**////Title:** **Reconstructing Parts of Quantum Theory from Two Conceptual Variables**

**////Standfirst:**

The Hilbert space formulation is a central idea in quantum theory, but the ideas used by physicists to interpret the formulation widely differ. Furthermore, concepts in quantum mechanics are very abstract to those outside the field. Professor Inge Helland from the University of Oslo approaches these problems through what he calls ‘conceptual variables’, which belong to the minds of one or more conscious observers. From this basis, he achieves a new derivation of the Hilbert space formulation, which he hopes will lead to more satisfying studies of the foundations of quantum theory.

**////Main text:**

Hilbert space is a key concept in many branches of physics and mathematics. Its rules are rooted in the more conventional concept of Euclidian space – in which intuitive statements, or ‘postulates’, are assumed to be true. Postulates themselves provide the building blocks of more complex mathematical statements, or ‘theorems’, which can be proven definitively.

The Hilbert space formulation of quantum mechanics has its origin in Schrödinger’s wave mechanics and Heisenberg’s matrix mechanics, two theories that were unified through this abstract formulation.

Today, the postulates of this formulation have been laid out in textbooks, and physicists continue to draw on them in all quantum theory calculations. Professor Inge Helland of the University of Oslo proposes that these postulates should be replaced with other postulates.

He shows how the Hilbert space formulation can indeed be derived from more intuitive postulates than those found in textbooks and most quantum theory research. His recent paper contains only parts of the derivations; more details can be found in the book ‘Epistemic Processes. A Basis for Statistics and Quantum Theory.’ A simple formulation of the full theory can be found in the future article: ‘A simple quantum model related to decisions’.

To start with, Helland imagines a scientist asking the question: ‘what will this quantity turn out to be if I measure it?’ He calls the quantity and more general quantities ‘conceptual variables’, which exist within the mind of this observer, in addition to being related to some objective variables. To gain answers to his question, the scientist’s first task will be to set up an experiment or measurement. This may result in some data, which will give the scientist some information about the variable.

If the variable is discrete, and if the experiment is good enough, the data will consist of a single, clearly defined value. As an example of a discrete variable, one can look upon the spin component of an electron. The theory for continuous variables – such as position or momentum – is more complicated, but can be derived by starting with a discrete approximation, and then taking limits.

Before an electron’s spin in a certain direction is measured, it ‘exists’ across a range of possible values. After measurement, that range collapses into a single value.

Building on this idea, Inge Helland argues that the essence of quantum theory can be described in terms of conceptional variables in the mind of an observer, or in the joint minds of a group of communicating observers. The problem is approached through the notion of ‘accessible’ and ‘inaccessible’ conceptual variables.

A conceptual variable is said to be ‘accessible’ if one can assign a specific numerical value to it through an experiment or measurement; and ‘inaccessible’ if this isn’t possible. This latter case can be seen in the impossible task of precisely measuring both the position and momentum of a quantum particle – which is expressly forbidden by Heisenberg’s uncertainty principle. A vector constructed of position and momentum is inaccessible. Also, the full spin vector of an electron is also inaccessible.

In addition, the notion of symmetry is important, and this notion is made precise by using group theory. A group action on a variable ***t*** can be seen as a simple transformation of each value of ***t*** into another value.

The main result in Inge Helland’s article is as follows. Assume that, in some context, there are two related maximally accessible conceptual variables. These notions have precise definitions. In addition, there are group actions defined on one of the variables that satisfy certain technical requirements, resulting in essential elements of the Hilbert space formulation. Importantly, each accessible conceptual variable has a quantum operator attached to it.

This can seem like a very technical result, but it represents a new entrance into quantum mechanics as a science. Several important scientists, including Richard Feynman, have said that it is very difficult to understand quantum theory. Through the above result, the theory is based on a simple model that can be understood, taking the mind of the observer, and the mind of any scientists trying to model the physical system, into account.

To arrive at a full theory of quantum mechanics, one also needs arguments leading to the Born formula for calculating probabilities, and arguments for the Schrödinger equation, which describes the time development of a quantum system between measurements. Such arguments are discussed in Helland’s book.

One additional aspect of the main theorem in this article, is that the result also is valid for other variables aside from measurement variables, such as ‘decision variables’. This couples the theory to a theory of decisions – an aspect that is discussed in more detail in Inge Helland’s most recent article that we previously mentioned.

As previously stated, there are many different and conflicting interpretations of quantum mechanics. One Wikipedia article mentions 16 different interpretations. The interpretation presented in Inge Helland’s article is a general epistemic one. This means that the predictions given by quantum mechanics are seen as statements of an observer’s *knowledge* of the quantum system, or of the joint knowledge of a group of communicating observers. It is important that a derivation of essential aspects of quantum mechanics can be obtained using these ideas.

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