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Large-scale magnetic field generation via the kinetic Kelvin-Helmholtz instability in unmagnetized scenarios

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(Submitted on 29 Jul 2011 (v1), last revised 6 Dec 2011 (this version, v2))

Collisionless plasma instabilities are fundamental in magnetic field generation in astrophysical scenarios, but their role has been addressed in scenarios where velocity shear is absent. In this work we show that velocity shears must be considered when studying realistic astrophysical scenarios, since these trigger the collisionless Kelvin-Helmholtz instability (KHI). We present the first self-consistent three-dimensional (3D) particle-in-cell (PIC) simulations of the KHI in conditions relevant for unmagnetized relativistic outflows with velocity shear, such as active galactic nuclei (AGN) and gamma-ray bursts (GRBs). We show the generation of a strong large-scale DC magnetic field, which extends over the entire shear-surface, reaching thicknesses of a few tens of electron skin depths, and persisting on time-scales much longer than the electron time scale. This DC magnetic field is not captured by MHD models since it arises from intrinsically kinetic effects. Our results indicate that the KHI can generate intense magnetic fields yielding equipartition values up to \epsilon_B/\epsilon_p ~ 10^-3 in the electron time-scale. The KHI-induced magnetic fields have a characteristic structure that will lead to a distinct radiation signature, and can seed the turbulent dynamo amplification process. The dynamics of the KHI are relevant for non-thermal radiation modeling and can also have a strong impact on the formation of relativistic shocks in presence of velocity shears.

Subjects: **High Energy Astrophysical Phenomena (astro-ph.HE)**; Plasma Physics (physics.plasm-ph)

Cite as: **arXiv:1107.6037 [astro-ph.HE]**
(or **arXiv:1107.6037v2 [astro-ph.HE]** for this version)

Submission history

From: Eduardo Paulo Alves [view email]
[v1] Fri, 29 Jul 2011 18:42:36 GMT (2814kb,D)
[v2] Tue, 6 Dec 2011 18:19:08 GMT (8964kb)