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Original Paper

Exploring the Effect of DNA Noise and Current on the Berry Phase Effects

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Abstract

We have studied here that bend and twist are not two separate entities but one depends on the other, also other hand entanglement of two DNA molecule inserting spin-echo to one of them marks the transform of Berry phase that can be exact as a calculate of entanglement. This formalism helps us to depict the thermodynamic entropy as entanglement entropy and the entanglement of spin can be used as a resource for genetic in order. This implies that the transcription of genetic in order can be considered in the structure of quantum in sequence hypothesis.

Keywords

antiferromagnetic spin, entanglement entropy, DNA molecule, DNA noise, Berry phase.

1. Introduction

We consider that as two polynucleotide chains are coiled about the same axis with a specific helical sense in a DNA molecule, this can be viewed as if a spin with a specific orientation is inserted on the axis of the coil such that two adjacent coils have opposite orientations of the spin. In fact with each turn two strands move in the opposite side of the axis and so the spin orientation assigned for the two adjacent coils should be opposite to each other. Thus a DNA supercoil may be viewed as a long chain of an antiferromagnetic spin system when the spin is considered to be located on the axis of the supercoil. A unit vector depicting the tangent $\vec{t} = \partial_s \vec{r}$ where $\vec{r}(s)$ is a space curve parameterized by the arc length *s* can be associated with a spin vector when the spin is located at the spatial point x on the axis. A spin vector in the Lie algebra of $SU(2)$ representation can be constructed with bosonic or fermionic oscillators. We write the spin vector $\vec{S}(x)$ as

$$\vec{S}(x) = \psi_{\alpha}^{\dagger}(x)\vec{\sigma}_{\alpha\beta}\psi_{\beta}(x) \tag{1}$$

where $\psi^{\dagger}(\psi)$ is the fermionic oscillator function and $\vec{\sigma}_{\alpha\beta}$ is the vector of Pauli matrices. A unit vector $\vec{n}$ is constructed as

$$\vec{n} = (\psi_1^* \psi_2^*)\vec{\sigma}\begin{pmatrix}\psi_1 \\ \psi_2\end{pmatrix} \tag{2}$$

with

$$\psi_1 = \left(\cos \theta/2\right) e^{i\varphi/2} \tag{3.a}$$

$$\psi_2 = \left(\sin \theta/2\right) e^{-i\varphi/2} \tag{3.b}$$

We now will study the appearance of Berry phase in the entanglement of two identical spin $1/2$ quantized particles. The antisymmetric Bell State of two spin $1/2$ DNA molecules is

$$|\psi_2\rangle = \cos\theta|\psi_1\rangle = \frac{1}{2\pi}(\Delta^{up} - \Delta^{down})|\psi_1\rangle \tag{3.c}$$

By the difference of Berry phase factor.

The most general antisymmetric Bell state for two particles A and B situated at the points x and y becomes

$$|\psi_2(t)\rangle = (\alpha|\uparrow(t)\rangle|\downarrow(t)\rangle - \beta|\uparrow(t)\rangle|\downarrow(t)\rangle \tag{3.d}$$

Where α and β are two complex coefficients,

With the idea of one DNA molecule rotation of one fermion for a time interval τ the spinor comes to its orginal state acquiring only Berry phase and loosing the dynamical phase., We have the new form of the entangle state as

$$|\psi_2(t=\tau)\rangle = (\alpha|\uparrow(t)\rangle|\downarrow(t)\rangle - e^{2i\Delta^{up}}|\uparrow(t)\rangle\beta|\downarrow(t)\rangle \tag{3.e}$$

As we consider $\theta = \pi$ the Berry phase is removed along with dynamical phase in the 'spin-echo' method.

This helps us to write

$$\vec{S}(x) = \left(\sqrt{3}/2\right)\psi_{\alpha}^{\dagger}(x)\vec{\sigma}_{\alpha\beta}\psi_{\beta} \tag{4}$$

We can now construct a unit vector n_μ with $\mu = 0,1,2,3$ in 3+1 dimensions incorporating the unit vector $\vec{n}$ given by eqn. (2)

$$n_\mu = \left(1/\sqrt{2}\right)(\psi_1^* \psi_2^*)\sigma_\mu\begin{pmatrix}\psi_1 \\ \psi_2\end{pmatrix} \tag{5}$$

with $\sigma_0 = \mathrm{I}$, I being the identity matrix and $\vec{\sigma}$ are Pauli matrices. We now construct the topological current

$$J_\mu = \left(1/12\pi^2\right)\varepsilon_{\mu\nu\lambda\sigma}\varepsilon_{abcd}\, n_a \partial_\nu n_b \partial_\lambda n_c \partial_\sigma n_d \tag{6}$$

where (a, b, c, d) correspond to (0, 1, 2, 3) and (μ,ν,λ,σ) correspond to space-time indices. The current J_μ can be written in the form [1]

$$J_\mu = (1/24\pi^2)\varepsilon_{\mu\nu\lambda\sigma} Tr(g^{-1}\partial_\nu g)(g^{-1}\partial_\lambda g)(g^{-1}\partial_\sigma g) \quad (7)$$

with $g = n_0 \mathrm{I} + i\vec{n}.\vec{\sigma}$ which belongs to the group $SU(2)$. If we now demand that in Euclidean 4-dimensional space-time the field strength $F_{\mu\nu}$ of a gauge potential A_μ vanishes at all points on the boundary S^3 of a certain volume V^4 inside which $F_{\mu\nu} \neq 0$ the gauge potential tends to a pure gauge towards the boundary and we write

$$A_\mu = g^{-1}\partial_\mu g \quad (8)$$

with $g \varepsilon SU(2)$.

We can now write the topological current given by (7) as [2]

$$J_\mu = (1/16\pi^2)\varepsilon^{\mu\nu\lambda\sigma} Tr\{A_\nu F_{\lambda\sigma} + (2/3)A_\nu A_\lambda A_\sigma\} \quad (9)$$

with A_μ given by eqn.(8). It is noted that as the spin vector is constructed from the unit vector $\vec{n}$ given by (2) which is incorporated in the current J_μ as is evident from eqn. (6), we can associate spin with this current J_μ. In fact we can consider the topological Lagrangian in terms of the $SU(2)$gauge fields in affine spece

$$L = -(1/4) Tr \varepsilon^{\mu\nu\alpha\beta} F_{\mu\nu} F_{\alpha\beta} \quad (10.a)$$

Now the gauge connection associated with the Lagrangian in this equation

$$L_{eff}^{up} = -(i/2)(\dot{\xi} - \dot{\varphi} Cos\theta) \quad (10.b)$$

due to any change in θ, φ, ξ resulting a gauge transformation, this equation giving rise to Berry phase.

Now the necessary geometrical phase of the only quantized spinor

$$\Delta^{up} = i\int L_{eff}^{up} dt = i\oint A^{up}(\lambda) d\lambda = (1/2)(\oint d\xi - \cos\theta \oint d\varphi) = \pi(1-\cos\theta) \quad (10.c)$$

This gives rise to the topological current [3]

$$\vec{J}_\mu = \varepsilon^{\mu\nu\lambda\sigma} \vec{a}_\nu \times \vec{f}_{\lambda\sigma} = \varepsilon^{\mu\nu\lambda\sigma} \partial_\nu \vec{f}_{\lambda\sigma} \quad (11)$$

where we have taken the $SU(2)$ gauge field A_μ and corresponding field strength $F_{\mu\nu}$ as

$$A_\mu = \vec{a}_\mu . \vec{\sigma} \text{ and } F_{\mu\nu} = \vec{f}_{\mu\nu} . \vec{\sigma} \quad (12)$$

$\vec{\sigma}$ being vector of Pauli matrices. From this it appears that the spin vector $\vec{S}(x)$ can be depicted as the topological current $\vec{J}_\mu$ given by eqn.(11). In terms of this current a spin system on a lattice can be viewed as if currents are located on the vertices when gauge fields lie on links [10]. This helps us to consider the spin system associated with a DNA supercoil in terms of the Chern-Simons topology as will be discussed in the next section.

We find the effect of noise in the Berry phase of quantized spinor and in its entangled state both in the presence and the absence of spin –echo method**,** on the influence of classical fluctuation of field on Berry phase of spin ½ particle [4,5]. We define noise by a shift like residual dipolar couplings crucially (RDCs). If we consider that with the lapse of time, the parameter λ suffer a deviation $\lambda \rightarrow \lambda + \delta\lambda$ due to any change in θ, φ, ξ resulting a gauge transformation.

$$Z(\lambda) \rightarrow Z(\lambda) + \frac{\partial Z(\lambda)}{\partial \lambda}\delta\lambda \tag{13}$$

Here $Z(\lambda)$ is the gauge connection associated with the Lagrangian in this eqn.10.b, this equation giving rise to Berry phase.

This fluctuation of gauge relations by the parameter λ, is the extremely cause of transfer in magnetic flux line equivalent chiral equilibrium contravention.

Now the necessary geometrical phase of the only quantized spinor eqn. 10.c,

This shows that for quantized spinorthe Berry Phase is a solid angle subtended about the quantization axis. For $\theta = 0$ the minimum value of Δ^{up} is 0 and $\theta = \pi$ maximum.

Spin up case we have

$$Z^{up}(\lambda) = (1/2)(1 - \cos\theta) \tag{14}$$

This leads to have the noise dependent Berry Connection of the quantized spinor

$$Z^{up}(\lambda) = (1/2)(1 - \cos\theta + \sin\theta\delta\theta) \tag{15}$$

Now the result a modification of Berry phase

$$\Lambda^{up} = \pi(1 - \cos\theta + \sin\theta\delta\theta) \tag{16}$$

And similar for down spinor

$$\Lambda^{down} = \pi(1 - \cos\theta - \sin\theta\delta\theta) \tag{17}$$

Where we consider $\Lambda^{up}, \Lambda^{down}$ as the noise induced Berry phase for the spin up and spin down quantized practices in that order [5-7]. Now the entangled state of two identical spinor, as we find in eqn.3.c, that the evolution of the state at a exacting instant depends on the distinction of Δ^{up} and Δ^{down} which implies boost of noise by twice. The effect of noise in the entangled state formed after 'spin-echo' will be less as realized from eqn. 3.e. On the conclusion, we similar to observation that here the noise is accountable for the fluctuation of quantization that can be practical for the entanglement of Quantum Hall particles in the non-plateau and plateau area.

2. Discussion

We have formulated bending (curvature) and twisting (torsion) in terms of these gauge fields. A significant result of this formalism is that bending and twisting are not independent entities. In fact

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bending influences the propagation of twisting strain along the DNA which has been supported by experiments. Also the dynamical phase of DNA molecule can be separate in the spin-echo system. During this process the addition of Berry phase in the entangled state is accountable for the calculate of entanglement. Variation in DNA molecule helicity is considered as noise that change the fixed significance of Berry phase [8-9]. The consequence of noise doubles as two pure identical spinor entangle. We like to study further this effect of noise, decoherence and entanglement in association with quantization feature of Berry phase in previous quantum aspect DNA molecule development.

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