Geneva Summer School in the Philosophy of Physics

Scientific Programme — 27 July-2 August 2008

Organizing Committee

Kevin Mulligan (Director), Department of Philosophy, University of Geneva

Philipp Keller, Department of Philosophy, University of Geneva

Vincent Lam, Department of Philosophy, University of Lausanne

Christian Wüthrich, Department of Philosophy, University of California, San Diego

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1 Short Programme

Sunday, 27 July

Evening: Registration and welcome drink

20:00-21:40 Mulligan and then Leuenberger 1

Monday, 28 July

09:30-11:00 Butterfield 1

11:00-11:30 Coffee break

11:30-13:00 Dieks 1

13:00-14:30 Lunch

14:30-16:00 Norton 1

16:00-16:30 Coffee break

16:30-18:00 Leuenberger 2

19:00-20:00 Dinner

Tuesday, 29 July

09:30-11:00 Butterfield 2

11:00-11:30 Coffee break

11:30-13:00 Dieks 2

13:00-14:30 Lunch

14:30-16:00 Huggett 1

16:00-16:30 Coffee break

16:30-18:00 Rovelli 1

19:00-20:00 Dinner

Wednesday, 30 July

09:30-11:00 Norton 2

11:00-11:30 Coffee break

11:30-13:00 Dieks 3

13:00-14:00 Lunch

14:00-19:00 Excursion

19:00-20:00 Dinner

Thursday, 31 July

09:30-11:00 Huggett 2

11:00-11:30 Coffee break

11:30-13:00 Butterfield 3

13:00-14:30 Lunch

14:30-16:00 Lam 1

16:00-16:30 Coffee break

16:30-18:00 Wüthrich 1

19:00-20:00 Dinner

Friday, 1 August

09:30-11:00 Rovelli 2

11:00-11:30 Coffee break

11:30-13:00 Huggett 3

13:00-14:30 Lunch

14:30-16:00 Lam 2

16:00-16:30 Coffee break

16:30-18:00 Wüthrich 2

19:00-20:00 Dinner

Saturday, 2 August

09:30-11:00 Rovelli 3

11:00-11:30 Coffee break

11:30-13:00 Norton 3

13:00-14:30 Lunch

14:30 End

2 Notes on Speakers

Jeremy Butterfield is a Senior Research Fellow in philosophy of physics at Trinity College, Cambridge, England. He previously worked at the University Cambridge (1981-97), and All Souls College, Oxford (1998-2006). He has published in various journals in philosophy and in physics.

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Dennis Dieks studied theoretical physics at the University of Amsterdam, after which he wrote a dissertation in Foundations of Physics at Utrecht University. Since 1993 he is Professor of the Philosophy and Foundations of the Natural Sciences at Utrecht University and director of the Utrecht Institute for the History and Foundations of Science. Dennis Dieks is a member of several professional organisations, Editor of the journal *Studies in the History and Philosophy of Modern Physics* and Associate Editor of *Foundations of Physics*. He has published widely on subjects relating to space and time, the foundations and philosophy of quantum theory, and the philosophy of physics in general.

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Nick Huggett (University of Illinois at Chicago) works in the philosophy of physics and science. He is completing a book on the metaphysics of space, *True Motion*, which deals with the history of space in mechanics from the early modern period to the present, and proposes a new relational account of spacetime, based on his "The Regularity Account of Relational Spacetime" (*Mind*, 2006). He also works on the foundations of quantum mechanics, particularly in quantum field theory (e.g., "Philosophical Foundations of Quantum Field Theory', *British Journal for the Philosophy of Science* 2000), and the theory of identical particles. His interests in space and quantum mechanics come together in work on quantum theories of gravity: with Craig Callender he edited *Physics Meets Philosophy at the Planck Scale* (CUP, 2001) and currently is working on the metaphysical implications of string theory.

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Vincent Lam is a Junior Fellow in Epistemology and Philosophy of Science at the University of Lausanne, where he wrote his dissertation about space-time philosophy. He has previously studied theoretical physics at the Swiss Federal Institute of Technology. He has published in various journals in philosophy of physics.

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Stephan Leuenberger (University of Leeds) works in metaphysics and neighbouring areas of the philosophy of science and the philosophy of mind. He has published on physicalism, modality, and supervenience. After studies in Bern (Lic. Phil), Oxford (BPhil), and Princeton (PhD), and research fellowships at the Australian National University and the University of Leeds, he will take up a Lectureship at the University of Glasgow in September 2008.

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John D. Norton is Director of the Center for Philosophy of Science, University of Pittsburgh. He writes in history and philosophy of physics, with special emphasis on the work of Einstein and his discovery of general relativity. He also writes on general philosophy of science including theories of induction and confirmation, causation and thought experiments.

`jdnorton@pitt.edu` `http://www.pitt.edu/~jdnorton/`

Carlo Rovelli is Professor of Physics at the University of Marseille and member of the Institut Universitaire de France. PhD in Padova 1986. He has worked in Italy, the USA and France. Main research interest: quantum gravity. Books: *Quantum Gravity* (CUP), *What is time? What is space?* (DiRenzo).

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Christian Wüthrich is an Assistant Professor of Philosophy and Science Studies at the University of California, San Diego. He received his PhD in History and Philosophy of Science from the University of Pittsburgh after having read physics, mathematics, philosophy, and history and philosophy of science at Berne, Cambridge, and Pittsburgh. He has published in various journals in philosophy and in physics.

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3 Long Programme

Sunday, 27 July

Registration and Welcome (Evening)

Mulligan: Welcome Message from the Director (20:00-20:10)

Leuenberger: "Time and tense" (20:10-21:40) **Leuenberger 1**

Some present-day physical theories suggest that there is no such thing as time. In metaphysics, the question of the reality of time has a longer history: it came to prominence with McTaggart's famous argument. I will discuss his argument, and the main positions in the metaphysics of time that have been developed in reaction to it. One response is to deny McTaggart's premise that the reality of time requires the reality of the A-series: the B-series is enough. Time is then seen on the model of space. Another response is to deny McTaggart's claim that the A-series generates a contradiction. To do that, one can construe non-present times akin to non-actual possibilities, or possible worlds. Time bears striking analogies and also some disanalogies to both space and modality, and one's metaphysical view of time will depend largely on which analogy one is more impressed by. My discussion will focus on the analogies between time and modality, and on how this can be taken to support presentism, the view that only present things exist. I may also give an introduction to tense logic and its semantics, which treats time instants in the same way as modal logic treats possible worlds.

Suggested readings:

- J. Ellis McTaggart, "The Unreality of Time", *Mind* (New Series) **17** (1908): 457-474.

Alternatively, the slightly revised text from McTaggart's book *The Nature of Existence*, which is reprinted in various anthologies.

Monday, 28 July

Butterfield: "The persistence of objects through time" (9:30-11:00) **Butterfield 1**

I will first introduce the metaphysical debate whether objects persist over time by the selfsame object existing at different times (nowadays called '*endurance*' by metaphysicians), or by different temporal parts, or stages, existing at different times (called '*perdurance*'). Then I will discuss the rotating discs argument (RDA) against perdurantism. I will argue for three main conclusions. The first is that the RDA can be formulated more strongly than is usually recognized: it is not necessary to 'imagine away' the dynamical effects of rotation. The second is that in general relativity, the RDA fails because of frame-dragging. The third is that even setting aside general relativity, the strong formulation of the RDA can after all be defeated. Namely, by the perdurantist taking objects in classical mechanics (whether point-particles or continuous bodies) to have only temporally extended, i.e. non-instantaneous, temporal parts.

Suggested readings:

- Jeremy Butterfield, "On the Persistence of Particles", *Foundations of Physics* **35** (2005): 233-269. Weblink.
- Jeremy Butterfield, "The Rotating Discs Argument Defeated", *British Journal for the Philosophy of Science* **57** (2006): 1-45. Weblink.

Dieks: "Time in special relativity" (11:30-13:00) **Dieks 1**

After reviewing the structure of special relativistic spacetime, both from an Einsteinian and a Minkowskian viewpoint, I will turn to the peculiarities of special relativistic time. I will pay particular attention to the question of whether special relativistic simultaneity is in an interesting sense merely conventional (as was proposed and defended by Reichenbach). In connection with this I will also discuss a bit of the history of the philosophy of space and time, relating to the development of Reichenbach's ideas.

Suggested readings:

- Dennis Dieks, "The Adolescence of Relativity: Einstein, Minkowski, and the Philosophy of Space and Time" (and references contained therein). Weblink

Norton: "Causation as folk science" (14:30-16:00) **Norton 1**

Causal talk and causal notions permeate our discussions both inside and outside science. Most of us feel that we have not really understood a phenomenon until we have a grasp of the causal processes that underlie it. Is this pervasive use of causal talk merely a convenient language through which we can readily picture the processes of the natural world? Or does it derive from a deeper fact about nature that is antecedent to all science? That deeper fact I call "causal fundamentalism." It presupposes that the world is governed by a factual principle of cause and effect and that the burden of the individual sciences is to find its expression in their particular domain.

I will describe a form of skepticism about causation that denies this doctrine of causal fundamentalism. It will be defended by general arguments and also through an examination of the causal principles that form part of the foundations of many physical theories.

Suggested readings:

- John D. Norton, "Causation as Folk Science," *Philosophers' Imprint* **3** (2003): 1-22. Weblink.
- John D. Norton, "Do the Causal Principles of Modern Physics Contradict Causal Anti-Fundamentalism?" in P. K. Machamer and G. Wolters (eds.), *Thinking about Causes: From Greek Philosophy to Modern Physics*, Pittsburgh: University of Pittsburgh Press (2007), 222-234. Weblink.
- An optional reading for those who are really keen: (This is my end of a debate with Mathias Frisch over whether dispersion theory requires an independent principle of causality.) "Is There an Independent Principle of Causality in Physics?" Weblink.

Leuenberger: "Causation" (16:30-18:00) — Leuenberger 2

Causation is appealed to in many influential philosophical theories. But do we have a good understanding of what causation is? Many purported analyses, involving regularities, counterfactuals, and probabilities, have been offered, and none seems to be successful. In the recent debate, there has been a re-evaluation of what a philosophical account of causation is meant to achieve. According to Phil Dowe, we should distinguish the project of giving a conceptual analysis from the project of offering a theory what causation actually is in our world. According to Ned Hall, we should distinguish two different concepts of causation. I will discuss their views, and will also touch on themes of Norton's Lecture 1. I may also talk about the interplay between philosophical accounts of time and of causation.

Suggested readings:

- Phil Dowe, "The Conserved Quantity Theory of Causation and Chance Raising", *Philosophy of Science* **66** (1999): S486-S501. Supplement. *Proceedings of the 1998 Biennial Meetings of the Philosophy of Science Association*, Part I (Contributed papers).
- optional: Ned Hall, "Two Concepts of Causation", in Collins, Hall, Paul (eds.), *Causation and Counterfactuals*, OUP 2004. Weblink.

Tuesday, 29 July

Butterfield: "Spacetime in classical theories, including field theories" (9:30-11:00) Butterfield 2

I aim to cover three topics. (i): I will review some basic concepts and issues of spacetime theories; the recommended reading is Norton's Chapter in Introduction to the Philosophy of Science (1992) edited Merrilee Salmon. (ii) I will briefly discuss the Putnam-Rietdijk argument that relativity theory is incompatible with temporal becoming (or a "flow of time"). (iii) I will introduce Machian and relationist approaches to spacetime theories; emphasizing the metaphysical aspects of the views of Julian Barbour.

Suggested readings:

- For (i): John Norton, "Introduction to the Philosophy of Space and Time," in *Introduction to the Philosophy of Science*, Prentice-Hall (reprinted 1999, Hackett; Greek edition, 1998). Reprinted in J. Butterfield, M. Hogarth and G. Belot (eds.), *Spacetime: The International Research Library of Philosophy* (Aldershot: Dartmouth) **17** (1996): 3-56. Weblink.

- For (iii): Jeremy Butterfield, "The End of Time?", *British Journal for the Philosophy of Science* **53** (2002): 289-330 (Ostensibly a review of J. Barbour, *The End of Time*, this is in effect a survey of some Machian themes in dynamics); Weblink to BJPS (short version) Weblink to the long version.

Dieks: "Kinematical vs dynamical explanation in special relativity" (11:30-13:00) **Dieks 2**

Lorentz once complained that Einstein just postulated what he himself tried to explain. Indeed, one of the significant differences between the theories of Lorentz and Einstein is Lorentz's bottom-up versus Einstein's top-down approach (corresponding to the difference between a constitutive theory and a theory of principle). From the early days of relativity Einstein's rather abstract top-down methodology has given rise to the misunderstanding that causal explanations of effects like time dilation and length contraction are impossible. A more sophisticated issue is whether causal, bottom-up explanations, even if possible, are appropriate; this question has become the subject of extensive debate during the last decade or so. We will discuss this history and the various positions that can be taken; and will adopt a rather "relativist" and pragmatic position ourselves.

Suggested readings:

- Dennis Dieks, "Bottom-Up versus Top-Down: The Plurality of Explanation and Understanding in Physics" (and references contained therein). Weblink.
- Dennis Dieks, "Space, Time and Coordinates in a Rotating World", in G. Rizzi and M.L. Ruggiero (eds.), *Relativity in Rotating Frames* Kluwer (2004), 29-43. Weblink.

Huggett: "Absolute space and motion" (14:30-16:00) **Huggett 1**

In the historical component of my first two lectures we will discuss the attempts of some key figures—Descartes, Newton and Leibniz—to understand the role and nature of motion in the developing mechanics of the late Seventeenth Century. On the one hand there is the question of relativity—apparent in linear collisions but seemingly not in rotations—while on the other attempts to define a notion of motion in the face of the needs of mechanics and the evolving understanding and debates about scientific norms.

In this lecture we will focus on Newton's development of absolute motion as a response to the inadequacy of conceptions provided by Descartes for mechanics. We will see how twentieth century philosophers developed an interpretation of spacetime theories from certain aspects of Newton's views, in the light of subsequent developments in physics and philosophy.

Suggested readings:

- Descartes, *Principles of Philosophy*, Book II 10-25. Weblink.
- Newton, *Scholium on Time and Space*. Weblink.
- Huggett and Hoefer, "Absolute and Relational Theories of Space and Motion", *Stanford Encyclopedia of Philosophy*, §1-5. Weblink.

The primary sources I have provided are not necessarily the best translations, but they are what is available online. A source of some better versions is my *Space from Zeno to Einstein* (MIT Press, 1999).

Rovelli: "General Relativity. What have we learned about space and time?" (16:30-18:00) **Rovelli 1**

General Relativity, which Landau called "the most beautiful" of the scientific theories, has modified our basic understanding of the world in great depth, to an extent which, in my opinion, has not been fully unraveled yet. In this lecture, I try to summarize how the theory has modified our understanding of Nature. The change goes much deeper than the idea that spacetime is curve; it questions the very notions of "state", "observable quantity" and "evolution" that were so effective in Newtonian physics.

Suggested readings:

- Excerpts from Carlo Rovelli, *Quantum Gravity*, Cambridge University Press (2004).

Wednesday, 30 July

Norton: "Einstein's Methods and His Discovery of General Relativity" (9:30-11) **Norton 2**

No one in science, not even an Einstein, makes worthy discoveries without undertaking a systematic investigation. What sorts of conceptions governed the systematic part of Einstein's investigations? I will outline one notion that played an important role in Einstein's discovery of general relativity. It is Einstein's distinction between thinking physically and thinking formally. I will illustrate how Einstein consciously shifted back and forth between these two modes of thinking in the years leading up to his discovery of general relativity. We will see some pages from Einstein's "Zurich Notebook" which contains Einstein's scratch pad calculations at the decisive period of his discovery of general relativity.

Suggested readings:

- John D. Norton, " 'Nature in the Realization of the Simplest Conceivable Mathematical Ideas': Einstein and the Canon of Mathematical Simplicity," *Studies in the History and Philosophy of Modern Physics* **31** (2000): 135-170. Weblink.
- For an easy read on a big topic: John D. Norton, "How Did Einstein Think?". Goodies Page.
- John D. Norton, "A Peek into Einstein's Zurich Notebook". Weblink.
- Optional: For a fairly detailed reconstruction of one episode, see: "A Conjecture on Einstein, the Independent Reality of Spacetime Coordinate Systems and the Disaster of 1913," pp. 67-102 in A. J. Kox and J. Einsenstaedt, eds., *The Universe of General Relativity.* Einstein Studies Volume 11. Boston: Birkhaeuser, 2005. Weblink.

Dieks: "Mach's principle and the beginning of modern cosmology" (11:30-13:00) **Dieks 3**

One of the heuristic motifs guiding Einstein's thought during his work on general relativity was "Mach's principle". Mach himself was not all too clear about this principle, and different versions of it can be found in the literature. The way Einstein understood it was in a relationist way: only material systems and their mutual relations should be accepted as physically significant, and there should be no role for an independently existing spacetime. However, Einstein soon realized that general relativity was not in accordance with this desideratum. In his paper of 1917, "Cosmological considerations on the general theory of relativity" which marks the beginning of modern cosmology, he attempted to rectify the situation by introducing the "cosmological constant" in his field equations. Later folklore has it that Einstein's motivation for this modification of GRT was first of all his wish to ensure the possibility of a static solution, but this was only coincidental to his project: Mach's principle was essential. However, after 1917 Einstein's adherence to this principle started to quickly evaporate.

Suggested readings:

- Dennis Dieks, "Another look at general covariance and the equivalence of reference frames", *Studies in History and Philosophy of Modern Physics* **37** (2006): 174-191 (and references contained therein!). Weblink.

Afternoon: Excursion

Thursday, 31 July

Huggett: "Relative space and motion" (9:30-11:00) Huggett 2

In this lecture we will continue to investigate the historical roots of the absolute-relative debate, this time understanding Leibniz's relationism--which turns out to look rather different from the way it is usually understood. We will then look at the critique of relationist views launched by contemporary philosophers in the absolute tradition.

Suggested readings:

- Leibniz, Extracts from the Leibniz-Clarke Correspondence. Weblink.
- Huggett, "Quick Guide to the Leibniz-Clarke Correspondence". Weblink.
- Huggett and Hoefer, "Absolute and Relational Theories of Space and Motion", *Stanford Encyclopedia of Philosophy*, §6-8. Weblink.
- Huggett, "Relationism, Explanation and Instrumentalism". Weblink 1 and Weblink 2.

Butterfield: "The interpretation of general relativity" (11:30-13:00) Butterfield 3

The interpretation of general relativity I aim to cover three topics. (i) I will say more about Machian and relationist themes, as they apply to general relativity; cf. topic (iii) of Butterfield Lecture 2. (ii) I will discuss the constructivist approach to spatial and spacetime geometry, in particular Brown's recent defence of it. This will give an interpretative perspective for discussing the principle of equivalence. It will also pick up on some themes in Norton's Lecture 1 and Dieks Lecture 2. (iii) I will discuss from a philosophical, indeed mostly metaphysical, perspective, Einstein's hole argument. This will give an interpretative perspective on the principle of general covariance. It will also pick up on some themes in Rovelli's Lecture 1, Norton's Lecture 2, Lam's Lecture 1 and Huggett's Lecture 2.

Suggested readings:

- For (ii) Jeremy Butterfield, "Reconsidering Relativistic Causality", *International Studies in the Philosophy of Science* **21** (2007): 295-328. ArXiV or PhilSci Archive (OMITTING the final Section 5).
- For (iii): Jeremy Butterfield, "The Hole Truth", *British Journal for the Philosophy of Science* **40** (1989): 1-28.

Lam: "Spacetime structuralism" (14:30-16:00) **Lam 1**

Structural realism is a family of positions in the philosophy of science that have been much debated recently. Indeed, under the banner "structuralism" or "structural realism", broadly conceived, can be found a great variety of conceptions with different motivations. Some of these aim to account for the two main arguments in the debate about scientific realism, namely the "no-miracle" argument and the argument of "pessimistic meta-induction", whereas others rather aim to provide a convincing understanding of (some aspects of) the world as described by current science and in particular by current fundamental physics (some ambitious structuralist conceptions pursue both aims). This lecture will be mainly concerned with this second motivation: I propose to review and discuss the possible relevance of the various contemporary structural realist positions for the interpretation of spacetime as described by the (classical) theory of general relativity. In particular the claim that (suitable) spacetime structuralism provides a meaningful account for the gauge-theoretical aspects of ("substantive") general covariance and of background independence will be evaluated. The various structuralist conceptions of spacetime will also be discussed within the framework of the contemporary debate about the nature of space-time and special attention will be paid to the question of space-time points.

Suggested readings:

- Mauro Dorato, "Substantivalism, relationism, and structural spacetime realism", *Foundations of Physics* **30** (2000): 1605-1628.
- Michael Esfeld and Vincent Lam, "Moderate structural realism about space-time", *Synthese* **160** (2008): 27-46. Weblink.
- Steven French and James Ladyman, "Remodelling Structural Realism: Quantum Physics and the Metaphysics of Structure", *Synthese* **136** (2003): 31-56.
- Dean Rickles and Steve French, "Quantum Gravity Meets Structuralism: Interweaving Relations in the Foundations of Physics", in D. Rickles, S. French and J. Saatsi (eds.), *The Structural Foundations of Quantum Gravity.* Oxford University Press (2006), 1-39.

Wüthrich: "Let's take a ride on a time machine" (16:30-18:00) **Wüthrich 1**

Time travel is compatible with general relativity. At least it is if one defines time travel as the existence of closed timelike curves in spacetime. The question then arises whether the operation of a time machines, i.e. of a device that *produces* closed timelike curves where none would have existed otherwise, is permissible in general relativity. The physics literature contains various theorems which purport to establish that, under physically plausible assumptions, the operation of a time machine is impossible. While I will argue that no conclusive "no-go" theorem of this kind exists either in classical general relativity or in various semi-classical approaches, I hope to convince the audience that the topic is far from merely entertaining as it allows insights into foundational issues at the intersection of classical and quantum gravity.

Suggested readings:

- John Earman, Christopher Smeenk, Christian Wüthrich, "Do the laws of physics forbid the operation of time machines?", *Synthese*, in print.
- John Earman and Christian Wüthrich, "Time machines", *Stanford Encyclopedia of Philosophy* (2004). Weblink.

Friday, 1 August

Rovelli: "Mechanics without time. Is it possible?" (9:30-11:00) **Rovelli 2**

All conventional formulations of mechanics are based on notions (such as "state at given time") that loose their meaning in the general relativistic context. I discuss the possibility of defining the notions of "state" and "observable" in a way that is compatible with the fact that the world is general relativistic. Conceptually, this is the key lecture of the three. I discuss how we can think about the world if a unique time evolution variable is not given.

Suggested readings:

- Excerpts from Carlo Rovelli, *Quantum Gravity*, Cambridge University Press (2004).

Huggett: "The regularity account of relational spacetime" (11:30-13:00)**Huggett 3**

A Humean about laws thinks that they are nothing but the "best" description of the regularities that are manifested in particular events. I propose that the best strategy for the relationist is to argue that the laws of mechanics are nothing but the best description of the regularities that are manifested by the relations between bodies. I show how this view deals with various puzzles about motion and the shape of space—at least in pre-relativistic physics.

Suggested readings:

- Huggett, "The Regularity Account of Relational Spacetime", *Mind* **115** (2006): 41-73. Weblink.

Lam: "Spacetime singularities" (14:30-16:00) **Lam 2**

Within the framework of the (classical) theory of general relativity, there are two main positions with respect to space-time singularities and their generic character due to the famous singularity theorems. First, they can exclusively be thought of as physically meaningless, only revealing that in these cases the theory of general relativity breaks down and must be superseded by another theory (like a future theory of quantum gravity for instance). Therefore, as such space-time singularities do not tell us anything physically relevant. Second, space-time singularities can be taken more "seriously": they can well be considered as physically problematic but nevertheless as involving some fundamental features of space-time as described by (classical) general relativity. In this sense, they truly constitute a foundational issue in the theory and, within this framework, their careful study may be helpful in order to understand the nature of space-time. This lecture aims to investigate this line of thought (which has been importantly advocated by Earman (1995) in the philosophical literature) and discuss some of the philosophically interesting aspects of the "problem" of spacetime singularities. In particular, I will discuss the question of the very definition of the spacetime singularities within classical general relativity and the limitations to the attempts to consider spacetime singularities as "local" entities (in some precise sense).

Suggested readings:

- Eric Curiel, "The Analysis of Singular Spacetimes", *Philosophy of Science* **66** (1999): 119-145 (Proceedings).
- John Earman, *Bangs, Crunches, Whimpers, and Shrieks: Singularities and Acausalities in Relativistic Spacetimes*, Oxford University Press (1995), chapters 2 and 3.

- Vincent Lam, "The singular nature of spacetime", *Philosophy of Science* **74** (2007). Weblink.
- Optional: R. Geroch and G. Horowitz, "Global structure of spacetime", in S. Hawking and W. Israel (eds.), *General relativity*, Cambridge University Press (1979), 212-289.

Wüthrich: "Einstein's nemesis conquered at last?" (16:30-18:00) Wüthrich 2

Loop quantum cosmology is an attempt to produce cosmological models based on a quantum theory of gravity, loop quantum gravity. It freezes out all but one degree of freedom and thus achieves a drastic simplification of a major technical obstacle in fulfilling the canonical quantization programme of loop quantum gravity. Proponents of loop quantum cosmology have claimed that their models "smooth out" the classically unavoidable initial singularity in two different senses: first, the curvature does not increase without bound for arbitrarily small scale factors; and second, there exists a principled way of extending the models through the initial singularity into a mirror universe. The singularity, as my evaluation will show, does vanish in the sense that the unphysical dynamical evolution so dear to loop quantum cosmologists effectively manages to penetrate back into a mirror world of "before the big bang". At the same time, however, the singularity is not completely exterminated despite what is claimed. It survives in the sense that Laplacean determinism still fails at the big bang, although the failure is milder than in classical models.

Suggested readings:

- Christian Wüthrich, *Approaching the Planck Scale from a Generally Relativistic Point of View: A Philosophical Appraisal of Loop Quantum Cosmology*, Dissertation, University of Pittsburgh (2006), Chapters 7 and 8.
- Martin Bojowald, "Loop Quantum Cosmology", *Living Reviews in Relativity* **8** (2005): 11. Weblink.
- Abhay Ashtekar, Martin Bojowald, and Jerzy Lewandowski, "Mathematical structure of loop quantum cosmology", *Adv. Theor. Math. Phys.* **7** (2003): 233-268. Weblink.

Saturday, 2 August

Rovelli: "Quantum mechanics without time. Is it possible?" (9:30-11:00)Rovelli 3

This is the most technical lecture. I ask wether *quantum* mechanics can be compatible with the general relativistic and time-independent notions of "state" and "observable". Until we answer this question, we cannot say that modern physics provides any coherent conceptual framework on Nature at the elementary physical level.

Suggested readings:

- Excerpts from Carlo Rovelli, *Quantum Gravity*, Cambridge University Press (2004).

Norton: "That Damn Dome: Indeterminism in Classical Physics" (11:30-13:00) Norton 3

It has been known for a long time that classical Newtonian physics admits indeterministic systems. They are systems whose present state does not fix their future. These long-known failures of indeterminism, however, have involved exotic systems, such as "space invaders" that rush in from spatial infinity at arbitrarily high velocities; or "supertask systems" in which an infinite collection of masses at rest spontaneously sets itself into motion.

One might convince oneself that these systems can be ignored because they are too exotic to take seriously. That attitude is harder to maintain for the case of the dome. In it, a mass sits at the top of a dome with a specified shape, over which it can slide freely. Newton's laws permit the mass to stay there indefinitely; and, as two lines of calculus show, also permit the mass spontaneously to move at any time and in any direction.

The dome is interesting not just since it displays an interesting sense in which Newtonian physics is indeterministic. It also raises a series of broader questions: Just what is Newtonian physics? Just which idealization are permitted? What does it mean to say a system is "physical"? This last notion proves to be a notion of possibility peculiar to physics that has slipped under the modal philosopher's radar.

Suggested readings:

- The dome is described briefly with animations in: John D. Norton, "The Dome: A Simple Violation of Determinism in Newtonian Mechanics" Goodies page (Section 3 of "Causation as Folk Science"). Weblink.
- John D. Norton, "The Dome: An Unexpectedly Simple Failure of Determinism", *Proceedings of the 2006 Biennial Meeting of the Philosophy of Science Association, Philosophy of Science*, forthcoming. Short version for publication or Original longer version.