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Collisionless coupling of a high-β expansion to an ambient plasma[1]

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We report on an experimental study of collisionless coupling between a high-β ($\sim 10^6$) expansion and a quiescent, magnetized plasma via laminar electric fields. The dynamic, 3D structure of the electrostatic field, $-\nabla\phi$, and the induced electric field, $-\partial_t\vec{A}$, of a laser-produced plasma (LPP) were measured in situ [1] within the uniform plasma provided by the Large Plasma Device at UCLA. The LPP was generated using a graphite target and oriented to provide Alfvnic expansion speeds along the initially uniform magnetic field, $\vec{B}_0$. The strongest measured electric field was an inward, radial electrostatic field established by charge separation of the ions and electrons across $\vec{B}_0$. The imbalance between the charge layers also resulted in a radially outward electrostatic field that appeared to be responsible for the observed magnetic compression. Global neutralization of this charge distribution is connected with previously observed energetic electrons and subsequent whistler wave radiation [2]. The cumulative effect of the total electric field is to pull ambient ions inward against the expansion. This is in contrast to models that neglect $-\nabla\phi$ in favor of $-\partial_t\vec{A}$ due to the large-scale motion of the magnetic field lines. Planar laser-induced fluorescence imaging in an argon background plasma confirmed this effect by measuring directly the velocity of the ambient ions. A simple model is presented of these results and other high-β expansions that is similar to Lord Rayleigh's work on gaseous bubble cavitation [3]. It predicts relative magnitudes of $-\nabla\phi$ and $-\partial_t\vec{A}$ as well as an approximate description of their ability to couple energy and momentum to the ambient plasma. This model also provides scaling quantities appropriate for similar collisionless plasma expansions including explosions near young stellar objects, magnetospheric chemical releases, and high-altitude nuclear explosions. [1] Bonde, J et al., Phys. Rev. E 92, 051102 (2015). [2] Vincena, S et al., Phys. Plasmas 15, 072114 (2008). [3] Rayleigh, L. Philos. Mag. 34 (200), 94 (1917).

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