STABILITY OF AN INTERSTELLAR MEDIUM WITH CURVED MAGNETIC FIELD LINES

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Parker (1966) has considered a simple equilibrium state of the interstellar gas and fields system, such that the magnetic field lines are parallel to the galactic plane; he has shown that this state is subject to the Rayleigh-Taylor instability. The gravitational pull of the stars on the gas and the buoyancy of the magnetic field tend to bend the field lines, allowing the gas to slide down towards the plane. The stability of equilibria with curved magnetic field lines remained to be considered.

In collaboration with E. Asséo, M. Lachièze-Rey and R. Pellat, I have applied the extended energy principle of Bernstein et al. (1958) to two-dimensional, periodic, curved equilibrium configurations of the interstellar medium. We find that, in addition to the Rayleigh-Taylor effects brought about by gravity, a second cause of instability appears: the curvature of the field lines. Sufficient instability criteria have been obtained, assuming that the adiabatic index of the gas is $\gamma=1$, for two types of perturbations: (i) "flute" perturbations, where the shape of the lines of force is conserved; (ii) anti-symmetric perturbations, where the volume of each tube of flux is conserved, and the perturbation extends over several cycles of the equilibrium configuration. We can show that the type of curved equilibria constructed by Mouschovias (1974),which are related through flux-freezing to an initially unstable equilibrium of the Parker type, are stable to "flute" perturbations, but unstable according to the second criterion. The unstable modes have short wavelengths in the direction perpendicular to the planes containing the magnetic field lines. Thus, that type of equilibrium cannot represent the present state of the interstellar medium.

The interaction of cosmic rays with curved magnetic field lines is another source of instability, and probably the dominant one, especially at some height above theplane. The time of growth of this type of instability can be much shorter than the Rayleigh-Taylor time, which is $\sim 10^7$ years.

W. B. Burton (ed.), The Large-Scale Characteristics of the Galaxy, 321 - 322.

REFERENCES

Bernstein, I. B., Frieman, E. A., Kruskal, M. D., and Kulsrud, R. M.: 1958, Proc. Roy. Soc. (London), A244, 17.
Mouschovias, T. Ch.: 1974, Astrophys. J. 192, 37.
Parker, E. N.: 1966, Astrophys. J. 145, 811.

DISCUSSION

Lockman: Would your conclusions be changed if the interstellar medium were filled almost entirely with coronal gas?

Cesarsky: These studies, following Parker, consider the interstellar medium as a "gas of clouds"; the "sound velocity" which I quoted would then be approximately the dispersion velocity of clouds, say 7 km s^{-1}. The same analysis could be applied to an interstellar medium of hot gas; but then the sound velocity would be higher by a factor of order 10.

Kronberg: There seem to be systematic shearing motions on the insides of spiral arms. This must surely have implications for the large scale magnetic field structure in the galactic disk?

Cesarsky: Probably. But this is very far from the problem I just discussed.

Greyber: An old observation by Morris and Berge using Faraday rotation of distant radio sources shows that the magnetic field tends to be along the spiral arm but in one direction above the galactic plane and in the opposite direction below. This magnetic field configuration in spiral arms, predicted on theoretical grounds (Greyber, Liège Symposium, 1966) is the same as observed in the earth's magnetotail.

Verschuur: When we discuss cooling of clouds we should bear in mind that there are neutral hydrogen clouds, as cold as 10 K, that appear devoid of dust and molecules such as OH and CO. How do clouds get that cold without dust or molecules to help cool them? Until we can explain that, we should remain cautious about cooling mechanisms for interstellar clouds.

Cesarsky: Two comments: (1) Cloud models where clouds are supported by magnetic fields always exhibit the "wrong" curvature, and thus could easily be unstable because of the kind of processes I just discussed in connection with the galactic disk. (2) The rate of angular momentum you quoted is derived for the case of a uniform field; possibly distortions of the magnetic field, brought about by the contraction associated with cloud formation, could alter this rate. Thus one has to be careful when applying the Eberts et al. formula to a contracting, or already contracted, cloud.