Some Philosophical Prehistory of the (Earman-Norton-Stachel) "Hole Argument"

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As the story usually goes, the infamous "hole argument" was originally posed by Einstein in 1913, only to be rejected two years later when he published his eponymous field equation (Norton, 2011). It then lay dormant for seven decades, before being resurrected by John Earman and John Norton in a famous paper (Earman and Norton, 1987). In its new form, the argument was not about the possibility of a "generally covariant" field theory—as Einstein originally understood it to be—but rather about whether a certain interpretation of the formalism of general relativity, which Earman and Norton called "manifold substantivalism," led to a pernicious form of indeterminism. In this form, the argument has led to three decades of dispute.

Although the new form of the argument is typically attributed to Earman and Norton as I have just described, it is generally acknowledged to have some pre-history. In particular, Stachel (1989), in a paper first presented at a conference in 1980 but only published in 1989, also emphasized the significance of Einstein's hole argument. Norton (1984) and Earman (1986) are also sometimes noted for exploring similar themes.

What is apparently less well known is that the hole argument as presented by Earman and Norton (1987) has another lineage, stretching back through a series of Earman's papers in the late 1970s (Earman, 1977a,b, 1979) and culminating in Earman (1986). The reason this particular thread is often overlooked is that on their face, these papers have little to do with general relativity: instead, in these papers Earman explores features of *Leibniz's* views on space and time, arguing that on one reconstruction, no deterministic theory is possible in an appropriately Leibnizian space-time.

It is only in 1986 that Earman makes an explicit connection to general relativity, showing that an argument he had repeated in the earlier papers could be extended to that context—and in so doing, describes what is essentially the hole argument. Even so, that these earlier papers bear a close connection to the hole argument as Earman understood it in 1987 is made abundantly clear in Earman (1989, Ch. 9), when he explores a response to the hole argument based on a reformulation of relativity theory using what he calls *Leibniz algebras* (see also Geroch, 1972)—precisely the mathematical tools he had introduced in the earlier papers as a way of saving Leibniz's philosophy.

In the first of his papers on the subject (Earman, 1977a), Earman notes that the ideas presented there were inspired by papers and lectures by Howard Stein, and cites a paper ultimately published in the same year, in a volume co-edited by Earman, though apparently distributed previously (Stein, 1977). In this paper, Stein presents precisely the argument that Earman takes to show that no deterministic theory can be set in Leibnizian space-time. Earman attributes this argument to Stein in multiple places—along with the conclusion that he (Earman) draws from it, concerning determinism. It is striking, then, that Stein explicitly disavows this interpretation of the argument, writing "It must not be thought that this argument demonstrates the impossibility of a deterministic Leibnizian dynamics" (p. 6). Stein goes on to offer a different take on what the argument shows: namely, that Leibnizian space-time does not have the resources to express differential equations.

In this talk, I will argue that an important shift takes place between Stein's version of the argument and Earman's, concerning both how to interpret the formalism of differential geometry as applied to space-time structure, and also what it would take for a theory set in a given space-time structure to be deterministic. My claim will be that Earman, in his early papers on the subject, took for granted a different interpretation of Leibnizian space-time structure from Stein—one that ultimately amounted to a kind of "manifold substantivalism". With this view in the background, he drew the stronger conclusion from Stein's argument. Later, Earman (1986), and then Earman and Norton (1987), showed that the same argument could be run in general relativity, now isolating manifold substantivalism explicitly as the troublesome assumption. Implicit throughout—and explicit in Earman (1989)—is the idea that manifold substantivalism is somehow the default or natural interpretation of the formalism of any space-time theory described with tensor fields on a manifold, and thus, to avoid indeterminism, one must adopt a new, different formalism.

But, as Stein's own discussion of the argument shows, manifold substantivalism is by no means forced on us by the formalism, at least in the Leibnizian case. Indeed, another interpretation of the formalism, and the argument, is available—one that is arguably even more natural, and which was certainly available during the 1970s, because Stein clearly described it. By comparing the arguments in Leibnizian space-time and in general relativity, I will conclude that the Earman-Norton hole argument does not after all force us to either confront a dilemma concerning determinism or else adopt a different formalism for relativity theory. (Perhaps unsurprisingly, the view ultimately derived from Stein's remarks will be strikingly similar to that espoused by Weatherall (2015)!)

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James Owen Weatherall. Regarding the 'Hole Argument'. *The British Journal for Philosophy of Science*, 2015. Forthcoming. arXiv:1412.0303 [physics.hist-ph].