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Highlights

Optimal Helical Radius

Nonlinear Evolution Equation

Discovering Thoughts, Inventing Future

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Sun Structure Mathematic Physics Models Release Solar Lights Emission, Proton Event, Jets, and Cool Atmosphere

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Abstract- Sun structure have research for hundreds years, which were very important for cosmic physics and earth science. This paper build 121 balls mathematic physics model, by Newton attract force equation. This model deduced out that solar internal parts got outward attract force. The internal particles might be accelerated to high speed to form light emission and jets. The surface parts got inward attract force, to show cool atmosphere. This model may deduce out and explain the sun light emission, flare, prominence, jets, and cool atmosphere phenomena. The 121 balls model can help research for solar physics, cosmic physics and earth science.

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Sun Structure Mathematic Physics Models Release Solar Lights Emission, Proton Event, Jets, and Cool Atmosphere

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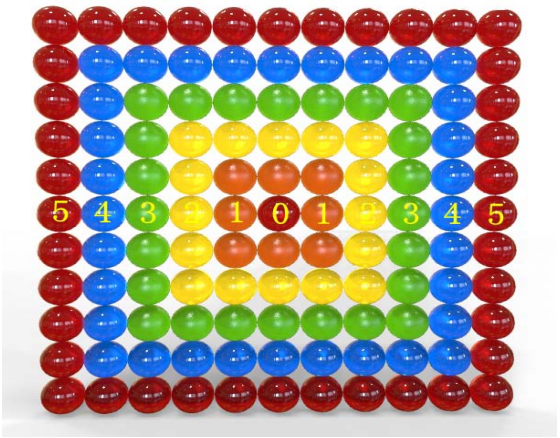
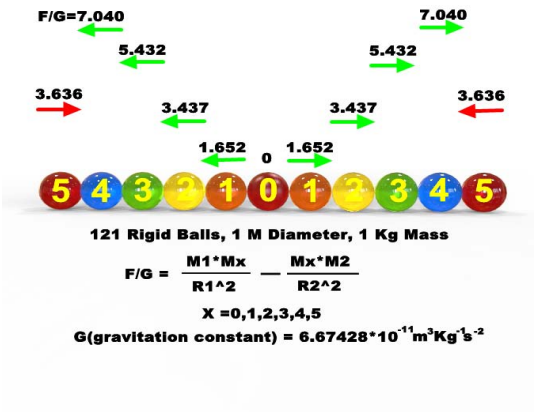
Abstract- Sun structure have research for hundreds years, which were very important for cosmic physics and earth science. This paper build 121 balls mathematic physics model, by Newton attract force equation. This model deduced out that solar internal parts got outward attract force. The internal particles might be accelerated to high speed to form light emission and jets. The surface parts got inward attract force, to show cool atmosphere. This model may deduce out and explain the sun light emission, flare, prominence, jets, and cool atmosphere phenomena. The 121 balls model can help research for solar physics, cosmic physics and earth science.

I. Introduction

Sun science have been taken long time, which connected with the almost all kinds of actions of earth biology. So the Sun research should be very important in cosmic physics, and earth environmental science, and biology. The solar structure was still unknown, which may be connected with many solar phenomena, such as light emission, jet, flare, prominence. This paper report a kind of mathematic physics model, try to build the solar structure model and help to explain some solar phenomena. The model was based on rigid balls array, to build attract force mathematic physics model (Figure 1).





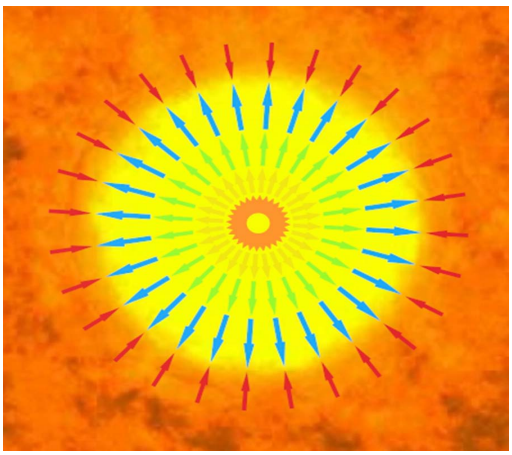


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Fig. 1 the 121 balls array mathematic physics model to describe the solar structure and explain some phenomena of Sun. the ball was all 1kg mass, 1M diameter, set as rectangle array. The attract force of every ball got from other balls were calculated by Newton Attract Force Equation. The F/G values was gave by equation [1]$F/G = (M_1*M_x)/(R_1\hat{}2)-(M_x*M_2)/(R_2\hat{}2)$. There were 11 ballspicked out to display the calculated results. The No. 0 received zero attract force. The No.1, 2, 3, 4 balls received outward directions attract force, with increasing attract force from No.1 to No.4 , while the No. 5 balls received inward directions attract force. So the Sun internal parts attract force situations as the arrows array figure. Arrow direction were the points got the attract force directions, length of arrows were for attract force relative intensity.

The 121 balls rigid array simulate the bodies attract force environment. Every ball in model was 1 Kg mass and 1 M diameter. The middlelevels 11 balls received attract force was calculated respectively by Newton Attract Force Equation. The F/G values [$F/G = (M_1*M_x)/(R_1\hat{}2)-(M_x*M_2)/(R_2\hat{}2)$] was gave in Figure 1, which show the No.1,2,3,4 balls received outward directions attract force, with increasing attract force from No.1 to No.4 , while the No. 5 balls received inward directions attract force. So from the 121 balls model, it can be conclude the internal parts all received attract force directions were all outwards, only the surface layers received attract force direction inwards. The internal parts have accelerated received increased attract force from center to sub surface. The 121 balls model was aimed todescribe globe bodies internal attract force situations, and was tried to be used to explain some solar phenomena.

121 balls model was tried to explain Sun light emission. It was known that the accelerated particles can be emission synchrotron radiation light [2]. The particles, such as H proton and He atom at center parts of sun, which received outward directions attract force, and the received attract force increased from center to subsurface. These mean the particles were accelerated from solar center to subsurface, when acceleration was high to make the particles to near light speed, and fly out of Sun atmosphere to external space, then Sun gave light. So the Sun light was from the particles attract force accelerate to emission synchrotron radiation light.

When the internal protons were accelerated by the increased outward attract force to fly out sun, the proton event [3] happen that observed on earth. The proton events were proton fly from Sun to earth. The 121 balls model might explain the proton events. The protons in Sun internal parts accelerated to high speed and fly out Sun to earth. The proton events speed decided the accelerated length and proton amounts.

The internal small particles, such as H and He were accelerated by outward attract force, fly from center to surface through millions kilometers acceleration, these particles speed can be or nearby light speed, to fly out of sun to form different emission and jet, such as sun light, flare, or prominence, which decided from the particles speed and amount. There were many other huge or small mounts particles in internal Sun can be accelerated to high speed and fly out of Sun, to form prominence [4], fare [5], and the small scale jets (observed and reported by H. Tian [6])

From the 121 balls model, the surface parts of Sun were received attract force were in ward directions, which make the surface attract many external space gas atmosphere go into solar surface. The Sun surface attract cold atmosphere to mix the hot jets flow, then form the inward direction cooling atmosphere phenomena. The Sun cool atmosphere was observed (reported by H.Peter [7]). The sun surface heat flow emissions meet the inward going atmosphere cool gases, which form the cooling atmosphere. The 121balls model might deduce that Sun surface attract external gas inward to Sun, to supply Sun for lots of cool gases, such as H2. These external gases were attracted to go into sun and cooling sun atmosphere.

In conclusion, 121 balls array attract force mathematics physics model show that: Internal parts got outward direction attract force, which produce outward particles acceleration actions, then to form light emission, proton events, small jets, and flare. The surface parts got in ward attract force, which attracted external gases go inside Sun. This model tries to explain the experimental observation phenomena of Sun, such as small-scale jets and cool atmosphere. So the 121 balls model might well explain some phenomena of Sun, and will help for cosmic physics and Sun related researches.

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Verifiable Multiverse

By Alexander Alexandrovich Antonov

Abstract- Up to the present time a lot of interesting hypotheses of Multiverses have been offered. However, their common shortcoming is the fact that even in the distant future they will not be able to obtain experimental confirmation. They can not be refuted either. In other words, they are unverifiable. I.e. they are in fact non-existent for us. As opposed to them, the hypothesis of the hidden Multiverse considered in the article is completely verifiable, because its physical reality can be confirmed experimentally already now. This hypothesis is based on the principle of physical reality of imaginary numbers repeatedly proven by the author, which has allowed establishing a number of fundamental errors in the generally accepted version of the special relativity theory. Eliminating these errors allowed to offer a corrected relativistic formula, based on which the hidden Multiverse hypothesis was created, named in such a way because all the parallel universes included in it are mutually invisible. The reason for their invisibility is explained. It is established that such invisible universes are dark matter and dark energy. It is shown where in the hidden Multiverse the different types of antimatter are located. The data obtained by WMAP and Planck spacecrafts allowed to determine the parameters and structure of the hidden Multiverse, which proved to be a quaternion.

Keywords: *multiverse, dark matter, dark energy, imaginary numbers, the special relativity theory.*

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VERIFIABLEMULTIVERSE

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Verifiable Multiverse

Alexander Alexandrovich Antonov

Abstract- Up to the present time a lot of interesting hypotheses of Multiverses have been offered. However, their common shortcoming is the fact that even in the distant future they will not be able to obtain experimental confirmation. They can not be refuted either. In other words, they are unverifiable. I.e. they are in fact non-existent for us. As opposed to them, the hypothesis of the hidden Multiverse considered in the article is completely verifiable, because its physical reality can be confirmed experimentally already now. This hypothesis is based on the principle of physical reality of imaginary numbers repeatedly proven by the author, which has allowed establishing a number of fundamental errors in the generally accepted version of the special relativity theory. Eliminating these errors allowed to offer a corrected relativistic formula, based on which the hidden Multiverse hypothesis was created, named in such a way because all the parallel universes included in it are mutually invisible. The reason for their invisibility is explained. It is established that such invisible universes are dark matter and dark energy. It is shown where in the hidden Multiverse the different types of antimatter are located. The data obtained by WMAP and Planck spacecrafts allowed to determine the parameters and structure of the hidden Multiverse, which proved to be a quaternion.

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I. Introduction

In what physical world we live in - it is one of the main problems which has always occupied the minds of people. What is the organization of the macrocosm and the microcosm? Do we live in Monoverse or Multiverse? Is this or that hypothesis of the universe verified? What is dark matter and dark energy? Where is the antimatter located? In fact, there is still no recognizable and distinct evidentiary response to these and many other questions, like thousands of years ago, despite the optimistic statements of some scholars.

Indeed, the theory of relativity (Einstein, 1920; Bohm,1965), which is the basic theory of the macrocosm, and quantum physics (Kaku, 2008), which is the basic theory of the microcosm, contradict each other in every way. And the string theory (Kaku, 2012) which was trying to combine them was unable to solve the task set.

A few decades ago, dark matter and dark energy (Freeman, McNamara, 2006; Nicolson 2007) have been discovered in the macrocosm, which even seemed to deny the modern atomic molecular concept of a microcosm, as none of the known chemical elements were found in dark matter and dark energy.

Even none of the known subatomic particles. And experiments on the Large Hadron Collider, the Tevatron collider and other accelerators, aiming at resolution of the relevant fundamental issues of physics, perhaps, have generated even more questions than gave answers. An example of this is unsuccessful experiments of MINOS (Adamson, Ashby, Bumgarner, 2014) and OPERA (Adam, T., Agafonova, N., Aleksandrov, A. et al. 2011). That is why the problem of explaining dark matter and dark energy is so important in science.

However, the solution to this problem has been found. It is explained further.

II. Fundamental Errors of Special Relativity Theory

Established in the early 20th century, special relativity theory (SRT), in contrast to the generally accepted in physics throughout its history experimentally based approach, uses axiomatic approach previously accepted only in mathematics. Out of two of its postulates the second (Antonov, 2014a) is subjected to most criticism, which is now called the principle of the constancy of the speed of light. But in the following years as supposedly identical wording[1] it became known as the principle of non-exceeding of the speed of light, the need for which arose in connection with the fact that the creators of SRT did not know how to explain some provisions of their theory. And they thought they made unnecessary the need an explanation of the principle of non-exceeding of the speed of light.

The fact is that according to the formulas of relativistic formulas of SRT at hyperlight speeds STO the mass, time, and other physical values are measured by imaginary numbers discovered 500 years ago, whose physical meaning over all those years even the most outstanding scientists by their own admission were not able to explain. But in SRT this problem can not be solved at all, because otherwise this theory would not have been recognized by the scientific community. Therefore, the principle of non-exceeding of the speed of light was in fact postulated (as it was nowhere proved), which was justified as follows. According to the formula of Lorentz-Einstein

$$m = \frac{m_0}{\sqrt{1-(v/c)^2}} \qquad (1)$$

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[1] In any other science, except for SRT, the use of several different formulations of axioms, theorems, postulates, laws is nonaccepted

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where m_0 is the rest mass of the moving body;
m is relativistic mass of the moving body;
v is the speed of movement of the physical body;
c is the speed of light;

relativistic mass m of a moving body approaching the speed of light adopts an infinitely large value, i.e. $\lim_{v \to c} m(v) = \infty$. Therefore, it is stated in SRT that the light-speed barrier can not be overcome, as it requires an infinitely larger energy. And if it can not be overcome, it was concluded that there is nothing behind this barrier. And, therefore, it becames no longer necessary to explain for this situation the meaning of imaginary mass imaginary, time, and other imaginary values.

However this justification is easily refuted even at the mundane level. For example, everyone knows that the inability to get into the next room of one's home, breaking the barrier separating them in the form of the wall does not mean that this room with all of its content behind the wall does not exist and that it is impossible to get there otherwise - through the door. The situation is similar with many other barriers.

Thus, a fundamental error of STR (in the form of the principle of the speed of light nonexceedance) entailed two other fundamental errors (in the form of denial of other than ours, universes, as well as the denial of the physical reality of imaginary numbers). These allegations will be proven further.

III. The Reasons of Fundamental Errors of STR

But first let us note that, despite the opinion of the Nobel Prize winner Albert Einstein that *"No single idea, which I would be sure that it will stand the test of time"*, the supporters of STR currently completely ignore the criticism to its address. I.e. they believe that SRT development is completely finished. Although there are quite a lot of noteworthy critical publications (Logunov, 1987; Galeczki, Marquard, 1997; Arteha, 2003; Atsyukovsky, 2003).

To some extent this is due to the fact that in the first half of the 20th century the criticism of SRT was often politically engaged. Therefore the supporters of SRT acquired some immunity to it. This is explained by the peculiarities of the human psyche as well and that the people are much more inclined to protest than to accept (Le Bon, 1898). Finally, in the words of Winston Churchill; "*The history written by the victors*". And they do not need criticism. And SRT is the winning theory nowadays.

Nobel Prize winner Max Planck wrote on this subject: "*New ideas do win not by heated discussions, as a result of which the creators of the new persuade their opponents. Old ideas give way to the new in a way that the carries of the old are dying, a the new generation is brought up in the new ideas, taking them for granted*".

The existing version of SRT, as it is shown in this article, still is not quite perfect and requires some correction. Therefore, one can not but agree with the author of the concept of 'open society' Karl Raimund Popper (Popper, 1972) that "*the struggle of opinions in scientific theories is inevitable and is a necessary prerequisite for the development of science*".

IV. Correction of The Fundamental Errors of STR

a) Evidence of physical reality of the imaginary numbers

Since mathematics is a universal language of science, then in relation to physical problems (for example, to refute the principle of speed of light non-exceedance) it is quite unnecessary to prove the reality of imaginary numbers by physical means - such as it was done in experiments of MINOS and OPERA. Therefore, the author has used the analysis of oscillating processes in linear electric circuits for this purpose, as a result of which he has proved that:

- Resonance in fact does exist not in the real frequencies, as it is stated[2] in all textbooks on the theory of linear electric circuits, but in complex frequencies (Antonov, 2010a; 2015a; 2016a). This proves that the complex frequencies of resonant vibrations are physically real. Consequently, physically real are other complex (in particular, imaginary) numbers as well.
- Oscillatory transient phenomena (including shock waves) exist at physically real complex frequencies (Antonov, 2010b; 2016a). Therefore, naturally occurring shock fluctuations - the tsunami, the sound of church bells, the tuning fork, musical instruments and even the swings swinging after the parents push - prove the physical reality of complex and imaginary numbers as well.
- Finally, the physical reality of imaginary numbers is most simply and convincingly proven by Ohm's law (Antonov, 2015b; 2015c; 2016a; 2016b) in the interpretation of Charles Proteus Steinmetz (Steinmetz, 2010), as the imaginary electric resistance of induction coils and capacitors is measured by existing devices[3].

The specified studies can be repeated and verified in any radio-electronic or electrotechnical laboratory. So they, in contrast to the OPERA and MINOS experiments, absolutely, are quite reliable and conclusive.

[2] Under the dominant influence of SRT

[3] Likewise, i.e. as a result of the use of devices the people have ascertained the real physical existence of radioactivity and the magnetic field, infra- and ultrasound, atoms and molecules, dark matter and dark energy, and many other physical entities, not perceived by our sensory organs

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b) *The refutation of the principle of nonexceeding the speed of light, a proof of the existence of the Multiverse*

Since the physical reality of imaginary numbers is proved, in the corrected version of STR it is now necessary to do what its creators could not do - to abandon the principle of non-exceeding of the speed of light and to explain the physical meaning of imaginary mass, imaginary time, and other imaginary physical values that appear in the relativistic formulas on hyper-light speeds.

And this is explanation is the following (Antonov, 2014b). Since, when $v > c$ the relativistic mass m in the formula (1) becomes imaginary and the physical reality of imaginary numbers have just been proven, the corresponding material objects - such as tachyons (Tanaka, 1960; Feinberg, 1967) are not in our universe, but somewhere else. And we shall call this other place the tachyonic universe to be definite. Moreover, in view of the condition $v > c$ the tachyonic universe is behind the event horizon and therefore is invisible from our universe. And our universe we shall call the tardyonic universe (by the name of elementary particles traveling at sub-light speeds).

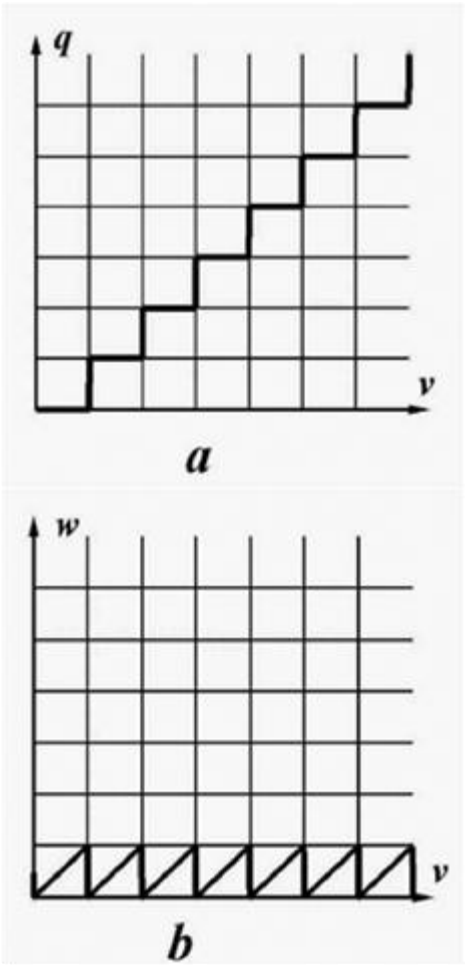

Fig. 1: Graphs of functions $q(v)$ and $w(v)$

Then it is quite permissible to assume that in tachyonic universe act the same physical, chemical, biological and other laws as in our universe and that it has its own inhabitants having high intelligence. And this tachyonic universe is the inertial reference system according to the first postulate of SRT.

However, the formula (1) does not comply with this assumption as at the intervals of the argument variation $v < c$ and $v > c$ the character of variation of the value $m(v)$ is different. In our tardyonic universe, when the argument v increases the relativistic mass m increases, and in tachyon universe when the argument v increases the relativistic mass m decreases. Therefore, the Lorentz-Einstein formula should be corrected as follows (Antonov, 2011; 2012a; 20121b)

$$m = \frac{m_0 i^q}{\sqrt{1-(v/c - q)^2}} = \frac{m_0 i^q}{\sqrt{1-(w/c)^2}} \qquad (2)$$

where $q = \lfloor v/c \rfloor$ is "floor" function (its graph is shown in the Fig. 1a) of the argument v/c;

$w = v - qc$ its own local for each universe speed (its graph is shown in the Fig. 1b), that can only take values in the range of $0 \le w < c$;

v is the speed, measured from our tardyonic universe, which we shall call tardyonic velocity for this reason.

Other relativistic formula of SRT can be corrected in a similar manner.

Thus, it clearly appears from the above mentioned that we do not live in Monoverse, but in Multiverse.

V. The Structure of the Hidden Multiverse

As follows from the formula (2) this Multiverse may include (and later it is shown that are included) more than two universes, i.e. the value q can take meanings and larger units, which corresponds to larger number of universes in the hidden Multiverse. In this case, the value $q = 2$ will correspond to tardyonic Antiuniverse (since $i^2 = -1$), the value $q = 3$ will correspond to tachyon Antiuniverse (since $i^3 = -i$), the value $q = 4$ will correspond to the other tardyonic universe (since $i^4 = 1$), the value $q = 5$ will correspond to another tachyon universe (since $i^5 = -i$), etc. And these parallel universes, called in such a way because, despite their immensity, they never intersect with each other, form (see Fig. 2) a structure in the form of a helically-formed ring.

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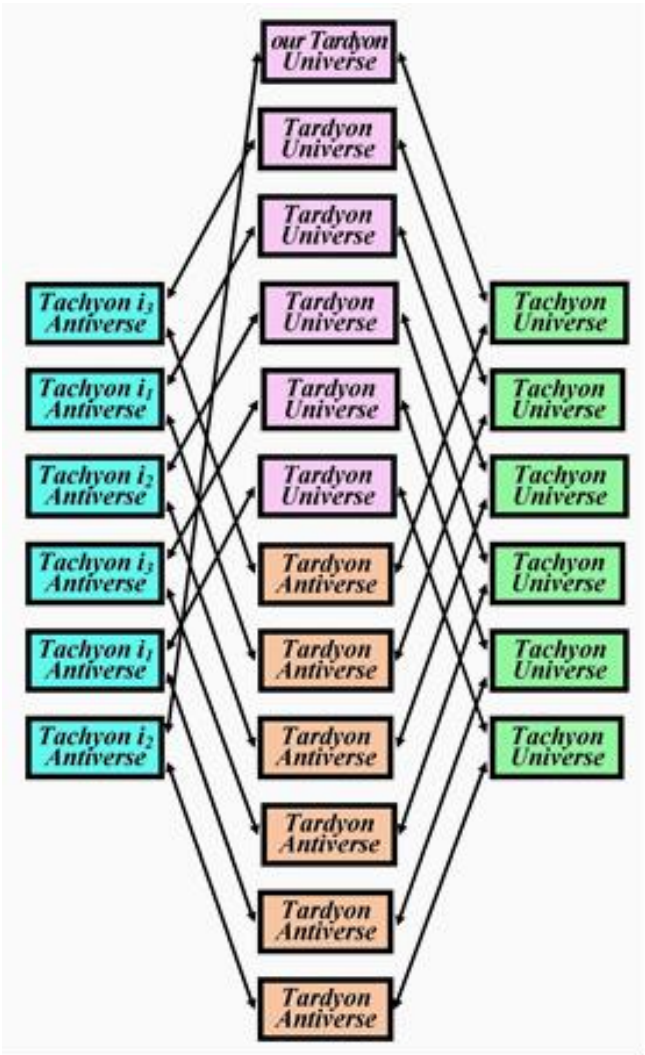

Fig. 2: Estimated structure of the hidden Multiverse, corresponding to the principle of the physical reality of complex numbers

And as in the Multiverse under review the different parallel universes, for the reasons explained above are mutually invisible, then it can be called hidden.

If the value *q* in the formula (2) is to be considered an independent variable, then it can be stated that different parallel universes of the hidden Multiverse are in different dimensions. And floating in the multidimensional space, parallel universes in some places sometimes or even at all times touch each other, and even sink in each other a little, forming certain transition zones (Antonov,2016c) which are referred to in the fiction as portals or stellar gates (shown in the Fig. 2 with single double-headed arrows). On Earth, these are the so-called anomalous zones. And they have nothing in common with the transitions in the form of so-called wormholes, referred to in the general relativity theory.

VI. Explanation of the Phenomenon of Dark Matter and Dark Energy

Any hypothesis of the Multiverse is unfinished, if it does not explain the phenomenon of dark matter and dark energy. But to explain this phenomenon certainly within the hypothesis of Monoverse corresponding to the current erroneous version of STR, despite intensive research, until now in no way can be managed.

And the reason for that is obviously in the wrong formulation of the problem.

As Albert Einstein wrote: *"Insanity: doing the same thing over and over again and expecting different results"*.

The same opinion was held by Confucius: *"The hardest thing of all is to find a black cat in a dark room, especially if there is no cat"*.

If you change the formulation of the problem and seek an explanation of the phenomenon of dark matter and dark energy within the concept of the hidden multiverse, it is not necessary to look for it - it is obvious (Antonov, 2015d; 2015e; 2015f; 2015g; 2015h; 2015j; 2016d; 2016e):

- Dark matter and dark energy are the rest, except ours, invisible universes of the hidden Multiverse;
- At the same time dark matter are the adjacent to our universe invisible universes of the hidden Multiverse
- Dark energy are the rest except our and the universe and the universes forming dark matter, invisible universes of the hidden Multiverse;
- It is impossible to determine the chemical composition of the content of dark matter and dark energy because this content is located outside of our universe.

Of course, the proposed option of the phenomenon of dark matter and dark energy explaining is very unusual. But Sir Isaac Newton wrote: "*No great discovery was done without a bold assumption*".

VII. Antiuniverses Discovery

After creation of the big bang theory, as the result of which not only matter but also antimatter would have to be formed in equal amounts, the physicists have wondered - where that antimatter is located (Alfvén, 1966; Frazer, 2004). And at present it is no less a mystery than the phenomenon of dark matter and dark energy. Many outstanding physicists - Arthur Schuster, Paul Dirac, Rolf Landua, Walter Ehlert, Andrei Sakharov and others tried to solve this puzzle, but their research was mainly focused on the creation of anti-particles using the Large Hadron Collider and other accelerators.

However, the attempts to solve the problem of detection of antimatter in the microcosm, although after the big bang it had to exist in the macrocosm in the form of galaxies and even universes, do not look quite logical. Even the impression is created that in modern physics

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the scientists compared with the entire previous history of its development have kept for themselves almost the only way of its perception - by using increasingly large colliders.

But this is not so, as evidenced by the fact that *antimatter is already discovered* (Antonov, 2015d; 2015e; 2015f; 2015g; 2015h; 2015j; 2016d; 2016e). As shown above, in the hidden Multiverse, there are two pairs of matter and antimatter (it is shown below that in fact there are even four pairs of them). And they exist in the hidden Multiverse, precisely because there are several matters and antimatters. And this is specifically due to the above-mentioned interlace (see Fig. 2) of matter and antimatter both the tardyonic, and the tachyonic - that their annihilation is for sure excluded.

VIII. Correction of the Hidden Multiverse Hypothesis According to the Data of WMAP and Planck Spacecrafts

The data received by WMAP (Hinshaw, Larson, Komatsu et al., 2012) and Planck (Adam, Ade, Aghanim et al., 2015) spacecrafts allow to substantially supplement our knowledge on the hidden Multiverse. According to the data obtained by these crafts the total mass-energy of the whole universe (in fact of the hidden Multiverse) consists by 4.9% from the ordinary (baryonic) matter (the previous estimate of WMAP - 4,6%), by 26.8% from dark matter (according to the data of WMAP - 22.4%) and by 68.3% from dark energy (according to the data of WMAP - 73%). Therefore it can be concluded as following:

- According to WMAP data the hidden Multiverse contains *100%/ 4,6%= 21,7* universes or according to the later Planck data contains *100%/ 4,9%= 20,4* universes.
- According to WMAP data the dark matter contains *22,4%/ 4,6%= 4,9* universes or according to Planck data contains *26,8%/ 4,9%= 5,5* universes.
- According to WMAP data the dark energy contains *73,0%/ 4,6%= 15,9* universes or according to Planck data contains *68,3%/ 4,9%= 13,9* universes.

As can be seen, these results do not correspond to the structural scheme shown in the Fig. 2. Therefore, they require adequate explanation and a structural scheme in the Fig. 2 needs corresponding corrections.

A non-integer number of universes, of course, can be attributed to the measurement error.

The most important difference is the number of neighboring to the tardyonic universes tachyonic universes (corresponding to dark matter) which is not equal to two, but to five or six. And this difference can be explained by the fact that the hidden Multiverse does not correspond to the principle of the physical reality of complex numbers as we previously thought, but to the principle of the physical reality of quaternions, i.e. hypercomplex numbers (Kantor, Solodovnikov,1989), containing three imaginary units i_1 ,i_2 ,i_3 , that are related to each other like

$$i_1^2 = i_2^2 = i_3^2 = -1 \tag{3a}$$

$$i_1 i_2 i_3 = i_2 i_3 i_1 = i_3 i_1 i_2 = -1 \tag{3b}$$

$$i_1 i_3 i_2 = i_2 i_1 i_3 = i_3 i_2 i_1 = 1 \tag{3c}$$

Therefore, the Lorentz-Einstein formula applied to the quaternion structure of the hidden Multiverse appears in the form

$$m = \frac{m_0 (i_1)^q (i_2)^r (i_3)^s}{\sqrt{1 - [v/c - (q+r+s)]^2}} = \\ = \frac{m_0 (i_1)^q (i_2)^r (i_3)^s}{\sqrt{1 - (w/c)^2}} \tag{4}$$

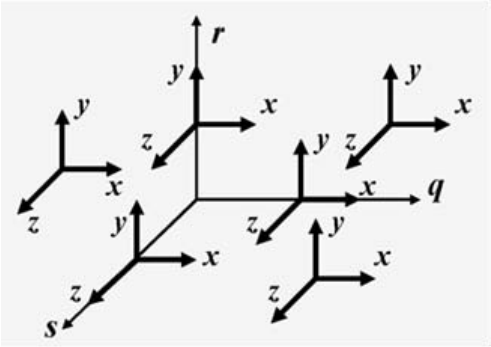

Fig. 3: The six-dimensional space of the hidden Multiverse

where we use the notation similar to notations in the formula (2). Other relativistic formulas of SRT can be corrected in a similar manner.

Therefore, the structure of the multidimensional space in which there are parallel universes of such hidden Multiverse is determined by three independent variables *q* , *r* and *s*. Therefore, the space of the hidden Multiverse (excluding the time) is six-dimensional (see Fig. 3): the three coordinates *x*, *y* and *z*, are the measurements within each universe, and the other three coordinates *q*, *r* and ***s*** are the measurements that define the mutual spatial position of parallel universes to each other.

Thus, as seen in Fig. 4, not all tardyonic universes have a full set of six neighboring tachyonic universes and anti-verses: some tardyonic universes have five neighboring tachyonic universe and anti-verses. So the question arises - what is located beyond the edges of the hidden Multiverse, corresponding to absent neighboring tachyonic universes and / or antiuniversse. And the most plausible answer to this question is the statetement that there are other hidden

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Multiverses (inaccessible to our observations, not only by electromagnetic but also by gravitational manifestations), which together form Supermultiverse. It is possible even that such Supermultiverses form yet larger structures.

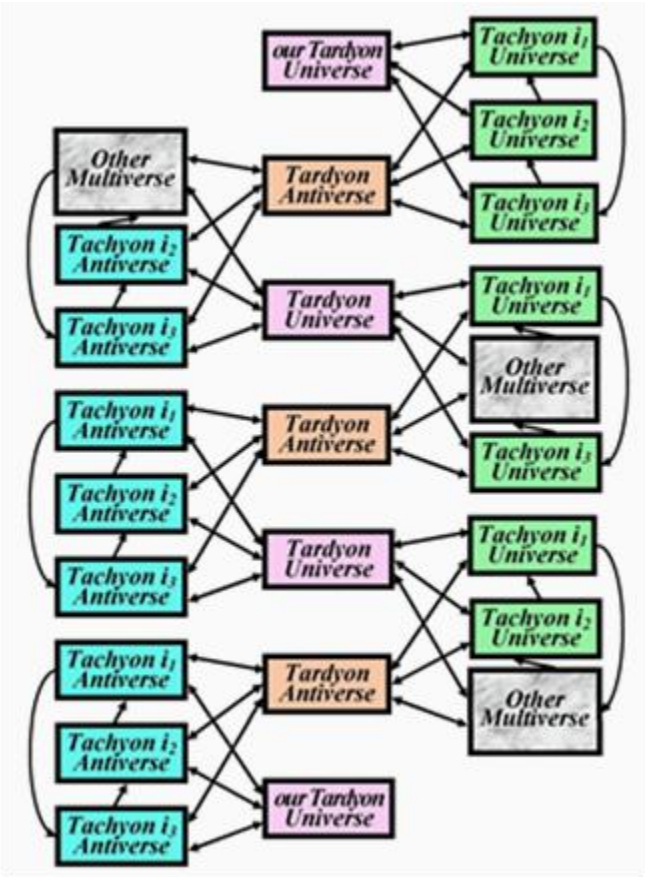

Fig. 4 : The most probable structure of the hidden Multiverse, corresponding to the principles of physical reality of quaternions

In the structural scheme shown in the Fig. 4 the multiple portals between the neighboring universes are shown with single bidirectional arrows (for bilateral portals) corresponding to the formula 3a, or single unilateral arrows (for unidirectional portals) corresponding to the formulas (3b) and (3c). And unidirectional portals are obviously more dangerous for researchers, because you can not go back through them. In general, as a result of law of communicating vessels the parameters of habitat in fore-portal and over-portal areas are almost identical, the visit of neighboring universes through the portals can be fairly safe occupation (as far as unknown can be safe).

Thus, the assumption made in the article on the correspondence of the dark matter and dark energy to the invisible parallel universes of the hidden multiverse meets the criterion of "Occam's Razor." That is why, because it explains everything, it is quite possible. And the meaningfulness of this scientific result is characterized by the saying of the famous American astrophysicist Professor Michio Kaku (Kaku, 2006): "*Of course, a whole bunch of Nobel Prizes awaits the discerning scientists who will be able to unravel the mysteries of dark energy and dark matter*".

IX. Verifiability of Hidden Multiverse Hypothesis

The outlined hypothesis of the hidden quaternionic Multiverse as opposed to other hypotheses of the Multiverses (Deutch, 1998, 2012; Steinhardt, Turok, 2007; Vilenkin, 2007; Kaku, 2008; Weinberg, 2008; Carr, 2009; Greene, 2010, 2011; Lucash, Mikheyeva, 2010; Tegmark, 2015) is verifiable, since:

- Experimental proof of its physical reality is the existence of dark matter and dark energy.
- The proof of its physical reality is also all those experiments on the Large Hadron Collider and other accelerators, as a result of which there was a mass defect. This result is explained by the tachyons formation and consequently the existence of tachyonic universes and anti-verses.
- Its indisputable experimental evidence will be the detection of portals and visiting of the neighboring universes through them (if we are allowed to do so by their inhabitants).

X. Conclusion

Consequently, the existing version of SRT applies only to our tardyonic universe, and the corrected version of SRT - to all the hidden Multiverse. And in this is adjusted SRT the principle of non-exceeding of the speed of light turned out to be unnecessary.

The proposed in the article corrected version of STR allowed to create a hidden Multiverse hypothesis, which is verifiable, and which explains the phenomenon of dark matter and dark energy. And practical discovery of the hidden Multiverse and establishing contacts with existing in them civilizations (Antonov, 2015k) by their consequences for our human civilization will considerably surpass the results of the discovery of America by Columbus.

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Helical Iodine Chains inside Single-Walled Boron Nitride Nanotubes: Finding the Optimal Helical Radius and Helical Angles

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Keywords: peapod, nanotube, iodine chain.

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Zhen Yao [α], Chun-Jian Liu [σ], Li-Qiang Feng [ρ], Yi Li [ω] & Zhong-Li Wu [¥]

Abstract- **The helicity of stable single, double, and triple helical iodine chains inside singe-walled boron nitride nanotubes is studied using the calculation of the systematic interaction energy. The results indicate that the optimal helical radius increases linearly with the radius of the tube. Hence, there is a constant distance between the I-chain and the tube's wall. The optimal helical angle depends on the inter-chain interaction. It is affected, however, by the tube's confinement effect: a small opt(φ) can be induced by large inter-chain for the same tube or a large tube for the same chain structure. The helicity of the encapsulated I-chains is insensitive to the tube's chirality but depends strongly on the tube diameter.**

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I. Introduction

The synthesis and characterization of new one-dimensional (1-D) crystal structures with novel properties are common research areas in the worldwide scientific community [1, 2]. It is clear that the unique hollow structure of macromolecules like nanotubes and zeolite molecules provides an ideal opportunity to create new and well-defined 1-D molecular/atomic structures [3, 4]. Various peapod structures that use nanotube packing of molecules or atoms have been studied in both experiments and theory [5-9]. For example, single-walled carbon nanotube (SWCNT) hosts can greatly enhance the thermal stability of encapsulated C_{60} molecules compared with their bulk structures [10]. Upon high temperature annealing, the decomposed ferrocene molecules inside SWCNTs can produce another interior tube, which represents a new route for material design [7, 11]. Theoretical studies indicate that the distance between host and guest molecules is responsible for the stability and electronic hybrid properties of the peapod system [12-14]. Moreover, different achiral and chiral phases, such as the 1-D linear chain, the 2-D zigzag phase, and the 3-D helical phase of encapsulated guest molecules have been observed in SWCNTs with different distributions of tube diameters [15-19]. Similarly, studies of atomic crystals formed inside nanotubes have also attracted considerable attention due to their novel electronic and structural properties [20-24]. Atomic chain structures, which are absent in its bulk phase, can be fabricated in the 1-D confined channel of macromolecules. Studies such as the growth of linear carbon chains inside nanotube/iodine chains inside AlPO4 molecules have been performed in both experiment and theory [25-29]. Recent experimental progress is encouraging. A novel double helical chain organized using iodine atoms (the so-called helical I-chain) has been produced inside SWCNTs [30]. Theoretical analysis indicates that the charge transfer from the tube to the I-chain is responsible for its stability. The study also indicates that the observed different periodicities of I-chains are induced by the different chirality of the tubes. Another experimental study shows that single, double and triple helical I-chain structures can be stable inside SWCNTs when the diameter matches a certain size [31]. For a diameter larger than 1.45 nm, the chain structure decomposes and crystalizes into the bulk phase, which indicates there is a critical size of the hollow nanospace for a stable formation of I-chains. Undoubtedly, these studies open a pathway for the exploration and design of new material structures within confining 1-D nanospace.

Similar to the structure of CNTs, boron nitride nanotubes (BNTs) are also rolled up using a hexagonal sheet, but they are constructed by alternating boron and nitrogen atoms. BNTs exhibit some superior properties compared to CNT, such as much higher chemical and thermodynamic stability [32, 33]. Due to their unique hollow structure, BNTs can also be used as the host molecule to prepare a hybrid peapod by filling it with various guest molecules. A theoretical study indicates that BNTs are more suitable to prepare peapod systems than CNTs with the same chiral index. This is because much energy can be gained upon encapsulation [34]. *Ab-initio* calculation shows that the doped C_{60} molecule with a potassium atom inside BNTs can induce a significantly higher density of electronic states at the Fermi level than any of the currently available C_{60} crystals can. This makes the BNT-peapod structure a promising material to study superconducting properties in fullerene-based materials [35]. High-resolution transmission electron microscopy (HRTEM) images show that the encapsulated C_{60} molecules inside single-

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walled boron-nitride nanotubes (SWBNTs) also exhibit ordered phases similar to the C_{60}@SWCNT peapod systems. However, there are different stacking configurations for the same tube diameter [36]. The strikingly different properties of BNTs compared to CNTs offers great promise for applications in future molecular electronic devices. From the studies mentioned above, we know that novel single, double, and triple helical I-chains can be produced inside SWCNTs with a certain size of diameter. However, no theoretical or experimental study of a helical I-chain inside BNTs has been reported up to now. We also study how the tube diameter and chirality affect the stability of encapsulated I-chains. Thus, this detailed analysis of stable structures of encapsulated helical I-chains inside SWBNTs may open new insights and further possibilities for applications.

In the present work, the single, double, and triple helical I-chains were constructed inside different SWBNTs. This study focuses on the helicity (including the helical radius and helical angle) of stable helical I-chains inside SWBNTs for different diameters and chirality. We use the Lanner-Jones 12-6 potential function to describe the systematic van der Waals interaction. The results show that the optimal helical radius, opt(r), of encapsulated helical I-chains increases linearly with the tube radius (R_T), which produces a constant gap (~3.7-3.9 Å) between the I-chain and the tube wall. The optimal helical angle, opt(φ), cannot be determined for a single helical I-chain due to the lack of inter-chain interaction. For the investigated double and triple helical I-chains, a small opt(φ) can be induced using large inter-chain for the same tube or a large tube for the same chain structure. The comparative analysis indicates that the helicity of a stable helical I-chain is insensitive to tube chirality, but it depends on the tube diameter. This study aims to better understand the competing mechanism of chain/tube interaction and inter-chain interaction on the helicity of stable helical I-chains inside SWBNTs.

II. Model and Simulation Method

For the simulation of the I-chain@SWBNTs peapod system, we position the tube in a Cartesian coordinate system with its center of mass as the origin *O*. As shown in Fig.1, the tube's long axis coincides with the *OZ*-axis with its length exceeding 1200 Å. This is long enough for the longest helical I-chain (~1100 Å) we use in this study. Thus, the systematic edge effect can be ignored. In the *O-XY* projection plane, two circles with the radius R_T and r correspond to the cross section of SWBNT and the growth trajectory of the chain structures, respectively. The black, red, and purple solid points stand for the iodine atoms of single, double, and triple helical chains, respectively. Because the coordinates of a single helical chain coincide with the coordinates of the first chain structure of double and triple helical chains, the atoms of single helical chains are shown with mixed colors. For a given helical radius r, the initial coordinates for the chain structures can be defined as ($r\cos\varphi_0$, $r\sin\varphi_0$, 0) with the initial helical angle $\varphi_0=(n\text{-}1)2\pi/m$. Here, parameter m =1, 2, and 3 stand for the type of helical chain, and the parameter n (which ranges from 1 to m) stands for the nth chain. For a given φ, the total number of atoms in a single chain structure can be obtained using $N=2\pi/\varphi$ with N being an integer. The length of a complete periodic structure is determined by $L=N(d^2-(2r\sin(\varphi/2))^2)^{1/2}$ with the bonding length (d) of the I-chains set as 2.9 Å, based on Refs. 30. Thus, the spatial positions of arbitrary iodine atoms in each chain structure are defined using the coordinates $(r\cos(\varphi_0+k\varphi), r\sin(\varphi_0+k\varphi), k(d^2-(2r\sin(\varphi/2))^2)^{1/2}-L/2)$ with the parameter k =0, 1, 2, 3, … (N -1). Due to the square root $d^2-(2r\sin(\varphi/2))^2$ of the z coordinate should be equal to or larger than zero, the maximum value of φ for the fixed r and d of a helical chain is given by equation (1).

$$0\le\varphi\le 2\arcsin(d/2r) \tag{1}$$

Similar to the fullerene peapod system, a systematic interaction such as the interaction between the I-chains and tubes (referred to as chain/BNT interaction) as well as the internal interaction between two I-chains (referred to as inter-chain interaction) are due to the van der Waals interaction given by the Lennard-Jones 12-6 potential. The total interaction energy $V(R_T, r, \varphi)$ of the single, double, and triple helical I-chain peapod system, with a given R_T, r, and φ, can be obtained using the nanotube field potential given by equations (2-4).

$$V(R_T, r, \varphi)_{\text{Single}} = \sum_{N_\tau}\sum_{N_{\lambda 1}} v\left(|\rho_\tau - \rho_{\lambda 1}|\right) \tag{2}$$

$$\begin{aligned} V(R_T, r, \varphi)_{\text{Double}} &= \sum_{N_\tau}\sum_{N_{\lambda 1}} v\left(|\rho_\tau - \rho_{\lambda 1}|\right) \\ &+\sum_{N_\tau}\sum_{N_{\lambda 2}} v\left(|\rho_\tau - \rho_{\lambda 2}|\right) + \sum_{N_{\lambda 1}}\sum_{N_{\lambda 2}} v\left(|\rho_{\lambda 1} - \rho_{\lambda 2}|\right) \end{aligned} \tag{3}$$

$$\begin{aligned} V(R_T, r, \varphi)_{\text{Triple}} &= \sum_{N_\tau}\sum_{N_{\lambda 1}} v\left(|\rho_\tau - \rho_{\lambda 1}|\right) \\ &+\sum_{N_\tau}\sum_{N_{\lambda 2}} v\left(|\rho_\tau - \rho_{\lambda 2}|\right) + \sum_{N_\tau}\sum_{N_{\lambda 3}} v\left(|\rho_\tau - \rho_{\lambda 3}|\right) \\ &+\sum_{N_{\lambda 1}}\sum_{N_{\lambda 2}} v\left(|\rho_{\lambda 1} - \rho_{\lambda 2}|\right)+\sum_{N_{\lambda 1}}\sum_{N_{\lambda 3}} v\left(|\rho_{\lambda 1} - \rho_{\lambda 3}|\right) \\ &+\sum_{N_{\lambda 2}}\sum_{N_{\lambda 3}} v\left(|\rho_{\lambda 2} - \rho_{\lambda 3}|\right) \end{aligned} \tag{4}$$

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The parameters τ and λ (λ1, λ2, and λ3) correspond to the atoms of BNT and the helical I-chain, respectively. Here, ρ_i and N_i (i=τ and λ) index the coordinates and the number of corresponding atoms. Since the total number of atoms in a single chain structure depends on the variable parameter φ, the monatomic interaction energy, $V(R_T, r, \varphi)_{atom}$, which gives the average interaction energy for a single iodine atom, can be calculated for a simple analysis using equation (5).

$$V(R_T, r, \varphi)_{atom} = V(R_T, r, \varphi)/mN. \quad (5)$$

The Lennard-Jones 12-6 potential used in the calculation is given in equation (6).

$$v(r)=D_{IJ}(-2(R_{IJ}/r)^6+(R_{IJ}/r)^{12}) \quad (6)$$

The potential parameters for the van der Waals distance RIJ and energy DIJ are listed in Table I [37]. This interaction potential has been used, widely and successfully, to study different interacting peapod systems [38-40].

The helical I-chains only stabilize for a radius smaller than 7.25 Å when filled into the CNTs - according to a previous study [31]. BNTs that include three armchair tubes and sixteen achiral tubes with R_T ranging from 6.905 Å to 8.435 Å are selected for the study. This radius distribution range is slightly larger than for CNTs due to a larger confinement effect produced by the BNTs [39]. Detailed structural information of the BNTs is listed in Table II. The calculation is performed as described in the following steps. For a fixed tube with a given R_T, the r of the helical I-chain changes from 1.5 Å to R_T with the step size Δr =0.1 Å. The φ begins at 1° and increases with a step size $\Delta\varphi=1°$ to the maximum defined in Equation (1). For each increase of r or φ, a complete period of the helical chain (with m =1, 2 and 3 corresponding to the single, double and triple helical chains, respectively) is obtained with the calculation. Then, the systematical interaction energies $V(R_T, r, \varphi)_{atom}$ for the constructed single, double, and triple helical chain peapod systems can be obtained using the equations (2-4), and combining equations (5-6). Thus, opt(r) and opt(φ), which correspond to the most stable helical chain for a given R_T, can be determined using the obtained minimum interaction energy.

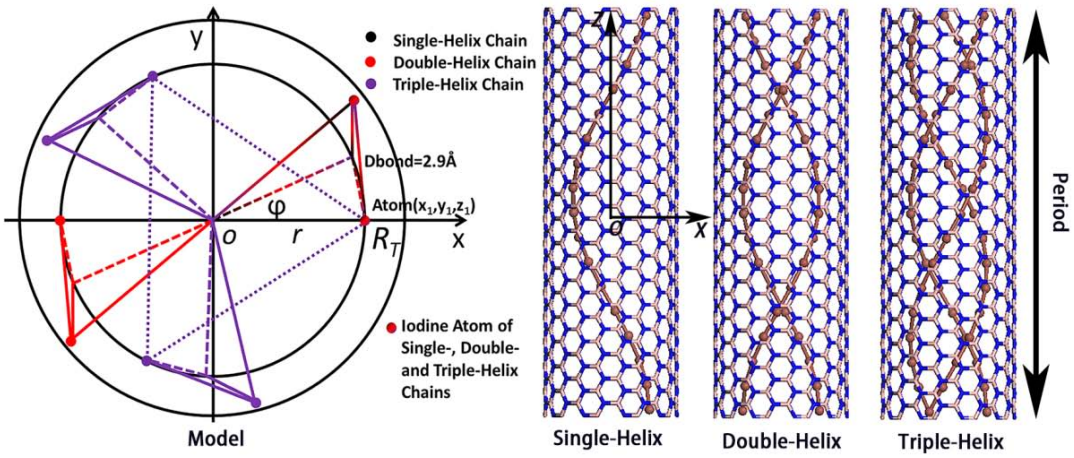

Fig. 1: Image of the constructed model in a Cartesian coordinate system. Parameters r and φ correspond to the helical radius and helical angle of the I-chain for a given tube radius R_T. The atoms of the single, double, and triple helical chains are colored as black, red, and purple, respectively

Table 1: The L-J 12-6 potential parameters for I-I, I-N, and I-B used in this study

Type	I-I	I-N	I-B
DIJ	0.339	0.153	0.247
RIJ	4.50	4.08	4.292

III. Results and Discussions

Two equations are addressed in this section. One is the optimal helicity (including opt(r) and opt(φ)) of encapsulated single, double and triple helical chains inside different SWBNTs. The other is the mechanism of the influence of the tube's confinement effect (or chain-BNT interaction: including the diameter and chirality) and the inter-chain interaction on the helicity of a stable helical chain. Firstly, we select the minimum (10, 10) armchair tube as an example to determine the opt(r) and opt(φ) of the encapsulated three constructed helical chains by calculating the systematic interaction energies (V_{atom}). In Fig.2 we can see that the opt(r) values that correspond to the minimum value of V_{atom} for single, double, and triple helical chains. They are 3.1 Å, 3.0 Å and 3.1 Å, respectively. The similar opt(r) obtained here lead to a similar distance (~3.8 Å-3.9 Å)

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between the tube's wall and the helical chain, which is in good agreement with the reported experimental results [30, 31]. Similarly, the V_{atom}-φ curves of three constructed helical chains are presented in Fig.3. It can be seen that the V_{atom} of a single helical chain is generally invariant with the increased φ, which means there is an insensitive dependency between them. For the presented results of double and triple helical chains, the V_{atom} exhibits a generally invariant and decreased tendency with φ for the low and high angle region. The obtained opt(φ) values, which correspond to the minimum value of V_{atom} of double and triple helical chains are 50° and 40°, respectively. The V_{atom} of a single helical chain only considers the chain/BNT interaction, while the V_{atom} of the double and triple helical structures considers both the chain/BNT interaction and the inter-chain interaction. Consequently, the exhibited different V_{atom}-φ behavior of the single helical structure from the double and triple helical chains must be due to the absence of inter-chain interaction. In particular, opt(φ) can be determined only for the case where inter-chain interaction is considered for the chain structures parameter $m \geq 2$. However, the results above only show the importance of inter-chain interaction to determine opt(φ). No direct evidence is confirmed for whether the tube's confinement effect can affect opt(φ) or not. A more detailed discussion of this open question is below.

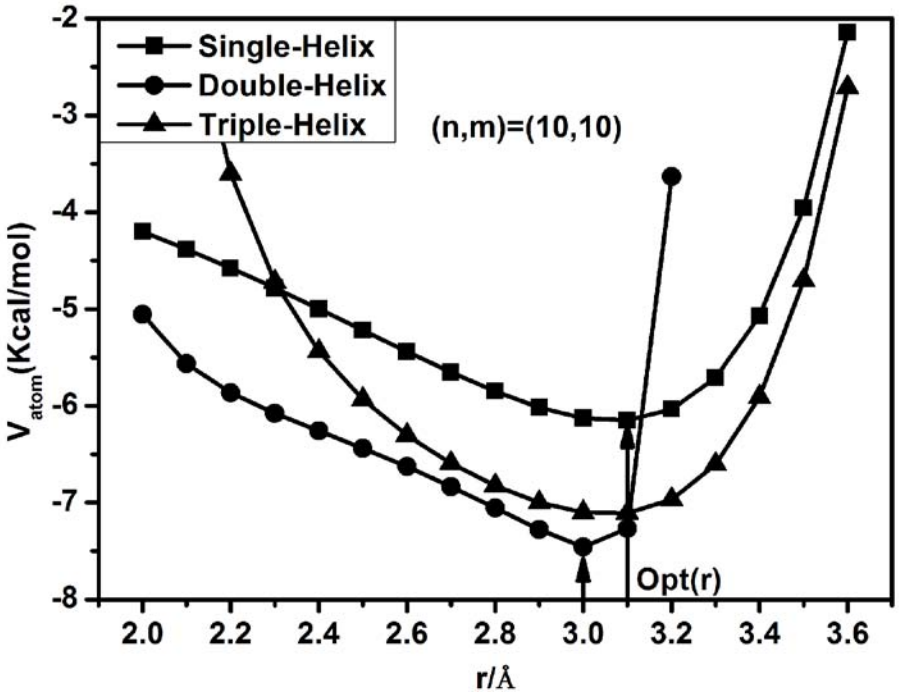

Fig. 2: Systematic interaction energies (V_{atom}) as a function of helical radius (r) for the select armchair (10, 10) tube. The square, circular, and triangular solid points correspond to the V_{atom} of single, double and triple helical chains, respectively

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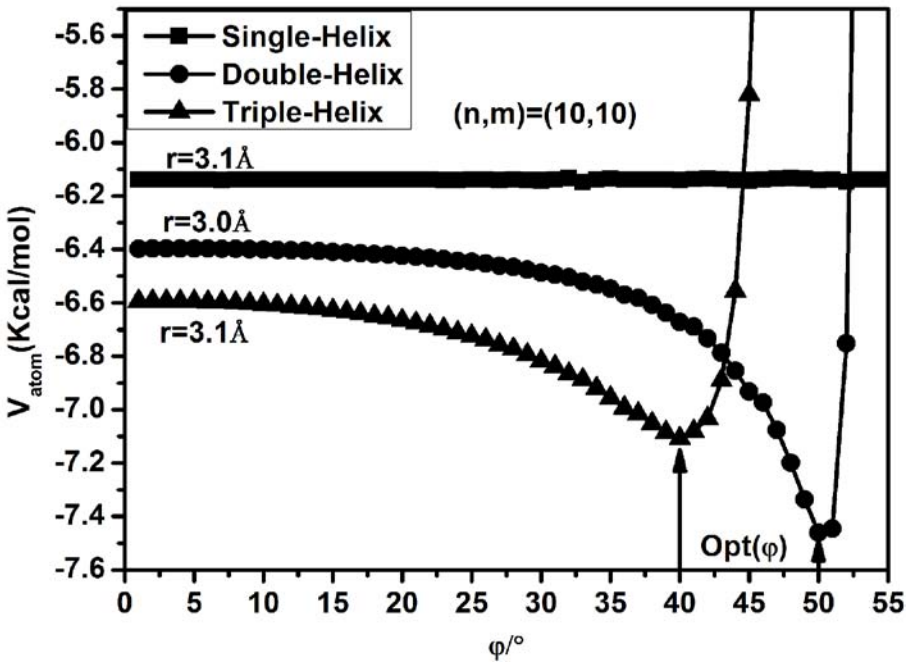

Fig. 3: Systematic interaction energies (V_{atom}) as a function of the helical angle (φ) for the select armchair (10, 10) tube with the corresponding opt(r) is fixed. The square, circular, and triangular solid points correspond to the V_{atom} of single, double, and triple helical chains, respectively

All calculated results, including opt(r), the distance between iodine chains and tube's wall (space), and opt(φ) are listed in Table II. For an intuitive analysis, the opt(r)-R_T and space-R_T, and opt(φ)-R_T are presented in Fig.4 and Fig.5, respectively. Moreover, some optimal double and triple helical chains are shown in Fig.7 and Fig.8. We can see that the opt(r) of single helical chain increases linearly from 3.1 Å to 4.6 Å as R_T increases from 6.905 Å to 8.435 Å. Similarly, opt(r) of double and triple helical chains increases linearly from 3.0 Å to 4.6 Å, and from 3.1 Å to 4.7 Å, respectively, for the same interval of R_T like the single helical chain (see Fig.7 and Fig.8). The obtained identical increasing tendency of opt(r) for the single helical structure as the studied double and triple helical chains (considering the different interactions between them) indicates that opt(r) mainly depends on the tube's confinement effect. The tube's confinement effect is associated with the tube diameter and chirality. It can be seen that some small platforms, which correspond to the same opt(r) for a similar R_T but different chirality, are visible in Fig.4. This indicates that opt(r) is insensitive to the tube's chirality but strongly depends on the tube diameter. Additionally, a similar distance (~3.7 Å to 3.9 Å) between the chain structure and tube's wall is obtained for these three helical chains, which is consistent with reported experimental results [30, 31]. The small fluctuations for the obtained distance (~3.7 Å to 3.9 Å) here are caused by the calculation accuracy of Δr=0.1 Å. A more uniform space should be produced by using a smaller value for Δr such as 0.01 Å or 0.001 Å. It is, however, impractical because the calculation is complex and expensive.

Since opt(φ) can not be determined for a single helical chain structure due to the absence of inter-chain interaction, we only show the opt(φ)- R_T curves for double and triple helical chains - see Fig.5. It can be seen that the double helical chain exhibits a larger opt(φ) than the triple helical chain when they were filled into the same tubes. Additionally, the obtained opt(φ) decreases, in general, from 50° to 35°, and from 40° to 32° for the double and triple helical chain, respectively (see Fig.7 and Fig.8). The obtained different opt(φ), but identical variation tendency as R_T for the double and triple chains, can be interpreted as follows. For the same tube, similar opt(r) values are obtained for the double and triple helical chains. However, a larger inter-chain interaction, due to a smaller inter-chain distance, can be produced for the triple helical chain than by encapsulating the double helical chain. Thus, the large inter-chain interaction can induce a small opt(φ). On the other hand, for the same chain structure with different tubes, the decreased value of opt(φ) as the increased R_T shows that a large tube with a small confinement effect can induce a small helical angle. More specifically, opt(φ) shows an inverse proportional relationship with the inter-chain interaction for the same tubes. However, a direct proportional relationship between opt(φ) and the tube's confinement effect is observed for the same chain structures. Similarly, some

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small platforms, i.e. the same opt(φ) for similar R_T but different chirality, are also shown in Fig.5. This indicates that opt(φ) is insensitive to the tube's chirality, but it depends on the tube diameter. A similar conclusion has been reported for the case of encapsulated C_{60} molecules inside carbon nanotubes, where the stable orientation mainly depends on the tube diameter [41]. The periodic length *L* of the obtained optimal helical structures is shown in Fig.6. The periodic length *L* of double and triple helical chains decreases generally with increasing R_T (see Fig.7 and Fig.8). This can be interpreted as the expression $L=N(d^2-(2r\sin(\varphi/2))^2)^{1/2}$ where the period *L* obeys an inverse relationship with the variables φ and r for the invariable d. Thus, the competing relationship of an increasing r and decreasing φ causes the *L* to decrease with R_T. In comparison, the *L* of the triple helical chain is larger than the double helical chain for the same R_T /similar opt(r). This is because a smaller opt(φ) is obtained for the triple helical chain.

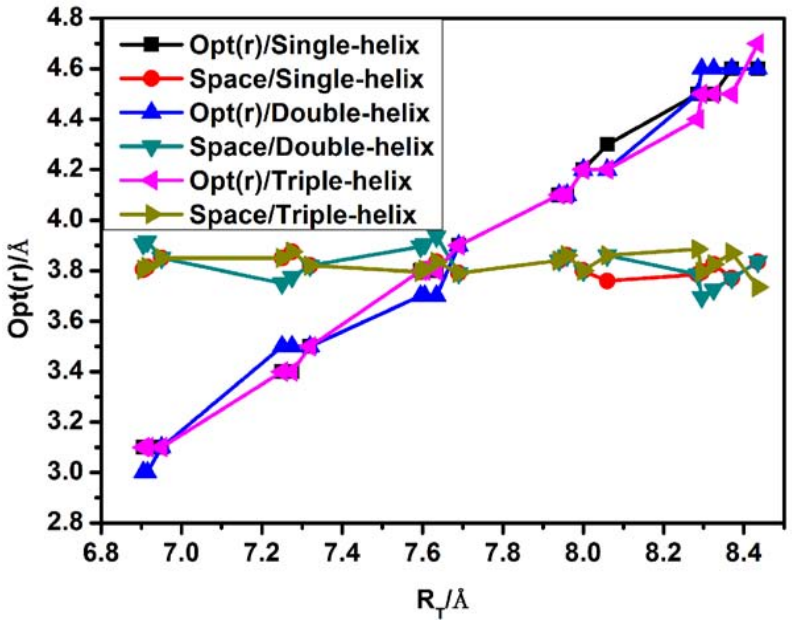

Fig. 4: Values for opt(r) and the distance between the I-chains and tube wall for three studied helical chains, as a function of the tube radius R_T

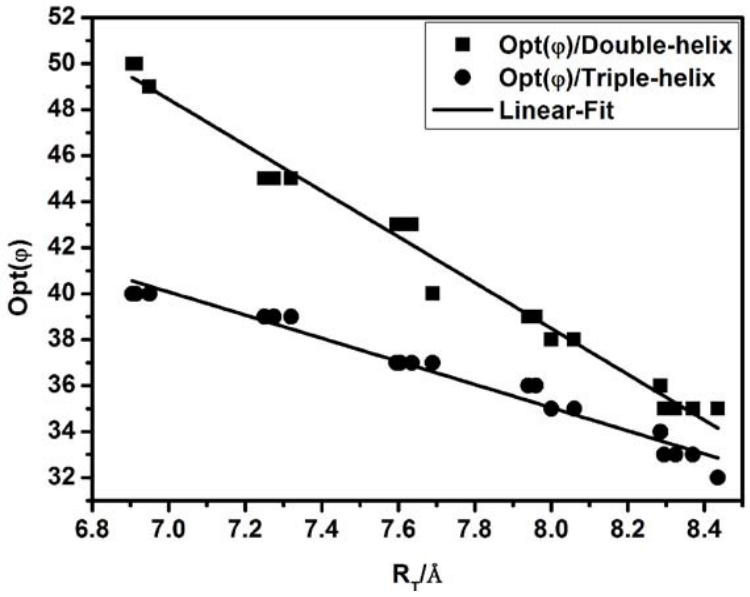

Fig. 5: The opt(φ) values for double (squares) and triple (circles) helical chains, as a function of the tube radius R_T. The linear fits are shown as a guide for the eye

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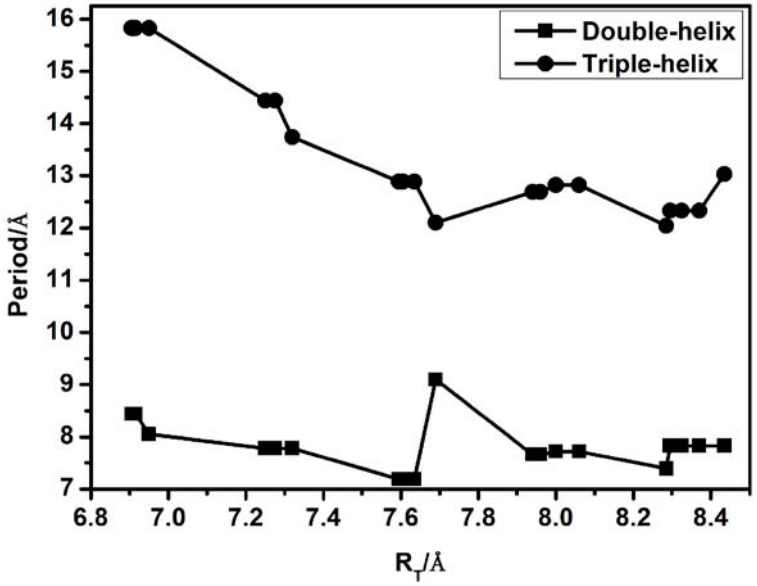

Fig. 6: The length of the periodic length unit *L* for optimal double (squares) and triple (circles) helical chains, as a function of the tube radius R_T

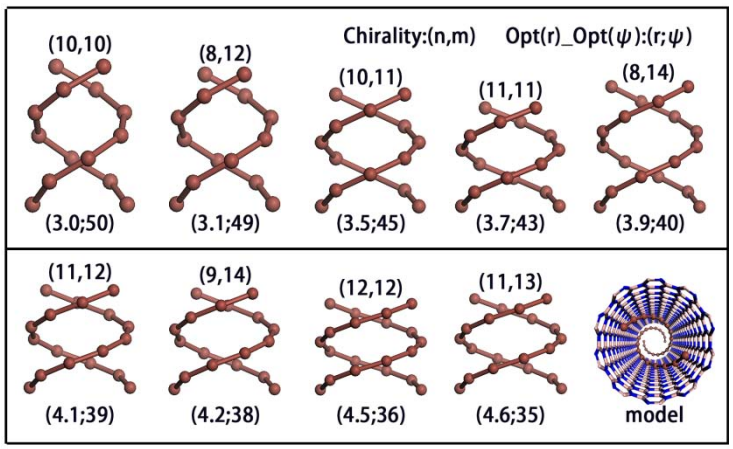

Fig. 7: Illustration of some optimal double helical chains as shown in Fig.4 and Fig.5. The tube's chiral index (n, m) and opt(*r*)_opt(φ) are labeled at the top and bottom, respectively

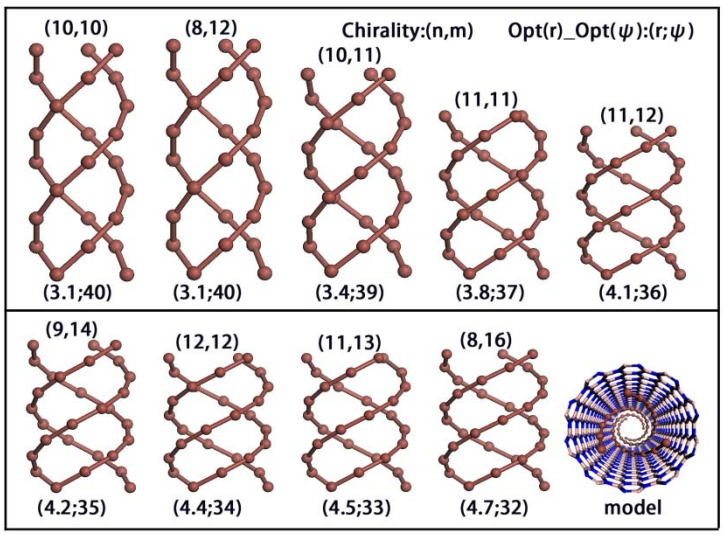

Fig. 8: Similar illustrations as in Fig.7 but for the triple helical chain

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Table II. Detailed structural properties of SWBNTs and the calculated results in this study. Columns I and II show the tube's chirality and radius, respectively. Columns III and IV show the optimal helical radius and space for a single helical chain, respectively. Columns V-VII and VIII-X show the optimal helical radius, the space, the optimal helical angle of double and triple helical chains, respectively.

Table 2

(n,m)	R_T/Å	Single Helix		Double Helix			Triple Helix		
		Opt(*r*)/Å	Space/Å	Opt(*r*)/Å	Space/Å	Opt(φ)/°	Opt(*r*)/Å	Space/Å	Opt(φ)/°
(10,10)	6.905	3.1	3.805	3.0	3.905	50	3.1	3.805	40
(9,11)	6.915	3.1	3.815	3.0	3.915	50	3.1	3.815	40
(8,12)	6.95	3.1	3.85	3.1	3.85	49	3.1	3.85	40
(10,11)	7.25	3.4	3.85	3.5	3.75	45	3.4	3.85	39
(9,12)	7.275	3.4	3.875	3.5	3.775	45	3.4	3.875	39
(8,13)	7.32	3.5	3.82	3.5	3.82	45	3.5	3.82	39
(11,11)	7.595	3.8	3.795	3.7	3.895	43	3.8	3.795	37
(10,12)	7.605	3.8	3.805	3.7	3.905	43	3.8	3.805	37
(9,13)	7.635	3.8	3.835	3.7	3.935	43	3.8	3.835	37
(8,14)	7.69	3.9	3.79	3.9	3.79	40	3.9	3.79	37
(11,12)	7.94	4.1	3.84	4.1	3.84	39	4.1	3.84	36
(10,13)	7.96	4.1	3.86	4.1	3.86	39	4.1	3.86	36
(9,14)	8.00	4.2	3.8	4.2	3.8	38	4.2	3.8	35
(8,15)	8.06	4.3	3.76	4.2	3.86	38	4.2	3.86	35
(12,12)	8.285	4.5	3.785	4.5	3.785	36	4.4	3.885	34
(11,13)	8.295	4.5	3.795	4.6	3.695	35	4.5	3.795	33
(10,14)	8.325	4.5	3.825	4.6	3.725	35	4.5	3.825	33
(9,15)	8.37	4.6	3.77	4.6	3.77	35	4.5	3.87	33
(8,16)	8.435	4.6	3.835	4.6	3.835	35	4.7	3.735	32

IV. Conclusions

In summary, this study comprises a simulation of encapsulated single, double, and triples helical I-chains inside SWBNTs with different diameters and chirality distributions. We focused on the helicity of stable helical I-chains and their formation mechanism inside SWBNTs by calculating the interaction energy using the van der Waals potential. The results show that the optimal helical radius, opt(*r*), of encapsulated I-chains increases linearly with the tube radius (R_T), which produces a constant distance (~3.7-3.9 Å) between the I-chain and the tube wall. The optimal helical angle, opt(φ), can not be determined for a single helical I-chain due to the lack of inter-chain interaction. The opt(φ) for the double helical chain is larger than the value for the triple helical chain when they are filled into the same tubes. This is because the larger inter-chain interaction can induce a smaller opt(φ). The obtained opt(φ) for double and triple helical I-chains decreases linearly with increasing R_T because the large tubes can induce a small opt(φ). The comparative analysis indicates that the helicity of stable I-chain structures is insensitive to the tube's chirality, but it strongly depends on the tube diameter. Additionally, the periodic length *L* for the triple helical chain is larger than for double helical chain for the same R_T and similar opt(r). This is because a smaller opt(φ) is obtained for the triple helical chain. This work not only provides images of the structure of encapsulated double and triple helical I-chains inside SWBNTs, but also reveals the formation mechanism for stable helical structures.

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The Mechanism of Generation of Nonlinear Interactions of Microscopic Particles and its Properties in Quantum Systems

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Abstract- The mechanisms of generation of the nonlinear interactions in the quantum systems are studied using a nonlinear Schrodinger equation, which can describe the states and properties of motion of the microscopic particles. The investigations show that the interactions arises from the interaction between the moved particle and background field. the difficulties, limitations and approximations of the quantum mechanics and its roots and reasons are first revealed and pointed out. The quantum mechanics simplifies and blots out the real motions and interactions of the microscopic particles including the nonlinear interactions, thus the particles have only a wave feature, not corpuscle feature. In view of these problems and difficulties we add the nonlinear interaction, $b|\phi|^2\phi$, into the dynamic equation and use again it to describe the particles. Thus the wave or dispersive effect of the particles is suppressed by the nonlinear interactions, thus its localization and wave-corpuscle duality are displayed and exhibited naturally.

Keywords: microscopic particle, nonlinear interaction, nonlinear schrodinger equation, quantum mechanics, mechanism, counteraction.

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THEMECHANISMOFGENERATIONOFNONLINEARINTERACTIONSOFMICROSCOPICPARTICLESANDITSPROPERTIESINQUANTUMSYSTEMS

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The Mechanism of Generation of Nonlinear Interactions of Microscopic Particles and its Properties in Quantum Systems

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Abstract- The mechanisms of generation of the nonlinear interactions in the quantum systems are studied using a nonlinear Schrodinger equation, which can describe the states and properties of motion of the microscopic particles. The investigations show that the interactions arises from the interaction between the moved particle and background field. the difficulties, limitations and approximations of the quantum mechanics and its roots and reasons are first revealed and pointed out. The quantum mechanics simplifies and blots out the real motions and interactions of the microscopic particles including the nonlinear interactions, thus the particles have only a wave feature, not corpuscle feature. In view of these problems and difficulties we add the nonlinear interaction, $b|\phi|^2\phi$, into the dynamic equation and use again it to describe the particles. Thus the wave or dispersive effect of the particles is suppressed by the nonlinear interactions, thus its localization and wave-corpuscle duality are displayed and exhibited naturally. Subsequently, we investigate the features of the particles and find that the nonlinear interactions exist always, if and only if the real motions of the particles and background fields as well as the interactions between them are considered simultaneously. On the basis of analyses of dynamics of the electrons and nucleon or lattice (background) fields we give two mechanisms of self-interaction and self-trapping for the generation of nonlinear interactions and corresponding representations. Finally we discuss the properties of the nonlinear interactions in the two mechanisms and obtain the relations between the action and counteraction of the two nonlinear interactions of the particles and background fields. We find that although the nonlinear interaction accepted by the particles and background field can generate simultaneously in the nonlinear quantum systems, the two nonlinear interactions do not completely satisfy the law of action and counteraction of the forces in the classical mechanics. This shows clearly that the natures of the microscopic particles in the nonlinear quantum systems are different from those of classical particles, even though the microscopic particles have also the corpuscle feature. This conclusion is of important and interest to physics and nonlinear science.

Keywords: microscopic particle, nonlinear interaction, nonlinear schrodinger equation, quantum mechanics, mechanism, counteraction.

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I. Introduction, the Limitations of Quantum Mechanics

As are known, the quantum mechanics established by several great scientists, such as Bohr, Born, Schrodinger and Heisenberg, etc., in the early 1900s [1-6] is the foundation of modern science and used extensively to study the properties and rules of motion of microscopic particles. In the theory the states of microscopic particles are often described by a Schrodinger equation:

$$i\hbar\frac{\partial\psi}{\partial t}=-\frac{\hbar^2}{2m}\nabla^2\psi+V(\vec{r},t)\psi \qquad (1)$$

where $\hbar^2\nabla^2/2m$ is the kinetic energy operator, $V(\vec{r},t)$ is the externally applied potential operator, m is the mass of the particles, $\psi(\vec{r},t)$ is a wave function describing the states of the particles, $\vec{r}$ is the coordinate or position of the particle. Equation (1) is a wave equation, if only the externally applied potential is known, we can find the solutions of the equation[7-9]. However, for all externally applied potentials, its solutions are always a linear or dispersive wave, for example, at $V(\vec{r},t)=0$, the solution is a plane wave as follows:

$$\psi(\vec{r},t)=A'\exp[i(\vec{k}\cdot\vec{r}-\omega t)] \qquad (2)$$

where k is the wavevector of the wave, ω is its frequency, and A' is its amplitude. This solution denotes the state of a freely moving microscopic particle with an eigenenergy of

$$E=\frac{p^2}{2m}=\frac{1}{2m}(p_x^2+p_y^2+p_z^2),(-\infty<p_x,p_y,p_y<\infty) \qquad (3)$$

This energy is continuous, this means that the probability of the particle to appear at any point in the space is a constant, thus the microscopic particle cannot be localized, can only propagate freely in a wave in total space. Then the particle has nothing about corpuscle feature.

If the free particle is artificially confined in a small finite space, such as, a rectangular box of dimension a, b and c, then the solution of Eq.(1) is a standing wave of

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$$\psi(x,y,z,t) = A\sin\left(\frac{n_1\pi x}{a}\right)\sin\left(\frac{n_2\pi y}{b}\right)\sin\left(\frac{n_3\pi z}{c}\right)e^{-iEt/\hbar} \quad (4)$$

In such a case, the particle is also dispersed in total box, but its eigenenergy is quantized, i.e.,

$$E = \frac{\pi^2\hbar^2}{2m}\left(\frac{n_1^2}{a^2}+\frac{n_2^2}{b^2}+\frac{n_3^2}{c^2}\right), \quad (5)$$

thus corresponding momentum is also quantized. This means that the wave feature of microscopic particle has been not changed in this condition.

If the potential field is further varied, i.e., $V(r,t)\neq 0$, the solutions of Eq.(1) is still some waves with different features[5-12]. This shows clearly that the microscopic particles have only a wave feature, not corpuscle feature, this is inherent nature of particles in the quantum mechanics. However, these features of microscopic particles are not only incompatible with de Broglie relation of wave-corpuscle duality and Davisson and Germer's experimental result of electron diffraction on double seam in 1927[6-8] but also contradictory with regard to the traditional concept of particles[7-9]. These are just the limitations or difficulties of the quantum mechanics. These difficulties result in a duration controversy of a century in physics[8-12] , the disputed problems were as follows. Is the quantum mechanics correct?, How to describe the wave-corpuscle duality of microscopic particles? Is the quantum mechanics a dynamic or a statistical theory? Does it depict the motion of a single particle or a system of particles? Was the uncertainty relationship due to the intrinsic features of microscopic particles or a result of uncontrollable interaction between the measuring instruments and the system being measured", etc...More surprising, the way and method solving these problems have not sought up to now.

Why does the quantum mechanics have these limitations? in other word, what are the roots generating these limitations of the quantum mechanics? As is known, the Hamiltonian operator of the system corresponding Eq.(1) in quantum mechanics is represented by

$$\hat{H}(t) = \hbar^2\nabla^2/2m + V(\vec{r},t) \quad (6)$$

Obviously, it consists only of kinetic and potential operator of particles; the latter is only determined by an externally applied field, and not related to the state or wave function of the particle. Equation (6) means that all interactions among the particles and between the particles and background fields, such as the lattices in solid matter, must belong in the externally applied potential $V(\vec{r},t)$ no matter what forms of linear, nonlinear and other complicated interactions[13-16]. In other word, when the forms of the external potential field $V(\vec{r},t)$ are changed successively, we find that the dispersion and decaying nature of the microscopic particle always persists. This means that the external potential field $V(\vec{r},t)$can only change the shape of the microscopic particle, such as, its amplitude and velocity, but not its wave nature because its natures are only determined by the kinetic energy term, $h^2\nabla^2/2m = \hat{P}^2/2m$, with dispersive effect in Eq.(1). Because microscopic particles are always in motion, then the dispersion effect always exists, but there is not an interaction, which can obstruct and suppress the dispersive effect of kinetic energy and make the microscopic particles the localization in Eqs.(1) and (6) in quantum mechanics, thus the particles have only the dispersive or wave feature., not the corpuscle feature. These are just the roots resulting in the wave feature, or speaking, the reason why the microscopic particles have only in quantum mechanics. Therefore, a key problem solving the difficulties and limitations of the quantum mechanics is to seek for a new interaction between the particles, which obstruct and suppress the dispersive effect of kinetic energy.

II. The Nonlinear Interactions can Suppress the Dispersive Effect and make the Particles the Localization

As mentioned above, in order to solve the difficulties and limitations of quantum mechanics we must seek for an interaction to obstruct and suppress the dispersive effect of kinetic energy to make the microscopic particles the localization. Thus we must make much account of the nonlinear interaction among the particles, which could play the above role because it can distort and collapse also the wave[9-11], eventually can balance and cancel the dispersive effect. Thus the nature of the particle could be changed, its feature of corpuscle could be displayed[13-18]. In the light of this idea we now evaluate and add further the nonlinear interaction of $b|\phi|^2\phi$ related to the states of the particles into Eq.(1), thus the dynamic equation of microscopic particles should be replaced by the following nonlinear Schrodinger equation.

$$ih\frac{\partial\phi}{\partial t} = -\frac{h^2}{2m}\nabla^2\phi \pm b|\phi|^2\phi + V\left(\vec{r},t\right)\phi \quad (7)$$

where $\phi(\vec{r},t)$ is a wave function representing the states of microscopic particles, b is a nonlinear interaction coefficient, On account of the nonlinear interaction, $b|\phi|^2\phi$, is considered, then we expect that the particles could be localized. For this purpose we now investigate a simple example of Eq.(7) at $V\left(\vec{r},t\right) = 0$. In such a

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case, in the one-dimensional case, the equation (7) at V(x,t)= 0 becomes as

$$i\phi_{t'} + \phi_{x'x'} + b|\phi|^2\phi = 0 \quad (8)$$

where $x' = x\sqrt{2m}/h, t' = t/h$. We now assume the solution of Eq.(8) to be of the form

$$\phi(x',t') = \varphi(x',t')e^{i\theta(x',t')} \quad (9)$$

Inserting Eq. (9) into Eq.(8) we can obtain

$$\varphi_{x'x'} - \varphi\theta_{t'} - \varphi\theta_{x'}^2 - b\varphi^2\varphi = 0, (b>0) \quad (10)$$

$$\varphi\theta_{x'x'} + 2\varphi_{x'}\theta_{x'} + \varphi_{t'} = 0 \quad (11)$$

If let $\theta = \theta(x'-v_c t'), \varphi = \varphi(x'-v_e t'),$ then Equations (10)-(11) become

$$\varphi_{x'x'} - v_c\varphi\theta_{t'} - \varphi\theta_{x'}^2 - b\varphi^3 = 0 \quad (12)$$

$$\varphi\theta_{x'x'} + 2\varphi_{x'}\theta_{x'} - v_e\varphi_{t'} = 0 \quad (13)$$

If fixing the time t' and further integrating Eq.(13) with respect to x' we can get

$$\varphi^2(2\theta_{x'} - v_e) = A(t') \quad (14)$$

Now let integral constant A(t')=0, then we can get $\theta_{x'} = v_e/2$. Again substituting it into Eq.(13), and further integrating this equation we then yield

$$\int_{\varphi_0}^{\varphi} \frac{d\varphi}{\sqrt{Q(\varphi)}} = x'-v_e t' \quad (15)$$

where $Q(\varphi) = -b\varphi^4/2 + (v_e^2 - 2v_e v_c)\varphi^2 + c'$.

When c'=0, $v_e^2 - 2v_c v_e > 0,$ then $\varphi = \pm\varphi_0, \varphi_0 = [(v_e^2 - 2v_e v_c)/2b]$ is the roots of $Q(\varphi) = 0$ except for $\varphi = 0$. Thus from Eq. (15) we obtain the solution of Eq. (10)-(11) is

$$\varphi(x',t') = \varphi_0 \sec h[\sqrt{\frac{b}{2}}\varphi_0(x'-v_e t')].$$

Then the solution of nonlinear Schrodinger equation in Eq. (8) eventually is of the form

$$\phi(x,t) = A_0 \sec h\left\{\frac{A_0\sqrt{bm}}{\hbar}\left[(x-x_0)-vt\right]\right\}e^{i[mv(x-x_0)-Et]/\hbar} \quad (16)$$

where $A_0 = \sqrt{\frac{mv^2/2 - E}{2b}}$, v is the velocity of motion of the particle, $E = \hbar\omega$. The solution in Eq. (16) can be also found by the inverse scattering method [13, 14, 18-,22]. This solution is completely different from Eq. (2), and consists of a envelop and carrier waves, the former is $\varphi(x,t) = A_0 \sec h\{\frac{A_0\sqrt{bm}}{h}[(x-x_0)-vt]\}$ which is a bell-type non-topological soliton with an amplitude A_0, the latter is the $\exp\{i[mv(x-x_0)-Et]/h\}$. This solution is shown in Fig.1(a) Therefore, the particle described by nonlinear Schrodinger equation (8) is a soliton[22-23]. The envelop φ(x, t) is a slow varying function and the mass centre of the particle, the position of the mass centre is just at x_0, A_0 is its amplitude, and its width is given by $W' = 2\pi h/\sqrt{mb}A_0$. Thus, the size of the particle is $A_0 W' = 2\pi h/\sqrt{mb}$ and a constant. This shows that the particle has exactly a mass centre and determinant size, thus the particle localized at x_0. According to the soliton theory [22-23], the bell-type soliton in Eq.(16) can move freely over a macroscopic distances in a uniform velocity *v* in space-time retaining its form, energy, momentum and other quasi-particle properties. Just so, the vector $\vec{r}$ or *x* has definitively physical significance, and denotes exactly the positions of the particle at time *t*. Then, the wave-function $\phi(\vec{r},t)$ or φ(x, t) can represent exactly the states of the particle at the position $\vec{r}$ or *x* and time *t*. These features are consistent with the concept of particles. Thus the feature of corpuscle of the particle is displayed clearly and outright.

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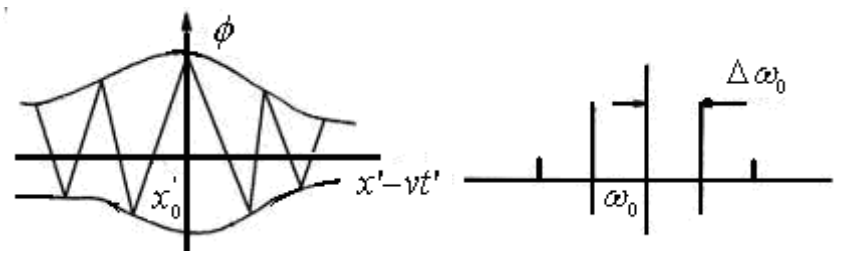

(a) (b)

Fig. 1: The solution in Eq. (8) and its features

we now re-write the solution Eq. (16) as the following form

$$\phi(x,t)=2\sqrt{\frac{2}{b}}k\sec h\left\{2k\left[\left(x'-x_0^{'}\right)-v_e t'\right]\right\}e^{iv_e\left[\left(x'-x_0^{'}\right)-v_c t'\right]/2} \quad (17)$$

where $2^{3/2}k/b^{1/2}= A_0$, $A_0=\sqrt{\frac{v_e^2-2v_cv_e}{2b}}$, v_e is the group velocity of the electron, v_c is the phase speed of the carrier wave. For a certain system, v_e and v_c are determinant and do not change with time. From the above results we see clearly that the particle is a soliton. According to the soliton theory[22-23], the soliton has determinant mass, momentum and energy, which can be represented by [14,22-23]

$$N_s=\int_{-\infty}^{\infty}|\phi|^2dx'=2\sqrt{2}A_0$$

$$p=-i\int_{-\infty}^{\infty}\left(\phi^*\phi_{x'}-\phi\phi_{x'}^*\right)dx'=2\sqrt{2}A_0v_e=N_sv_e=const$$

$$E=\int_{-\infty}^{\infty}\left[|\phi_{x'}|^2-\frac{1}{2}|\phi|^4\right]dx'=E_0+\frac{1}{2}M_{sol}v_e^2 \quad (18)$$

in such a case, where $M_{sol}=N_s=2\sqrt{2}A_0$ is just effective mass of the particle, which is a constant. Obviously, the energy, mass and momentum of the particle cannot be dispersed in its motion. This manifests again that the particle represented by $\phi(\vec{r},t)$ or φ(x,t) in the system has a particle feature. This means that the nonlinear interaction, $b|\phi|^2\phi$, related to the wave function of the particle balance and suppress really the dispersion effect of the kinetic term in Eq. (1) to make the particle to be eventually localized[13-14,22-26].

However, the envelope of the solution in Eq.(16),or (17) is a solitary wave. It has a certain wavevector and frequency as shown in Fig. 1(b), and can propagate in space-time, which is accompanied with the carrier wave. The feature of propagation depends only on the concrete nature of the particle. Figure 1(b) shows the width of the frequency spectrum of the envelope φ(x,t), the frequency spectrum has a localized structure around the carrier frequency ω_0. Thus, the particle has exactly a wave-corpuscle duality[13-14,22-26], which is first obtained. The Equation (16) or (17) and Figure 1a are just a most beautiful and perfect representation of wave-corpuscle duality of the particle. This consists also of de Broglie relation of wave-corpuscle duality and Davisson and Germer's experimental result of electron diffraction on double seam in 1927[6-8].

From the above investigations we see clearly that the nonlinear interactions result in the localization and wave-corpuscle duality of the microscopic particles, which are completely different from those of the quantum mechanics, thus this could solve the difficulties, problems and disputations existed in the quantum mechanics. In this theoretical framework the states and properties of microscopic particles are described by the nonlinear Schrodinger equation(7), instead of the linear Schrodinger equation (1). Therefore, when the nonlinear interactions are introduced in the quantum mechanics, not only the quantum mechanics but also the natures of microscopic particles are considerably changed.

III. The Mechanism of Generation of Nonlinear Interaction of Microscopic Particles in the Quantum Systems

At present, a key problem is how does the above interaction generate? or speaking, what is the mechanism of generation of the nonlinear interaction? Why does the quantum mechanics consider not this interaction? For replying these problems we return to look at the method solving the questions of quantum mechanics, especially in the atoms and molecules of many electrons and complicated solids, using linear Schrodinger equation (1). As known, we, in general, use an averagely external applied potential $V(\vec{r},t)$ to replace all real interactions among the particles or between the particles and background fields including the nonlinear interactions through applying average field approximation, free electron approximation, Born-

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Oppenheimer approximation, Hartree-Fock approximation and Thomas-Fermi approximation, and so on [6-8,13-16]. The essences of these approximations are to freeze or blot or simplify the real motions of background fields or lattices in solids and of nuclei in atoms and molecules. Thus the quantum mechanics simplify the motions of microscopic particles, the Schrodinger equation include not truthfully all practical interactions among the particles and between the particles and background fields or nuclei, then the nonlinear interactions of particles are also blotted and neglected. Thus the microscopic particles have only the wave feature. For example, the Coulomb potential of $V(\vec{r})$=-$e^2/\vec{r}$, which was used in the calculation of the states of the electron in hydrogen atom using Eq.(1), is just an average potential, in which the origin of coordinate is fitted at the nucleon, then the nucleon was thought to be static, thus the inherent motion of the nucleon is completely frozen and rubbed. Obviously, this is not reasonable and appropriate to practical case. In fact, the nucleon is always in harmonic vibration around its equilibrium position. The motion of the nucleon result necessarily in change of distance between the electron and nucleon, thus the Coulomb potential is correspondingly varied, i.e., the Coulomb potential relates closely to the positions of the nucleon, then the natures of the electron are also changed. We now assume that the displacement of the nucleon leaving the equilibrium position is $\vec{u}$, thus the Coulomb potential between the electron and nucleon should now be the form of $V(\vec{r},\vec{u})=-e^2/(\vec{r}+\vec{u})$, instead of $V(\vec{r})$=-$e^2/\vec{r}$. Since

$$\frac{1}{r+u}=\frac{1}{r(1+u/r)}=\frac{1}{r}(1-\frac{u}{r}+....)=\frac{1}{r}-\frac{u}{r^2}+.....=\frac{1}{r}+\frac{d}{dr}(\frac{1}{r})u+...., \quad (19)$$

then the motion equation of the electron in hydrogen atom should be of the form

$$ih\frac{\partial}{\partial t}\phi=-\frac{h^2}{2m}\nabla^2\phi-\frac{e^2}{r}\phi-\chi\phi u \quad (20)$$

We here use $\phi(\vec{r},t)$ to represent the state of the electron due to its difference from those denoted by Eq.(1). Where $\chi=-e^2\frac{d}{dr}(\frac{1}{r})=\frac{e^2}{r^2}$ denotes a coupling coefficient between the electron and nucleon, in essence, is the Coulomb force between them, m is mass of the electron. Obviously, the change of the Coulomb force result in the variations of state of both the electron and the nucleon. Thus the nucleon is now in the forced vibration, instead of harmonic vibration. On account of the change of the Coulomb force relates closely to both the distance between them and the density of the electrons, then the Coulomb force accepted by the nucleon are different, when the electron is in different positions. Thus the vibration of the nucleon are changed under a action of Coulomb force arising from the gradient fluctuation of distribution or density of the electron. In such a case it is easy to obtain that the vibration of the nucleon should satisfy the equation:

$$M(\frac{\partial^2 u}{\partial t^2}-v_0^2\frac{\partial^2 u}{\partial x_i^2})=\alpha^2 a_0^2\chi\frac{\partial^2}{\partial x_i^2}|\phi|^2, (i=1,2,3) \quad (21)$$

in continuity approximation, where M is mass of the nucleon, a_0 is the Bohr radius, α is a fraction. Equation (21) shows that the Coulomb force accepted by the nucleon is represented by $(\alpha a_0)^2\chi\frac{\partial^2}{\partial x_i^2}\left|\phi(\vec{r},t)\right|^2$ in its motion process. From (21) we can obtain

$$u=-\frac{\chi a_0^2}{M(v^2-v_0^2)}|\phi|^2 \quad (22)$$

Inserting Eq.(22) into Eq.(20) we obtain the equation of motion of the electron to be

$$i\hbar\frac{\partial}{\partial t}\phi=-\frac{\hbar^2}{2m}\nabla^2\phi-\frac{e^2}{r}\phi-b|\phi|^2\phi \quad (23)$$

This is a concrete representation of the nonlinear Schrodinger equation of Eq. (23) in the hydrogen atom, where $b=\frac{\alpha^2 a_0^2\chi^2}{M(v^2-v_0^2)}$ is the nonlinear coupling coefficient or interaction energy between the electron and nucleon in the system and is proportional to the square of Coulomb force and inversely proportional to kinetic energy of the nucleon.

From the above investigation we know that if and if only we consider seriously and completely real motions and interactions of the electron and nucleon in hydrogen atom, then the nonlinear interaction of the electron, $b|\phi|^2\phi$, will occur certainly, thus the motion of the electron satisfies the nonlinear Schrodinger equation (7) or (23), instead of linear Schrodinger equation (1). In such a case, the electron is no longer a wave, and is localized, has a wave-corpuscle duality. Obviously, the coupling interaction in the hydrogen atom is the Coulomb force between the electron and nucleon, which exists permanently, thus the nonlinear interaction, $b|\phi|^2\phi$, in Eq.(23) also exists always. Therefore, the motion of the electron in the hydrogen atom should be depicted by the nonlinear Schrodinger equation (23), instead of linear Schrodinger equation (1).

The generation of nonlinear interaction mentioned above in the hydrogen atom is referred to as the self-interaction mechanism. Naturally, it can generalize into other atoms and molecules of many electrons and some solid matter. The general form of

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this mechanism can be represented by the following equations of motion and interactions of particles. The motion of studied particle, which is denoted by $\phi(\vec{r},t)$, can be depicted by

$$ih\frac{\partial}{\partial t}\phi = -\frac{h^2}{2m}\nabla^2\phi + V(\vec{r},t)\phi - \chi\phi F \qquad (24)$$

The motion of the background field or nuclei is represented by

$$M(\frac{\partial^2 F}{\partial t^2} - v_0^2\frac{\partial^2 F}{\partial x_i^2}) = \chi\frac{\partial^2}{\partial x_i^2}|\phi|^2, (i=1,2,3) \qquad (25)$$

where F is the wave vector of the background field (phonon) or nuclei, χ is a coupling coefficient between them. The relation between the two motion modes is

$$F = \frac{\chi}{M(v^2 - v_0^2)}|\phi|^2 \qquad (26)$$

Thus the nonlinear Schrodinger equation of the studied particle can be obtained as follows

$$ih\frac{\partial}{\partial t}\phi = -\frac{h^2}{2m}\nabla^2\phi + V(\vec{r},t)\phi - b|\phi|^2\phi \qquad (27)$$

where $b = \frac{\chi^2}{M(v^2 - v_0^2)}$.

In fact, the nonlinear interaction of the particles, $b|\phi|^2\phi$, can be also generated by another mechanism in solid, condensed matter, polymer and macromolecules, in which the interaction between the particle and background field, such as, the lattice field, results in the deformation of the latter, which provides a potential well for the particle and makes it localization. Therefore, we refer to it as self-trapping mechanism. In the mechanism the microscopic particles are possibly the electron or exciton or polaron, its interactions with the background field may be the electron- phonon coupling, or dipole-dipole interaction, and so on. The dynamical equations of the electron (or, exciton or polaron) and vibration of the background field or lattice in this model can be often represented, respectively, by

$$ih\frac{\partial}{\partial t}\phi = -\frac{h^2}{2m}\nabla^2\phi + V(\vec{r},t)\phi - \chi\phi\frac{\partial F}{\partial x_i} \qquad (28)$$

and

$$M(\frac{\partial^2 F}{\partial t^2} - v_0^2\frac{\partial^2 F}{\partial x_i^2}) = \chi\frac{\partial}{\partial x_i}|\phi|^2, \qquad (29)$$

where ϕ is the wave function of state of the electron, F is the characteristic quantity of vibration of the background field (or phonon). The coupling between the two modes of motion is caused by the deformation of the background field through the electron- phonon coupling, or dipole-dipole interaction. The equation (28) describes the influences of change of the background field arising from its deformation on the states of the electrons. Equation (29) indicates the changes of vibration of the background field with velocity v_0 under the influence of the distribution or density of the electrons. Where χ is the coupling coefficient between them and represents the change of interaction energy between the electron and background field due to an unit variation of the field. From Eq.(29) we can obtain

$$\frac{\partial F}{\partial x_i} = \frac{\chi}{M(v^2 - v_0^2)}|\phi|^2 \qquad (30)$$

Inserting (30) into Eq.(28) yields the nonlinear Schrodinger equation (7), where $b = \frac{\chi^2}{M(v^2 - v_0^2)}$ is a nonlinear coupling coefficient. The equation (7) is just the nonlinear Schrodinger equation of the electron in the system in the case, where the nonlinear interaction $b|\phi|^2\phi$ is formed by the electron-phonon or dipole-dipole interactions between the motion of electron (or exciton or polaron) and vibration of background field in virtue of mechanism of self-trapping or self-condensation. Thus the electron(or exciton or polaron) is localized and has a wave-corpuscle duality. In such a case these particles satisfy no longer the quantum mechanics, but are described by the nonlinear Schrodinger equation (7).

From the above investigations from Eq.(19) to Eq.(30) we see that if and if only the real motions of these particles and the interactions between them are considered, then the nonlinear interactions exist certainly in the systems. Thus the motions of the microscopic particles should be depicted by the nonlinear Schrodinger equation (7), cannot be manifested by linear Schrodinger equation (1) or quantum mechanics. On account of any physical systems including the hydrogen atom are composed of many electrons and many bodies, in which the interactions among the particles or between the particles and background fields exist always, thus the nonlinear interactions mentioned above occur permanently. Therefore, the nonlinear Schrodinger equations are a correct and universal dynamic equation for the microscopic particles in all physical systems. This is just a new studied result. However, the microscopic particles in the atoms and molecules of many electrons and bodies and solids should be, in general, described by the following nonlinear Schrodinger equation:

$$ih\frac{\partial}{\partial t}\phi = -\frac{h^2}{2m}\nabla^2\phi + V(\vec{r},t)\phi - b|\phi|^2\phi + A(\phi(\vec{r},t)) \qquad (31)$$

where $A(\phi(\vec{r},t))$ is a function of $\phi(\vec{r},t)$ and represents differently complicated interactions related to the wave

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functions including higher order nonlinear interactions, such as $D|\phi|^4\phi$, which is caused by the interactions of many electrons or many bodies. Thus we can calculate and study correctly and really the states and properties of motion of the microscopic particles in atoms, molecules, solids, condensed matter, polymers and biomolecules, and so on, using Eq.(7) or Eq.(31).

IV. The Relation between the Action and Counteraction of the Nonlinear Interaction in Nonlinear Quantum Systems

As known, there is a law of the action and counteraction for the force in classical mechanics, this law shows that the sizes of the acted force and counteracted force are equal, but their directions are inverse with each other. Is this law for the above nonlinear interactions correct? We have the reasons to doubt the correctness for the nonlinear interactions because the nonlinear interactions occur in microscopic or quantum systems and relate to the wave function of state of the particles or bodies. This is the reason why we here investigate seriously and deeply the relation between the action and counteraction of the nonlinear interaction.

We first establish and determine this relation from Eqs.(7) and (28)-(30) in one-dimensional case. We know that at V(x,t)=0 in one-dimensional case, equation (7) becomes as Eq.(8), then the state of the particle described by Eq.(8) is represented in Eq.(16) or (17). Inserting Eq.(16) into Eq.(30) we can obtain

$$F(x,t)=\frac{A_0 h\chi}{M(v^2-v_0^2)\sqrt{bm}}\tanh\{\frac{A_0\sqrt{bm}}{h}[(x-x_0)-vt]\} \quad (32)$$

Substituting Eqs.(16) and (32) into Eq.(29) we can get

$$M(\frac{\partial^2 F}{\partial t^2}-v_0^2\frac{\partial^2 F}{\partial x^2})=-CF+D'F^3 \quad (33)$$

where $C=\frac{2A_0^2M(v^2-v_0^2)bm}{h^2}, D'=\frac{2M^3(v^2-v_0^2)^3(bm)^2}{\chi^2h^4}$

Equation (33) is just the equation of motion of the background field. Obviously, it is also a nonlinear equation of the field, its solution is represented by Eq.(32), which is also a soliton[13-14,22-23], thus the field particle is also localized. Clearly, its localization is caused by the nonlinear interaction DF^3. This is a very interesting result. Thus we can draw a quite important conclusion from the investigation of Eqs.(7)-(16) and Eqs.(28)-(33) that the nonlinear interactions accepted by the particle and the background field in the system generate simultaneously through the cross correlation in Eq.(30), and the particle and the background field also are simultaneously localized under the actions of the nonlinear interactions, when the motions of the particle and the background field and their interactions are simultaneously considered as Eqs.(28)-(29) in the self-trapping mechanism. The nonlinear interactions accepted by the particle and the background field are represented by $-b|\phi|^2\phi$ and $+D'F^3$, respectively, their symbols are inverse, but the sizes are different because they relate all to themselves wave functions of states and have same powers, respectively, as well as $b|\phi|^2\phi$ has the dimension of energy, but $D'F^3$ is the dimension of force. This is just the relation between the action and counteraction for the nonlinear interactions in the self-trapping mechanism in nonlinear quantum systems. Therefore, this rule is different from the law of the action and counteraction for the force in classical mechanics.

We now study the relation between the action and counteraction for the nonlinear interactions in the self-interaction mechanism in nonlinear quantum systems from Eqs.(7) –(16) and Eqs.(24)-(27) in one-dimensional case.

Inserting Eq.(16) into Eq.(26) we can obtain

$$F(x,t)=\frac{A_0^2\chi}{M(v^2-v_0^2)}\sec h^2\{\frac{A_0\sqrt{bm}}{h}[(x-x_0)-vt]\} \quad (34)$$

Substituting Eqs.(16) and (34) into Eq.(25) we can get

$$M(\frac{\partial^2 F}{\partial t^2}-v_0^2\frac{\partial^2 F}{\partial x^2})=C_1F-D_1F^2 \quad (35)$$

where $C_1=\frac{8A_0^2M(v^2-v_0^2)bm}{h^2}, D_1=\frac{1}{\chi h^2}M^2(v^2-v_0^2)^2(bm)$

Equation (35) is just the equation of motion of the background field in this case. Obviously, it is also a nonlinear equation of the field particle, its solution is represented by Eq.(34), which is also a soliton[13-14,22-23], thus the field particle is also localized. Clearly, its localization is also caused by the nonlinear interaction D_1F^2. Thus we can draw also a conclusion from the above investigations in Eqs.(7)-(16), Eqs.(24)-(27) and (34)-(35) that the nonlinear interactions accepted by the particle and the background field in the system generate simultaneously through the cross correlation in Eq.(26), and the particle and the background field particle also are simultaneously localized under the actions of the nonlinear interactions, when the motions of the particle and the background field particle and their interactions are simultaneously considered as Eq.(24)-(25) in the self-interaction mechanism. The nonlinear interactions accepted by the particle and the background field are represented by $-b|\phi|^2\phi$ and $-D_1F^2$, respectively, the former is the dimension of energy, the latter is the

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dimension of force. As distinct from the above results in the self-trapping mechanism, the symbol of the nonlinear interactions accepted by the particle is same with those of the background field, but their powers are also different, the former is three powers, the latter is two powers, therefore, their sizes are also different, and the localization of the background field particle, which is denoted by Eq.(34), is enhanced in the self-interaction mechanism.

From this investigation of the relation of the action and counteraction of the nonlinear interaction we know that the interactional particles or bodies or matters (background fields) have and can accept simultaneously the nonlinear interactions in the nonlinear quantum systems, but their nonlinear interactions accepted do not completely satisfy the law of action and counteraction of the forces in the classical mechanics, although the microscopic particles in the nonlinear quantum systems have also corpuscle feature. This shows clearly that the natures of the particles in the nonlinear quantum systems are different from those of classical particles. This conclusion is of important interest to physics and nonlinear science.

V. Conclusion

We here first studied and revealed the difficulties, limitations and approximations of the quantum mechanics and the roots and reasons of these difficulties. The reasons of these difficulties and problems are that the quantum mechanics simplifies and blots out the real motions of the microscopic particles and background field particle and interactions between them including the nonlinear interactions, and use an average fields to replace a much variety of real interactions by using various different approximate ways,. thus the particles have only a wave feature, not corpuscle feature. In view of these problems and difficulties we add the nonlinear interaction, $b|\phi|^2\phi$ into the dynamic equation of the microscopic particles, and use a nonlinear Schrodinger equation to depict their states of motion. Thus the wave or dispersive effect of the microscopic particles is suppressed by the nonlinear interactions, its localization and wave- corpuscle duality are displayed and exhibited naturally. Subsequently, we seek and investigate the mechanism of generation of the nonlinear interactions of the particles, and find that the nonlinear interactions of the particles exist always, when the real motions of the particles and background fields and the interactions between them are considered simultaneously. On the basis of analyses of dynamics of the electrons and nucleon or lattice (background) fields in atoms or lattices we give two mechanisms of self-interaction and self-trapping for the generation of nonlinear interactions and corresponding representations. of their dynamic equations. Finally we discuss the properties of the nonlinear interactions in the two mechanisms and obtain the relations between the action and counteraction of the two nonlinear interactions of the particles and background fields. We find that although the nonlinear interaction accepted by the particles and background field particle can generated simultaneously in the nonlinear quantum systems, the two nonlinear interactions do not completely satisfy the law of action and counteraction of the forces in the classical mechanics. This shows clearly that the natures of the microscopic particles in the nonlinear quantum systems are different from those of classical particles, even though the microscopic particles have also the corpuscle feature in nonlinear quantum systems. This shows clearly that the natures of the particles in the nonlinear quantum systems are different from those of classical particles. This conclusion is of important interest to physics and nonlinear science.

In the meanwhile, we obtained a correct and universal nonlinear Schrodinger equation in Eq.(31), which considers various interactions involving the different nonlinear interactions in the atoms and molecules of many electrons, solid, condensed matter, polymers, biomolecules. Thus we can calculate truthfully the natures and properties of the microscopic particles in these complicated systems by the nonlinear Schrodinger equation, but original quantum mechanics is difficult or impossible to describe these systems.

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Solitary Wave Solutions for the Generalized Zakharov-Kuznetsov- Benjamin-Bona-Mahony Nonlinear Evolution Equation

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Abstract- In this paper, we employ the exp $(-\varphi(\xi))$-expansion method to find the exact traveling wave solutions involving parameters of nonlinear evolution equations. When these parameters are taken to be special values, the solitary wave solutions are derived from the exact traveling wave solutions. It is shown that the proposed method provides a more powerful mathematical tool for constructing exact traveling wave solutions for many other nonlinear evolution equations.

Keywords: the exp (-φ (ξ))-expansion method, the generalized zakharov-kuznetsov- benjamin-bona-mahony nonlinear evolution equation, traveling wave solutions, solitary wave solutions.

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Keywords: *the exp (-φ(ξ)) -expansion method, the generalized zakharov-kuznetsov- benjamin-bona-mahony nonlinear evolution equation, traveling wave solutions, solitary wave solutions.*

I. Introduction

In recent years, due to the wide applications of soliton theory in mathematics, physics, chemistry, biology, communications, astrophysics and geophysics, etc., the search for explicit exact solutions, in particular, solitary wave solutions of nonlinear evolution equations (NEEs) has played an important role in the soliton theory. Various effective methods have been developed,. Such methods are tanh - sech method [1]-[3], extended tanh - method [4]-[6], sine - cosine method [7]-[9], homogeneous balance method [10, 11], F-expansion method [12]-[14], exp-function method [15, 16], trigonometric function series method [17], $(\frac{G'}{G})$-expansion method [18]-[21], Jacobi elliptic function method [22]-[25], the exp (-φ (ξ))-expansion method [26]-[28] and so on. The objective of this article is to apply the exp (-φ (ξ))-expansion method for finding the exact traveling wave solution of the generalized Zakharov-kuznetsov- Benjamin-Bona-Mahony nonlinear evolution equation system which play an important role in mathematical physics.

The rest of this paper is organized as follows: In Section 2, we give the description of the exp (-φ (ξ)) expansion method. In Section 3, we use this method to find the exact solutions of the nonlinear evolution equations pointed out above. In Section 5, we give the physical interpretations of the solutions. In Section 5, conclusions are given.

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II. Description of Method

Let us we have the following nonlinear evolution equation

$$P(u, u_t, u_x, u_{tt}, u_{xx}, \dots\dots) = 0, \quad (2.1)$$

since, P is a polynomial in $u(x,t)$ and its partial derivatives. In the following, we give the main steps of this method.

Step 1. We use the traveling wave solution in the form

$$u(x,t) = u(\xi), \qquad \xi = x - ct, \quad (2.2)$$

where c is a positive constant, to reduce Eq. (2.1) to the following ODE:

$$p(u, u', u'', u''', \dots\dots) = 0, \quad (2.3)$$

where P is a polynomial in u (ξ) and its total derivatives.

Step 2. Suppose that the solution of ODE (2.3) can be expressed by a polynomial in $exp(-\varphi(\xi))$ as follow

$$u(\xi) = a_m(\exp(-\varphi(\xi))^m + \cdots, a_m \neq 0, \quad (2.4)$$

where $\varphi(\xi)$ satisfies the ODE in the form

$$\varphi'(\xi) = \exp\big(-\varphi(\xi)\big) + \mu \exp\big(\varphi(\xi)\big) + \lambda. \quad (2.5)$$

The solutions of ODE (2.5) are:

When $\lambda^2 - 4\mu > 0, \mu \neq 0,$

$$\varphi(\xi) = ln\left(\frac{-\sqrt{\lambda^2-4\mu}\, tanh(\frac{\sqrt{\lambda^2-4\mu}}{2}(\xi+c_1))-\lambda}{2\mu}\right), \quad (2.6)$$

and

$$\varphi(\xi) = ln\left(\frac{-\sqrt{\lambda^2-4\mu}\, coth(\frac{\sqrt{\lambda^2-4\mu}}{2}(\xi+c_1))-\lambda}{2\mu}\right). \quad (2.7)$$

When $\lambda^2 - 4\mu > 0, \mu = 0,$

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$$\varphi(\xi) = -ln\left(\frac{\lambda}{exp(\lambda(\xi+C_1))-1}\right). \quad (2.8)$$

When $\lambda^2 - 4\mu = 0, \mu \neq 0, \lambda \neq 0,$

$$\varphi(\xi) = ln\left(-\frac{2(\lambda(\xi+C_1)+2}{\lambda^2(\xi+C_1)}\right). \quad (2.9)$$

When $\lambda^2 - 4\mu = 0, \mu \neq 0, \lambda = 0,$

$$\varphi(\xi) = \ln(\xi + C_1). \quad (2.10)$$

When $\lambda^2 - 4\mu < 0$

$$\varphi(\xi) = ln\left(\frac{\sqrt{4\mu-\lambda^2}tan\left(\frac{\sqrt{4\mu-\lambda^2}}{2}(\xi+c_1)\right)-\lambda}{2\mu}\right), \quad (2.11)$$

and

$$\varphi(\xi) = ln\left(\frac{\sqrt{4\mu-\lambda^2}cot\left(\frac{\sqrt{4\mu-\lambda^2}}{2}(\xi+c_1)\right)-\lambda}{2\mu}\right). \quad (2.12)$$

Where $a_m, \ldots, \lambda, \mu$ are constants to be determined later.

Step 3 Substitute Eq. (2.4) along Eq. (2.5) into Eq. (2.3) and collecting all the terms of the same power $exp(-m\varphi(\xi))$ (m = 0,1,2,3 ...) and equating them to zero, we obtain a system of algebraic equations, which can be solved by Maple or Mathematica to get the values of it.

Step 4. Substituting these values and the solutions of Eq. (2.5) into Eq. (2.3) we obtain the exact solutions of Eq. (2.1).

It is to be noted here that the construction of the $exp(-\varphi(\xi))$–expansion method is similar to the construction of the $\left(\frac{G'}{G}\right)$ - expansion. For better understanding of the duality of both methods we cite [29]-[31].

III. Application

Here, we will apply the exp (-φ (ξ))-expansion method described in Sec.2 to find the exact traveling wave solutions and the solitary wave solutions of the generalized Zakharov-kuznetsov- Benjamin-Bona-Mahony nonlinear evolution equation [32, 33]. We consider the generalized Zakharov-kuznetsov-Benjamin-Bona-Mahony nonlinear evolution equation.

$$u_t + u_x + \alpha(u^n)_x + \beta\left(u_{xt} + u_{yy}\right)_x = 0, \quad n > 1. \quad (3.1)$$

Where (α, β) are real constants. By using the wave transformation $u(\xi)=u(x,y,t)$, since $\xi=x+y-ct$, we get:

$$-cu' + u' + \alpha(u^n)' + \beta(-cu'' + u'')' = 0. \quad (3.2)$$

By integration Eq. (3.2) and neglect the constant of integration we obtain:

$$(1-c)u' + \alpha(u^n) + \beta(1-c)u'' = 0. \quad (3.2)$$

Balancing between the highest order derivatives and nonlinear terms appearing in Eq. (3.3) $\left(u^n and\, u'' \Rightarrow m=\frac{2}{n-1}\right)$. So that we use transformation $\left[u = v^{\frac{2}{n-1}}\right]$ and substituting this transformation into Eq. (3.3) we get:

$$(1-c)(n-1)^2v^2 + \alpha(n-1)^2v^4 + \beta(1-c)(6-2n)v'^2 + 3\beta(1-c)(n-1)vv'' = 0. \quad (3.2)$$

Balancing between the highest order derivatives and nonlinear terms appearing in Eq. (3.4) $(v^4 and\, vv'' \Rightarrow m = 1)$. So that, by using Eq. (2.4) we get the formal solution of Eq. (3.5)

$$v(\xi) = a_0 + a_1 \exp\left(-\phi(\xi)\right). \quad (3.5)$$

Substituting Eq. (3.5) and its derivative into Eq. (3.4) and collecting all term with the same power of $\exp\left(-4\phi(\xi)\right), \exp\left(-3\phi(\xi)\right), \exp\left(-2\phi(\xi)\right), \exp\left(-\phi(\xi)\right), \exp\left(0\phi(\xi)\right)$ we get:

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$$\begin{cases} \alpha(n-1)^2(a_1^4)+\beta(1-c)(6-2n)(a_1^2)+3\beta(1-c)(n-1)(2a_1^2)=0, \\ \alpha(n-1)^2(4a_0a_1^3)+\beta(1-c)(6-2n)(2a_1^2\lambda) \\ +3\beta(1-c)(n-1)(2a_0a_1+3a_1^2\lambda)=0, \\ (1-c)(n-1)^2(a_1^2)+\alpha(n-1)^2(6a_0^2a_1^2)+\beta(1-c)(6-2n)\begin{pmatrix}2a_1^2\mu \\ +a_1^2\lambda^2\end{pmatrix} \\ +3\beta(1-c)(n-1)(3a_0a_1\lambda+2a_1^2\mu+a_1^2\lambda^2)=0, \\ (1-c)(n-1)^2(2a_0a_1)+\alpha(n-1)^2(4a_0^3a_1)+\beta(1-c)(6-2n)(2a_1^2\mu\lambda) \\ +3\beta(1-c)(n-1)(2a_0a_1\mu+a_0a_1\lambda^2+a_1^2\mu\lambda)=0, \\ (1-c)(n-1)^2(a_0^2)+\alpha(n-1)^2(a_0^4)+\beta(1-c)(6-2n)(a_1^2\mu) \\ +3\beta(1-c)(n-1)(a_0a_1\lambda\mu)=0. \end{cases} \tag{3.6}$$

Solving above system by using maple 16, we get:

$$n=3,\alpha=\frac{-4(c-1)}{a_1^2(-\lambda^2+4\mu)},\beta=\frac{-4}{3(-\lambda^2+4\mu)},a_0=\frac{a_1\lambda}{2},a_1=a_1.$$

Thus the solution is

$$v(\xi)=\frac{a_1\lambda}{2}+a_1\exp\big(-\phi(\xi)\big). \tag{3.7}$$

Now, we discuss the following cases:

When $\lambda^2-4\mu>0,\mu\neq 0,$

$$v(\xi)=\frac{a_1\lambda}{2}+a_1\left(\frac{2\mu}{-\sqrt{\lambda^2-4\mu}\,tanh(\frac{\sqrt{\lambda^2-4\mu}}{2}(\xi+c_1))-\lambda}\right), \tag{3.8}$$

and

$$v(\xi)=\frac{a_1\lambda}{2}+a_1\left(\frac{2\mu}{-\sqrt{\lambda^2-4\mu}\,coth(\frac{\sqrt{\lambda^2-4\mu}}{2}(\xi+c_1))-\lambda}\right) \tag{3.9}$$

When $\lambda^2-4\mu>0,\mu=0,$

$$v(\xi)=\frac{a_1\lambda}{2}+a_1\left(\frac{\lambda}{exp\big(\lambda(\xi+C_1)\big)-1}\right). \tag{3.10}$$

When $\lambda^2-4\mu=0,\mu\neq 0,\lambda\neq 0,$

$$v(\xi)=\frac{a_1\lambda}{2}-a_1\left(\frac{\lambda^2(\xi+C_1)}{2(\lambda(\xi+C_1)+2}\right). \tag{3.11}$$

When $\lambda^2-4\mu=0,\mu\neq 0,\lambda=0,$

$$v(\xi)=\frac{a_1\lambda}{2}+a_1\left(\frac{1}{(\xi+C_1)}\right). \tag{3.12}$$

When $\lambda^2-4\mu<0$

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$$v(\xi) = \frac{a_1\lambda}{2} + a_1\left(\frac{2\mu}{\sqrt{4\mu-\lambda^2}\tan\left(\frac{\sqrt{4\mu-\lambda^2}}{2}(\xi+c_1)\right)-\lambda}\right), \tag{3.13}$$

and

$$v(\xi) = \frac{a_1\lambda}{2} + a_1\left(\frac{2\mu}{\sqrt{4\mu-\lambda^2}\cot\left(\frac{\sqrt{4\mu-\lambda^2}}{2}(\xi+c_1)\right)-\lambda}\right). \tag{3.13}$$

- *Note That:*

All the obtained results have been checked with Maple 16 by putting them back into the original equation and found correct.

IV. Conclusion

The exp (-φ (ξ))-expansion method has been applied in this paper to find the exact traveling wave solutions and then the solitary wave solutions of the generalized Zakharov-kuznetsov- Benjamin-Bona-Mahony nonlinear evolution equation. Let us compare between our results obtained in the present article with the well-known results obtained by other authors using different methods as follows: Our results of Nonlinear dynamics of the generalized Hirota-Satsuma couple KdV system are new and different from those obtained in [32,33], and figures show the solitary traveling wave solution of the generalized Zakharov-kuznetsov-Benjamin-Bona-Mahony nonlinear evolution equation. We can conclude that the exp (-φ (ξ))-expansion method is a very powerful and efficient technique in finding exact solutions for wide classes of nonlinear problems and can be applied to many other nonlinear evolution equations in mathematical physics. Another possible merit is that the reliability of the method and the reduction in the size of computational domain give this method a wider applicability.

V. Acknowledgment

(Corresponding author: Mostafa M. A. Khater) I would like to dedicate this article to my mother and the soul of my father, he was there for the beginning of this degree, and did not make it to the end. His love, support, and constant care will never be forgotten. He is very much missed.

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3. Submission of Manuscripts,

4. Manuscript's Category,

5. Structure and Format of Manuscript,

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- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

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Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

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	A-B	**C-D**	**E-F**
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Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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