**Philosophy of Cosmology**
Meeting time: Wednesday, 11:30 - 2:30, StH 1145

Chris Smeenk
Office Hours: Friday, 2:30 - 3:30, or by appointment
Email: csmeenk2@uwo.ca; phone ext. 85770

A number of challenging questions arise in contemporary cosmology, and philosophers can contribute constructively to answering them. Over the last century cosmologists have debated whether, for example, this field requires a distinctive methodology due to the unusual nature of its subject matter. In what sense is cosmology a "special case," in terms of its aims, the nature of cosmological theories, or the ability to establish theories empirically? New cosmological theories have also prompted new theories of how science works, with scientists revisiting basic questions about evidence and method. For example, "anthropic reasoning" is sometimes thought to require new rules for using evidence. Cosmology also has implications for various foundational problems in physics. For example, does modern cosmology support a neo-Boltzmannian account of the arrow of time? How should we understand "spacetime geometry" in alternative theories of gravitation, or in theories according to which spacetime "emerges"? This seminar will provide a survey of several central questions, with some topics explored in more depth. These topics connect with different areas of philosophy: philosophy of physics, general issues in philosophy of science (confirmation theory, modeling), and metaphysics (modalities). The choice of questions will be dictated in part by the interest and background of seminar participants.

*Evaluation:*

- Participation (20 %): participation during the seminar, and contributions to online discussions of assigned readings (due Tuesday before class at 5:00 pm).
- Paper(s) (80 %): either a research paper due at the end of the semester, or a series of three shorter papers (ca. 8 pages each) handed in over the course of the seminar.

**Tentative Schedule**

*Introduction and Background* (roughly 3 seminar sessions)

My aim in the opening sessions will be to provide a self-contained introduction to the Standard Model of cosmology, with an eye to topics we will focus on later in the term. I will provide handouts for these sessions, and there are many texts covering similar territory. Here are a few that are particularly useful texts (listed, roughly, in order of technical background assumed):

- Geroch (1981), *General Relativity from A to B*. University of Chicago Press. Beautifully executed introductory text.
- Torretti (2000), "Spacetime Models of the World" *SHPMP* **31**: 171-186. Concise historical and philosophical discussion of the early days of relativistic cosmology.
- Penrose (2003), *Road to Reality* (primarily Chapters 17-19, 27-28). Clear discussion, intermediate level (technical details not essential to exposition).
- Dodelson, S. (2003). *Modern cosmology.* New York: Academic Press. A good textbook treatment, not presuming knowledge of general relativity and covering a variety of topics in addition to relativistic models.
- Malament, D. (2007). "Classical General Relativity," in *Handbook for the Philosophy of Physics*, J. Earman and J. Butterfield, eds., Elsevier, 2007; and (2012). *Topics in Foundations of General Relativity and Newtonian Gravitation Theory*. Masterful treatments of foundations of the theory, with assorted special topics. (Both available online here.)

- Wald, R. (1984). *General Relativity*. Chicago: University of Chicago Press. Exemplary graduate level physics textbook.

Recent surveys of philosophy of cosmology might also be useful, although they do not cover the same topics we will discuss:

- Ellis, G. F. R. (2007). "Issues in the philosophy of cosmology." In *Handbook for the Philosophy of Physics*, J. Earman and J. Butterfield, Elsevier, pp. 1183 - 1286; and "On the philosophy of cosmology" *SHPMP* **46**: 5-23.
- "Philosophy of Cosmology" in *Oxford Handbook for the Philosophy of Physics*, ed. by Batterman. Oxford: Oxford University Press (2013), pp. 607-652.

We will then consider some of the topics listed below, based in part on the interests of enrolled students. I will also adjust the reading list as the term progresses, depending on how much time we devote to each topic, and what level of technical detail is appropriate.

*Cosmology as a Special Case?*

Modalities, Laws, and Explanation in Cosmology

- Munitz, M. K. (1962). "The Logic of Cosmology." *British Journal for the Philosophy of Science*, **13**:34 - 50.
- Smolin and Unger (2015), *The Singular Universe and the Reality of Time*. Cambridge University Press. (Selections.)
- Sklar, L. (1990). "How free are initial conditions?" In *Proceedings of the Biennial Meeting of the PSA*, pp. 551-564).

*Cosmology and Epistemology: Fine-Tuning, Anthropic Reasoning, and All That...*

The Anthropic Principle, Selection Effects, and Typicality

- Bostrom, N. (2002b). *Anthropic Bias: Observation Selection Effects in Science and Philosophy.* New York: Routledge.
- Earman, J. (1987). "The SAP also rises: A critical examination of the anthropic principle." *American Philosophical Quarterly* 24, 307317.
- Elga, A. (2000). "Self-locating belief and the sleeping beauty problem." *Analysis* 60, 143147.
- Hartle and Srednicki (2007), "Are We Typical?" hep-th/0704.2630.
- Neal, R. (2006). "Puzzles of Anthropic Reasoning Resolved Using Full Non-indexical Conditioning." arXiv:math/0608592
- Roush, S. (2003). "Copernicus, Kant, and the anthropic cosmological principles." *SHPMP* **34**: 5-35.

Fine-Tuning and the Multiverse

- Norton, John D. "Cosmic confusions: Not supporting versus supporting not" *Philosophy of Science* **77** (2010): 501-523.
- Kotzen, M. (2012). "Selection Biases in Likelihood Arguments" *BJPS* **63**: 825-239.
- Parfit, D. (1998). "Why Anything? Why This?" *London Review of Books*
- Weinberg, S. (2007). "Living in the multiverse." In B. Carr (ed). *Universe or multiverse?*. Cambridge: Cambridge University Press.
- White, R. (2000). "Fine-tuning and multiple Universes." *Noûs* **34**, 260276

Non-Empirical Confirmation

- Dawid (2014), *String Theory and the Scientific Method.* (Selections)

· (Articles from “Why Trust Theory?” conference, if available.)

*Foundations of Physics*

Cosmology, Time’s Arrow, and the “Past Hypothesis”

· Albert, D. (2000). *Time and Chance*. Cambridge, MA: Harvard University Press. (Selections.)

· Earman, J. (2006). “The ‘Past Hypothesis’: Not even false.” *SHPMP* **37**: 399-430.

· North, J. (2011). “Time in thermodynamics,” in *The Oxford Handbook of Philosophy of Time*: 312-350.

· Torretti, R. (2007) “The problem of time’s arrow historico-critically reexamined.” *SHPMP* **38**: 732-756.

· Wallace, D. (2010). “The Logic of the Past Hypothesis.”

· Winsberg, E. (2004). “Can conditioning on the ‘past hypothesis’ militate against the reversibility objections?” *Philosophy of Science*.

Underdetermination of Global Structure

· Malament, D. (1977). “Observationally Indistinguishable Spacetimes,” in Earman, J., Glymour, C., Stachel, J. *Foundations of Space-Time Theories*, University of Minnesota Press, 1977.

· Manchak, J. B. (2009). “Can we know the global structure of spacetime?” *SHPMP* **40**: 53-56.

Dark Matter / Energy vs. Modified Gravity

· Uzan, J. P. (2010) “Dark Energy, Gravitation, and the Copernican Principle,” in *Dark Energy*, ed. by P. Ruiz-Lapuente. Cambridge: Cambridge University Press.

· Bekenstein, J. (2010) “Modified Gravity as an alternative to dark matter” astro-ph/1001.3876.

Inflationary Cosmology

· Background on inflationary cosmology (e.g.): “An Introduction to Cosmological Inflation,” A.R. Liddle, astro-ph/9901124.

· Earman and Mosterin (1999). “A Critical Look at Inflationary Cosmology” *Philosophy of Science*

· Ijjas, Steinhardt, and Loeb (2014). “Inflationary Schism” *Physics Letters B*: 736: 142-146.

· Guth, Kaiser, and Nomura (2014).“Inflationary paradigm after Planck 2013.” *Physics Letters B* 733 (2014): 112-119.

The Cosmological Constant Problem

· Zee (2010), *Quantum Field Theory in a Nutshell* (selection).

· Saunders (2002). “Is the Zero-Point Energy Real?” in *Ontological aspects of quantum field theory*, pp. 313-343.

· Bianchi and Rovelli, “Why all these prejudices against a constant?” astro-ph/1102.3966

*Other Possible Topics*

· Cosmology as a “historical science”

· Physics in a large (or infinite) universe (e.g., status of the Born rule)

· Modeling and simulations in cosmology

· Emergence of spacetime

· Cosmological Phase Transitions

· Measure Problem in the Multiverse

**Spacetime**

"Object $A$ truly moves iff ..."

(i) Object A occupies different regions of absolute space over time; *inertial motion* is motion such that A moves in a straight line with uniform speed (equal distances traversed in equal times);

(ii) Object A occupies different regions of a relative space over time – i.e. space defined with respect to an (arbitrarily chosen) reference frame;

(iii) Object A truly moves is if there is a force acting on the body; inertial motion corresponds to no net force applied to the object.

Newton's arguments (contra Descartes, Leibniz): (ii) cannot be used in place of (i); dynamical account of the causes of motion, with emphasis on (iii), requires (i).

Newton's formulation of Galilean Relativity (Corollary V to the Laws of Motion):

> When bodies are enclosed in a given space, their motions in relation to one another are the same whether the space is at rest or whether it is moving uniformly straight forward without circular motion.

What assumptions about space and time are actually needed to formulate classical, Newtonian mechanics? What spacetime structures are compatible with Galilean relativity?

Classical Spacetime Structures

- *Chrono-geometric structure: separate* structures for spatial distances on instantaneous slices $\Sigma$ (Euclidean geometry) and temporal distance. Spacetime treated as a "stack" of instants, $\Sigma \times \Re$.
- *Inertial structure:* definition of force-free motions, requires definition of "straight line in space-time" (affine connection). *Do not* have (non-degenerate) "space-time metric" that gives *four-dimensional* distance between events; locations over time only defined with respect to an inertial reference frame (choice of "vertical line" in stack).
- *Affine Connection:* This is the structure that allows for definition of inertial motion in four dimensions. (Allows one to define "acceleration," but without treating it as the second derivative of position.)

Steps Toward General Relativity

- *Absolute Simultaneity:* observer-independent sorting of events into instantaneous slices $\Sigma$, conflicts with electrodynamics: light has fixed, frame-independent speed $c$, does not obey usual velocity addition laws; symmetries of electrodynamics include "Lorentz boosts" rather than "Galilean boosts". Leads to Minkowski spacetime, in which simultaneity is frame-dependent. Fundamental geometric quantity: four-dimensional spacetime distance between events; separate spatial and temporal intervals frame-dependent.
- *Distinction between Inertia and Gravity:* principle of equivalence undermines attempt to separate inertial structure and gravitational force, leads to combined "inertio-chrono-geometric" structure with gravity represented via spacetime curvature. Force-free motions now treated as *geodesics*, shortest paths in curved geometry; geometry dynamical, curvature depends upon presence of matter.