Review of Mathias Frisch's *Causal Reasoning in Physics*.[*]

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1 Introduction.

The role of causality in physics presents a problem. Although physics is widely understood to aim at describing the causes of observable phenomena and the interactions of systems in experimental set-ups, the picture of the world given by fundamental physical theories is largely *a*causal: e.g. complete data on timeslices of the universe related by temporally bidirectional dynamical laws. The idea that physics is acausal in nature, or worse, incompatible with the notion of causality, has attracted many adherents. *Causal scepticism* in physics is most associated with Russell's (1913) arguments that a principle of causality is incompatible with actual physical theories. For causal sceptics, insofar as causal reasoning is used in physics, it is at best extraneous and at worst distorts the interpretation of a theory's content.

Mathias Frisch's *Causal Reasoning in Physics* (CRP) is an engaging, persuasive and timely defence of the legitimacy and importance of causal reasoning in physics. Frisch demonstrates that causal scepticism can be overcome via a proper appreciation of the pragmatics of modelling within physics. Frisch argues that causal reasoning plays a key role in physics in this representational way, holding that "there is no good reason for not treating causal structures on a par with other kinds of representational resources that we employ in physics, such as dynamical laws or other kinds of constraints" (p. 11). In this piece I'll

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first summarise what I take to be the key steps in Frisch's defence of causality in physics and, second, assess the significance of the alleged indispensability of causal reasoning in physics. Granted that causal reasoning is indispensable from physics in the sense Frisch describes, it does not follow that physics is 'causal' in a way that conclusively dispels causal scepticism about physics.

2 Overview of *Causal Reasoning in Physics*.

To situate the position of CRP, we can ask:

Q. Is causal reasoning (i.e. the application of causal principles and assumptions):

(a) Possible in physics?

(b) Actually used in physics practice?

(c) Indispensable from physics practice?

Frisch answers 'yes' in each case. However, the consequences in each case are left open, with Frisch taking his project to entail "no commitment to any particular causal metaphysics" (p. 34), nor a pronouncement on the status of causality in 'fundamental' physics. Rather, CRP demonstrates that causal assumptions, principles and structures play a central role in the application of established classical theories.

The 'causal structures' Frisch describes are the Markovian directed acyclic graphs central to the Bayesian causal modelling frameworks of Pearl (2000) and Spirtes et al. (2001), in which causation is understood in interventionist terms, as further developed by Woodward (2003). Causal modelling has answered one of (the 1913[1]) Russell's concerns—a rigorous account of causality is applicable to mature scientific theories, and so is not an anti-scientific relic of folk theory. However, it is commonly held that causal modelling is inapplicable to physics due to key differences between physics and the special sciences. Causal modelling involves: (a) the assignment of probability distributions over variables, and so an incomplete knowledge of the microscopic state of a system; and (b) interventions understood as 'exogenous' variables, i.e. from outside the system in question. Physics, however, aims at generality and completeness—the

[1] Russell (1927) defends the legitimacy of causal assumptions in science in his causal theory of perception.

ideal physical theory describes the complete microstate of the world as a closed system, with higher-level phenomena being supervenient upon parts of this micro-structure.

Frisch argues that this picture overlooks key features of physics practice. Although abstract physical theories may be understood as sets of complete possible world models, it doesn't follow that such idealised models represent the world. Frisch (ch. 2) defends a pragmatist account of scientific representation according to which a model represents some phenomenon only if it is *used* in such a way. On this account, complete abstract theory models cannot represent the world since this would require a total knowledge of the state of the world and an unfeasible amount of computation. This pragmatist account allows one to understand physics as retaining the key features of imprecise knowledge and incompleteness necessary for Markovian interventionist approaches to causality (chapters 3–4), countering the claim that causal modelling is inextendible to physics; Frisch holds that "[m]odeling in physics [...] is no less hospitable to causal reasoning and causal structures than is modeling in the special sciences" (p. 234).

Representation is key to Frisch's treatment of Russellian-style incompatibility arguments (ch. 4–5). Incompatibility arguments typically proceed by taking a theory to consist of dynamical laws and constraints, and showing that these lack the asymmetries sufficient to motivate a causal interpretation. Frisch rejects the idea that physical theories are "exhausted by [...] formulas or state-space models" (p. 113), holding this to overlook the role of causal reasoning in their construction and confirmation. Frisch shows how taking the pragmatics of modelling in physics into account serves to resolve standard incompatibility arguments—in particular the alleged incompatibility between the time symmetry of physical laws and the time asymmetry of causation (ch. 5).

Having made the case against causal scepticism, Frisch details the function and importance of causal assumptions in specific cases of physics practice: first in linear response theory (ch. 6); and second in classical electrodynamics (ch. 7). The book closes with a convincing critique of 'entropy theories' of causation, which seek to reduce the directionality of causation to the time asymmetry of thermodynamics (ch. 8). There is much valuable and insightful content in these chapters that warrants further discussion, particularly Frisch's illuminating analysis of the Einstein–Ritz correspondence (ch. 7), but due to constraints of space the remainder of this review focuses on the details of Frisch's rejection of causal scepticism.

3 Discussion.

CRP's case against causal scepticism is convincing insofar as causal reasoning is shown to be both applicable to and practically indispensable from physics for agents with our epistemic and computational limitations. However, there are a couple of key senses in which causal scepticism remains legitimate in light of CRP, which I'll now detail: first, at the level of fundamental theories; second, in systems that lack sufficient probabilistic asymmetries for the assignment of causal arrows by causal discovery algorithms.

3.1 Causality and fundamental physics.

Frisch's claim that causal modelling can be extended to classical physics raises the question of what it means to label physics 'causal'. Frisch restricts his claims to classical theories—in which modelling practices closely resemble causal modelling in the special sciences—and not to "truly fundamental" theories (p. 23). This leaves open what to make of fundamental physics. Regardless of the pragmatics of modelling in physics, quantum physics poses a problem: the violation of the Bell inequalities by quantum systems implies the existence of correlated variables that violate the Causal Markov Condition (or alternatively violate another causal modelling axiom, e.g. causal faithfulness—cf. Wood and Spekkens (2015)—, or licence retrocausality—cf. Price (1994)). If some part of physics is 'causal' only if its modelling practices sufficiently resemble those of the special sciences, then theories that violate key axioms of causal modelling, e.g. quantum theories, are not causal, and so by CRP's lights fundamental physics is largely acausal. This is problematic for a couple of reasons. First, it reopens the door to causal scepticism at the level of fundamental physics. Second, CRP appears unable to accomodate putative 'quantum causal models'—which adopt alternative sets of axioms for causal discovery and require screening-off to be understood as something like a classical approximation of a quantum causal structure[2]—as being properly causal.

3.2 The epistemology of causal direction.

Central to CRP is Frisch's rejection of the alleged incompatibility between time-asymmetric causal structures and the time symmetry of fundamental physics (ch. 5). Though Frisch's defence of compatibility is convincing, there is greater

[2]Cf. Leifer and Spekkens (2013); Henson et al. (2014); Costa and Shrapnel (2015).

agreement between Frisch and causal sceptics than is implied by CRP's polemic. Let's focus on Frisch's treatment of Norton's (2009) example (which I simplify) of a possible world consisting solely of two processes: 'A' and its time reverse, 'B'. The crux of Norton's argument is that a 'principle of causality' (i.e. that an effect cannot precede its cause) can be applied to A if and only if an inverse causal principle applies to B, since by time reversal symmetry A and B share the same physical properties and so can't be distinguished on causal grounds without violating physicalism. Frisch notes that Norton presupposes that "the physical properties of a physical system are exhausted by those captured in the dynamical equations governing the system" (CRP, p. 122), and that A and B can be distinguished on *extrinsic* grounds—relative to a wider causal environment containing the right kind of probabilistic asymmetries for the assignment of causal arrows via causal discovery algorithms. Though Frisch is right in that a wider causal environment is generally available to break the underdetermination in practice, this reasoning overlooks the implications of the lack of *intrinsic* differences between A and B.

Consider the case that the environment lacks the required probabilistic asymmetries. One could be: (1) a *hyperrealist*—hold there is a direction of causation that outruns the physical facts; or (2) a *deflationist*—hold there is a direction of causation *only* in the presence of the right kind of probabilistic asymmetries (e.g. irreversible processes, time-asymmetric screening-off conditions, etc.), and so no direction in this case. I read CRP as taking a deflationist attitude and to be opposing a hyperrealist approach. Otherwise, it's not clear why causal arrows should match those prescribed by causal discovery algorithms—after all, they come apart precisely in this case. The deflationist position is taken by Reichenbach (1956) in this context, holding that for highly time-symmetric systems, causal-direction-talk breaks down. Central to Reichenbach's account of the direction of causation is the thermodynamic asymmetry: entropy gradients, rather than being *explained* by causal structures, are *constitutive* of causal structures.

If Frisch is a deflationist about causal direction, then he shares key concerns with Norton, and also Price and Weslake (2010), despite arguing against them in this context. Price and Weslake criticise hyperrealism in that it makes the direction of causation "epistemically inaccessible and practically irrelevant" (Price and Weslake, 2010, sec. 1.2), which Frisch reads as implying that "[i]n a physics with time-symmetric laws that pose a well-defined initial-value problem, there can be no empirical justification for positing causal relations" (CRP, p. 125). But

Price and Weslake's criticism is of hyperrealists who hold there is a fact about causal direction *in the absence* of causal reference points. In the case where a wider causal environment *is* available, it's unclear why either Norton or Price and Weslake would disagree with Frisch that a *deflationist* principle of causality is viable—there's no requirement for a causal sceptic to make this stronger claim. Though Frisch entertains a 'non-Humean' reading of causal principles in the conclusion of CRP (p. 244)—amounting to a hyperrealist reading—, I don't see how this is compatible with CRP's general thesis of deferring to Markovian causal models as constitutive of causal relations. On a hyperrealist reading, to the contrary, the direction of causation is logically independent of the causal arrows given by causal discovery algorithms. It appears preferable to read CRP as deflationist.

4 Closing thoughts.

Causal Reasoning in Physics deserves significant attention in the literature. It makes the best case there is against causal scepticism in physics, and additionally offers a detailed and engaging account of the function of causal reasoning in the application of physical theories. There is, I have argued, an important sense in which a restricted causal scepticism is compatible with the position of CRP, namely where traditional causal modelling techniques break down, such as in quantum theories and in sufficiently probabilistically symmetric systems. This is not to undermine the central claims of CRP, but rather to give them the right caveats and to emphasise the deflationist aspects of CRP.

Finally, is the indispensability of causal reasoning from physics in tension with the claim that fundamental physical theories motivate an *acausal* ontology? On the one hand physics is an enterprise that crucially involves causal reasoning in the construction and application of theories; on the other, physics, more than any other science, aims at an acausal picture of the world wholly independent of the contingencies and asymmetries of our perspective, and it is precisely in this sense that symmetries such as time reversal invariance play a key role. I feel no significant tension in being sympathetic towards both the causal and acausal pictures as different but complementary accounts of physics. I take the key lesson of CRP to be that the former picture is at least as legitimate as the latter.

References

Costa, F. and S. Shrapnel (2015). Quantum causal modelling. *arXiv preprint arXiv:1512.07106*.

Henson, J., R. Lal, and M. F. Pusey (2014). Theory-independent limits on correlations from generalized bayesian networks. *New Journal of Physics 16*(11), 113043.

Leifer, M. S. and R. W. Spekkens (2013). Towards a formulation of quantum theory as a causally neutral theory of bayesian inference. *Physical Review A 88*(5), 052130.

Norton, J. D. (2009). Is there an independent principle of causality in physics? *The British Journal for the Philosophy of Science 60*(3), 475–486.

Pearl, J. (2000). *Causality: Models, Reasoning and Inference*. Cambridge: Cambridge University Press.

Price, H. (1994). A neglected route to realism about quantum mechanics. *Mind 103*(411), 303–336.

Price, H. and B. Weslake (2010). The time-asymmetry of causation. In H. Beebee, C. Hitchcock, and P. Menzies (Eds.), *The Oxford Handbook of Causation*, pp. 414–443. Oxford: Oxford University Press.

Reichenbach, H. (1956). *The Direction of Time*. Berkeley: University of California Press.

Russell, B. (1912–1913). On the notion of cause. *Proceedings of the Aristotelian Society 13*, pp. 1–26.

Russell, B. (1927). *The Analysis of Matter*. London: Kegan Paul.

Spirtes, P., C. Glymour, and R. Scheines (2001). *Causation, prediction, and search*. The MIT Press.

Wood, C. J. and R. W. Spekkens (2015). The lesson of causal discovery algorithms for quantum correlations: Causal explanations of bell-inequality violations require fine-tuning. *New Journal of Physics 17*(3), 033002.

Woodward, J. (2003). *Making things happen: A theory of causal explanation*. Oxford: Oxford University Press.