IS THE PHYSICAL METRIC A REAL NUMBER?

STEPHEN L. ADLER
INSTITUTE FOR ADVANCED STUDY, PRINCETON

REFS:

S.L.A. QUANTUM THEORY AS AN EMERGENT PHENOMENON
CAMBRIDGE, 2004

S.L.A. INCORPORATING GRAVITY INTO TRACE DYNAMICS: THE INDUCED GRAVITATIONAL ACTION
arXiv: 1306.0482

S.L.A. + F.M. RAMAZANOĞLU
SPHERICALLY SYMMETRIC SOLUTIONS ARISING FROM TRACE DYNAMICS MODIFICATIONS TO GRAVITATION
arXiv: 1308.1448

S.L.A. GRAVITATION AND THE NOISE NEEDED IN OBJECTIVE REDUCTION MODELS
arXiv: 1401.0353

TRACE DYNAMICS BACKGROUND (CAMBRIDGE BOOK)

- START FROM A MATRIX THEORY WITH GLOBAL UNITARY INVARIANCE

  CONSERVED QUANTITIES:

  TRACE HAMILTONIAN $\underset{\sim}{H}$

  OPERATOR $$\tilde{C} = \sum_{r \in B} [q_r, p_r] - \sum_{r \in F} \{q_r, p_r\}$$

- STATISTICAL MECHANICS

  CANONICAL ENSEMBLE

  $$\rho = Z^{-1} \exp[-\mathrm{Tr}\, \tilde{\lambda}\, \tilde{C} - \tau \underset{\sim}{H}]$$

- EQUIPARTITION (SMALL τ)

  EFFECTIVE QUANTUM THEORY FOR AVERAGES

  $$\langle \tilde{C} \rangle_{AV} = i_{eff}\, \hbar$$

- FRAME DEPENDENCE THROUGH $\underset{\sim}{H}$

  ROTATIONAL SYMMETRY $\Rightarrow$ CMB REST FRAME

INCORPORATE A CLASSICAL BACKGROUND METRIC (1306.0482)

CORRECTIONS TO CLASSICAL GRAVITATIONAL ACTION FROM PRE-QUANTUM MATRIX FIELDS

- ASSUME MASSLESS FIELDS ⇒ WEYL SCALING INVARIANCE
- THREE SPACE GENERAL COORDINATE INVARIANCE

$$\Rightarrow \Delta S = \int d^4x \, \frac{\sqrt{g}}{g_{00}^2} \left[\bar{A} + \text{METRIC DERIVATIVE TERMS} \right]$$

- FOR ROBERTSON-WALKER COSMOLOGY, $g_{00} = 1$

  ⇒ $\bar{A}$ TERM LOOKS LIKE COSMOLOGICAL CONSTANT ("DARK ENERGY")

  SO IDENTIFY $A_0 = -\Lambda / 8\pi G$ [(1,-1,-1,-1) METRIC]

- THEN CAN USE ΔS TO STUDY EFFECTS ON OTHER GEOMETRIES

SPHERICALLY SYMMETRIC METRIC (1308.1448)

$$S_{total} = \frac{1}{16\pi G}\int d^4x \sqrt{g}\, R - \frac{\Lambda}{8\pi G}\int d^4x \frac{\sqrt{g}}{g_{00}^2}$$

ANALYTIC AND NUMERICAL RESULTS

- g_{00} NON-VANISHING FOR FINITE VALUES OF THE POLAR RADIUS – BEHAVIOR CHANGES WITHIN 10^{-17} M/M_{sun} CM OF NOMINAL HORIZON

  SO NO HORIZON

- g_{00} IN POLAR COORDINATES HAS A SQUARE ROOT BRANCH POINT NEAR THE NOMINAL HORIZON

$$g_{00} = x + C\,(x-2)^{1/2} \qquad x = \Lambda^{1/2} r$$

COMPLEX g_{00} FOR $x < 2$ CUSP AT $x = 2$

- **<u>CUSP A COORDINATE SINGULARITY</u>**

$$R_{\mu\nu}R^{\mu\nu} = \frac{12\Lambda^2}{a^4} - \frac{48\Lambda^2}{a^5}c(x-a)^{1/2} + \cdots$$

$\frac{d}{dx}(x-a)^{1/2} \propto (x-a)^{-1/2}$ SINGULAR

BUT FOR D = PROPER DISTANCE

$\frac{d}{dD}(R_{\mu\nu}R^{\mu\nu})$ FINITE AT $x = a$

- **<u>RICCI SCALAR $R \equiv 0$</u>**

- g_{00} REAL IN ISOTROPIC COORDINATES
  <u>NO HORIZON</u>

- **<u>PHYSICAL SINGULARITY</u>** AT COSMOLOGICAL DISTANCES

  ARTIFACT OF STATIC ASSUMPTION?

NOISE NEEDED IN OBJECTIVE REDUCTION MODELS

(1401.0353 AND BELL VOLUME)

GHIRARDI - RIMINI - WEBER - PEARLE CSL MODEL

CONTINUOUS SPONTANEOUS LOCALIZATION

ADD ANTI-HERMITIAN NOISE TO HAMILTONIAN

TWO REQUIREMENTS

- STATE VECTOR NORMALIZATION:
  UNIT NORM PRESERVED IN TIME
- NO FASTER THAN LIGHT SIGNALING:
  NOISE AVERAGED DENSITY MATRIX
  HAS LINEAR EVOLUTION

$\Rightarrow$ UNIQUE FORM, CAN PROVE PROBABILITIES OBEY BORN RULE, LÜDERS RULE FOR DEGENERATE SYSTEMS

EXPERIMENTAL CONSTRAINTS $\rightarrow$ MASS-PROPORTIONAL NOISE COUPLING

CSL EXTENDED TO NON-WHITE NOISES

$$\frac{d|\psi(t)\rangle}{dt} = \left[-iH + \sqrt{\gamma} \int d^3x \, M(\hat{x}) \, \Phi(\vec{x},t) + O \right] |\psi(t)\rangle$$

$\uparrow$ NONLINEAR TERMS

$$M(\vec{x}) = \sum_i m_i \, \delta^3(\vec{x} - \hat{q}_i)$$

$\Phi(\hat{x},t)$ = CLASSICAL NOISE FIELD

$$\mathbb{E}[\Phi(\vec{x},t)] = 0 \qquad \mathbb{E}[\Phi(\vec{x},t_1)\,\Phi(\vec{y},t_2)] = D(\vec{x}-\vec{y},\, t_1 - t_2)$$

$\sqrt{\gamma}$ = COUPLING

D = NOISE AUTOCORRELATOR

WHAT IS THE PHYSICAL ORIGIN OF THE NOISE?

SUPPOSE

$$g_{\mu\nu} = \bar{g}_{\mu\nu} + \phi_{\mu\nu}$$

$\bar{g}_{\mu\nu}$ REAL SPACE-TIME METRIC

$$(ds)^2 = \bar{g}_{\mu\nu}\, dx^\mu\, dx^\nu$$

$\phi_{\mu\nu}$ AN IRREDUCIBLY COMPLEX FLUCTUATION

$$\mathcal{E}[\phi_{\mu\nu}] = 0$$

$$\mathcal{E}[\phi_{00}(\vec{x},t_1)\, \phi^*_{00}(\vec{y},t_2)] = D(\vec{x}-\vec{y}, t_1 - t_2)$$

$$\mathcal{E}[\phi_{00}(\vec{x},t_1)\, \phi_{00}(\vec{y},t_2)] = \tilde{D}(\vec{x}-\vec{y}, t_1 - t_2)$$

$$\delta S_{\substack{\text{MATTER} \\ \text{INTERACTION}}} = -\frac{1}{2}\int d^4x\, \sqrt{g}\, T^{\mu\nu} \phi_{\mu\nu}$$

$$= -\delta H_{\text{INTERACTION}}$$

WHEN T^{00} DOMINATES, GET INTERACTION TERM

$$\delta H_{\text{INTERACTION}} \approx \frac{1}{2}\int d^4x \sqrt{g}\, T^{00}\, \phi_{00}$$

$\mathrm{Im}(\phi_{00})$ GIVES A COUPLING $\sqrt{\gamma}\,\Phi$ IN CSL EQUATION

THIS SUGGESTS:

STATE VECTOR REDUCTION IS DRIVEN BY
A COMPLEX NUMBER VALUED "SPACETIME FOAM"

COULD COME FROM A COMPLEX MINIMUM OF THE GRAVITATIONAL EFFECTIVE ACTION

$\Gamma(g_{\mu\nu})$: $\delta\Gamma = 0$ AT $\eta_{\mu\nu} + \phi_{\mu\nu}$