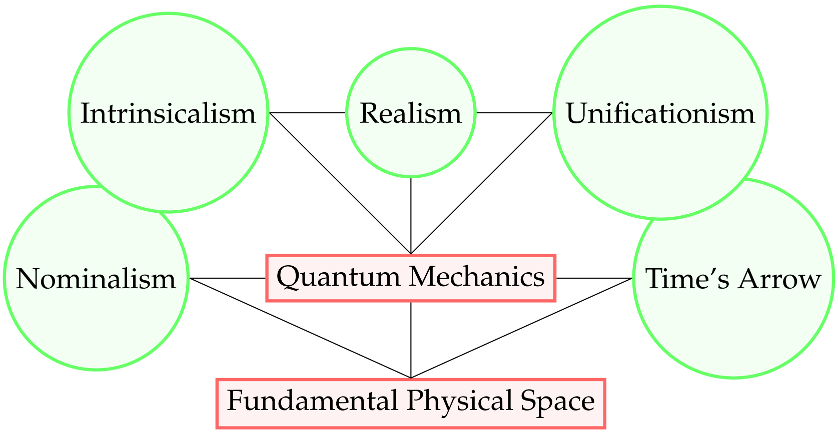
Rutgers University PhD Dissertation Defense:
Essays on the Metaphysics of Quantum Mechanics

Eddy Keming Chen
eddy.chen@rutgers.edu
www.eddykemingchen.net

March 12, 2019

Introduction



Two steps of metaphysical / scientific inquiries about quantum mechanics:

1. How to solve the measurement problem;
2. How to interpret the universal quantum state (usually represented by a wave function).

For concreteness, I focus on the case of non-relativistic quantum mechanics for N particles.

Difficulties with interpreting the quantum state:

1. The universal wave function includes redundant degrees of freedom that do not seem to correspond to any physical structures (e.g. overall phase).
   - What is the intrinsic structure of the quantum state?
2. On a straightforward ontological interpretation, the universal wave function suggests the fundamentality of a high-dimensional space (the "configuration space").
   - What is the status of physical space in a quantum world?
3. If we were to interpret the universal wave function as something on par with laws of nature, it may be too complicated to be nomological.
   - How to choose a simple quantum state?

Chapter 1: The Intrinsic Structure of Quantum Mechanics

I propose that the quantum state can be understood intrinsically as four relations on physical space-time:

1. Amplitude-Sum (S),
2. Amplitude-Geq ($\succeq_A$),
3. Phase-Congruence ($\sim_P$),
4. Phase-Clockwise-Betweenness (C_P).

These are relations holding among space-time regions composed of N points, where N is the number of particles in the universe. From these relations, we can recover a wave function uniquely up to an amplitude normalization constant and an overall phase factor. This is achieved by two pairs of representation and uniqueness theorems, one of them is a new result.

Payoffs: Some steps towards a completely intrinsic fundamental theory. A significant step towards nominalistic metaphysics of science. A defense of "field" interpretations of the wave function against objections about redundant structures.

Chapter 2: Our Fundamental Physical Space

I suggest that our overall evidence favors the view that the fundamental physical space is low-dimensional rather than high-dimensional:

- Evidence #1: dynamics and kinematics.
- Evidence #2: our ordinary experiences.
- Evidence #3: mathematical symmetries in the wave function.

Published in *The Journal of Philosophy*, 114(7), 2017: 333-65.

Chapter 3: Quantum Mechanics in a Time-Asymmetric Universe

I propose a new hypothesis in a relatively unknown framework:

- Framework: Density Matrix Realism
- Hypothesis: Initial Projection Hypothesis (IPH)

IPH pins down a simple and unique initial quantum state of the universe. The proposal brings together the foundations of quantum mechanics and the foundations of statistical mechanics in a new way. As it is formulated, IPH makes use of the Past Hypothesis (Albert 2000), but it may be a ladder we can eventually kick away (Chen 2019).

Payoffs: time's arrow; quantum ontology; fundamentality of space-time; Humean supervenience; narratability and Lorentz invariance; nomic vagueness; imprecise probabilities; strong determinism; unification of quantum mechanical and statistical mechanical probabilities; unification of universe-level and subsystem-level descriptions.

Forthcoming in *The British Journal for the Philosophy of Science*.