

Chapter 12

Magnetorotational instability

... much of the fluid and stellar community was aware of the instability, however, and of its curious behavior of ostensibly changing the Rayleigh criterion discontinuously ...

S. A. Balbus [28]

12.1 Magnetorotational instability in axial and helical magnetic fields

12.1.1 Cylindrical Couette–Taylor flow

In 1890 Maurice Couette, a student of Gabriel Lippmann, defended his thesis “Etudes sur le frottement des liquides” and was awarded his doctorate at the Sorbonne “with all white balls” and *cum laude* for the experiments with a viscometer of his own design [311]. Seventy years later Evgeny Velikhov, then a physics student of Stanislav Braginsky at the Moscow State University, discovered the magnetorotational instability of the *Couette–Taylor flow* [581].

The fates of the first scientific works of both young scientists were similar in a sense that the reaction of the scientific community in both cases was quiescent for almost 30 years, until Geoffrey Taylor investigated stability of the rotating Couette flow in 1923 [566] and Steven Balbus and John Hawley demonstrated in 1991 the crucial role of magnetorotational instability for the explanation of transition to turbulence and thus the anomalous viscosity in accretion disks surrounding gravitating bodies [28].

The aim of Couette was to measure the kinematic viscosity of water. In 1888 [135] he reported on the design of a viscometer that he presented at the 1889 Universal Exhibition in Paris [478]. In the Couette viscometer the liquid occupied a space between two co-axial cylinders, the outer one rotating while the inner one remained fixed, Figure 12.1. Couette found that at small speeds of rotation the moment of the drag which the fluid exerted on the inner cylinder was indeed proportional to the velocity of the outer cylinder, from which the kinematic viscosity was determined. At higher speeds the drag increased at a greater rate than the velocity, indicating the onset of turbulent motion.

In his thesis Couette referred [478] to the work of Arnulph Mallock from Rayleigh’s laboratory [403] who independently designed a similar device with either the inner or