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Coherent Emission from 3D Relativistic Shocks

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The origin of fast radio bursts (FRBs) is one of the unsolved problems in astrophysics [1]. FRBs are extremely bright and millisecond duration pulse at radio frequency and often show high linear polarization. Many observations of FRBs indicate that FRBs must be coherent emission in the sense that coherently moving electrons radiate electromagnetic waves. In relativistic shocks, it is well known that coherent electromagnetic waves are excited by synchrotron maser instability (SMI) in the shock transition [2]. The SMI, which is called cyclotron maser instability in the weakly relativistic context, is also known as the emission mechanism of coherent radio sources such as auroral kilometric radiation at Earth and Jovian decametric radiation and has been widely studied in the study of space plasma [3]. Recently, some models of fast radio burst based on the coherent emission from relativistic shock via the SMI have been proposed [7-10] and the SMI in the context of relativistic shocks attracts more attention from astrophysics. In the shock transition, the incoming electrons begins to gyrate due to the shock-compressed magnetic field and the ring-like momentum distribution is generated, which triggers the SMI. Previous two-dimensional (2D) particle-in-cell (PIC) demonstrates that the coherent electromagnetic waves are indeed excited in the shock transition and propagate toward the upstream [4-6].

In this study, by performing the world's first 3D PIC simulation of ion-electron relativistic shocks, we will demonstrate that large-amplitude electromagnetic waves are indeed excited by the SMI even in 3D and that the wave amplitude is significantly amplified and comparable to that in pair plasmas due to a positive feedback process associated with ion-electron coupling. We also measure the wave polarization and quantitatively characterize the wave property. Based on the simulation results, we will discuss the applicability of the SMI for FRBs in this talk.

References

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