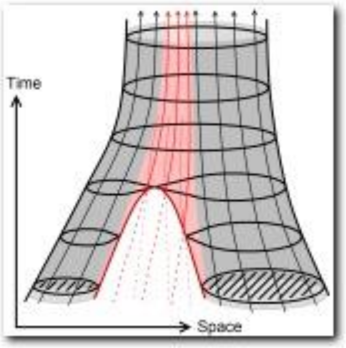
GENERAL RELATIVITY



It could be said that I "stumbled upon" general relativity inadvertently while studying a related field in physics. On a few attempts prior to entering Caltech, I had tried to understand the basics of quantum field theory from field theory textbooks. I failed every time. Eventually, I gave up on this pursuit and picked up a book on classical field theory after arriving at Caltech. After I had read through this book, I picked up the the Landau-Lifshitz classic, *The Classical Theory of Fields*. The second half of this book taught me general relativity.

General relativity is not something that you learn once. Rather, much like field theory, it is something that must be re-learned over and over again. Thus, when I took Caltech's gravitation course (Ph 236ab), I learned many more subtleties that had not stood out in Landau-Lifshitz.

In the summer of 2008, I worked on an undergraduate research project with Dr. Yanbei Chen, a theorist who earned his PhD at Caltech doing work with LIGO. Our task, to determine how the event horizon of a large black hole is deformed when a small black hole falls into it, looks fairly straightforward in retrospect, but without the experience I have today, it was quite nontrivial.

Over the summer and the ensuing academic year, I showed that it was possible to use black hole perturbation theory to model both the spacetime around the large black hole and the black hole's event horizon. Subsequently, it became clear that we could impose a "delta-function approximation" when the ratio of black hole masses was sufficiently large. This approximation allowed us to compute the event horizon's geometry analytically and determine the structure of the *caustic* — a spot at which the event horizon is pointed, i.e. locally cone-shaped. This worked developed into a senior thesis and a (submitted for) publication in Phys. Rev. D.

Senior Thesis »

Thesis Presentation »

Paper »

These results only apply to mergers of Schwarzschild black holes, however. Since real astrophysical black holes have spin, we are currently working on extending our results to the Kerr case. This is not as easy as it sounds. There is no widespread metric perturbation formalism for Kerr black holes, and even if such a formalism did exist, it would be very, very nasty. Qualitatively different methods must be used if we are to tackle the Kerr case.

One such method takes note of the fact that the event horizon is only substantially affected *near the small black hole's trajectory*. If we take a local frame enclosing the small black hole (like a Fermi normal frame), the metric becomes nearly flat, and the large black hole becomes akin to a Rindler spacetime. We have been able to extend our results to the Kerr case using this method (at least for the part of the horizon near the small black hole's infall), but the work is not yet ready for publication.

Another plausible but less developed possibility is to abandon our coordinate-dependent approach and look only at coordinate-independent quantities — i.e. the expansion ρ and the shear σ. To find ρ and σ, one must first find ψ_0 using the Teukolsky Equation. Hopefully, this method too will bear fruit in the future, but only time will tell.

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