CAN STELLAR ATMOSPHERES BE IN QUASI-STATIC EQUILIBRIUM IN THE PRESENCE OF MAGNETIC FIELDS ?

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Among the observational astronomers it is quite customary to assume potential magnetic fields in calculating the strength and the direction of the magnetic fields on the stellar surface. People use this assumption because

1. it is easy to calculate,
2. it is possible to fit the observations with the calculations to some extent using the parameters inherent to the model,
3. at a first glance, there is no difficulty in assuming both potential magnetic fields and static stellar atmosphere because they do not interact each other (except at the pole).

However, the basis of this assumption is physically unsound because we have to introduce a current system around the magnetic pole in order to reproduce the magnetic fields in the outer region, and with this current system it is impossible to maintain the plasma in a static state near the pole and to keep the electromagnetic quantities time-independent at the same time.

It should also be kept in mind that the energy of plasma integrated in a flux tube is by far larger than the magnetic energy integrated in the same flux tube if we assume potential magnetic fields.

Once we admit the interaction between the electromagnetic fields and the stellar plasma, it follows immediately that the stellar atmosphere cannot be in equilibrium in the presence of magnetic fields.

DISCUSSION

Mestel: I am not sure if I have followed your arguments. Certainly a field that is curl-free near the surface must be maintained by a current deeper down. One can construct hydrostatic models of magnetic stars in which the current density falls off near the surface, e.g., like the

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density, so that near the surface the field approximates very closely to the curl-free state. Concerning one of your equations, Biermann showed many years ago that if ρ is not a function of $\underline{P}$, one can get the equivalent of a "battery" generating a magnetic flux. But the timescale of the process is very long, and there is no contradiction in assuming that the star remains in hydrostatic equilibrium.

Nariai: The treatments of stellar structure in the presence and in the absence of a magnetic field are quite different from each other, although they are concerned with the same equations. I agree with you that one can construct models of magnetic stars in which the current density falls off near the surface if you talk about the magnetic field from the standpoint of an astrophysicist concerned with the stellar interior. I am saying that we have to attack the problem of the surface field from the viewpoint of specialists in stellar atmosphere, to whom the current density is finite although it might be "zero" from the viewpoint of those who are concerned with the magnetic field in the interior.

Concerning the time scale of the process, I think that the problem is worth study, with special attention given to the region $\tau = 1$ because this is the region where γ varies greatly because of radiative transfer, and because ρ is almost zero from the viewpoint of specialists in stellar structure.