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Zur Interpretation der Heisenbergschen Unschärferelation, published in the journal "*Kutadgubilig*" March 2005, is translated by Google and slightly corrected by Halil Güveniş:

On the Interpretation of Heisenberg's Uncertainty Relation

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Abstract

According to Bohr, the uncertainty relation is attributed to the inseparability of observer and micro-objects. A closer consideration shows, however, that quantum systems are inseparably associated with spontaneously absorbed and emitted photons regardless of observation procedures. Hence, the observer cannot be *genuinely responsible* for the uncertainty relation. The characteristic uncertainties in nature are primarily to attribute to spontaneously absorbed and emitted photons.

Keywords: Uncertainty relation, observer, measuring process, spontaneously absorbed and emitted photons.

The first interpretation of the uncertainty relation was given by Werner Heisenberg in his famous work from March 1927 [1]. The core idea of this work was that the observer has to scatter photons on particles in order to measure position or momentum, thereby causing a discontinuous Compton recoil. The resulting position and momentum uncertainties can be calculated using elementary rules of the Compton effect that fulfill the relation

$$\Delta q \Delta p \sim h, \tag{1}$$

i. e., "*the more precisely the position is determined, the less precisely the momentum is known and vice versa.*" [1]

This justification of the uncertainty relation was criticized by Niels Bohr already in the appendix to the Heisenberg article. According to Bohr, the uncertainty in observation does not arise exclusively from the discontinuity of the recoil. Only the requirement to simultaneously do justice to the wave and particle character of quantum objects creates the indeterminacy. For example, in photon scattering, the divergence of the irradiated light beam must be taken into account. "*First this has the consequence that, when observing the electron position, the direction of the Compton recoil is only known with an inaccuracy, which then leads to relation* (1)." [1]

Bohr later formulated this interpretation more precisely by speaking of an uncontrollable disturbance of the micro-object by the measuring device [2]. The uncertainty relation is due to the inseparability of the observer and the micro-object. Since all of our knowledge about the physical world is mediated by measuring instruments, the uncontrollable interaction of measuring devices with quantum objects cannot be neglected. Consequently, measuring means and quantum objects are inseparably associated to one another [3].

What is characteristic of Bohr's interpretation is that he is not at all interested in the state of the quantum objects before the measurement. In principle, it is not possible to learn more about the history of particles through measurements than the uncertainty relation allows. The impossibility of making a clear separation between the measuring device and the measured object prevents the measured indeterminacies from being clearly assigned to objective causes.

However, it must be noted at this point that the disturbance of the measuring device is only uncontrollable for individual quantum objects, but the disturbance becomes controllable when moving to the statistical ensemble. It is possible to precisely calculate the uncertainty transferred from the measuring device to the ensemble. If we subtract the calculated contribution of the measuring device from the measured total uncertainty, we can objectively represent existing indeterminacies without distortion.

In the context of the ensemble interpretation of quantum mechanics [4], it makes therefore sense to ask about objective causes of the uncertainty relation. The characteristic indeterminacies could, similar to Brownian motion, be caused by random and discontinuous interactions with a sub-quantum system. But in order to be able to generate the constantly existing indeterminacies due to this sub-quantum system they must be inseparably associated to quantum objects.

When we look for such a sub-system, we immediately notice that in real physical events, particles with mass are inseparably associated with spontaneously absorbed and emitted photons [5]. All over space, quantum objects are subjected to spontaneous absorption and emission processes in the form of thermal radiation, virtual photons or vacuum fluctuations. It is fundamentally not possible to imagine a “dark corner” of space in which objects exist unaffected and unchanged by these photon processes. Consequently, all particles acquire a natural uncertainty that arises from random and discontinuous interactions with photons.

The quantum objects are therefore subjected to an objective uncertainty, which precedes the contribution of the measuring device. It is true that the observer's measurement intention represents an unavoidable intervention with photons. However, one cannot claim that this intervention originally creates the inaccuracies in position and momentum. The uncertainties were already there before the measurement, caused by spontaneously absorbed and emitted photons. What the observer has created is only an additional uncertainty, which, however, does not entitle him to claim that his measuring devices are genuinely responsible for the indeterminacy in nature.

One might now be inclined to argue that the controllability of the natural uncertainty that we postulate for the statistical ensemble is actually not important, but that the uncertainty relation is more about the uncontrollable disturbance of the individual quantum objects. The objection to this argument would be that the uncertainty principle only makes a compelling statement for the statistical ensemble and therefore the interpretation must take place at the level of the ensemble. A single particle, on the other hand, does not need to obey the uncertainty relation; there is a finite probability that its position and momentum uncertainties do not satisfy the relation $\Delta q \Delta p < \hbar / 2$.

References

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