Earman, John, *Bangs, Crunches, Whimpers and Shrieks: Singularities and Acausalities in Relativistic Spacetimes* (New York: Oxford University Press, 1995), pp.xi, 247, Cloth US$35.00

“Philosophers of science can be justly proud of their contributions to the foundations of QM and, in particular, to clarifying the measurement problem and to elucidating the meaning of the Bell inequalities. But thus far their meagre efforts towards understanding the foundations of the other great theory of modern physics, GTR, and, in particular, towards understanding the problem of spacetime singularities does not merit any corresponding pride”. Until now. For the above remark—at p.226 of Earman’s outstanding book—modestly overlooks the important contribution which his own work makes to our understanding of the various problems raised by spacetime singularities and acausalities. (There is, by the way, an obvious candidate explanation of the fact that philosophers of science have not contributed much towards understanding problems raised by spacetime singularities—namely, that the mathematics required for GTR and the discussion of spacetime singularities is so much harder than the mathematics required for QM and the discussion of the measurement problem. Even readers with a fair background in differential geometry and tensor analysis on manifolds may well struggle with parts of Earman’s book.)

Chapter 1 (“Introducing Spacetime Singularities and Acausalities”) is a brief tour through some of the early history of attempts to grapple with spacetime singularities and acausalities. Earman introduces the distinction between genuine singularities and mere coordinate singularities, and examines Einstein’s reasons for objecting to spacetimes which include genuine singularities. He faults Einstein for thinking that singularities are part of spacetime and—though there is no reason to think that Einstein was particularly culpable in this—for thinking that if something nasty happens to the spacetime metric but only at infinity, then no singularity in the spacetime is indicated. Moreover, he makes the point that, even though it is true that physical laws break down—'do not make sense'—at singularities, there is no obvious reason why this should be seen as a disaster for physics. True enough, there are kinds of singularites which would be disasters for physics—'naked' singularities will interfere with predictability and determinism—but the pioneers of GTR lacked the analytical tools needed to delineate this class precisely. Earman considers Einstein's comments on the Godel universe—the first solution to the field equations of GTR which was recognised to have an acausal structure—and makes the point that problems about singularities and problems about acausalities are not separable problems in GTR: investigating questions about one class of problems inevitably leads to questions from the other class.

Chapter 2 ("Defining, Characterising and Proving the Existence of Spacetime Singularities") begins with an examination of attempts to characterise singular spacetimes. Four fundamental ideas—that singular spacetimes are ones in which the metric breaks down ('blows up') at a finite distance; that singular spacetimes exhibit some kind of geodesic incompleteness; that singular spacetimes have missing points; and that singular spacetimes are ones which contain 'naked' singularities (in Penrose's sense)—are examined, with various versions of each being considered. There are things to be said on behalf of each of the last three ideas—incompleteness, missing points, and naked singularities—though they do not agree in extension. However, even when we have precisified these ideas, we still don't have a settled account of essential singularities—i.e. singularities which cannot be removed by extending the spacetime—until we specify the continuity and differentiability conditions on allowed extensions. Choosing these conditions is no easy matter, and so 'we are left with corresponding uncertainties about what an essential spacetime singularity is, and about how generic essential singularities are among solutions to EFE' (p.50). Various theorems—by Hawking and Penrose, and others—purport to tell us that spacetime singularities are very widespread amongst solutions to the field equations of GTR. Although these theorems rely upon reasonably strong assumptions about the continuity and differentiablity conditions on allowed extensions of spacetimes, and on quite strong assumptions about causality, there is good reason to think that they do show that singularities are a generic feature of general relativistic spacetimes. However, these theorems say nothing about the kinds of singularities which will be found; as suggested above, it is only singularities associated with acausal features or breakdowns in determinism which obviously pose troublesome questions for physics. (Some people think that quantum effects may save us from singularities. However, it is not clear whether this is anything more than a pious hope.)

Chapter 3 ("Cosmic Censorship") is devoted to an investigation of two related concepts: 'naked singularities' and 'cosmic censorship hypotheses'. The intuitive idea is that we need not worry about the singularities predicted by GTR since these singularities are guaranteed not to be too nasty ('naked'). Five approaches are investigated. According to the first, strong cosmic censorship guarantees the existence of a Cauchy surface (global hyperbolicity), while weak cosmic censorship guarantees only that singularities will be hidden in 'black holes', the exterior surfaces of which admit future Cauchy surfaces. According to the second approach, naked singularities are defined in terms of detectability—the point of cosmic censorship is to prohibit *local* naked singularities. According to the third approach we have a guarantee that naked singularities will not develop from regular initial data (so, for example, naked singularities will not develop under gravitational collapse). And so on. In every case, the 'guarantee' of the cosmic censorship hypothesis applies only to physically reasonable (physically realistic, physically possible) cases, and so there is a need to consider conditions which demarcate the relevant cases. Earman discusses seven classes of such conditions and then notes ‘there is the very real danger that the CCH will forever remain a hypothesis, and a rather vague hypothesis at that’ (p.86). The evidence for and against any form of cosmic censorship is indecisive, though black hole evaporation as a result of Hawking radiation may well pose a serious threat to any kind of cosmic censorship hypothesis. However, it is not clear that the failure of all cosmic censorship hypotheses must be a disaster for physics (although it could be). After all, predictability and determinism in GTR are already problematic, even apart from the problems raised by singularities. (Earman makes several rueful remarks about the neglect into which his *A Primer on Determinism*—which takes up these questions about determinism—has fallen. Sad; that’s another terrific book.)

Chapter 5 (“The Big Bang and the Horizon Problem”) discusses what is known as ‘the horizon problem’ in standard big bang cosmology. Very roughly, ‘the problem’ is that, as we look backwards in time towards the big bang, we observe that the cosmic microwave background radiation is remarkably homogeneous and isotropic at times for which directions in space with sufficiently large angular separation have no common causal past (according to standard big bang models of the universe). This means that the standard big bang models need to insist on very special initial conditions—generic initial conditions will not develop the observed homogeneity and isotropy—and that it turn suggests that these models are not sufficiently robust, and hence do not provide a satisfactory explanation of the currently observed uniformity in the cosmic microwave background radiation. Many physicists take this problem very seriously—Earman discusses seven quite different attempts to deal with it—but it is not clear that any of the proposed attempts comes anywhere near to success. (The most popular current candidate—inflationary scenarios—seems to be deficient in various respects.) Perhaps the right reponse lies in another direction: ‘perhaps what is needed is some deflation of the horizon problem rather than inflation of the universe' (p.157). (Since 'inflationary scenarios' are invoked to deal with other problems apart from 'the horizon problem', it should not be supposed that there is anything here which is supposed to be a knockdown objection to inflationary cosmology—the point is just that inflationary cosmology is not well–justified by appeals to 'the horizon problem' alone.)

The remaining chapters—Chapter 4 ("Supertasks"), Chapter 6 ("Time Travel") and Chapter 7 ("Eternal Recurrence, Cyclic Time and All That")—take up issues which have been much discussed by philosophers, though not in the context of discussions of singularities in GTR. Earman is dismissive of much of the philosophical discussion of these issues—particularly in the case of time travel—though perhaps unfairly. While I agree with him that it is important to ask questions about whether time travel and the performance of supertasks are physically realistic—in something like the sense of being permitted by our best physical theories—it isn't clear to me that we ought to insist that this is the only kind of question that is worth asking. Earman takes it that it is perfectly obvious that time travel and the performance of supertasks are logically possible—but there was considerable disagreement amongst philosophers about these questions over a long period of time (and it stands to the credit of philosophers such as Benacerraf and Lewis that we now have what clarity we do—what these philosophers have done more closely resembles work done by other philosophers on the measurement problem that Earman allows). It seems to me that if philosophers can profitably spend time mapping conceptual possibilities, then there are other questions about time travel and the performance of supertasks which are worth asking—and it also seems to me that there may not be much point quibbling about which questions are most important to ask. This complaint aside, there is much interesting material in these remaining chapters, but I cannot hope to do justice to it here.

I recommend this book to everyone. It’s not easy going; but it is exemplary philosophy of science. Even if one does not agree with all of Earman’s philosophical views—and I haven’t here mentioned what he has to say about the common cause principle, the nature of scientific explanation, and various other philosophical matters—one is bound to be instructed and entertained by this book.

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