

Study of Some Aspects of Quantum Gravity and Its Some Implications



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STUDY OF SOME ASPECTS OF QUANTUM GRAVITY AND ITS SOME IMPLICATIONS

A Thesis
Submitted by

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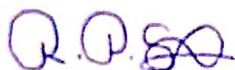
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Department of Physics
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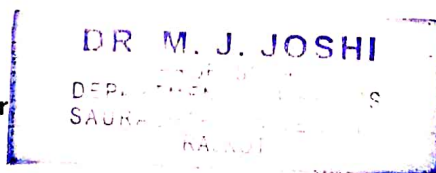
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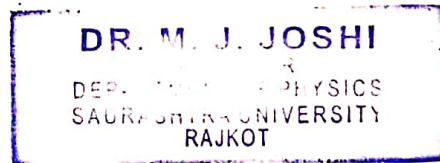
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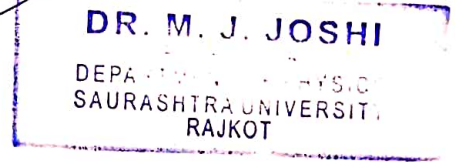
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अथ योगानुशासनम् ।
योगाश्चित्तवृत्तिनिरोधः।

*“Now concentration is explained and
Yoga means to restrain the mind-stuff
from taking various forms”*

*~ Verse: 1-2, Chapter - 1,
'Patanjali Yoga Sutras',
'Rajyoga' - Swami Vivekananda*

*Dedicated to my father
Late shri
'Prafulkumar N. Vyas'
and
'My family'*

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(Rakshit P. Vyas)

Place: Rajkot

Date:

Abstract

The thesis entitled, “**Study of Some Aspects of Quantum Gravity and Its Some Implications**”, representing an elaborated report of the author’s research work will be covering in the following seven chapters.

Chapter:1 - loop quantum gravity: a demystified view

There are many theories of quantum gravity in theoretical physics. Among all quantum gravity theories, the loop quantum gravity (LQG) is one of the supposed candidate of quantum gravity theory. In this thesis, more emphasis is put on LQG to study the quantum gravity. In the first chapter, prerequisites for LQG (necessary introduction of special and general theories of relativity, a brief introduction to mathematical theories for LQG, Lagrangian and Hamiltonian formulations, covariant electromagnetism, a brief introduction to quantum mechanics and quantum field theories), basic concepts of LQG, viz. (ADM formalism, metric formulation, Palatini action, connection formulation, Ashtekar’s variable, geometrical operators, spin network, spin foam and application of LQG), are discussed.

Chapter:2 - the Barbero Immirzi parameter: an enigmatic parameter of loop quantum gravity

The Barbero - Immirzi parameter γ is one free parameter that appears in the mathematical framework of LQG which appears in Ashtekar’s variable, black hole entropy calculation in LQG and in geometrical operators of LQG. The γ can be real as well as complex valued in LQG. The exact physical significance of γ is still unknown. In the second chapter, the origin, history and various proposals on the physical significance of the Barbero - Immirzi parameter (γ) are discussed.

Chapter:3 - solution of black hole information paradox in loop quantum gravity

Black hole information paradox is one of the frontier topic of modern theoretical physics. Each quantum gravity theory attempts to solve this paradox. Hence, the third chapter is about solution of black hole information paradox in LQG. In essence, in the third chapter, the basics of black hole physics, which includes brief introduction to gravitational collapse, naked singularity, laws of black hole thermodynamics, Hawking radiation and Bekenstein - Hawking black hole entropy calculation. In the information theory, the topics covered are brief introduction to information, quantum framework of information theory and cause of information paradox. Finally, the solution of black hole information in LQG covering Planck star and remnant scenario are discussed.

Chapter:4 - new quantum spin perspective and geometrical operators of quantum geometry

In the fourth chapter, firstly, new quantum spin perspective is proposed by using the framework of thermodynamics out of formula of temperature leading to new definition the total angular momentum J and reduced Planck constant \hbar . Thereafter, the equation of geometrical operators such as the area and volume operator are modified using this proposal. In the equation of operators of area and volume, by putting the new formula of reduced Planck constant \hbar , one can have modified formula of these geometrical operators. From this proposal, one can also explain smooth transition of quantum geometry from Planck scale to nuclear scale.

Chapter: 5 - implications of new quantum spin perspective in quantum gravity

Fifth chapter covers implications of new quantum spin perspective in quantum gravity. In essence, in the fifth chapter, the new formulas of fundamental constants such as gravitational constant G , Boltzmann constant k_B , speed of light c , fine structure constant α , the fundamental Planckian quantities such as Planck temperature T_P , Planck mass m_P , Planck length l_P , Planck time t_P , Planck temperature T_P , the derived Planckian quantities such as Planck density ρ_P , Planck momentum P_P , Planck acceleration a_P , Planck force F_P , Planck energy E_P , Planck frequency f_P , and Planck charge Q_P and the new formulas regarding some quantities of the Planck star are proposed using new quantum spin perspective. At last, relationship of quantum spin with Planck temperature, Planck mass, and Planck length is established using new quantum spin perspective.

Chapter:6 - new quantum spin perspective and space-time of mind-stuff

In the sixth chapter, the relation between new quantum spin perspective and space-time of the mind-stuff is established. In Yogic philosophy, there are three sort of space-time: (1) physical space-time, (2) space-time of mind-stuff and (3) space-time of consciousness. Using the basic concepts of spin network of LQG and the new quantum spin perspective, here, the quantization of the space-time of mind-stuff is proposed. This proposal will create new branch of physics, i.e., **Physics of Yoga** or **Yogic Physics** (It will provide a quantum theory of Yoga). At last, discrepancies between physical space-time and space-time of mind-stuff are given.

Chapter:7 - summary and future scopes

The seventh chapter is about summary and the future of scope of this work. New quantum spin perspective and Physics of Yoga is the outcome of this thesis. Both proposal have far reaching consequences in theoretical physics, especially in quantum gravity as well as philosophy.

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Some conventions

- $a, b, c, \dots = 1, 2, 3.$ — Lower case letters - Spatial indices. In general, it shows curved space. (unless otherwise specified).
- $\alpha, \beta, \gamma, \dots, \eta, \mu, \nu, \dots, \rho, \sigma, \dots, \omega$ - Greek alphabets spatial-temporal indices. (unless otherwise specified).
- $I, J, K, L, \dots = 0, 1, 2, 3.$ — Upper case middle indices - Internal indices of Lie algebra elements in gauge theory. It also comes in the range 1,2,3. (unless otherwise specified).
- $i, j, k, l, \dots = 1, 2, 3.$ — Lower case middle indices - Internal indices. In general, it shows flat space (unless otherwise specified).

List of some popular symbols

$U(1)$	Unitary (1) group
$SU(2)$	Special unitary (2) group
$SU(3)$	Special unitary (3) group
E_P	Planck energy
t_P	Planck time
T_P	Planck temperature
l_P	Planck length
m_P	Planck mass
$SL(2, \mathbb{C})$	Special linear group
$SO(3)$	Special orthogonal group
c	Speed of light
γ	Lorentz factor
ds^2	Line interval
\vec{v}	Four vector
\vec{p}	Four momentum
G	Universal gravitational constant
$g_{\mu\nu}$	Metric tensor
e_c	Basis vector or one form
ω^a	Basis one form
δ_y^x	Kronecker delta
Λ_b^a	transformation matrix or Jacobian matrix
η_{cd}	Minkowski metric
T	Tensor
$A \wedge B$	Wedge product
Γ_{ab}^c	Christoffel symbol
∇_a	Covariant derivative
$L_X Y$	Lie derivative
ε^{ijk}	Levi -Civita symbol
R_{bcd}^e	Riemann tensor
$G_{\mu\nu}$	Einstein tensor
$T_{\mu\nu}$	Energy - Momentum tensor
$R_{\mu\nu}$	Ricci tensor
R	Ricci scalar
A or A_μ	Gauge connection
$F^{\mu\nu}$	Field tensor
\hbar	Reduced Planck constant
\square	D'Alembertian operator
γ^μ	Dirac matrices
σ_i	Pauli matrices

t^J	Gauge group generator
$U(dx^\mu)$	Parallel transport operator
\mathcal{P}	Path ordered integral
W_ε	Wilson loop
\mathbb{R}^n	Flat space
\mathcal{M}	Manifold
N	Lapse function
N^μ	Shift vector
n^μ	Normal vector
Σ_t	Hypersurface
h_{cd}	Intrinsic metric
h_{cd}	Extrinsic metric
\mathcal{H}	Hamiltonian constraint
\mathcal{C}^c	Diffeomorphism constraint
ψ_μ^J	Spinorial field
J	Lie algebra index
e^J_μ	Tetrad
A_μ^{JK}	Lie algebra valued connection
E_j^c	Triad field
ω_β^{JK}	Spin connection
G_{cd}	Gauss constraint
\tilde{f}	Scalar density
\tilde{E}	Triad density
γ	Barbero - Immirzi parameter
\mathcal{H}_{EHA}	Einstein - Hilbert - Ashtekar Hamiltonian
Θ	Graph or network
g_j	Group element
Cyl	Cylindrical function
$d\mu$	Haar measure
A_S	Classical observable of area
\hat{A}_S	Area operator
\mathbf{J}^2	Casimir operator
V_S	Classical observable of Volume
\hat{V}_S	Volume operator
S_{BH}	Black hole entropy
k_β	Boltzmann constant
H_{MATTER}	Hamiltonian for matter field
$a(t)$	Scale factor
\mathbb{V}_0	volume of fiducial cell \mathcal{V}
H_{MATTER}	Hamiltonian for gravitational field
(\tilde{C}, \tilde{P})	Two c - number
$\tilde{\Gamma}$	Scalar two-complex connection
\mathcal{O}	Operator
$\Omega_{\mu\eta}^{JK}$	Curvature
Ω_{QNM}	Frequency of quasi normal modes
r^*	Tortoise coordinate
ρ	Density matrix
$ \phi\rangle$	State of entangled pair
$ \Phi\rangle$	Complete quantum state of black hole

$ \phi_{matter}\rangle$	State of matter that forms black hole
l_P^2	Planck area
J	Total angular momentum
α	Fine structure constant
ρ_P	Planck density
a_P	Planck acceleration
P_P	Planck momentum
F_P	Planck force
E_P	Planck energy
f_P	Planck frequency
Q_P	Planck charge
\mathcal{P}_{st}	Physical space-time
\mathcal{M}_{st}	Space-time of Mind-stuff
\mathcal{C}_{st}	Space-time of Consciousness

List of some standard abbreviation

<i>ADM</i>	Arnowitt - Deser - Misner
<i>AdS/CFT</i>	Anti De - Sitter/ conformal field theory
<i>AMPS</i> firewall	Almheiri - Marolf - Polchinski - Sully firewall
<i>BF</i> theory	Background field theory
<i>BI</i> parameter	Barbero - Immirzi parameter
<i>CM</i>	Classical mechanics
<i>EFE</i>	Einstein field equation
<i>EM</i>	Electromagnetism
<i>GR</i>	General relativity
<i>GFT</i>	Group field theory
<i>LQG</i>	Loop quantum gravity
<i>LQC</i>	Loop quantum cosmology
<i>NY</i> term	Nieh - Yan term
<i>OSD</i> model	Oppenheimer - Snyder - Datt model
<i>QM</i>	Quantum mechanics
<i>QFT</i>	Quantum field theory
<i>QED</i>	Quantum electrodynamics
<i>SR</i>	Special relativity
<i>TOCY</i>	Turaev-Ooguri-Crane-Yetter

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