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The FPU Recurrence Model of the Protein Synthesis

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Abstract

The paper suggests a theoretical model of the physical mechanism of recognizing and joining of the transport RNA molecules with the information RNA molecules on the basis of the Fermi-Pasta-Ulam (FPU) recurrence and the group resonance phenomena. Both were experimentally observed in plasma dynamics. The suggested mathematical model represents two coupled nonlinear Shrodinger equations for the description of interaction between the FPU recurrence electric fields in the chains of the tRNA and iRNA molecules.

The results of numerical study of the model of dynamics of the tRNA and iRNA molecules in the intracellular solution allow making a conclusion that in a cell there exists a physical mechanism of recognizing, attracting and repelling between the tRNA and iRNA molecules, providing the synthesis of protein. This mechanism is based on the FPU recurrence, whose spectrum structure gives a pattern – matrix for building a protein. Such resonant dynamics is generally characteristic for the dynamics of interaction between the FPU recurrences, in particular the elementary FPU recurrence of the tRNA molecule electrical field and full FPU recurrence of the iRNA molecule electrical field.

Moreover, the suggested physical mechanism allows offering a method of external influence on a cell aiming at acceleration of the protein synthesis in it by the applying electromagnetic fields in a form of the FPU recurrence spectrum.

Keywords: Dynamics; tRNA; FPU model; Acceleration; Spectrum

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Introduction

As it is known, the genetic information is transferred to ribosomes via molecules of the information RNA. The latter is synthesized on a gene along one of two spirals of the DNA molecule on the basis of the complementarities principle of the bases. One information RNA molecule contains the sequence of nucleotides, complementary to one that served as a matrix, and is identical to the sequence of the second spiral of the DNA molecule.

Information RNA is attached to ribosomes. Various amino acids with the help of specific enzymes join the transport RNA molecules, specific to each amino acid. The transport RNA with the amino acid attached to it "recognizes" among the sequence of the information RNA nucleotides the triplet encoding the amino acid being carried. The "recognizing" of it is carried out thanks to the complementary triplet –anticodon, allowing them to join temporarily. If the codon is complementary to the information RNA triplet, the amino acid is disconnected from the transport PHK and joins the growing protein sequence. However, the described sophisticated mechanism, as well as many other mechanisms of biological processes, which have only verbal descriptions of the sequences of actions are not yet physically explained. The physical bases of the processes which don't contain any conscious actions, in particular, "recognizing" and joining the transport RNA, having the amino acid, with the molecule of the information RNA among chaotically moving molecules of the intracellular solution is not found out yet.

Model of Protein Sythesis

The purpose of the paper was to develop a theoretical model of the physical mechanism of recognizing and joining of the transport RNA molecules with the information RNA molecules on the basis of the FPU recurrence [1] and the group resonance phenomena [2]. The group resonance approach has been used in the theory

of plasma for describing the dynamics of the particle movement in the field of a wave packet. This problem comprises many characteristic features typical for various physical situations [2]. The formal description of the problem is expressed as follows:

$$d^2x/dt^2 = q/m \sum_n E_n(\cos k_n x - \omega_n t) \quad (1)$$

Where x-is the coordinate, q-is the particle charge, m-is the particle mass, $\sum$ -is the wave packet of the field acting on the particle.

Together with this, the FPU recurrence [1], proved to be the main characteristic property of distributed dynamic systems including plasma, also looks as a useful tool for modeling the process under consideration.

As it was shown earlier an elementary FPU recurrence develops in a chain consisting of three coupled masses [3]. Representing the tRNA molecule as an elementary FPU recurrence chain and the iRNA molecule as the classical FPU recurrence chain [1], we can take an advantage of the approach suggested by Berman and Kolovsky [4] who have shown, that the dynamics of the FPU chains can be described within the framework of Nonlinear Shrodinger Equation (NSE). Besides the RNA electrical field dynamics can be given within the frame of coupled sine-Gordon and NSE equations forming the FPU recurrence in the cell of neuron [5]. Using the equation (1) for the description of the group resonance, and also the form of the Shrodinger equation with the dispersing potential, suggested by Bishop [6], we can write down the process of interaction between the tRNA and iRNA molecules electric fields in the form of the FPU recurrences raised in the quasi periodical structures of these molecules by the energy KT of the intracellular liquid, as the perturbed nonlinear Shrodinger equations. The hypothetical mechanism of extracting energy of random fluctuations of the medium and transforming it into the energy of oscillations in the FPU chains placed into this medium, for the first time was suggested by Frolich [7] and then was confirmed mathematically as a result of numerical study of the elementary model of the FPU recurrence [8] and then was proved experimentally through developing the physical model of that process [9].

Accounting that the tRNA molecule represents a closed FPU chain, and the iRNA molecule represents the FPU chain with open ends, he NSE equations for the description of interaction of the electric FPU fields in these chains will contain the packets having odd spatial harmonics (iRNA) [10] and even spatial harmonics (tRNA) [11] as perturbing functions:

$$i\partial E_1/\partial t + \partial^2 E_1/\partial x^2 + 2|E_1|^2 E_1 = a_1 \sum_n E_{n2} \cos k_n x + F_1 + F_2$$

$$i\partial E_2/\partial t + \partial^2 E_2/\partial x^2 + 2|E_2|^2 E_2 = a_1 \sum_n E_{n1} \sin k_n x + F_1 + F_2 \quad (2)$$

where $a_1 and a_2$ are the intensities of the tRNA and iRNA electric fields correspondingly, $a_1 and a_2$ are constants, $\sum E_{2n}$ and $\sum E_{2n}$ are the wave packets of the electric fields mutually acting on the iRNA and tRNA molecules correspondingly.

$F_1 and F_2$ are random functions describing correspondingly the high- and low-frequency chaotic fluctuations in the intracellular liquid.

Following Bishop's work [4], the solutions of the system (2) can be given as follows:

$$E_1 = A_1 \sec h(x_1 - x_2) \sum_n E_{n2} \sin(k_n(x_1 - x_2) + \varphi_{1random})$$

$$E_2 = A_2 \sec h(x_2 - x_1) \sum_n E_{n1} \cos(k_n(x_2 - x_1) + \varphi_{2random}) \quad (3)$$

where $\varphi_{1random}, \varphi_{2random}$ are the random phases

Using a reduced version of (1), the equations of a group resonance have been replaced by the equations of nonlinear pendulum with a changing frequency [1] in which the solutions of the system (3) have been included into the conservative members of the reduced equations. Then having a purpose of simplification of the obtained system, the perturbing wave packets have been left with only two harmonics – the odd ones - for a packet of the iRNA and the even ones - for a packet of the tRNA. The system looks as follows:

$$d^2 y_1/dt^2 = -c_1 y_1 \sec h(y_1 - y_2)(\sin((y_1 - y_2) + \varphi_1) + \sin(3(y_1 - y_2) + \varphi_2)) + F_1 + F_2 \quad (4)$$

where y_1, y_2 are the coordinates of the molecules tRNA and iRNA correspondingly, $\varphi_1, \varphi_2, \varphi_3, \varphi_4$ are the constants, $\varphi_1, \varphi_2, \varphi_3, \varphi_4$ are random functions describing correspondingly the high- and low-frequency chaotic fluctuations in the intracellular liquid.

Results and Discussion

Numerical study of the system (4) has shown, that within the framework of the proposed model, the RNA molecules proved to be able to "recognize" each other and then couple or divert from each other as a result of "unrecognition" depending on the certain phase combinations ($\varphi_1, \varphi_2, \varphi_3, \varphi_4$) of the wave packets harmonics of the tRNA and iRNA molecules. **Figures 1 and 2** illustrate the process of recognition and coupling of the RNA molecules. **Figures 3 and 4** demonstrate divergence of the RNA molecules after "unrecognition". The processes of recognition, attraction and repelling proved to be sophisticated ones. **Figures 5 and 6** show some of them. **Figure 7** shows a simple dynamics of the divergence process between the RNA molecules.

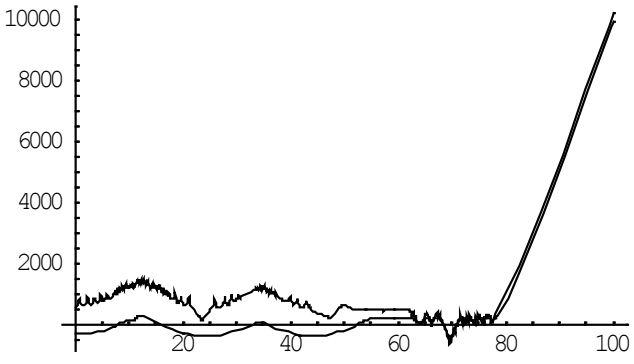

Figure 1 The dynamics of recognizing and coupling in the motion of the tRNA (upper curve) and the iRNA (lower curve) molecules. Vert. axis– coordinate, horix. Axis- time. Units conditional.

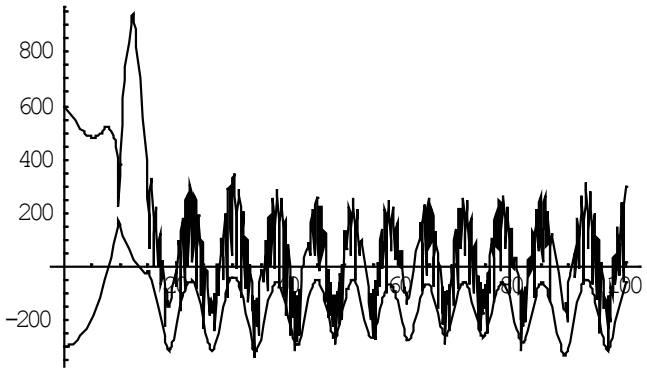

Figure 2 The dynamics of recognizing in the motion of the tRNA (upper curve) and the iRNA (lower curve) molecules. Vert. axis– coordinate, horix. Axis- time. Units conditional.

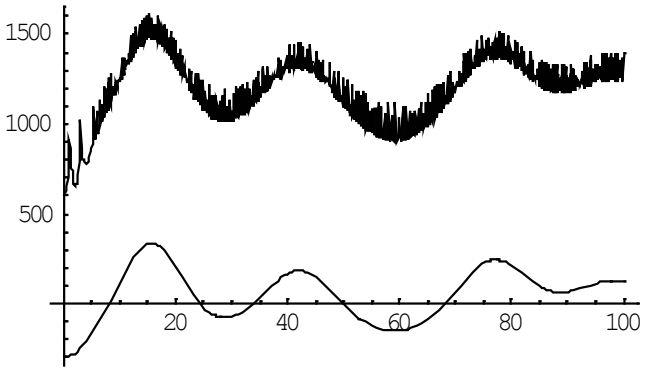

Figure 3 The dynamics of unrecognizing in the motion of the tRNA (upper curve) and the iRNA (lower curve) molecules. Vert. axis– coordinate, horix. Axis- time. Units conditional.

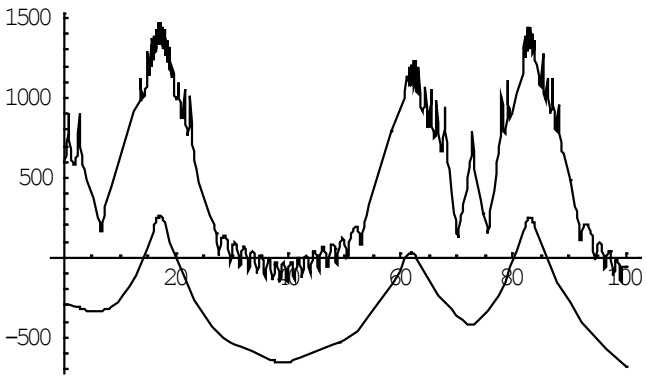

Figure 4 The dynamics of unrecognizing and diverging in the motion of the tRNA (upper curve) and the iRNA (lower curve) molecules. Vert. axis– coordinate, horix. axis- time. Units conditional.

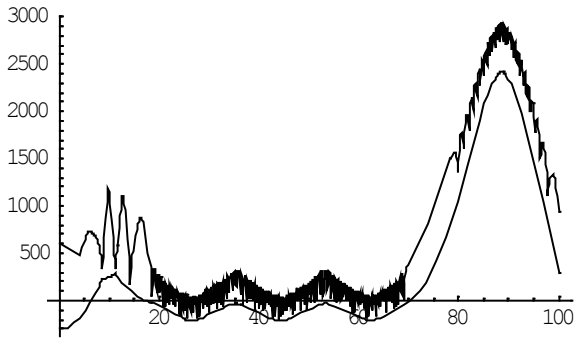

Figure 5 The sophisticated dynamics of unrecognizing and diverging in the motion of the tRNA (upper curve) and the iRNA (lower curve) molecules. Vert. axis– coordinate, horix. axis- time. Units conditional.

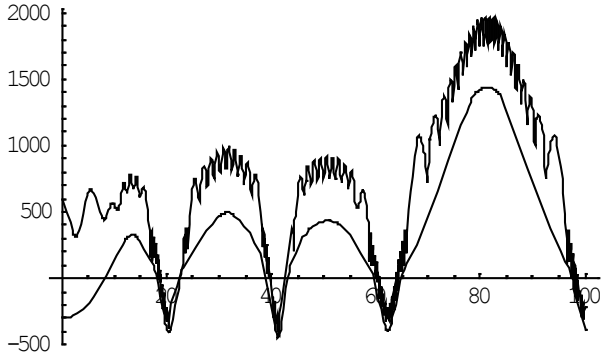

Figure 6 The sophisticated dynamics of recognizing and coupling in the motion of the tRNA (upper curve) and the iRNA (lower curve) molecules. Vert. axis– coordinate, horix. axis- time. Units conditional.

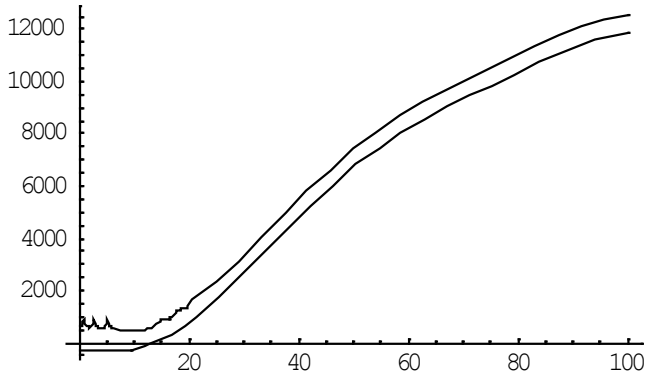

Figure 7 Simple non-coupling dynamics of motion of the tRNA (upper curve) and the iRNA (lower curve) molecules. Vert. axis– coordinate, horix. axis- time. Units conditional.

Conclusion

The results of numerical study of the model of dynamics of the tRNA and iRNA molecules in the intracellular solution allow making a conclusion that in a cell there exists a physical mechanism of recognizing, attracting and repelling between the tRNA and iRNA molecules, providing the synthesis of protein. Such resonant dynamics is characteristic for the dynamics of interaction between the FPU recurrences [12]: the elementary FPU recurrence of the tRNA molecule electrical field and the full FPU recurrence of the iRNA molecule electrical field.

Moreover, the suggested physical mechanism allows offering a method of external influence on a cell aiming at acceleration of the protein synthesis in it by the electromagnetic fields in a form of the FPU recurrence spectrum. The problem of breakage of the proposed mechanism was not considered but a probable fatal mode can occur in the wrongly differentiated cell in a form of a self parametric excitation of the protein assembling process when a distorted protein molecule will be constantly reproduced on a tumor iRNA at a much higher speed than that of a normal protein molecule triggering the process of self-sustained tumor cells reduplication through production of wrong proteins.

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