

# LOOP QUANTUM GRAVITY

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PHYSICS/ MATHEMATICS/ PHILOSOPHY

OBJECTIVES

ANALYSE CURRENT PHYSICS MODELS

WHY DO WE NEED A UNIFYING THEORY?

PRESENT THE KEY FEATURES OF LQG

QUESTION THE VERIFIABILITY OF THE THEORY

# CURRENT PHYSICS



TWO MODELS- RELATIVITY vs  
QUANTUM MECHANICS

TWO VERY DIFFERENT SCHEMES OF NATURE

# SPECIAL RELATIVITY

TIME DILATION

LENGTH CONTRACTION

MASS, ENERGY, MOMENTUM  
FLUCTUATIONS

# GENERAL RELATIVITY



GRAVITY AS A CURVATURE

THE BACKGROUND ITSELF

THE DIVERGENCE BETWEEN EINSTEIN AND NEWTON

FIXED SPACE OR DYNAMIC SPACE-TIME

BACKGROUND DEPENDANCE

$$\mathbf{F} = m\mathbf{a} = m \frac{d\mathbf{v}}{dt} = \frac{d(m\mathbf{v})}{dt} = \frac{d\mathbf{p}}{dt}$$

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} + \Lambda g_{\mu\nu} = kT_{\mu\nu}$$



**Newton's fixed space**



**Einstein's flexible space-time**

# THE MICROSCOPIC UNIVERSE



QUANTUM MECHANICS

CHAOTIC

VIOLENT

NOT CONTINUOUS VIEW OF SPACE-TIME

# MATTER AS WAVES

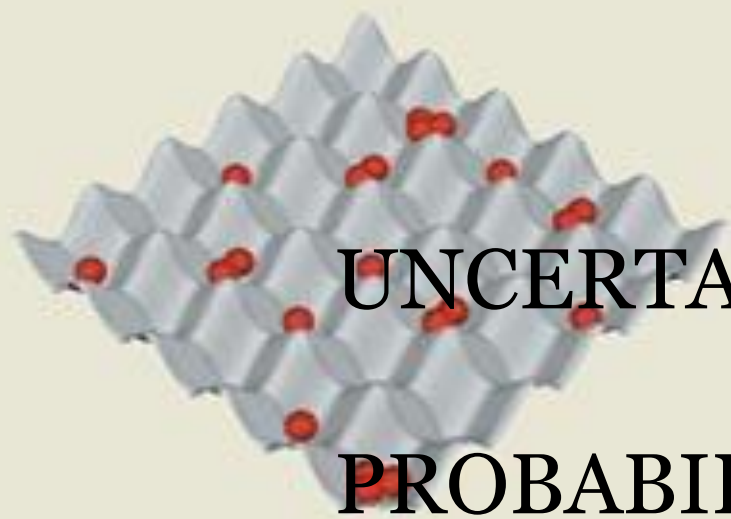
*de BROGLIE WAVELENGTH*

$$p = \frac{h}{\lambda} = \frac{hk}{2\pi} = \hbar k$$

The Schrödinger equation

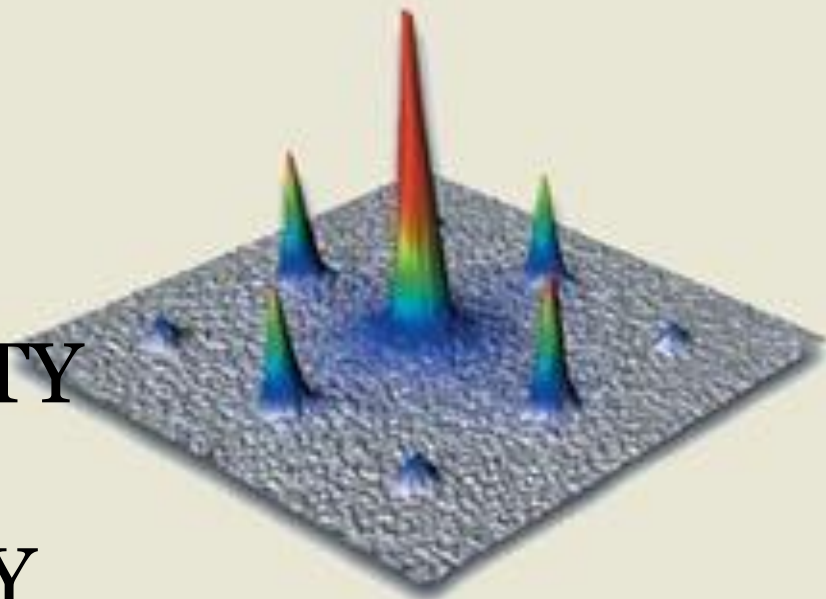
$$i\hbar \frac{\partial \psi(\mathbf{r}, t)}{\partial t} = -\frac{\hbar^2}{2m} \nabla^2 \psi(\mathbf{r}, t) + V(\mathbf{r})\psi(\mathbf{r}, t)$$

a

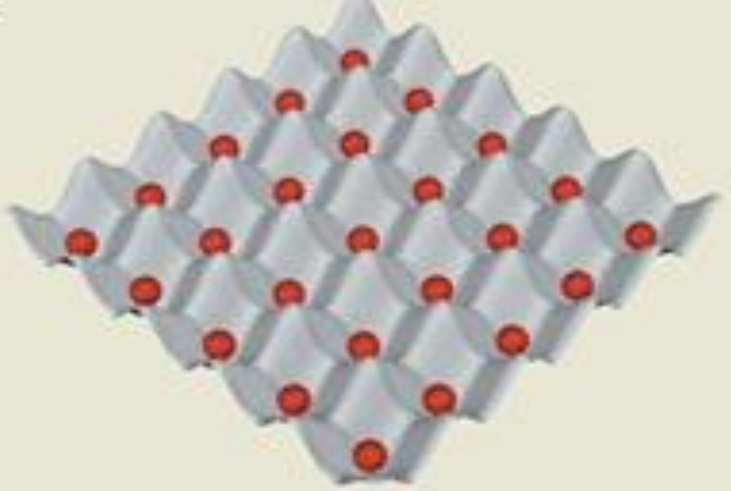


UNCERTAINTY

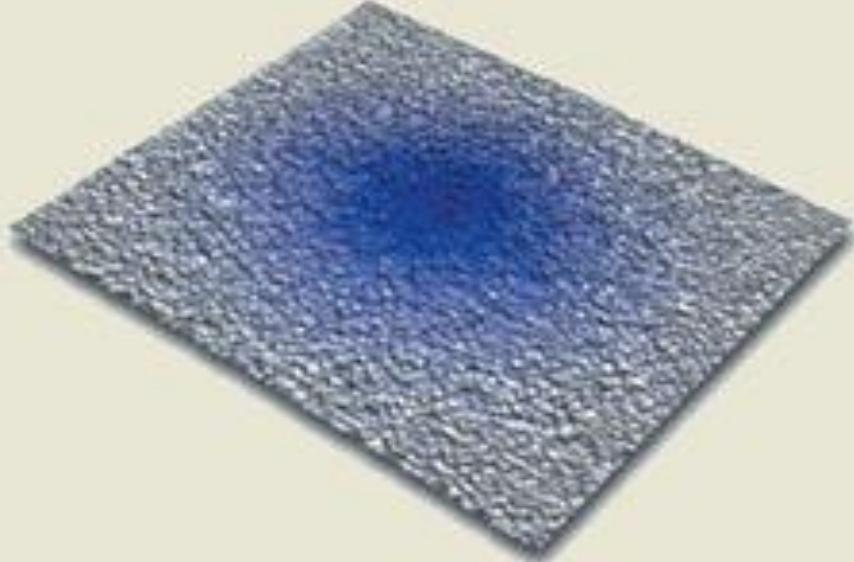
PROBABILITY



b



BACKGROUND DEPENDANCE





A black hole with a glowing accretion disk against a starry background. The black hole is a dark, circular void in the center, surrounded by a swirling disk of gas and dust that glows with purple and blue light. The background is a deep blue and black space filled with numerous small, bright stars.

WHY THE NEED FOR UNIFICATION

RELATIVITY- LARGE OBJECTS, LOW ENERGY

QUANTUM MECHANICS- SMALL SCALES, HIGH ENERGY

BLACK HOLES

A vast field of galaxies, including spirals, ellipticals, and irregular shapes, in various colors (yellow, blue, red, green) against a dark background. The galaxies are densely packed, illustrating the early universe.

# THE ORIGIN OF THE UNIVERSE

**Hubble Deep Field**

**HST · WFPC2**

PRC96-01a · ST ScI OPO · January 15, 1996 · R. Williams (ST ScI), NASA



SPACE-TIME ITSELF


DISCRETE

GRANULAR

# SCALES

UNCERTAINTY PRINCIPLE AND LENGTH  $\rightarrow$  BLACK HOLES

$10^{-12}$ cm



TIME ITSELF MUST BE DISCRETE.

$10^{-30}$ cm



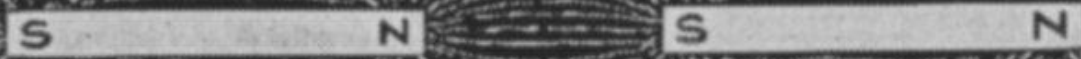
QUANTIZATION OF SPACE IS SIMILAR TO ENERGY LEVELS IN THE ATOM

$10^{-11}$ cm

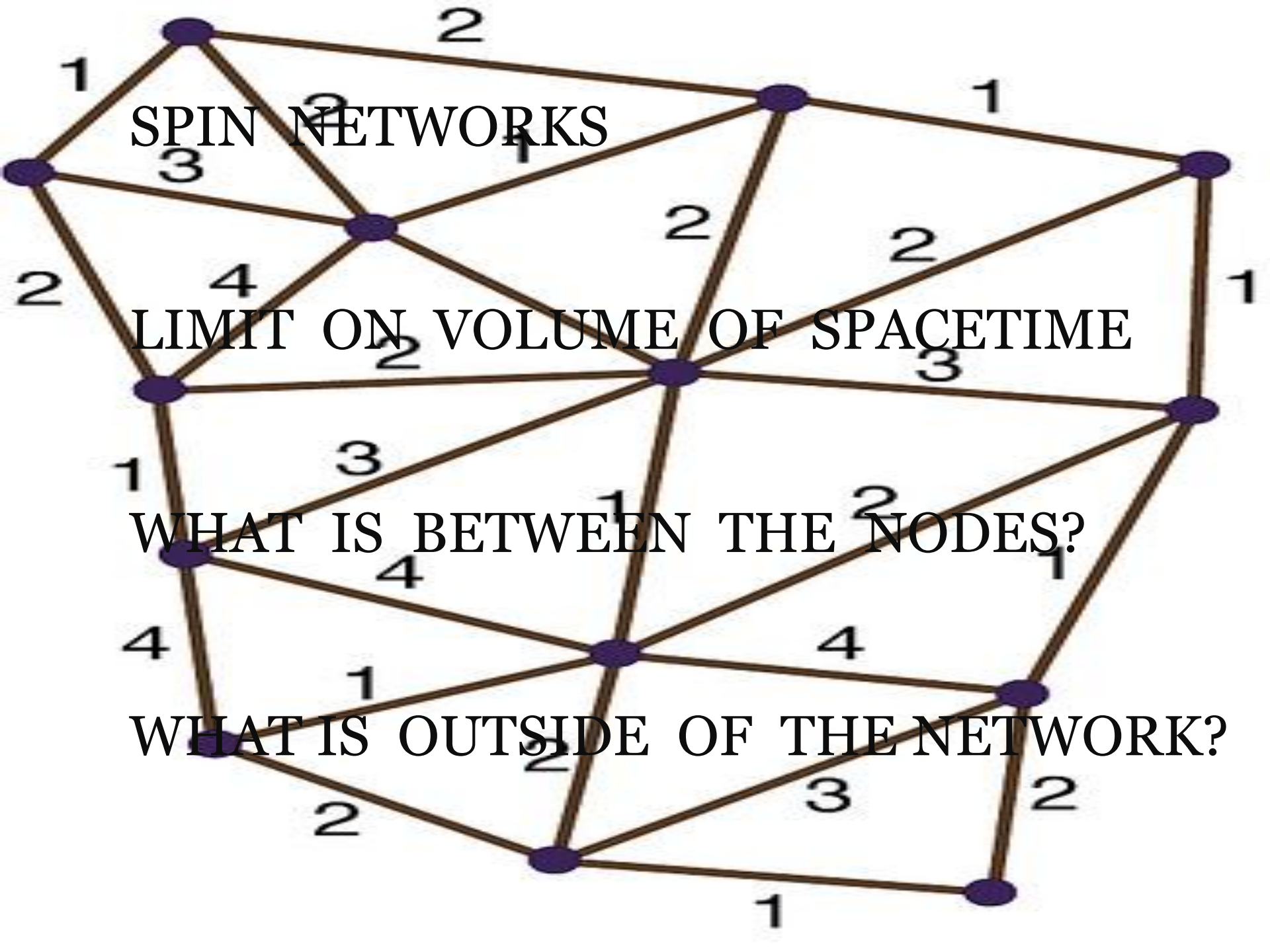


# SPACE-TIME CONSTRUCTION

## FARADAY LINES AND SPACE



## DERIVATION OF THE LOOPS IN LQG



SPIN NETWORKS

LIMIT ON VOLUME OF SPACETIME

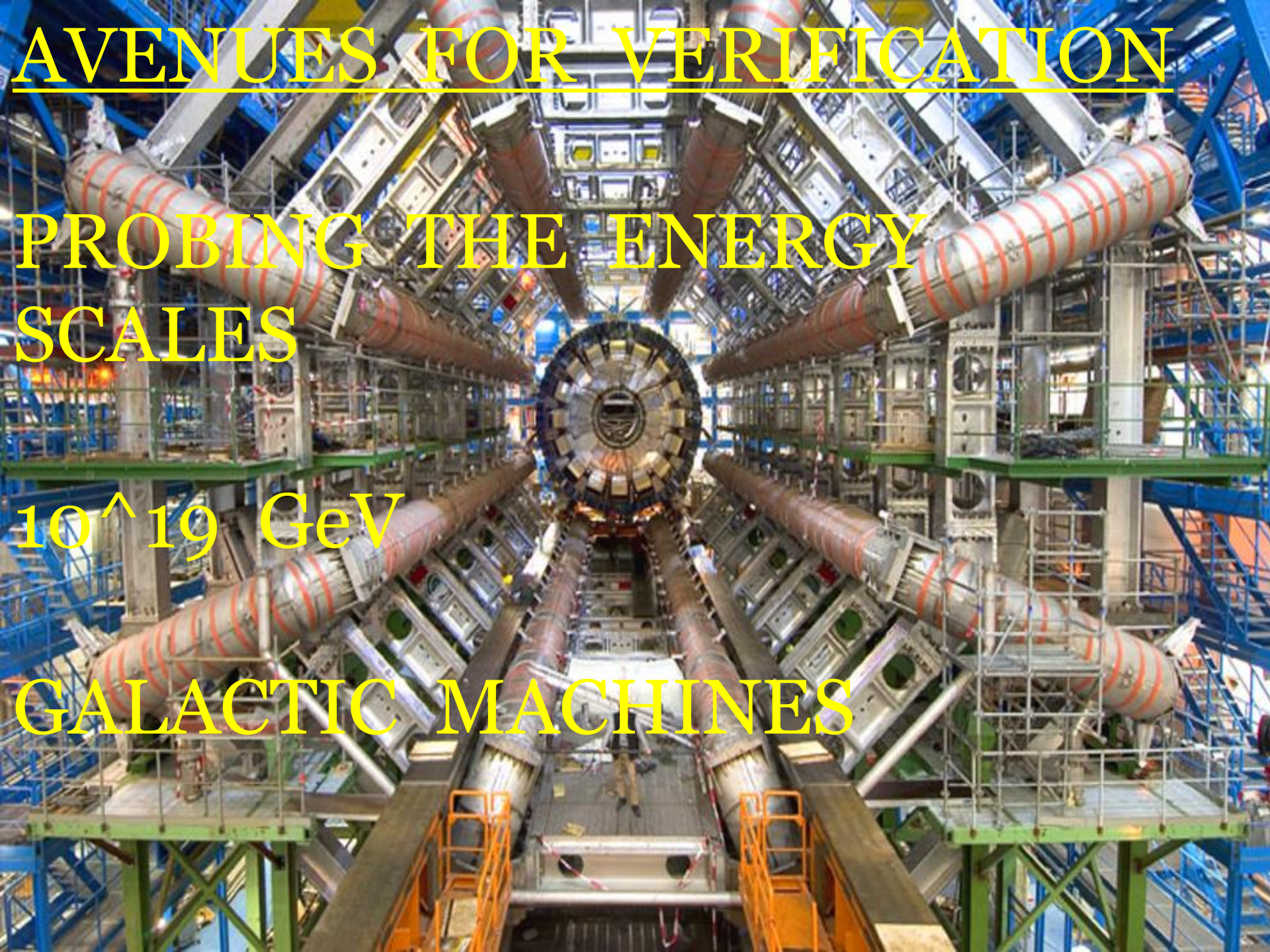
WHAT IS BETWEEN THE NODES?

WHAT IS OUTSIDE OF THE NETWORK?

SPIN FOAMS

**Time**  
↑  
**Space** →





# AVENUES FOR VERIFICATION

PROBING THE ENERGY  
SCALES

$10^{19}$  GeV

GALACTIC MACHINES



IF LQG IS CORRECT

1) DISCRETE SPACE WOULD LEAD  
TO CERTAIN PHOTON  
DISPERSIONS

2) LORENTZ INVARIANCE SHOULD  
BE VIOLATED

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- Carlo Rovelli. Loop Quantum Gravity
- Spin networks are simplicial quantum gravity
- **Brosl Hasslacher<sup>1</sup>**
- **Malcolm J. Perry<sup>2</sup>**
- **The future of spin networks**
- Authors: [Lee Smolin](#)