Time in Quantum Mechanics
Comparing Interpretations of Quantum Mechanics through the Problem of Time

Quantum mechanics is the theory that describes the behavior of the smallest things in nature, such as atoms, electrons, and photons. It is one of the most successful scientific theories ever developed, as it can predict the outcomes of quantum experiments with amazing precision. However, quantum mechanics also raises some of the deepest questions about the nature of reality, such as how to understand quantum phenomena and how they relate to what we observe.

There are many different ways of interpreting quantum mechanics, and some of them are very strange and puzzling. For example, some interpretations suggest that reality is not determined until we measure it and that many possible realities exist simultaneously. One of the main challenges in the philosophy of science is to compare these different interpretations and see if there is a way to test them experimentally. However, this is exceedingly difficult to achieve because most interpretations agree on what quantum mechanics predicts but disagree on what it explains. Therefore, to find differences among interpretations, we need to look for situations where quantum mechanics itself is not enough and where we need to change or improve the theory.

This issue concerns how quantum mechanics deals with time, which is a crucial aspect of our experience of the world. We use time to order events, measure durations, and coordinate our actions. However, many authors believe that quantum mechanics does not adequately describe the temporal aspects of quantum phenomena. This is commonly referred to as the problem of time in non-relativistic quantum mechanics.

For example, quantum mechanics does not provide a robust formal justification for the time-energy uncertainty relation, which lies at the heart of quantum theory. This also means that we do not have a clear understanding of this relation, whereas other uncertainty relations are easily proved and explained. These problems suggest that we need to revise quantum mechanics to account for time and explain the temporal features of quantum phenomena.

The aim of this project is to investigate whether the problem of time in quantum mechanics and its implications can provide empirical differences among these interpretations, potentially ruling out some of them. The project may also help in understanding temporal aspects of quantum phenomena that have no classical counterparts. If successful, the project would broaden our knowledge of quantum reality and bridge the gap between those who develop quantum physics (often adhering to Mermin's famous advice: 'Shut up and calculate!') and those who seek to understand reality at a fundamental level.