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Flow Driven MHD instabilities in Weakly Magnetized Laboratory Experiments: Dynamos and MRI

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Astrophysical plasmas are often characterized by high magnetic Reynolds number, turbulent, flowing plasma in which the flow energy is much larger than that of magnetic field. Examples include planetary interiors, accretion disks and the solar wind. Creating such conditions in laboratory plasma experiments is challenging since confinement is required to keep the plasma hot and conducting and requiring strong magnetic fields. For this reason, laboratory experiments using liquid metals have been addressing fundamental plasma processes in this unique parameter regime. This talk will begin by giving a elementary tutorial of two related processes: the dynamo in which magnetic energy is spontaneously generated from flow energy; and the magneto-rotational instability in which a weak magnetic field can act as a catalyst for transporting momentum. Then, I will then show how liquid metal experiments have been contributing the the understanding of such processes. Liquid metal experiments have (1) demonstrated self-excitation of magnetic fields, (2) two scale dynamos where a small scale flow drives a large scale magnetic field, (3) intermittent self-excitation and a variety of time dynamics including field reversals, (4) showed the existence of a turbulent electromotive force (mean-field current generation), and (5) MRI-like instabilities have been observed in Couette flow geometries. Liquid metals are, however, not plasmas: dynamos and MRI may differ in plasmas where the relative importance of viscosity, and resistivity can be interchanged, and new instability mechanisms, outside the scope of MHD may be critical in collisionless plasmas. This suggests that the next generation of experiments in this important astrophysics regime should be based upon plasmas.