

Ionic Migration in the Stars

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Received 4 June 2016; accepted 27 June 2016; published 30 June 2016

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Abstract

In this work, the impulsive force which is the dynamical mechanism that moves the ions inside the stars is obtained.

Keywords

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1. Introduction

The *ionic migration*, as well as the *convective streams*, is two related processes that occur inside the stars. Under certain conditions, both of them produce in the *Sun* dynamic mechanisms that are responsible for the existence of the *self-generated magnetic field*, the *Sunspots*, and the *Solar Wind*. Hence, it can be assumed that those phenomena are common in all gaseous stars. So, all of them produce an intense *self-generated magnetic field*, *Stellar Spots*, and *Stellar Wind*. Clearly, the mechanism generator of each phenomenon is different.

2. The Problem of the Force

The dynamic mechanism generator of the ionic movement must be some kind of an impulsive force closely related with the thermal agent that produces the instabilities which triggers convection streams.

In order to make an appropriate analysis of the problem, it is necessary to use the *momentum balance equation of magneto hydrodynamics* [1]. From it, and for any gaseous star, the following *equation of motion* is obtained [1].

$$\rho \frac{dv}{dt} = -\text{grad}(p + p_r) + \frac{\partial}{\partial x^j} \left[\sigma'_{ij} + \frac{H_i H_j}{4\pi} \right] \quad (1)$$

where $v(x, t)$ is the velocity, $\rho(x, t)$ is the mass density, $p(x, t)$ is the whole pressure, $p_r(x, t)$ is the radiation pressure, and $H(x, t)$ is the self-generated magnetic field.

The term $\sigma_{ij}(x, t)$ is the viscous part of the generalized stress tensor [2]. The viscosity is a concept defined for any continuous media. However, the phenomena considered in the theory are macroscopic; that is to say, the number of particles that form them is so big, that in any volume element it is neither possible nor desirable to distinguish individual particles. Hence, in the present problem, that viscous part can be considered as not relevant; in such a way that can be ignored for the following analysis. Thus, $v(x, t)$ is the average velocity of each sort of ions. On the other hand, it is also assumed that the mass density is only a function of the stellar radius [1]. In consequence, from (1) it follows that

$$\frac{d}{dt}(\rho v) = -\text{grad} \left[p_g + 2p_r - \frac{H^2}{4\pi} \right] \quad (2)$$

where [1]

$$p = p_g + p_r$$

and

$$\begin{aligned} p_g &= \frac{\mathcal{R}\rho T}{\mu} \\ p_r &= \frac{1}{3} aT^4 \\ H^2 &= 4\pi p_g \end{aligned} \quad (3)$$

In those equations, R is the gases universal constant, T is the temperature, μ is the average molecular weight, and $a = 7.64 \times 10^{-15}$ is the *Stefan's constant* [1] [3]. Then, from (2) the following final result is obtained.

$$\frac{d}{dt}(\rho v) = -\text{grad} \phi \quad (4)$$

where

$$\phi = \frac{2}{3} aT^4 \quad (5)$$

is the mechanical potential. Hence,

$$f = -\text{grad} \left(\frac{2}{3} aT^4 \right) \quad (6)$$

is the force per unit volume, which is the dynamic mechanism that move the ions, and clearly, is a function of the temperature which is the thermal agent generator of instabilities responsible of the production of convective currents.

3. Impulse and Momentum

From the mechanics of particles, it is well known that the change in momentum of a body acted on by an *impulsive force* is equal to the *impulse*. Thus, for any ion, it is fulfilled that

$$d(\rho v) = f dt \quad (7)$$

As the impulse is equal for both sorts of ions, from (7) the following result is obtained

$$\rho_{H^+} v_{H^+} = \rho_{e^-} v_{e^-} \quad (8)$$

So that, it has that

$$m_{H^+} v_{H^+} = m_{e^-} v_{e^-} \quad (9)$$

where the subscripts are referred to the mass and velocity of each ionic sort. Now, it seems natural to assume that the gaseous stars are formed by hydrogen. But, the mass of the ionized hydrogen is approximately equal to 2,000 times the mass of the free electron; in such a way that, from (9), it follows that

$$v_{e^-} = 2 \times 10^3 v_{H^+} \quad (10)$$

In other words, the impulsive force would drag positive and negative ions in a different way; that difference depends on the mass of each type. Then, it could be expected the migration of positive ions to be slower than that of negative ions; and such a difference could make the former to reach the regions where the *Sunspots* are produced with a delay of 11.5 years with respect to the latter; in each *Solar Cycle* [1] [3]. If the big thermal fluctuation inside the stars is ignored, it is possible to make a very gross estimation of those velocities.

Let us consider that the ionized hydrogen, and also the free electrons, must travel a distance approximately equal to the *Sun's* radius. That is to say, the distance and the time delay that must be travel by the negative ions are

$$R = 6.951 \times 10^5 \text{ km}$$

$$t_d = 3.5 \times 10^8 \text{ sec}$$

If those ions move with a constant velocity, it follows that

$$v_{H^+} \approx 1.9 \times 10^{-3} \text{ km} \cdot \text{sec}^{-1}$$

so that,

$$v_{e^-} \approx 3.8 \text{ km} \cdot \text{sec}^{-1}$$

3. Conclusions

The problem of ionic migration in gaseous stars is interesting because it is the primeval cause in the creation of certain dynamical mechanisms which originate noticeable stellar phenomena whose explanation is only possible if it is assumed that inside the stars such a motion is produced.

In all gaseous stars, the ionic transits across the convective zone produce the required conditions for the creation of a dynamic mechanism which is the generator of the *intense general magnetic field* [1] [3]. Once the ionic migration makes its contribution to the steady-state current distribution localized in some region inside the *convective zone*; immediately, that *ionic migration* follows its path toward the stellar surface, which is again the basic process for the creation of other dynamical mechanisms that generate the *Stellarspots*, and the *Stellar Wind*. In other words, the *magnetic field self-generated* by all gaseous stars, the phenomenon of the *Stellarspots*, and the *Stellar Wind*, are phenomena which are generated by the *ionic migration*.

References

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