TOWARDS RELATIVISTIC ATOMIC PHYSICS

AND

POST-MINKOWSKIAN GRAVITATIONAL WAVES

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LUSANNA - THE CHRONOGEOMETRICAL STRUCTURE OF SPECIAL AND GENERAL RELATIVITY: A REVISITATION OF CANONICAL GEOMETRODYNAMICS
42 KARPACZ WINTER SCHOOL INT. J. GEOM. METHODS IN MOD. PHYS 4 (2007) 79
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ALBA-LUSANNA - GENERALIZED RADAR 4-COORDINATES AND EQUAL TIME CAUCHY SURFACES FOR ARBITRARY ACCELERATED OBSERVERS
INT. J. MOD. PHYS. D16 (2007) 1149 gr-qc/0501090

ALBA-LUSANNA-PAURI - CENTERS OF MASS AND ROTATIONAL KINEMATICS FOR THE RELATIVISTIC N-BODY PROBLEM IN THE REST-FRAME INSTANT FORM
J. MATH. PHYS. 43 (2002) 1677 hep-th/0102087

CRATER-LUSANNA - THE REST-FRAME DARWIN POTENTIAL FROM THE LIENARD-WIECHERT SOLUTION IN THE RADIATION GAUGE
ANN. PHYS. ~~[illegible]~~ 289 (2001) 87

ALBA-CRATER-LUSANNA - HAMILTONIAN RELATIVISTIC 2-BODY PROBLEM: CENTER OF MASS AND ORBIT RECONSTRUCTION
J. PHYS. A40 (2007) 9585 gr-qc/0610200

ALBA-LUSANNA-CRATER - TOWARDS RELATIVISTIC ATOMIC PHYSICS. I. THE REST-FRAME INSTANT FORM OF DYNAMICS AND A CANONICAL TRANSFORMATION FOR A SYSTEM OF CHARGED PARTICLES PLUS THE ELECTROMAGNETIC FIELD
2008 ARXIV 0806.2383

II. COLLECTIVE AND RELATIVE RELATIVISTIC VARIABLES FOR A SYSTEM OF CHARGED PARTICLES PLUS THE ELECTROMAGNETIC FIELD IN PREPARATION

III. CLOCK SYNCHRONIZATION, QUANTIZATION AND RELATIVISTIC ENTANGLEMENT
IN PREPARATION

ACES { ESA FIRENZE (2008) FTP://CACCIAPUOTI:In73rn0@FTP.ESTEC.ESA.INT/
ESA MÜNICH GEODESY (2008) http://www.iapg.bv.tum.de/12735-naces-programme.html

ALBA-LUSANNA - CHARGED PARTICLES AND THE ELECTROMAGNETIC FIELD IN NON-INERTIAL FRAMES IN MINKOWSKI SPACETIME
0812.3057

GRAVITY
LUSANNA - THE REST-FRAME INSTANT FORM OF METRIC GRAVITY GRG 33 (2001) 1579

DEPIETRI-LUSANNA-MARTUCCI-RUSSO - ... TETRAD GRAVITY GRG 34 (2002) 877

ALBA-LUSANNA - YORK MAP GRG 39 (2007) 2149 gr-qc/0604086

LUSANNA-PAURI - DYNAMICAL 3-SPACE AND HOLE ARGUMENT
GRG 38 (2006) 187 and 229 gr-qc/0403081, 0407007
HISTORY AND PHILOSOPHY OF MODERN PHYSICS 37 (2006) 692 gr-qc/0604087

MOTIVATIONS FOR INTRODUCING THE LIGHTCONE

SPACE PHYSICS - LIGHT PROPAGATION IN THE SOLAR SYSTEM

CLOCK SYNCHRONIZATION AND INSTANTANEOUS 3-SPACE - ACES (POST-NEWTONIAN NULL GEODESICS FOR LIGHT), CAUCHY PROBLEM, PREDICTABILITY

"PHOTONS" OF PROTOCOLS FOR ENTANGLEMENT → MASSLESS PARTICLES ON NULL GEODESICS

2-LEVEL ATOMS - RELATIVISTIC POINT PARTICLES WITH STRUCTURE ($\neq$ SPIN)

INERTIAL AND TIDAL EFFECT IN NON-INERTIAL FRAMES

INTERACTION OF GRAVITATIONAL WAVES WITH PARTICLES AND LIGHT - ATOM INTERFEROMETERS

2-BODY PROBLEM IN POST-MINKOWSKIAN GRAVITY

COSMOLOGY - HOW MUCH DARK MATTER AND DARK ENERGY CAN BE EXPLAINED BY EINSTEIN GR?

WE NEED A FULLY RELATIVISTIC THEORETICAL FORMULATION OF ATOMIC PHYSICS (EFFECTIVE THEORY BELOW THE THRESHOLD OF PAIR PRODUCTION) INTERACTING WITH A DYNAMICAL ELECTROMAGNETIC FIELD AND ITS EXTENSION TO GRAVITY

A) INERTIAL AND NON-INERTIAL FRAMES IN MINKOWSKI SPACETIME

ISOLATED SYSTEMS, POINCARÉ GENERATORS, RELATIVISTIC CENTER OF MASS, INERTIAL AND NON-INERTIAL REST-FRAME INSTANT FORM OF DYNAMICS

B) LINEARIZATION TO POST-MINKOWSKIAN GRAVITY IN ASYMPTOTICALLY MINKOWSKIAN SPACETIMES (ONLY NON INERTIAL FRAMES DUE TO EQUIVALENCE PRINCIPLE)

GRAVITATIONAL WAVES WITH ASYMPTOTIC BACKGROUND 

C) RELATIVISTIC QUANTUM MECHANICS AND RELATIVISTIC ENTANGLEMENT

FAILURE OF ZEROTH POSTULATE → NON-LOCALITY AND SPATIAL NON-SEPARABILITY

RELATIVISTIC ASPECTS PRESENT AT $1/c^2$ LEVEL WHICH CANNOT BE IGNORED IN SPACE PHYSICS

NOT 1+3 BUT 3+1 AND RADAR COORDINATES

CLASSICAL AND QUANTUM THEORIES

PDE PREDICTABILITY → CAUCHY PROBLEM
↓
INSTANTANEOUS 3-SPACE
‖
CLOCK SYNCHRONIZATION

1) GALILEI SPACE-TIME { INERTIAL FRAMES; NON-INERTIAL FRAMES }

2) MINKOWSKI SPACE-TIME

3+1 SPLITTINGS AND THEIR GAUGE EQUIVALENCE { INERTIAL FRAMES; NON-INERTIAL FRAMES }

- ISOLATED SYSTEMS (PARTICLES, STRINGS, FIELDS, FLUIDS)
  RELATIVISTIC CENTER OF MASS AND POINCARÉ GROUP
- QUANTUM REL. MECHANICS
- REL. ATOMIC PHYSICS
- REL. ENTANGLEMENT
- QUANTIZATION IN NON-INERTIAL FRAMES

3) EINSTEIN SPACE-TIMES

3+1 SPLITTINGS — ONLY NON-INERTIAL FRAMES; EQUIVALENCE PRINCIPLE

- ACES - CLOCK SYNCHRONIZATION IN SOLAR SYSTEM (PN GRAVITY)
- YORK MAP - INERTIAL AND TIDAL EFFECTS IN CANONICAL GRAVITY
- COSMOLOGY - FRW PARADIGM
  - GR → DARK MATTER (RELATIVISTIC INERTIAL EFFECT ?)
  - GR → DARK ENERGY (BACKREACTION ? BUCHERT, ELLIS, ...)

3+1 / 1+3 VIEWPOINTS - BOTH NON FACTUAL → CAUCHY PROBLEM, CLOCK SYNCHRONIZATION

NON-RELATIVISTIC PHYSICS

(NEWTON'S THEORY IN GALILEI SPACETIME)

{ ABSOLUTE TIME
{ ABSOLUTE 3-SPACE (EUCLIDEAN)

⇓

ABSOLUTE SIMULTANEITY AND SPATIAL DISTANCE

GALILEI LAW OF INERTIA → INERTIAL OBSERVERS

GALILEI RELATIVITY PRINCIPLE – INVARIANCE IN FORM OF $\vec{F} = m\vec{a}$ IN INERTIAL FRAMES (CENTERED ON INERTIAL OBSERVERS) WITH CARTESIAN 3-COORDINATES – KINEMATICAL GALILEI GROUP

NEWTON'S GRAVITY – A-A-A-D INTERACTION WITH GALILEI EQUIVALENCE PRINCIPLE

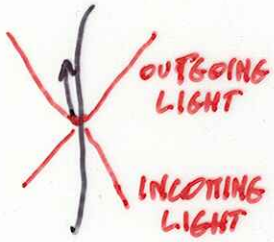
$$m\vec{a} = \vec{F}_G = m_G\,\vec{g} \qquad m = m_G$$

INERTIAL FRAMES – IDEAL LIMIT

RIGID NON-INERTIAL FRAMES CENTERED ON ACCELERATED OBSERVERS – INERTIAL FORCES $\propto$ INERTIAL MASS

$$\vec{a} = \frac{\vec{F}}{m} \underbrace{- \vec{W}(t)}_{\text{LINEAR}} + \underbrace{\vec{x} \times \frac{d\vec{\omega}(t)}{dt}}_{\text{JACOBI}} + \underbrace{2\,\frac{d\vec{x}}{dt} \times \vec{\omega}(t)}_{\text{CORIOLIS}} + \underbrace{\vec{\omega}(t) \times [\vec{x} \times \vec{\omega}(t)]}_{\text{CENTRIFUGAL}}$$

SPECIAL RELATIVITY (MINKOWSKI SPACETIME)



ABSOLUTE FLAT SPACETIME

$$ds^2 = \varepsilon\,[c^2 dt^2 - d\vec{x}^{\,2}] = \eta_{\mu\nu}\, dx^\mu dx^\nu$$

$$\eta_{\mu\nu} = \varepsilon\,(+---), \quad \varepsilon = \pm 1$$

CARTESIAN 4-COORDINATES

ONLY THE CONFORMAL STRUCTURE (THE LIGHT CONE) IS INTRINSICALLY GIVEN

NO NOTION OF {
- INSTANTANEOUS 3-SPACE, SPATIAL DISTANCE
- SIMULTANEITY (SYNCHRONIZATION OF DISTANT CLOCKS NEEDED)
- CAUCHY 3-SURFACE FOR MAXWELL EQs
- 1-WAY VELOCITY OF LIGHT (2 SYNCHRONIZED CLOCKS NEEDED)

LIGHT POSTULATES – THE 2-WAY (OR ROUND TRIP; ONLY 1 CLOCK NEEDED) VELOCITY OF LIGHT IS A) ISOTROPIC B) CONSTANT $c = 2.997924580\ 10^8\ m\,s^{-1}$

METROLOGY – c and standard of time

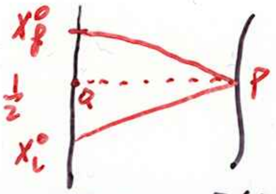
$L = \frac{1}{2} c\Delta t$

↳ but in which 3-space?

LAW OF INERTIA $\longrightarrow$ INERTIAL OBSERVERS

SPECIAL RELATIVISTIC RELATIVITY PRINCIPLE - INVARIANCE IN FORM OF PHYSIC'S LAWS IN INERTIAL FRAMES (CENTERED ON INERTIAL OBSERVERS) WITH CARTESIAN 4-COORDINATES - KINEMATICAL POINCARÉ GROUP

IDENTIFIED BY EINSTEIN'S $\frac{1}{2}$ CONVENTION FOR CLOCK SYNCHRONIZATION



A (INERTIAL) B (NON-INERTIAL)

$$x^0_p \overset{def}{=} x^0_q = x^0_l + \frac{1}{2}(x^0_g - x^0_l) = \frac{1}{2}(x^0_g + x^0_l)$$

$\Downarrow$

3 SPACES = EUCLIDEAN $x^0 = ct =$ const HYPERPLANES

1-WAY = 2-WAY = c

INERTIAL OBSERVERS = IDEAL LIMIT $\longrightarrow$ ACCELERATED OBSERVES

ACCELERATION LENGTH $\begin{cases} \mathcal{L} = c^2/a & \text{TRANSLATIONAL} \quad (\sim 1\ \text{LYR}) \\ \mathcal{L} = c/\omega & \text{ROTATIONAL} \quad (\sim 20\ \text{AU}) \end{cases}$

LOCALITY HYPOTHESIS - an accelerated observer is a succession of instantaneously comoving inertial observers

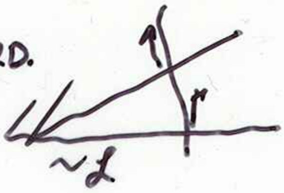
$\lambda > \mathcal{L}$ PROBLEMS

1+3 POINT OF VIEW

ONLY THE OBSERVER'S WORLDLINE AND 4-VELOCITY ARE GIVEN

NO KNOWN METHOD TO DEFINE GLOBAL INSTANTANEOUS 3-SPACES (CAUCHY SURFACES)

FERMI COORD.



ROTATING DISK

$\omega R = c \Rightarrow g_{oo}(Y^o, \vec{Y} = \omega R \hat{n} = c\,\hat{n})$
$= 0$

$\downarrow$ $\quad x^\mu \rightarrow y^\mu(x),\ \eta_{\mu\nu} \rightarrow g_{\mu\nu}(Y)$

SAGNAC EFFECT

COORDINATE SYNGULARITIES

PARAMETRIZED MINKOWSKI THEORIES

WORLD-LINE OF AN ACCELERATED OBSERVER (TIMELIKE)

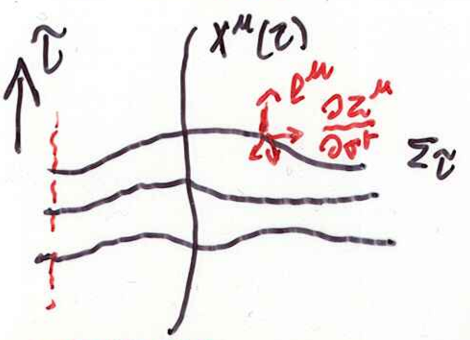
+ 3+1 SPLITTING OF MINKOWSKI SPACETIME

(= NICE FOLIATION WITH SPACELIKE 3-SURFACES =

= CLOCK SYNCHRONIZATION CONVENTION =

= DEFINITION OF THE INSTANTANEOUS 3-SPACE)

⇒ GLOBAL NON-INERTIAL FRAME CENTERED ON THE ACCELERATED OBSERVER



ASYMPTOTIC INERTIAL OBSERVER

FRAME- AND OBSERVER- DEPENDENT, LORENTZ-SCALAR RADAR 4-COORDINATES (BONDI) $(\tau; \sigma^r)$

[DIFFERENTLY FROM FERMI COORDINATES, THEY CAN BE OPERATIONALLY DEFINED]

$$\begin{cases} x^\mu \longmapsto \sigma^A(x) = (\tau; \sigma^r) \\ \sigma^A \longmapsto x^\mu = z^\mu(\tau, \sigma^r) \end{cases}$$

x^μ CARTESIAN 4-COORD. IN AN INERTIAL FRAME

EMBEDDING OF Σ_τ

$$\eta_{\mu\nu} \longrightarrow g_{AB}[z(\tau, \vec\sigma)] = \frac{\partial z^\mu(\sigma)}{\partial \sigma^A} \eta_{\mu\nu} \frac{\partial z^\nu(\sigma)}{\partial \sigma^B}$$

NORMAL TO Σ_τ

$$l^\mu = \frac{1}{\sqrt{g}} \varepsilon^\mu{}_{\alpha\beta\gamma} z^\alpha_1 z^\beta_2 z^\gamma_3$$

$$\frac{\partial z^\mu(\tau, \vec\sigma)}{\partial \tau} = \underbrace{N(\tau, \vec\sigma)}_{\text{LAPSE}} l^\mu(\tau, \vec\sigma) + \underbrace{N^r(\tau, \vec\sigma)}_{\text{SHIFT}} \frac{\partial z^\mu(\tau, \vec\sigma)}{\partial \sigma^r}$$

$\hookrightarrow = z^\mu_r(\tau, \vec\sigma)$ TANGENT TO Σ_τ

MØLLER ADMISSIBILITY CONDITIONS FOR THE 3+1 SPLITTINGS

$g_{\tau\tau}(\tau, \vec\sigma) > 0$, $g_{\tau r}(\tau, \vec\sigma) < 0$, $\det g_{rs}(\tau, \vec\sigma) < 0$

↓

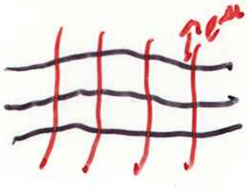
NO RIGID REL. ROTATIONS

$$\begin{vmatrix} g_{rr} & g_{rs} \\ g_{sr} & g_{ss} \end{vmatrix} (\tau, \vec\sigma) > 0,$$

$\Sigma_\tau \xrightarrow[\text{INFINITY}]{\text{SPATIAL}}$ SPACELIKE HYPERPLANE

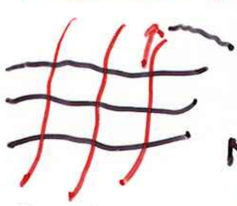
$\boxed{N(\tau, \vec\sigma) > 0}$ NO INTERSECTION OF 3-SPACES

2 CONGRUENCES OF ACCELERATED OBSERVER ASSOCIATED TO EVERY 3+1 SPLITTING



NORMAL = 4-VELOCITY
SURFACE-FORMING

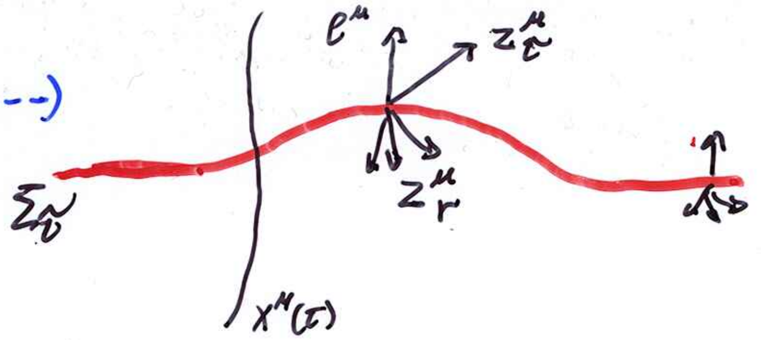
EULERIAN OBSERVERS



$\frac{\partial z^\mu}{\partial \tau} / \sqrt{g_{\tau\tau}}$ = 4-VELOCITY

NON-SURFACE-FORMING
(ROTATING DISK)

$\eta_{\mu\nu} = \epsilon(+---)$



ϵ^μ_A $\quad \epsilon^\mu_\tau = l^\mu_{(as)}$

ASYMPTOTIC INERTIAL OBSERVERS (FIXED STARS)

$z^\mu(\tau, \sigma^u)$

LAPSE SHIFT

$$\begin{cases} z^\mu_\tau(\tau,\sigma^u) = \dfrac{\partial z^\mu(\tau,\sigma^u)}{\partial \tau} = \left[(1+n)\, l^\mu + h^{rs} n_s\, z^\mu_r\right](\tau,\sigma^u) \\ z^\mu_r(\tau,\sigma^u) = \dfrac{\partial z^\mu(\tau,\sigma^u)}{\partial \sigma^r} \qquad l^\mu(\tau,\sigma^u) = \dfrac{1}{\sqrt{\gamma(\tau,\sigma^u)}}\, \epsilon^\mu{}_{\alpha\beta\gamma}\left[z^\alpha_1 z^\beta_2 z^\gamma_3\right](\tau,\sigma^u) \end{cases}$$

$$\begin{cases} g_{\tau\tau} = z^\mu_\tau \eta_{\mu\nu} z^\nu_\tau = \epsilon\left[(1+n)^2 - h^{rs} n_r n_s\right] \\ g_{\tau r} = z^\mu_\tau \eta_{\mu\nu} z^\nu_r = -\epsilon\, n_r \\ g_{rs} = z^\mu_r \eta_{\mu\nu} z^\nu_s = -\epsilon\, h_{rs} \end{cases}$$

h_{rs} $(+++)$, INVERSE h^{rs} $\begin{cases} \gamma = \det h_{rs} \\ \sqrt{|\det g_{AB}|} = (1+n)\sqrt{\gamma} \end{cases}$

$d\tau > 0$ $\quad \boxed{1+n(\tau,\sigma^u) > 0}$

$\rightarrow \omega r < c$

$$\epsilon\, g_{AB} = \begin{pmatrix} \boxed{\epsilon\, g_{\tau\tau}(\tau,\sigma^u) > 0} & -n_s(\tau,\sigma^u) \\ -n_r(\tau,\sigma^u) & -h_{rs} = -\left[R^T \begin{pmatrix} \lambda_1 & & \\ & \lambda_2 & \\ & & \lambda_3 \end{pmatrix} R\right]_{rs} \end{pmatrix}$$

MØLLER $\quad \boxed{\lambda_i(\tau,\sigma^u) > 0}$

$\Rightarrow \lambda_i = \gamma^{1/3} e^{2\sum_1^2 a \gamma_{ai} R_a}$

$h_{rs} = \gamma^{1/3} \sum_u e^{2\sum_1^2 a \gamma_{ai} R_a}\, V_{ru}(\theta^i) V_{su}(\theta^i) = \sum_u e_{(u)r}\, e_{(u)s}$ $\rightarrow$ COTRIADS ON Σ_τ

${}^3K_{rs} = \dfrac{1}{2(1+n)}\left(n_{r|s} + n_{s|r} - \partial_\tau h_{rs}\right)$

$\gamma, R_a, \theta^i, 1+n, n_r$ INERTIAL GAUGE VARIABLES

$\swarrow \mathcal{H} \approx 0$ $\quad \searrow$ NONLINEAR GRAVITON IN GR

$z^\mu(\tau,\sigma^u) = x^\mu(\tau) + \epsilon^\mu_r\, R^r{}_s\left(F(\sigma)\,\alpha_i(\tau)\right)\sigma^s$

MØLLER $\quad \dfrac{dF(\sigma)}{d\sigma} \neq 0, \; 0 < F(\sigma) < \dfrac{1}{A\sigma}$ $\qquad F(\sigma) = \dfrac{1}{1 + \frac{\omega^2\sigma^2}{c^2}}$

DIFFERENTIAL ROTATIONS (REL. STARS)

$h_{rs} \approx \delta_{rs} + \left[\Omega^r_{(s)u}(\tau,\sigma) + \Omega^s_{(r)u}(\tau,\sigma)\right]\sigma^u + \sum_w \Omega^w_{(r)u}(\tau,\sigma)\, \Omega^w_{(s)v}(\tau,\sigma)\, \sigma^u \sigma^v$

$\Omega = -\frac{1}{2} R^{-1}\partial_\tau R \qquad \Omega_{(r)} = R^{-1}\partial_r R$

ISOLATED SYSTEM (PARTICLES, STRINGS, FLUIDS, FIELDS) WITH LAGRANGIAN DESCRIPTION (CONFIGURATIONS WITH THE 10 POINCARÉ GENERATORS FINITE)

COUPLING TO EXTERNAL GRAVITATIONAL FIELD $g_{\mu\nu}(x)$ $\mathcal{L}(\text{matter}, g_{\mu\nu})$

$$g_{\mu\nu}(x) \mapsto g_{AB}[z^\mu(\tau,\vec\sigma)] \quad \Rightarrow \quad S = \int d\tau\, d^3\sigma\, \tilde{\mathcal{L}}(\text{matter}, z(\tau,\vec\sigma))$$

$\underline{\phi(\tau,\vec\sigma)} = \tilde\phi(z(\tau,\vec\sigma))$, $x_i^\mu(\tau) = z^\mu(\tau, \underline{\vec\eta_i(\tau)})$

ACTION PRINCIPLE FOR MATTER AND EMBEDDING $z^\mu(\tau,\vec\sigma)$

FLUIDS - ACTION OF BROWN (CQG 10 (1993) 1579)

S INVARIANT UNDER FRAME-PRESERVING DIFFEOMORPHISMS (SPECIAL RELATIVISTIC GENERAL COVARIANCE)

4 FIRST-CLASS CONSTRAINTS (DEPARAMETRIZED ANALOGUES OF THE SUPER-HAM. AND SUPER-MOMENTUM CONSTRAINTS OF GR)

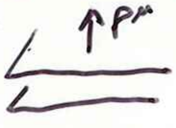
$$\left\{ \begin{array}{l} \mathcal{H}^\mu(\tau,\vec\sigma) = \underbrace{\rho^\mu(\tau,\vec\sigma)}_{\text{4-MOMENTUM OF } z^\mu(\tau,\vec\sigma)} - l^\mu(\tau,\vec\sigma)\, \underbrace{T^{\tau\tau}(\tau,\vec\sigma)}_{\text{MATTER ENERGY DENSITY}} - z^\mu_r(\tau,\vec\sigma)\, \underbrace{T^{\tau r}(\tau,\vec\sigma)}_{\text{MATTER 3-MOMENTUM DENSITY}} \approx 0 \\ \\ \{\mathcal{H}^\mu(\tau,\vec\sigma_1), \mathcal{H}^\mu(\tau,\vec\sigma_2)\} = 0 \end{array} \right.$$

$\Rightarrow$ $z^\mu(\tau,\vec\sigma)$ GAUGE VARIABLES $\Rightarrow$ GAUGE EQUIVALENCE OF ADMISSIBLE NON-INERTIAL FRAMES (I.E. OF CLOCK SYNCHRONIZATION CONVENTIONS AND OF CHOICE OF 3-COORDINATES ON THE INSTANTANEOUS 3-SPACES)

REST-FRAME INSTANT FORM OF DYNAMICS

INERTIAL 3+1 SPLITTING CENTERED ON AN INERTIAL OBSERVER (DESCRIBING THE COLLECTIVE VARIABLES OF THE ISOLATED SYSTEM)

WHOSE INSTANTENEOUS 3-SPACES ARE ORTHOGONAL TO THE 4-MOMENTUM OF THE ISOLATED SYSTEM (INTRINSICALLY DEFINED BY ITS CONFIGURATIONS)



$$z^\mu(\tau,\vec\sigma) = x^\mu(\tau) + \epsilon^\mu_r(P)\,\sigma^r$$

NON-INERTIAL REST FRAMES

ASYMPTOTIC INERTIAL OBSERVERS = FIXED STARS

ISOLATED SYSTEMS IN THE REST-FRAME INSTANT FORM

STANDARD DESCRIPTION — POINCARÉ GENERATORS $P^\mu, J^{\mu\nu}$ FINITE

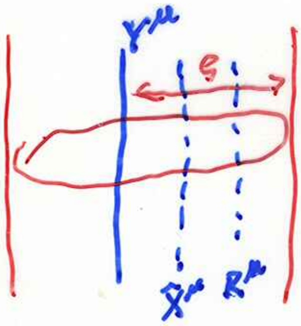
- NON-LOCAL QUANTITIES — THEY KNOW THE WHOLE INSTANTANEOUS 3-SPACE $P^\mu = \int_{\Sigma_\tau} d^3x \dots$
- LORENTZ BOOSTS: INTERACTION-DEPENDENT $[P^i, K^j] = \delta^{ij} P^o$ $\neq$ GALILEI BOOSTS

$P^\mu, J^{\mu\nu} \rightarrow$ 3 NOTIONS OF COLLECTIVE VARIABLES

- $\tilde{x}^\mu = (\tilde{x}^o; \vec{\tilde{x}})$ NON-COVARIANT CANONICAL CENTER OF MASS (CENTER OF SPIN)
- $Y^\mu = (\tilde{x}^o; \vec{Y})$ COVARIANT NON-CANONICAL FOKKER-PRYCE CENTER OF INERTIA
- $R^\mu = (\tilde{x}^o; \vec{R} = -\frac{\vec{K}}{Mc})$ NON-COVARIANT NON-CANONICAL MØLLER CENTER OF ENERGY

$\underset{c \to \infty}{\longrightarrow}$ NEWTON CENTER OF MASS

MØLLER WORLD-TUBE OF NON-COVARIANCE (LORENTZ SIGNATURE)



MØLLER RADIUS

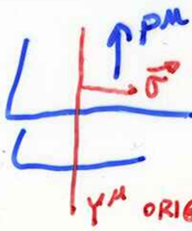
$$\rho = \frac{\sqrt{-W^2}}{P^2 c} = \frac{|\vec{S}|}{Mc}$$

$\rho \sim$ COMPTON WAVELENGTH OF ISOLATED SYSTEM

REMNANT OF ENERGY CONDITIONS OF GENERAL RELATIVITY

REST-FRAME INSTANT FORM

WIGNER INSTANTANEOUS 3-SPACES



$\tau = cT$ REST TIME (LORENTZ SCALAR)

$$z^\mu(\tau, \vec{\sigma}) = Y^\mu(\tau) + \epsilon^\mu_r(\vec{h})\, \sigma^r$$

$$P^\mu = Mc\left(\sqrt{1+\vec{h}^2}; \vec{h}\right) = L^\mu{}_\nu(P, \overset{\circ}{P})\, \overset{\circ}{P}{}^\nu$$

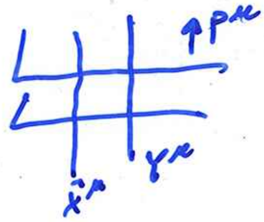
$$\overset{\circ}{P}{}^\mu = Mc(1; \vec{0}), \quad Mc = \sqrt{P^2}$$

$\downarrow$ WIGNER BOOST FOR TIMELIKE ORBITS

POSITIVE ENERGY PARTICLES $x^\mu_i(\tau) = z^\mu(\tau, \vec{\eta}_i(\tau)) = Y^\mu(\tau) + \epsilon^\mu_r(\vec{h})\, \eta^r_i(\tau)$

$\tilde{x}^\mu(\tau), Y^\mu(\tau), R^\mu(\tau)$ KNOWN FUNCTIONS OF $\tau, M, \vec{S}$, and of the FROZEN JACOBI DATA $\vec{z}, \vec{h}$ OF THE EXTERNAL CENTER OF MASS

$\vec{x}_{NW} = \frac{\vec{z}}{Mc}$ NEWTON-WIGNER POSITION



ISOLATED SYSTEM

1) NON-COVARIANT DECOUPLED EXTERNAL CENTER OF MASS (DESCRIBED BY THE FROZEN JACOBI DATA) CARRYING A POLE-DIPOLE STRUCTURE : M INTERNAL MASS , $\vec{S}$ REST SPIN

(UNIVERSAL BREAKING OF LORENTZ COVARIANCE BUT DECOUPLED)

EXTERNAL POINCARÉ GENERATORS

$$P^0 = Mc\sqrt{1+\vec{h}^2} \qquad \vec{P} = Mc\,\vec{h}$$
$$\vec{J} = \vec{z}\times\vec{h} + \vec{S} \qquad \vec{K} = -\sqrt{1+\vec{h}^2}\,\vec{z} + \frac{\vec{S}\times\vec{h}}{1+\sqrt{1+\vec{h}^2}}$$

2) INSIDE THE INSTANTANEOUS WIGNER 3-SPACE THERE ARE THE WIGNER-COVARIANT VARIABLES OF THE ISOLATED SYSTEM (INTERNAL SPACE) AND A UNFAITHFUL INTERNAL REALIZATION OF THE POINCARÉ GROUP

$\tau = cT$ LORENTZ-SCALAR REST TIME

$$\left\{\begin{array}{l} Mc = c\int d^3\sigma\, T^{\tau\tau}(\tau,\vec\sigma) \\ \vec{\mathcal{P}} \approx 0 \quad \text{REST-FRAME CONDITION} \qquad \mathcal{P}^r = \int d^3\sigma\, T^{r\tau}(\tau,\vec\sigma) \\ \vec{\mathcal{J}} = \vec{S} \qquad\qquad S^r = \frac{1}{2}\epsilon^{ruv}\int d^3\sigma\,\sigma^u\, T^{\tau v}(\tau,\vec\sigma) \\ \vec{\mathcal{K}} \approx 0 \end{array}\right.$$

(INTERACTION-DEPENDENT) ELIMINATION OF THE INTERNAL 3-CENTER OF MASS

$$\mathcal{K}^r = -\int d^3\sigma\,\sigma^r\, T^{\tau\tau}(\tau,\vec\sigma)$$

POSITIVE-ENERGY SCALAR FREE PARTICLES $\vec\eta_i(\tau), \vec\kappa_i(\tau)$

$$Mc = \sum_1^2{}_i \sqrt{m_i^2c^2+\vec\kappa_i^2}\,, \quad \vec{\mathcal{P}} = \sum_1^2{}_i \vec\kappa_i \approx 0\,, \quad \vec{S} = \sum_1^2{}_i \vec\eta_i\times\vec\kappa_i\,, \quad \vec{\mathcal{K}} = -\sum_1^2{}_i \vec\eta_i\sqrt{m_i^2c^2+\vec\kappa_i^2} \approx 0$$

$\Rightarrow$ $\vec\eta_i, \vec\kappa_i$, $i=1,..,N$ FUNCTIONS ONLY OF RELATIVE VARIABLES $\vec\rho_a, \vec\pi_a$, $a=1,..,N$

2-BODY CASE – ORBIT RECONSTRUCTION

$$x_i^\mu(\tau) = Y^\mu(\tau) + (-)^{i+1}\,\epsilon_r^\mu(\vec h)\,\frac{\sqrt{m_i^2c^2+\vec\pi_{12}^2}}{\sum_k\sqrt{m_k^2c^2+\vec\pi_{12}^2}}\,\rho_{12}^r(\tau) \xrightarrow[c\to\infty]{} \left\{\begin{array}{l} t \\ \vec{x}_{(n)} + (-)^{i+1}\frac{m_{i+1}}{m_1+m_2}\vec{r}_{(n)} = \vec{x}_{(n)i} \end{array}\right.$$

COVARIANT WORLDLINES – DERIVED NON-CANONICAL QUANTITIES

$\{x_i^\mu, x_j^\nu\} \neq 0$ PREDICTIVE COORDINATES
VIOLATION OF MICROCAUSALITY

DERIVED P_i^μ SATISFY $P_i^2 = m_i^2c^2$ ALSO IN PRESENCE OF INTERACTIONS

THE SIMPLEST INTERACTING 2-BODY SYSTEM

$$\begin{cases} M = \sqrt{m_1^2+\vec{\kappa}_1^2+\underline{\phi(\vec{\rho}^2)}} + \sqrt{m_2^2+\vec{\kappa}_2^2+\underline{\phi(\vec{\rho}^2)}} \\ \vec{P} = \vec{\kappa}_1+\vec{\kappa}_2 \approx 0 \\ \vec{J} = \vec{S} = \vec{\eta}_1\times\vec{\kappa}_1+\vec{\eta}_2\times\vec{\kappa}_2 \\ \vec{K} = -\vec{\eta}_1\sqrt{m_1^2+\vec{\kappa}_1^2+\underline{\phi(\vec{\rho}^2)}} - \vec{\eta}_2\sqrt{m_2^2+\vec{\kappa}_2^2+\underline{\phi(\vec{\rho}^2)}} \approx 0 \end{cases} \qquad \vec{\rho} = \vec{\eta}_1 - \vec{\eta}_2$$

THE INTERNAL POINCARÉ ALGEBRA IS SATISFIED

$$\Pi \approx M = \sqrt{m_1^2+\vec{\pi}^2+\phi(\vec{\rho}^2)} + \sqrt{m_2^2+\vec{\pi}^2+\phi(\vec{\rho}^2)}$$

HAMILTONIAN FOR THE RELATIVE MOTION

$$M_0 = \sqrt{m_1^2+\vec{\pi}^2} + \sqrt{m_2^2+\vec{\pi}^2}$$

$\vec{K} \approx 0$

$$\Rightarrow \quad \vec{q} \approx \vec{q}(\vec{\rho},\vec{\pi}) = \frac{m_1^2-m_2^2}{2}\left(\frac{1}{M_0^2}-\frac{1}{M^2}\right)\vec{\rho}$$

$$\Rightarrow \quad \vec{\eta}_i \approx \frac{(-)^{i+1}}{2}\left(1-\frac{m_1^2-m_2^2}{M^2}\right)\vec{\rho} \xrightarrow[c\to\infty]{} (-)^{i+1}\frac{m_i}{m_1+m_2}\vec{\rho}$$

IN THE PAPER THERE ARE THE ORBITS FOR COULOMB-LIKE POTENTIALS

$$\phi(\vec{\rho}^2) = -2\mu\frac{e^2}{\sqrt{\vec{\rho}^2}}$$

N.B. FOR $\quad \Pi = \sqrt{m_1^2+\vec{\kappa}_1^2} + \sqrt{m_2^2+\vec{\kappa}_2^2} + \dfrac{e^2}{4\pi|\vec{\eta}_1-\vec{\eta}_2|}$ (REAL COULOMB POTENTIAL)

IT IS <u>NOT KNOWN</u> THE FORM OF THE INTERNAL BOOST $\vec{K}$

(IT IS NOT KNOWN THE LAGRANGIAN, FROM WHICH TO GET THE ENERGY-MOMENTUM TENSOR)

RELATIVISTIC PSEUDOCLASSICAL ATOMIC PHYSICS

GRASSMANN-VALUED ELECTRIC CHARGES $\quad Q_i^2 = 0\,,\ Q_i Q_j \neq 0 \ \ i \neq j$

- ULTRAVIOLETT REGULARIZATION OF SELF-ENERGIES 
- INFRARED REGULARIZATION 
- POTENTIAL IN CAUCHY PROBLEM AND IN THE RADIATION GAUGE FOR 1-PHOTON EXCHANGE 

$\Rightarrow$ DARWIN AND SALPETER POTENTIALS ADDED TO THE COULOMB ONE (TILL NOW FROM BETHE-SALPETER EQ. FOR RELATIVISTIC BOUND STATES)

WAY OUT OF HAAG THEOREM WITH A CLASSICAL CANONICAL TRANSF.

$\vec{\eta}_i, \vec{\kappa}_i$ + COULOMB
$\vec{A}_\perp, \vec{E}_\perp$ (INTERPOLATING FIELDS) $\longmapsto$ $\tilde{\vec{\eta}}_i, \tilde{\vec{\kappa}}_i$ (COULOMB DRESSED) + + COULOMB + DARWIN
$\vec{A}_{\perp RAD}, \vec{E}_{\perp RAD}$ (IN OR OUT FREE FIELDS)
ONLY IN THE GLOBAL REST-FRAME

MISSING – RELATIVISTIC STATISTICAL MECHANICS WITH LONG RANGE FORCES

FIND MICROCANONICAL PARTITION FUNCTION IN REST FRAME

LIKE IT HAS BEEN DONE FOR NEWTONIAN GRAVITY

D.H.E. GROSS ET AL. PRL 89 (2002) 031101

A) MASSLESS PARTICLES IN THE REST-FRAME INSTANT FORM

B) 2-LEVEL ATOM (JAYNES-CUMMING MODEL) – MASSIVE RELATIVISTIC PARTICLE WITH STRUCTURE $\quad (\vec{\eta}, \vec{\kappa})$ POINT, $(\vec{\varsigma}, \vec{\pi})$ DIPOLE

$$H = \sqrt{m^2c^2 + 2\omega\,\theta^*\theta + \vec{\kappa}^2} + A\,(\theta^*\alpha + \alpha^*\theta)\,\vec{\varsigma}\cdot\vec{\pi}_\perp(\tau, \vec{\eta}(\tau)) + \frac{1}{2c}\int d^3\sigma\,(\vec{\pi}_\perp^2 + \vec{B}^2)(\tau, \vec{\sigma})$$

$$\vec{\pi}^{\,2} \approx 2\omega\,\theta^*\theta \qquad \alpha^*\alpha + \theta^*\theta \approx 0 \qquad \theta^*, \theta, \alpha^*, \alpha \text{ GRASSMANN}$$

- QUANTIZZATION → KG FIELD + 2-LEVEL STRUCTURE
- TRY TO SIMULATE ABCD BORDÉ METHOD FOR ATOM INTERFEROMETER
- COUPLING TO GRAVITY (BORDÉ, KASEVICH et al ...)

$$
\begin{cases}
Mc = \sum_i \sqrt{m_i^2c^2 + \left(\vec{\kappa}_i(\tau) - \frac{Q_i}{c}\vec{A}_\perp(\tau,\vec{\eta}_i(\tau))\right)^2} + \sum_{i\neq j} \frac{Q_iQ_j}{4\pi|\vec{\eta}_i(\tau)-\vec{\eta}_j(\tau)|} \\
\qquad + \frac{1}{2}\int d^3\sigma \left[\vec{\pi}_\perp^2 + \vec{B}^2\right](\tau,\vec{\sigma}) \\
\vec{P} = \sum_i \vec{\kappa}_i(\tau) + \frac{1}{c}\int d^3\sigma \left(\vec{\pi}_\perp \times \vec{B}\right)(\tau,\vec{\sigma}) \approx 0 \\
\vec{J} = \vec{S} = \sum_i \vec{\eta}_i(\tau) \times \vec{\kappa}_i(\tau) + \frac{1}{c}\int d^3\sigma \left[\vec{\sigma} \times (\vec{\pi}_\perp \times \vec{B})\right](\tau,\vec{\sigma}) \\
\vec{K} = -\sum_i \vec{\eta}_i(\tau)\sqrt{m_i^2c^2 + \left(\vec{\kappa}_i(\tau) - \frac{Q_i}{c}\vec{A}_\perp(\tau,\vec{\eta}_i(\tau))\right)^2} + \\
\qquad + \frac{1}{c}\sum_{i\neq j} Q_iQ_j \left(\frac{1}{\Delta_{\vec{\eta}_j}}\frac{\partial c(\vec{\eta}_i(\tau)-\vec{\eta}_j(\tau))}{\partial \vec{\eta}_j} - \vec{\eta}_j(\tau)\, c(\vec{\eta}_i(\tau)-\vec{\eta}_j(\tau))\right) \\
\qquad + \sum_i \frac{Q_i}{c}\int d^3\sigma\, \vec{\pi}_\perp(\tau,\vec{\sigma})\, c(\vec{\sigma}-\vec{\eta}_i(\tau)) - \\
\qquad - \frac{1}{2c}\int d^3\sigma\, \vec{\sigma}\left(\vec{\pi}_\perp^2 + \vec{B}^2\right)(\tau,\vec{\sigma}) \approx 0
\end{cases}
$$

$Q_i^2 = 0$

$Q_iQ_j \neq 0$

$\vec{\pi}_\perp = \frac{1}{c}\vec{E}_\perp = \frac{\partial \vec{A}_\perp}{\partial \tau}$

$c(\vec{\sigma}) = \frac{1}{4\pi|\vec{\sigma}|}$

CRATER - LL - ANN. PHYS. 289 (2001) 87
hep-th/0001046

ALBA, CRATER, LL
INT. J. MOD. PHYS. A16 (2001) 3365
hep-th/0103109

2 PARTICLES WITH DARWIN POTENTIAL

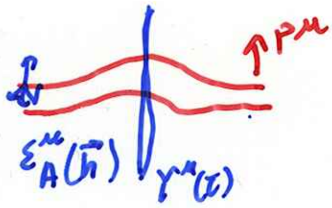
$$
\begin{cases}
Mc = \sqrt{m_1^2c^2 + \vec{\kappa}_1^2(\tau)} + \sqrt{m_2^2c^2 + \vec{\kappa}_2^2(\tau)} + \frac{Q_1Q_2}{4\pi|\underbrace{\vec{\eta}_1(\tau)-\vec{\eta}_2(\tau)}_{\vec{\rho}}|} + V_{DARWIN} \\
\vec{P} = \vec{\kappa}_1(\tau) + \vec{\kappa}_2(\tau) \approx 0 \\
\vec{J} = \vec{S} = \vec{\eta}_1(\tau) \times \vec{\kappa}_1(\tau) + \vec{\eta}_2(\tau) \times \vec{\kappa}_2(\tau) \\
\vec{K} = -\sum_{i=1}^{2} \vec{\eta}_i(\tau)\sqrt{m_i^2c^2 + \vec{\kappa}_i^2(\tau)} - \\
\qquad - \frac{Q_1Q_2}{2c}\left[\vec{\eta}_1 \frac{\vec{\kappa}_1}{\sqrt{m_1^2c^2+\vec{\kappa}_1^2}} \cdot \left(\frac{1}{2}\frac{\partial K_{12}}{\partial \vec{\rho}} - 2\vec{A}_{\perp S2}(\vec{\kappa}_2,\vec{\rho})\right) + \vec{\eta}_2 \frac{\vec{\kappa}_2}{\sqrt{\vec{\kappa}_2^2+m_2^2c^2}} \cdot \left(\frac{1}{2}\frac{\partial K_{12}}{\partial \vec{\rho}} - 2\vec{A}_{\perp S1}(\vec{\kappa}_1,\vec{\rho})\right)\right]
\end{cases}
$$

$$
- \frac{Q_1Q_2}{2c}\left(\sqrt{m_1^2c^2+\vec{\kappa}_1^2}\,\frac{\partial}{\partial \vec{\kappa}_1} + \sqrt{m_2^2c^2+\vec{\kappa}_2^2}\,\frac{\partial}{\partial \vec{\kappa}_2}\right) K_{12}(\vec{\kappa}_1,\vec{\kappa}_2,\vec{\rho}) -
$$

$$
- \frac{Q_1Q_2}{4\pi c}\int d^3\sigma \left(\frac{\vec{\pi}_{\perp S1}(\vec{\sigma}-\vec{\eta}_1,\vec{\kappa}_1)}{|\vec{\sigma}-\vec{\eta}_1|} + \frac{\vec{\pi}_{\perp S2}(\vec{\sigma}-\vec{\eta}_2,\vec{\kappa}_2)}{|\vec{\sigma}-\vec{\eta}_2|}\right) - \qquad \approx 0
$$

$$
- \frac{Q_1Q_2}{c}\int d^3\sigma \left[\vec{\pi}_{\perp S1}(\vec{\sigma}-\vec{\eta}_1,\vec{\kappa}_1)\cdot\vec{\pi}_{\perp S2}(\vec{\sigma}-\vec{\eta}_2,\vec{\kappa}_2) + \vec{B}_{S1}(\vec{\sigma}-\vec{\eta}_1,\vec{\kappa}_1)\cdot\vec{B}_{S2}(\vec{\sigma}-\vec{\eta}_2,\vec{\kappa}_2)\right]
$$

NON-INERTIAL REST-FRAME INSTANT FORM



$$z^\mu(\tau,\sigma^u) = Y^\mu(\tau) + u^\mu(\vec h)\, g(\tau,\sigma^u) + \epsilon^\mu_r(\vec h)\left[\sigma^r + g^r(\tau,\sigma^u)\right]$$

$$\xrightarrow[\sigma\to\infty]{} Y^\mu(\tau) + \epsilon^\mu_r(\vec h)\,\sigma^r$$ ASYMPTOTIC WIGNER 3-SPACES

$\downarrow$ FOKKER-PRYCE

$$H_D = \underbrace{M_c}_{\text{INVARIANT MASS}} + \underbrace{\int d^3\sigma \left(\partial_\tau g\, Z_\tau + \partial_\tau g^r Z_r\right)(\tau,\vec\sigma)}_{\text{INERTIAL POTENTIALS}} + (\text{em constraints})$$

$$\int d^3\sigma \left[(1+n)\, T_{\tau\tau} - n^r T_{\tau r}\right]$$

ASYMPTOTIC INTERNAL POINCARÉ GENERATORS

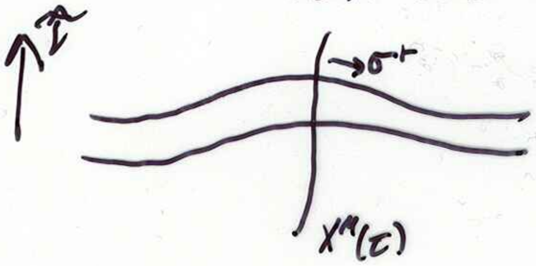
$$M_c,\quad S^r = \dots,\quad \begin{cases} P^\mu = \int d^3\sigma \left[A^\mu T_{\tau\tau} - (\delta^u_r + \partial_r g^u)\, h^{rs} T_{\tau s}\right](\tau,\sigma^u) \approx 0 \\ K^u = \int d^3\sigma \left[(\sigma^u + g^u) Z^\tau + g Z^r\right](\tau,\sigma^u) \approx 0 \end{cases}$$

REST FRAME CONDITION

ELIMINATION OF INTERNAL COM

MISSING - FIND RIEMANN NORMAL COORDINATES (RADAR) COORDINATES

FOR THE 3+1 SPLITTING



NO COORDINATE SINGULARITIES (LIKE IN 1+3:

SEE FERMI COORDINATES AND ROTATING DISK)

EQUATIONS OF MOTION OF CHARGED PARTICLES IN NON-INERTIAL FRAMES IN THE RADIATION GAUGE

$$m_i c \frac{d}{d\tau} \frac{\dot\eta_i^r(\tau) + n^r(\tau, \vec\eta_i(\tau))}{\sqrt{[1+n(\tau,\vec\eta_i(\tau))]^2 - h_{uv}(\tau,\vec\eta_i(\tau))[\dot\eta^u_i(\tau)+n^u(\tau,\vec\eta_i(\tau))][\dot\eta^v_i(\tau)+n^v(\tau,\vec\eta_i(\tau))]}} =$$

$$= \frac{Q_i}{c}\, h^{rs}(\tau,\vec\eta_i(\tau)) \Big[\underbrace{E_{\perp s}(\tau,\vec\eta_i(\tau)) + \varepsilon_{suv}\,\dot\eta^u_i(\tau)\, B_v(\tau,\vec\eta_i(\tau))}_{\text{LORENTZ FORCE}} -$$

$$- \frac{1}{c}\frac{\partial}{\partial \eta_i^s} \underbrace{W(\vec\eta_1(\tau),\dots,\vec\eta_N(\tau))}_{\text{NON-INERTIAL COULOMB POTENTIAL}} + \underbrace{F_{is}(\tau)}_{\text{INERTIAL FORCES}} \Big]$$

in h_{rs} and γ are hidden the GRAVITON effects in GR

$$F_{ir} = \frac{m_i c}{\sqrt{(1+n)^2 - h_{uv}(\dot\eta^u+n^u)(\dot\eta^v+n^v)}} \Big\{ \frac{1}{1+n}\Big[\frac{\partial h_{st}}{\partial \eta_i^r}(\dot\eta^s+n^s)(\dot\eta^t+n^t) - \frac{\partial n}{\partial \eta_i^r} +$$

$$+ \frac{\partial n^s}{\partial \eta_i^r} h_{st}(\dot\eta^t+n^t)\Big] - \Big(\frac{\partial h_{ru}}{\partial \tau} + \dot\eta_i^v \frac{\partial h_{ru}}{\partial \eta_i^v}\Big)(\dot\eta^u+n^u)\Big\}$$

$$W = \frac{1}{24\pi}\sum_{i\neq j}\sum_r \Big\{ \delta^{rs}\frac{h_{rs}(1+n)}{2\sqrt\gamma} \frac{Q_iQ_j}{|\vec\eta_i(\tau)-\vec\eta_j(\tau)|} + \int d^3\sigma \sum_{i\neq j}\Big\{ \frac{Q_iQ_j}{8\pi|\vec\sigma-\vec\eta_i(\tau)|}\Big[\frac{h_{rs}(1+n)}{2\sqrt\gamma} \mathcal{E}^{rs}(\vec\sigma-\vec\eta_j(\tau))$$

$$- \frac{1}{4\pi}\frac{\sigma^r-\eta_i^r(\tau)}{|\vec\sigma-\vec\eta_i(\tau)|^3}\frac{\partial}{\partial\sigma_s}\frac{h_{rs}(1+n)}{2\sqrt\gamma}\Big](\tau,\vec\sigma) + i \leftrightarrow j \Big\} +$$

$$+ \sum_j \int d^3\sigma \frac{Q_j}{4\pi|\vec\sigma-\vec\eta_j(\tau)|}\frac{\partial}{\partial\sigma^s}\Big[\frac{h_{rs}(1+n)}{2\sqrt\gamma}\pi^r_\perp + n^r F_{rs}\Big](\tau,\vec\sigma)$$

$$\mathcal{E}^{rs}(\vec\sigma) = \frac{1}{|\vec\sigma|^3}\Big(\delta^{rs} - 3\frac{\sigma^r\sigma^s}{\sigma^2}\Big) = \frac{4\pi}{3}\delta^{rs}\delta^3(\vec\sigma) + \bar{\mathcal{E}}^{rs}(\vec\sigma)$$

NON-RELATIVISTIC LIMIT ~~(WITHOUT EM FIELDS)~~ $\quad R(\tau,\sigma) \rightarrow R(\tau) + O(c^{-2})$

$$m_i \frac{d^2\vec\eta_i(t)}{dt^2} = \frac{Q_i}{c}\Big[\vec E + \frac{d\vec\eta_i(t)}{dt}\times\vec B\Big] - \frac{\partial}{\partial\vec\eta_i} W + \vec F_{i\,(in)}$$

$$\vec F_{i\,(in)} = m_i\Big[\underbrace{-\frac{d\vec v(t)}{dt} - \vec\Omega(t)\times\vec v(t)}_{\text{LINEAR ACCELERATION}} + \underbrace{\vec\eta_i(t)\times\frac{d\vec\Omega(t)}{dt}}_{\text{JACOBI}} + \underbrace{2\frac{d\vec\eta_i(t)}{dt}\times\vec\Omega(t)}_{\text{CORIOLIS}} + \underbrace{\vec\Omega(t)\times[\vec\eta_i(t)\times\vec\Omega(t)]}_{\text{CENTRIFUGAL}}\Big]$$

$$W = -\sum_{i\neq j}\frac{Q_iQ_j}{4\pi|\vec\eta_i(t)-\vec\eta_j(t)|} + \frac{1}{c}\int d^3\sigma\, \Sigma_i \frac{Q_i}{4\pi|\vec\sigma-\vec\eta_i(t)|}\Big\{-\vec v(t)\cdot\vec\sigma\times\vec B(\tau,\vec\sigma) -$$

$$- \vec\sigma\cdot\big[\vec\sigma\cdot\vec B\,\vec\Omega(t) - \vec\Omega(t)\cdot\vec B\,\vec\sigma\big](\tau,\vec\sigma)\Big\}$$

QUANTUM MECHANICS OF SCALAR AND SPINNING PARTICLES IN NON-INERTIAL FRAMES

ALBA, LL - INT. J. MOD. PHYS. 21, 2781 (2006) [hep-th/0502060]

NON-REL. CASE ALBA - INT. J. MOD. PHYS 21, 3917 (2006) [hep-th/0504060]

MULTITEMPORAL QUANTIZATION - QUANTIZE THE PARTICLES BUT NOT THE INERTIAL APPEARANCES [$z^{\mu}(\tau, \sigma^{u})$ c-NUMBER]

ATOMIC SPECTRA - OK

OPEN PROBLEM

QUANTIZATION OF KG FIELD IN NON-INERTIAL FRAMES

(STANDARD MODEL OF PARTICLES IN NON-INERTIAL FRAMES)

TORRE - VARADARAJAN - CLAS. Q. GRAV. 16, 2651 (1999)

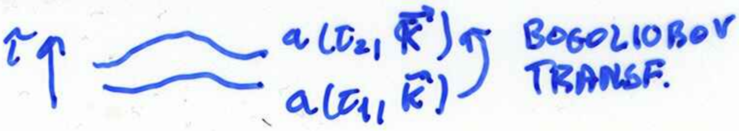
ARAGEORGIS, EARMAN, RUETSCHE - STUDIES HIST. PHIL. MODERN PHYSICS 33, 151 (2002)

FIND HOW TO AVOID THE TORRE-VARADARAJAN NO-GO THEOREM (NO UNITARY EVOLUTION IN THE TOMONAGA-SCHWINGER FORMALISM)

1) USE INSTANTANEOUS 3-SPACES ADMITTING FOURIER TRANSFORM $\Rightarrow$ FOCK SPACE (INSTEAD OF DETECTORS REPLACING PARTICLES LIKE IN QFT IN CURVED SPACETIMES)

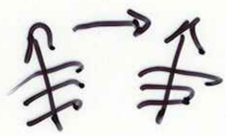
2) HAMILTONIAN EVOLUTION DEFINED ONLY IN A 3+1 SPLITTING

a) 3+1 SPLITTINGS WITH FT ON Σ_{τ}



b) FIND 3+1 SPLITTINGS WITH HILBERT-SCHMIDT BOGOLIUBOV TRANSF.

$$a'_k = \sum_{\ell} [\alpha_{k\ell}\, a_{\ell} + \beta_{k\ell}\, a^{+}_{\ell}] \qquad \sum_{k\ell} |\beta_{k\ell}|^2 < \infty$$



c) UNITARY EQUIVALENCE OF HS 3+1 SPLITTINGS

NON-RELATIVISTIC QUANTUM MECHANICS

2-BODY PROBLEM

$\vec{x}_{(n)i}, \vec{p}_{(n)i} \rightarrow \vec{x}_{(n)}, \vec{P}_{(n)}, \vec{r}_{(n)}, \vec{q}_{(n)}$

m_1, m_2
$m = m_1 + m_2$
$\mu = m_1 m_2 / m$

GALILEI GENERATORS

$$\begin{cases} E = H = H_{com} + H_{rel}, \quad H_{com} = \dfrac{\vec{P}_{(n)}^2}{2m}, \quad H_{rel} = \dfrac{\vec{q}_{(n)}^2}{2\mu} + V(\vec{r}_{(n)}) \\ \vec{P} = \vec{P}_{(n)} = \Sigma_i \vec{p}_{(n)i} \\ \vec{L} = \Sigma_i \vec{x}_{(n)i} \times \vec{p}_{(n)i} = \vec{x}_{(n)} \times \vec{P}_{(n)} + \vec{S}_{(n)}, \quad \vec{S}_{(n)} = \vec{r}_{(n)} \times \vec{q}_{(n)} \\ \vec{K} = -m \vec{x}_{(n)} + \vec{P}_{(n)} t \end{cases}$$

REST FRAME CENTERED IN $\vec{x}_{(n)}$

EXTERNAL C.O.M. $\vec{x}_{(n)}, \vec{P}_{(n)}$ DECOUPLED WITH POLE-DIPOLE STRUCTURE : $H_{rel}, \vec{S}_{(n)}$

$\rightarrow$ EXTERNAL GALILEI GROUP

+ INTERNAL SPACE WITH $\vec{\eta}_{(n)i} = \vec{x}_{(n)i}\big|_{\vec{x}_{(n)}=0}, \quad \vec{\kappa}_{(n)i} = \vec{p}_{(n)i}\big|_{\vec{P}_{(n)}=0}$ $\quad \vec{\eta}_{(n)1} - \vec{\eta}_{(n)2} = \vec{r}_{(n)}$

and unfaithful Galilei realisation $\quad H_{rel}, \vec{P} \approx 0, \vec{S}_{(n)}, \vec{K} \approx 0$ $\quad \begin{cases} \vec{\eta}_i \longrightarrow \vec{\eta}_{(n)i} \\ \vec{\kappa}_i \longrightarrow \vec{\kappa}_{(n)i} \end{cases}$

$$\boxed{\mathcal{H} = \mathcal{H}_1 \otimes \mathcal{H}_2 \qquad = \qquad \mathcal{H}_{com} \otimes \mathcal{H}_{rel}}$$

COMPOSITE SYSTEM SEPARABILITY (ZEROTH POSTULATE of QM, ZEH) $\quad \psi(t, \vec{x}_{(n)1})\, \psi(t, \vec{x}_{(n)2})$

UNITARY TRANSF. DICTATED BY SEPARATION OF VARIABLES IN SCHR. EQ

$\psi(t, \vec{x}_{(n)})\, \phi(t, \vec{r}_{(n)})$

$$i\frac{\partial}{\partial t}\psi(t, \vec{x}_{(n)}, \vec{r}_{(n)}) = (\hat{H}_{com} + \hat{H}_{rel})\, \psi(t, \vec{x}_{(n)}, \vec{r}_{(n)})$$

$$\begin{cases} i\dfrac{\partial}{\partial t}\left(e^{-i\frac{\vec{P}^2}{2m}t}\, \psi_{\vec{P}}(\vec{x}_{(n)})\right) = \hat{H}_{com}\left(e^{-i\frac{\vec{P}^2}{2m}t}\, \psi_{\vec{P}}(\vec{x}_{(n)})\right) \\ i\dfrac{\partial}{\partial t}\left(e^{-i\varepsilon_n t}\, \phi_{nem}(\vec{r}_{(n)})\right) = \hat{H}_{rel}\left(e^{-i\varepsilon_n t}\, \phi_{nem}(\vec{r}_{(n)})\right) \end{cases}$$

$\psi_{\vec{P}}(\vec{x}_{(n)}) \sim e^{i\vec{x}_{(n)}\cdot\vec{P}_{(n)}}$

HAMILTON-JACOBI FOR CENTER OF MASS

FROZEN JACOBI DATA $\vec{x}_{(n)}(0), \vec{P}_{(n)}$ FOR COM

INTERNAL SPACE $\vec{r}_{(n)}, \vec{q}_{(n)}$

$$\begin{cases} \hat{\vec{P}}\, \psi_p(\vec{P}_{(n)} | t\, \vec{r}_{(n)}) \\ i\dfrac{\partial}{\partial t}\psi_p(\vec{P}_{(n)} | t\, \vec{r}_{(n)}) = \hat{H}_{rel}\, \psi_p(\vec{P}_{(n)} | t\, \vec{r}_{(n)}) \end{cases}$$

$H_{com} \xrightarrow{e^{i\hat{S}}} 0 \qquad S = -H_{com} t$

QUANTIZATION OF THE REST-FRAME INSTANT FORM

$$\boxed{H = H_{com} \otimes H_{rel} \quad \neq \quad H_1 \otimes H_2}$$

TENSOR PRODUCT OF 2 KLEIN-GORDON

NO CORRELATION BETWEEN x^o_1 and x^o_2

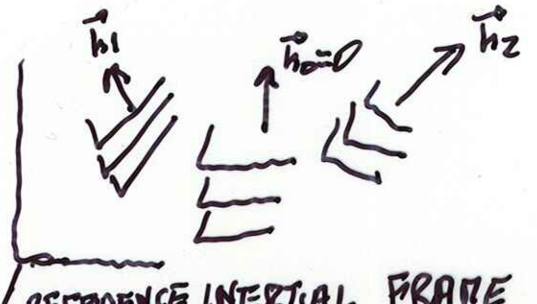
$\frac{\partial}{\partial x^o_i} \langle \psi_{1i} | \psi_{2i} \rangle = 0$

IN MOST OF THE STATES PARTICLE i IN THE ABSOLUTE FUTURE OF PARTICLE j

IRRELEVANT FOR S-MATRIX $\quad x^o_i \to \pm\infty$

ALL THE IMPLICATIONS OF POINCARÉ GROUP TAKEN INTO ACCOUNT

$$P^\mu = mc\left(\sqrt{1+\vec{h}^2}\,;\, \vec{h}\right)$$



REFERENCE INERTIAL FRAME

GLOBAL (NOT LOCALLY DEFINED)

CLOSED UNIVERSE $\quad \vec{h} =$ CONSTANT OF MOTION

1) H_{com} $\quad$ FROZEN JACOBI DATA (NON-COVARIANT) $\hat{\vec{z}}, \hat{\vec{h}}$ OF EXTERNAL CENTER OF MASS $\quad [\hat{z}^i, \hat{h}^j] = i\hbar\delta^{ij}$

PREFERRED $\hat{\vec{h}}$-BASIS FOR DEFINITION OF ISTANTANTANEOUS WIGNER 3-SPACE

$\hat{\vec{h}}\, \psi_{\vec{k}}(\vec{h}) = \vec{k}\, \psi_{\vec{k}}(\vec{h}) \qquad \psi_{\vec{k}}(\vec{h}) = \delta^3(\vec{h} - \vec{k})$

$\langle \psi_1 | \psi_2 \rangle = \int \frac{d^3h}{\sqrt{1+\vec{h}^2}}\, \psi_1^*(\vec{h})\, \psi_2(\vec{h})$

$\vec{X}_{NW} = \frac{\vec{z}}{mc}$ $\quad$ DEPENDS ON MASS EIGENVALUES

$\vec{h} =$ CONSTANT OF MOTION $\; - \; \vec{z}$ NOT MEASURABLE (WIGNER-ARAKI-YANASE TH.)

CLOSED UNIVERSE $\qquad \psi_{\vec{k}}(\vec{z}) = \int d^3h\, e^{-i\vec{h}\cdot\vec{z}}\, \psi_{\vec{k}}(\vec{h}) = e^{-i\vec{k}\cdot\vec{z}}$

COM WAVE PACKETS

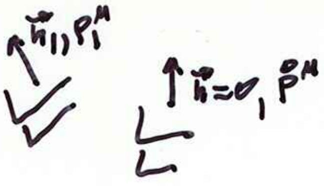
a) ALLOWED ? (ALSO SUPERPOSITION OF 3-SPACES)

b) FORBIDDEN FROM SUPERSELECTION RULE ?
(LIKE IN CANONICAL GRAVITY - GIULINI, MAROLF)

WHO WILL OBSERVE THE WAVE FUNCTION OF THE UNIVERSE ?

FROZEN JACOBI DATA - NO EVOLUTION OF COM - NO INSTANTANEOUS SPREADING OF COM WAVEPACKETS (WAY OUT OF HEGERFELDT'S THEOREM)

2) UNIVERSAL INTERNAL SPACE H_{rel} DUE TO WIGNER COVARIANCE $\qquad \overset{o}{P}{}^\mu = mc(1;0)$



$P_1^\mu = L^\mu{}_\nu(P_1, \overset{o}{P})\, \overset{o}{P}{}^\nu = mc\, L^\mu{}_o(\overset{o}{P}_1, \overset{o}{P}) \;, \quad h_1^i = L^i{}_o(P_1, \overset{o}{P})$

$\eta^r_i \xrightarrow{\Lambda} R^r{}_s(P, \Lambda)\, \eta^s_i \qquad \Lambda = L(P, \overset{o}{P}) \qquad \boxed{R(P, L(P, \overset{o}{P})) = 1}$

$\vec{\eta}_i \longrightarrow \vec{\eta}_i$

$$H_{rel} = \otimes_i H_{\vec{\eta}_i}\Big|_{\substack{\vec{P}\approx 0\\ \vec{K}\approx 0}} = \otimes_a H_{\vec{\rho}_a}$$

INTERMEDIATE UNPHYSICAL HILBERT SPACE

$$\langle \phi_1 | \phi_2 \rangle = \int \prod_a d^3\rho_a \, \phi_1^*(\tau, \vec{\rho}_a)\, \phi_2(\tau, \vec{\rho}_a)$$

$$i\frac{\partial}{\partial \tau}\phi(\tau, \vec{\rho}_a) = \hat{M}c\, \phi(\tau, \vec{\rho}_a)$$

$$\langle \psi_1 | \psi_2 \rangle = \int \prod_i d^3\eta_i \, \psi_1^*(\tau, \vec{\eta}_i)\, \psi_2(\tau, \vec{\eta}_i)$$

$$i\frac{\partial}{\partial \tau}\psi(\tau, \vec{\eta}_i) = \hat{M}c\, \psi(\tau, \vec{\eta}_i)$$

? INTERACTION DEPENDENT

$$\begin{cases} \hat{M}c\, \phi_{n\ell m}(\vec{\rho}_a) = \epsilon_n \phi_{n\ell m} \\ \hat{\vec{S}}^2 \phi_{n\ell m} = \ell(\ell+1)\phi_{n\ell m} \\ \hat{S}_3 \phi_{n\ell m} = m\, \phi_{n\ell m} \end{cases}$$

GUPTA-BLEULER FOR REST-FRAME CONDITIONS

$$\langle PHYS | \vec{P} | PHYS \rangle = \langle PHYS | \vec{K} | PHYS \rangle = 0$$

ELEMENTARY SOLUTIONS
↓
WAVE PACKETS

$$\psi_{\vec{k}\, n\ell m}(\vec{h} \,|\, \tau, \vec{\rho}_a) = \psi_{\vec{k}}(\vec{h})\, e^{-i\epsilon_m \tau}\, \phi_{n\ell m}(\vec{\rho}_a)$$

$$\xrightarrow[c\to\infty]{} e^{-imc^2}\,\Big($$ NON-REL WAVE FUNCTION IN HAMILTON-JACOBI FOR COM $\Big)$

STANDARD ATOMIC PHYSICS − $O(\frac{1}{c})$ − NEITHER GALILEI NOR POINCARÉ GROUP

RELATIVISTIC ATOMIC PHYSICS − EFFECTIVE THEORY FOR E < THRESHOLD FOR PAIR PRODUCTION

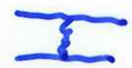
FIXED NUMBER OF POSITIVE-ENERGY SCALAR (OR SPINNING) PARTICLES WITH COULOMB MUTUAL INTERACTION + TRANSVERSE ELECTRO-MAGNETIC FIELD (RADIATION GAUGE)

ISOLATED SYSTEM IN THE REST-FRAME INSTANT FORM

GRASSMANN-VALUED ELECTRIC CHARGES $Q_i^2 = 0$, $Q_i Q_j = Q_j Q_i \neq 0$ for $i \neq j$

UV REGULARIZATION OF SELF-ENERGIES

IR REGULARIZATION (NO SOFT PHOTON EMISSION)

POTENTIAL IN CAUCHY PROBLEM OF 1-PHOTON EXCHANGE 

LIENARD-WIECHERT POTENTIALS = FUNCTIONS OF $\vec{\eta}_i, \vec{K}_i$ INDEPENDENT OF RETARDED, ADVANCED, ... GREEN FUNCTIONS

CLASSICAL CANONICAL TRANSF

BETHE SALPETER

$\vec{\eta}_i, \vec{K}_i$ + COULOMB $\longrightarrow$ $\tilde{\vec{\eta}}_i, \tilde{\vec{K}}_i$ (COULOMB DRESSED) + COULOMB + DARWIN

$\vec{A}_\perp, \vec{E}_\perp$ INTERPOLATING FIELDS $\longrightarrow$ $\vec{A}_{\perp RAD}, \vec{E}_{\perp RAD}$ IN, OUT FREE FIELDS (NO HAAG THEOREM QUANTUM ?)

IMPLICATIONS FOR RELATIVISTIC ENTANGLEMENT

ISOLATED SYSTEMS - CLOSED UNIVERSE

CLOCK SYNCHRONIZATION (INSTANTANEOUS 3-SPACE, CAUCHY PROBLEM)

KINEMATICAL NON-LOCALITY - THE RELATIVISTIC CENTER OF MASS IS A GLOBAL QUANTITY NOT LOCALLY MEASURABLE

+ PREFERRED $\vec{h}$-BASIS (3-SPACE)

SEE NEWTON-WIGNER LOCALIZATION PROBLEM

THE NW POSITION OPERATOR CANNOT BE BUILT WITH LOCAL OR QUASI-LOCAL OPERATORS

$\Rightarrow$ NON-COVARIANCE OF $\vec{z} = Mc\vec{X}_{NW}$ IRRELEVANT

KINEMATICAL SPATIAL NON-SEPARABILITY

$H = H_{com} \otimes H_{rel} \neq H_1 \otimes H_2 \otimes \dots$

POSITION OR MOMENTUM BASES KINEMATICALLY PREFERRED

PREFERRED ROBUST POINTER BASES IN H_{rel} FROM DECOHERENCE

NO ZEROTH POSTULATE ON COMPOSITE SYSTEMS, NO EINSTEIN SEPARABILITY

ONLY RELATIVE VARIABLES (WEAK RELATIONISM $\neq$ ROVELLI)

THESE RELATIVISTIC PROPERTIES BEFORE QUANTUM NON-LOCALITY (ENTANGLEMENT)

NON-LOCALITY (FAKE A-A-A-D INTERACTION) - FROM KINEMATICS OF POINCARÉ GROUP (NO SUPERLUMINAL SIGNALS)

NO EINSTEIN REALISM - LOCAL HIDDEN VARIABLES RULED OUT BY EXPERIMENTS

SUPERPOSITION OF MACROSCOPIC OBJECTS (DOUBLE SLIT EXPERIMENT WITH FULLERENE MOLECULES) SHIELDED FROM RELEVANT ENVIRONMENT

REALITY? - PROBABILISTIC RULES + PROBLEM OF OUTCOMES (COLLAPSE AND EIGENVECTOR-EIGENVALUE LINK OR SPONTANEOUS COLLAPSE OR EVERETT OR BOHM)

INTERPRETATION OF THE REDUCED DENSITY MATRIX (IMPROPER MIXTURE)

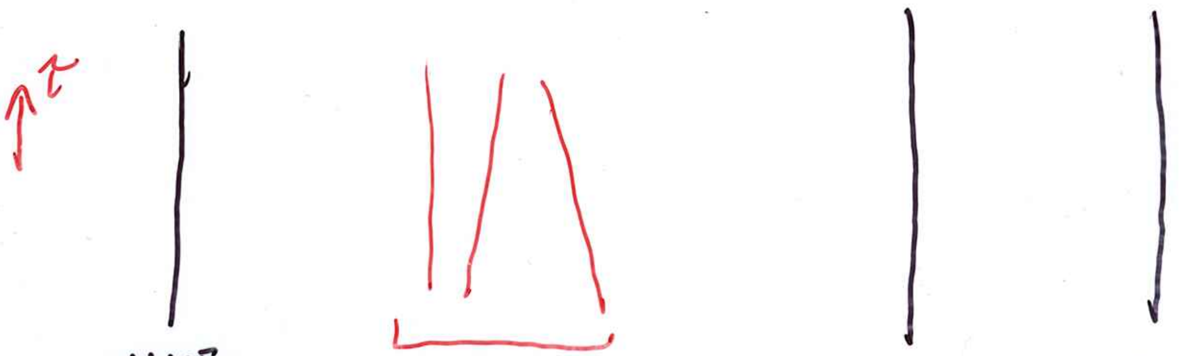
DECOHERENCE - OPEN SUBSYSTEMS, BREAKING OF UNITARITY, PREFERRED ROBUST POINTER BASES (BUT SPECIAL INTERACTIONS, SCHMIDT DECOMPOSITION, 3 SUBSYSTEMS?)

NO SOLUTION TO PROBLEM OF OUTCOMES

EMERGENCE OF QUASI-CLASSICAL MACROSCOPIC OBJECTS (EHRENFEST, GAUSSIAN MINIMAL UNCERTAINTY WAVE PACKETS, WITH POSITIVE WIGNER FUNCTION) - OPEN PROBLEM

O. PESSOA JR - WE NEED AN ENVIRONMENT-INDUCED COLLAPSE (MANY-BODY PROBLEM)

ISOLATED SYSTEM IN REST-FRAME QM $H_{com} \otimes H_{rel}$



RELEVANCE OF TRAJECTORIES OF PARTICLES AND PHOTONS (ABSENT IN NRQM)

ALICE
OBSERVER 1
MEASURING APPARATUS
MACROSCOPIC
QUASI-CLASSICAL

SYSTEM
MICROSCOPIC

BOB
OBSERVER 2
MEASURING APPARATUS
MACROSCOPIC
QUASI-CLASSICAL

ENVIRONMENT
MACROSCOPIC
EITHER QUANTUM
OR QUASI-CLASSICAL

LOOK FOR THE SET OF CANONICAL RELATIVE VARIABLES MORE SUITABLE TO THE PROTOCOL OF THE EXPERIMENT (BELL INEQUALITIES, TELEPORTATION, ...)

LIKE IN MOLECULAR PHYSICS → CANONICAL JACOBI COORDINATES MOST SUITABLE TO DESCRIBE THE STRONGEST CHEMICAL BONDS INSIDE THE MOLECULE (THE OTHERS TREATED WITH PERTURBATION THEORY)

→ MAX. NUMBER OF CONSTANTS OF MOTION
PREFERRED MACROSCOPIC OBJECTS

NO MICROCAUSALITY BUT CLUSTER DECOMPOSITION
(CRITICISM TO LOCAL QFT - UNSHARP MEASUREMENTS)

STUDY $\langle \hat{x}^{\mu}_{i}(\tau) \rangle$ OF PREDICTIVE WORDLINES (NOT COMMUTING) TO RECOVER CLASSICAL TRAJECTORIES

ENTANGLEMENT WITH EXTERNAL NON-LOCAL CENTER OF MASS NOT MEASURABLE

SUPERSELECTION RULE? $\Psi = \Psi_{com} \sum \prod_a \Psi(\vec{\tau}, \vec{S}_a)$

$H_{rel} = \otimes_a H_{\vec{\xi}_a}$ OR $\otimes_i H_{\vec{\eta}_i} \Big|_{\vec{P} \approx 0, \ \vec{K} \approx 0}$ (INTERACTION-DEPENDENT)

→ WITH MACROSCOPIC BODIES $\vec{K} \approx 0$ MAY BE APPROXIMATED WITH $\vec{\eta}_{INT.C.O.M.} \approx 0$ AND WE ~~[illegible]~~ MAY WORK IN THE SEPARABLE UNPHYSICAL HILBERT SPACE $\otimes_i H_{\vec{\eta}_i}$ RESTRICTED AT THE END ($\vec{P} \approx 0, \vec{K} \approx 0$)

STUDY SIMPLE EXAMPLES

ATOMIC PHYSICS → RAY OF LIGHT + POLARIZATION (IN NRQM ONLY POLARIZATION)
SPINNING PARTICLES

TELEPORTATION TO SPACE STATION → DIFFICULT CONTROL OF POLARIZATION DUE TO ATMOSPHERE

GENERAL RELATIVITY

EINSTEIN SPACETIMES AND BEYOND

GEOMETRICAL VIEW OF THE GRAVITATIONAL FIELD

DESER

$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

EVERYTHING IS DYNAMICAL

CAUCHY SURFACE NEEDED

DOUBLE ROLE OF THE METRIC TENSOR $g_{\mu\nu}(x)$

A) POTENTIAL OF THE GRAVITATIONAL FIELD (LIKE IN EM and YM)

B) DYNAMICAL CHRONOGEOMETRICAL STRUCTURE OF SPACETIME

$$ds^2 = g_{\mu\nu}(x) dx^\mu dx^\nu$$

$g_{\mu\nu}(x)$ TEACHES RELATIVISTIC CAUSALITY TO ALL OTHER FIELDS

POINT-DEPENDENT TRAJECTORY OF MASSLESS PARTICLES (PHOTONS, GLUONS ----) - NULL GEODESICS ($ds^2 = 0$)

ACES WINDOW ON IT! (2013 - GRAV. REDSHIFT OF THE GEOID)

NON-GEOMETRICAL PARTICLE VIEW

FEYNMAN

QFT, SM ------ STRING THEORY

FIX THE BACKGROUND SPACE-TIME - ONLY KNOWN WAY TO DEFINE FOCK SPACE AND QFT

PROPERTY B) IS LOST! GRAVITON - MASSLESS PARTICLE LIKE PHOTON, ---

TO RECOVER IT IS A UNSOLVED NON-PERTURBATIVE PROBLEM

EVEN NOT KNOWN HOW TO FORMULATE QFT (PARTICLE SM) IN NON-INERTIAL FRAMES IN MINKOWSKI SPACETIME (TORRE-VARADARAJAN NO-GO THEOREM 1999 - NO UNITARY EVOLUTION)

RELATIVITY PRINCIPLE → PRINCIPLE OF GENERAL COVARIANCE

POINCARÉ GROUP → DIFFEOMORPHISM GROUP

EQUIVALENCE PRINCIPLE - GLOBAL INERTIAL FRAMES DO NOT EXIST

ONLY LOCAL FREE FALL

CHOICE OF THE CLASS OF SPACETIMES
AND THE PROBLEM OF TIME

CANONICAL GRAVITY REQUIRES GLOBALLY HYPERBOLIC SPACETIMES (EXISTENCE OF GLOBAL TIME) AND ABSENCE OF SINGULARITIES FOR FINITE TIMES

A1) SPATIALLY COMPACT SPACETIMES WITHOUT BOUNDARY (LOOP QG, MACH PRINCIPLE)

NO BACKGROUND SPACETIME

NO POINCARÉ GROUP (PARTICLES?), NO EXTRA DIMENSIONS
AND NO FOCK SPACE

3+1 SPLITTING OF SPACETIME, QUANTIZATION OF 3-SPACE

$H \approx 0$ FROZEN PICTURE, TIME EVOLUTION DEFINED ONLY LOCALLY
NO TIME PICTURE (ROVELLI, BARBOUR, ...)

AVOIDS SINGULARITIES (BOUNCES) IN QUANTUM LOOP COSMOLOGY

A2) QFT AND STRING THEORY

FIXED BACKGROUND SPACETIME (USUALLY MINKOWSKI), EXTRA DIMENSIONS

GRAVITY REDUCED TO SPIN 2 GRAVITON OVER MINKOWSKI SPACETIME

TO GET A VARYING LIGHTCONE IS A NON-PERTURBATIVE PROBLEM

HOW TO DEFINE THE LIGHTCONE WITH COMPACTIFIED EXTRA DIMENSIONS?

NOT YET EXISTING IN NON-INERTIAL FRAMES

IN BOTH CASES THE USE OF NUCLEOSYNTHESIS IS A BIG EXTRAPOLATION

PARTICLE PHYSICS → LOOK FOR A FORMULATION OF GENERAL RELATIVITY CONTAINING A POINCARÉ GROUP

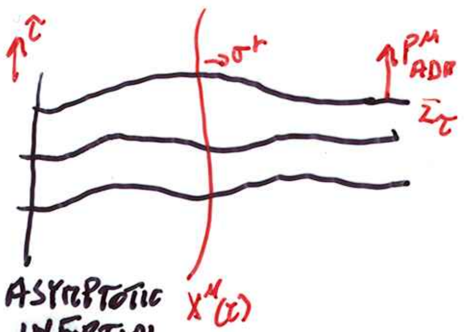
SPACETIMES ASYMPTOTICALLY FLAT AT SPATIAL INFINITY

WITHOUT SUPER-TRANSLATIONS

THE ASHTEKAR SPI GROUP OF ASYMPTOTIC SYMMETRIES

REDUCES TO THE ASYMPTOTIC ADM POINCARÉ GROUP

$P^{\mu}_{ADM}\,,\; J^{\mu\nu}_{ADM}$



REST-FRAME OF 3-UNIVERSE

GLOBAL NON-INERTIAL FRAMES CENTERED ON ACCELERATED OBSERVERS

ASYMPTOTIC INERTIAL OBSERVERS → FIXED STARS

ASYMPTOTIC BACKGROUND

$G \to 0$ DEPARAMETRIZATION TO THE NON-INERTIAL REST-FRAME INSTANT FORM OF PARTICLE PHYSICS

$P^{\mu}_{ADM} \to P^{\mu}\,,\; J^{\mu\nu}_{ADM} \to J^{\mu\nu}$

$g_{\mu\nu}(x) \xrightarrow[\text{SPATIAL INFINITY}]{} \eta_{\mu\nu}$ (IN A DIRECTION-INDEPENDENT WAY)

NOT THE STANDARD BOUNDARY CONDITIONS OF FRW COSMOLOGY

IN ABSENCE OF MATTER CHRISTODOULOU-KLAINERMANN SPACETIMES ARE OK

MODEL OF UNIVERSE AFTER THE LAST SCATTERING (OR RECOMBINATION) TIME, CORRESPONDING TO A 3-SPACE Σ_{CMB} WHERE THE EMISSION OF THE PHOTONS OF CMB HAPPENED ($\sim 3 \cdot 10^5$ YEARS AFTER BIG BANG)

NO FROZEN PICTURE $\quad H_D \approx \check{E}_{ADM} \neq 0$

WEAK ADM ENERGY $\quad \check{E}_{ADM} = \int d^3\sigma\, \check{\mathcal{E}}_{ADM}(\tau, \vec{\sigma}) \approx E_{ADM} = \int_{S_\infty} \ldots$

STRONG ADM ENERGY

USE ADM ACTION FOR EINSTEIN THEORY WITH THE 4-METRIC EXPRESSED IN TERMS OF TETRADS (REQUIRED BY THE COUPLING TO FERMIONS)

$${}^4g^{\mu\nu}(x) = {}^4E^{\mu}_{(\alpha)}(x)\; {}^4\eta^{(\alpha\beta)}\; {}^4E^{\nu}_{(\beta)}(x)$$

NO DEGENERACIES DUE TO KILLING SYMMETRIES

1) GO TO RADAR 4-COORDINATES ADAPTED TO THE 3+1 SPLITTING AND HAVING AN ACCELERATED OBSERVER AS ORIGIN

$$x^\mu \mapsto \sigma^A(\tau;\sigma^r)$$

$$\sigma^A \mapsto x^\mu = z^\mu(\tau,\vec{\sigma}) \quad \text{EMBEDDING OF } \Sigma_\tau \qquad z^\mu_A = \frac{\partial z^\mu}{\partial \sigma^A}$$

$$ {}^4g_{AB} = z^\mu_A z^\nu_B\, {}^4g_{\mu\nu} \qquad {}^4E^\mu_{(\alpha)} = z^\mu_A\, {}^4E^A_{(\alpha)}$$

2) IN THE TANGENT SPACE OF EACH POINT OF Σ_τ BOOST TETRADS AND COTETRADS TO TETRADS AND COTETRADS ADAPTED TO Σ_τ WITH STANDARD WIGNER BOOST

COTETRADS

$$E^{(\alpha)}_A = \underbrace{L^{(\alpha)}{}_{(o)}(\varphi_{(a)})\begin{pmatrix} N \\ 0 \end{pmatrix}}_{\mathring{E}^A_{(o)}} + \underbrace{L^{(\alpha)}{}_{(a)}(\varphi_{(a)})\begin{pmatrix} n_{(a)} \\ {}^3e_{(a)r} \end{pmatrix}}_{\mathring{E}^A_{(a)}}$$

$N = 1+n$ LAPSE

$n_{(a)} = {}^3e_{(a)r}\, n^r$ SHIFT

${}^3e^r_{(a)}$ TRIADS ON Σ_τ

${}^3e_{(a)r}$ COTRIADS ON Σ_τ

$\varphi_{(a)}$ BOOST PARAMETERS

$$ {}^4g_{\tau\tau} = \varepsilon\left[(1+n)^2 - \sum_a n^2_{(a)}\right]$$
$$ {}^4g_{\tau r} = -\varepsilon\, n_r = -\varepsilon\, n_{(a)}\, {}^3e_{(a)r}$$
$$ {}^4g_{rs} = -\varepsilon\, {}^3g_{rs} = -\varepsilon \sum_a {}^3e_{(a)r}\, {}^3e_{(a)s}$$

$\varepsilon = +$ $\quad \eta^{\mu\nu} = (+---)$

$\varepsilon = -$ $\quad (-+++)$

${}^3g_{rs}$ $(+++)$

CANONICAL BASIS

$\varphi_{(a)}$	$1+n$	$n_{(a)}$	${}^3e_{(a)r}$
≈ 0	≈ 0	≈ 0	${}^3\pi^r_{(a)}$

16 FIELDS + 16 MOMENTA

14 FIRST CLASS CONSTRAINTS (GENERATORS OF GAUGE TRANSF.)

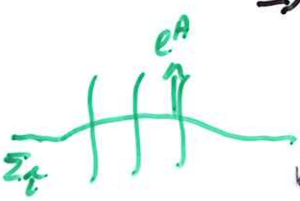
$\Downarrow$

14 GAUGE VARIABLES (INERTIAL EFFECTS)

$\Rightarrow$ 2+2 PHYSICAL D.O.F. OF THE GRAV. FIELD (TIDAL EFFECTS)

$\downarrow$

POLARIZATION OF GRAV. WAVES IN WEAK FIELD APPROX.



CONGRUENCE OF EULERIAN OBSERVERS

VORTICITY = 0, $\sigma_{(a)(b)}$ SHEAR $(= {}^3e^r_{(a)}\, {}^3e^s_{(b)}\, \sigma_{rs})$

EXPANSION $\theta = -\varepsilon\, {}^3K$, ACCELERATION ${}^3a_r = \partial_r \ln(1+n)$

YORK CANONICAL BASIS

AFTER A SUITABLE CANONICAL TRANSF. SUCH THAT

ADAPTED TO 10 OF THE 14 CONSTRAINTS

$$ {}^3e_{(a)r} = R_{(a)(b)}(\alpha_{(c)})\; V_{rb}(\theta^n)\; \tilde{\phi}^{1/3}\; e^{\sum_{\bar a}^{1,2} \gamma_{\bar a a} R_{\bar a}} $$

$$ {}^3g_{rs} = \sum_a {}^3e_{(a)r}\, {}^3e_{(a)s} = \tilde{\phi}^{2/3} \sum_a V_{ra}(\theta^n) V_{sa}(\theta^n)\, e^{2\sum_{\bar a}^{1,2} \gamma_{\bar a a} R_{\bar a}} $$

DIAGONALIZED WITH ROTATION MATRIX

$\varphi_{(a)}$	$\alpha_{(a)}$	$1+n$	$\bar{n}_{(a)}$	θ^n	$\tilde{\phi}$	$R_{\bar a}$
≈ 0	≈ 0	≈ 0	≈ 0	$\pi_n^{(\theta)}$	$\pi_{\tilde\phi}$	$\pi_{\bar a}$

$R_{\bar a}$ → TIDAL EFFECTS → ABSENT WITH A TIMELIKE KILLING VECTOR

$\pi_{\bar a} \leftrightarrow \sigma_{(a)(a)}$

O GAUGE VARIABLES (INERTIAL EFFECTS)

$\pi_{\tilde\phi}$ → ONLY GAUGE MOMENTUM (LORENTZ SIGNATURE)

$\varphi_{(a)}, \alpha_{(a)}$ – NEWMAN-PENROSE $O(3,1)$ FREEDOM IN THE CHOICE OF TETRADS

- GAUGE FREEDOM OF EACH OBSERVER IN THE ORIENTATION OF 3 GYROSCOPES AND IN THE CHOICE OF THE LAW OF TRANSPORT ALONG THE WORLDLINE

$\varphi_{(a)}(\tau,\vec\sigma) \approx 0$, $\alpha_{(a)}(\tau,\vec\sigma) \approx 0$ SCHWINGER TIME GAUGES

θ^n – GAUGE FREEDOM IN THE CHOICE OF 3-COORDINATES ON Σ_τ

$\pi_n^{(\theta)} \leftrightarrow \sigma_{(a)(b)}|_{a\neq b}$ DETERMINED BY SUPERMOMENTUM CONSTRAINTS $\mathcal{H}_{(a)}(\tau,\vec\sigma) \approx 0$

3-COORD-DEPENDENT CORIOLIS ---- INERTIAL EFFECTS

$\bar{n}_{(a)}$ – GAUGE FREEDOM IN GRAVITOMAGNETISM

$\tilde{\phi} = \phi^6 = |{}^3e_{(a)r}| = \sqrt{\det {}^3g_{rs}}$ – 3-VOLUME ELEMENT DETERMINED BY THE SUPER-HAMILTONIAN CONSTRAINT (LICHNEROWICZ EQ.)

$\mathcal{H}(\tau,\vec\sigma) \approx 0 \rightarrow \tilde{\phi} \approx F(R_{\bar a}, \pi_{\bar a}, \theta^n, \pi_{\tilde\phi})$

$\pi_{\tilde\phi} = \frac{c^3}{12\pi G}\, {}^3K$ – YORK TIME – GAUGE FREEDOM IN THE CHOICE OF THE INST. 3-SPACE (CLOCK SYNCHRONIZATION)

${}^3K = -\epsilon\,\theta$

THIS INERTIAL EFFECT IS ABSENT IN NEWTONIAN GRAVITY

Σ_τ ${}^3K_{rs}$ EXTRINSIC CURVATURE (HOW Σ_τ IS EMBEDDED IN 4-SPACE)

$1+n$ – GAUGE FREEDOM IN THE CHOICE OF THE LOCAL UNIT OF PROPER TIME

HAMILTONIAN

$$H_D = \frac{1}{c}\check{E}_{ADM} + \int d^3\sigma \left[n\,\mathcal{H} + \bar{n}_{(a)}\mathcal{H}_{(a)} + \lambda_n \Pi_n + \lambda_{(a)} \Pi_{n(a)} \right](\tau,\vec{\sigma})$$

$\lambda_n \circeq \partial_\tau n$, $\lambda_{(a)} \circeq \partial_\tau \bar{n}_{(a)}$, REST-FRAME CONDITION $\check{P}^r_{ADM} \approx 0$

WEAK ADM ENERGY

INERTIAL EFFECT
CLOCK SYNCHR. GAUGE FREEDOM

$$\frac{1}{c}\check{E}_{ADM} = M_{ADM}c = \int d^3\sigma \left[\frac{4\pi G}{c^3}\tilde{\phi}^{-1}\sum_{\bar{a}}\Pi_{\bar{a}}^2 + \frac{c^3}{16\pi G}\tilde{\phi}\sum_{a\neq b}\sigma^2_{(a)(b)} - \frac{c^3}{4\pi G}\tilde{\phi}\,({}^3K)^2 \right](\tau,\vec{\sigma})$$

TIDAL KINETIC TERM

GRAVITOMAGNETIC KINETIC TERM
MATTER CURRENT $\mathcal{M}_r$

NEGATIVE ENERGY DENSITY IN EVERY GAUGE $\boxed{{}^3K = \epsilon\,\vartheta}$
$= 0$ IN CMC 3-SPACES ${}^3K(\tau,\vec{\sigma}) \approx 0$

$$-\frac{c^3}{16\pi G}\int d^3\sigma\, \mathcal{S}(\tau,\vec{\sigma})$$

$\mathcal{S}[R_{\bar{a}}, \tilde{\phi}, \vartheta^n]$ – THE $\Gamma\Gamma$ TERM IN ${}^3R$
3-COORD-DEPENDENT POTENTIAL

$$+\int d^3\sigma\, \mathcal{M}(\tau,\vec{\sigma})$$

MATTER DENSITY

$\mathcal{S}(\tau,\vec{\sigma}) \propto \mathcal{M}(\tau,\vec{\sigma})$

SUPERHAMILTONIAN CONSTRAINT (LICHNEROWICZ EQ)

${}^3R[\phi, \vartheta^n, R_{\bar{a}}] = \phi^5\left(-8\hat{\Delta}\phi + {}^3\hat{R}[\vartheta, R_{\bar{a}}]\phi\right)$

$\phi = \tilde{\phi}^{1/6}$

$$\phi\left(\hat{\Delta}\phi - \frac{1}{8}{}^3\hat{R}\,\phi\right) + \frac{8\pi^2G^2}{c^6}\phi^{-6}\sum_{\bar{a}}\Pi_{\bar{a}}^2 + \frac{1}{8}\phi^6\sum_{a\neq b}\sigma^2_{(a)(b)} - \frac{1}{12}\phi^6({}^3K)^2 = -\frac{2\pi G}{c^3}\mathcal{M}$$

MASS DENSITY

SUPERMOMENTUM CONSTRAINTS $\mathcal{H}_{(a)}(\tau,\vec{\sigma}) \approx 0$ DEPEND ON THE MASS CURRENT (GRAVITOMAGNETISM)

ADM EQS $\partial_\tau\, {}^3g_{rs} \circeq \ldots$, $\partial_\tau\, {}^3K_{rs} \circeq \ldots$

A) CONTRACTED BIANCHI IDENTITIES $\partial_\tau \tilde{\phi} \circeq \ldots$, $\partial_\tau \sigma_{(a)(b)}|_{a\neq b} \circeq \ldots$

PRESERVATION IN TIME OF THE CONSTRAINTS (PROBLEM IN NUMERICAL GRAVITY)

B) EVOLUTION EQS FOR GAUGE VARIABLES $\begin{cases} \partial_\tau \vartheta \circeq \ldots \\ \partial_\tau \vartheta^n \circeq \ldots \end{cases}$ $\vartheta = -\epsilon\,{}^3K$ RAYCHAUDHURI EQ.

GAUGE FIXING

$\begin{cases} \vartheta^n \approx \ldots \Rightarrow \partial_\tau \vartheta^n \circeq \ldots & \text{EQ FOR SHIFT } \bar{n}_{(a)} \\ \vartheta = -\epsilon\,{}^3K \approx \ldots \Rightarrow \partial_\tau \vartheta \circeq \ldots & \text{EQ FOR LAPSE } 1+n \end{cases}$

C) EVOLUTION EQS FOR TIDAL VARIABLES $R_{\bar{a}}$, $\Pi_{\bar{a}}$ $(\leftrightarrow \sigma_{(a)(a)})$

$\begin{cases} \partial_\tau R_{\bar{a}} \circeq \ldots \\ \partial_\tau \Pi_{\bar{a}} \circeq \ldots \end{cases}$ $\rightarrow \Pi_{\bar{a}} \circeq \ldots$ $\longrightarrow \partial^2_\tau R_{\bar{a}} \circeq \ldots$

ONLY FREE CAUCHY DATA

D) MATTER HAMILTON EQS

RESEARCH PROGRAM

A) DARK ENERGY FROM BACKREACTION - BUCHERT'S AVERAGING APPROACH

HE ADDS A COSMOLOGICAL PERFECT FLUID (DUST), ASSUMES THAT IT IS IRROTATIONAL AND USES THE 3-SPACES Σ_{DUST} $\perp$ FLUID 4-VELOCITY AS INST. 3-SPACES

N.B. IN FRW COSMOLOGY BASED ON THE COSMOLOGICAL PRINCIPLE THE FLUID HAS ZERO VORTICITY, SHEAR AND 3-ACCELERATION, ONLY THE EXPANSION IS NOT ZERO (COMOVING OBSERVERS FOR CMB)

N.B. FLATNESS PROBLEM - IT CONCERNS THE INTRINSIC CURVATURE OF 3-SPACE, NOT ITS EXTRINSIC CURVATURE AS A 3-SPACE EMBEDDED IN SPACETIME

USE DUST AS MATTER - NO REASON FOR BEING IRROTATIONAL

ADD BY HAND 3 CONSTRAINTS $\omega_r(\tau, \vec{\sigma}) \approx 0$ (VANISHING VORTICITY)

LOOK FOR CONSISTENCY WITH THE EINSTEIN'S EQS $\{\omega_r(\tau, \vec{\sigma}), H_D\} \approx 0$

IF CONSISTENT (I.E. IF THERE IS A SUBSET OF SOLUTIONS OF EINSTEIN'S EQS WITH IRROTATIONAL DUST), THEN

a) THERE IS A PREFERRED 3+1 SPLITTING IDENTIFIED BY MATTER (CMB ?)

b) IF THE PREFERRED 3-SPACES ARE NOT CMC (${}^3K \neq 0$), THERE IS A NEGATIVE TERM IN $\check{E}_{ADM}$

c) FIND THE GAUGE SELECTING THE PREFERRED 3+1 SPLITTING FOR INSTANCE BY IMPOSING $l^A(\tau, \vec{\sigma}) \approx u^A_{DUST}(\tau, \vec{\sigma})$

d) REDO BUCHERT'S CALCULATIONS

AVERAGED UNIVERSE EXPANDS AT AN ACCELERATED PACE IF

$$\frac{2}{3} \langle ({}^3K - \langle {}^3K \rangle)^2 \rangle - 2 \langle \sigma^2 \rangle \;>\; \frac{1}{2} \langle \rho \rangle$$

$\to$ MATTER DENSITY

$\sigma^2 \to \sum_{a \neq b} \sigma^2_{(a)(b)} + \alpha \sum_a \pi_a^2$

$\uparrow$ MATTER CURRENT

3) DARK MATTER

STUDY THE 2-BODY PROBLEM, AT LEAST IN THE WEAK FIELD APPROXIMATION, TO FIND POST-MINKOWSKIAN GRAVITY IN 3-ORTHOGONAL GAUGES [${}^3g_{rs}(\tau,\vec{\sigma})$ DIAGONAL - IS IT A HARMONIC GAUGE FOR SOME ${}^3K(\tau,\vec{\sigma})$?]

a) FIND THE POST-MINKOWSKIAN NEWTON AND GRAVITOMAGNETIC POTENTIALS BETWEEN THE TWO PARTICLES FOR SOME ${}^3K(\tau,\vec{\sigma})$

b) TRY TO SOLVE THE TIDAL EVOLUTION EQS. $\partial_\tau^2 R_{\bar{a}}(\tau,\vec{\sigma}) \overset{\circ}{=} \text{-----}$ IN THE WEAK FIELD APPROXIMATION [IF $R_{\bar{a}}(\tau,\vec{\sigma}) \sim e^{i[\omega\tau - \vec{k}\cdot\vec{\sigma}]} \Rightarrow \omega^2 - \vec{k}^2 \approx$ GAUGE FUNCTION OF MATTER AND ${}^3K(\tau,\vec{\sigma})$]

$\Downarrow$

c) FIND THE POST-MINKOWSKIAN GRAVITATIONAL WAVES WITH ASYMPTOTIC BACKGROUND, BOTH THE HOMOGENEOUS PART AND THE MATTER-DEPENDENT PART (LIKE WITH THE LIENARD-WIECHERT SOLUTION IN ELECTROMAGNETISM) FOR SOME ${}^3K(\tau,\vec{\sigma})$.

d) FIND THE EMBEDDING $z^\mu(\tau,\vec{\sigma})$ OF Σ_τ IN SPACETIME FOR SOME ${}^3K(\tau,\vec{\sigma})$ - -IT DESCRIBES THE DYNAMICAL NON-INERTIAL FRAMES

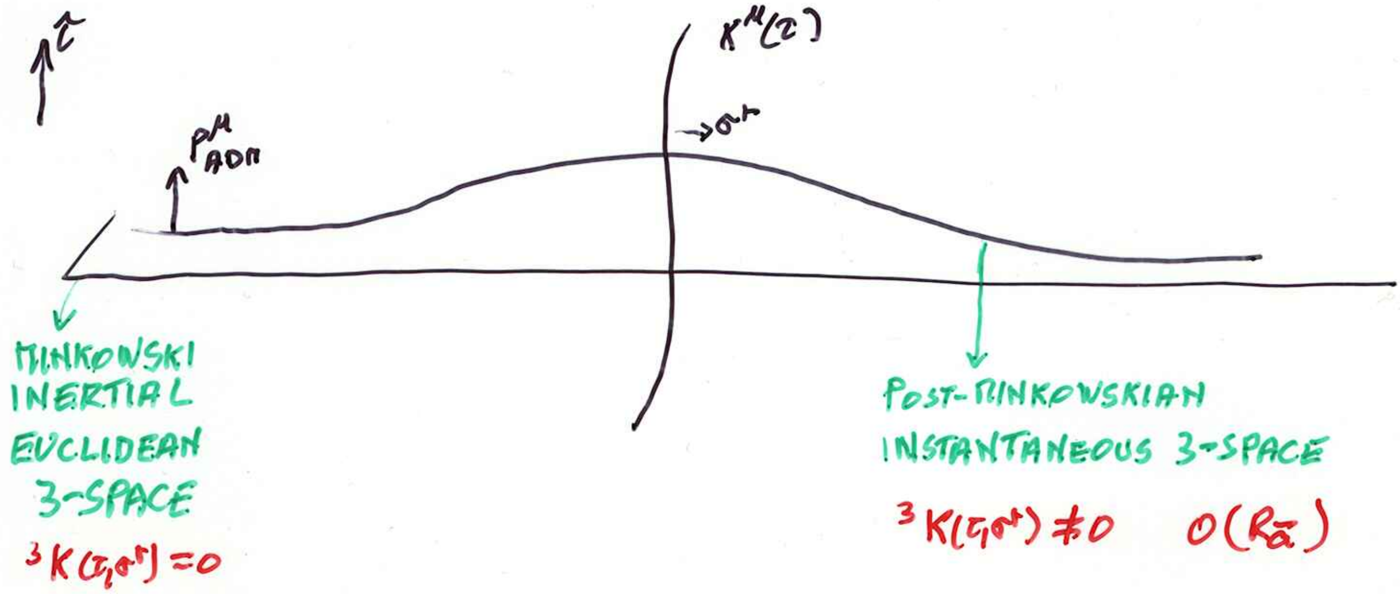
e) FIND THE (${}^3K$-DEPENDENT) TIMELIKE GEODESICS OF THE PREVIOUS SOLUTIONS AND STUDY THE MOTION OF A TEST PARTICLE CIRCULATING AROUND THE 2-BODY SYSTEM (SIMULATING A GALAXY). FIND THE POST-MINKOWSKIAN VIRIAL THEOREM, REPLACING THE KEPLER ONE ($v^2 \sim \frac{M}{R}$) USED FOR THE ROTATION CURVES OF GALAXIES. HOW MUCH DARK MATTER CAN BE DESCRIBED AS A RELATIVISTIC INERTIAL EFFECT INDUCED BY ${}^3K(\tau,\vec{\sigma})$ TOGETHER WITH GRAVITOMAGNETISM (COOPERSTOCK-TIEU) ?

THE RELATIVISTIC EQ. OF MOTION OF THE TEST PARTICLE CAN BE PUT IN THE FORM $m\,\vec{a} = \vec{F}_{TIDAL+INERTIAL}$

IN NEWTON EUCLIDEAN 3-SPACE, THE MOND APPROACH WRITES THEM IN THE FORM $m\,\vec{f}(\vec{a}) = \vec{F}_{GRAVITY}$ WITH $\vec{f}(\vec{a}) \neq \vec{a}$ AT LOW ACCELERATIONS.

$\Rightarrow$ THE INERTIAL COMPONENT OF $\vec{F}_{TIDAL+INERTIAL}$ SHOULD BE EFFECTIVE FOR LOW ACCELERATIONS.

POST-MINKOWSKIAN GRAVITATIONAL WAVES IN 3-ORTHOGONAL GAUGES



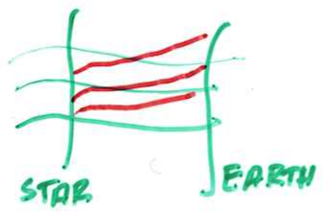
$$
\begin{cases}
{}^3g_{rs}(\tau,\sigma^r) \cong \tilde{\phi}^{2/3}_{(0)}(\tau,\sigma^r)\left[1+2\sum_{\bar a}\gamma_{\bar a a}R_{\bar a}(\tau,\sigma^r)\right]\delta_{rs} \\
= -\epsilon\,{}^4g_{rs}(\tau,\sigma^r) \\
\epsilon\,{}^4g_{\tau\tau}(\tau,\sigma^r) \approx 1+2\,n_{(0)}(\tau,\sigma^r) \\
\epsilon\,{}^4g_{\tau r}(\tau,\sigma^r) \approx \tilde{\phi}^{1/3}_{(0)}(\tau,\sigma^r)\left[1+\sum_{\bar a}\gamma_{\bar a a}R_{\bar a}(\tau,\sigma^r)\right]\bar{n}_{(r)(0)}(\tau,\sigma^r)
\end{cases}
$$

$\tilde{\phi}_{(0)}(\tau,\sigma^r)=\sqrt{\det {}^3g_{rs}}$ 3-VOLUME ELEMENT

FINAL COMMENTS

A) IN GR THE LIGHT-POSTULATES ON THE 2-WAY VELOCITY OF LIGHT ARE ASSUMED LOCALLY VALID

THE FITTING PROBLEM, THE EVALUATION OF THE LUMINOSITY DISTANCE, THE 1-WAY VELOCITY OF LIGHT REQUIRE 3+1 SPLITTINGS AND THE STUDY OF THE NULL GEODESICS OF SOLUTIONS OF EINSTEIN'S EQS



PROBLEMS OF LIGHT PROPAGATION, LENSING, ...

$\downarrow$

ALSO FOR BEPI-COLOMBO!

B) INHOMOGENEOUS AND ANISOTROPIC UNIVERSES REQUIRE SOLUTIONS OF EINSTEIN'S EQS WITHOUT KILLING VECTORS. INSTEAD THE COSMOLOGICAL (AND COPERNICAN) PRINCIPLE LEADS TO FRW COSMOLOGICAL MODEL WITH 6 KILLING VECTORS.

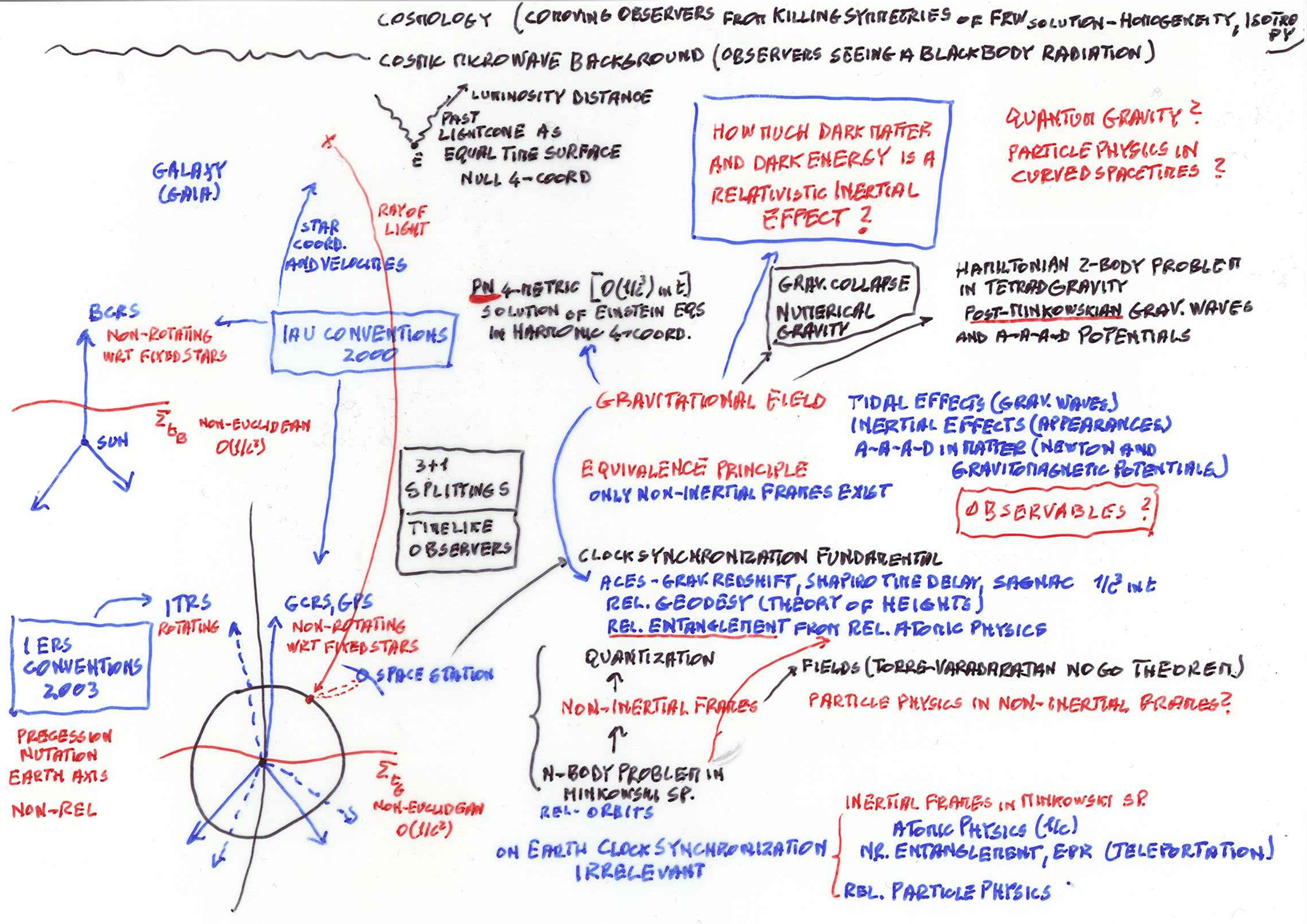
SPACE OF METRICS - STRATIFIED MANIFOLD WITH SINGULARITIES (CONE OVER CONE STRUCTURE - FISHER, MARSDEN ...)

NO REAL CONTROL OVER POSSIBLE DISCONTINUITIES IN THE GAUGE PROBLEM OF COMPARISON OF SPACETIMES WITHOUT KILLING VECTORS WITH FRW SPACETIMES

c) HORIZON PROBLEMS (CURED WITH INFLATION) - RELATIVISTIC ENTANGLEMENT INTRODUCES "NON-LOCALITY AND SPATIAL NON-SEPARABILITY". AFTER A 3+1 SPLITTING OF SPACETIME CAUSALLY DISCONNECTED REGIONS HAVE A NON-SEPARABILITY IN THE INSTANTANEOUS 3-SPACES AND THE CAUCHY DATA HAVE TO BE GIVEN FOR RELATIVE VARIABLES (THE NON-LOCAL AND NON-COVARIANT RELATIVISTIC CENTER OF MASS OF THE 3-UNIVERSE IS DECOUPLED).

d) OBSERVABLES FOR GENERAL RELATIVITY (IN ABSENCE OF KILLING VECTORS)

- TIDAL $R_{\bar a}, \Pi_{\bar a}$ $\rightarrow$ 4 EIGENVALUES OF WEYL TENSOR (4 ALGEBRAIC INVARIANTS INDEPENDENT FROM 4-COORDINATES AND TETRADS)
- MANY INERTIAL EFFECTS, ELECTRO-MAGNETIC FIELD $\rightarrow$ 4-SCALARS BUT TETRAD-DEPENDENT (NEWMAN-PENROSE FORMALISM - FIND CANONICAL FORMULATION)
- MATTER (THINK TO GPS SATELLITES) - INTRINSICALLY COORDINATE-DEPENDENT


COSMOLOGY (COMOVING OBSERVERS FROM KILLING SYMMETRIES OF FRW SOLUTION - HOMOGENEITY, ISOTROPY)
COSMIC MICROWAVE BACKGROUND (OBSERVERS SEEING A BLACKBODY RADIATION)
LUMINOSITY DISTANCE
PAST LIGHTCONE AS EQUAL TIME SURFACE
NULL 4-COORD
HOW MUCH DARK MATTER AND DARK ENERGY IS A RELATIVISTIC INERTIAL EFFECT ?
QUANTUM GRAVITY ?
PARTICLE PHYSICS IN CURVED SPACETIMES ?
GALAXY (GAIA)
STAR COORD. AND VELOCITIES
RAY OF LIGHT
PN 4-METRIC [O(1/c³) in t]
SOLUTION OF EINSTEIN EQS IN HARMONIC 4-COORD.
GRAV. COLLAPSE
NUMERICAL GRAVITY
HAMILTONIAN 2-BODY PROBLEM IN TETRADGRAVITY
POST-MINKOWSKIAN GRAV. WAVES AND A-A-A-D POTENTIALS
BCRS
NON-ROTATING WRT FIXED STARS
IAU CONVENTIONS 2000
GRAVITATIONAL FIELD
TIDAL EFFECTS (GRAV. WAVES)
INERTIAL EFFECTS (APPEARANCES)
A-A-A-D IN MATTER (NEWTON AND GRAVITOMAGNETIC POTENTIALS)
SUN
Σ_{t_B}
NON-EUCLIDEAN O(1/c³)
3+1 SPLITTINGS
TIMELIKE OBSERVERS
EQUIVALENCE PRINCIPLE
ONLY NON-INERTIAL FRAMES EXIST
OBSERVABLES ?
CLOCK SYNCHRONIZATION FUNDAMENTAL
ACES - GRAV. REDSHIFT, SHAPIRO TIME DELAY, SAGNAC 1/c³ in t
REL. GEODESY (THEORY OF HEIGHTS)
REL. ENTANGLEMENT FROM REL. ATOMIC PHYSICS
ITRS
ROTATING
GCRS, GPS
NON-ROTATING WRT FIXED STARS
IERS CONVENTIONS 2003
SPACE STATION
QUANTIZATION
FIELDS (TORRE-VARADARAJAN NO GO THEOREM)
NON-INERTIAL FRAMES
PARTICLE PHYSICS IN NON-INERTIAL FRAMES ?
PRECESSION NUTATION EARTH AXIS
NON-REL
N-BODY PROBLEM IN MINKOWSKI SP.
REL. ORBITS
Σ_{t_G}
NON-EUCLIDEAN O(1/c²)
INERTIAL FRAMES IN MINKOWSKI SP.
ATOMIC PHYSICS (1/c)
NR. ENTANGLEMENT, EPR (TELEPORTATION)
REL. PARTICLE PHYSICS
ON EARTH CLOCK SYNCHRONIZATION IRRELEVANT