

REFEREED PUBLICATIONS

Recent publications

For the last 10 years I have been working mainly in Applied Noncommutative Analysis and Stochastic and Quantum Dynamical Systems. I was fortunate to be able to develop my own approach to the mathematical solution of three fundamental problems of modern systems theory and physics.

First, I discovered the linear and nonlinear structure of the stochastic generators for classical and quantum semigroups and flows. It can be applied for canonical derivation and interactional interpretation of nonlinear kinetic equations for diffusion-reaction processes. Such models are equally applicable to physical, chemical, biological and even artificial complicated dynamical systems, consisting of many similar interacting components of one or several sorts. They are based on the theory of Markov point processes and their Fock space representation. Having in mind the applications to quantum physics, I developed in [60] the noncommutative analog of this theory. I proved in the series of papers [49–52] that under condition of weak interaction, such models can be reduced to the nonlinear single component dynamics by use of the quantum law of large numbers. Also other important results concerned with the corresponding central limit theorems and large deviations, can be obtained in this direction. I expect the solution of the corresponding nonlinear kinetic equations can be reduced to an iterative procedure by the methods of noncommutative and nonadapted stochastic integration in Fock space developed recently in [61, 69–72, 74, 77,78].

The development of the noncommutative and nonadapted stochastic analysis was a result of another piece of good luck. It extends the white noise analysis to the noncommutative case and is based on the discovered universal matrix representation of the Ito $*$ -algebras. This construction provides a new efficient algebraic language for quantum stochastic calculus known as the Belavkin notation. It is based on use of indefinite metrics in the Minkowski space and the involutions associated with them. It enables one to generalize the functional Ito's formula to the noncommutative and nonanticipative cases [77, 84]. In the purely nonstochastic case it extends the chain rule to the noncommutative case, giving a new elegant formula [82] for the differential of functions of ordered operators. A deep insight into the necessity of the Fock space set-up in the quantum stochastic analysis is provided by the dilation theorems [72, 78, 81] for positive-definite infinitely divisible functions and maps. The recently discovered structure [104, 112] of the generators for these functions and maps is used for the construction of the solutions for the quantum stochastic evolution equations of the general type.

The third my success was the discovery of a new fundamental wave equation, giving the dynamical interpretation of the problem of wave-function collapse [53–86]. This was a result of my long time investigation and analysis of the mathematical models of quantum measurement which I began in the 70's working on my first doctorate thesis in quantum communication. This stochastic equation, called in the mathematical literature by my name, has been widely accepted by physicists in the quantum jumps and state diffusion phenomenological quantum theories. I derived this equation by conditioning of the quantum stochastic dynamical model with respect to continuous observation. There is a surprising connection with stochastic control theory. This is a far reaching development of the classical statistics and nonlinear filtering of Markov processes into the field of quantum probability. It uses the powerful methods of quantum stochastic calculus on operator algebras, initiated by the Nottingham applied mathematics group. Unlike the Schrödinger equation the quantum filtering equation obeys an ergodic property which explains most of the paradoxes of quantum mechanics. My recent publications on this subject [86-102] have been received with great interest not only by mathematicians and physicists but also by engineers working in quantum optics and communications.

Early publications

My first three papers [ref. 1–3] of the list of publications were concerned with the problem of *optimal quantisation* (discretisation) of random vectors in metric spaces, which arises in the processing of continuous sample data for statistical computations. The connections of the *validity information theory* with the ϵ -*entropy theory* were established by corresponding limit theorems, and Kramer–Rao statistical methods were used for the building of efficient adaptive algorithms of quantization for the distributions with unknown parameters.

Other early work [4–9] included an examination of the *statistics of quantum measurements*, which is the problem of parameter estimation and hypothesis testing for quantum statistical distributions under the physical uncertainty relations. All these works were quoted in the fundamental book "*Quantum detection and estimation theory*", (Academic Press, 1976), written by C W Helstrom, who initiated researches in connection with the perspectives of the use of lasers for communication. Developing the Bayes and likelihood statistical methods in the following papers [10–21], I obtained the solution of the multialternative problem of optimal discrimination of quantum noncommutative distributions and proved the linearity of optimal decision for the quantum normal distributions. Another result was the establishing of a quantum Cramer–Rao inequality and its relationship to the Heisenberg uncertainty principle [22, 23]. All these results give rise to the new statistical discipline of noncommutative decision theory, which has applications to wave discrimination and pattern recognition in optical communication. This is described in my book "*Mathematical aspects of audio and visual pattern recognition*", written with Soviet Academician V P Maslov. Some of the problems formulated in this book are still to be solved and there are good prospects for interesting applications in communication and control.

Another subject of my researches [24, 33, 34, 44] is the investigation of *continuous dynamical models of multicomponent systems* by the methods of Markov point processes on operator algebras. I proved that under the condition of weak interaction, such models can be reduced by use of the law of large numbers to nonlinear Markov models described by quantum kinetic equations. Also other important results concerned with the corresponding central limit theorems and large deviations, can be obtained for classical as well as for quantum Markov interacting processes. These Markov models of nonlinear irreversible dynamics have various applications in solid and fluid mechanics, chemistry and biology as well as in mathematical physics.

A series of papers [26, 32, 39–43, 46, 48] is concerned with the *reconstruction and dilatation problem* of quantum probabilistic operational models on the basis of statistical data of sequential measurements and the characteristic functions of the statistical states. The corresponding theorems give the necessary operator-algebra generalisation of the well-known Kolmogorov main theorem for classical stochastic processes, as well as the Araki–Woods construction for *-semigroups. This provides the background for the usual Hilbert space formalism in quantum probability and noncommutative integration with various applications such as the definition of the entropy of the states on arbitrary *-algebras and relative entropy in quantum information theory [35, 36, 40, 41].

Most of my publications are single authored full research papers, and I was also a major contributor to all jointly authored works.

List of books

1. Belavkin V.P. *Mathematical Foundation of General Systems Theory*. MIEM Publisher, Moscow 1987, 78p. (textbook in Russian).
2. Belavkin V.P. and V.P. Maslov. *Mathematical Aspects of Audio and Visual Pattern Recognition*. Higher School Publisher, Moscow 1987, 75p. (textbook in Russian).
3. Belavkin V.P. and V.P. Maslov. *Design of Optimal Dynamic Analyzer*. In book "Mathematical aspects of Computer Engineering", edited by V Maslov (extended version of 2. in English). Mir Publishers, Moscow 1988, 117 p.
4. Belavkin V.P., O. Hirota and R.L. Hudson (editors). *Quantum Communications and Measurement*. Plenum Publisher, New Yourk 1995, 560p.

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