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COLLIDING SOLITARY WAVES SOLUTION FOR THE SCALAR FIELD OF THE ZEROTH-ORDER AXIONLESS EFFECTIVE STRING FIELD EQUATIONS

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ABSTRACT

Colliding solitary waves solution for the scalar field of the zeroth-order axionless effective string field equations is found. These solitary waves collide at the considered ten dimensional spacetime point. The physical meaning of this solution is observation that the interactions between the fundamental particles in the very early universe are mediated in collisions of the solitary waves modes of the scalar field of the relevant string theory.

Key Words: *Colliding Solitary Waves, Effective String Field Theory, The Scalar Field*

SIFIRINCI MERTEBE AKSİYONSUZ ETKİN SİCİM ALAN DENKLEMLERİNİN SKALER ALANI İÇİN ÇARPIŞAN YALNIZ (MÜNZEVİ) DALGALAR ÇÖZÜMÜ

ÖZET

Sıfırıncı mertebe aksiyonsuz etkin sicim alan denklemlerinin skaler alanı için çarpışan yalnız (münzevi) dalgalar çözümü bulunur. Bu yalnız (münzevi) dalgalar incelenen on boyutlu uzayzaman noktasında çarpışırlar. Bu çözümün fiziksel anlamı ilk evrende temel parçacıklar arasındaki etkileşmelerin ilgili sicim teorisinin skaler alanının yalnız (münzevi) dalgalar kiplerinin çarpışmaları aracılığı ile gerçekleştiğinin gözlenmesidir.

Anahtar Kelimeler: *Çarpışan Yalnız (Münzevi) Dalgalar, Etkin Sicim Alan Teorisi, Skaler Alan*

1.INTRODUCTION

The string theory has been proposed as the gauge theory of the strong interactions. The ten dimensional superstring theory is the powerful candidate as the unified field theory of the physical interactions. Effective string theory is the lower energy form of the underlying string theory. The soliton solutions are used to explain the fundamental particles and their interactions. For these reasons, in this paper, a colliding solitary waves solution for the scalar field of the relevant string theory is presented [1,3].

2. THEORY AND COLLIDING SOLITARY WAVES SOLUTION

The field equations of the zeroth-order effective string field theory in ten dimensional spacetime are given by

$$R_{\mu\upsilon} = 2\,\Phi_{,\mu\upsilon} \qquad (1)$$

$$g^{\mu\upsilon}\,\Phi_{,\mu\upsilon} = 0 \ , \qquad (2)$$

where $R_{\mu\upsilon}$ is the Ricci tensor, Φ is the scalar field and $g^{\mu\upsilon}$ is the contravariant metric tensor of the ten dimensional spacetime. The comma super(sub)script (,μ) denotes the covariant derivative with respect to the index [4].

As the solution for the scalar field Φ, the following expression is considered:

$$\Phi = 3\, g_{\mu\upsilon} X^{\mu} X^{\upsilon} \quad (3)$$

The proposed Φ is tailored around the any ten dimensional spacetime point (X_o^{μ}) , and the effect of the quantum fluctuations (x^{μ}) to the scalar field Φ is studied [4]. As the result the following expression is obtained:

$$\Phi (X_o^{\mu} + x^{\mu}) = \Phi (X_0^{\mu}) + (1/2) (\partial^2 \Phi / \partial X^{\mu} X^{\upsilon}) |_{X = Xo} (x^{\mu} x^{\upsilon}) \quad (4)$$

Applying of the Feynman contraction $< x^{\mu} x^{\upsilon} >$ to $\Phi (X_o^{\mu} + x^{\mu})$ gives :

$$<\Phi (X_o^{\mu} + x^{\mu}) > = (1/2) (\partial^2 \Phi / \partial X^{\mu} X^{\upsilon}) |_{X = Xo} <x^{\mu} x^{\upsilon}> , \quad (5)$$

where the Feynman contraction $< x^{\mu} x^{\upsilon} >$ is proportional to $(\eta^{\mu\upsilon} / 2\, \varepsilon)$, ε is an infinitesimal positive number and $\eta^{\alpha\beta}$ is the ten dimensional Minkowski metric.

The same process for the $g_{\mu\upsilon}$ in the Riemann normal coordinates results :

$$< g_{\mu\upsilon} > = (1/3)\ R_{\mu\alpha\upsilon\beta} (X_o^{\mu}) <x^{\alpha} x^{\beta} > , \quad (6)$$

where $R_{\mu\alpha\upsilon\beta} (X_o^{\mu})$ is Riemann curvature tensor at the X_o^{μ} point.

Finally, in the result of the above operations, the following equations are obtained:

$$R_{\mu\upsilon} = 2\, \Phi_{,\mu\upsilon} \quad (7)$$

$$g^{\mu\upsilon} \Phi_{,\mu\upsilon} = 0 , \quad (8)$$

The equation (8) is satisfied by means of the geodesic equation $X^{\mu}{}_{,\upsilon} = 0$. At the X_o^{μ} point, the $g_{\mu\upsilon}$ metric equals to the Minkowski metric $\eta_{\mu\upsilon}$ so that

$$\Phi = g_{\mu\upsilon} X_o^{\mu} X_o^{\upsilon} = \eta_{\mu\upsilon} X_o^{\mu} X_o^{\upsilon} = (X^o)^2 - \mathbf{X}^2 , \quad (9)$$

where $X^o = c\, t$ (c is the velocity of the soliton) , t is the time coordinate and $\mathbf{X}^2$ denotes magnitude square of vector **X** .

The result $\Phi = (c\, t - \mathbf{X}) (c\, t + \mathbf{X})$ represents the colliding solitary waves at the $X_o^{\mu} = (c\, t , \mathbf{X})$ spacetime point. When solitons collide, a complicated nonlinear interaction occurs. But, numerical experiments showed that the sizes and the velocities of the solitons do not change as a result of collision [1, 6].

This solution is a perturbative solution. However, it reflects the main properties of the solitary waves [2, 5, 7].

3. CONCLUDING REMARKS

Colliding solitary waves solution for the scalar field of the effective string field equations has been given. The physical meaning of the solution has been explained. Finally, some properties of the colliding solitons have been mentioned.

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