

Randomness in Quantum Mechanics: Philosophy, Physics and Technology

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This progress report covers recent developments in the area of quantum randomness, which is an extraordinarily interdisciplinary area that belongs not only to physics, but also to philosophy, mathematics, computer science, and technology. For this reason the article contains three parts that will be essentially devoted to different aspects of quantum randomness, and even directed, although not restricted, to various audiences: a philosophical part, a physical part, and a technological part. For these reasons the article is written on an elementary level, combining very elementary and non-technical descriptions with a concise review of more advanced results. In this way readers of various provenances will be able to gain while reading the article.

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I. INTRODUCTION

Randomness is a very important concept finding many applications in modern science and technologies. At the same time it is also quite controversial, and may have different

meanings depending on the field of science it concerns. In this short introduction to our report we explain, in a very general manner, why randomness plays so important role in various branches of science and technology. In particular we elaborate the concept of “*apparent randomness*”, to contrast it with what we understand under the name “*intrinsic randomness*”.

Apparent randomness as an element of more efficient description of nature is used practically in all sciences, and in physics in particular (cf. (Halmos, 2013; Khinchin, 2014; Penrose, 1979; Schrödinger, 1989; Tolman, 2010)). This kind of randomness expresses our lack of full knowledge of the considered system. Paradigmatic example concerns classical mechanics of many-body systems that are simply too complex to be considered with all details. The complexity of the dynamics of systems consisting of many interacting constituents makes predictions, even assuming perfect knowledge of initial conditions, practically impossible. This fact motivates the development of statistical mechanics and thermodynamics. The descriptions that employ probability distributions and statistical ensembles, or even more reduced thermodynamic description, are more adequate and useful. Another paradigmatic example concerns chaotic systems. In deterministic chaos theory (cf. (Bricmont, 1995; Gleick, 2008; Ivancevic and Ivancevic, 2008)) even for the small systems involving few degrees of freedom, the immanent lack of precision in our knowledge of initial conditions leads to the impossibility of making long time predictions. This is due to an exponential separation of trajectories, when small differences at start lead to large end-effects. Also here, intrinsic ergodicity allows one to use the tools of statistical ensembles.

In quantum mechanics *apparent (a.k.a. epistemic) random-*

Physics Philosophy And Quantum Technology

Somnath Bhattacharyya



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