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Magnetohydrodynamics with chiral anomaly: formulation and phases of collective excitations and instabilities

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We discuss chiral magnetohydrodynamics (MHD) which serves as a low-energy effective theory of the chiral matter in the presence of a finite chirality imbalance and dynamical magnetic field [1]. It may have applications not only to relativistic heavy-ion collisions but also condensed matter physics and astrophysics.

Based on our derivative expansion for the chiral MHD and the second law of thermodynamics, we show that a current in ordinary MHD is modified due to the chiral anomaly, which is identified as the chiral magnetic effect (CME). While the similar derivation of CME was performed by Son and Surowka, our derivative expansion is significantly different from theirs due to the presence of the dynamical magnetic field. Our result exemplifies the universal nature of the CME that persists in MHD.

We also discuss that, when the chirality imbalance exceeds a critical value, a new type of gapless collective excitation emerges as a result of the interplay among the magnetic field, flow velocity, and chiral anomaly, which we call the chiral magnetohelical mode (CMHM). These modes carry definite magnetic and fluid helicities, and either grow or dissipate exponentially in time, depending on the relative sign between their helicities and the chirality imbalance. The presence of exponentially growing CMHM indicates a new hydrodynamic instability.

[1] Koichi Hattori, Yuji Hirono, Ho-Ung Yee, Yi Yin, "Magnetohydrodynamics with chiral anomaly: phases of collective excitations and instabilities,"[arXiv:1711.08450 [hep-th]].

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