SWING EXCITATION OF GALACTIC MAGNETIC FIELDS INDUCED BY SPIRAL DENSITY WAVES

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ABSTRACT. The generation and maintenance of galactic magnetic fields are considered when the dynamo-acted disk is perturbed by spiral density waves. The periodic change of gaseous density and shear is coupled with the field oscillation as a dynamo wave. We find the conditions for parametric resonance which increases the efficiency of dynamos. Special attention is paid to two-armed spiral galaxies, in which the BSS field structure is possibly the most effectively excited configuration owing to the present mechanism.

1. Introduction

The purpose of this paper is to elucidate the role of spiral arms in generation and maintenance of galactic magnetic fields. Following the density wave theory (e.g. Binney & Tremaine 1987), we regard the spiral arm as a density-wave pattern of the gas rigidly rotating at Ω_p, and consider the change of the large-scale velocity fields which modifies the conventional galactic dynamo.

2. Basic process of swing excitation (*parametric resonance*)

The interstellar gas flowing along its streamline is subject to compression and expansion in the arm and interarm regions, respectively. In response to these perturbations, the magnetic field strength is also varied. If there is no coupling between the dynamo action and density-wave oscillation, the density wave makes no net contribution to the dynamo but simply oscillates the field strength periodically. However, if the field becomes oscillatory and thus propagates as a dynamo wave owing to galactic dynamos, this field oscillation can be coupled with that of the density-wave perturbation through resonance.

Basic process in this modified dynamo can be clearly understood on the assumption of axisymmetric magnetic fields and density waves. We investigate the corresponding dynamo equations analytically and numerically. Assuming linear waves with small amplitude, basic equations can be reduced to the Mathieu's equations, which describe the evolution of an oscillator whose intrinsic parameters vary periodically with time so as to amplify its amplitude. This phenomenon is called parametric resonance (Landau & Lifshitz 1969). That is, the amplitude of the field oscillation increases as a result of the coupling between the field oscillation due to the dynamo (frequency ω_o) and that due to the density wave (frequency

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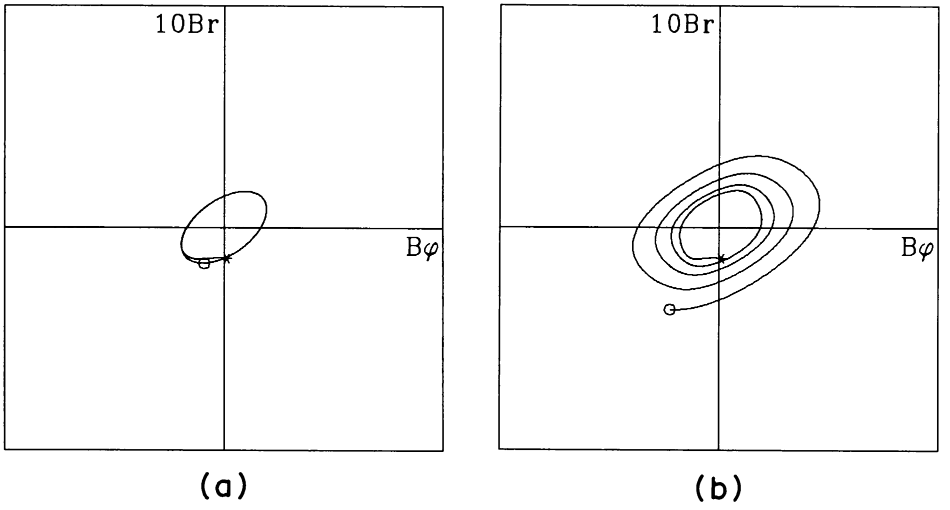

Fig.1 The unperturbed neutral dynamo with frequency ω_o (a) turns to the excited state due to the density wave with frequency $\omega = 2\omega_o$ (b).

ω). We propose this mechanism to call *SWING EXCITATION* of galactic fields. The fastest growth is realized when $\omega = 2\omega_o$, and when the proper phase difference between two oscillators is established. We also perform the numerical computation, and confirm the adequacy of the above analysis (Fig.1).

3. Non-axisymmeric structure for resonance

Let m_B and m_D be the azimuthal wavenumbers of magnetic fields and density waves, respectively. The conditions for frequencies and phase difference for resonance lead to the relation $m_B = m_D/2$, otherwise the net dynamo effect of density waves is vanished. This condition further implies that the field-pattern should corotate with the density-wave pattern for resonance, with no winding of pattern itself because of rigid rotation.

It is interesting to remark that in two-armed spiral galaxies with $m_D = 2$, the BSS field with $m_B = 1$ has the most favourable configuration for resonance in accordance with the condition $m_B = m_D/2$; it could have the fastest growth rate due to the combination of the galactic dynamo and density-wave effect, which is in agreement with the dominant BSS field observed in nearby galaxies.

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