These are a few of my favourite things

Francesca Vidotto

Western UNIVERSITY · CANADA

with Hal HAGGARD, Sebastian STEINHAUS & Edward WILSON-EWING

CANONICAL
LOOP GRAVITY

Art by Clifford Johnson

Art by Clifford Johnson

Art by Clifford Johnson

CANONICAL LOOP GRAVITY

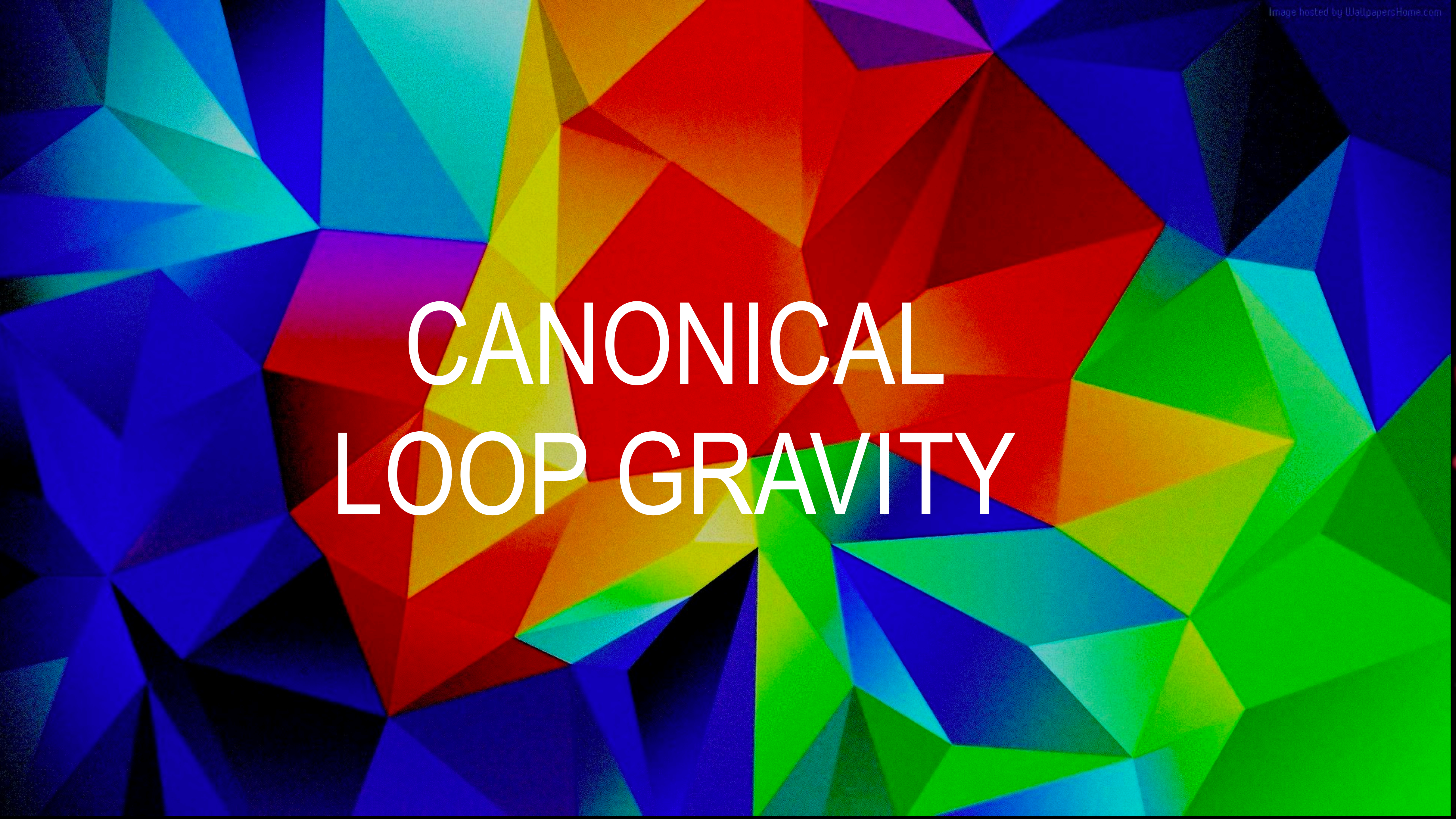
CANONICAL LOOP GRAVITY

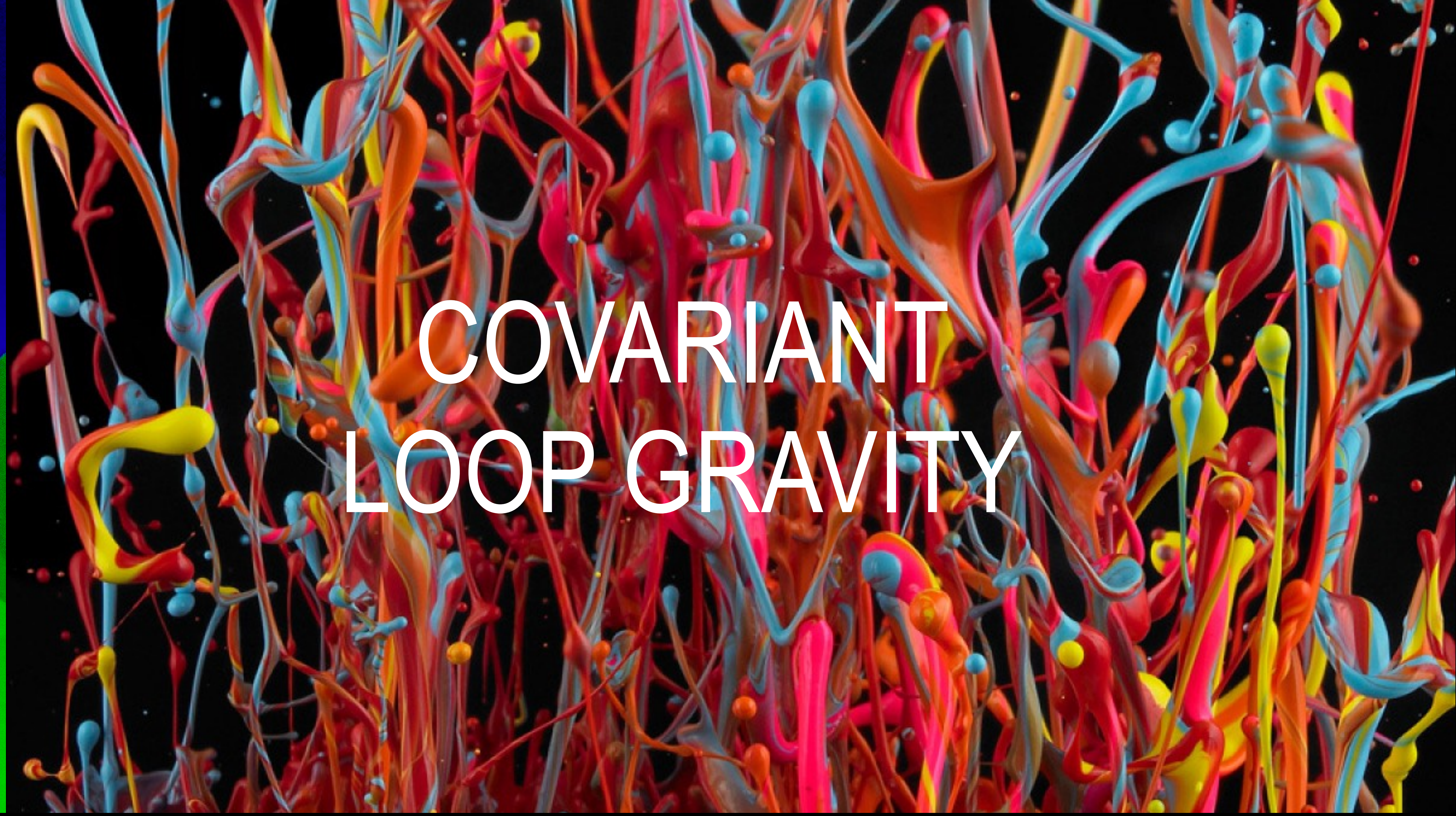
COVARIANT LOOP GRAVITY

Art by Clifford Johnson

Art by Clifford Johnson


I have been told that
you do not have a classical limit…
There was progress,
old confusions are clearing up!
Art by Clifford Johnson


CANONICAL
LOOP GRAVITY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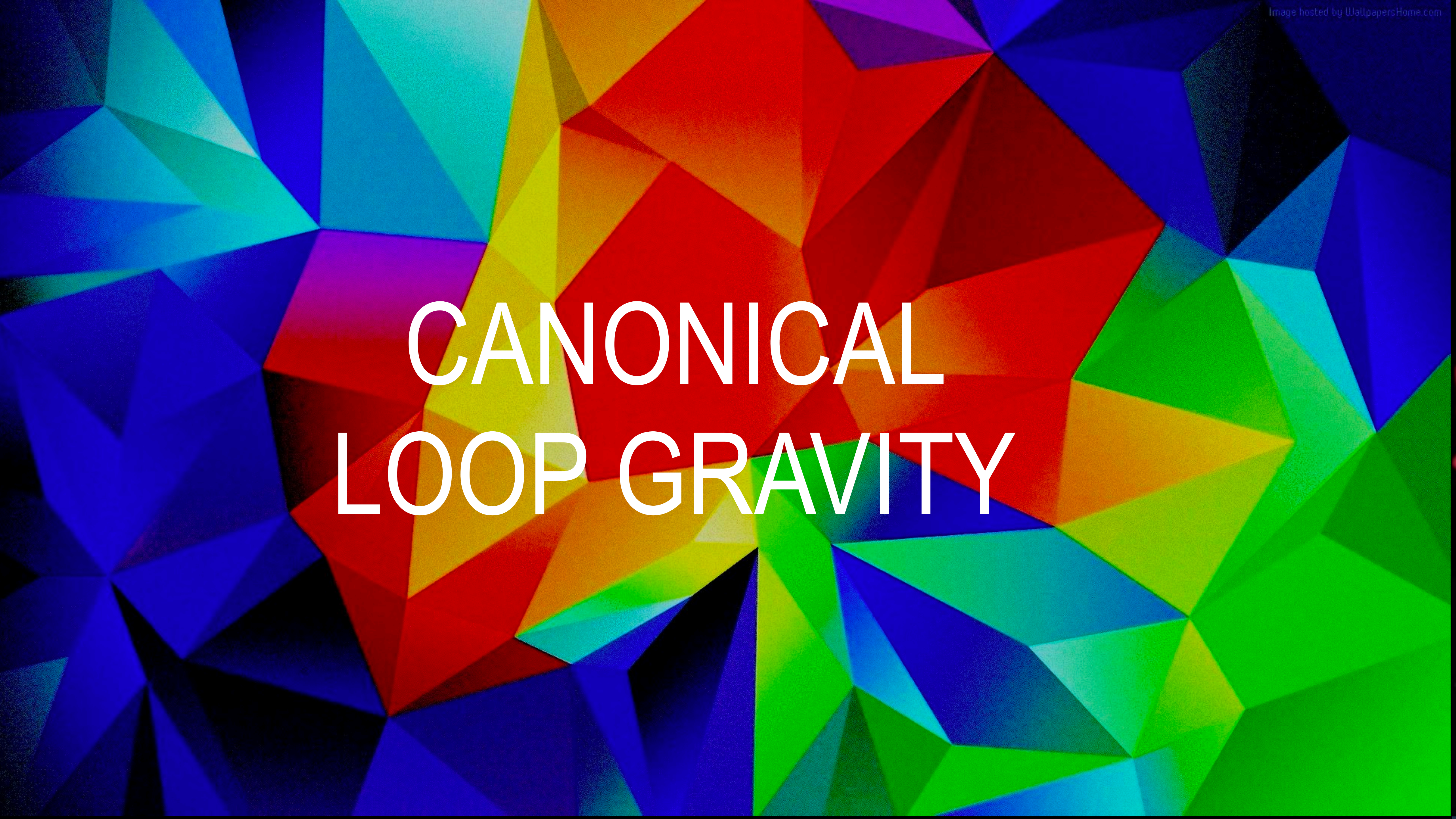
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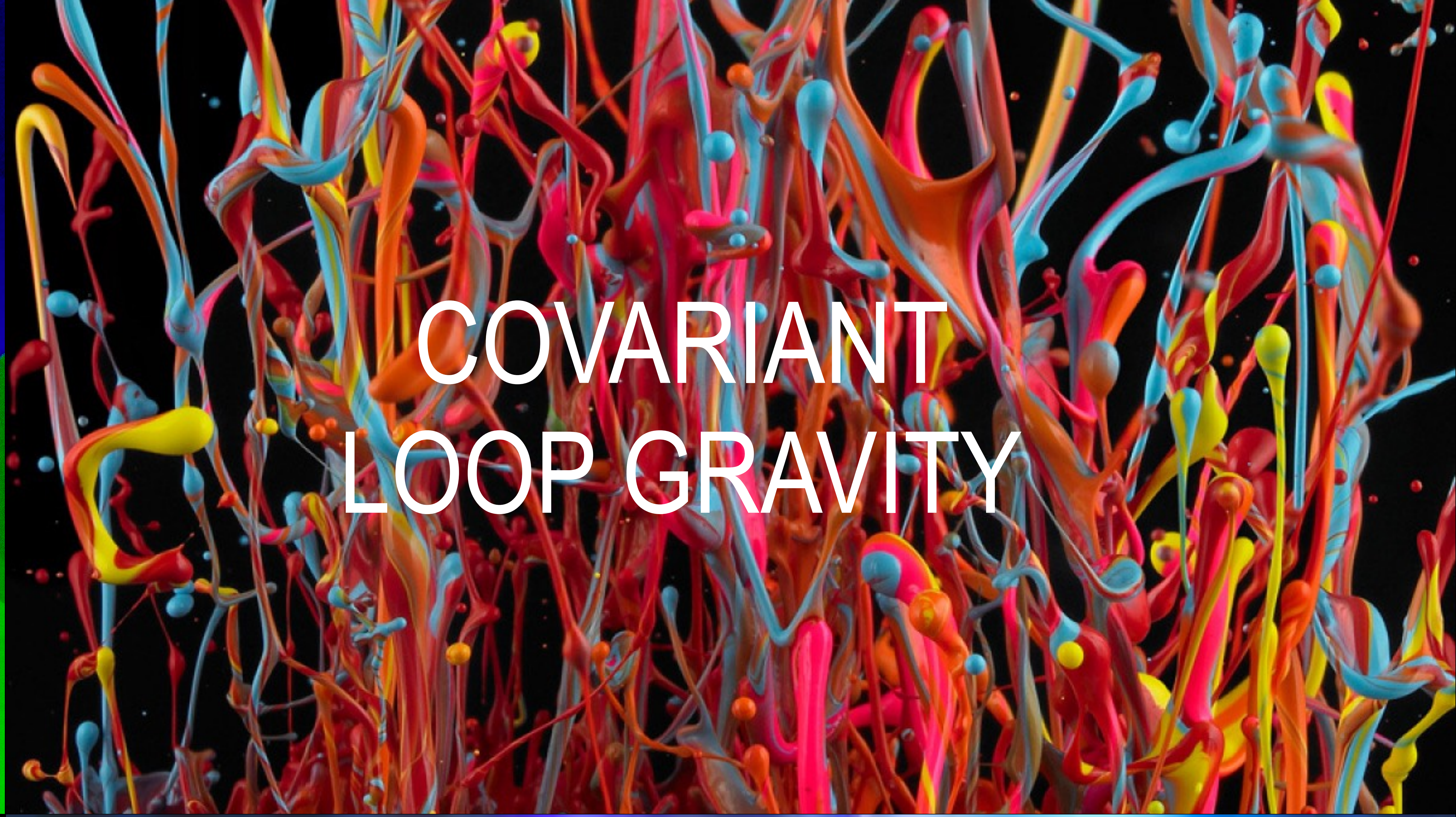
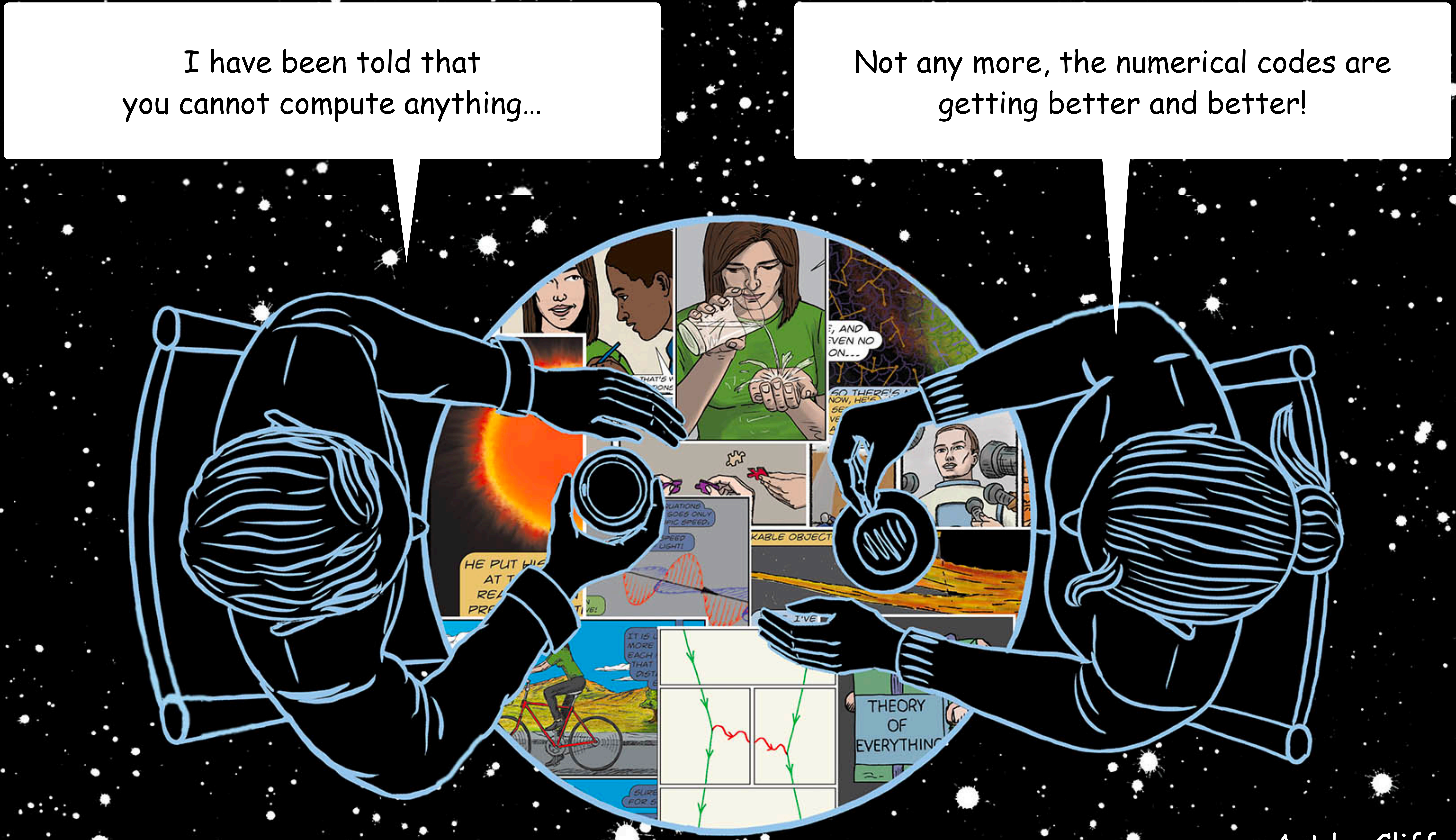

COVARIANT
LOOP GRAVITY


NUMERICS

Art by Clifford Johnson


I have been told that
you cannot compute anything…
Art by Clifford Johnson



Art by Clifford Johnson

AN EFFICIENT ALGORITHM FOR THE RIEMANNIAN $10j$ SYMBOLS

J. DANIEL CHRISTENSEN AND GREG EGAN

ABSTRACT. The $10j$ symbol is a spin network that appears in the partition function for the Barrett-Crane model of Riemannian quantum gravity. Elementary methods of calculating the $10j$ symbol require $\mathcal{O}(j^9)$ or more operations and $\mathcal{O}(j^2)$ or more space, where j is the average spin. We present an algorithm that computes the $10j$ symbol using $\mathcal{O}(j^5)$ operations and $\mathcal{O}(j^2)$ space, and a variant that uses $\mathcal{O}(j^6)$ operations and a constant amount of space. An implementation has been made available on the web.

1. Introduction

The Barrett-Crane model of four-dimensional Riemannian quantum gravity [6] has been of significant interest recently [1, 2, 10, 12]. The model is discrete and well-defined, and the partition function for the Perez-Rovelli version has been rigorously shown to converge [11] for a fixed triangulation of spacetime. The Riemannian model serves as a step along the way to understanding the less tractable but physically more realistic Lorentzian version [7]. However, despite its simplicity, we are currently lacking explicit numerical computations of the partition function and of expectation values of observables in the Riemannian model. These are necessary to test its large-scale behaviour and other physical properties.

It has been shown [3] that the amplitudes in the Barrett-Crane model are always non-negative, and therefore that the expectation values of observables can be approximated using the Metropolis algorithm. This greatly reduces the number of samples that must be taken, and thus the remaining obstacle is the time required to compute each sample. This paper presents a very efficient algorithm for doing these computations. The algorithm is used in [4] and [5] to understand the asymptotic behaviour of the $10j$ symbols and the dependence of the partition function on a cutoff.

To explain further, we need to describe the Barrett-Crane model in more detail. It has been formulated by Baez [2] as a discrete spin foam model, in which faces in the dual 2-skeleton of a fixed triangulation of spacetime are labeled by spins. The dual 2-skeleton consists of a dual vertex at the center of each 4-simplex of the triangulation, five dual edges incident to each dual vertex (one for each tetrahedron in the boundary of the 4-simplex), and ten dual faces incident to each dual vertex (one for each triangle in the boundary of the 4-simplex). ... that the partition function for this model is the sum, over all labelings ... expression that contains the product of a $10j$ symbol ... detail in Section 2, is a Spin(4) spin

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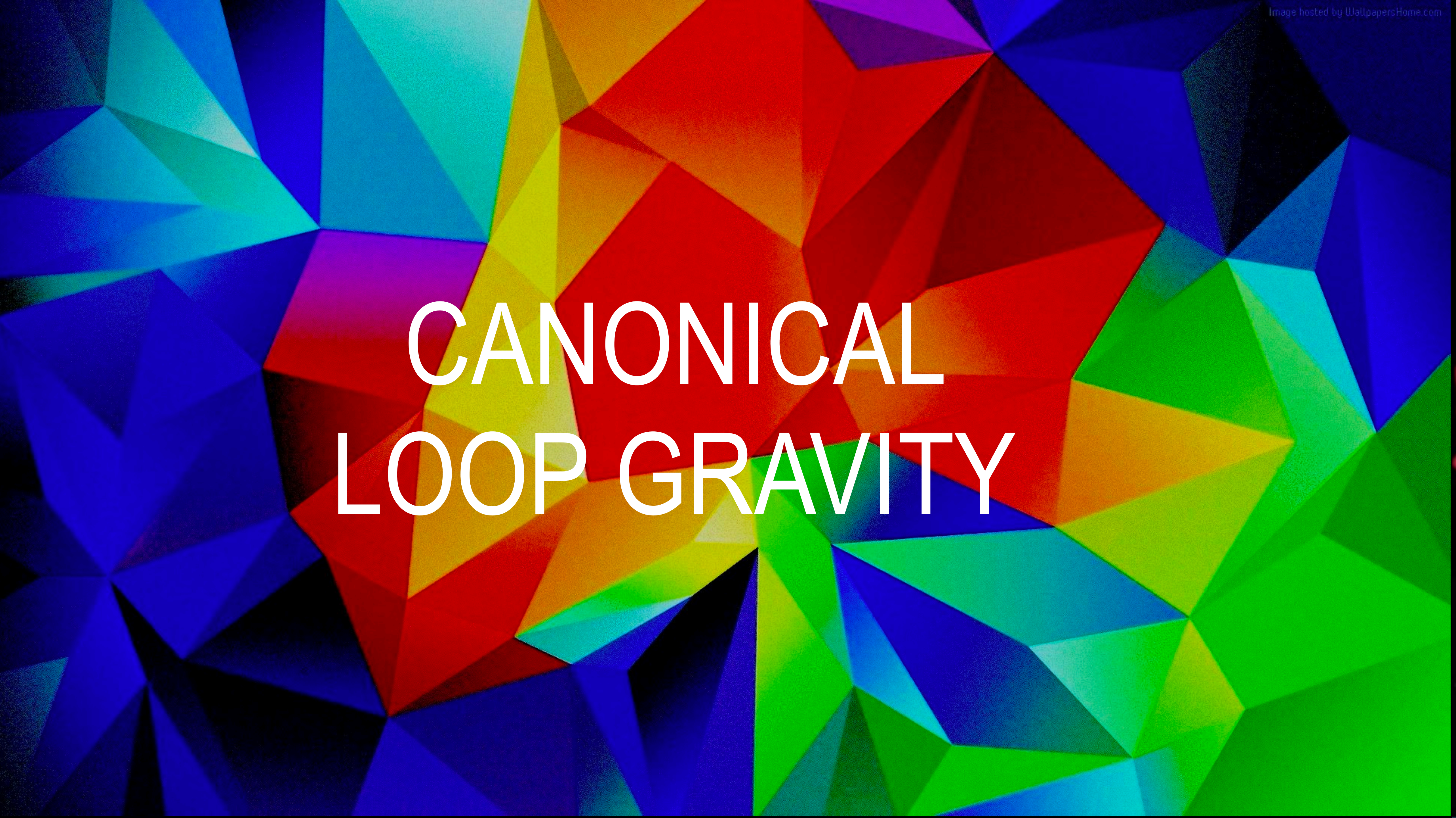
CANONICAL
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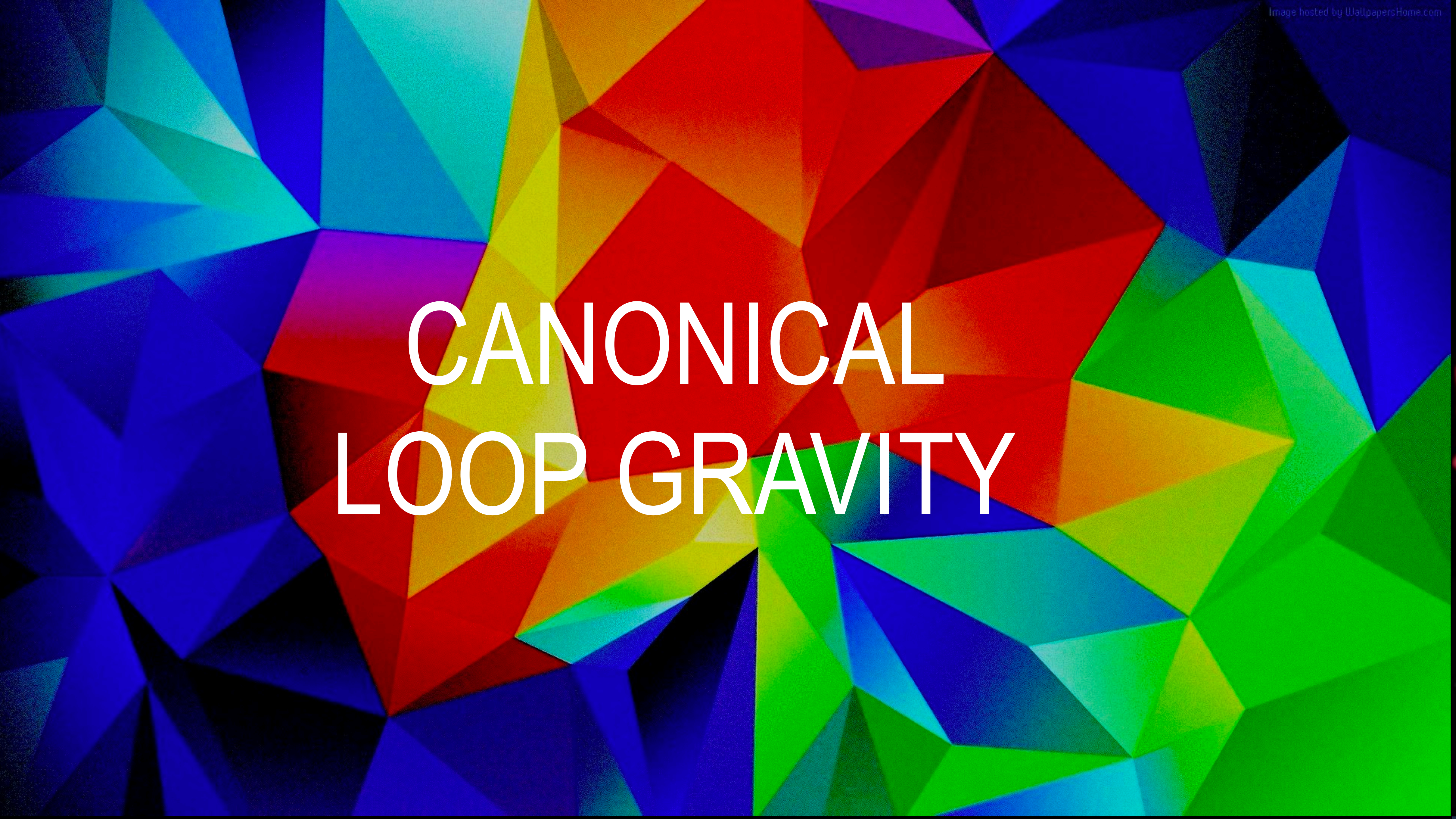
COVARIANT
LOOP GRAVITY


NUMERICS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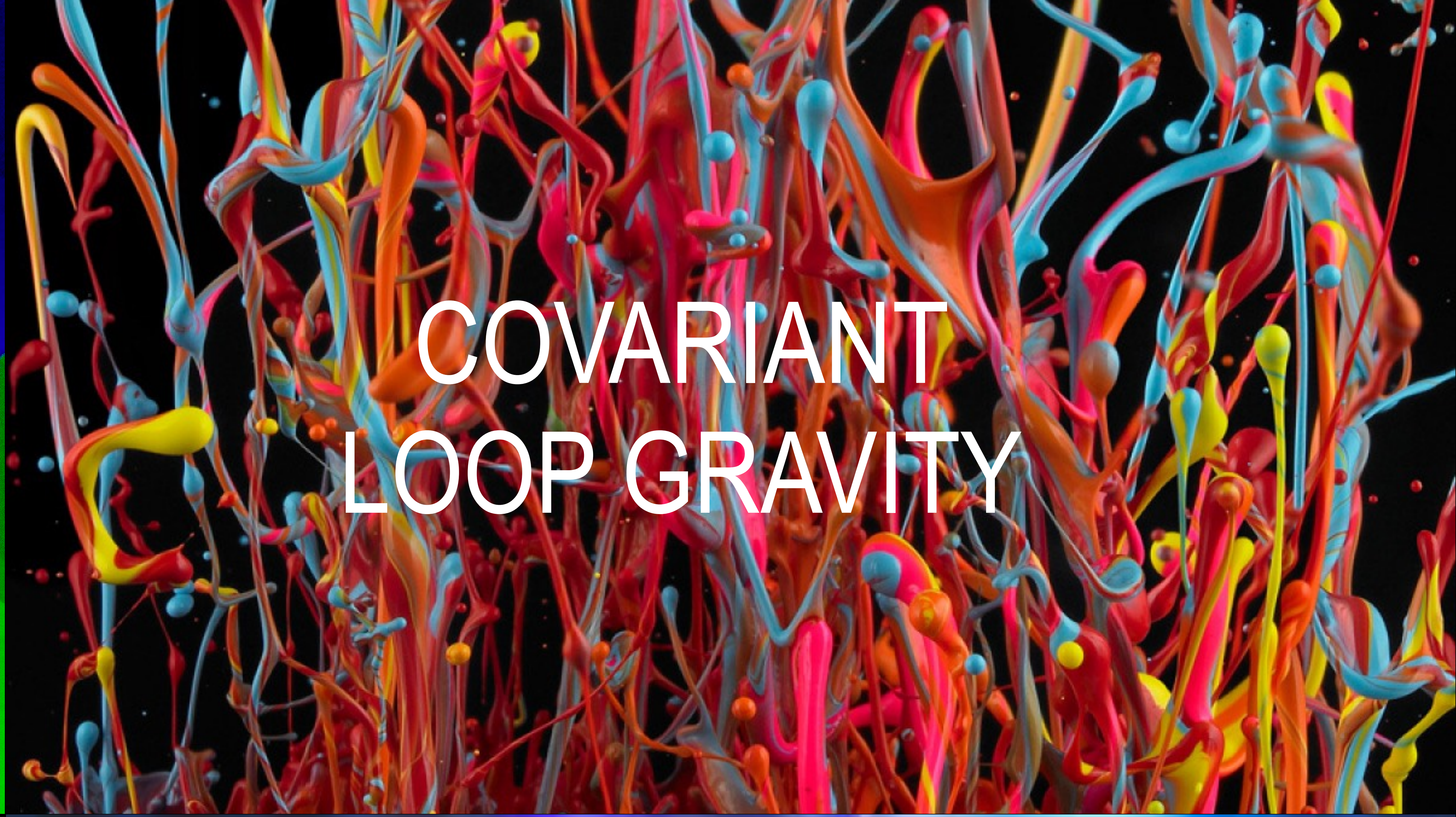
COVARIANT
LOOP GRAVITY


QUANTUM INFORMATION


NUMERICS

Art by Clifford Johnson

Yet you do not have holography, tensor networks, spacetime from entanglement…

Art by Clifford Johnson

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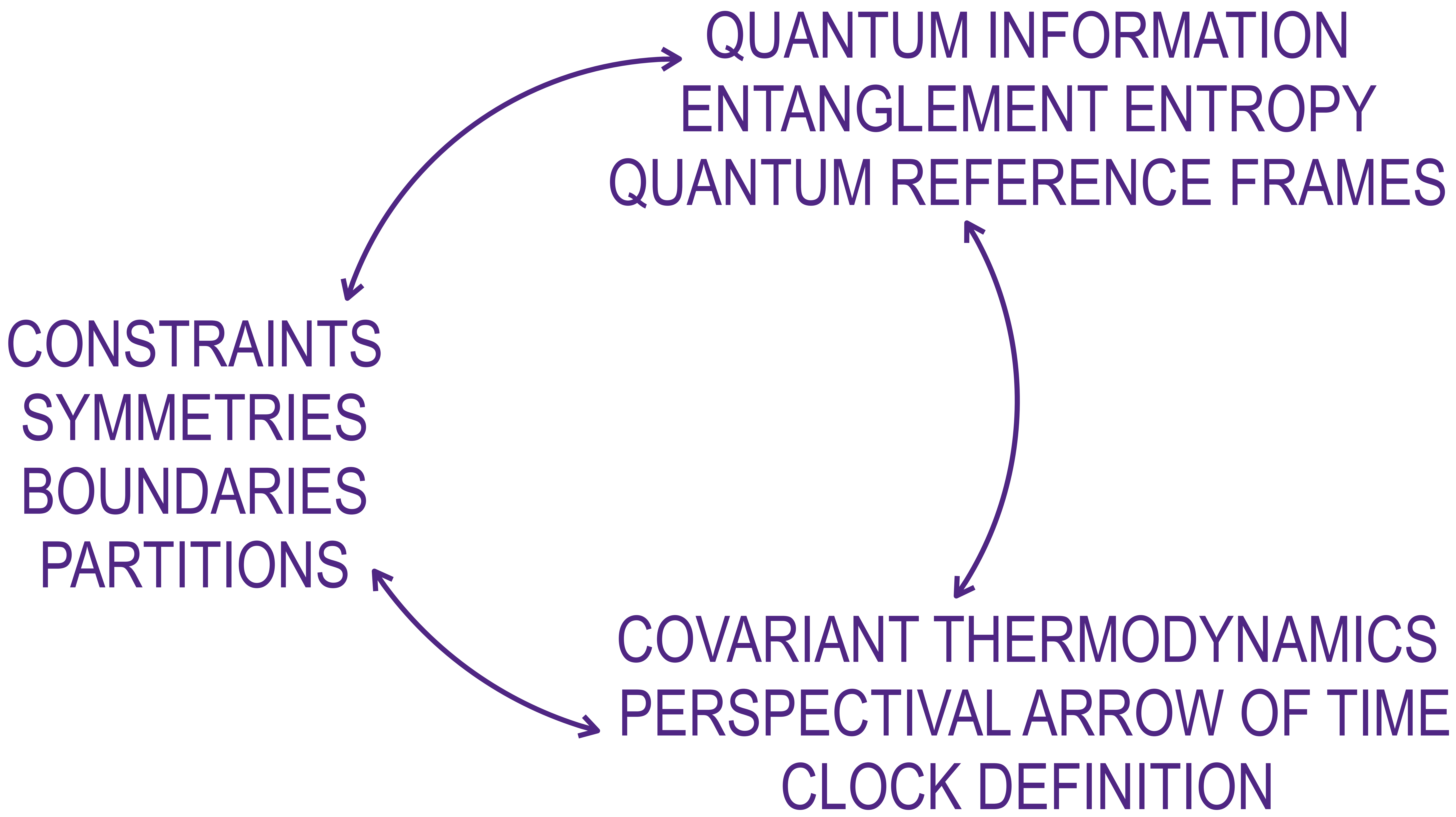
QUANTUM INFORMATION
ENTANGLEMENT ENTROPY
QUANTUM REFERENCE FRAMES
CONSTRAINTS
SYMMETRIES
BOUNDARIES
PARTITIONS
COVARIANT THERMODYNAMICS
PERSPECTIVAL ARROW OF TIME
CLOCK DEFINITION

A (MINIMAL) BIBLIOGRAPHY ON COVARIANT THERMODYNAMICS

- On energy for accelerating observers in black hole spacetimes
  S. A. Major • e-Print: 2203.00085
- On Generalised Statistical Equilibrium and Discrete Quantum Gravity
  I. Kotecha • e-Print: 2010.15445
- Statistical equilibrium of tetrahedra from maximum entropy principle.
  G. Chirco, I. Kotecha, D. Oriti • e-Print: 1811.00532
- Statistical Mechanics of Covariant Systems with Multi-fingered Time
  G. Chirco, T. Josset • e-Print: 1606.04444
- Is Time's Arrow Perspectival?
  C. Rovelli • e-Print: 1505.01125
- **Statistical mechanics of reparametrization-invariant systems.**
  G. Chirco, T. Josset, C. Rovelli • e-Print: 1503.08725
- Coupling and thermal equilibrium in general-covariant systems
  G. Chirco, H. M. Haggard, C. Rovelli • e-Print: 1309.0777
- Death and resurrection of the zeroth principle of thermodynamics
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- Why Gauge?
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- General relativistic statistical mechanics
  C. Rovelli • e-Print: 1209.0065
- Thermal time and the Tolman-Ehrenfest effect: temperature as the 'speed of time'
  C. Rovelli, M. Smerlak • e-Print: 1005.2985
- Von Neumann algebra automorphisms and time thermodynamics relation in general covariant quantum theories
  A. Connes, C. Rovelli • e-Print: 9406019
- Statistical mechanics of gravity and the thermodynamical origin of time
  C. Rovelli • 1993
- On the Weight of Heat and Thermal Equilibrium in General Relativity
  R. C. Tolman • 1930
- Temperature Equilibrium in a Static Gravitational Field
  R. Tolman, P. Ehrenfest • 1930

PHENOMENOLOGY
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MY FAVOURITE THINGS

- Spinfoam primordial vacuum state (high correlations?)
- Cosmological bounce (with matter, no inflation?)
- White holes and remnants (astrophysical effects? pre-bounce?)

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- Cosmological bounce (with matter, no inflation?)
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Too good not to fit together?

PHENOMENOLOGY
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TRUE OR FALSE?

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We do not have direct access to the Plank scale. ☐

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We do not have direct access to the Plank scale. ☑

We do not have quantum-gravity measurements. ☐


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We do not have quantum-gravity measurements.

TRUE OR FALSE?

We do not have direct access to the Plank scale. ✓

We do not have quantum-gravity measurements. ✗

- Supersymmetric particles
- Violation Lorentz Invariance
- QG imprint on initial cosmological perturbations
- Cosmological variation of couplings
- Quantum decoherence and state collapse
- TeV Black Holes
- Generalized uncertainty principle
- Violation of discrete symmetries

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- Gravitational Wave Echo
- Planck scale spacetime fuzziness
- …
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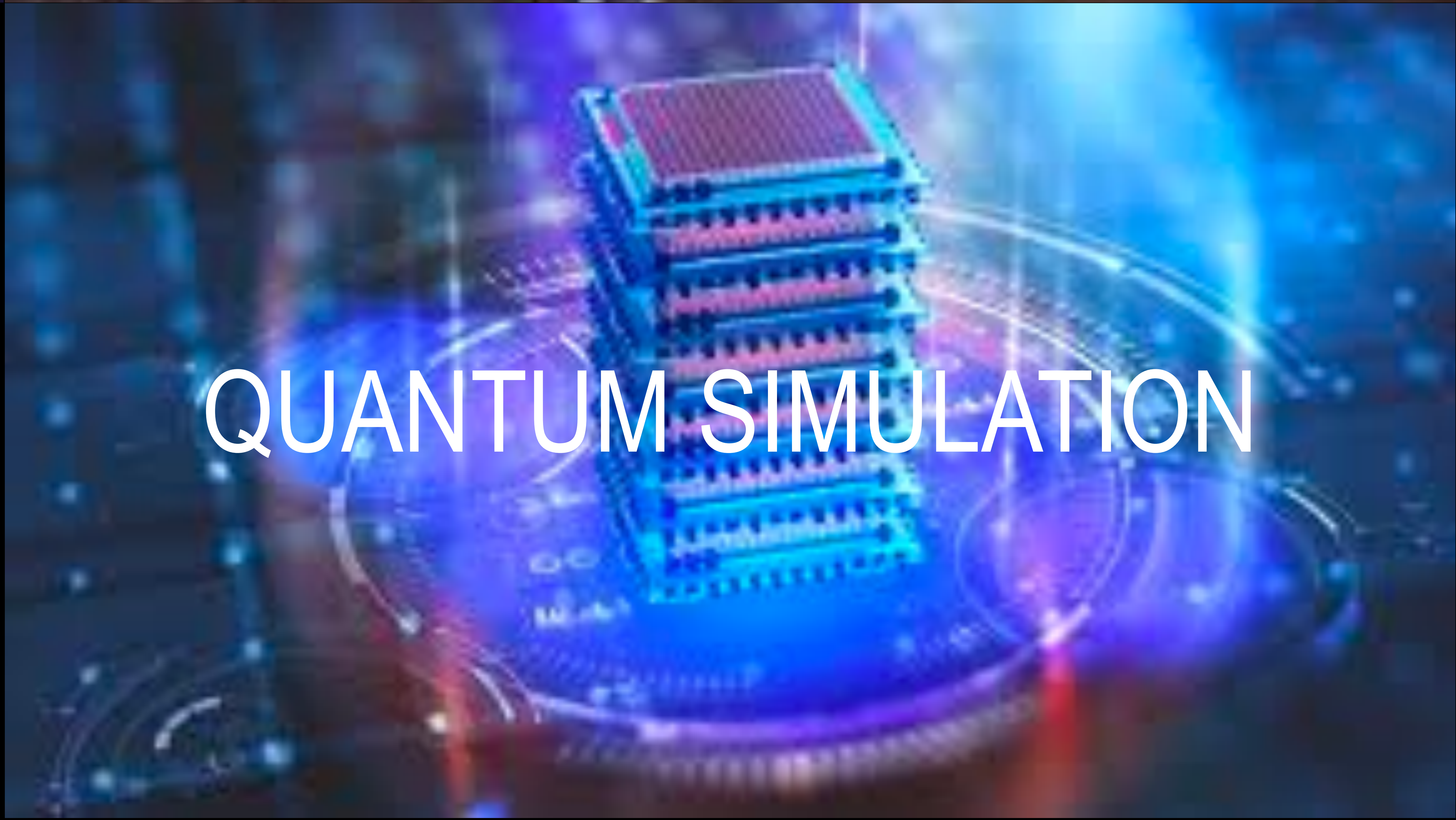
PHENOMENOLOGY
NOT BY BRUTE FORCE
BUT SMART THINKING

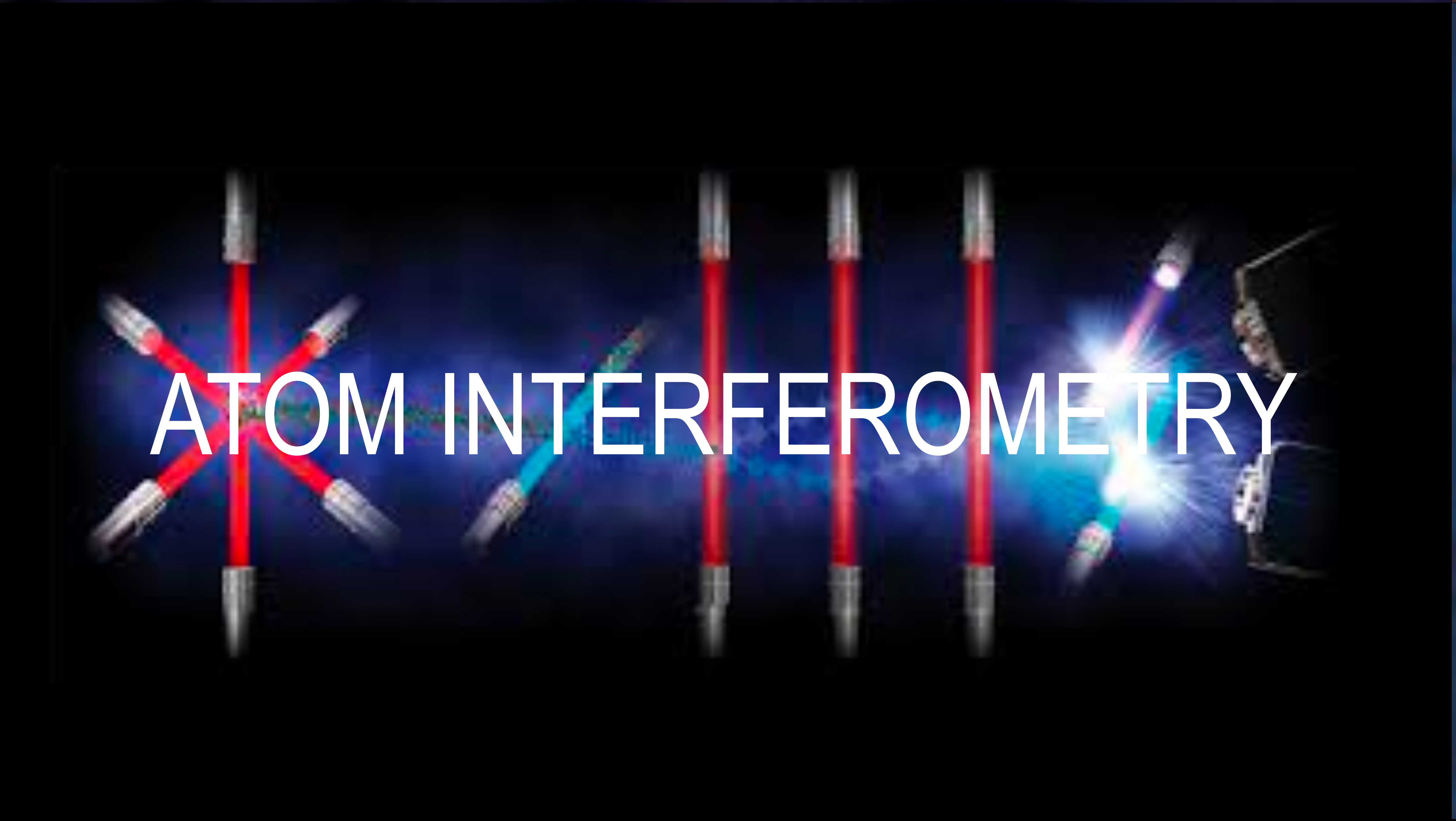
NEW IDEAS FOR
PHENOMENOLOGY
ARE FROM ANYWHERE


LARGE TELESCOPES

TEV ASTRONOMY

QUANTUM SIMULATION


LARGE TELESCOPES


TEV ASTRONOMY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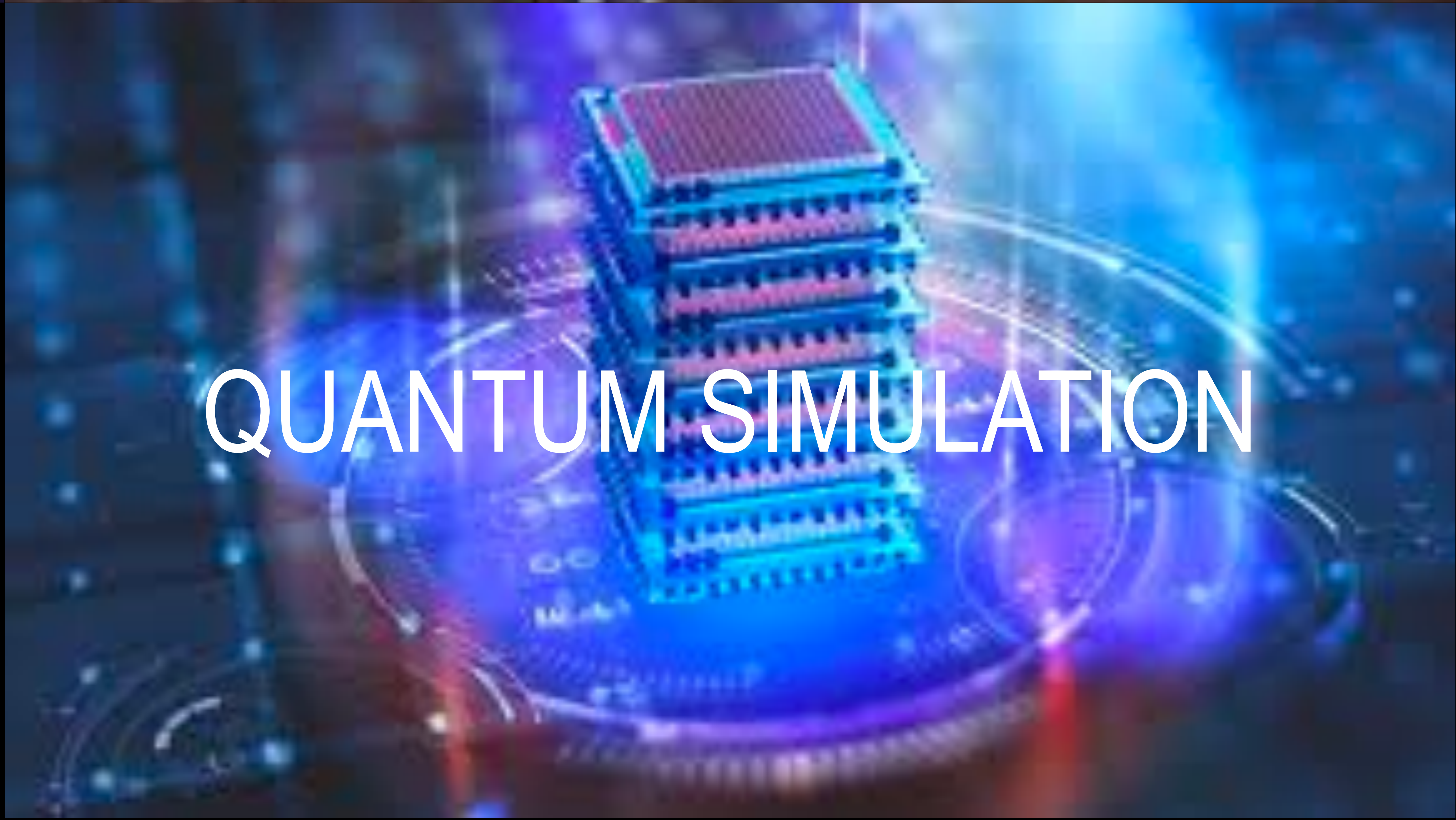
QUANTUM SIMULATION

LOOP QUANTUM GRAVITY MAP

https://bit.ly/LQGmap


You are part of the team:
Rakuten
PADDY'S CORNER
BE THE CHANGE YOU WANT TO SEE!