Journey to the center of a Schwarzschild-de Sitter black hole using quantum computing

Amy Joseph, School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85281

Michael McGuigan, Computational Science Initiative, Brookhaven National Laboratory, Upton, NY 11973

The intricacies and features of de Sitter space are explored using both classical and quantum computing methods. de Sitter space is defined to have positively curved space-time with a positive cosmological constant and energy density. It is considered to be empty of matter - both dark and ordinary. Despite our Universe being filled with matter currently, it's expanding, foreshadowing its future as a de Sitter universe (i.e. it is asymptotically de Sitter). This means that the solution to Einstein's field equation without matter will be de Sitter space. At the same time, a large amount of information is becoming available about the properties of black holes both from stellar collapse and from supermassive black holes at the centers of galaxies. In this case, the solution to Einstein's equation is the Schwarzschild solution. The way to reconcile these two phenomena is through the de Sitter-Schwarzschild solution. However, there are difficulties in understanding the connection between the entropy of de Sitter space and that of black holes. In addition, it is an outstanding problem to understand the microstates whose counting could lead to this entropy. In this paper, we use quantum computing to analyze the Hamiltonian constraint for the de Sitter-Schwarzschild solution in order to obtain a fresh perspective on this problem. We compare the results from the classical computer to the quantum computer. The entirety of the research project was conducted remotely, under the supervision of Brookhaven National Laboratory's Computer Science Initiative. As a result of this internship, I have become familiar

with black hole astrophysics and how it can be applied to cosmology as a whole. I am also able to add more experience with quantum computing to my repertoire.