Tim Maudlin
Philosophy of Physics: Space and Time.
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Tim Maudlin's *Philosophy of Physics: Space and Time* is the first of a two-volume survey of key foundational issues in the philosophy of physics. The two volumes concern the two historically distinct subject matters of physics: space and time; and their material contents. The present volume is an accessible and highly engaging introduction to the major issues in the physics of space and time that guides the reader through the philosophical foundations of physical geometry, the special and general theories of relativity and the topology of time, and is suitable both for the philosopher with minimal physics background and for the physicist interested in the main historical philosophical issues concerning spacetime theories.

The central theme of Maudlin's presentation of the history of spacetime is a focus on geometrical rather than arithmetical methods. The absence of equations from the presentation of the Newtonian laws of motion is due not to a fear of putting off the lay reader, but rather to the conviction that the arithmetisation of physics is unnecessary and misleading. Aside from the fact that Newton himself used geometry rather than arithmetic to present his theory, Maudlin emphasises that "[t]o put it bluntly, the physical world is not composed of *numbers* or of entities for which the standard arithmetic operations are defined." Rather, "[t]he physical world contains *physical magnitudes* that have a geometrical structure," and hence "[g]eometry is more directly connected to the physical world than is arithmetic" (p. 25, emphases in original). This focus on the geometrical rather than algebraic presentation of theories reflects a major theme in Maudlin's wider work in the philosophy of physics, the idea that the geometrical structure of a theory is a guide to the theory's ontology – what the theory says about the structure of the world. For instance, Maudlin informs the reader that it is crucial to understand Newtonian space in terms of E_3 – a Euclidean three space of points – rather than in terms of $\mathbb{R}_3$ – a triple of real numbers. The reason for this is that it is the former and not the latter that reflects the proper ontological commitments of Newtonian mechanics. Of course, using the algebraic representation of Newtonian spacetime is particularly useful in terms of solving equations, performing calculations, etc., but one should *not* consult the algebraic formulation as a guide to the theory's ontology. What Newtonian mechanics says about the world is encoded in the theory's geometrical structure.

The preference for geometric rather than algebraic presentations of physics focuses on one chief culprit: the coordinate system. Maudlin notes the standard textbook presentations of classical mechanics as centrally involving coordinate systems, origins, frames of reference and other such terms absent from Newton's own presentation ("Newton makes no mention of an "origin""; "[Newton] would have had no idea what a "frame of reference" *was*" [both p. 31, emphasis in original]). The misleading nature of coordinate-dependent representations is most acute in the context of relativity theory (chapters 4-6), Maudlin's transparent and engaging discussion of which being the book's highlight. As with Newtonian mechanics, the special theory of relativity (SR) is presented geometrically and, accordingly, traditional philosophical problems arising from the theory are taken to be aspects of the algebraic approach - “[SR] is a very simple theory that is commonly presented in a complex and confusing way” (p. 67). Due to this, the presentations of special and general relativity (GR) do not follow the historical approach of chapters 1-3. Instead, Maudlin uses a (geometrical) principle-based derivation of the key features of relativistic physics, bypassing a discussion of the pre-Einsteinian development of relativity theory.

At the heart of SR is the light postulate – labelled by Einstein as the ‘principle of the constancy of the velocity of light’. Maudlin notes that the inclusion of terms such as ‘velocity’ at the conceptual heart of the theory is an unfortunate and misleading throwback to Newtonian absolute space and time – “[t]o understand Relativity, we have to expunge all ideas of things having speeds, including light” (p. 68). Rather than grounding SR on the constancy of the speed of light (which Maudlin deems “physically very complicated” [p. 69]), Maudlin takes the heart of the theory to be the lightcone structure – i.e. the geometry of Minkowski spacetime. As such, Maudlin uses geometrical principles (the ‘Law of Light’, ‘Relativistic Law of Inertia’ and ‘Clock Hypothesis’) in place of Einstein’s principles. This makes for a helpful presentation of SR, including a particularly lucid analysis of the twin paradox (pp. 76-83). Here, the heuristic value of the geometrical explanation of relativistic effects is emphasised by contrasting Maudlin’s geometrical account of the ‘paradox’ with a famous account given in Richard Feynman's *Lectures on Physics*; Maudlin notes (polemically though persuasively) of Feynman’s account that “Everything in this “explanation” is wrong” (p. 81). The discussion of relativity culminates in a detailed exploration of the status of spacetime substantivism in the context of GR (ch. 6), with a useful survey of philosophical treatments of the hole argument.

The book takes a marked turn in style in the final chapter, ‘The Direction and Topology of Time’, in which Maudlin declares “we are all inevitably headed toward the grave and away from the nursery” (p. 166). Although as seemingly obvious as it is bleak, Maudlin’s strong form of realism about the direction of time is hardly read off the physics. To point to the relevant background: although weak interactions in particle physics have been shown experimentally to violate time-reversal symmetry (modulo some assumptions that need not worry us here), this in no way distinguishes the two time directions in such a way as to support one being the direction in which processes unfold nor motivate realism about an asymmetric ‘causal production’ relation. We are still left with a key time symmetry - the physics can be taken to govern interactions in either time direction - and so it is superfluous to talk of the 'direction' of processes, or whether the universe is 'really' expanding or contracting, just as coordinate-dependent terms in the context of relativity theory are superfluous. Indeed, just as Maudlin takes the use of terms vestigially attached to coordinate systems (e.g. velocity) to be both parochial and an impediment to understanding the invariant commitments of relativity theory, so too is the use of time-directed terms in the context of physics that requires no distinction between ‘earlier’ and ‘later’. It is natural, for instance, to understand a Newtonian system to be determined by ‘initial’ (as opposed to ‘final’) conditions and a (‘future’-directed) dynamical law, but Newtonian physics does not require this.

Nonetheless, Maudlin’s account of time direction involves a commitment to a fundamental directionality of causation: “there is […] a fundamental direction of time, in virtue of which it is correct to say that the universe is *expanding* and new matter being *created*, rather than *contracting* with matter being *destroyed*" (p. 166). (Maudlin has elaborated on his particular take on time's directionality elsewhere [Maudlin 2007, ch. 4].) Though it may appear quite harmless to attach such a background metaphysic of the passage of time to the physical description of the world, Maudlin takes his realism about time direction to place specific restrictions upon physical explanation, in particular ruling out as unphysical (a) spacetimes containing closed timeline curves (CTCs; worldlines that allow an object to time-travel to its own local past) and (b) temporally non-orientable spacetimes (spacetimes in which there exists no globally consistent division of lightcones into future and past lobes). There is a clear tension between this line of reasoning and the geometrical approach to relativity endorsed in earlier chapters. For instance, Maudlin prescribes the rejection of CTC-containing spacetimes as unphysical in order to preserve the distinction between earlier and later. This line of reasoning is incongruous to that employed in his argument (p. 126) that the existence of vacuum solutions of GR show that spacetime geometry is not determined by matter distribution. Were one to similarly take vacuum solutions, like CTC solutions, to be unphysical, one could maintain the dependence of spacetime geometry upon matter distribution. Just as Maudlin makes the case that classical and relativistic physics needs to be freed from coordinate-dependent presentations (e.g. "modern physics has become so thoroughly arithmetized […] that we cannot readily recognize Newton's original theory in a modern presentation" [p. 31]), one is tempted to read Maudlin's claim that "the direction of time is embedded so deeply into our language and concepts that it is impossible to expunge" (p. 166) as a further challenge for a time-direction-neutral presentation of textbook physics. Maudlin does not view this as a challenge worth taking.

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References

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