EPISTEMIC VS. ONTIC FREQUENCY APPROACH TO QUANTUM MEASUREMENTS

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Measurements carried out on continuous observables or on discrete observables in the presence of a conservation law are neither repeatable nor predictable, as proven in Refs. [1] and [2], respectively.

In the case of discrete observables of individual systems on which measurements of the first kind are carried out we can assume repeatability for *individual* systems and thus endorse the individual (also called the Copenhagen) interpretation of quantum mechanics. In doing so we express our belief that the statistics, notably probability equal to one, is *about* a 'property' of every individual quantum object from a measured ensemble. If this belief turned into reality, the interpretation would become ontological, i.e. unique. Untill it does let us call the interpretation '*ontic*'.

Thus, for the time being, we can also assume that the repeatability hypothesis does not hold for discrete observables of individual systems but only for the ensemble and thereby endorse the 'strong' statistical interpretation. Since the question "What is truth?" is typical of epistemology, let us call the interpretation '*epistemic*'.

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Which of the two interpretations is actually valid is essential for the quantum theory of measurement. For, if there is no repeatable measurement then there exists no objective and verifiable property of individual system and consequently there is no measurement 'problem' which can be formulated with the help of the currently used quantum formalism. In other words, we would be left with the measurement statistics and measurement outcomes without having any property of the measured individual systems corresponding to the elements of the quantum Hilbert space formalism. Therefore it was important to find a difference between the interpretations *within* the quantum formalism regardless whether the difference is measurable or not. (To date, all arguments for either interpretation have been given outside the formalism.)

In Refs. [3] and [4] a relative frequency criterion for the validity of each of the two interpretation is established. In effect, an expression is constructed which is a function of the relative frequency of the mesured data as well as of the corresponding theoretical (Hilbert space) probability (for the number of detections approaching infinity) and which has a well defined physical meaning.

We then consider a measurement of a discrete observable carried out on individual systems which confirms the observable with probability equal one, i.e. statistically repeatable measurements. Can such measurements be considered repeatable with respect to every particular individual system from the measured ensemble? We are able to prove that this is so if and only if the afore–mentioned function exhibits a jump at one end point of the closed interval [0,1]. Thus according to the ontic interpretation the function exhibits a jump at just one mathematical point of the interval. According to the epistemic interpretation the function is continuous on the whole interval.

While a difference in experimental values of the function on the semi–closed interval [0,1) as opposed to the closed interval [0,1] cannot be expected to be measurable, an important physical contribution of this result is that the assumptions of repeatability and 'non–repeatability' correspond to properties of a well defined function.

The result prompts the consideration of a frequency theory of measurements without cats and other individual 'problems'. This approach turns out to be attractive since it suggests a unification of descriptions of quantum measurements in the sense that the approximately repeatable measuring process might be a model not only for continuous and restricted discrete observables but also for unrestricted discrete observables.

On the other hand, the obtained result supports considering the (quantum) logic underlying the Hilbert space formalism as an *a priori* calculus characterizing nothing but our statistical description of quantum measurements. To this aim, a 'non–operational' quantum deductive calculus based on the unified operation of implication [6], i.e. *unified quantum logic*, has been formulated in Ref. [5]. (For a discussion see Ref. [7].)

My contribution to this meeting is a discussion of the approach and a presentation of new results.

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