Where Does General Relativity Break Down?

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A Galilean Dialogue

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Sagredo: That's great! My favorite theory, general relativity, faces conceptual puzzles, such as singularities. Will those problems be resolved by new high-energy physics?
Salviati: Yes. We should expect general relativity to break down at high energies and be replaced by a quantum theory of gravity.

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It depends.

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(Non-local and quasi-local gravitational energy do not help: general relativity should break down locally and independently of background structures.)

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3. Curvature scalars measure energy density in other theories, such as electromagnetism.

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EM analogue: In flat spacetime, $F_{ab} = f(u)x_{[a}\nabla_{b]}u)$, where $\nabla_a u$ is null and constant, x_a is constant, and $x^a\nabla_a u = \mathbf{0}$. Then stress-energy vanishes, as do all scalars constructed from F_{ab} and its derivatives—even if $f(u)$ is singular.

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But there does not seem to be a single, scalar quantity whose large value always and unambiguously signals this regime.

This apparently means we cannot set a scale by a (scalar) cutoff, such that general relativity breaks down (only) when curvature scalars approach this value.

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Stipulate: only curvature singularities (broadly construed) are "physical"; then it is plausible to think they will be resolved by quantum gravity.

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I contend: **Cauchy horizons** are just as troubling as singularities, and for similar reasons.

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Some spacetimes with Cauchy horizons may be extended beyond the Cauchy horizon. But such extensions have a "global" character rather than a "local" one.

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Like singularities, Cauchy horizons are logically unrelated to curvature. There exist flat (extendible) spacetimes with Cauchy horizons.

Even in Kerr spacetime, curvature (and curvature scalars) are bounded in the vicinity of the Cauchy horizon.

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Question

Will quantum gravity resolve (physical) Cauchy horizons?

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Generically*, the maximal Cauchy evolution of (suitable) initial data is (locally) inextendible.*

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Physical intuition (Penrose): Signals approaching a Cauchy horizon will be blue-shifted to arbitrarily high frequency near the horizon, generating (curvature) singularities.

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*Is **continuous** extendibility what we should care about?*

No.

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From this perspective, falsifying the C^0 conjecture is **(physically) uninteresting**.

The Dafermos and Luk result is nonetheless important.

It provides evidence **for** a more physically relevant SCCH: quantum gravity, insofar as it resolves (curvature) singularities will also generically resolve Cauchy horizons.

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2. Can we take problems in general relativity to be "high energy" problems that will be resolved by a UV successor?
It depends on both the resolution of the (physical) strong cosmic censorship hypothesis, and also whether low-curvature pathologies can be eliminated by other considerations—such as kinematical constraints arising from quantum gravity.

Thank you.[1]

[1] Based on work supported by the John Templeton Foundation. I am grateful to Sam Fletcher, Serge Rudaz, and Bob Wald for very helpful discussions in connection with this talk.