前　　言

中国科学院紫金山天文台成立于1934年。在半个多世纪曲折复杂的历史演变中，它不断成长和进步，并与国外天文机构建立联系。尤其是最近十年来，随着我国改革、开放政策的深入贯彻，我台与世界上许多天文单位的学术交流愈趋密切，这对我们的科研工作发挥出积极的促进作用，对当代天文科学的发展也有一定的意义。作为国际交流的一种主要方式，我台天文工作者在国外专业刊物上不断发表科学论文，并为一些国际会议提供学术报告。为了集中展示这些交流活动的成果，我们把收集到的 1979——1987 年间我台人员在国外正式发表的论文和报告汇编成这个专集，现在奉献给国内外广大的天文工作者。我们希望它对进一步加强我台与国际天文界的学术交流，将发挥重要的作用

这本论文集共收录文章62篇。按其内容分为“恒星和星系物理”、“太阳物理”、“太阳系天体物理”、“天体力学”等四类，而每一类的文章均按发表时间依次排列。每篇论文均用在国外发表的原件影印，不作任何改动。

本论文集的编辑组由张培瑜、纪晓禾、宋森和叶式辉组成。我台许多同志热情支持和协助这项编辑工作，谨致衷心的谢意！

台　长　童傅

主　编　叶式辉

一九八八年五月

FOREWORD

The Purple Mountain Observatory, Academia Sinica, was founded in 1934. In the tortuous and complicated historical evolution of more than half a century, it continuously grew up, made progress and kept contacts with foreign astronomical institutions. Especially in the last ten years, in pace with the deepgoing implement of the policy of reform and opening in our country, the scientific intercourses between our Observatory and many astronomical units all over the world have become more and more intimate. This has exerted an active effect of promotion of our research works and also has some significance in the development of contemporary astronomical science. As a main form of international cooperation, astronomers of our Observatory incessantly publish scientific papers in foreign technical periodicals and provide academic reports to international conferences. In order to exhibit these fruits of interchange activities in a concentrated form, we compile this publication with the papers and reports formally published abroad by staff-members of PMO in the period of 1979—1987 and collected by us and we would like to dedicate it to the wide circle of astronomers both in China and in other countries. We wish that it will play an important part in the further strengthening of academic intercommunication between our Observatory and the international astronomical community.

This collection consists of sixty-two articles. According to the contents they are divided into four groups, i.e. "physics of stars and stellar systems", "solar physics", "astrophysics of the solar system" and "celestial mechanics". In each group the papers are arranged according to the time of publication. Every article is printed photomechanically with its original text published abroad and no any alteration is made.

The Editorial Group of this collection of papers is composed of Zhang Pei-yu, Ji Xiao-he, Song Sen and Ye Shi-hui. Many staff-members of our Observatory enthusiastically support and assist this editorial work and it is a pleasure for us to express to them our sincere gratitude.

Director of Observatory Tong Fu

Editor-in-Chief Ye Shi-hui

May 1988

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DYNAMO MECHANISM FOR TURBULENT WAVE IN CELESTIAL BODIES

LI XIAO-QING

Purple Mountain Observatory, Academia Sinica, The People's Republic of China

and

SONG GUO-XUAN

Shanghai Observatory, Academia Sinica, The People's Republic of China

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Abstract. It is well known that under cosmic conditions the various modes of plasma turbulence waves (including MHD waves) are easily excited. In this paper we are trying to show that the turbulent wave also generates a source-term for the magnetic induced equations as does the turbulent fluid with nonzero helicity. By expanding the turbulent field in Fourier series, we have obtained dynamo equation for turbulent wave and a reasonable solution which indicates that the poloidal field may be built-up in the turbulent source region. Perhaps, we may think that the poloidal field of Equation (9) is the analytical form of the magnetic field in a turbulent source region of celestial bodies.

1. Introduction

The magnetic field in the celestial bodies would decay over a long period of time by dissipation if no energy was supplied. In fact, we do not observe such a phenomenon. The analysis of paleomagnetism has shown that there exists a magnetic field in Earth in most geological time-scale. This leads us to study dynamo mechanism in celestial bodies.

Up to now a lot of work has been done in this field. Due to the complexity of this problem, the solution is far from complete.

The governing equations constituting the dynamo theory are composed of not only the Maxwell equations but also the kinetic equations describing the motion of media. They are coupled with the Lorentz force. We have met a mathematical difficulty in obtaining the perfect analytical solution to this set of equations. A way to solve this problem is that we may find a form of motion in media so that the magnetic field can be maintained for a long time. Such a dynamo is called 'kinematic dynamo'. We assume that the magnetic field is weak; therefore, the action of the Lorentz force on the motion of media is ignored and the solution coupled with the kinetic equations need not be considered.

The idea of a turbulent dynamo was proposed by Parker (1955), but the analysis was completed by Steenbeck and Krause (1966). They have since done a series of works in this field (Roberts and Stix, 1971).

We consider a conducting turbulent fluid with magnetic field where the

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magnetic field is weak and the conductivity is low so that the turbulence is not influenced by the Lorentz force.

Roberts and Stix have assumed that there is a gradient of density or pressure in a certain direction, i.e., a gradient of turbulence in this direction. Therefore, the turbulence loses the mirror symmetry and it is inhomogeneous, as a result the magnetic field in media is induced.

It is known that the turbulent wave in plasma (e.g., Alfvén wave or MHD wave) is very different from the turbulence in fluid. The former has the characteristic frequency $\omega_k \neq 0$, i.e., they can propagate in a certain direction. Of course, in inhomogeneous media the amplitude and the wave vector are inhomogeneous also. We have got the source term in the Maxwell equations of mean magnetic field: i.e., dynamo equation, in terms of the existence of plasma turbulence wave that is weak and inhomogeneous. Thereby, the magnetic field in celestial bodies can be maintained. .

2. The Dynamo Equation

The induced magnetic equation is of the form

$$\frac{\partial B_i}{\partial t} - \eta \nabla^2 B_i = -v_j \frac{\partial B_i}{\partial x_j} + B_j \frac{\partial v_i}{\partial x_j} - B_i \frac{\partial v_j}{\partial x_j}. \tag{1}$$

We separate the field B_i and the velocity v_i into mean and fluctuating components

$$B_i = B_i^R + b_i^T, \langle b_i^T \rangle = 0,$$

$$v_i = v_i^R + V_i^T, \langle V_i^T \rangle = 0,$$

where the symbol $\langle\ \rangle$ represents to average over the ensemble, e.g., over the random phases of the turbulent wave.

By averaging the induced Equation (1) in consideration of $\langle B_i \rangle = \langle B_i^R \rangle \equiv B_i^R$, we obtain

$$\left(\frac{\partial}{\partial t} - \eta \nabla^2\right) B_i^R = \left\langle b_j^T \frac{\partial V_i^T}{\partial x_j} \right\rangle - \left\langle V_j^T \frac{\partial b_i^T}{\partial x_j} \right\rangle - \left\langle b_i^T \frac{\partial V_j^T}{\partial x_j} \right\rangle. \tag{2}$$

For simplicity we assume the fluid is at rest $v_i^R = 0$. Subtracting Equation (2) from from (1), we arrive at an equation for b_i^T of the form

$$\left(\frac{\partial}{\partial t} - \eta \nabla^2\right) b_i^T = -V_j^T \frac{\partial B_i^R}{\partial x_j} - V_j^T \frac{\partial b_i^T}{\partial x_j} + B_j^R \frac{\partial V_i^T}{\partial x_j} + b_j^T \frac{\partial V_i^T}{\partial x_j} - $$
$$- B_i^R \frac{\partial V_j^T}{\partial x_j} - b_i^T \frac{\partial V_j^T}{\partial x_j} + \left\langle V_j^T \frac{\partial b_i^T}{\partial x_j} \right\rangle - \left\langle b_j^T \frac{\partial V_i^T}{\partial x_j} \right\rangle +$$
$$+ \left\langle b_i^T \frac{\partial V_j^T}{\partial x_j} \right\rangle. \tag{3}$$