Degenerate Extensions Of Schwarzschild Exterior As Alternatives to Black hole Geometries

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Abstract:
We present vacuum spacetime solutions of first order gravity, which are described by the exterior Schwarzschild geometry in one region and by degenerate tetrads in the other. Unlike the Kruskal-Szekeres construction based on invertible metrics, these spacetimes represent extensions of the exterior Schwarzschild geometry based on degenerate tetrads. The invertible and noninvertible phases of the tetrad meet at an intermediate hypersurface across which the components of the metric, affine connection and field-strength are all continuous. Within the degenerate spacetime region, the noninvertibility of the tetrad leads to nonvanishing torsion. In contrast to the Schwarzschild spacetime which is the unique spherically symmetric solution of Einsteinian gravity, all the field-strength components associated with these vacuum geometries remain finite everywhere. These vacuum geometries could be particularly relevant in the context of singularities in general relativity as well as that of the information loss problem.

Summary:
Einstein's theory of general relativity is known to exhibit black hole solutions. These are associated with curvature singularity. The simplest representative of a black hole spacetime is the Schwarzschild metric, which happens to be be the unique spherically symmetric vacuum solution. As long as the metric is demanded to be invertible and spherically symmetric, there seems to be no escape from such singular solutions in the classical theory.

However, the first order gravity theory in vacuum admits, besides a phase with invertible tetrads (metric), another (non-Einsteinian) phase based on tetrads which have vanishing determinants and hence are not invertible. The classical theories for these two phases are not equivalent. In fact, the solution space with noninvertible tetrads possesses a rich structure. In view of this, it is worthwhile to explore whether there could be possible extension(s) of the Schwarzschild exterior geometry such that the full spacetime is regular everywhere, within a formulation of gravity theory that admits both the phases.

Here we present a general method to construct extensions of the Schwarzschild exterior using degenerate tetrads (metrics), such that the whole spacetime is a solution of the first order equations of motion everywhere. These geometries are characterized by the two different phases of first order gravity in two different regions, one with nondegenerate tetrads and other with degenerate tetrads. The field variables associated with the whole spacetime are continuous across the boundary between the two phases. Also, the field-strength components are finite everywhere in the manifold, unlike in the case of the standard Schwarzschild case (with a nondegenerate interior). Even though it is not possible to construct four dimensional curvature scalars in regions where the metric is degenerate, it is still possible to define effective lower-dimensional curvature scalars associated with the nondegenerate subspace of the four geometry in such regions. All these scalars are shown to be finite a well.

It should be an intriguing possibility to think of the geometries discussed here superceding a black hole geometry. This would necessarily imply a modification of the standard picture of a singular black hole interior in a purely classical setting (of first order gravity). This may be contrasted with some of the interesting recent proposals, such as Firewall, Fuzzbal or other frameworks invoked in order to resolve the celebrated information loss paradox.

References:

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