КНИЖНОЕ ОБОЗРЕНИЕ

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REVIEW BOOK GALIEV Sh.U. «EXTREME MULTIVALUED WAVES IN SCALAR FIELDS» PLANNED BY SPRINGER FOR PUBLICATION IN EARLY 2024

Book's contents

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Book abstract. The purpose of the book is a mathematical and experimental study of the circumstances that determine the occurrence of extreme multivalued waves, their evolution and description. The interdisciplinary nature of extreme waves is emphasized. It is known that Einstein tried to build a unified (interdisciplinary) field theory that would unite all interactions in Nature into a single system. The book uses this idea. The known equations of the scalar field are considered as the basis for the unification and description of extreme waves in the environment. This approach will allow us to raise fundamental questions about the many-valued, corpuscular-wave, nonlinear nature of the world around us. The idea that everything in the world obeys non-linear laws is illustrated. Various strongly non-linear wave processes are modeled, ranging from modeling the Euler figures and ocean waves to describing the birth of particle-waves and the Universe.

It is shown that extreme waves model many patterns observed in liquid layers, optical systems, Bose-Einstein condensates, micro- and electronic resonators. Thus, the extreme waves discussed in this book can be applied to a variety of technologies and systems, from the atomic scale to space.

Brief description and purpose.

The theory of extreme multivalued waves is developed. The origin of them is connected with resonant phenomena in the environment and with singular terms in the governing equations.

The puzzle of extreme waves attracted the attention of scientists at the beginning of this century [1]. The most important feature of such waves is characterized as follows – The waves that appear from nowhere and disappear without a trace [2]. Thus, according to [2] the properties of these mysterious waves resemble the properties virtual particles. Books were written, to one degree or another, devoted to them [3, 4]. To describe them mathematical, equations and solutions were used which described huge waves with continuous and smooth profiles. At the same time, there is experimental and numerical data which shows that sometimes the profiles of these waves can lose continuity, collapse, and the waves themselves are transformed into some clots of matter. Thus, strongly nonlinear, multivalued processes are observed. During these processes, extreme, multivalued waves arise. They may be described by scalar fields and corresponding nonlinear equations.

It is known that the analytical solution of nonlinear equations is associated in the general case with almost insurmountable difficulties, which are often associated with the interaction of linear and nonlinear effects. Another difficulty is related to the presence of areas where the solution gives infinity for certain parameters of the problem.These are the so-called singular or resonant regions. However, namely is in these singular regions that the influence of nonlinearities increases so strongly that the influence of the most important linear terms can be neglected (the influence of the d'Alembert operator practically disappears). It greatly simplifies the mathematical solution of the equations.

It is also shown that many fundamental wave nonlinear equations, under certain assumptions, can be reduced to the same form. It has wave solutions corresponding to the Leonhard Euler figures at singular points and in their vicinity (Fig. 1).

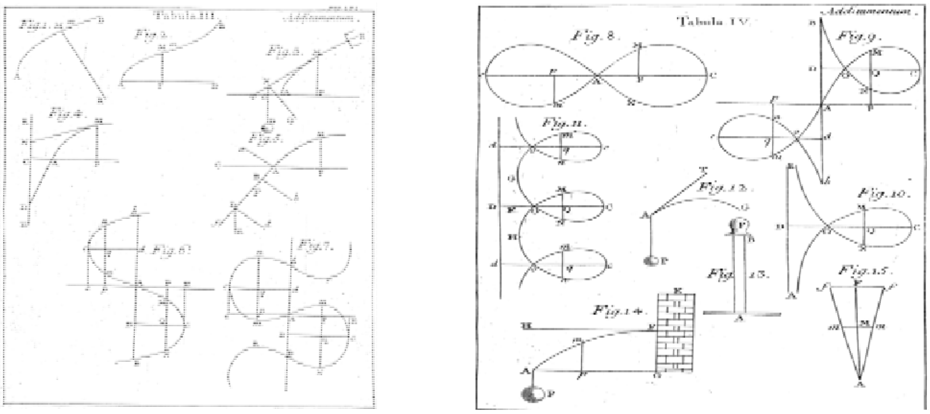


Fig. 1. Some Euler figures [5]

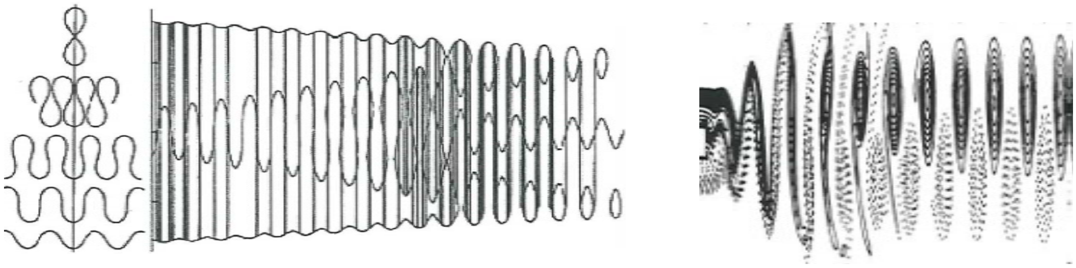


Fig. 2. Elastica figures of Euler (left), and examples of the evolutions of harmonic waves into elastica-like waves, particle – waves and von Karman chain (centre and right (experiment data))

Pierre Laplace connected Euler's results with extreme wave processes [6]. However, this relationship was not further explored until the early 21st century. In particular, the similarity was not emphasized between the mathematical description of the Euler figures and extreme waves. Extreme waves can change in time and space so that they break up into waves, vortices and particles, or into a chain of isolated particle-waves (Figs. 2 and 3).

In particular, the idea is consistently carried out in the book that the nonlinear theory opens up the possibility of describing elementary particles not as harmonic functions but as extreme particle-waves. The motion and oscillations of these waves can be very complex. Waves can vary their velocity, stop, and change the direction of their motion. These effects are strictly localized in resonant bands and depend on the wave system detuning from resonance

It is known that there are two points of view on the understanding of Nature. The first point of view is that Nature is fundamentally unpredictable (incomprehensible). The second point of view is that Nature is initially predictable (understandable). For example, Richard Feynman stated that "Nature is absurd".

The author of the books disagrees with Feynman's statement. He thinks that if, when describing the most fundamental properties of Nature, we take into account highly nonlinear effects, then in this case we will be able to understand Nature more correctly. Of course, the problem of understanding is most relevant for the foundations of quantum mechanics and models of the origin of the Universe.

In particular, Galiev describes the origin and propagation of particle -waves that explain the results of double-slit and Casimir-type experiments, which are fundamental to quantum physics.

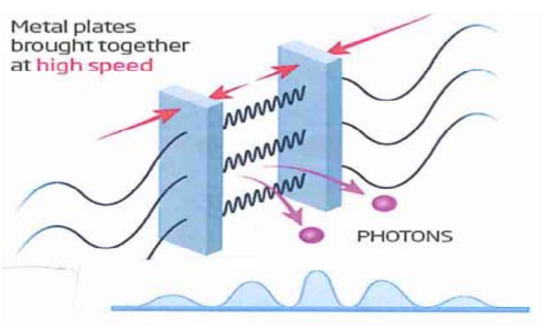


Fig. 3. Casimir-type experiment as an explanation for double-slit experiments

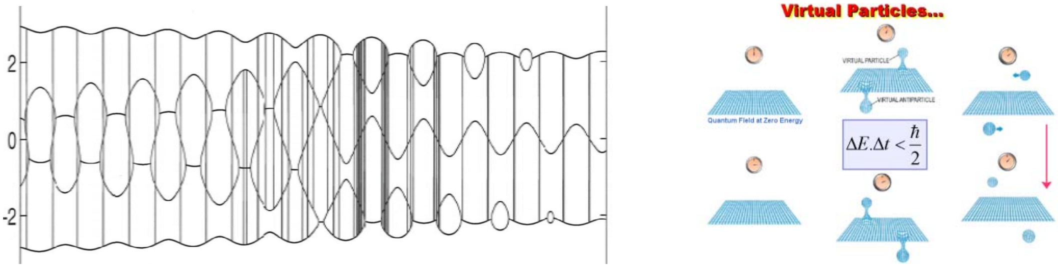


Fig. 4. The initial harmonic wave can evolve into shock waves, Euler figures 7 and particle-waves (left). The Euler figure 7 can be amplified into the particle-wave (right)

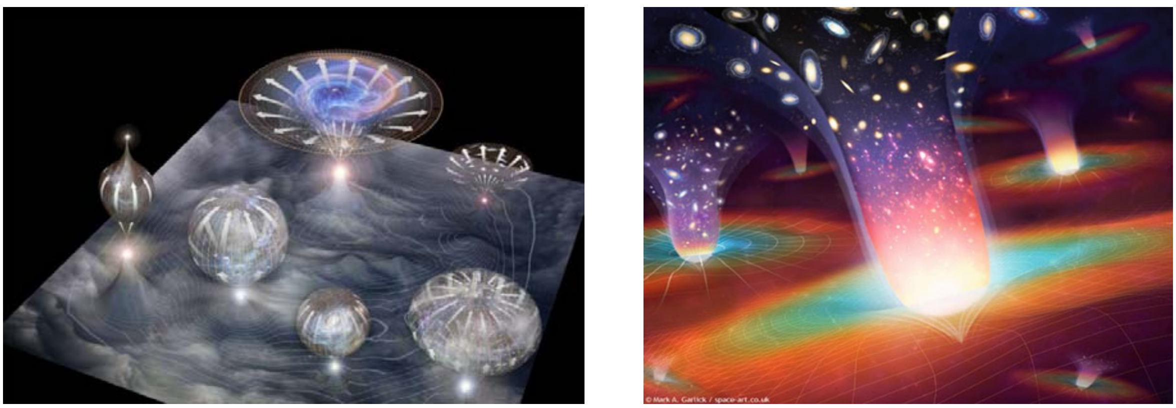


Fig. 5. Imaginary pictures of the origin of universes in the representation of artist. Two scenarios of the eruption of the universes from the potential wells of a pre-universe

Harmonic moving boundaries could induce particle creation from a vacuum. Scenarios corresponding to the particle-wave birth are shown in Fig. 3. It is shown that cases are possible when even a weak quantum fluctuation can, due to a certain resonant condition, increase the field magnitude by many order locally (Fig. 4).

Galiev connects the appearance of real and virtual quantum particles, as well as our Universe, with certain resonant wave phenomena. Inside an extreme multivalued wave, the initial substance evolves into different types of extreme elementary particles and waves, which could have different shapes and energies, and, also, could transform into into high-temperature plasma.

Extreme multivalued waves simulate qualitatively many patterns observed in liquid layers, optical systems, Bose–Einstein condensates, and micro- and electron resonators. In addition, highly nonlinear resonant effects can explain the amplification and the transformation of waves in large systems (for example, technical systems, ocean, the earth, etc.) and very large systems (e.g., the early Universe). Thus, the extreme waves considered in this book may be applied to different technologies and systems ranging from the atomic scale to the cosmos [7–13].

I emphasize that the main ideas of the book and even many of the results were published more than 20 years ago [11]. All of Galiev's books [7–10] are devoted to their development. Apparently the most interesting thing about them is that he described and introduced the concept of extremal multi-valued waves and connected their theory with some results of the brilliant Russian scientist Leonhard Euler. At the same time, despite the interest aroused in the scientific world, these results did not have an explicit experimental confirmation. Only literally last year these experimental results were published [14, 15].

Summary of chapters.

CHAPTER I. Reduction of one-dimensional wave equations of physics and mechanics to a unified (basic, fundamental) form for extreme waves.

The modern wave theory is a well developed area of science. The first wave equation was obtained by d'Alembert and bears his name. It describes linear waves, that is, waves whose forms does not change during propagation. These waves have a small amplitude and are usually well described by harmonic functions. Since the middle of the 20th century, many researchers began to study more complex formations – nonlinear waves. The latter can change their forms during propagation. The most famous of them are acoustic shock waves and solitons. The latter can spread without changing their forms. Nonlinear waves are described by special equations, which are generalizations of the d'Alembert equation.

Extreme waves were discovered at the beginning of this century. They are distinguished by the fact that they have huge amplitudes and can have a complex, including ambiguous, form. The chapter discusses the basic nonlinear wave equations of physics and mechanics, which can describe the extreme waves. It is shown that these equations can be obtained under some additional assumptions from the nonlinear Klein-Gordon equation (NKGE). The last is basic equation of scalar fields. In particular, the nonlinear Schrödinger equation, equations for an absolutely flexible string and bubble continuum are derived from NKGE. In the case of waves propagating in one direction, the main nonlinear wave equations can be written in a unified form.

CHAPTER II. Euler figures, unidirectional extreme waves and vortices

Exact and approximate solutions of NKGE and other nonlinear wave equations are constructed. The main attention is paid to the construction of solutions for the parameters of equations laying in resonant and singular regions. There the solutions describe the Euler figures, which correspond to multivalued extreme waves.

Fig. 6 illustrates further the calculations presented in Figs. 2 and 4. The appearance of waves similar to Euler figures on the surface of a liquid is shown. Liquid particles detach from the surface. The results presented in Figs. 2, 4 and 6 show that the Euler figures (see Fig. 1) can evolve into particle-waves. According to calculations, there are two scenarios of evolution of harmonic waves into particle-waves (loops, closed isolated structures, ellipses or vortices). The scenarios are shown in Figs. 2, 4, 6 (left). It can be seen that during the wave evolution various Euler figures appear. One of them (Fig. 6, right) describes a capillary wave on the liquid surface. This was first shown by Laplace in the 1807 publication. Thus, Laplace first interpreted the Euler figure as a wave. It was easy to imagine after Laplace that another figures of Euler can also describe some counterintuitive wave structures. Indeed, this interpretation was found at the beginning of the 21st century.

The consideration of capillary waves by Laplace suggests that the surface tension may be so significant that the surface can be considered as a string (or a membrane) with strongly nonlinear properties.

Thus, in the course of the wave evolution the Euler figures, in other words the elastic strings, can acquire various forms far from those described by harmonic functions. The chapter emphasizes that this fact may be of interest for string theory, which is currently rapidly developing and claims to describe all fundamental processes in Nature.

The chapter contains a lot of calculation results and comparisons with experimental data. It is shown that there is a significant variety of Extreme Multivalued Waves (EMW). No wonder. Various forms of overturning waves, unstable waves, and internal waves are well known [16–23].

Many authors use the term mushroom –like waves to emphasize that they can be stable. Galiev previously used the term elastic – like waves.

In this chapter, he distinguishes 4 EMW configurations.

CLASSIFICATION Extreme Multivalued Waves (EMW).

1. Elastica -like EMW. Some wave profiles repeat the Euler figures. They can be called elastic – like EMW elastics (see Fig. 7, where experimental data are also included).

Fig. 8 shows one of the possible processes of evolution of the EMW elastica into vortices.

2. In the process of evolution, the wave profile goes beyond the Euler theory and transforms into particles – waves (Fig. 9).

3. The above cases, generally speaking, can arise in the absence or very weak influence of gravity. However, this condition is usually not met in experiments, and in reality, solutions that ensure the ambiguity of the wave profile are not implemented. An example of such waves is given in Fig. 10 (top). He describes a wave whose rise is like a step. There are also experimentally recorded waves arising on the surface of ordinary and magnetic fluids (bottom).

4. Waves with hair. The most complex version of the wave profile occurs when it begins to transform (enclose) with vortices. This case is shown in Fig. 11.

Of course, this case of the proposed classification is the most difficult, since it directly passes into the non-stationary part of the development of the wave profile associated with the appearance of vortices on it. This evolution is already entering the region of turbulence, and is beyond the scope of this book. At the same time, this question is so interesting and so close to the problem of many-valued wave profiles that the author repeatedly returns to it in the book.

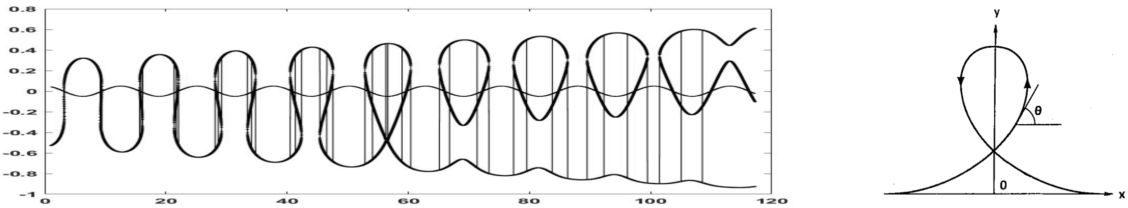


Fig. 6. The second scenario of the evolution of a harmonic wave into particle-waves (left). Elastica form (see figure 10 in Fig.1) describing surface capillary wave (right)

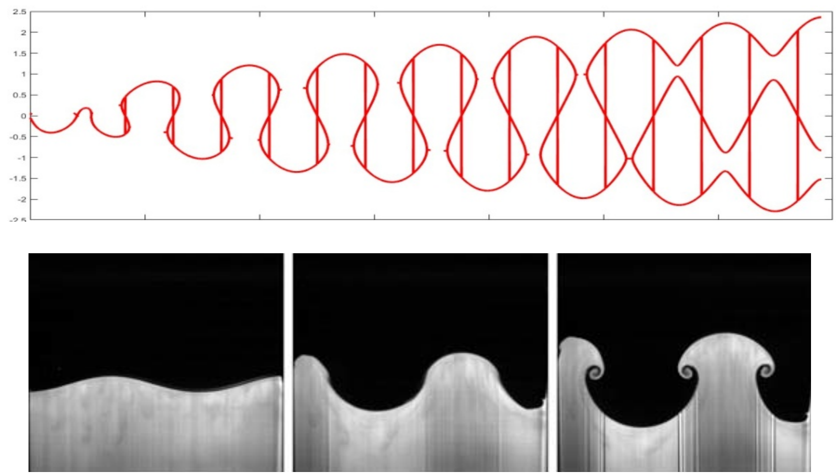


Fig. 7. Solution of the algebraic equation (top). A sequence of images of waves generated due to the Richtmyer–Meshkov instability of incompressible liquids (bottom) [17]

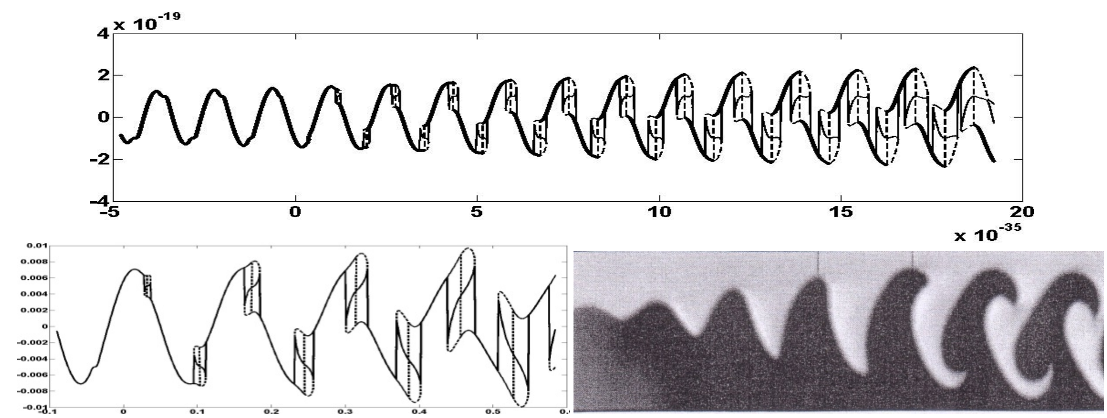


Fig. 8. A process of the evolution of waves into vortices: calculations, observations (bottom, right) [18]

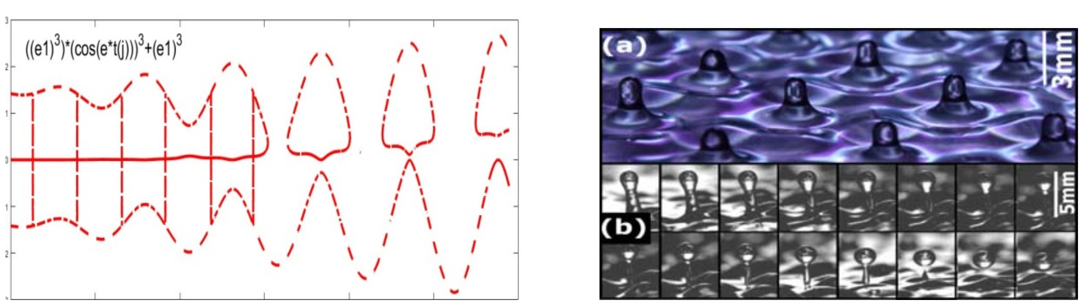


Fig. 9. Solution of the algebraic equation (left): (*a*) A side view of the extended Faraday waves; (*b*) Time sequence of a droplet ejection event. Successive images are separated by 1/800 s [19]

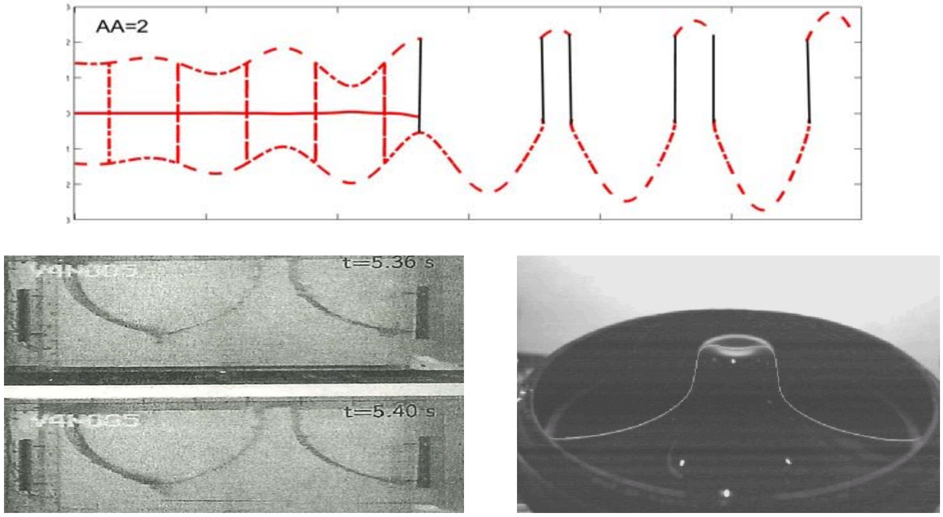


Fig. 10. Results of calculations (top) and experiments (bottom [20, 21]

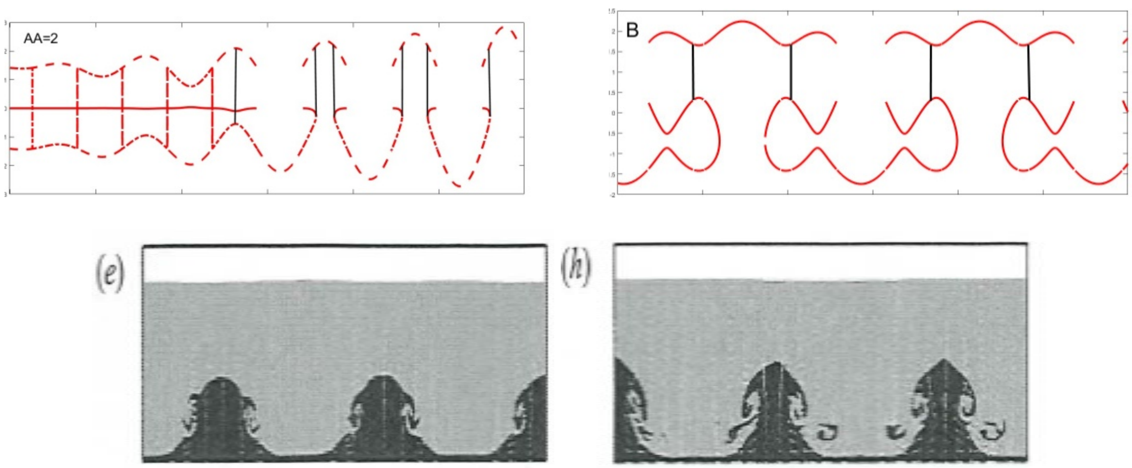


Fig. 11. Results of calculations (top) and experiments (bottom [15]

CHAPTER III. Forced and parametrically excited Extreme Multivalued Waves (EMW).

Of the variety of waves indicated in the heading of the chapter, the author focuses on the cases of longitudinal waves and Faraday waves.

A lot of attention is paid to the comparison of theory and experiments. It seems to me that in all cases the author is trying to show that in the cases of resonances in various systems, Extreme Multivalued Waves (EMW) arise, the profile of which resembles the Euler figures. As an example of such waves, we present Fig. 12, which shows longitudinal waves excited in a scalar field.

In particular, such waves are excited in gas and liquids, in cases where the influence of the earth's gravity does not manifest itself or is minimized. By virtue of what has been said, in terrestrial conditions Extreme Multivalued Waves manifest themselves as capillary waves or internal waves.

In cases of studying parametrically excited EMWs, liquid layers are considered and two cases are distinguished.

In the first case, the driving amplitude is much less than the thickness of the liquid layer. The solution is sought in the form of a sum of a standing wave and traveling waves. Moreover, the speed of traveling waves depends on the forcing vertical acceleration. Therefore, the speed may change. The wave can stop, change direction and oscillate depending on the applied vertical acceleration [7–11].

Examples of such wave systems are given in fig. 13. The results of both calculations and experiments are given there. The two upper calculations describe qualitatively the dynamics of the interaction between standing and traveling waves.

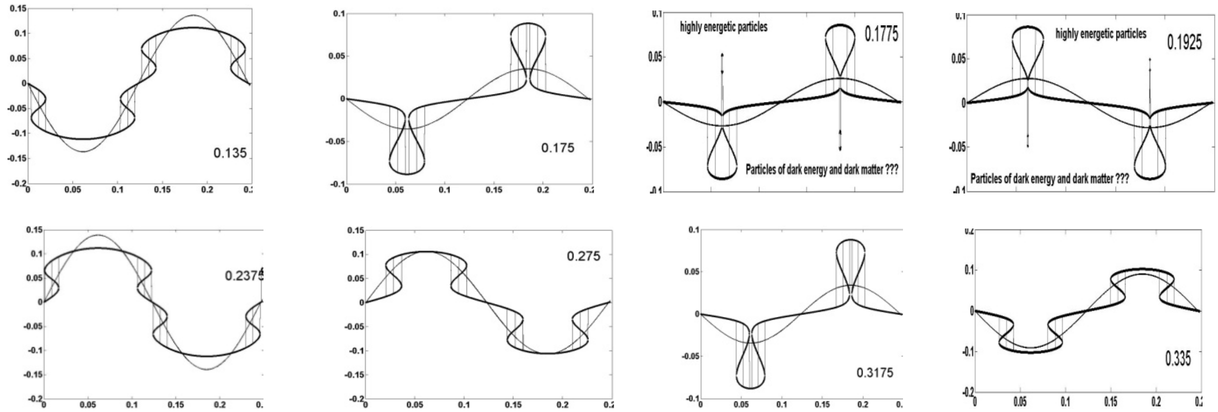


Fig. 12. Resonant EMW

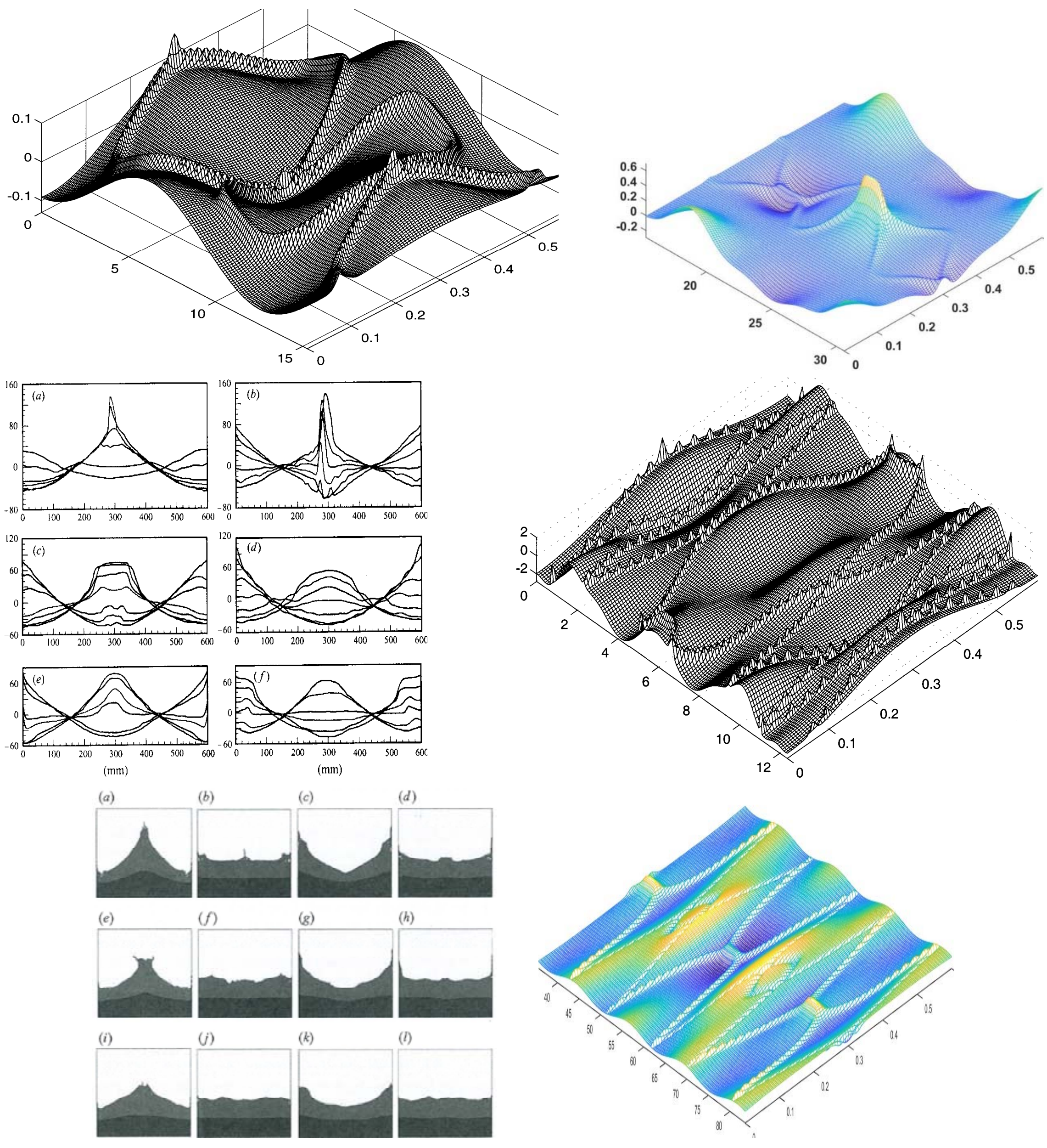


Fig. 13. Comparison of the results of experiments and calculations [15, 22]

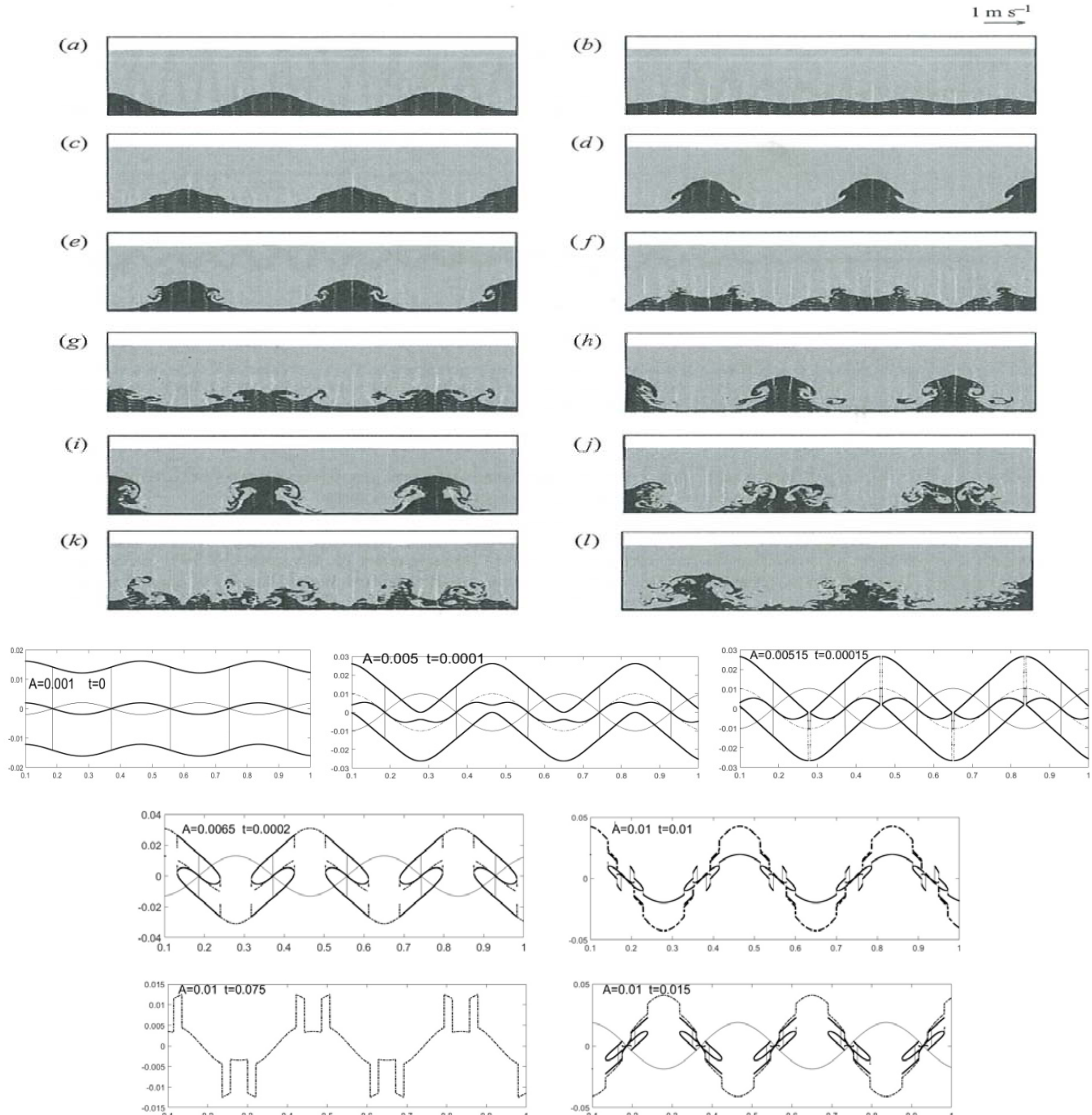


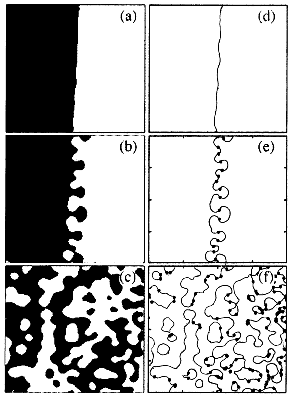
Fig. 14. Results of experiments (top) and calculations [15]

The second row shows the experimentally measured wave profiles (on the left) together with the corresponding wave pattern obtained in the calculation (on the right). The bottom row presents the results of experiments and calculations of resonant wave fields in a similar way.

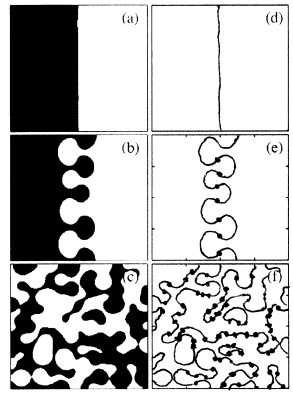
According to Fig. 13 the maximum amplitudes arise when the opposite traveling waves meet each other at the standing wave peak. The waves form the plane crests in cases when these meetings take place on a slope of the standing wave at the moment of its growth. At last, if this meeting takes place on a slope of the main wave at the moment of its recession, the waves form the dome-like crest.

In the second case, the amplitude of the vertical excitation is comparable to the thickness of the liquid layer. Therefore, the layer thickness changes periodically and this is taken into account in the corresponding wave equations [10].

On Fig. 14 a comparison of the results of remarkable experiments [5] and the results of the author's theory is given.



a



b

Fig. 15. Evolution of initial perturbations of some interface into Euler figures, vortices and turbulence. Occurrence of vortices shown by spots during the Belousov-Zhabotinsky reaction (*a*). The emergence of Euler figures, vortices and turbulence according to the numerical solution of the scalar wave equation (*b*) [23]

CHAPTER IV. Nonlinear, discontinuous and quantum eigenfunctions describing extreme waves.

Simulation of own nonlinear waves in vacuum.

Many natural vibrations of physical systems are well approximated by harmonic ones. However, in Nature systems are whose own nonlinear oscillations are not described by harmonic functions. Of course, for the occurrence of such fluctuations, special conditions are needed. The effect of nonlinearity is especially pronounced in the region of short waves. Their peculiarity is that they carry a very large energy. At high energies, these waves are extreme and, in particular, can break up into chains of individual particles–waves.

As an example is given Fig. 15. There the extreme waves (the Euler figure 7 (Fig. 1)) with vortices on the profiles appears at the interface between two media during the development of the initial perturbation.

It is shown that nonlinear eigenoscillations take place under certain conditions in different finite physical systems. To illustrate nonlinear eigenoscillations and the conditions for their occurrence, the author uses the most simple and understandable models and equations.

Oscillations (rotation) of an electron in an atom are considered as one of the examples of such an approach. In the simplest case, if we use NKGE, then the electron and its motion are described by extreme waves, which, in particular, can correspond to Euler figures or particle-waves.

That is, the model of a nonlinear scalar field describes an electron, on the one hand, as a particle – wave, and on the other, it is an oscillating nonlinear string describing one from Euler figures (Figs. 2, 4, 6)!

Thus the wave averaged properties of vacuum are described by the modified nonlinear Klein-Gordon equation (NKGE). Solutions to this equation are constructed for various resonant cases. In particular, the creation of real particles in vacuum between plates is simulated.

The idea is used that elementary particles are not point objects, but local fluctuations of various physical fields. They fill the vacuum in which there are spontaneously appearing and disappearing virtual particles and antiparticles. In the book the appearance of elementary particles in vacuum is being connected with resonance phenomena.

It is assumed that the space, namely vacuum, has a certain periodic structure, similar to a crystal, in the nodes of which there are resonators. Thus, modern physical concepts are used that vacuum can have a complex structure. In particular, it can exhibit viscous properties with respect to the motion of virtual particles. On the other hand, vacuum friction may depend on the structure of the vacuum and the curvature of the waves propagating there.

CHAPTER V. Nonlinear quantum waves in the light of recent slit experiments.

The history of the double slit experiment (DSE) is going more two centuries (Fig. 16). His results played a significant role in the discovery of the wave nature of light, and then formed the basis of important provisions of quantum mechanics. However, its results are still difficult to interpret unambiguously. It is possible that this is due to the use of the Schrödinger equation for mathematical analysis of the results of the experiments. In the chapter, these results are analyzed on the basis of solutions to the Klein–Gordon equation. The influence of virtual particles and Casimir forces on the passage of particles through the slits and the final results of experiments is emphasized.

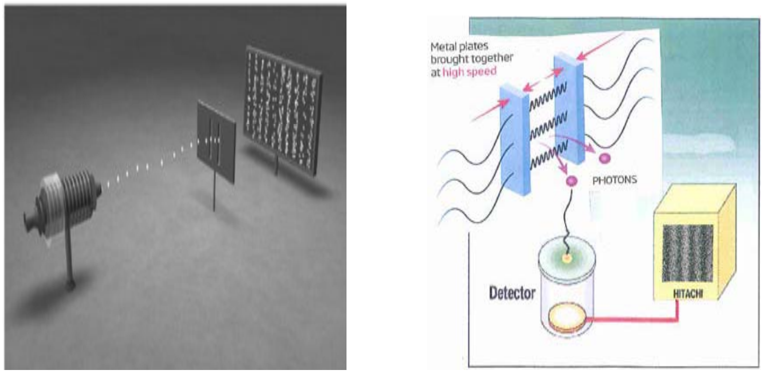


Fig. 16. Slit experiments and appearance of particles because of "the acoustical Casimir forces"

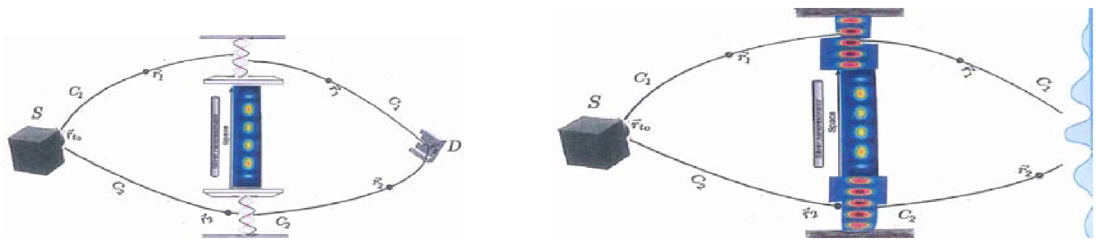


Fig. 17. Schemes of the thought experiment. The springs in the slits model the standing wave of virtual particles (left). Ellipse-like particles are the virtual particles modeling "the acoustical Casimir forces" (right)

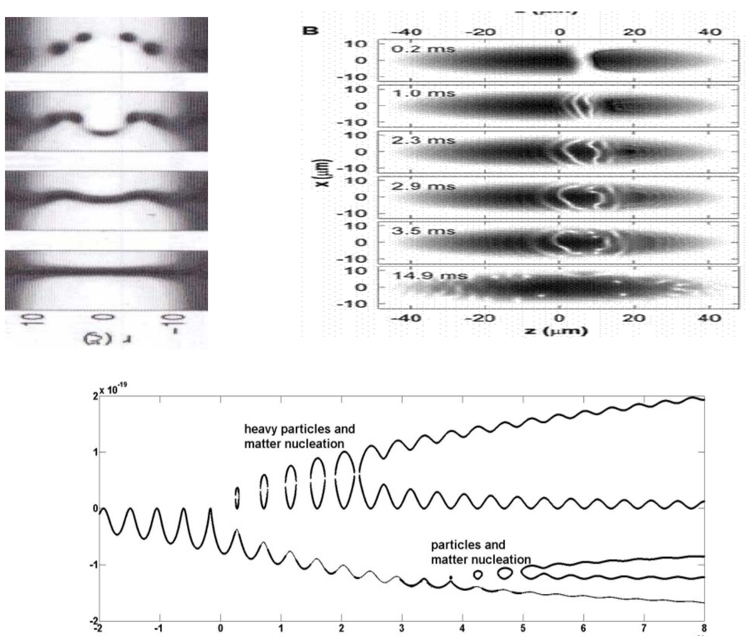


Fig. 18. Examples of the evolution of the linear perturbations into vortices (points) in Bose-Einstein condensate (BEC). The originally direct lines are being distorted into the harmonic lines. After that the folds appear which resemble the Euler fig. 7. Then the last break up into isolated elliptic structures (points , wave – particles, vortices) (experiments, upper). Bifurcations of initially harmonic wave and the birth of particles (calculations, below) [25]

Thus, NKGE is used instead of the Schrödinger equation to analyze mathematically the results of the experiments. According to the analysis, the nonlinearity and resonances are important elements that open a new understanding of the results of the experiments. The results DSE are explained by the hypothesis that there is a standing wave of virtual particles in the slit (Fig.17).

The standing wave forming by virtual particles is similar to those existing between metal plates in Casimir's experiments. The interference pattern on the screen (Fig. 9) is the consequence of the standing wave in the slits! The author abandoned the notion of probability in the double slit experiment [24].

CHAPTER VI. The origin of particle – waves.

It is assumed that some scalar fields have both static and dynamic properties. In particular, static properties are determined by some localized resonators (see Chapter I). According to the Heisenberg Uncertainty Principle, energy peaks form instantly and quickly disappear in the field. This process is known as "quantum fluctuations". Their influence is taken into account by the appearance of an inhomogeneous term in NKGE. This term can extremely amplify its own vacuum waves in resonators and in their vicinity. This amplification, that is a strong jump in the energy of the field, is interpreted as the birth of real particle-waves (Fig. 4, right).

The generation of particle-waves in different physical fields is the known effect. Apparently during instability both sole particle-waves and vortices may appear in scalar fields. In particular, in Bose-Einstein condensate they were created due to the snake instability (Fig. 18, upper).

Fig. 18 gives an example of particle-wave processes discussed in the book. It can be seen that the Euler figures 6 and 7 describe the evolution of the given experimental curves much better than the harmonic curves that are usually used in constructing linear solutions. In particular, harmonic curves do not describe the destruction and disintegration of waves.

This is a very complex problem. Indeed, the coefficients and terms of NKGE depend on the quantum fluctuations of the vacuum. Moreover, NKGE can have several solutions. These solutions are different, but they are at the same point in space-time. It is important that the energy and pressure of the scalar field depend on the derivatives and the scalar potential which can increase indefinitely at the points of bifurcations and jumps. Due to the above circumstances, different particle-waves having huge energy, in particular, our Universe, which has practically infinite energy and mass, could appear in vacuum (Fig. 4).

CHAPTER VII. The origin of the Universe as an extreme resonant wave event.

The recent results of the Planck satellite and other observations are favorable for modeling the earliest Universe using the wave equations, in particular, nonlinear equation of the Klein-Gordon type. At the early stage of the existence of the Universe, waves existed (appeared) in it, similar to waves in resonators. The very early Universe vibrated like certain condensed matter in some kind of resonator (figuratively speaking, like a spherical bell). This resonator was tunnelled from some pre-universe. In the book the origin of the Universe and its first moments are associated with wave and resonance effects that took place in the pre-universe. Thus, the author considers the moment of the birth of the Universe from the pre-universe. As a matter of fact, the author explores the moments before or at the moment of the appearance of spacetime foam (Fig. 19).

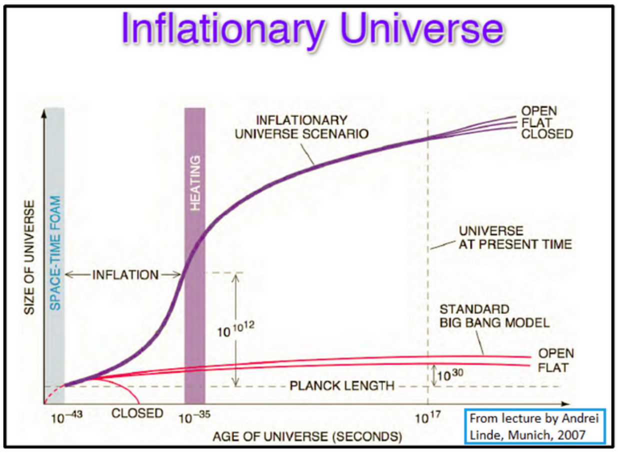


Fig. 19. The evolution of the size of the Universe over time. The causal mechanisms of the initiation of the inflation period (left of the purple vertical bar) as well as the actual creation of the Universe remain unknown to us. In this image, the very first moments of the Universe are indicated (see the grey vertical bar) as spacetime foam, i.e., quantum fluctuations within spacetime. (Source: Matt Strassler)

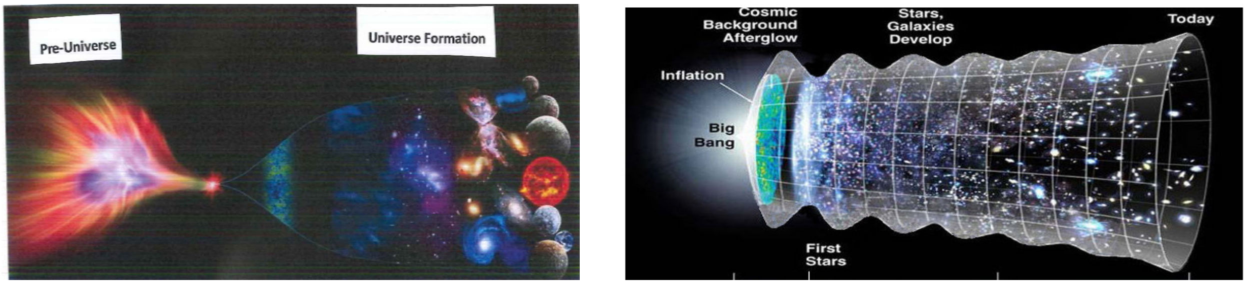


Fig. 20. Imaginary pictures of the origin and evolution of the Universe as seen by the artist

A strict sequence the evolution of the Universe arising from the pre-universe, as results of quantum perturbations, bifurcations and resonances, is being built. Namely, solutions of NKGE are found that describe jumps from the pre-universe billions of "seeds" of rapidly developing universes. Most of them are Planck-sized 'flicker' universes. However, there are some universes that evolve to a large size. One of them accidentally formed our Universe with the fundamental parameters that we have. The starting point of the Universe from a singularity is rejected. The pre-history of the Universe is introduced instead of the singularity.

The jump of a clot (sphere) of the scalar field from the pre-universe to a new, very high, energy level corresponds to the birth of our Universe (see, also, Fig. 2 (right)).

In conclusion of the review, I bring to the attention of the reader my reviews [26, 27] of earlier books by my student and long-term collaborator Shamil Usmanovich Galiev. I have posted several reviews on the Internet [28].

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28. See also: Ilgamov M.A. Reviews.
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ОБЗОР КНИГИ GALIEV SH.U. «EXTREME MULTIVALUED WAVES IN SCALAR FIELDS», ПЛАНИРУЕМОЙ ИЗДАТЕЛЬСТВОМ SPRINGER К ПУБЛИКАЦИИ В НАЧАЛЕ 2024 г.

Целью книги является математическое и экспериментальное исследование обстоятельств, определяющих возникновение экстремальных многозначных волн, их эволюцию и описание. Делается акцент на междисциплинарный характер экстремальных волн. Известно, что Эйнштейн пытался построить единую (междисциплинарную) теорию поля, которая объединила бы все взаимодействия в Природе в единую систему. В книге автор использует эту идею. Известные уравнения скалярного поля рассматриваются как основа для унификации и описания экстремальных волн в окружающей среде. Такой подход позволяет ставить фундаментальные вопросы о многозначной, корпускулярно-волновой, нелинейной природе окружающего нас мира. Проиллюстрирована идея о том, что все в мире подчиняется нелинейным законам. Моделируются различные сильно нелинейные волновые процессы, начиная от моделирования фигур Эйлера и океанских волн и заканчивая описанием рождения частиц-волн и Вселенной.

Показано что экстремальные волны моделируют многие закономерности, наблюдаемые в слоях жидкости, оптических системах, конденсатах Бозе – Эйнштейна, микро- и электронных резонаторах. Таким образом, экстремальные волны, рассматриваемые в этой книге, могут быть применены к различным технологиям и системам, начиная от атомного масштаба и заканчивая космосом.