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Large scale dynamics of laboratory and astrophysical plasmas: bridging the lab/astro scale gaps and its limitations[1]

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Large scale dynamics in a high temperature plasma tend to produce strong, large scale magnetic fields in the laboratory and astrophysical settings. It underlies two types of theory. The first is the conventional magnetic dynamo, which explains how plasma energy can be transformed into large scale magnetic energy. The second is the so-called magnetic self-organization, which explains how magnetic helicity introduced at a small scale source can be self-organized into system-scale magnetic fields. Examples of the first kind include the self-generated magnetic field in an inertially confined (ICF) plasma and the magnetic field in the accretion disk of stellar objects. The second kind includes the dramatic example of the megaparsec-scale radio lobe magnetic fields which are powered by the parsec-scale accretion disk of supermassive black holes, and the laboratory formation of spheromak and reversed field pinch by electrostatic helicity injection. Despite the huge scale separation between laboratory and astrophysical cases, the underlying physics appear to be surprisingly robust. Here I will first describe the theory of magnetic self-organization, and illustrate how a radio lobe can be formed and how it relates to the spheromak experiment. Specifically, the required extremely high efficiency in transferring gravitational infall energy into large scale radio lobe magnetic fields will be understood as the result of a resonant coupling between accretion disk and radio lobe plasmas, similar to a driven oscillator. The second part of the talk concerns a new form of kinetic magnetic dynamo, which is the result of anisotropic transport when hot plasmas meet a colder boundary. I will describe the underlying physical mechanisms and its laboratory and astrophysical implications. Since kinetic transport physics plays a decisive role in determining large scale dynamics, we are confounded with the interesting and difficult question of how to most effectively incorporate such physics in macro-modeling, especially in the case of nearly collisionless astrophysical plasmas.

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