PHIL 245: Philosophy of Science, Spring 2017

Scientific Realism and Quantum Physics

Time: Monday 4-7
Location: HSS 7077

Instructors: Craig Callender; Charles T. Sebens
Email: ccallender@ucsd.edu; csebens@ucsd.edu
Office Hours: Callender, M 11-12; Sebens, T/Th 5-6

Course Description

This course will examine philosophical issues in quantum theory and their relation to scientific realism. We will begin by discussing variants of scientific realism and arguments for and against scientific realism in the context of general philosophy of science. We will then explore how these general issues apply in the specific context of quantum mechanics. Quantum mechanics is of particular interest since some argue that the theory should not be interpreted in a realist way, others argue in favor of particular realist interpretations, and some conclude from the multiplicity of proposed realist interpretations that we are faced with a case of underdetermination of theory by data. We will cover the basic physics of quantum mechanics and study in-depth three realist interpretations: the Ghirardi-Rimini-Weber (GRW) theory of collapse, Bohmian mechanics, and the many-worlds interpretation. In the course of this discussion we will touch on questions about locality, determinism, the dimensionality of space, laws of nature, personal identity, physical probabilities, theory confirmation, and ontology.

Readings

Required Texts

Philosophy of Physics, Volume 2: Quantum Theory (forthcoming), Maudlin
[manuscript available on the course website]
Quantum Ontology: A Guide to the Metaphysics of Quantum Mechanics (2016), Lewis

Optional Texts

Scientific Realism: How Science Tracks Truth (1999), Psillos
Speakable and Unspeakable in Quantum Mechanics (1987), Bell
Quantum Mechanics and Experience (1992), Albert
Sneaking a Look at God's Cards: Unraveling the Mysteries of Quantum Mechanics (2005), Ghirardi
The Wave Function: Essays on the Metaphysics of Quantum Mechanics (2013), Albert and Ney
The Emergent Multiverse: Quantum Theory According to the Everett Interpretation (2012), Wallace
Many Worlds?: Everett, Quantum Theory, and Reality (2010), Saunders, Barrett, Kent, and Wallace

Assignments

Presentation (10%)
Each student will give one presentation of approximately 10-15 minutes for which they should prepare a handout or slides. This presentation should present original ideas and arguments (it should not merely be an explanation of some part of the reading).

Option A: Short Assignments (90%, 10% each)
There will be weekly short assignments due in class. A typical assignment will focus on the reading for the week in which the assignment is due, posing two questions each of which should be answered in approximately one page.

Option B: Research Paper (90%)
Although we expect the majority of students to benefit most from taking option A, we offer the alternative of writing a single extended research paper to students who would like to dive more deeply into a specific topic. This paper should be 20-30 pages.

Readings

All readings not from Lewis's textbook are either hyperlinked in the below schedule or available on the course website (or both).

Late Assignments

Late assignments will receive a one letter grade deduction for each 48 hour period they are late. An extension may be granted if requested in advance of the due date for the assignment. In general, extensions will only be granted for reasons of religious observance, illness, or personal or family emergency.

Special Accommodations for Students with Disabilities

If you require any special arrangements for completing the course assignments or participating fully in class meetings, please let us know at the beginning of the course.

Plagiarism

As this is a graduate level course we expect that you are all quite aware about issues of academic dishonesty. Still, to be explicit. Here is our policy on the issue: You are encouraged to work together on the short assignments. However, the work you submit should be your own. If you incorporate the ideas of others, cite those sources. Do not copy language too closely. Even when summarizing and paraphrasing cited sources, you must use your own language and present the ideas in an original way. If we have reason to believe that you have plagiarized, we will report the case to the Academic Integrity Office for review. If they determine that it is indeed a case of plagiarism, you will receive a zero on the assignment.

SCHEDULE

Accessible Sources to Set the Stage

"Scientific Realism" (2017), Goldstein

Measure for Measure: Quantum Physics and Reality (2014), Greene, Albert, Carroll, Goldstein, and Schack [video from the World Science Festival]

"The Trouble with Quantum Mechanics" (2017), Weinberg

Wk 1 **Scientific Realism, Constructive Empiricism, and Underdetermination**

Reading: "Refusing the Devil's Bargain: What Kind of Underdetermination Should We Take Seriously" (2001), Stanford

The Scientific Image (1980), van Fraassen, Chapters 1 and 2

Optional: "Three Views Concerning Human Knowledge" (1956), Popper

"Scientific Realism" (2011), Chakravartty

Language, Truth, and Logic (1936), Ayer, Chapter 1: The Elimination of Metaphysics

"Two Dogmas of Empiricism" (1951), Quine

The Essential Tension: Selected Studies in the Scientific Tradition and Change (1970), Kuhn, Chapter 13: Objectivity, Value Judgment, and Theory Choice

"Demystifying Underdetermination" (1990), Laudan

"The Underdetermination of Theory by Data" (1980), Newton-Smith

Wk 2 **The Pessimistic Meta-Induction, Selective Realism, and Structural Realism**

Reading: *Scientific Realism: How Science Tracks Truth* (1999), Psillos, pg. 96-114, 146-151

"Structural Realism: The Best of Both Worlds?" (1989), Worrall

Optional: "A Confutation of Convergent Realism" (1981), Laudan

"What is Structural Realism?" (1998), Ladyman

"Realist Ennui and the Base Rate Fallacy" (2003), Magnus and Callender

Wk 3 **Theory and Experiment in Quantum Mechanics**

Reading: *Quantum Ontology: A Guide to the Metaphysics of Quantum Mechanics* (2016), Lewis, Introduction and Chapter 1: Phenomena and Theory

Philosophy of Physics, Volume 2: Quantum Theory (2017), Maudlin, Chapters 1 and 2

Optional: *The Character of Physical Law* (1965), Feynman, Chapter 6: Probability and Uncertainty – the Quantum Mechanical View of Nature [also available as a video]

"Against 'Measurement'" (1990), Bell

"What Bell Did" (2014), Maudlin [also available as a video]

"Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?" (1935), Einstein, Podolsky, and Rosen

"The Measurement Problem" (2015), Norton

Wk 4 **Quantum Realism Versus Quantum Anti-Realism**

Reading: *Quantum Ontology: A Guide to the Metaphysics of Quantum Mechanics* (2016), Lewis, Chapter 2: Realism

Philosophy of Physics, Volume 2: Quantum Theory (2017), Maudlin, Chapter 3: The Wave Function

"Quantum Theory Needs No 'Interpretation'" (2000), Fuchs and Peres

Optional: "Does Orthodox Quantum Theory Undermine, or Support, Scientific Realism?" (1993), Maxwell

"Quantum Mechanics and Scientific Realism" (2015), Ruyant

"An Introduction to QBism with an Application to the Locality of Quantum Mechanics" (2014), Fuchs, Mermin, and Schack

Physics and Philosophy (1959), Heisenberg, Chapter 3: The Copenhagen Interpretation of Quantum Theory

"Einstein's Interpretation of Quantum Mechanics" (1972), Ballentine

"The Statistical Interpretation of Quantum Mechanics" (1970), Ballentine

"Guest Post: David Wallace on the Physicality of the Quantum State" (2011), Wallace

Wk 5 **Collapse**

Reading: *Quantum Ontology: A Guide to the Metaphysics of Quantum Mechanics* (2016), Lewis, pg. 44-55, 72-97, and Chapter 7: Dimensions

Philosophy of Physics, Volume 2: Quantum Theory (2017), Maudlin, Chapter 4: Collapse Theories and the Problem of Local Beables

Optional: "On the Common Structure of Bohmian Mechanics and the Ghirardi-Rimini-Weber Theory" (2008), Allori, Goldstein, Tumulka, and Zanghì, Section 3

"Elementary Quantum Metaphysics" (1996), Albert

"The Status of our Ordinary Three-Dimensions in a Quantum Universe" (2010), Ney

"Parameter Diagrams of the GRW and CSL Theories of Wavefunction Collapse" (2012), Feldmann and Tumulka

"The Quantum Measurement Problem: State of Play" (2007), Wallace, Section 5

Wk 6 **Bohmian Mechanics**

Reading: *Quantum Ontology: A Guide to the Metaphysics of Quantum Mechanics* (2016), Lewis, Section 3.3 and Chapter 5: Causation

Philosophy of Physics, Volume 2: Quantum Theory (2017), Maudlin, Chapter 5: Pilot Wave Theories

Optional: *Quantum Mechanics and Experience* (1992), Albert, Chapter 7: Bohm's Theory [see the glossary on Albert's terminology posted on the course website]

"Understanding Bohmian Mechanics: A Dialogue" (2004), Tumulka

"Bohmian Mechanics" (2017), Goldstein

LMUcast: FAQ on Bohmian Mechanics (2013), workgroup on Bohmian mechanics at Ludwig-Maximilians-Universität München [video]

"Quantum States for Primitive Ontologists: A Case Study" (2012), Belot

"Bohmian Mechanics and the Meaning of the Wave Function" (1996), Dürr, Goldstein, and Zanghì

Bohmian Mechanics (2013), Teufel [video lecture from QTWOIII]

"Quantum Equilibrium and the Origin of Absolute Uncertainty" (1992), Dürr, Goldstein, and Zanghì

The Quantum Theory of Motion (1993), Holland, Section 3.6

"Beyond the Quantum" (2009), Valentini

"The Emergence and Interpretation of Probability in Bohmian Mechanics" (2007), Callender

Wk 7 **The Many-Worlds Interpretation (the case in favor)**

Reading: *Quantum Ontology: A Guide to the Metaphysics of Quantum Mechanics* (2016), Lewis, Sections 3.4 and 3.5

The Emergent Multiverse (2012), Wallace, Chapters 1 and 4 + First and Second Interludes

Optional: "'Relative State' Formulation of Quantum Mechanics" (1957), Everett

"The Everett Interpretation" (2013), Wallace

"Probability in the Everett Interpretation" (2006), Greaves

"How to Prove the Born Rule" (2010), Wallace

"Understanding Deutsch's Probability in a Deterministic Multiverse" (2004), Greaves

"Probability in the Many-Worlds Interpretation of Quantum Mechanics" (2011), Vaidman

"Bell Inequality and Many-Worlds Interpretation" (2015), Vaidman

"Solving the Measurement Problem: De Broglie–Bohm Loses Out to Everett" (2005), Brown and Wallace

Wk 8 **The Many-Worlds Interpretation (the case against)**

Reading: *Philosophy of Physics, Volume 2: Quantum Theory* (2017), Maudlin, Chapter 6: Many Worlds

"Many Worlds and Schrödinger's First Quantum Theory" (2010), Allori, Goldstein, Tumulka, and Zanghì

Optional: *Quantum Ontology: A Guide to the Metaphysics of Quantum Mechanics* (2016), Lewis, Chapter 6: Determinism

"Probability in the Everett Picture" (2010), Albert

"Decisions, Decisions, Decisions: Can Savage Salvage Everettian Probability?" (2010), Price

"Measurement Outcomes and Probability in Everettian Quantum Mechanics" (2007), Baker

"Everettian Quantum Mechanics and Physical Probability: Against the Principle of 'State Supervenience'" (2016), Jansson

Wk 9 **Removing the Wave Function**

Reading: "One World, One Beable" (2015), Callender

"Guest Post: Chip Sebens on the Many-Interacting-Worlds Approach to Quantum Mechanics" (2014), Sebens

"Quantum Mechanic as Classical Physics" (2015), Sebens

Optional: "Humean Supervenience" (1996), Loewer

"Quantum Entanglement, Bohmian Mechanics, and Humean Supervenience" (2014), Miller

"Quantum Phenomena Modeled by Interactions between Many Classical Worlds" (2014), Hall, Deckert, and Wiseman

"Communication: Quantum Mechanics without Wavefunctions" (2012), Schiff and Poirier

"Inequivalence between the Schrödinger Equation and the Madelung Hydrodynamic Equations" (1994), Wallstrom

The Quantum Theory of Motion (1993), Holland, pg. 27-78

Wk 10 **Revisiting the Scientific Realism Debate in Light of Quantum Mechanics**

Reading: "Scientific Realism and Primitive Ontology" (2016), Allori

"Realism and Underdetermination: Some Clues from the Practices-Up" (2001), Cordero

Optional: "Everett and Structure" (2003), Wallace

"What Should Philosophers of Science Learn from the History of the Electron?" (2004), Bain and Norton

"Are our Best Physical Theories (Probably and/or Approximately) True?" (2003), Barrett

"Scientific Realism in the Age of String Theory" (2007), Dawid

Summer Reading

Philosophy of Physics, Volume 2: Quantum Theory (2017), Maudlin, Chapter 7: Relativistic Quantum Field Theory