Quantizations of the Schwarzschild interior from diffeomorphism covariance and other criteria

We propose an approach to the quantization of the interior of a Schwarzschild black hole, represented by a Kantowski-Sachs (KS) framework, by requiring its covariance under a notion of residual diffeomorphisms, preservation of the Bohr Hilbert space of Loop Quantum KS and the usual correct (naïve) classical limit, resulting in a family of quantum Hamiltonian constraints. A single form of solution is then reached by imposing the Hamiltonian to have a minimal number of terms (i.e., shift operators) -- a form of Occam's razor. We compare this solution with other Hamiltonian constraints proposed for Loop Quantum KS in the literature, with special attention to the Ashtekar-Olmedo-Singh (AOS) model, currently the most well developed model, but with a Hamiltonian that is not exactly covariant under residual diffeomorphisms.

In addition, we discuss a lapse commonly chosen to decouple the evolution of the two degrees of freedom of the model, yielding exact solubility, and we show that such choice can indeed be quantized as an operator densely defined on the Bohr Hilbert space, but must include an infinite number of shift operators. Also, we show the that the common (naïve) approach to classical limit is equivalent of taking the eigenvalues of the extrinsic curvature to zero, which is not a sufficient condition to assure low spacetime curvatures -- a limitation that is related to the appearance of quantum effects at the horizon for some prescriptions.