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Ion-electron temperature equilibration in magnetized collisionless shocks

Chuang Ren
Department of Mechanical Engineering and
Department of Physics and Astronomy, University of Rochester
e-mail (speaker): chuang.ren@rochester.edu

Collisionless shocks are regarded as sources for GRB afterglow, cosmic rays, and loop-top hard X-rays. They are also studied in laboratory for their rich and interesting physics in shock formation, particle acceleration and energy equipartition. Micro-instabilities, driven by flows or energetic particles, play key roles in all these processes.

One of the important unresolved questions is how energy in the shocked downstream plasma partitions between the electrons and ions. The Rankine-Hugoniot relation only prescribes the total energy of the two species. Lacking of collisions or any other interactions, the electrons and the ions would convert their respective flow energy into thermal energy, which would lead to $\Delta T_e/\Delta T_i = m_e/m_i << 1$. However, collisonless interactions do exist and large electron heating has been observed in shocks from sources such as supernova remnants (SNR), solar winds interacting with Earth and Saturn, and galaxy cluster gases

Recently, we performed some 2D particle-in-cell (PIC) simulations to show that collisonless quasi-parallel shocks can be created using the NIF laser and ion acceleration can be observed [1]. The simulations also showed significant electron heating in the downstream, ranging from $T_e/T_i = 0.23$ in the quasi-perpendicular shocks to $T_e/T_i = 0.75$. The heating is much larger than the mass ratio of $m_e/m_i = 1/50$. Due to computation resource limitation, these simulations, like many other collisonless shock PIC simulations, used a reduced mass ratio.

In this talk, we will report some recent PIC and linear stability analysis results that show the ion-electron temperature equilibration is via electron Landau damping of a right-handed circular-polarized (RHCP) wave driven by counter-streaming ion beams along a magnetic field. When analytical results can be obtained, they can give mass-scaling of the growth rates that shows the importance of the RHCP mode even under the realistic electron-ion mass ratio. The analytical results are compared with a new spectral Valsov code SpectaVla [2].

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References

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