DIFFERENTIAL GEOMETRY/PDE SEMINAR

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3:45 PM

Proof of the Riemannian Penrose Conjecture in General Relativity Using the Positive Mass Theorem

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The topic of this talk is the Penrose Conjecture in General Relativity, which is a conjecture closely related to the Positive Mass Theorem. The Penrose Conjecture and the Positive Mass Theorem can both be thought of as basic attempts at understanding the relationship between the local energy density of a space-time N^4 (whose metric has signature 3,1) and the total mass of N^4. In physical terms, the Positive Mass Theorem states that an isolated gravitational system with nonnegative local energy density must have nonnegative total energy. The idea is that nonnegative energy densities must "add up" to something nonnegative. The Penrose Conjecture, on the other hand, states that if an isolated gravitational system with nonnegative local energy density contains black holes contributing a mass m, then the total energy of the system must be at least m.

Curiously, these compelling physical statements translate into highly nontrivial geometric statements about asymptotically flat 3-manifolds with nonnegative scalar curvature. The Positive Mass Theorem was not proven until 1979 by Schoen and Yau, and the most general version of the Penrose Conjecture is still open. However, the speaker has recently proven the Riemannian Penrose Conjecture, which is the Penrose Conjecture for a 3-dimensional space-like hypersurface M^3 of N^4 which has zero second fundamental form. The proof uses a new approach to the problem (which will be described in the talk) and yields the strongest version of the Penrose Conjecture proven to date. The main idea is to flow the original metric on M^3 continuously to a Schwarzschild metric (which is spherically symmetric and represents an isolated time-symmetric black hole). The flow has the property that the total mass of the metrics is non-increasing while the mass contributed by the black holes stays fixed. Then since the Riemannian Penrose Conjecture is true for the Schwarzschild metric, it follows for the original metric. It should be noted that Huisken and Ilmanen have also recently made very important progress on this problem using $1/H$ flows of surfaces in M^3, and proved the Riemannian Penrose Conjecture in the case that there is only one black hole in the space-time.

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