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Effects of electron-ion collisions on stopping powers in warm dense matter

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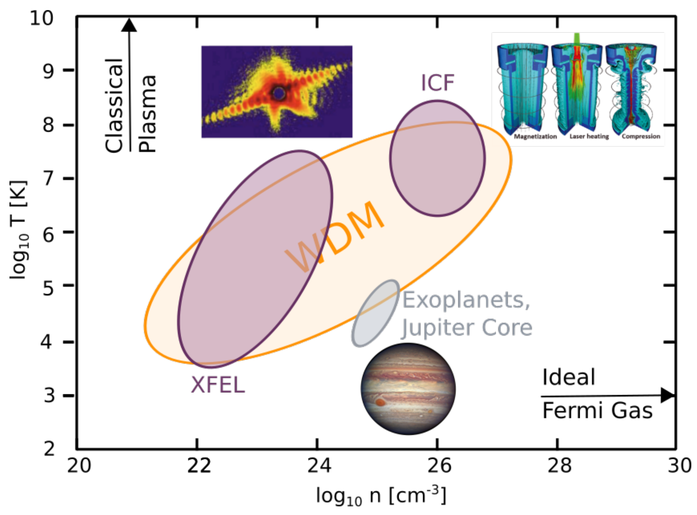
- Accurate **electron-ion collision frequencies** are important for **stopping power** calculations.
- Our approach to stopping powers is **computationally faster** than *ab initio* calculations, and **relatively accurate**.

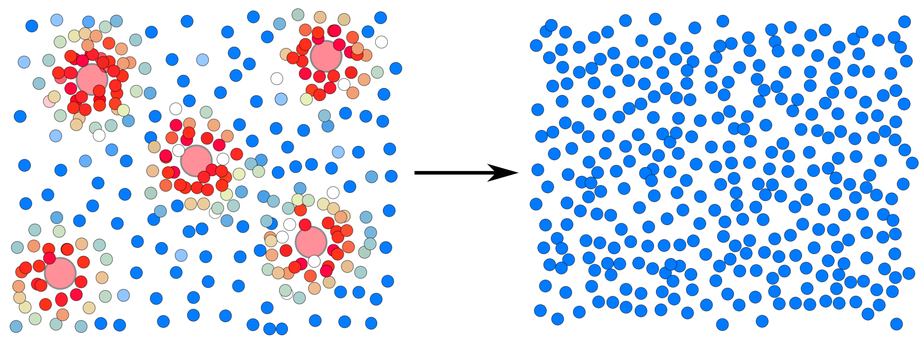
Motivation

- The stopping power is the energy lost as a charged particles moves through a plasma
- Stopping powers describe α-particle **self-heating** in fusion experiments, which go through the **warm, dense matter** regime (image: [1, 2])



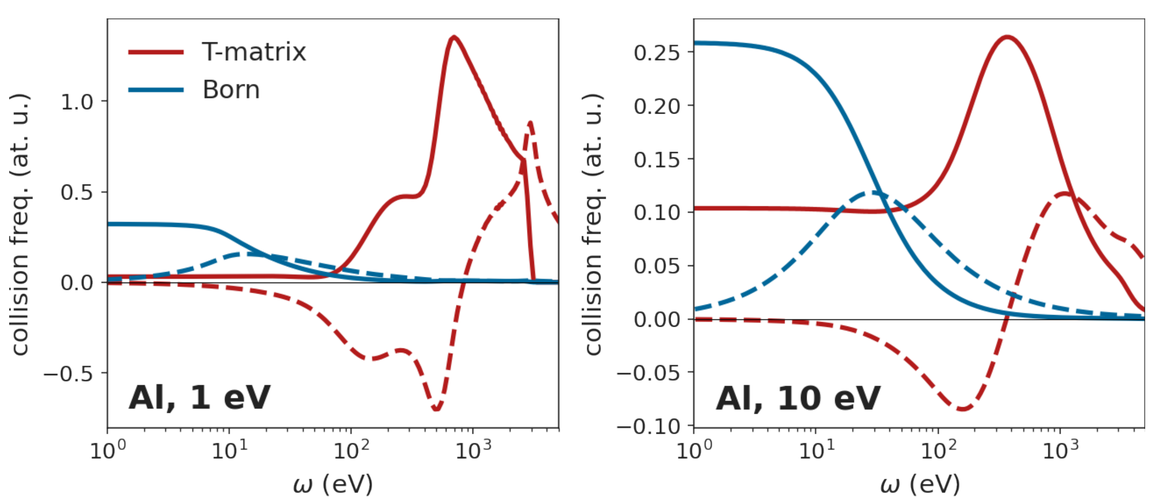
Methods

- First-principle methods, like time-dependent density functional theory (TD-DFT), are restricted to certain temperature and density regimes due to computational complexity
- Our stopping power model is based on a simple jellium description of a plasma (**random phase approximation**)



Left: A cartoon of the positive-energy electrons with ions present (larger red circles). Right: uniform electron gas and assuming plane-wave states.

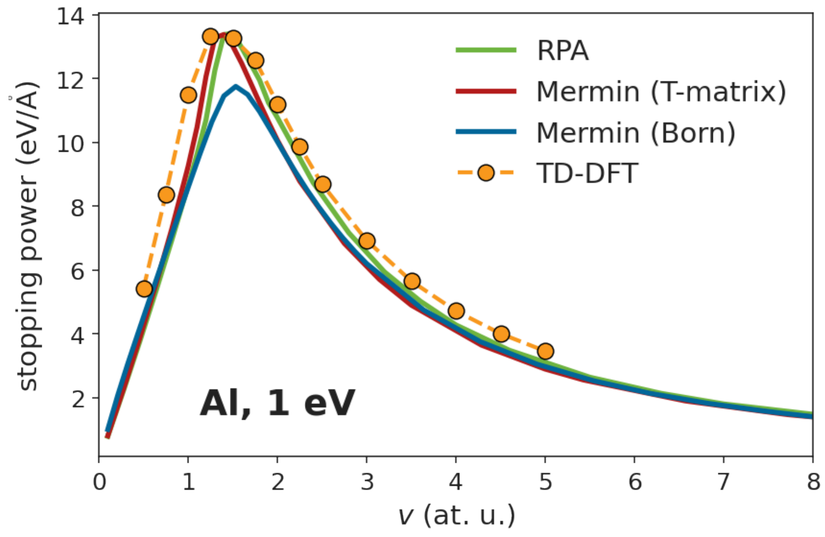
- We improve this by incorporating dynamic **electron-ion collision frequencies** (**Mermin ansatz**)
- These are calculated with **Born** or **transition-matrix** cross sections using an **average atom** code [3]



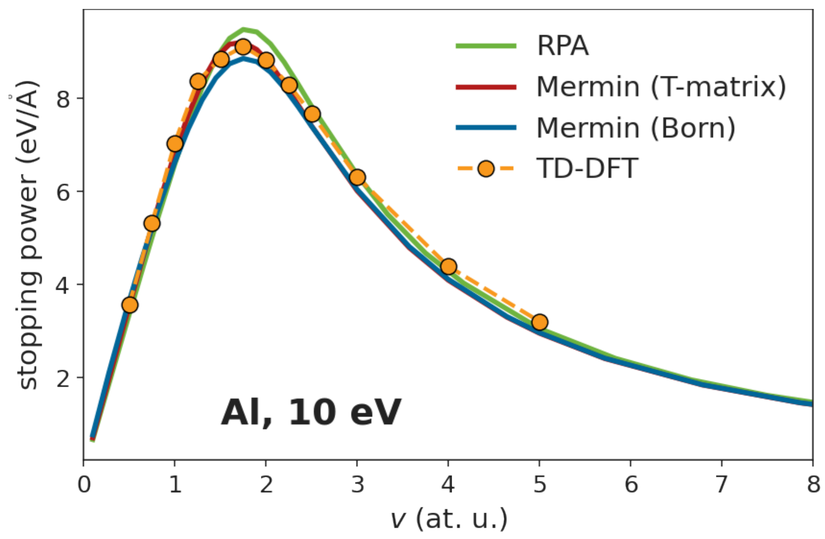
Dynamic collision frequencies for aluminum at $T = 1$ and 10 eV. Solid lines are the real part and dashed are the imaginary. Colors correspond to the cross section.

Stopping in Aluminum

- We consider the **stopping of a proton projectile as a function of velocity** in solid density aluminum
- We compare our simplified models to our TD-DFT calculations of the free-electron stopping

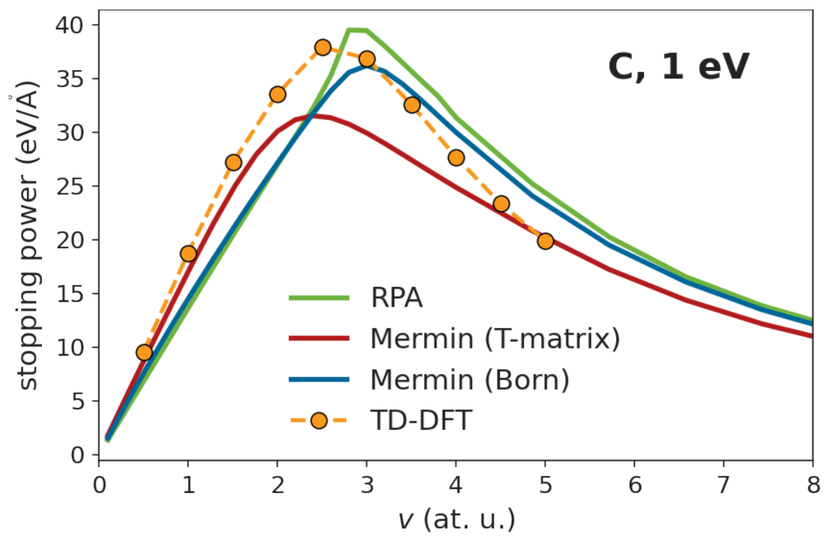


- At higher temperatures, the collisions have less of an effect but are still important



Stopping in Carbon

- For more complicated systems like carbon at $10\,\mathrm{g\,cm^{-3}}$, the simplified models are less accurate



References

1. Dornheim, T., Groth, S. & Bonitz, M. *Phys. Reports* **744** (2018).
2. Knapp, P. F. *et al.* *Physics of Plasmas* **22** (2015).
3. Hentschel, T. W. *et al.* *in preparation.*

Acknowledgements

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