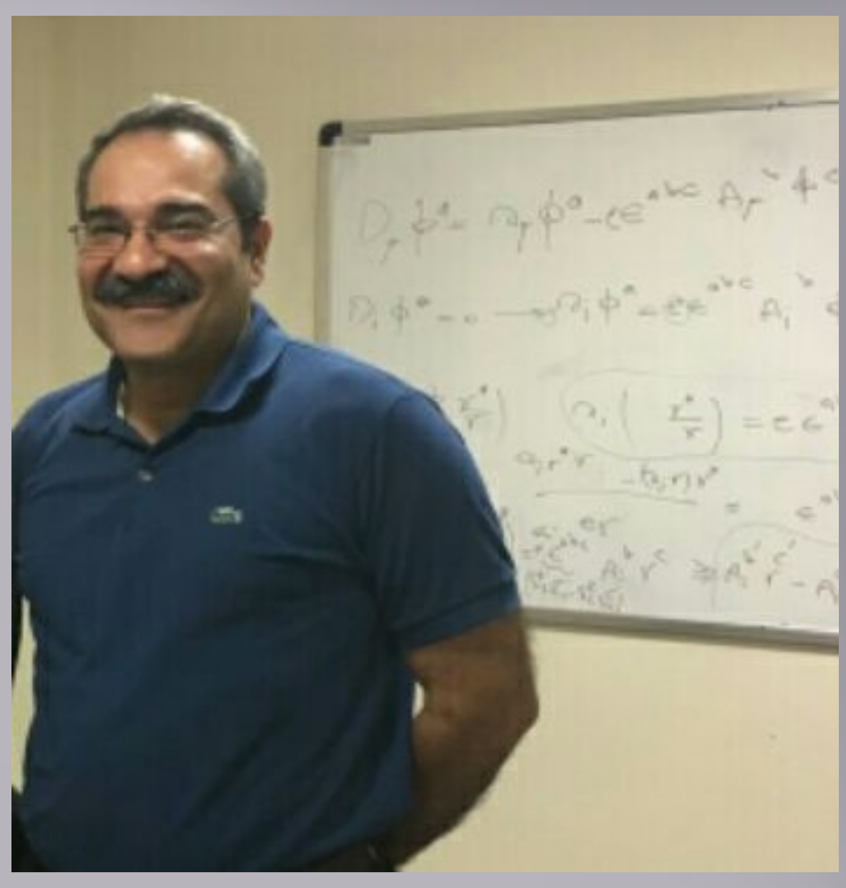

RESEARCH GROUP ON FOUNDATIONS OF QUANTUM THEORY AND INFORMATION

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Aims and Scope

In the group, the main research topics are quantum interference and Bell's theorem, interpretation of quantum mechanics and manipulating new theoretical models to explain the mysteries of quantum world. Some other topics such as the measurement problem, macroscopic quantum coherence, quantum decoherence, quantum thermodynamics, quantum Information and Bohmian Mechanics are included.

In quantum information and thermodynamics, the research group focuses on the origin of first and second law of thermodynamics and its relation with quantum processes and also on the relationship between entropy and information.

We also work on quantum aspects of life as well as the origin of chirality, and the role of information in biological cells.

Macrorealism

Macrorealism (MR) demands that, first, one can assign definite states to a macrosystem, so that it could be actually in one of these states independent of any observation, Second, it requires the non-invasive measurability of such macrostates which should not be affected, when they are measured. Leggett-Garg inequality (LGI) examine whether the theories satisfying MR are compatible with quantum mechanics or not. For an asymmetric double-well potential in a harmonic environment, by using a time-dependent approach, tunneling probabilities for the system which contain oscillation effects have been calculated. For the system described, this shows that the violation of the inequality occurs for a broader range compared to previous results obtained for two-level systems.

Macroscopic Quantum Coherence

The macroscopic quantum systems are considered as a bridge between quantum and classical systems. We describe the dynamics of quantum systems by introducing dimensionless parameters. Through this method the new parameter is presented as

$$\bar{h} = \frac{\hbar}{P_0 R_0}$$

which P_0 *and* R_0 *are defined as characteristic length and momentum of the system. When* $\bar{h} \ll 1$ *the system behaves quasi-classically. The values of* $\bar{h}$ *between* 0.1 *and* 0.01 *are fair enough to show the macroscopic disposition of our works. This approach lets us to study the quantum effects on the classical behavior of macroscopic systems.*

Uncertainty Relation for Macroscopic Quantum Systems

We have instantiated a macroscopic quantum harmonic oscillator interacting with various numbers of micro-oscillating particles in the environment. The parameter $\bar{h}$ *indicates the macroscopic disposition of the system. The calculations show that for the quasi-classical system the macroscopic behavior could be indicated by the violation of position-momentum HUR*

$$\Delta q^2 \Delta p^2 < \frac{\bar{h}^2}{4},$$

when similar limited numbers of the particles of the environment N *are in the interaction. The violation of HUR for a macroscopic quantum system is beyond our consideration. Also, as the number of the particles of the environment increases, there would appear other factors which could affect the quantum traits of the system. By the way, with the different values of environment interacting particles* N*, generally, the lower limit of the violation range for* $\bar{h}$ *in the HUR relation would be*

$$\frac{1}{N^3 \pi^{N-1}} < \bar{h}^{N-1}$$

Earth as a Quantum System

For quantum systems, we expect to see classical behavior at the limit of large quantum numbers. Hence, we apply Bohmian approach to describe the Earth revolution around the Sun. We obtain possible trajectories of the Earth system with different initial conditions which converses to a definite stable orbit after a given time, known as the Kepler orbit. The trajectories are resulted from the guidance equation $p = \vec{\nabla} S$ *in Bohmian mechanics which relates the momentum of the system to the phase part of the wave function at large quantum numbers (classical limit). Quantum potential is also shown to have no significant role in the Earth dynamics due to the macroscopic trail of the system.*

Quantum Study of Biosystems

Quantum mechanics have been used in the study of biomolecule structures and functions recently. Several attempts have been made to explain the structure of the genetic code using quantum mechanical methods. The model presented by I. G. Karafylidis 2008, based on the assumption that genetic information is conserved, and models DNA are the sender and proteins as the receiver of this information. Genetic information for protein synthesis is encoded in nucleotide triplets.

A 64-dimensional Hilbert space is used to describe the information stored on DNA side, based on 64 possible codons. Each amino acid is described by a Hilbert subspace. The idea is to study the transition probabilities related to different types and sources of mutations using open system quantum mechanics.

Recent Publications

-H. R. Naeij and A. Shafiee, J. Stat. Phys. ***6****, 1141-1152 (2016).*

-H. R. Naeij and A. Shafiee, Found. Phys. ***12****, 1634-1648 (2016).*

-A. Tirandaz, F. Taher Ghahramani and A. Shafiee, Phys. Rev. E ***92****, 032724 (2015).*

-A. Shafiee and F. Taher Ghahramani, Quantum Stud: Math. Found. ***5****, 1-14 (2015).*

-A. Tirandaz, F. Taher Ghahramani and A. Shafiee, J. Biol. Phys. ***40****, 369-386 (2014).*

-I. Khatam and A. Shafiee, Found. Sci. ***3****, 241-255 (2014).*