Paradoxes of Time Travel Revisited

Extended Abstract,
Fourth International Conference on the Nature and Ontology of Spacetime

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There has been extensive discussion in the philosophical and physical literature of the last couple of decades about the possibilities of time travel. In particular, the existence of solutions of the Einstein equations in which closed time-like loops (CTCs) occur has bestowed scientific respectability on time travel, even though the physical possibility of these CTCs remains controversial in view of energy conditions and the chronology protection conjecture. On the philosophical side, the so-called grandfather-paradox and its possible relation to free will has attracted much attention. It is unclear, however, whether CTCs add anything to this discussion which is not already there in the more general issue of the relation between determinism and freedom of the will.

What seems to be more interesting is the occurrence of constraints in the specification of boundary and initial data, and the status of these constraints. When time-like curves emanating from a hypersurface $\sum$ intersect this surface more than once, clearly a kind of "periodicity" is required in the solutions of the field and matter equations to ensure consistency. This means that certain constraints in the boundary/initial values will have to be satisfied on $\sum$. If, however, a chronology violating region (where CTCs occur) is located to the future of $\sum$, while no worldlines cross $\sum$ more than once, there is no clear reason why constraints on $\sum$ will have to be satisfied. So the prospects for finding signs of the existence of CTCs in $\sum$'s causal future, by inspecting $\sum$, seem dim. In this case the unusual aspect is rather that a kind of indeterminism (or rather underdetermination) will obtain, so that the initial value problem on $\sum$ is not well-posed and $\sum$ cannot qualify as a Cauchy surface as we normally understand it.

In the talk we will compare this notion of indeterminism (or underdetermination) with types of indeterminism that occur elsewhere in physics: in probabilistic theories (as in quantum physics), in the recently much-discussed cases in classical mechanics in which there is no uniqueness of the solution of the differential equations, and in the "hole-problem" in general relativity. We will in particular focus on the question of whether the underdetermination connected with CTCs signals a breakdown of the notion of physical law in these situations. If so, it seems that we would actually be in need of chronology protection---various forms of a protection hypothesis seem possible though.

We will then turn to the status of the constraints that need to be taken into account in chronology violating spacetimes. It is often suggested that these constraints have a law-like status and, from this perspective, are nothing special. For example, it has been maintained

that they may be compared to the requirement that the specification of magnetic fields should respect the condition that the divergence of these fields vanishes: the 'no-monopoles law'. We will argue, however, that it is implausible that the constraints that are needed in the case of CTCs generally have the status of laws.

In order to judge whether or not the constraints are law-like, we first of all need to be clear about the criteria of law-hood themselves. As it will turn out, it makes a difference whether one subscribes to an analysis à la Lewis or to a more "Platonistic" conceptions of laws. Moreover, results of the analysis vary with the cases that are being considered. For example, topological features of the spacetime may or may not come out as lawlike depending on the analysis of law-hood and the physical situation.

Finally, we will discuss whether the distinction between lawlike and only contingent constraints makes any difference at all for the possibilities of CTCs and time travel.

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