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Institute For Plasma Research

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Relaxation rates using Binary Collision in Plasma Simulation

Sumitava Kundu (under the guidance of Mrityunjay Kundu)

Introduction:

Binary collision model is such type of a model where particles collide pair-wise. The model conserves the total number of particle, total energy and total momentum quasi-locally. Collision effects in spatially, homogeneous plasma is simulated. The results of measurement on various relaxation rates in velocity space are shown to agree well with test particle theory.

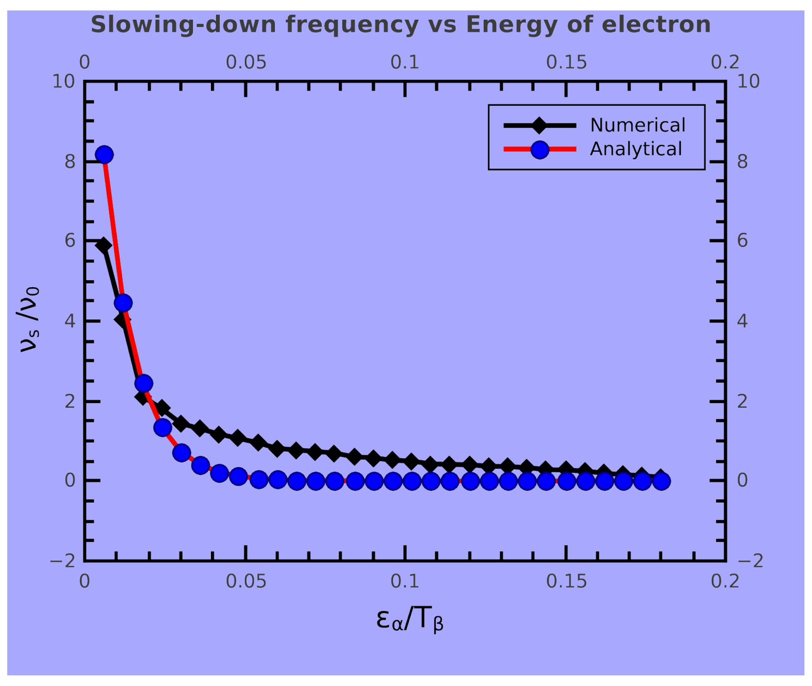
Theory:

Let, electrons are moving through ionized gas in plasma (homogeneous). Then electrons are making collisions with the ions, whose velocity distribution is Maxwellian distribution with a fixed temperature. After colliding electrons will scatter in various directions. So, scattering angle will be random. If the scattering angle be random, then the relative velocity between electrons and ions will be random, because the relative velocity in the laboratory frame is transformed into that in the frame of the relative velocity at time t. After calculating the relative velocity we will calculate the velocity component of electrons and ions separately. From there we will be able to calculate our desired measurements.

Results:

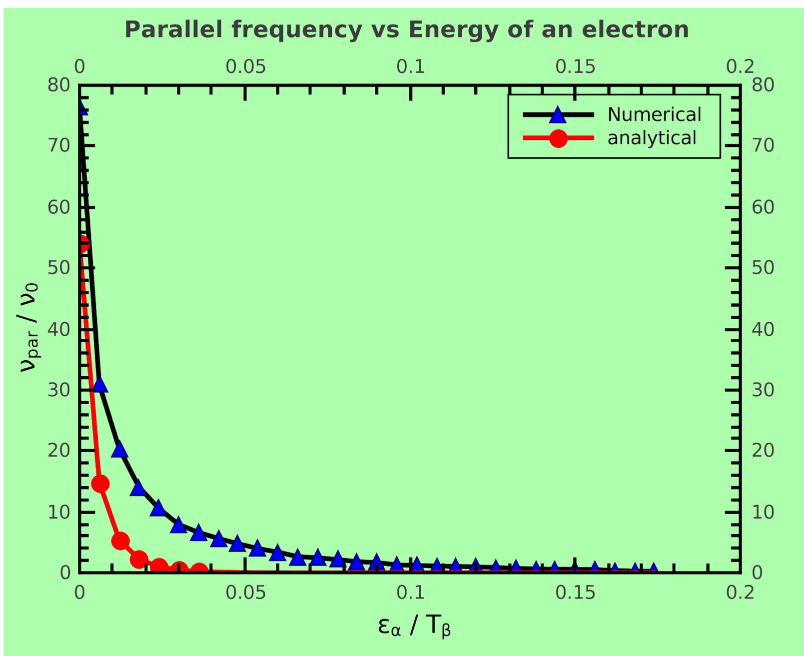
Relaxation Rates: Various relaxation rates can be calculated analytically by the test particle theory in which electrons are assumed to have to have no effects on the ion medium,whose velocity distributionis maxwellian with a certain temperature. Here electrons are moving like a beam and collide with the ions background. So, they are trying to relax. This is the physics problem we are dealing with here.

$$\nu_s = (1+\frac{m_\alpha}{m_\beta})\mu(x)\nu_0(\frac{T_\beta}{T_\alpha})^{3/2}$$



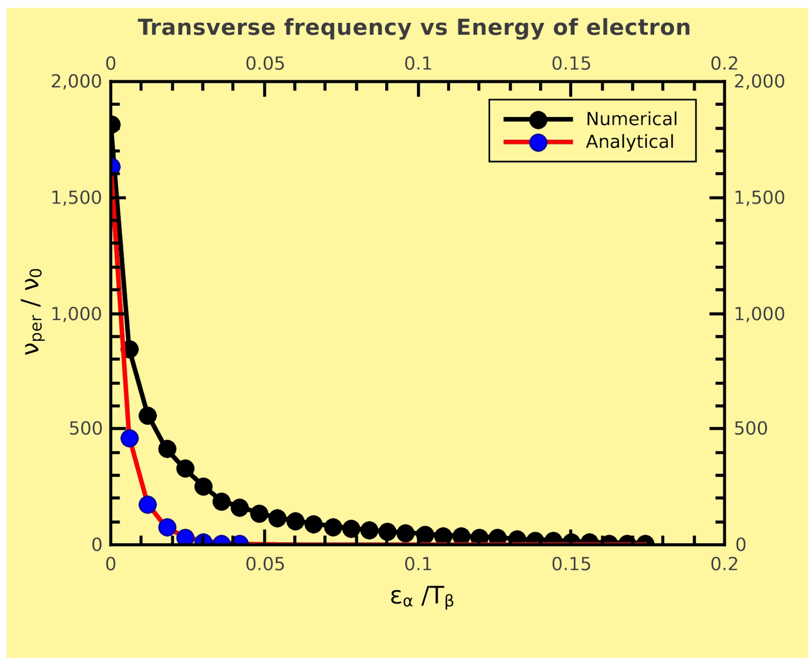
a)Slowing-down rate vs energy of electron

$$\nu_\perp = 2((1-\frac{1}{2x})\mu(x)+\frac{d\mu(x)}{dx})\nu_0(\frac{T_\beta}{T_\alpha})^{3/2}$$



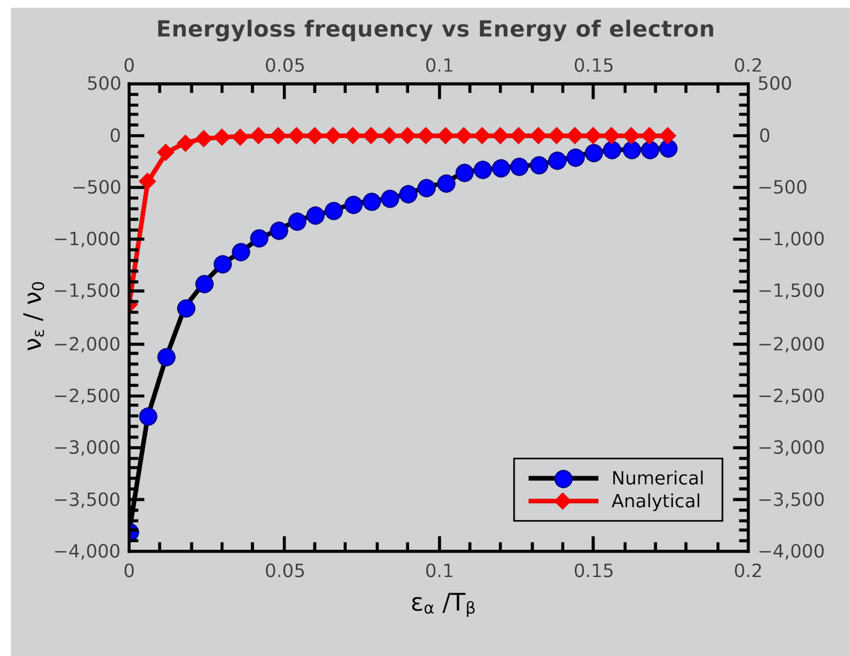
b) Parallel velocity diffusion rate vs energy of electron

$$\nu_\parallel = \frac{\mu(x)}{x}\nu_0(\frac{T_\beta}{T_\alpha})^{3/2}$$



c) Transverse velocity diffusion rate vs energy of electron

$$\nu_\varepsilon = 2(\frac{m_\alpha}{m_\beta}\mu(x)-\frac{d\mu(x)}{dx})\nu_0(\frac{T_\beta}{T_\alpha})^{3/2}$$



d) Energy loss rate vs energy of electron

Thermal Relaxation :

It is the case where the initial temperature of electrons is different than that of ions. First one is for electron-ion collision and second one is for electron-electron collision.

$$\frac{d}{dt}(T_i - T_e) = -2\nu_{eq}(T_i - T_e)$$

$$\frac{d}{dt}(T_\parallel - T_\perp) = -\nu(T_\parallel - T_\perp)$$

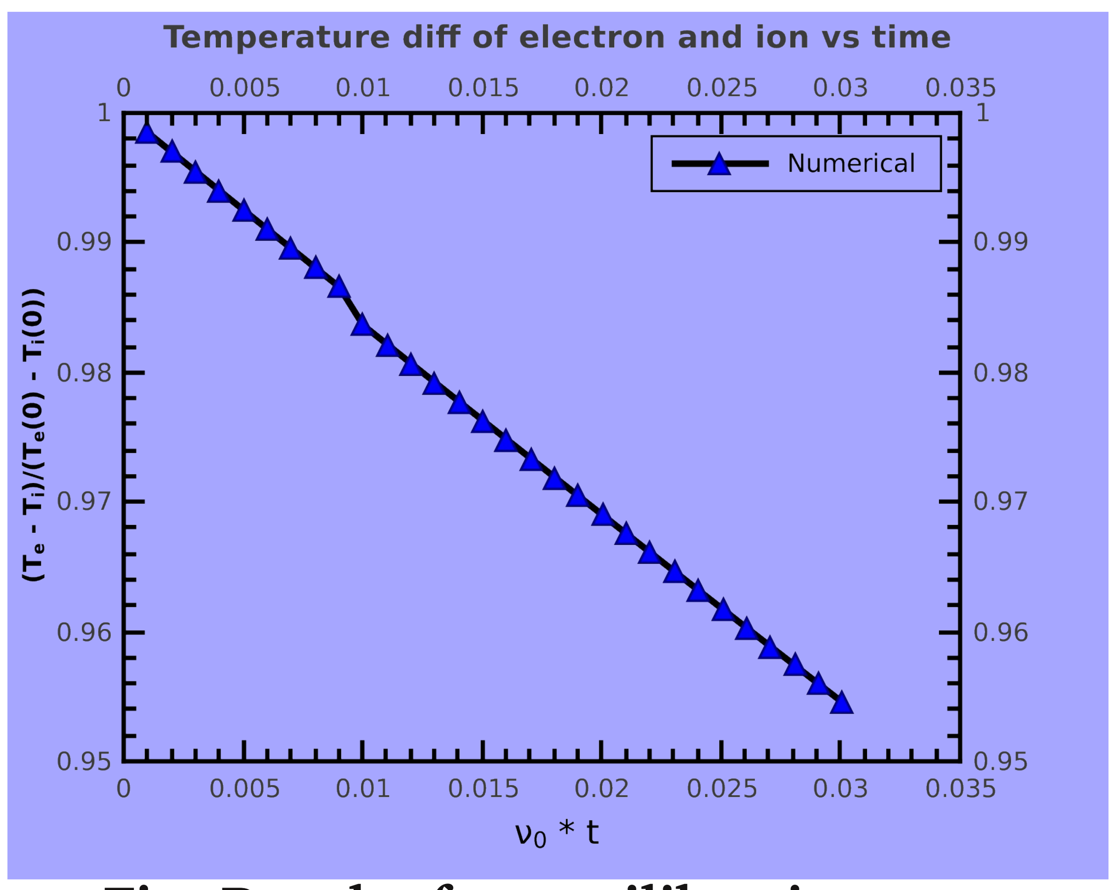


Fig: Results for equilibration

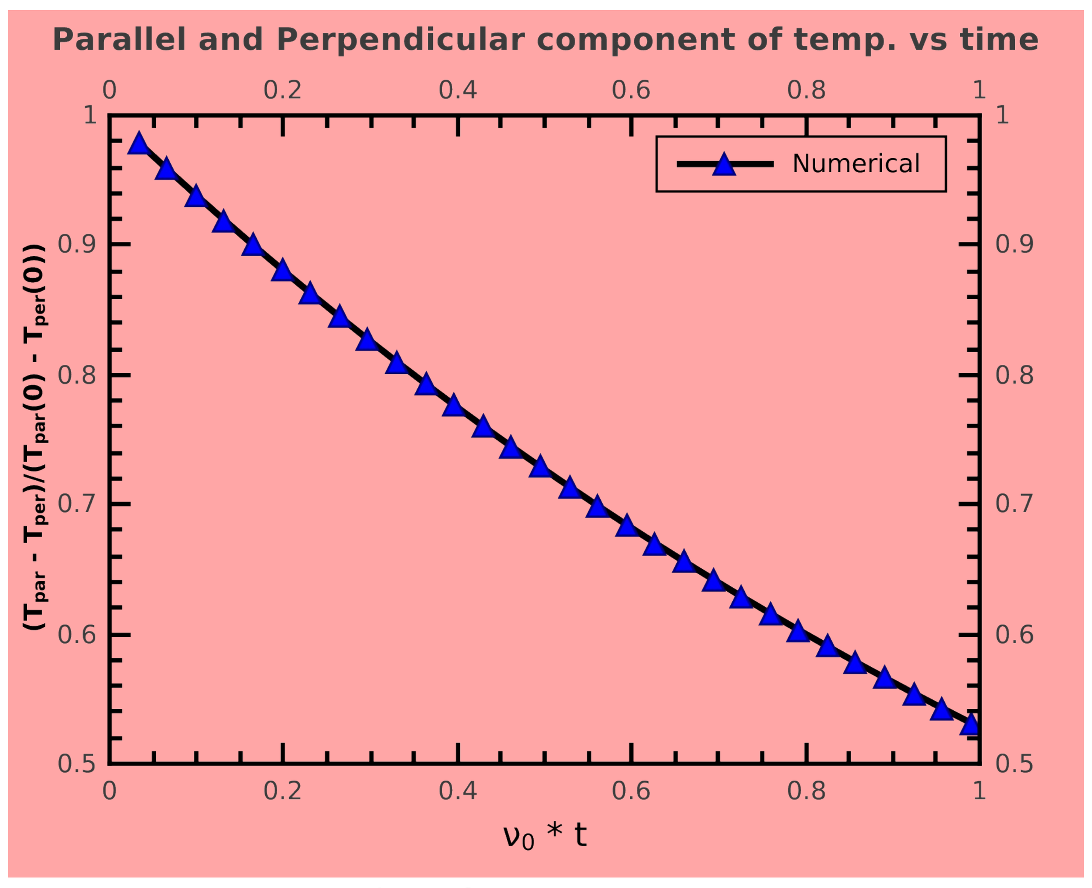


Fig: Results for isotropization

Conclusion:

I have re-examined a binary collision model and tested it under various physical situations[1,2]. The model closely describes the collisions in plasmas at the kinetic level. For computational simplicity, I have considered only Coulombic force between the particles and thermal energy is completely responsible for the particle's motion. Influence of magnetic field is not considered, because I have used the assumption that the particle's trajectory can be treated as Coulombic orbit without magnetic field. When the magnetic field is so strong that the cyclotron frequency is comparable to or larger than the plasma frequency,then some corrections are required.

References:

1)Binary collision model in gyrokinetic simulation plasmas(1993),by S. Ma, RD. Sydora and J.M. Dawson

2)A Binary Collision Model for Plasma Simulation with a Particle Code(1976),by TOMONORI TAKIZUKA and HIROTADA ABE