Integrated mechanism that both removes accretion disk angular momentum and drives astrophysical jets

P. M. Bellan[1],

[1]*Caltech, Pasadena, California, USA*

Using concepts from laboratory experiments, Hamiltonian mechanics, Hall MHD, and weakly ionized plasmas, a mechanism is proposed [1] that simultaneously drives astrophysical jets and removes accretion disk angular momentum. The mechanism depends on the extreme stratification of ionization between the weakly ionized accretion disk and the highly ionized region exterior to the disk. In the exterior region, axisymmetric Hamiltonian mechanics constrain charged particles to move on nested poloidal flux surfaces as in the magnetosphere and in fusion toroidal magnetic confinement devices. In contrast, fluid elements in the weakly ionized, highly collisional accretion disk behave like *collisionless meta-particles* with effective q/m reduced from than that of an ion by the nominal accretion disk 10^{-15} – 10^{-8} fractional ionization. This reduction means that the effective cyclotron frequency ω_c of a meta-particle can be of the order of the Kepler frequency $\omega_K = (MG/r^3)^{1/2}$. The special sub-class of meta-particles with $\omega_c = -2\omega_K$ have zero canonical angular momentum, and Hamiltonian mechanics shows that this sub-class experiences *no* centrifugal force and so *spirals in* towards the central body. Thus, these special meta-particles move collisionlessly *across* poloidal flux surfaces under the combined effect of gravity and magnetic forces. The radially inward disk current is a Hall current because it results entirely from the inward spiralling positively charged meta-particles and not from electron motion. Because these inward spiralling meta-particles are positive, their accumulation near the central body produces radially and axially outward electric fields. The axial outward electric field drives a poloidal electric current carried by electrons along poloidal flux surfaces in the fully ionized region external to the disk. This external-to-disk current is a conventional ideal MHD current, not a Hall current, and completes the poloidal circuit initiated by the inward spiralling meta-particles in the disk. As in lab experiments, forces from the gradient of the toroidal magnetic field associated with this poloidal current circuit drive MHD jets flowing normal to and away from the disk. In accordance with Faraday's law, the in-disk radial voltage drop associated with the in-disk radial electric field creates and injects new toroidal flux frozen into the lengthening jets.

[1] Bellan, P.M., Monthly Notices Royal Astronomical Society **458**, 4400 (2016)