Implementation of RE-plasma collisions in JOREK

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A very brief overview of JOREK particles

JOREK has a particle module for:

- Studying the dynamics of trace particles in tokamak plasmas
- Perform coupled particle-MHD simulation of MHD-active plasmas

Features of the particle code (main branch):

- Support to full 3D time-varying MHD fields
- Multiple models of particles are supported: field lines, non-relativistic full orbits, relativistic full orbits and relativistic guiding-center orbits
- Routines for particle initialisation, post-processing, testing, …

Multiple developments are underway: additional types, integrators, particle ionisation, recombination, collisions, coupling scheme, ….

The collision operator implemented in JOREK-particle

The JOREK-particle module already has a test particle – plasma background collision operator:

- Binary Monte-Carlo method based on the Takizuka-Abe kernel [1]
    - Represents the Landau collision operator
- Background particle sampled from distorted Maxwellian distribution [2,3]

What are the drawbacks for RE applications?

- Absence of relativistic effects
- Absence of inelastic processes
- Partially screened impurities are not considered
- Not valid for guiding-center
- The order of convergence might too low for RE applications

[1] T. Takizuka, H. Abe, J. Comp. Phys, vol. 25, p. 205, 1977
[2] Y. Homma, A. Hatayama, J. Comp. Phys, vol. 231, p. 3211, 2012
[3] Y. Homma, A. Hatayama, J. Comp. Phys, vol. 250, p. 250, 2013

A strategy for implementing a RE-background plasma collision operator in JOREK particle

Step 1: finalise the present collision feature in JOREK

- Implement examples, unit and non regression tests
- Merge the collision feature in the main JOREK particle

Step 2: extend the current Takizuka-Abe kernel to relativistic electrons

Step 3: extend the collision kernel to partially screened impurities (Hesslow's model [4])

⇒ Requires a fast method for computing the collision "coefficients"

⇒ Possible to construct a database and train a neural network

[4] L. Hesslow et al., J. Plasma Phys, vol. 84, p. 905840605, 2018
[5] K. Sarkimaki et al. , Comp. Phys. Comm., vol. 222, p.374, 2018
[6] E. Hirvijoki et al, Phys. of Plasmas, vol. 20, p. 092505, 2013

A strategy for implementing a RE-background plasma collision operator in JOREK particle

Step 4: test the binary collision performance

⇒ If unsatisfactory, implement a Langevin solver [5]

Step 5: extend the collision operator to Guiding-Center particles [5,6]

[4] L. Hesslow et al., J. Plasma Phys, vol. 84, p. 905840605, 2018
[5] K. Sarkimaki et al. , Comp. Phys. Comm., vol. 222, p.374, 2018
[6] E. Hirvijoki et al, Phys. of Plasmas, vol. 20, p. 092505, 2013