

“The Metaphysics Behind Quantum Mechanics - II”
The University of Chicago

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Mondays 6:00 – 8:30
Gleacher Center Room TBA

Course Description

Reductionism, mechanism, materialism... These are the bedrock concepts upon which modern science has been erected over the past 500 years. We understand the whole by understanding its more fundamental parts. But what does it mean when the physics by which we describe and understand the whole is found to be incompatible with the physics by which we describe and understand the parts? Such incompatibility is, for many, the defining feature of the relationship between classical and quantum mechanics. Recent years, however, have brought new interpretations of quantum theory which suggest a simple and intuitive way by which we might bridge the realms of the quantum and the classical--a bridge which might one day lead physics to its long sought-after goal of providing a truly coherent and unified description of nature.

This course will offer an introduction to quantum mechanics for non-specialists by way of these modern, metaphysically coherent interpretations--interpretations developed by theorists including Nobel laureate Murray Gell-Mann, Robert Griffiths, Roland Omnès, Wojciech Zurek, and others. We will examine the way in which these new interpretations bridge quantum and classical mechanics--a way suggestive of a coherent, logical, and empirically adequate metaphysical scheme.

Reading

1. Roland Omnès, *Quantum Philosophy: Understanding and Interpreting Contemporary Science*. Princeton: Princeton University Press, 2002 (ISBN: 0691095515)
2. Werner Heisenberg, *Physics and Philosophy: The Revolution in Modern Science*. Prometheus Books, Reprint Edition, 1999 (ISBN: 1573926949)
3. Gell-Mann, Murray. *The Quark and the Jaguar: Adventures in the Simple and the Complex*. New York: W.H. Freeman and Company, 1994 (ISBN: 0716727250)
4. Selected readings (distributed in class).

Recommended supplemental reading

Bell, John. “Against Measurement” in *Sixty-Two Years of Uncertainty: Historical, Philosophical, and Physical Inquiries into the Foundations of Quantum Mechanics*, Arthur I. Miller ed. New York: Plenum, 1990.

_____. "On the Einstein Podolsky Rosen Paradox," *Physics* 1, no. 3, 1964, 195-200.

Bohm, David, Hiley, B.J. *The Undivided Universe: An Ontological Interpretation of Quantum Theory*. London: Routledge, 1993. (selections)

Bohr, Niels, "Discussion with Einstein," in *Albert Einstein: Philosopher-Scientist*, Paul Arthur Schilpp, ed. Evanston: Library of Living Philosophers, 1949, 210.

Born, Max "Bemerkungen zur statistischen Deutung der Quantenmechanik" in *Werner Heisenberg und die Physik unserer Zeit*, F. Bopp ed. Braunschweig: F. Vieweg, 1961, 103-118 (translated)

Epperson, *Quantum Mechanics and the Philosophy of Alfred North Whitehead*. New York: Fordham University Press, 2004 (selections)

Everett, Hugh. *Rev. Mod. Phys.* 29, 1957, 44.

Gell-Mann, Murray. *The Quark and the Jaguar: Adventures in the Simple and the Complex*. New York: W.H. Freeman and Company, 1994 (selections)

Ghirardi, G., Rimini, A., Pearle, P. in *Sixty-two Years of Uncertainty*, A. Miller, ed. New York: Plenum, 1990, 167, 193.

Ghirardi, G. in *Structures and Norms in Science*, M.L. Dalla Chiara *et al.*, eds. Dordrecht, Netherlands: Kluwer Academic, 1997.

_____. *Physics Today* (Letters) April 1993, 15.

Hartle, James and Hawking, Stephen. "The Wave Function of the Universe" *Physical Review D* 28, 1983, 2960-75.

Hartshorne, Charles. "Bell's Theorem and Stapp's Revised View of Space-Time" *Process Studies*, 7,3, 1977, 183-191.

Hawking, Stephen. "Quantum Cosmology" in *Three Hundred Years of Gravitation* S. Hawking and W. Israel, eds. Cambridge: Cambridge University Press, 1987.

Heisenberg, Werner. *Physics and Philosophy*. New York: Harper Torchbooks, 1958 (selections)

_____. "The Development of the Interpretation of the Quantum Theory" in *Niels Bohr and the Development of Physics*, Wolfgang Pauli, ed. New York: McGraw-Hill, 1955.

James, William. *Pragmatism and the Meaning of Truth*. Cambridge: Harvard University Press, 1978. (selections)

Popper, Karl. *Quantum Theory and the Schism in Physics*. New Jersey: Rowman and Littlefield, 1956. (selections)

- Schrödinger, Erwin "Die gegenwärtige Situation in der Quantenmechanik," *Naturwissenschaften*. 23 : 807-812; 823-823, 844-849. (1935). English translation: John D. Trimmer, *Proceedings of the American Philosophical Society*, 124, 1980, 323-338.
- Shimony, Abner "Search for a Worldview Which Can Accommodate Our Knowledge of Microphysics" in *Philosophical Consequences of Quantum Theory: Reflections of Bell's Theorem*, J. Cushing and E. McMullin, eds. Notre Dame University Press, 1989.
- _____. "Quantum Mechanics, Local Causality, and Process Philosophy" *Process Studies* 7, 3, 1977, 173-182.
- Von Neumann, John. *Mathematical Foundations of Quantum Mechanics*. Princeton: Princeton University Press, 1955. (selections)
- Wigner, E. P. in *The Scientist Speculates: An Anthology of Partly-Baked Ideas.*, Irving John Good, ed. New York: Basic Books, 1962, 284.
- Żurek, Wojciech. "Decoherence and the Transition from the Quantum to the Classical" *Physics Today*, October, 1991, 40.
- _____. "Letters" *Physics Today*, April 1993, 84.
- Życiński, Joseph. "Metaphysics and Epistemology in Stephen Hawking's Theory of the Creation of the Universe" *Zygon* 31, 2, 1996, 269-284.

Lectures

- Week 1: Quantum mechanics and the beginnings of a new philosophy. **READINGS:** Omnès, Chapters 13-14
- Week 2: The interpretation of quantum mechanics according to a new, speculative metaphysics. **READINGS:** Omnès, Chapters 15-16
- Week 3: A brief review of the history of quantum mechanics; an overview of the Copenhagen Interpretation. **READINGS:** Heisenberg, Chapters 1-3.
- Week 4: An ontological interpretation of the quantum formalism. **READINGS:** Epperson: "The Ontological Interpretation of the Quantum Formalism" from *Quantum Mechanics and the Philosophy of Alfred North Whitehead* (1994).
- Week 5: Criticism and counterproposals to the Copenhagen Interpretation: **READINGS:** Heisenberg, Chapter 8; Epperson (continued discussion of the previous reading).

- Week 6: The evolution of actuality to probability: The quantum mechanical valuation of potentia; the formal description of state evolution. The evolution of the pure state density matrix to the reduced density matrix: Von Neumann's proposal for non-unitary evolution; the decoherence effect and the process of negative selection; decoherence of alternative states and 'consistent histories' of alternative states. **READINGS:** Epperson: "The Evolution of Actuality to Probability" from *Quantum Mechanics and the Philosophy of Alfred North Whitehead* (1994).
- Week 7: The Decoherent Histories Interpretation of Quantum Mechanics: **READINGS:** Gell-Mann, Chapters 11-12; Epperson (continued discussion of the previous reading).
- Week 8: Cosmological implications: quantum mechanical cosmogonic models. Theological implications: the necessary presupposition of primordial actuality in Hartle & Hawking's proposed quantum mechanical state evolution of the universe. **READINGS:** Życiński, "Metaphysics and Epistemology in Stephen Hawking's Theory of the Creation of the Universe"; Hartshorne, "Bell's Theorem and Stapp's Revised View of Space-Time"