# Exploring Possible Resolutions to General Relativity’s Singularity Discrepancy

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# Introduction

- Explain flaws in **General Relativity** and its disconnect with **Quantum Mechanics**
- Introduce **LOOP QUANTUM GRAVITY (LQG)**
- Show research using LCQ
- Bring up flaws with LCQ

# General Relativity

- Posed by Albert Einstein in 1915 redefined how we view gravity
- Defines space-time as a singular body
- Postulated that gravity wasn't a force, rather a byproduct of the warping of space-time
- Introduced phenomenon such as **black holes** and their **singularities**

# Black Holes and Singularities

- Black holes are dense bodies of mass that extremely distort space
- Located throughout space and at the center of galaxies
- Singularities are the core of black holes
- Point of infinite density
- Break down of relativity occurs

# Discrepancy

- Gravity distorting space should affect electrons but this is currently unseen based on a quantum mechanical understanding
- Singularities break relativity the curvature of space cannot be calculated at an infinitely small point
- Quantum mechanics does not explain gravity so a bridge theory must be made

# Loop Quantum Gravity

- Major theory to resolve GR & QM
- Quantizes space to discrete levels
- Space is made up of finite loops connected at nodes
- Mass warps the loops which warps space

# Observational Test of Quantum Extensions… Yan et al

- Singularities replaced by **quantum bounce** connecting black holes and white holes
- Looked into the $A_\lambda$ parameter which determines quantum effects
- Studied 17 S-stars orbiting Sgr A* by modeling their orbit based on LQG space-time and compared to observational results

# Observational Test of Quantum Extensions… Yan et al Cont.

- Data from the S2 star showed greatest results
- No significant signs of LQG were found
- Results were consistent with general relativity
- Showed galactic centers were useful for studying strong gravitational theories
- Developed first constraint on LQG models

# Quantum Black Holes in LQG Gambini et al

- Reduced the system to be spherically symmetric dependant on 2 constraints
    - Diffeomorphism and Hamiltonian
- Constraints were manipulated and defined in order to have defined kinematical Hilbert space
- Superposition can be considered which results in wave states being elements of the set Hilbert space

# Quantum Black Holes in LQG Gambini et al Cont

- Nontrivial solutions to the Hamiltonian constraints can be made to create scenarios where classical singularities do not exist
- Evolving quantum constant can be added to the previous solution that still resolve singularities
- With resolution other black hole properties can still be estimated through use of more classical geometries, which also allows to understand what happens at the classical singularity

# Callan-Giddings-Harvey-Strominger Vacuum in LQG

- Similar approach to Gambini et al through redefining constraints and determining the Hamiltonian
- Used dirac quantization along with diffeomorphism to better relate quantum mechanically
- Again used kinematical Hilbert space where a hamiltonian constraint must be identified

# Callan-Giddings-Harvey-Strominger Vacuum in LQG Cont.

- Allowed for singularities to be resolved as well as found new dirac observables
- Singularities were determined to be present if volume were to vanish
    - This was seen in some spots calculating in 2D
    - When looking at 4D space this was not present
- "In other words, the subspace of quantum spacetime states without a singularity is preserved under the action of the quantum Hamiltonian constraint." [3]

# Problems with LQG

- LQG issues have not had in depth research with foundational forces present
- Not fully solved as the mathematics behind it is very complex and hard to implement
- Fails to take into account possible existence of gravitons and explain them

# Conclusion

- Shows a promising possibility to resolve QM and GR
- Shown to resolve singularities
- Is a leading theory so there is more research on LQG than other fields