A Review of Magnetorotational Instability in Astrophysics

J. Goodman

Princeton University Observatory, Princeton, NJ 08540

Abstract

Plasma parameters and other important physical characteristics of astrophysical disks are summarized. The observed luminosity of such disks is proportional to their radial mass flux (accretion rate) onto the central star or black hole around which the disk orbits. Anomalous outward transport of angular momentum is required to balance its inward advection by accretion. We explain why magnetorotational instability (MRI) is the most likely cause of this transport and sketch the essential physics of the linear MRI modes, together with the history of their discovery by Velikhov, Chandrasekhar, and Balbus and Hawley. Plasma inertia is essential to MRI, which appears to be an intrinsically high-β phenomenon. During the past decade, several groups have studied MRI-driven turbulence by numerical simulations. Dynamo action is observed, and indeed required for sustained MRI-driven turbulence (TMRI) absent an externally applied magnetic field. A consensus has emerged from this work, but important questions remain. Cool and weakly-ionized disks are probably too resistive for TMRI, but the threshold for TMRI is uncertain; Hall conductivity may be critical in this regime. In the opposing high-temperature limit, it is unclear whether the orbital energy dissipated by TMRI goes mostly into ions or electrons; observations of the Galactic Center and other low-luminosity systems appear to favor a two-temperature plasma. Even for fully-ionized disks of moderate temperature with $T_e = T_i$, simulations may underestimate the anomalous angular-momentum transport because of their limited range of resolved spatial scales. Also, the response of the turbulence to time-dependent perturbations of the disk, such as pressure waves excited by embedded planets, has scarcely been investigated but is likely to be nontrivial since the frequency of such perturbations is often comparable to, or shorter than, the MRI growth rate. If time permits, we will sketch prospects for laboratory studies of MRI in differentially rotating liquid metals.