NON-INERTIAL FRAMES IN MINKOWSI AND IN EINSTEIN SPACE-TIMES

LUCA LUSANNA

SENIOR INFN, FIRENZE

BALFEST 80

CLASSICAL
QUANTUM THEORIES $\to$ PDE – PREDICTABILITY

$\downarrow$

WELL POSED CAUCHY PROBLEM

$\downarrow$

WELL DEFINED INSTANTANEOUS 3-SPACE FOR CAUCHY DATA

$\downarrow$

CLOCK SYNCHRONIZATION CONVENTION

(METROLOGY – TIME : A GIVEN ATOMIC CLOCK)

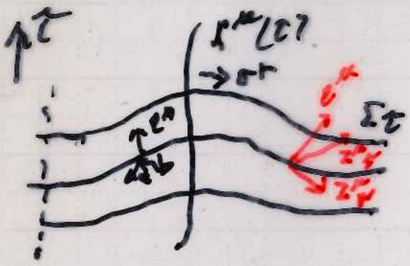
GALILEI SPACETIME – TIME AND 3-SPACE ABSOLUTE

MINKOWSKI SPACETIME – NO NOTION OF 3-SPACE (ONLY CONFORMAL STRUCTURE INTRINSIC – LIGHTCONE)

3+1 POINT OF VIEW

a) WORLDLINE OF A TIMELIKE OBSERVER WITH ATOMIC CLOCK

b) 3+1 SPLITTING WITH A NICE FOLIATION



ASYMPTOTIC INERTIAL OBSERVERS

SCALAR OBSERVER-ADAPTED RADAR 4-COORD.

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

$\sigma^A \mapsto x^\mu = z^\mu(\tau, \sigma^r)$ EMBEDDING OF 3-SPACES Σ_τ

→ IT IS A CONVENTION FOR SYNCHRONIZING ALL THE CLOCKS WITH THE CLOCK OF THE OBSERVER

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

$\eta_{\mu\nu} \mapsto g_{AB}[z(\tau,\sigma^r)] = z^\mu_A \eta_{\mu\nu} z^\nu_B \qquad z^\mu_A = \frac{\partial z^\mu}{\partial \sigma^A}$

g_{AB}, ${}^3K_{rs}$

INDUCED INERTIAL POTENTIALS

$\frac{\partial z^\mu}{\partial \tau} = N\, l^\mu + N^r z^\mu_r$ LAPSE, SHIFT

${}^3K_{rs} = \frac{1}{2N}\left(N_{r|s} + N_{s|r} - \partial_\tau g_{rs}\right)$

WITH ALBA
INT. J. GEOM. METHODS IN PHYS. 7 (2010) 33 and 185
0908.0213 and 0215

GLOBAL NON-INERTIAL FRAME CENTERED ON THE OBSERVER

$N(\tau, \sigma^r) > 0$ NO CROSSING OF 3-SPACES (IT HAPPENS WITH FERMI COORD IN 1+3 APPROACH)

$\epsilon\, g_{\tau\tau}(\tau,\sigma^r) > 0$ NO ROTATING DISK PATHOLOGY (HORIZON PROBLEM: $\frac{\partial z^\mu}{\partial \tau}$ BECOMES A NULL VECTOR AT $\omega R = c$)

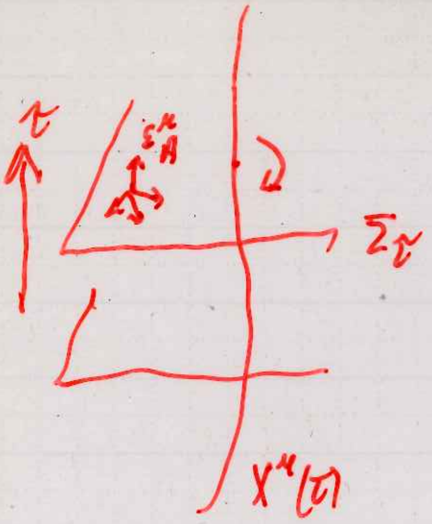
MØLLER

⇒ ONLY DIFFERENTIAL ROTATIONS ALLOWED

$-\epsilon\, g_{rs}(\tau,\sigma^r)$ WITH 3 NON-DEGENERATE POSITIVE EIGENVALUES

$\Sigma_\tau \xrightarrow[|\sigma| \to \infty]{}$ τ-INDEPENDENT SPACELIKE HYPERPLANE

DIFFERENTIALLY ROTATING RADAR 4-COORDINATES



$$z^\mu(\tau,\vec{\sigma}) = X^\mu(\tau) + \epsilon^\mu_r \, R^r{}_s(\tau,\vec{\sigma})\, \sigma^s$$

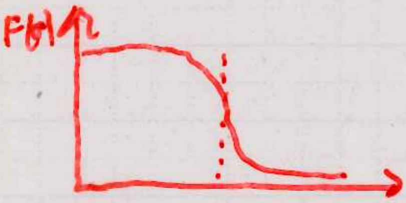
$$R(\tau,\vec{\sigma}) = R\big(\alpha_i(\tau,\vec{\sigma})\big)$$

$$\alpha_i(\tau,\vec{\sigma}) = F(\vec{\sigma})\, \tilde{\alpha}_i(\tau)$$

MØLLER CONDITIONS

$$\begin{cases} \dfrac{dF(\vec{\sigma})}{d\sigma} \neq 0 \\[2ex] 0 < F(\vec{\sigma}) < \dfrac{k}{|\vec{\sigma}|} \end{cases}$$

TO SIMULATE RIGID ROTATIONS WITH ω

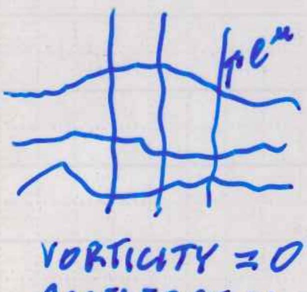


$$F(\sigma) = \frac{1}{1 + \frac{\omega^2}{c^2}\sigma^2}$$

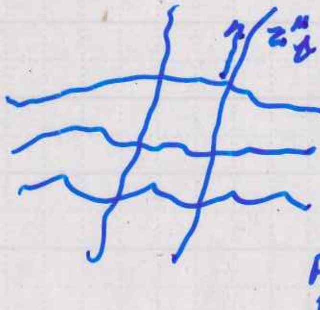
EACH ADMISSIBLE 3+1 SPLITTING HAS 2 ASSOCIATED CONGRUENCES OF TIME-LIKE OBSERVERS

EULERIAN $u^\mu(\tau,\vec{\sigma}) = l^\mu(\tau,\vec{\sigma})$

ROTATING $u^\mu(\tau,\vec{\sigma}) = \dfrac{z^\mu_\tau(\tau,\vec{\sigma})}{\sqrt{\epsilon\, {}^4g_{\tau\tau}(\tau,\vec{\sigma})}}$



VORTICITY = 0
ACCELERATION ~ $\partial_r \ln(1+n)$
EXPANSION ~ ${}^3K$
SHEAR σ_{rs}



NON-SURFACE FORMING

VORTICITY $\neq 0$

ACCELERATION
EXPANSION
SHEAR

ISOLATED SYSTEMS IN THE REST-FRAME INSTANT FORM

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

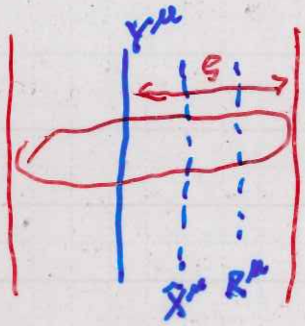
- NON-LOCAL QUANTITIES – THEY KNOW THE WHOLE INSTANTANEOUS 3-SPACE $\quad P^\mu = \int_{\Sigma_\tau} d^3x \, \text{----}$
- LORENTZ BOOSTS: INTERACTION-DEPENDENT $\quad [P^i, K^j] = \delta^{ij} P^o$
  $\neq$ GALILEI BOOSTS

$P^\mu, J^{\mu\nu} \longrightarrow$ 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

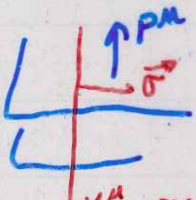
$$\rho = \frac{\sqrt{-W^2}}{P^2 c} = \frac{|\vec{\bar{S}}|}{Mc}$$

$\rho \sim$ COMPTON WAVELENGTH OF ISOLATED SYSTEM

REMNANT OF ENERGY CONDITIONS OF GENERAL RELATIVITY

REST-FRAME INSTANT FORM

WIGNER INSTANTANEOUS 3-SPACES



Y^μ ORIGIN OF 3-COORD.

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

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

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

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

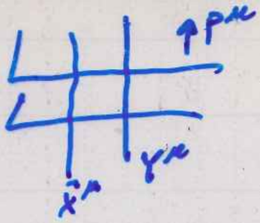
$\downarrow$ WIGNER BOOST FOR TIMELIKE ORBITS

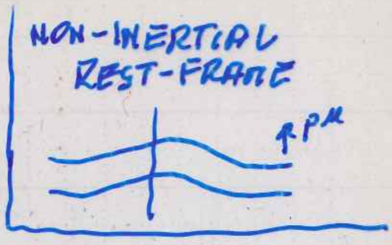
POSITIVE ENERGY PARTICLES $\quad \boxed{x_i^\mu(\tau) = Z^\mu(\tau, \vec{\eta}_i(\tau))} = Y^\mu(\tau) + \epsilon^\mu_r(\vec{h}) \, \eta_i^r(\tau)$

$\tilde{x}^\mu(\tau), Y^\mu(\tau), R^\mu(\tau)$ KNOWN FUNCTIONS OF $\tau, M, \vec{\bar{S}}$, 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, $\vec{\bar{S}}$ REST SPIN

(UNIVERSAL BREAKING OF LORENTZ COVARIANCE BUT DECOUPLED)

EXTERNAL POINCARÉ GENERATORS

$$P^0 = Mc\sqrt{1+\vec{h}^2} \qquad \vec{P} = Mc\,\vec{h}$$

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

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

$$\begin{cases} Mc = c\int d^3\sigma\, T^{\tau\tau}(\tau,\vec{\sigma}) & \\ \vec{\mathcal{P}} \approx 0 \quad \text{REST-FRAME CONDITION} & \mathcal{P}^r = \int d^3\sigma\, T^{\tau r}(\tau,\vec{\sigma}) \\ \vec{\mathcal{J}} = \vec{\bar{S}} & \bar{S}^r = \frac{1}{2}\varepsilon^{ruv}\int d^3\sigma\, \sigma^u\, T^{\tau v}(\tau,\vec{\sigma}) \\ \vec{\mathcal{K}} \approx 0 & \end{cases}$$

(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 $\vec{\eta}_i(\tau), \vec{\kappa}_i(\tau)$

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

$\Rightarrow$ $\vec{\eta}_i, \vec{\kappa}_i$, $i=1,..,N$ FUNCTIONS ONLY OF RELATIVE VARIABLES $\boxed{\vec{\rho}_a, \vec{\pi}_a,\ a=1,..,N}$

J. PHYS. A40, 9585 (2007) (gr-qc/0610200) WITH ALBA, CRATER

2-BODY CASE – ORBIT RECONSTRUCTION

FREE CASE $$x_i^\mu(\tau) = Y^\mu(\tau) + (-)^{i+1}\,\varepsilon_r^\mu(\vec{h})\,\frac{\sqrt{m_i^2c^2+\vec{\pi}_{12}^2}}{\sum_k\sqrt{m_k^2c^2+\vec{\pi}_{12}^2}}\,\vec{\rho}_{12}(\tau) \xrightarrow[c\to\infty]{} \begin{cases} t \\ \vec{x}_{(n)} + (-)^{i+1}\frac{m_{i+1}}{m_1+m_2}\vec{r}_{(n)} = \vec{x}_{(n)i} \end{cases}$$

COVARIANT WORLDLINES – DERIVED NON-CANONICAL QUANTITIES

$\{x_i^\mu, x_j^\nu\} \neq 0$ PREDICTIVE COORDINATES — NON-COMMUTATIVE STRUCTURE

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

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

$\vec{s} = \vec{\eta}_1-\vec{\eta}_2$

NOW SOME N-BODY SYSTEM UNDER CONTROL

THE INTERNAL POINCARÉ ALGEBRA IS SATISFIED

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

HAMILTONIAN FOR THE RELATIVE MOTION

$$\mathcal{M}_0 = \sqrt{m_1^2+\vec{\pi}^2}+\sqrt{m_2^2+\vec{\pi}^2}$$

EXPLICIT POINCARÉ ALGEBRA FOR

- MASSLESS PARTICLES
- OPEN NAMBU STRING
- 2-LEVEL ATOMS

$\vec{K} \approx 0$

$$\Rightarrow \quad \vec{q} \approx \vec{q}(\vec{s},\vec{\pi}) = \frac{m_1^2-m_2^2}{2}\left(\frac{1}{\mathcal{M}_0^2}-\frac{1}{\mathcal{M}^2}\right)\vec{s}$$

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

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

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

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

IT IS NOT KNOWN THE FORM OF THE INTERNAL BOOST $\vec{K}$

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

ISOLATED SYSTEMS IN MINKOWSKI SPACETIME

$T^{\mu\nu}$

FINITE POINCARÉ GENERATORS $P^\mu, J^{\mu\nu}$ $\begin{cases} \text{NON-LOCAL (THEY KNOW THE WHOLE } \Sigma_\tau) \\ \text{INTERACTION-DEPENDENT BOOSTS} \end{cases}$

A) PARAMETRIZED MINKOWSKI THEORIES

$\begin{cases} \text{POS. EN. PARTICLE} & X^\mu(\tau) = z^\mu(\tau, \eta^r_i(\tau)) \\ \text{KG FIELD} & \tilde{\phi}(z(\tau,\sigma^r)) = \phi(\tau,\sigma^r) \end{cases}$

$S = \int d\tau\, d^3\sigma\, \mathcal{L}\,(\text{MATTER}, g_{AB}[z(\tau,\sigma^r)])$ ⟶ CONJUGATE MOMENTUM $\rho_\mu(\tau,\sigma^r)$

INVARIANT UNDER FRAME-PRESERVING DIFF $\tau \mapsto f(\tau,\sigma^r)$, $\sigma^r \mapsto g^r(\sigma)$ (PLEBANSKI)

⇒ 4 FIRST CLASS CONSTRAINTS

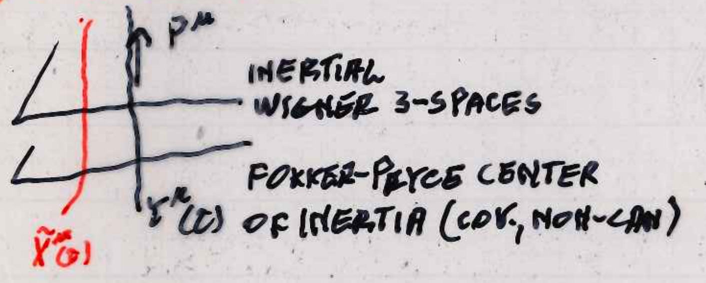
$\mathcal{H}_\mu(\tau,\sigma^r) = \rho_\mu(\tau,\sigma^r) -$
$- (l_\mu T^{\tau\tau} + z_{r\mu} T^{\tau r})(\tau,\sigma^r) \approx 0$

⇒ $z^\mu(\tau,\sigma^r)$ GAUGE VARIABLES

⇓

CHANGE OF CLOCK SYNCHRONIZATION AND/OR OF 3-COORD σ^r = GAUGE TRANSF.

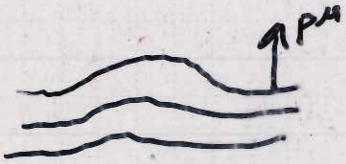
B) INERTIAL REST-FRAME INSTANT FORM OF DYNAMICS



NON-COVARIANT CANONICAL (NEWTON-WIGNER) CENTER OF MASS $\tilde{x}^\mu(\tau)$
+
WIGNER-COVARIANT RELATIVE VARIABLES ON Σ_τ

⇒ ISOLATED SYSTEM = DECOUPLED NON-COV. (NON-LOCAL ⇒ UNOBSERVABLE) C.O.M. CARRYING A POLE-DIPOLE STRUCTURE M, $\vec{S}$ (DEPENDING ON RELATIVE VARIABLES INSIDE Σ_τ) WITH EXTERNAL REALIZATION OF POINCARÉ ALGEBRA

C) NON-INERTIAL REST-FRAME INSTANT FORM



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RELATIVISTIC ATOMIC PHYSICS

POS. EN. PARTICLES + TRANSVERSE EM FIELD (RADIATION GAUGE) - COULOMB POT.

GRASSMANN-VALUED ELECTRIC CHARGES → $^{UV}_{IR}$ REGULARIZATION — I

↓

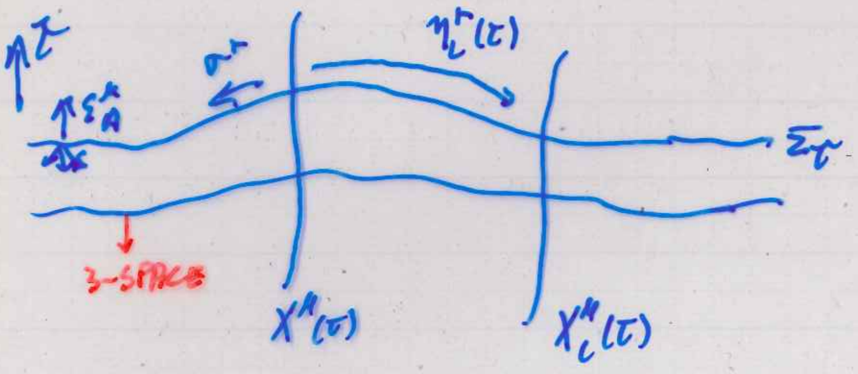
NO SELF-ENERGIES (RADIATIVE CORRECTIONS) - HAM. EXPRESSION OF LIENARD-WIECHERT SOLUTION AND ASYMPTOTIC LARMOR FORMULA

CAN. TRANSF. IN REST-FRAME TO COULOMB-DRESSED PARTICLES WITH COULOMB + DARWIN POTENTIALS (SALPETER FOR SPINNING P.) + FREE RADIATION FIELD (NO CLAS. HARG TH)

⇒ RELATIVISTIC BOUND STATES (TILL NOW DARWIN FROM BETHE-SALPETER EQ)

RELATIVISTIC KINETIC THEORY AND RELATIVISTIC MICROCANONICAL ENSEMBLE

POSITIVE ENERGY SCALAR PARTICLES



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

$\sigma^A \mapsto x^\mu = z^\mu(\tau, \sigma^r)$

$x^\mu_i(\tau) = z^\mu(\tau, \eta^r_i(\tau))$

$\eta^r_i(\tau)$, $K_{ir}(\tau)$ CANONICAL VARIABLES

WORLD-LINES $x^\mu_i(\tau)$, $P^\mu_i(\tau)$ DERIVED VARIABLES $P_i^2 = \epsilon\, m_i^2 c^2$

$\{x^\mu_i(\tau), x^\nu_i(\tau)\} \neq 0$ $\left\{ \begin{array}{l} \text{PREDICTIVE 4-COORDINATES} \\ \text{NON-COMMUTATIVE STRUCTURE} \end{array} \right.$

$$m_i \sqrt{\dot{x}^2_i(\tau)} \mapsto m_i \sqrt{g_{\tau\tau}(\tau, \eta^u_i(\tau)) + 2\, g_{\tau r}(\tau, \eta^u_i(\tau))\, \dot{\eta}^r_i(\tau) + g_{rs}(\tau, \eta^u_i(\tau))\, \dot{\eta}^r_i(\tau)\, \dot{\eta}^s_i(\tau)}$$

$\left\{ \begin{array}{l} \text{SR} - z^\mu(\tau, \sigma^r) \quad \text{MØLLER ADMISSIBLE EMBEDDING} - \text{3-SPACE} = \text{GAUGE} \\ \text{GR} - z^\mu(\tau, \sigma^r) = x^\mu(\tau) + \epsilon^\mu_r \sigma^r \quad \to \text{3-SPACE } \Sigma_\tau \text{ DYNAMICALLY DETERMINED MODULO GAUGE VARIABLES} \end{array} \right.$

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

REGULARIZATION OF EM SELF-ENERGIES

GRASSMANN-VALUED SIGN OF ENERGY $\eta_i m_i$, $\eta_i^2 = 0$, $\eta_i \eta_j = \eta_j \eta_i \neq 0$ $i \neq j$

REGULARIZATION OF GRAVITATIONAL SELF-ENERGIES

THEN GRASSMANN $\mapsto$ CLIFFORD 2-LEVEL SYSTEM

LORENTZ SIGNATURE OF SPACETIME AND POINCARÉ GROUP

NON-LOCALITY AND NON-MEASURABILITY OF REL. CENTER OF MASS
(NON-COVARIANT BUT DECOUPLED)

PREFERRED $\vec{h}$ - BASIS — OR PLANE WAVE WITH FIXED MOMENTUM LIKE IN SCATTERING THEORY

SPATIAL NON-SEPARABILITY

$$H = H_{com} \otimes H_{REL} \neq H_1 \otimes H_2 \otimes \cdots$$

$\downarrow$

ENTANGLEMENT

$$|\vec{h}_{com}\rangle \otimes \sum_\alpha \beta_\alpha(\vec{s}_\alpha)\, |\alpha, \vec{s}_\alpha\rangle$$

DECOHERENCE

ROBUST POSITIONAL POINTER BASES
IN A DIAGONAL REDUCED DENSITY MATRIX

ATOMIC PHYSICS - EM FIELD
$\Rightarrow$ BEYOND GALILEI SPACETIME

REFORMULATE NON-REL ENTANGLEMENT IN THE $H_{com} \otimes H_{REL}$ PRESENTATION
STANDARD APPROACH $H_1 \otimes H_2 \cdots$
ONLY WITH MANY COMPONENTS WHEN THE REST-FRAME CONDITIONS ARE NEGLIGIBLE !

REL NON-LOCALITY WITH DIFFERENT ORIGIN FROM STANDARD NON-REL QUANTUM NON-LOCALITY (BELL INEQUALITIES, EPR, ---)

PROBLEM OF LOCALIZABILITY OF WORLDLINES

- REL — NEWTON-WIGNER NON SELF-ADJOINT (FLEMING, BUTTERFIELD, ..)
  ONLY SYMMETRIC (KEMPF, ...
  $\Rightarrow$ BAD LOCALIZABILITY
- NON-REL — POVM, UNSHARP POSITIONS FROM WIGNER-ARAKI-YANESA TH (BUSCH, ...) - ONLY RELATIVE VARIABLES MEASURABLE (DUNNINGHAM ....)

FOUNDATIONAL PROBLEMS OF QM

REFORMULATION IN RQM

ALSO NEWTON C.O.M. NON MEASURABLE

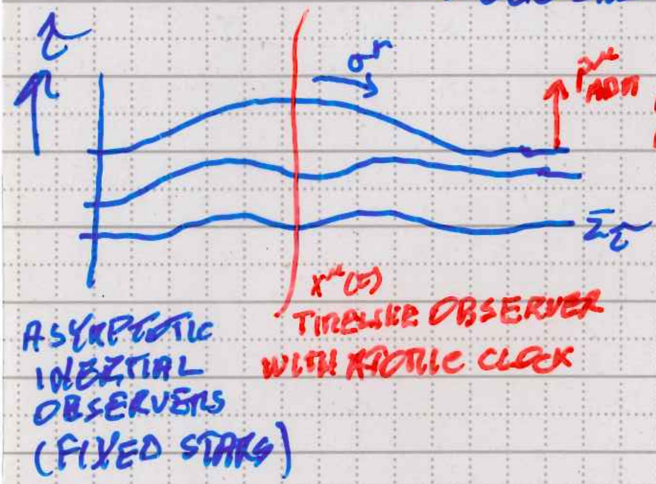
- EMERGENCE OF CLASSICAL WORLD
- THEORY OF MEASUREMENT

EINSTEIN GENERAL RELATIVITY

SPACETIMES
- GLOBALLY HYPERBOLIC (TIME, CLOCKS, ...)
- ASYMPTOTICALLY MINKOWSKIAN (ASYMPTOTIC FLAT BACKGROUND)
- NO SUPERTRANSLATIONS
  - ASYMPTOTIC SYMMETRIES (SPI GROUP) REDUCE TO ADM POINCARE GROUP (NEEDED FOR PARTICLE PHYSICS)
  - NON-INERTIAL REST-FRAME OF 3-UNIVERSE

PDE - PREDICTABILITY → WELL POSED CAUCHY PROBLEM
→ WELL DEFINED INSTANTANEOUS 3-SPACES FOR CAUCHY DATA
→ CLOCK SYNCHRONIZATION CONVENTION NEEDED

3+1 POINT OF VIEW AND RADAR 4-COORDINATES
→ GLOBAL NON-INERTIAL FRAMES (EQUIVALENCE PRINCIPLE)



NON-INERTIAL REST FRAME

AFTER RECOMBINATION SURFACE

$G \to 0$ NON-INERTIAL FRAMES IN MINKOWSKI SPACETIME

RADAR 4-COORDINATES

$$\begin{cases} x^\mu \mapsto \sigma^A(x) = (\tau, \sigma^r) \\ \sigma^A \mapsto x^\mu = z^\mu(\tau, \sigma^r) \quad \text{EMBEDDING OF } \Sigma_\tau \end{cases}$$

$$g_{AB}(\tau,\sigma^r) = \frac{\partial z^\mu(\tau,\sigma^r)}{\partial \sigma^A} \frac{\partial z^\nu(\tau,\sigma^r)}{\partial \sigma^B} g_{\mu\nu}(z(\tau,\sigma^r)) = E^{(\alpha)}_A(\tau,\sigma^r)\, \eta_{(\alpha)(\beta)}\, E^{(\beta)}_B(\tau,\sigma^r)$$

$\boxed{\text{4-SCALARS}}$ COTETRADS (FERMIONS)

$$ds^2 = g_{\mu\nu}\, dx^\mu dx^\nu = g_{AB}\, d\sigma^A d\sigma^B$$

CHRONOGEOMETRICAL STRUCTURE (METROLOGY, ATOMIC CLOCKS, ...)

USE ADM ACTION AS A FUNCTIONAL OF COTETRADS
→ HAMILTONIAN FORMULATION AND DIRAC THEORY OF CONSTRAINTS

$$H = \check{E}_{ADM} + \text{CONSTRAINTS} = \int d^3\sigma\, \mathcal{E}_{ADM}(\tau,\sigma^r) + \text{CONSTRAINTS}$$

WEAK ADM ENERGY

NO FROZEN PICTURE

ADM TETRAD GRAVITY WITHOUT KILLING SYMMETRIES

LAPSE — SHIFT

$$E^{(\alpha)}_A = L^{(\alpha)}{}_{(o)}(\varphi_{(a)}) \begin{pmatrix} N = 1+n \\ 0 \end{pmatrix} + \sum_a^{1..3} L^{(\alpha)}{}_{(a)}(\varphi_{(a)}) \begin{pmatrix} n_{(a)} \\ {}^3e_{(a)r} \end{pmatrix}$$

COTETRAD — ↑ WIGNER BOOST FOR TIMELIKE ORBITS — COTRIADS ON Σ_τ

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

16 FIELDS + 16 MOMENTA

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

CANONICAL BASIS ADAPTED TO 7 OF THE 14 FIRST CLASS CONSTRAINTS

⇓

14 GAUGE VARIABLES = INERTIAL EFFECTS

2+2 PHYSICAL D.O.F. = TIDAL EFFECTS

↓ CANONICAL TRANSFORMATION TO THE YORK CANONICAL BASIS ADAPTED TO 10 CONSTRAINTS (NOT SUPER-HAM AND SUPER-MOM)

→ FROM SUPER-HAM C.

$\varphi_{(a)}$	$\alpha_{(a)}$	$N = 1+n$	$\bar n_{(a)}$	θ^i	$\tilde\phi$	$R_{\bar a}$
≈ 0	≈ 0	≈ 0	≈ 0	π^θ_i	$\pi_{\tilde\phi} = \frac{c^3}{12\pi G}\, {}^3K$	$\pi_{\bar a}$

4-SCALARS

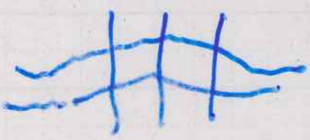
O(3,1) GYROSCOPES — ↳ FROM SUPER-MOM C. — $\bar a = 1,2$ TIDAL — → YORK TIME

$$\begin{cases} {}^3e_{(a)r} = R_{(a)(b)}(\alpha_{(c)})\, {}^3\bar e_{(b)r} \qquad {}^3\bar e_{(a)r} = \tilde\phi^{1/3}\, V_{ra}(\theta^i)\, e^{\sum_{\bar a} \gamma_{\bar a a} R_{\bar a}} \\ {}^3g_{rs} = \sum_a {}^3e_{(a)r}\, {}^3e_{(a)s} = \tilde\phi^{2/3} \sum_a V_{ra}(\theta^i) V_{sa}(\theta^i)\, e^{2\sum_{\bar a} \gamma_{\bar a a} R_{\bar a}} \\ g_{\tau\tau} = \epsilon\left[(1+n)^2 - \sum_a \bar n_{(a)}^2\right] \qquad g_{\tau r} = -\epsilon\, \bar n_{(a)}\, {}^3\bar e_{(a)r} \end{cases}$$

↳ ORTHOGONAL MATRIX

$\tilde\phi = \sqrt{\det {}^3g_{rs}}$ 3-VOLUME IN Σ_τ

CONGRUENCE OF EULERIAN OBSERVERS



$$\begin{cases} \text{VORTICITY} = 0 \qquad \text{EXPANSION } \theta = -\epsilon\, {}^3K \\ \text{SHEAR } \sigma_{(a)(b)} \quad \left[\sigma_{(a)(b)}\big|_{a\neq b} \leftrightarrow \pi^\theta_i \;;\; \sigma_{(a)(a)} \leftrightarrow \pi_{\bar a}\right] \\ \text{ACCELERATION } \; {}^3a_r = \partial_r \ln(1+n) \end{cases}$$

$\tilde{\phi} = \sqrt{\det {}^3g_{rs}}$ 3-VOLUME ELEMENT FROM LICHNEROWICZ EQ.

YORK TIME ${}^3K$ INERTIAL MOMENTUM - REMNANT IN GR OF THE SPECIAL RELATIVISTIC GAUGE FREEDOM IN CLOCK SYNCHRONIZATION

$${}^3K_{rs} = \tilde{\phi}^{2/3} \sum_{ab} \left(\tfrac{1}{3}\, {}^3K\, \delta_{ab} + \sigma_{(a)(b)} \right) V_{ra}(\theta^i) V_{sb}(\theta^i)\; e^{\sum_{\bar{a}} (\gamma_{\bar{a}a} + \gamma_{\bar{a}b}) R_{\bar{a}}}$$

3-SPACE DYNAMICALLY DETERMINED EXCEPT FOR ${}^3K$

Σ_τ

GAUGE FIXING - θ^i - FIXATION 3-COORD ON Σ_τ - IMPLIES EQS. FOR $\bar{n}_{(a)}$ GRAVITOMAGNETISM

${}^3K$ - FORM OF Σ_τ AS 3-SUBMANIFOLD → IMPLIES EQ FOR $N = 1 + n$

SCHWINGER TIME GAUGE $\boxed{\varphi_{(a)}(\tau, \sigma^r) \approx 0, \quad \alpha_{(a)}(\tau, \sigma^r) \approx 0}$

FIXATION OF $O(3,1)$ GAUGE FREEDOM

WEAK ADM ENERGY (INVARIANT MASS OF 3-UNIVERSE)

$$\frac{1}{c} \check{E}_{ADM} = \int d^3\sigma \Big[\frac{4\pi G}{c^3} \tilde{\phi}^{-1} \sum_{\bar{a}} \Pi^2_{\bar{a}} + \quad \text{TIDAL KINETIC TERM}$$

$$+ \frac{c^3}{16\pi G} \tilde{\phi} \sum_{a \neq b} \sigma^2_{(a)(b)} [{}^3K] - \quad \text{GRAVITOMAGNETISM}$$

$$- \frac{c^3}{4\pi G} \tilde{\phi} \left({}^3K \right)^2 - \quad \text{GAUGE NEGATIVE KINETIC TERM}$$

$$- \frac{c^3}{16\pi G} \mathcal{S} + \mathcal{M} \Big] (\tau, \sigma^r)$$

ΓΓ TERM INERTIAL POTENTIAL — MATTER

A) SUPER-HAM AND -MOM CONSTRAINTS - ELLIPTIC EQS

B) 4 CONTRACTED BIANCHI IDENTITIES $\partial_\tau \tilde{\phi} = \cdots$, $\partial_\tau \sigma_{(a)(b)}|_{a \neq b} = \cdots$

C) 4 EQS FOR PRIMARY GAUGE VARIABLES $\begin{cases} \partial_\tau {}^3K = \cdots \text{ (RAYCHAUDHURI)} \\ \partial_\tau \theta^i = \cdots \end{cases}$

D) 4 HYPERBOLIC EQS FOR TIDAL VARIABLES

E) HAMILTON EQS FOR MATTER

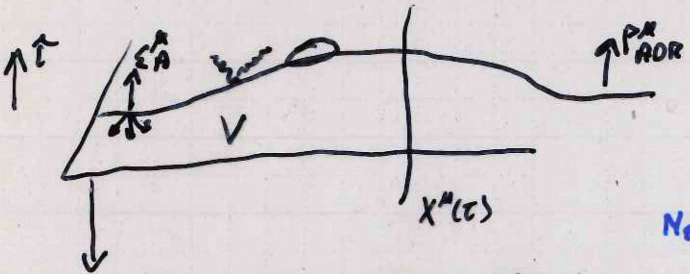
12 ADM EQS: $\partial_\tau {}^3g_{rs} = \cdots$, $\partial_\tau {}^3K_{rs} = \cdots$

FAMILY OF NON-HARMONIC 3-ORTHOGONAL GAUGES $\theta^i(\tau, \sigma^r) \approx 0$ $\begin{cases} {}^3K \text{ FREE} \\ g_{rs} = A_r \delta_{rs} \end{cases}$

HAMILTONIAN POST-MINKOWSKIAN EXPANSION (WEAK FIELD APPROXIMATION)

IN THE FAMILY OF NON-HARMONIC 3-ORTHOGONAL GAUGES $\quad {}^3K_{(1)}(\tau\vec\sigma)$ FREE

ASYMPTOTIC BACKGROUND - MINK. METRIC AT SPATIAL ∞ FOR $\Delta, \Box, \dots$



$R_{\bar a}(\tau,\vec\sigma) = O(\xi)$ GRAVITATIONAL WAVES (GW)

$${}^4g_{AB}(\tau,\vec\sigma) = {}^4\eta^{(ASYM)}_{AB} + {}^4h_{(1)AB}(\tau,\vec\sigma) + O(\xi^2)$$

NON-INERTIAL REST FRAME OF 3-UNIVERSE

ASYMPTOTIC EUCLIDEAN 3-SPACE
(IN HARMONIC GAUGES IT IS USED IN THE BULK)

$$\tilde\phi = 1 + 6\phi_{(1)} + O(\xi^2)$$

$$\epsilon\, {}^4g_{\tau\tau} = 1 + 2n_{(1)} + O(\xi^2), \quad -\epsilon\, {}^4g_{\tau r} = \bar n_{(1)(r)} + O(\xi^2)$$

$$-\epsilon\, {}^4g_{rs} = {}^3g_{rs} = \delta_{rs}\left[1 + 2\left(\Gamma^{(1)}_r + 2\phi_{(1)}\right)\right] + O(\xi^2)$$

$\Gamma^{(1)}_r = \sum_{\bar a} \gamma_{\bar a r} R_{\bar a}$

GRAVITATIONAL WAVES

ULTRAVIOLET CUTOFF m ON MATTER TO AVOID POST-NEWTONIAN EXPANSIONS

$$\frac{m_i}{m},\ \frac{\vec\kappa_i}{m},\ \frac{E_M}{m} = O(\xi) \implies T^{AB} = T^{AB}_{(1)} + O(\xi^2)$$

THE APPROXIMATION IS NOT RELIABLE AT DISTANCES FROM POINT PARTICLES LESS THAN THE GRAVITATIONAL RADIUS $\ell_m = \frac{mG}{c^2} \approx 10^{-29}\,m$ OF CUTOFF

WEAK ADM POINCARÉ GENERATORS = MATTER MINKOWSKI POINCARÉ GEN. $+O(\xi^2)$

ISOLATED 3-UNIVERSE - DECOUPLED CENTER OF MASS + RELATIVE VARIABLES

LIKE IN NON-INERTIAL REST-FRAMES OF MINKOWSKI SP.

$$\begin{cases} \frac{1}{c}\hat E_{ADM} = M_{(1)}c + \frac{1}{c}\hat E_{ADM(2)} \\ \hat P^r_{ADM} = P^r_{(1)} + P^r_{(2)} \approx 0 \\ \hat J^{rs}_{ADM} = J^{rs}_{(1)} + J^{rs}_{(2)} \\ \hat K^r_{ADM} = K^r_{(1)} + K^r_{(2)} \approx 0 \end{cases}$$

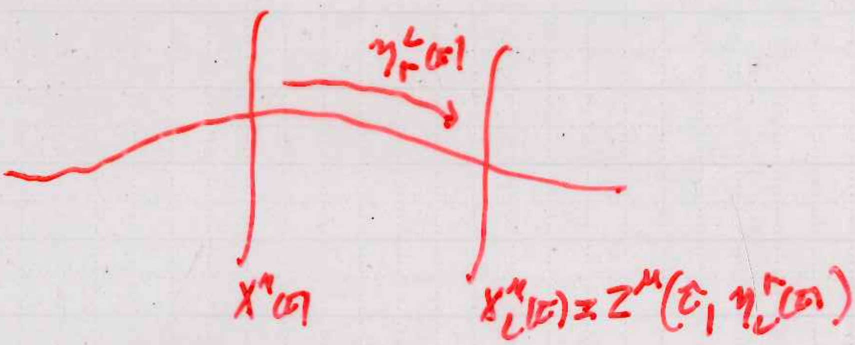
$$\begin{cases} M_{(1)}c = \sum_i \eta_i \sqrt{m_i^2c^2 + \vec\kappa_i^2} \\ P^r_{(1)} = \sum_i \eta_i \kappa_{ir} \\ J^{rs}_{(1)} = \sum_i \eta_i \left(\eta_i^r \kappa_{is} - \eta_i^s \kappa_{ir}\right) \\ K^r_{(1)} = -\sum_i \eta_i\, \eta_i^r \sqrt{m_i^2c^2 + \vec\kappa_i^2} \end{cases}$$

HPM EXPANSION IN NON-HARMONIC 3-ORTHOGONAL SCHWINGER TIME GAUGES

- ALL CONSTRAINTS SOLVED
- RETARDED ~~GW~~ NON-HARMONIC GW
- RELATIVISTIC MASS QUADRUPOLE EMISSION FORMULA
- BALANCE IN THE EMISSION OF ENERGY, MOMENTUM, ANGULAR MOMENTUM FROM CONSTANCY OF ADM POINCARÉ GENERATORS WITHOUT GRAVITATIONAL SELF-FORCES

PARTICLES

$\eta_i^r(\tau)$, $\kappa_{ir}(\tau)$



GRASSMANN-VALUED SIGN OF ENERGY η_i ($\eta_i^2 = 0$, $\eta_i \eta_j = \eta_j \eta_i$)
TO REGULARIZE GRAVITATIONAL SELF-ENERGY

ELECTRIC CHARGE Q_i ($Q_i^2 = 0$, $Q_i Q_j = Q_j Q_i$)
TO REGULARIZE EM SELF-ENERGIES

HPM EQS OF MOTION

$$m_i \, \eta_i \, \frac{d^2 \eta_i^r(\tau)}{d\tau^2} = \eta_i \, F_i^r(\tau)$$

↳ TERM IN $\partial_\tau^2 \, {}^3K$ FROM LAPSE

$\boxed{n_{(1)} = \check{n}_{(1)} - \partial_\tau \, {}^3\tilde{K}}$

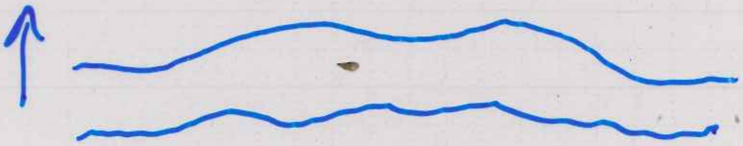
$\boxed{{}^3\tilde{K} = \frac{1}{\Delta} \, {}^3K}$

PN LIMIT $\quad \tau = ct \quad \eta_i^r(\tau) = \tilde{\eta}_i^r(t)$

$$m_i \, \eta_i \, \frac{d^2 \tilde{\eta}_i^r(t)}{dt^2} = \eta_i \, \tilde{F}_i^r(t) = \eta_i \Big[\underset{\text{0PN}}{\text{KEPLER}} + \underset{\text{0.5 PN}}{\frac{1}{2} \frac{d\tilde{\eta}_i^s(t)}{dt} \, \partial_t^2 \, {}^3\tilde{K}(\tau, \tilde{\eta}_i^r(\tau))} +$$

$$+ \underset{\text{BINARIES (DAMOUR-DERUELLE)}}{\text{1PN}} + \ldots \Big]$$

DARK MATTER AS A RELATIVISTIC INERTIAL EFFECT



Σ_τ

3-SPACE AS 3-SUBMANIFOLD OF SPACETIME

INTRINSIC CURVATURE SMALL

EXTRINSIC CURVATURE WITH ${}^3K(\tau,\vec{\sigma})$, YORK TIME, ARBITRARY

HPM LAPSE $\quad 1 + n(\tau,\vec{\sigma}) = 1 +$ NEWTON POTENTIAL + REL. CORRECTIONS $\underbrace{- \partial_\tau \frac{1}{\Delta}\, {}^3K(\tau,\vec{\sigma})}$,

THE TIME VARIATION OF 3-SPACE AS A 3-SUBMANIFOLD (I.E. OF CLOCK SYNCHRONIZATION CONVENTION) IS EQUIVALENT TO A POTENTIAL, FOR INSTANCE IT MAY COINCIDE WITH THE YUKAWA-LIKE POTENTIAL OF $f(R)$ THEORIES, USED TO SIMULATE DARK MATTER

MATTIA VILLANI – ARXIV 1502.06801

EINSTEIN GR $\quad m_{GR} = m_{IN}$ $\begin{cases} m_{IN} & \text{BARYONIC FROM SPECTROSCOPY} \\ m_{GR} & \text{FROM GALAXY DYNAMICS} \end{cases}$

BUT 3-SPACE IS NOT EUCLIDEAN (EQUIVALENCE PRINCIPLE)

IS THE NEWTON VERSION OF $m_{GR} = m_{IN}$ VALID IN THE PN LIMIT OF GR ?

NO – 0.5PN EQS OF MOTION OF MATTER CONTAIN TERMS IN $\partial_\tau^2 \frac{1}{\Delta}\, {}^3K(\tau,\vec{\sigma})$

SIGNATURES OF DARK MATTER

1) GALAXY MASSES FROM VIRIAL THEOREM $\qquad M_{GR} = \frac{R}{G} \langle \vec{v}^{\,2} \rangle = M_{IN} + M_{DM}({}^3K)$

2) GALAXY MASS FROM WEAK GRAVITATIONAL LENSING

EINSTEIN RADIUS $\sqrt{\frac{4 G M_{GR}}{c^2} \frac{d}{d'}}$ (FERMAT PRINC.) $\qquad M_{GR} = M_{IN} + M_{DM}({}^3K)$

3) ROTATION CURVES OF GALAXIES

$$\frac{d^2}{dt^2}\left(\vec{r}_{(o)} + \vec{r}_{(1)}\right) = \underbrace{- G M_{IN} \frac{\vec{r}_o}{|\vec{r}_o|^3}}_{\text{KEPLER}} - \frac{\mu}{c} \frac{d\vec{r}_{(o)}}{dt}\, \gamma({}^3K) \qquad \hat{n}^2 = 1$$

CIRCULAR ORBITS $\quad \vec{r}_{(o)} = r_o\, \hat{u}(t) \qquad \frac{d}{dt}\left(\vec{r}_{(o)} + \vec{r}_{(1)}\right)(t) = \sqrt{\frac{G\, M_{GR}(t, r_o)}{r_o}}\ \hat{n}(t, r_o)$

$$M_{GR} = M_{IN}\left[1 - \frac{2\mu}{c} A({}^3K)\right] = M_{IN} + M_{DM}({}^3K)$$

NOT MOND, NOT $f(R)$, NOT WIMP $\qquad \boxed{{}^3K \text{ IN VOIDS ?}}$

0.5 PN EQUATIONS OF MOTION FOR $\vec{\tilde{\eta}}_i(t)$

+ PM SOLUTION FOR 4-METRIC

1) GALAXY MASSES FROM VIRIAL THEOREM

MEASURED GRAV. MASS $M_{GR} = \frac{R}{G}\langle v^2\rangle = M_{IN} + M_{DM}({}^3K_{(1)})$

↳ BARYONIC (SPECTROSCOPY)

2) GALAXY MASS FROM WEAK GRAVITATIONAL LENSING

EINSTEIN RADIUS $\sqrt{\frac{4GM_{GR}}{c^2}\frac{d}{d'}}$ $\quad M_{GR} = M_{IN} + M_{DM}({}^3K_{(1)})$

(FERMAT PRINCIPLE REFRACTION INDEX) BARYONIC

3) ROTATION CURVES OF GALAXIES

RELATIVE VARIABLES $\frac{d^2}{dt^2}\underbrace{\left(\vec{r}_{(0)} + \vec{r}_{(1)}\right) = -G M \frac{\vec{r}_{(0)}}{|\vec{r}|^3}}_{\text{KEPLER}} - \frac{M}{c}\frac{d\vec{r}_{(0)}}{dt}\gamma({}^3K_{(1)})$

M = BARYONIC MASS $= M_{IN}$

CIRCULAR ORBITS $\vec{r}_{(0)} = r_0\,\hat{u}(t)$

$$\frac{d}{dt}\left(\vec{r}_{(0)} + \vec{r}_{(1)}\right)(t) = \sqrt{\frac{G\,M_{EFF}(t, r_0)}{r_0}}\;\hat{n}(t, r_0), \quad \hat{n}^2 = 1$$

$$M_{GRA} = M_{EFF} = M_{IN}\left(1 - \frac{2M}{c}A({}^3K_{(1)})\right) = M_{IN} + M_{DM}({}^3K_{(1)})$$

SINCE 3-SPACE IS NOT EUCLIDEAN

NEWTON $M_{IN} = M_{GR}$ LAW IS NOT VALID

$M_{GR} = M_{IN} + M_{DM}({}^3K_{(1)})$

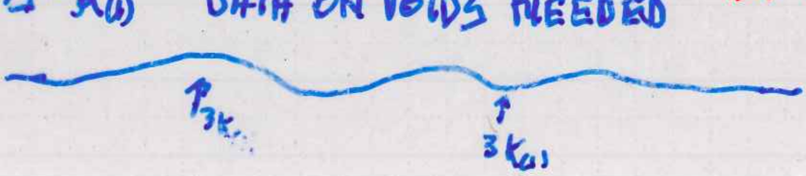
↳ DARK MATTER AS A RELATIVISTIC INERTIAL EFFECT

NOT MOND
NOT f(R)
NOT WIMP

BUT $\partial_\tau {}^3K$

FIT ${}^3\mathcal{K}_{(1)} = \frac{1}{\Delta}{}^3K_{(1)}$ TO DATA

BUT TO FIND ${}^3K_{(1)} = \Delta\,{}^3\mathcal{K}_{(1)}$ DATA ON VOIDS NEEDED



GAUGE PROBLEM IN GR VERSUS METROLOGY

4-DIFF – GAUGE FREEDOM IN THE CHOICE OF 4-COORDINATES — 4-SCALARS – GAUGE INVARIANTS

ON-SHELL AGREEMENT (INVERSE LEGENDRE, MONCRIEF ...)

HAMILTONIAN GAUGE GROUP – DIRAC OBSERVABLES (3-SCALARS)

GAUGE FREEDOM IN 3-COORD. AND ${}^3K$ OF 3-SPACE

TIDAL VARIABLES $\longrightarrow$ 4 EIGENVALUES OF WEYL TENSOR (4-SCALARS)

2+2 (3-SCALARS)

LAPSE – 4-SCALAR

EM FIELD
GRAVITOMAGNETISM (SHIFT) } TETRAD-DEPENDENT 4-SCALARS (NEWMAN-PENROSE)

MACROSCOPIC MATTER – ITS DESCRIPTION IS COORDINATE-DEPENDENT

IT DEPENDS ON THE METROLOGICAL CONVENTIONS OF ATOMIC PHYSICS, NASA ENGENIERS, ASTRONOMERS

EARTH – ITRS (IERS 2003)

GPS, GCRS (IAU 2000)] $\theta^i \approx 0$, ${}^3K = O(c^{-3})$ REL, HARMONIC GAUGES — SATELLITES

BCRS (IAU 2000) (SOLAR SYSTEM) — SPACECRAFTS, BODIES IN SOLAR SYSTEM

MILKY WAY] GAIA

ICRS — NON-REL EUCLIDEAN 3-SPACE Σ_τ (CMB, FLWR COSMOLOGY) — AGAINST EQUIVALENCE PRINCIPLE

NECESSITY OF POST-MINKOWSKIAN EXTENSION OF ICRS TO TAKE INTO ACCOUNT THE EXTRINSIC 3-CURVATURE OF NON-EUCLIDEAN 3-SPACES

BEGIN WITH MILKY WAY WHEN DATA FROM GAIA AVAILABLE

WHICH VALUE OF THE YORK TIME ${}^3K(\tau, \sigma^r)$, I.E. WHICH CLOCK SYNCHRONIZATION CONVENTION, GIVES RISE TO A 3-SPACE IN ACCORD WITH RELATIVISTIC METROLOGY IN THE SOLAR SYSTEM AND ABLE TO CLARIFY THE DARK SIDE OF UNIVERSE

OPEN PROBLEMS

NEWTON AND RELATIVISTIC CENTER OF MASS - NON-MEASURABLE

QUANTIZATION? WAVE FUNCTION OF UNIVERSE

QUANTUM METROLOGY - ONLY RELATIVE VARIABLES

FOCK SPACE ONLY OF RELATIVE MOTIONS

QUANTIZATION IN NON-INERTIAL FRAMES

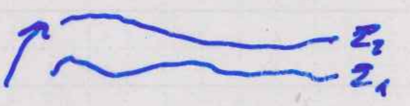
DEFINITION OF PARTICLES, KILLING VECTORS AND

BOGOLIUBOV TRANSFORMATIONS

ACCELERATED OBSERVERS: KINEMATICAL OR DYNAMICAL?

UNRUH-DEWITT DETECTORS - RINDLER OBSERVERS

TORRE-VARADARAJAN NO-GO THEOREM -



- TOMONAGA-SCHWINGER BREAKS UNITARY EVOLUTION

OF MASSIVE KG FIELD: THE BOGOLIUBOV TRANSFORMATION

$\Sigma_1 \to \Sigma_2$ IS NOT HILBERT-SCHMIDT

⋮

GR - ALSO DARK ENERGY MAY BE A RELATIVISTIC

INERTIAL EFFECT

FRW SPACETIMES - KILLING SYMMETRIES (ISOTROPY, HOMOGENEITY)

IMPLY $^3K_{(s)} = -\frac{\dot a(\tau)}{a(\tau)} \approx -\frac{1}{3} H$ HUBBLE CONSTANT

WITHOUT KILLING SYMMETRIES (SZEKERES, --) ⇒

$\to$ ^3K GAUGE VARIABLE

....

⇓

BALFEST 90!

L. LUSANNA – THE CHRONOGEOMETRICAL STRUCTURE OF SPECIAL AND GENERAL RELATIVITY: A REVISITATION OF CANONICAL GEOMETRODYNAMICS

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- 7 (2010) 33 0908.0213
- 7 (2010) 185 0908.0215

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I) THE REST-FRAME INSTANT FORM OF DYNAMICS AND A CANONICAL TRANSFORMATION FOR A SYSTEM OF CHARGED PARTICLES PLUS THE ELECTROMAGNETIC FIELD

CANAD. J. PHYS 88 (2010) 379 0806.2383

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

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– ON THE RELATIVISTIC MICROCANONICAL ENSEMBLE AND RELATIVISTIC KINETIC THEORY FOR N RELATIVISTIC PARTICLES IN INERTIAL AND NON-INERTIAL REST FRAMES

ARXIV 1202.4667

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~~[illegible]~~ arXiv 1306.6524

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L. LUSANNA – NON-INERTIAL FRAMES IN SPECIAL AND GENERAL RELATIVITY
arXiv 1310.4465

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– ENTROPY 2017, 19(9) 436 (SPECIAL ISSUE: ADVANCES IN RELATIVISTIC STATISTICAL MECHANICS)

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THE EINSTEIN–MAXWELL–PARTICLE SYSTEM IN THE YORK CANONICAL BASIS OF ADM TETRAD GRAVITY

I) THE EQUATIONS OF MOTION IN ARBITRARY SCHWINGER TIME GAUGES
CANAD. J. PHYS 90 (2012) 1017 (ARXIV 0907.4087)

II) THE WEAK FIELD APPROXIMATION IN THE 3-ORTHOGONAL GAUGES AND HAMILTONIAN POST-MINKOWSKIAN GRAVITY: THE N-BODY PROBLEM AND GRAVITATIONAL WAVES WITH ASYMPTOTIC BACKGROUND
CANAD. J. PHYS 90 (2012) 1077 (ARXIV 1003.5143)

III) THE POST-MINKOWSKIAN N-BODY PROBLEM, ITS POST-NEWTONIAN LIMIT IN NON-HARMONIC 3-ORTHOGONAL GAUGES AND DARK MATTER AS AN INERTIAL EFFECT

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ISBN 978-953-51-0584-8

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IN-TECH BOOK - TRENDS IN MODERN COSMOLOGY 2017

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INT. J. GEOM. METH. MOD. PHYS 12 (2015) 1530001 (ARXIV 1401.1375)

FROM CLOCK SYNCHRONIZATION TO DARK MATTER AS A RELATIVISTIC INERTIAL EFFECT

SPRINGER PROC. PHYS. 144 (2013) 267 (ARXIV 1205.2481) SCHOOL BOSS 2011

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