work in progress
- Plasma-emiter interraction - model one

but the results are proven to be usable

QM model potential pt.1

Multiparticle system is represented with single particle system that has a modeled interaction with plasma by the means of modeling pseudoptential.

Cut-off Coulomb potential

$$U_c(r) = \begin{cases} -\frac{e^2}{r} + \frac{e^2}{r_c}, & 0 < r \leq r_c, \\ 0, & r_c < r < \infty, \end{cases} \tag{1}$$

QM model potential pt.2

$$U_c(r) = \begin{cases} -\dfrac{e^2}{r} + \dfrac{e^2}{r_c}, & 0 < r \leq r_c, \\ 0, & r_c < r < \infty, \end{cases}$$

- Close vicinity of the emitter - Coulomb
- Far field - average plasma potential
- Cut-off plasma-emiter interaction

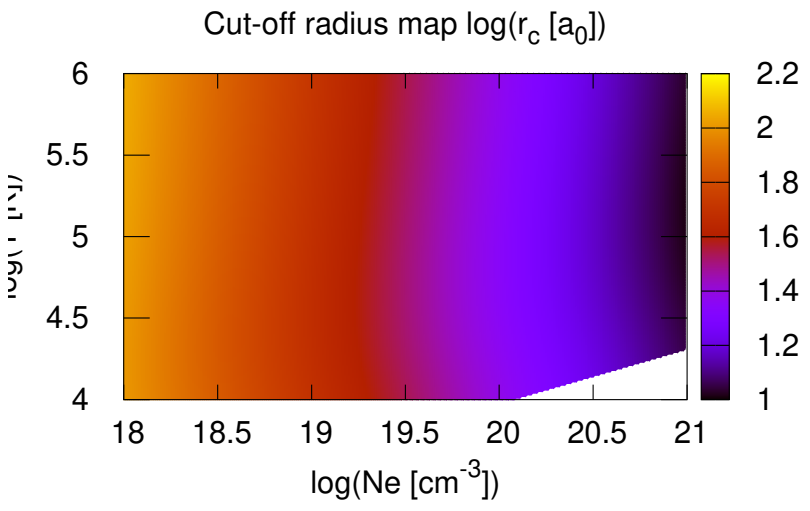
QM model potential pt.3

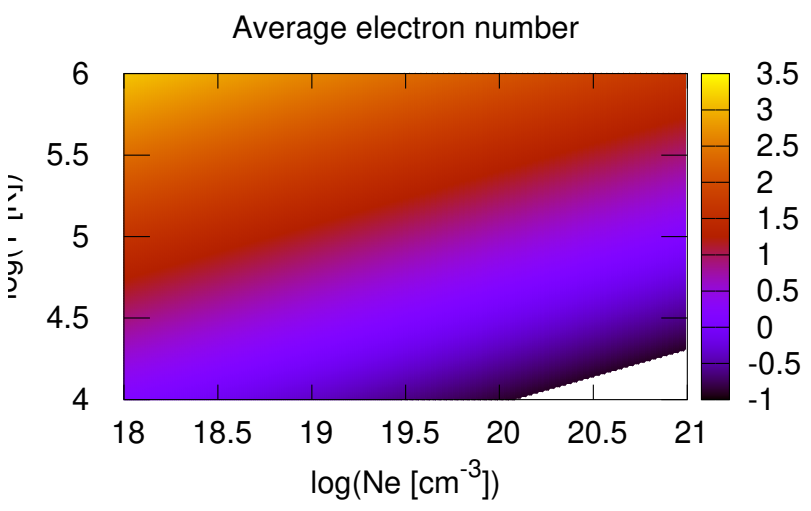
Behind all quantities in a dipole approach lies a dipole matrix element. For instance for the photoionization the dipole matrix element is given by

$$\hat{D}_{n,l;\,E,l'} = \int P_{nl}\, r P_{El'}\, dr.$$

P is analytically and numericaly solvable for used cut-off Coulomb model potential. Cut-off Coulomb potential is a simple approximation, but it is open for inclusion of more complex models of plasam interaction.

Expected area of good agreement

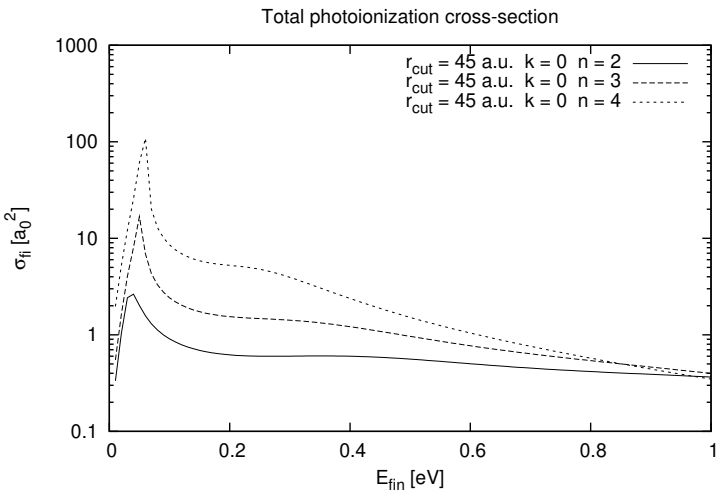


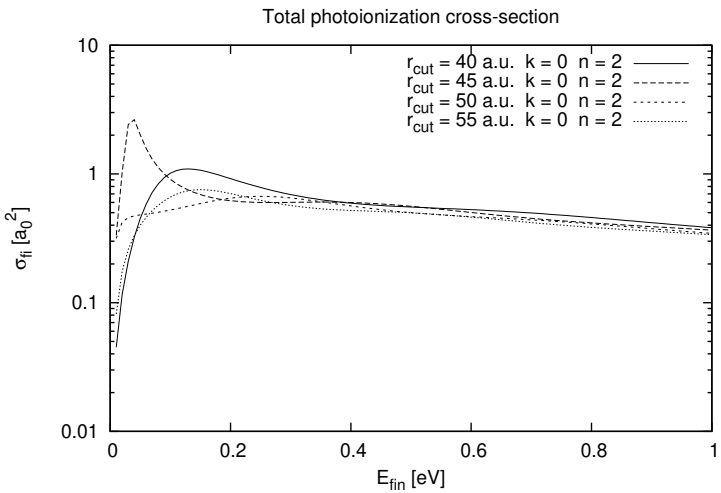


Dense plasma: $5 \times 10^{20}\ cm^{-3} \geq N_e \geq 1 \times 10^{18}\ cm^{-3}$

Up untill now pt.1

Hydrogen model yeilded good good agreement with the theory of unperturbed emmiter, e.g. pure Coulomb model potential, the Inglis–Teller behaviour is confirmed. The results ae usable for modeling





like a displayed cross sections.

Up untill now pt.2

Hydrogen model is proven, the cut-off Coulomb potential is used in several calculations up untill now.

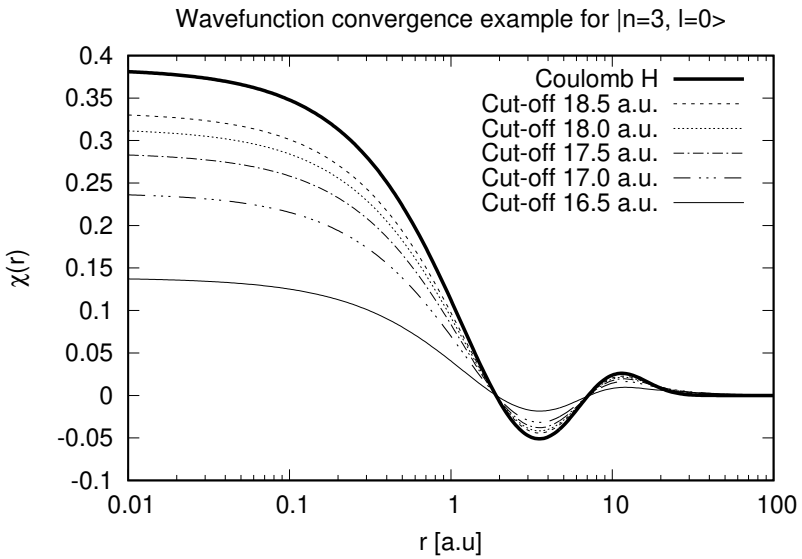
- Mihajlov, A.A., Sakan, N.M., Srećković, V.A., Vitel, Y., "Modeling of continuous absorption of electromagnetic radiation in dense partially ionized plasmas." J. Phys. A 2011, 44, 095502.
- Mihajlov, A.A., Srećković, V.A., Sakan, N.M., "Inverse Bremsstrahlung in Astrophysical Plasmas: The Absorption Coefficients and Gaunt Factors.", J. Astrophys. Astron., 2015, 36, 635–642.

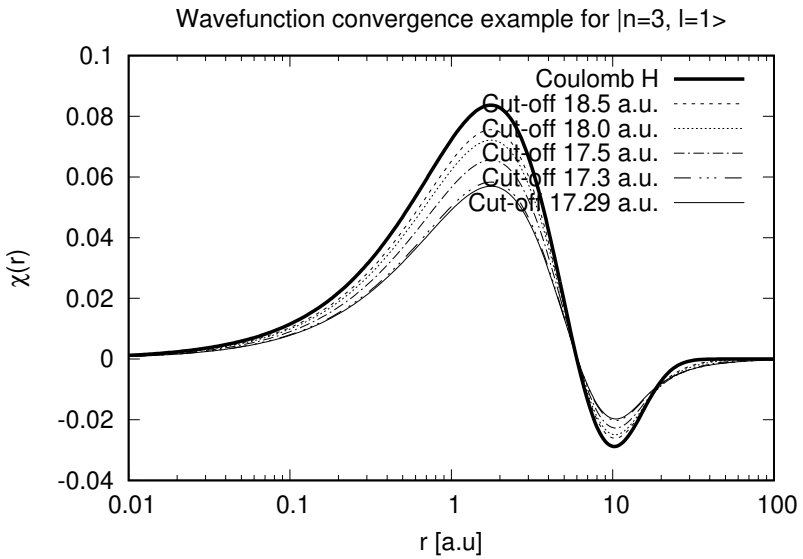
Up untill now pt.3

- Srećković, V.A., Mihajlov, A.A.,"The application of the cut-off Coulomb potential for the calculation of a continuous spectra of dense hydrogen plasma.", Mem. S. A. I. Suppl., 2005, 7, 221–224.
- Sakan, Nenad M. and Srećković, Vladimir A. and Simić, Zoran J. and Dimitrijević, Milan S., "The Application of the Cut-Off Coulomb Model Potential for the Calculation of Bound-Bound State Transitions", Atoms, 2018, 6, 1, 4

NOW pt.1

The wavefunctions for the bond states are calculated, the convergence towards unperturbated ones are tested

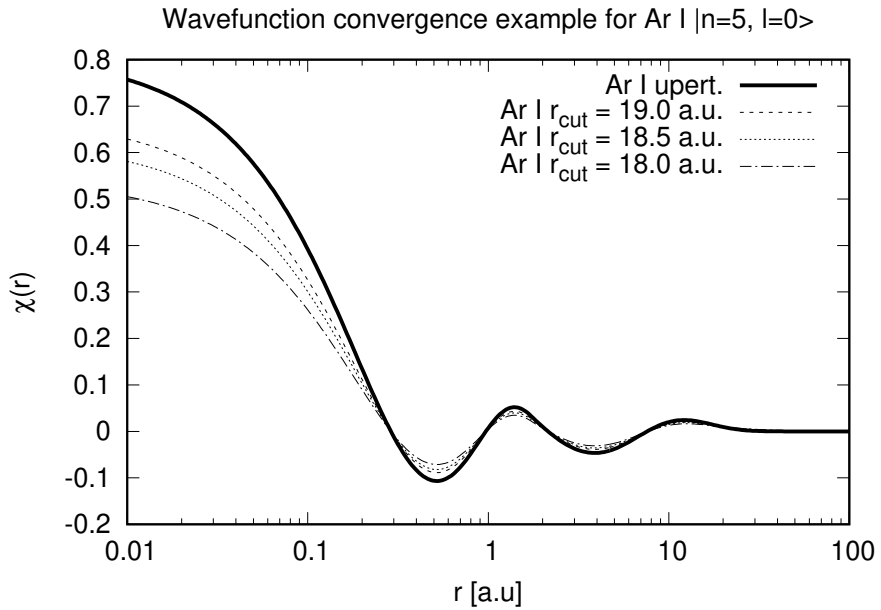




The model yielded results for dipole matrix element that converged towards unperturbated, pure Coulomb model ones.

NOW pt.2

The code for inclusion a more complex model potentials, e.g. for Ar I is finished and the results are tested



The dipole matrix elemets as well as oscillator strengths and total photoionization cross section are calculated for both hydrogen and argone cases.

Thak You for the attention

- Inclusion of more complex emitters, He I, He II, Ar I...
- More precise modeling of plasma-emiter interaction, maybe coupling with MD simulation
- Transport coefficients
- Magnetic field effects inclusion
- Going torwards more dense plasmas - strong Coulomb coupling
- Source for cross-section used for more complex plasma modelling