Interaction of Complex Scalar Fields and Electromagnetic Fields in Klein-Gordon-Maxwell Theory in Cosmological Inertial Frame

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ABSTRACT

We found equations of complex scalar fields and electromagnetic fields on interaction of complex scalar fields and electromagnetic fields in Klein-Gordon-Maxwell theory from Type A of wave function and Type B of expanded distance in cosmological inertial frame.

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Key words: Klein-Gordon-Maxwell Theory;

Cosmological Inertial Frame;

Complex Scalar fields;

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1.Introduction

The Lagrangian L of complex scalar fields ϕ,ϕ^* and Electromagnetic fields $F^{\mu\upsilon},F_{\mu\upsilon}$ is Klein-Gordon-Maxwell theory in special relativity theory,

$$L=(\partial_\mu\phi+ieA_\mu\phi)(\partial^\mu\phi^*-ieA^\mu\phi^*)-\frac{m^2c^2}{\hbar^2}\phi\phi^*-\frac{1}{4}F^{\mu\upsilon}F_{\mu\upsilon}$$

ϕ^* is ϕ 's adjoint scalar, m is the mass of scalar fields ϕ,ϕ^*

$$F^{\mu\upsilon}=\partial^\mu A^\upsilon-\partial^\upsilon A^\mu, F_{\mu\upsilon}=\partial_\mu A_\upsilon-\partial_\upsilon A_\mu \tag{1}$$

2. Equations of Interaction of Complex Scalar Fields and Electromagnetic Fields in Cosmological Inertial Frame

The Lagrangian L of interaction of complex scalar fields and Electromagnetic fields is Klein-Gordon-Maxwell theory in cosmological inertial frame,

$$L=(\bar{\partial}_\mu\phi+ie\bar{A}_\mu{}'\phi)(\bar{\partial}^\mu\phi^*-ie\bar{A}^\mu{}'\phi^*)-\frac{m^2c^2}{\hbar^2}\phi\phi^*-\frac{1}{4}F^{\mu\upsilon}{}'F_{\mu\upsilon}{}' \tag{2-1}$$

We consider Type A of wave function and Type B of expanded distance,[1],[2],[3],[4]

Type A of wave function: $r\rightarrow r\sqrt{\Omega(t_0)}$, $t\rightarrow\frac{t}{\sqrt{\Omega(t_0)}}$,

Type B of expanded distance: $r\rightarrow r\Omega(t_0), t\rightarrow t$

$$\bar{\partial}_\mu=(\sqrt{\Omega(t_0)}\frac{\partial}{c\partial t},\frac{1}{\sqrt{\Omega(t_0)}}\vec{\nabla}), \bar{\partial}^\mu=(\sqrt{\Omega(t_0)}\frac{\partial}{c\partial t},-\frac{1}{\sqrt{\Omega(t_0)}}\vec{\nabla})$$

$$\bar{A}_\mu{}'=(\phi,\vec{A}\Omega(t_0)), \bar{A}^\mu{}'=(\phi,-\vec{A}\Omega(t_0)), \bar{F}_{\mu\upsilon}{}'=F_{\mu\upsilon}\Omega(t_0), \bar{F}^{\mu\upsilon}{}'=F^{\mu\upsilon}\Omega(t_0)$$

t_0 is the cosmological time. $\Omega(t_0)$ is the expanding ratio of universe in the cosmological time t_0 .

(2-2)

Complex scalar field equations are in Klein-Gordon-Maxwell theory in cosmological inertial frame,

$$\bar{\partial}_\mu(\frac{\partial L}{\partial(\bar{\partial}_\mu\phi)})-\frac{\partial L}{\partial\phi}=(\bar{\partial}_\mu-ie\bar{A}_\mu{}')(\bar{\partial}^\mu\phi^*-ie\bar{A}^\mu{}'\phi^*)+\frac{m^2c^2}{\hbar^2}\phi^*=0 \tag{3}$$

The other equation is in Klein-Gordon-Maxwell theory in cosmological inertial frame,

$$\bar{\partial}_\mu(\frac{\partial L}{\partial(\bar{\partial}_\mu\phi^*)})-\frac{\partial L}{\partial\phi^*}=(\bar{\partial}^\mu+ie\bar{A}^\mu{}')(\bar{\partial}_\mu\phi+ie\bar{A}_\mu{}'\phi)+\frac{m^2c^2}{\hbar^2}\phi=0 \tag{4}$$

If operator $\bar{\partial}_\mu{}',\bar{\partial}^\mu{}'$ are in cosmological inertial frame,[1],[2],[3],[4]

$$\bar{\partial}_{\mu}' = (\frac{\partial}{c\partial t}, \frac{1}{\Omega(t_0)}\vec{\nabla}), \bar{\partial}^{\mu}' = (\frac{\partial}{c\partial t}, -\frac{1}{\Omega(t_0)}\vec{\nabla})$$

$$\bar{F}^{\mu\upsilon}' = \bar{\partial}^{\mu}'\bar{A}^{\upsilon}' - \bar{\partial}^{\upsilon}'\bar{A}^{\mu}', \bar{F}_{\mu\upsilon}' = \bar{\partial}_{\mu}'\bar{A}_{\upsilon}' - \bar{\partial}_{\upsilon}'\bar{A}_{\mu}' \quad (5)$$

Electromagnetic field equations are in Klein-Gordon-Maxwell theory in cosmological inertial frame,

$$\bar{\partial}_{\upsilon}'(\frac{\partial L}{\partial(\bar{\partial}_{\upsilon}'\bar{A}_{\mu}')}) - \frac{\partial L}{\partial \bar{A}_{\mu}'}$$

$$= \frac{1}{4}\bar{\partial}_{\upsilon}'(\bar{\partial}^{\mu}'\bar{A}^{\upsilon}' - \bar{\partial}^{\upsilon}'\bar{A}^{\mu}') - ie\phi(\bar{\partial}^{\mu}\phi^* - ie\bar{A}^{\mu}'\phi^*) + ie\phi^*(\bar{\partial}^{\mu}\phi + ie\bar{A}^{\mu}'\phi)$$

$$= \frac{1}{4}\bar{\partial}_{\upsilon}'\bar{F}^{\mu\upsilon}' - ie\phi(\bar{\partial}^{\mu}\phi^* - ie\bar{A}^{\mu}'\phi^*) + ie\phi^*(\bar{\partial}^{\mu}\phi + ie\bar{A}^{\mu}'\phi) = 0 \quad (6)$$

Hence,[5],

$$\bar{\partial}_{\upsilon}'\bar{F}^{\mu\upsilon}' = \frac{4\pi}{c}\bar{J}^{\mu}' = 4ie[\phi(\bar{\partial}^{\mu}\phi^* - ie\bar{A}^{\mu}'\phi^*) - \phi^*(\bar{\partial}^{\mu}\phi + ie\bar{A}^{\mu}'\phi)]$$

$$\bar{J}^{\mu}' = \frac{c}{\pi}ie[\phi(\bar{\partial}^{\mu}\phi^* - ie\bar{A}^{\mu}'\phi^*) - \phi^*(\bar{\partial}^{\mu}\phi + ie\bar{A}^{\mu}'\phi)] \quad (7)$$

The other equation is in Klein-Gordon-Maxwell theory in cosmological inertial frame,

$$\bar{\partial}^{\upsilon}'(\frac{\partial L}{\partial(\bar{\partial}^{\upsilon}'\bar{A}^{\mu}')}) - \frac{\partial L}{\partial \bar{A}^{\mu}'}$$

$$= \frac{1}{4}\bar{\partial}^{\upsilon}'(\bar{\partial}_{\mu}'\bar{A}_{\upsilon}' - \bar{\partial}_{\upsilon}'\bar{A}_{\mu}') + ie\phi^*(\bar{\partial}_{\mu}\phi + ie\bar{A}_{\mu}'\phi) - ie\phi(\bar{\partial}_{\mu}\phi^* - ie\bar{A}_{\mu}'\phi^*)$$

$$= \frac{1}{4}\bar{\partial}^{\upsilon}'\bar{F}_{\mu\upsilon}' + ie\phi^*(\bar{\partial}_{\mu}\phi + ie\bar{A}_{\mu}'\phi) - ie\phi(\bar{\partial}_{\mu}\phi^* - ie\bar{A}_{\mu}'\phi^*) = 0 \quad (8)$$

Hence,[5],

$$\bar{\partial}^{\upsilon}'\bar{F}_{\mu\upsilon}' = \frac{4\pi}{c}\bar{J}_{\mu}' = -4ie[\phi^*(\bar{\partial}_{\mu}\phi + ie\bar{A}_{\mu}'\phi) - \phi(\bar{\partial}_{\mu}\phi^* - ie\bar{A}_{\mu}'\phi^*)]$$

$$\bar{J}_{\mu}' = -\frac{c}{\pi}ie[\phi^*(\bar{\partial}_{\mu}\phi + ie\bar{A}_{\mu}'\phi) - \phi(\bar{\partial}_{\mu}\phi^* - ie\bar{A}_{\mu}'\phi^*)]$$

$$= \frac{c}{\pi}ie[\phi(\bar{\partial}_{\mu}\phi^* - ie\bar{A}_{\mu}'\phi^*) - \phi^*(\bar{\partial}_{\mu}\phi + ie\bar{A}_{\mu}'\phi)] \quad (9)$$

3. Conclusion

We found equations of complex scalar fields and electromagnetic fields on interaction of complex scalar fields and electromagnetic fields in Klein-Gordon-Maxwell theory from Type A of wave function and Type B of expanded distance in cosmological inertial frame.

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