Astrophysical magnetic helicity injection: jets, lobes, and LAPD-U

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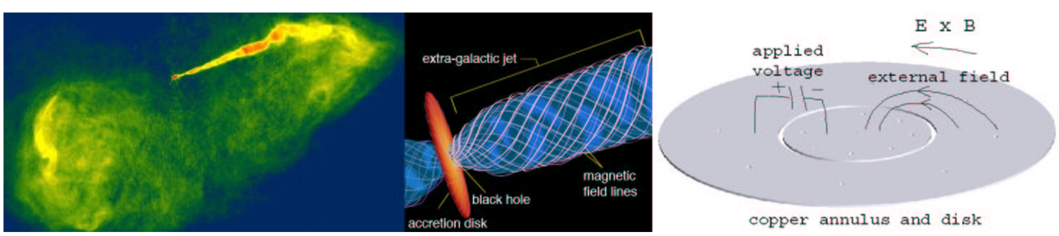
Two spectacular astronomical observations inspire a number of basic plasmas physics problems that have laboratory relevance. The first is the ubiquity of 10^{8-9} solar-mass super-massive black holes at the center of galaxies[1] and on the order of 10^{62} ergs of gravitational energy released *via* accretion. The second is the existence of an almost equally large amount of magnetic energy ($\sim 10^{61}$ ergs) in galactic jet radio lobes[2](see figure left). The physical process by which the accretion disk drives the jet/lobe is thought to be magnetic helicity injection, in which the differential Keplerian disk rotation twists up a magnetic arcade above the disk, directly converting mechanical energy into magnetic energy. In the laboratory, a radial electric field imposed by coaxial electrodes faithfully simulates the same process by drawing current from a power supply to run through a plasma threaded by an externally imposed poloidal magnetic field (see figure right). The toroidal magnetic flux is then injected by the current into the discharge chamber, driving a magnetic bubble expansion. Laboratory electrostatic helicity injection has found usage from spheromak formation[3] to non-inductive current drive in spherical tori[4]. Here we describe the underlying plasma physics for astrophysical jet/lobe that can be addressed by a proposed dedicated experiment on LAPD-U at UCLA.[5] These include theoretical/computational considerations of (1) why jets form? the collimation mechanism for an under- and over-pressured jet; (2) jet stability limit; (3) jet magnetic energy and helicity content, and the *curse of the spheromak*; (4) jet $P\,\mathrm{d}V$ work, cosmic shoveling, and angular momentum transfer from the accretion disk by electromagnetic torque. The experimental plan will also be explained, along with the justification of its astrophysical relevance. Useful discussions with H. Li, S. Colgate, R. Lovelace on jet/lobe, A. Boozer on helicity injection, R. Raman and S. Woodruff on laboratory experiments, are gratefully acknowledged. This work was supported by LANL LDRD program.



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