OSCILLATIONS IN THE PRIMEVAL AMBIPLASMA IN THE
UNIVERSE

BHUPINDER SINGH and G. L. KALRA
Department of Physics and Astrophysics, University of Delhi, India

(Received 30 July, 1984)

Abstract. This paper discusses the propagation of waves in the early Universe simulated by rarefied, homogeneous ambiplasma (a mixed matter-antimatter ionized gas) placed in a uniform magnetic field. A rich variety of oscillations appear due to enhanced degrees of freedom in the ambiplasma. These oscillations have been analyzed for the propagation vector along and across the direction of magnetic field both in a symmetric and asymmetric ambiplasma. It is found that the oscillations do not grow in different situations which have been discussed. Dispersion curves have been drawn and various cut-offs and resonances have been found out. The study is concluded by highlighting some characteristic features of the waves in the ambiplasma.

1. Introduction

Studies relating to matter-antimatter have for the last several years been attracting great attention in cosmology as well as particle physics. A number of authors have worked on the problems such as abundance of matter-antimatter in the Universe, separation of matter-antimatter, formation of matter-antimatter galaxies, etc. Numerous workers (Alfvén, 1965, 1967, 1975a, b; Bonnevier, 1964; Carlqvist and Laurent, 1976a, b; Ekspong et al., 1966; Klein, 1966; Laurent and Söderholm, 1969; Lehnert, 1977, 1978; Omnès, 1971; Sofia and van Horn, 1974; Thompson, 1978; Vincent, 1976) adopted a general approach to symmetric cosmology where equal abundance of matter and antimatter was assumed. In contrast to the hypothesis of matter-antimatter symmetry, some recent work (Weinberg, 1979; Stecker, 1981; Brown and Stecker, 1979) support universal matter-antimatter asymmetry.

There are a number of observations which suggest the possibility for the existence of large-scale abundance of antimatter. These observations are, however, not precise enough to decide conclusively between the symmetric and the asymmetric Universe. Serious attempts are being made to improve sensitivity of experimental techniques (Ahlen et al., 1982) to detect the antimatter in the Universe.

Assuming that the primodial Universe consisted of a rarefied, large-scale homogeneous ambiplasma (Alfvén, 1965) so that the rate of annihilation was insignificant, several authors (Alfvén and Klein, 1962; Alfvén, 1966; Omnès, 1969; Lehnert, 1977, 1978; Thompson, 1978; Rogers and Thompson, 1982a, b) worked out possible mechanisms for the separation of matter-antimatter. In keeping with these ideas, we also assume that the initial state of the Universe can be simulated by a rarefied ambiplasma which consists of a homogeneous mixture of matter and antimatter. In an earlier work (Kalra and Singh, 1984) we investigated the stability of a gravitating ambiplasma and

found out the size of the biggest structure which may exist in a stable equilibrium when subjected to infinitesimal perturbations. The present work is concerned with the stability investigation of various modes supported by ambiplasma when an ambient magnetic field is also present. Such a study has been inspired by the suggestion (Alfvén, 1965) that the clue to the existence of the antimatter in the Universe can be found only through a sound knowledge of the basic properties of a mixed matter-antimatter ionized gas. The present study is of interest from different considerations as well; the ambiplasma consisting of negatively charged anti-protons and positively charged positron besides electrons and protons has more degree of freedom than are possible in normal plasma. This essentially leads to greater number of normal modes some of which will not have their analogue in the normal plasma.

It is not surprising that, owing to a greater number of normal modes, the dispersion relation becomes very involved. It is difficult to solve it in its general form and so recourse has to be taken to discuss special cases which may prove useful in visualising what may happen in the analytically untractable situation.

It is found that the various modes of oscillation which are supported by the ambiplasma do not grow unstable in the cases when the propagation is along or transverse to the direction of ambient magnetic field. Dispersion curves have been drawn for these cases and various resonances and cut-offs have been discussed. The appearance of new resonances and cut-offs – a characteristic feature of the asymmetry of the ambiplasma – has been highlighted.

2. Basic Equations and the Dispersion Relation

Consider a dilute ambiplasma consisting of a homogeneous mixture of matter and antimatter. In such a plasma, collision terms can be ignored since the characteristic collision frequency is much smaller than the wave-frequency. For simplicity, it is also assumed that annihilation and radiation processes can be neglected. In the simplified situation, the ambiplasma has only four kinds of particles: \( n_p \), proton; \( n_{\bar{p}} \), antiproton; \( n_e \), electron; and \( n_{\bar{e}} \), positron per unit volume. A set of equations for charged particles (both matter and antimatter) have been obtained by Nelson and Ikuta (1973) as moments of the Boltzmann equation. If we neglect collision and gravitational potential terms, these microscopic equations can be written in a form which is symmetrical with respect to particle charge and mass. In their linearized form these equations are

\[
\frac{\partial \vec{r}}{\partial t} + \nabla \cdot \vec{J}_r = 0 ,
\]

\[
\frac{\partial \vec{n}}{\partial t} + \nabla \cdot \vec{J}_n = 0 ,
\]

\[
\frac{\partial \vec{R}}{\partial t} + \nabla \cdot \vec{J}_R = 0 ,
\]