Tolerance for Spacetime Singularities

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A common reaction to the Penrose–Hawking singularity theorems is that Einstein’s general theory of relativity contains the seeds of its own destruction. This attitude is critically examined. A more tolerant attitude toward spacetime singularities is recommended.

"Progress in physics can proceed both from tolerance and intolerance." C. W. Misner

1. INTRODUCTION

Charles Misner\(^1\) distinguished three attitudes towards spacetime singularities in models of Einstein’s general theory of relativity (GTR).\(^2\) The first attitude ("Einstein avoids a singularity") holds that such singularities are merely artifacts of the unrealistic idealizations of the models (e.g., the perfect spherical symmetry and pressure-free dust matter of the Oppenheimer–Snyder model of gravitational collapse). This attitude was exemplified by the Russian school of Lifshitz, Khalatnikov, and co-workers, who claimed to have shown that a generic solution to Einstein’s field equations (EFE) is singularity free.\(^3\) They were eventually forced to recant\(^4\) in the face of a series of theorems, due principally to Penrose and Hawking,\(^5\) which were generally acknowledged as showing that singularities in solutions to EFE are to be expected in generic circumstances in both gravitational collapse and cosmology.\(^6\)

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\(^2\) Actually, Misner was concerned principally with the initial singularity in big bang cosmological models; but his remarks apply equally well to other types of spacetime singularities.

\(^3\) A bit of caution is required here: the Penrose–Hawking theorems demonstrate the existence of singularities only in the sense of geodesic incompleteness; see Sect. 2.
The second attitude ("Nature avoids Einsteinian singularities") holds that, since GTR does entail singularities, the theory fails to accurately describe nature. This is no doubt the attitude that Einstein himself would have espoused had he lived to read the Penrose–Hawking theorems, at least if we are to believe Peter Bergmann's report of Einstein's intolerance of singularities:

It seems that Einstein always was of the opinion that singularities in classical field theory are intolerable. They are intolerable from the point of view of classical field theory because a singular region represents a breakdown of the postulated laws of nature. I think one can turn this argument around and say that a theory that involves singularities and involves them unavoidably, moreover, carries within itself the seeds of its own destruction...4

The third, more tolerant and more optimistic, attitude ("Nature and Einstein are subtle but tolerant") was advocated by Misner himself. It views the existence of singularities in solutions to EFE "not as proof of our ignorance, but as a source from which we can derive much valuable understanding of cosmology."5

It is fair to say that advocates of this third attitude are few and far between. Not surprisingly, there have arisen two types of research programs to cope with the spacetime singularities of GTR. One seeks to modify classical GTR in such a way that singularities are avoided while retaining the verified predictions of GTR for weak gravitational fields.6, 7 The other program does not attempt to tinker with classical GTR but seeks to show that quantizing GTR will smooth away spacetime singularities.8, 9

There is, perhaps, a parallel here with quantum mechanics (QM) in that a growing number of physicists and philosophers of science hold that the measurement problem shows that QM contains the seeds of its own destruction.6 If these twin attitudes of intolerance are correct, we arrive at the stunning conclusion that, despite their many empirical and conceptual successes, the two main theories of twentieth century physics are self-refuting. This conclusion may well prove to be correct, but precisely because of its stunning quality, caution is in order. In the case of QM many attempts have been made to rebut the seeds-of-its-own-destruction charge. (In my opinion, the devices that have been invoked to preserve standard QM (many worlds, many minds, hidden variables,...7) are sufficiently

4 Reference 5, p. 186.
5 Reference 1, p. 1329.
6 Bell and Nauenberg wrote: "It seems that the quantum mechanical description will be superseded. In this it is like all theories made by man. But to an unusual extent its ultimate fate is apparent in its internal structure. It carries in itself the seeds of its own destruction." (Ref. 10, p. 285).
7 See Albert111 for a review of various approaches to the measurement problem in QM.