

Collisionless Weibel shocks: full formation mechanism and timing

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Collisionless shocks in plasmas play an important role in space physics (Earth's bow shock) and astrophysics (supernova remnants, relativistic jets, gamma-ray bursts, high energy cosmic rays). While the formation of a fluid shock through the steepening of a large amplitude sound wave has been understood for long, there is currently no detailed picture of the mechanism responsible for the formation of a collisionless shock.

We unravel the physical mechanism at work and show that an electromagnetic Weibel shock always forms when two relativistic collisionless, initially unmagnetized, plasma shells encounter. The predicted shock formation time is in good agreement with 2D and 3D particle-in-cell simulations of counter-streaming pair plasmas.

By predicting the shock formation time, experimental setups aiming at producing such shocks can be optimised to favourable conditions.