Naked And Uncensored

Anirbit

DTP, TIFR

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Dangerous curves ahead...

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A singularity in a spacetime can be either a curvature singularity or can be of more subtle kinds like geodesic incompleteness or "black holes". The relationship between the various ways in which things can go bad is not completely understood and the pursuit of an unifying picture is a major driving force for research.

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It is a still harder question to determine by looking at the initial conditions whether the final state can have any of these unpleasant features. Establishing formation of even trapped surfaces had defied all efforts till some very recent pathbreaking progress.

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Tied to all these is the very difficult question of establishing global hyperbolicity of spacetimes which will allow for usual intuitions of deterministic physics. The relationship between these various forms of singularities and the loss of complete determinism is widely open.

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- "On the uniqueness of smooth, stationary black holes in vacuum", *arXiv* : 0711.0040*v*1(2007) by A.D.Ionescu and S.Klainerman

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The following writing has evolved in the community as almost the canonical reference for all matters of definition,

- "On the global initial value problem and the issue of singularities" (Classical and Quantum Gravity, 16(1999), $A23 - A35$) by D.Christodoulou.

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Only over the last few years there has evolved some significantly clean ways of thinking about a "naked singularity" and that needed posibly unexpected lines of reasoning stemming from a careful fleshing out of the assumptions that go into thinking of a "black hole". But still it is hard to pin down one all encompassing definition.

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Naive thinking about black holes as regions from which light cannot escape can lead to quite harmless things like future of any event getting called a black hole! Hence black holes had to be thought of as regions which cannot communicate to infinity. But to match against intuitions about commonly known solutions with curvature singularities one needed to put in various other assumptions about the spacetime which are not a priori guaranteed.

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- The notion of being "complete" is highly debated. It tries to capture the intuition that nothing else in the spacetime is going wrong except where the singularity is and hence one can go as far as one wants away from the region one wants to call as a black hole. This also helps define a notion of "asymptotic observers".

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- The "future null infinity", $\mathcal{I}^+$, is defined as the future null boundary of the image in the larger spacetime into which the physical spacetime has been conformally embedded via the Penrose map.

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- Clearly if there are things going bad outside whatever one wants to call the "black hole" then it will affect the above property of completeness. (And hence the motivation of thinking about it!)

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- Often asymptotic strong predictability is assumed as a part of the definition of a black hole. Highly invoked properties of black holes like the non-decreasing nature of the event horizon's area holds only under still stronger assumptions like regular asymptotic strong predictability.
- Global hyperbolicity of the domain of outer communications, $J^-(\mathcal{I}^+) \cap J^+(\mathcal{I}^-)$, is also often assumed.

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- As a motivation one can note that it is possible for maximal analytic extensions of otherwise "good" solutions to have the somewhat unpleasant feature of singularity being able to communicate with a complete future null infinity. Hence in the definition the emphasis is on incompleteness of the Cauchy development rather than on the full spacetimes.

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Strong Cosmic Censorship Conjecture

states that generic asymptotically flat or compact initial data sets have maximal future developments which are locally inextendible.

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The qualification "generic" in these statements can be made more precise by demanding that the initial data that evolves to a naked singularity is of measure zero in the set of possible initial data in some relevant topology. But given the trend of the various recent results it seems that this precision may not be necessary since a possible proof is likely to show that this subset is of positive codimension and hence giving a stronger statement.

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- Primarily understanding the plethora of geometrical concepts which go into the recent formulations of the "Cosmic Censorship Conjecture". The focus being largely on delving deeper into the concept and methods of testing for global hyperbolicity and geodesic completeness.
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- Understanding the results obtained by Yvonne-Choquet Bruhat and Cotsakis in 2002 about geodesic completeness of a fairly large class of Lorentzian manifolds called regularly sliced spacetimes. Such kind of results are rarely known.

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- Compare if there exists a possibilty in the parameter space where a trapped surface can form "after" the formation of the curvature singularity.

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- Looking at the general trend of the frontiers it seems that the scope of progress is too limited if one looks at special gravitational collapse cases. Further progress needs putting in concerted effort to establish massive education programs to understand and explore further the analysis of Klainerman, Rodnianski, Christodoulou, Dafermos and their collaborators.

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My goal is simple. It is a complete understanding of the universe, why it is as it is and why it exists at all.

Stephen Hawking