ON THE SPOTTEDNESS, MAGNETISM AND INTERNAL STRUCTURE OF STARS

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ABSTRACT. It is hypothesized that kinematical structures within stellar interiors that are results of a self-organization of these interiors as thermodynamically open non-linear systems constitute the physical basis for stellar magnetism.

I. INTRODUCTION

Astrophysical observations give more and more evidences for heterogeneity of stellar surfaces. Using the obvious case of the Sun, one speaks about a spottedness of stars and connects it with stellar magnetism. As it is known, the contemporary theory of stellar magnetism is constructed on the principles of the magnetohydrodynamics whose basis has been formulated in the end of the fourties. However, in spite of strong efforts during decades, results of this theory are still rather modest. This fact becomes especially obvious if one compares these results and successes of the stellar evolution theory that was born also in the end of the fourties. Based on two simple hypotheses - stars are spherical gaseous bodies in a hydrostatical equilibrium and energy losses for radiation from most stars are compensated by thermonuclear reactions that are maintained with necessity within such bodies - the stellar evolution theory has permitted to order the vast volume of experimental data on physical features, chemical abundances, kinematics, spatial distributions and main non-stationarity events for such a diverse realm of stars, while the stellar magnetism theory is now a set of 'ad hoc' models for various manifestations of stellar magnetism. Such different intermediate finishes of two astrophysical disciplines - the both being very actively supported by the 'terrestrial' physics - have a simple explanation: magnetism of a star is determined completely by its internal motions which are known very badly, while these motions, if they

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are not too strong, can be not essential for global observable characteristics and evolution of the star.

The fragmentarity of the stellar magnetism theory is clearly seen not only if one looks at such different - in respect of structure, age and evolution status - objects as the Sun, Ap stars and pulsars; even if we restrict ourselves with the Sun, we find that models of sunspot magnetic structures, of isolated magnetic flux tubes and of background magnetic fields are being developed independently also. This fragmentarity stimulates a search for some more general principles that could be used to represent the whole variety of stellar magnetism manifestations. It seems natural to look for such general principles in properties of motions within stellar interiors.

2. HYPOTHESIS

According to the main conclusion of the open system thermodynamics, an open non-linear system with metastable states has a high probability to be in one of such a state. It is quite clear that an emitting star is an open system. A non-linearity of equations of a stellar internal structure takes place even in approximation of simplest static models, and this non-linearity increases strongly if one includes into consideration the effects of stellar rotation, convective energy transfer, magnetic fields and gravitational interaction in close binary systems. The statement on existence of metastable states in equilibrium gaseous bodies with internal power energy sources is a main point of my hypothesis. It seems very likely: if in laboratory - even kitchen! - experiments during a heating of a plane layer of a fluid the effect of a self-organization occurs - the Bernard cells appear - all the more such effects of the open system thermodynamics should be expected in stars where energy fluxes are much stronger, ranges of physical parameter values are much wider, systems are essentially three-dimentional and their spherical symmetry is broken by the cited factors that increase their non-linearity. Then, it is very unlikely that a complex kinematical structure within non-homogeneous plasma body does not stimulate magnetic effects. Thus, see the abstract above.

3. DISCUSSION

3.I. If the proposed hypothesis is correct, the magnetism should be inherent in all stars while magnetic fields have been found not in all stars. The matter is that a direct discovery of stellar magnetic fields is extremely hard task, and most studied manifestations of stellar magnetism

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are determined now mainly with an observational selection. However, many indirect indications on stellar magnetism that have been obtained for last years (Vaughan, 1983; Vaiana, 1983) show much more wide-spreadness of stellar magnetic fields than it follows from the direct magnetometry of F, G, K and M stars. Then, there are many magnetic Ap stars and, finally, magnetism of pulsars and white dwarfs evidences for the existence of magnetic fields in rather massive stars which are predecessors of these degenerated objects. Consequently, the ubiquitness of stellar magnetism that follows from the hypothesis proposed does not contradict to observations.

3.2. What is a relation between suggested 'thermodynamical' stellar magnetism and the dynamo and battery effect theories? One may expect that the proposed conception will provide physically based initial conditions to integrate equations of these theories and if one uses such conditions many problems of stellar magnetism theory will have to be reduced to estimations of deformations of permanently existing kinematical structures and respective magnetic features of stars.

3.3. As it is known, investigations of stellar internal structures have lead to conclusion that meridional circulation velocities are small and the main sequence star evolution occurs without a noticeable mixing of stellar interiors. However, proposed kinematical structures can give rise to some enrichment of central regions of stars and, in particular, of the Sun by hydrogen that will decrease an expected neutrino flux, since for the solar luminosity observed the higher the hydrogen abundance the less the temperature in its central region (Roxbugh, 1983).

3.4. The conception proposed may have direct relation to the problem of a radiation deficit from sunspots and starspots: as any metastable states, proposed kinematical structures can be some energy reservoirs, and changes in these structures can be connected with variations of an energy flux emergent from a stellar surface while its internal energy sources remain constant. While discussing the conclusion by Hartmann and Rosner (1979) that in the BY Dra case the flux deficit problem cannot be resolved with a redistribution of radiating energy over frequencies or over the stellar surface and therefore a real time variability of the stellar luminosity is most likely, I have suggested the necessity to use the open system thermodynamics' ideas to find out internal energy reservoirs within the star (Gershberg, 1983). Since in the ACRIM experiment (Willson et al., 1981) the correlation between sunspot visibility and the solar luminosity has been discovered, we need to have a variable reservoir of an internal energy for the Sun also. Finally, the qualitative model by Gershberg and Petrov (Gershberg, I982) and the quantitative model by Appenzeller and Dearborn (I984) have been proposed to explain significant brightness variations and other activity manifestations of the T Tau type stars; in the both models irregular in time and rather small in amplitude magnetic field strength variations have been supposed, and the cause of such variations of the magnetic field on a stellar surface can be some reconstructions of kinematical structures within the stellar interior.

3.5. In the solar research a more direct way to investigate the internal kinematical structures appears: it is the analysis of differential rotation rate variations with the phase of the solar cycle (Howard and LaBonte, I983).

In our days the astrophysics only begins to assimilate ideas of the open system thermodynamics. Laborious investigations of a self-organization of stellar interiors must be fulfilled. However, we may hope that such investigations will lead us to deeper and more complete understanding of the internal structure, magnetism and spottedness of stars.

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