Virial Theorem Analysis of the Structure and Stability of Magnetized Clouds

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I have used the tensor virial equations to develop models of magnetized, self-gravitating, isothermal clouds confined by an external medium. These models are characterized by five parameters; the mass M and isothermal speed C_s of the cloud, the pressure P_e of the ambient medium, the strength of the magnetic field at infinity B_∞, and the magnetic flux Φ which threads the cloud. The cloud is spheroidal, with semi major axis a and eccentricity e to be calculated from the two nontrivial components of the tensor virial equations with M_1, C_s, P_e, B_∞, and Φ as input parameters. This work is a logical extension of Strittmatter's (1966). A sketch of a cloud model is shown in Figure 1.

I calculate "critical states," which represent extremal solutions in the sense that if the external pressure is increased while keeping the other parameters fixed, no equilibrium exists and the system presumably collapses. These critical solutions are compared with the exact magnetostatic models of Mouschovias (1976; from Mouschovias and Spitzer 1976) and Tomisaka et al. (1988) in Figure 2. These latter models represent states which have contracted from uniformly magnetized spheres with frozen in magnetic flux. The virial theorem models are parameterized by q, the ratio of B_∞ to the fieldstrength B_0 in the cloud. The points at fixed q and increasing η_c have increasing values of e. The slope of the line through the q = 0.85 solution agrees with the magnetostatic models; the difference in intercept is due to the effects of central concentration, which the virial theorem models ignore.

I have also used the virial equation to study the stability of these models to small perturbations. A sufficiently strong, uniform field can completely stabilize a cloud while a field which is much stronger than the external field can destabilize it.

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References

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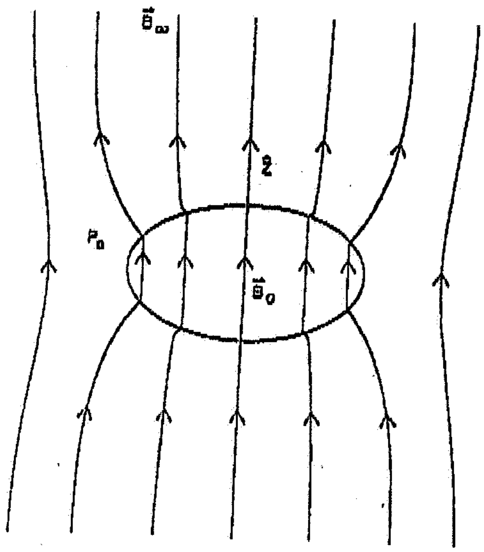

Figure 1

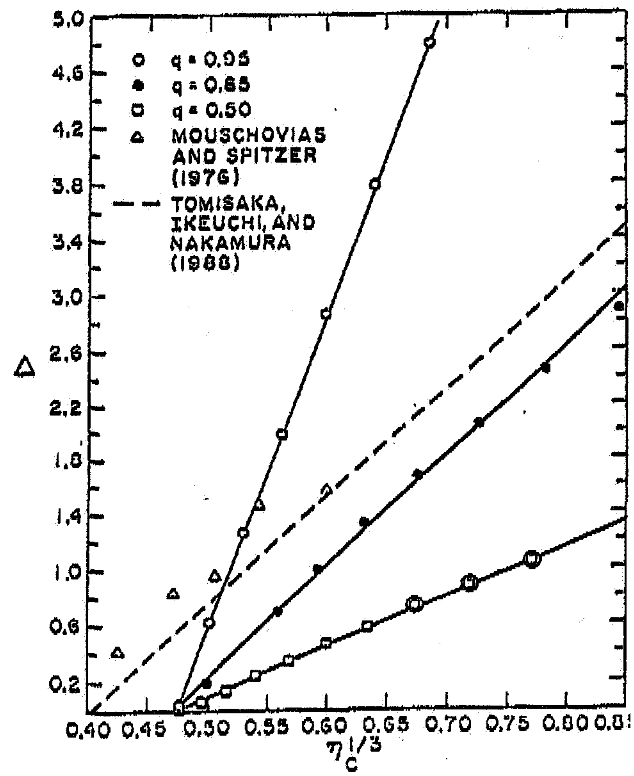

Figure 2

Figure 1: Sketch of a spheroidal, magnetically supported cloud.

Figure 2: The variation of magnetic flux parameter $\Delta_c \equiv \dfrac{5\Phi^2}{6\pi^2 G M^2}$ with critical pressure parameter $\eta_c^{1/3} = \dfrac{GM^{2/3}}{5\, C_s^{8/3}} \left(\dfrac{4\pi P_e}{3}\right)^{1/3}$; q is constant on each line while e increases in the direction of increasing η_c. The triangles are models of Mouschovias and the dashed line is proposed by Tomisaka et al.