How minkowski four-force generalized by Károly Novobatzky leads to scalar-tensor gravity

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Theories of Gravitation

V · T · E	Theories of gravitation [hide]	
Standard	Newtonian gravity (NG)	Newton's law of universal gravitation · **History of gravitational theory**
	General relativity (GR)	Introduction · History · Mathematics · Resources · Tests · Post-Newtonian formalism · Linearized gravity · ADM formalism
Alternatives to general relativity	Paradigms	Classical theories of gravitation · Quantum gravity · Theory of everything
	Classical	Einstein–Cartan · Bimetric theories · Gauge theory gravity · Teleparallelism · Composite gravity · f(R) gravity · Massive gravity · Modified Newtonian dynamics (MOND) · Nonsymmetric gravitation · Scalar–tensor theories (Brans–Dicke) · Scalar–tensor–vector · Conformal gravity · Scalar theories (Nordström) · Whitehead · Geometrodynamics · Induced gravity · Tensor–vector–scalar · Chameleon · Pressuron
	Quantisation	Euclidean quantum gravity · Canonical quantum gravity (Wheeler–DeWitt equation · Loop quantum gravity · Spin foam) · Causal dynamical triangulation · Causal sets · DGP model
	Unification	Kaluza–Klein theory (Dilaton) · Supergravity
	Unification and quantisation	Noncommutative geometry (Self-creation cosmology) · Semiclassical gravity · Superfluid vacuum theory (Logarithmic BEC vacuum) · String theory (M-theory · F-theory · Heterotic string theory · Type I string theory · Type 0 string theory · Bosonic string theory · Type II string theory · Little string theory) · Twistor theory (Twistor string theory)
	Generalisations / Extensions of GR	Liouville gravity · Lovelock theory · (2+1)-dimensional topological gravity · Gauss–Bonnet gravity · Jackiw–Teitelboim gravity
Pre-Newtonian theories and Toy models		Aristotelian physics · CGHS model · RST model · Mechanical explanations (Fatio–Le Sage · Entropic gravity) · Gravitational interaction of antimatter

~50 alternatives and extensions

http://en.wikipedia.org/wiki/History_of_gravitational_theory

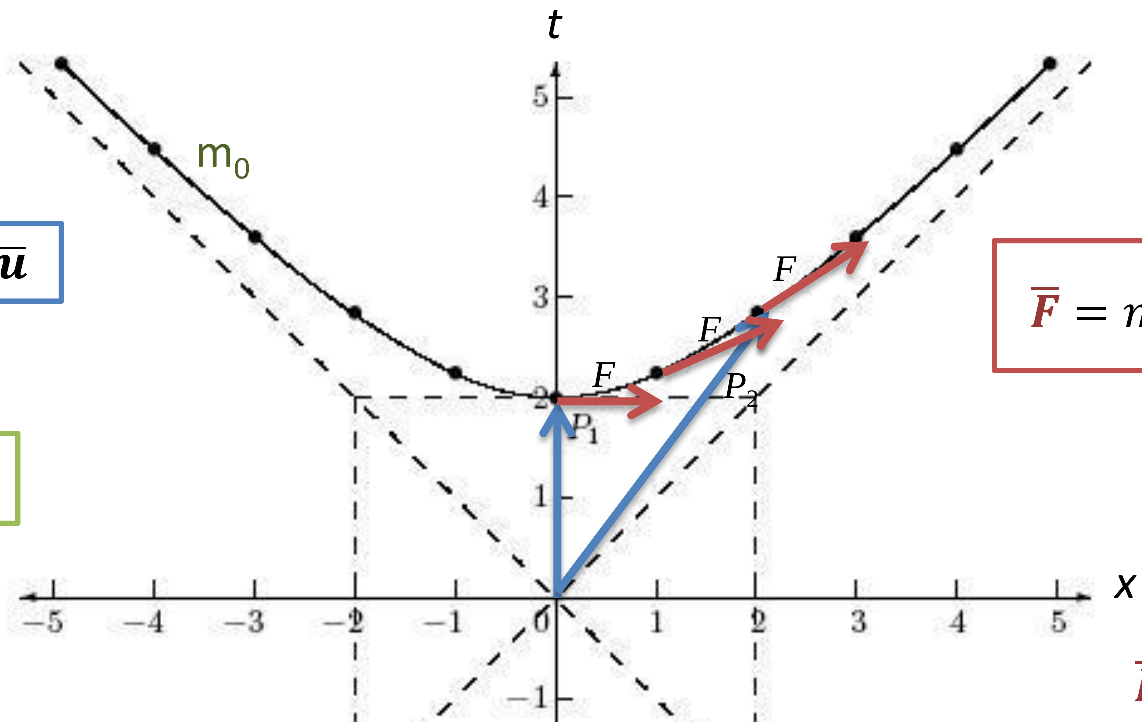
A lot of results in addition to GR

Minkowski (four)-force

$c = 1$

$\bar{\boldsymbol{p}} = (E, \bar{p}) = m\bar{\boldsymbol{u}}$

$m = \sqrt{E^2 - p^2}$



$$\bar{\boldsymbol{F}} = m\bar{\boldsymbol{a}} = m\frac{d\bar{\boldsymbol{u}}}{d\tau} = \frac{d\bar{\boldsymbol{p}}}{d\tau}$$

$\tau \rightarrow$ proper time

$\bar{\boldsymbol{F}} \perp \bar{\boldsymbol{u}} \leftrightarrow F_i u^i = 0$

REST MASS is INVARIANT

$\bar{\boldsymbol{F}} \perp \bar{\boldsymbol{p}}$ → **Special case**

Generalized minkowski-force

Károly Novobátzky in the ´50s

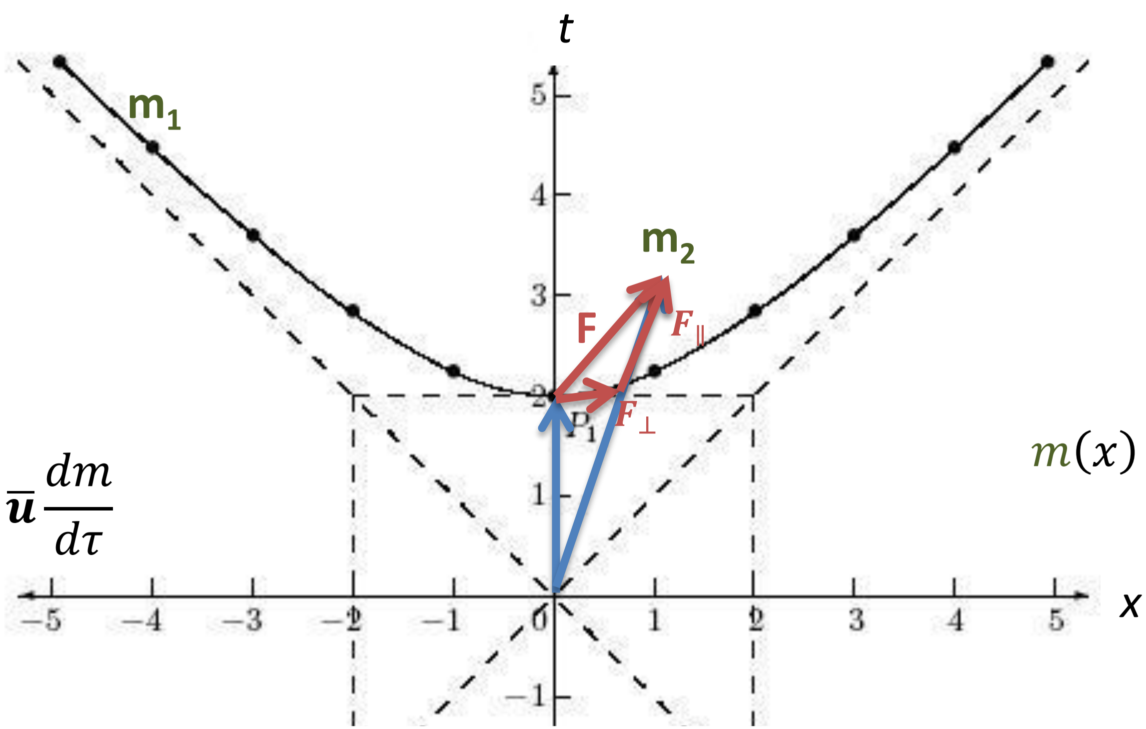
$F_i p^i \neq 0$

$\overline{\boldsymbol{F}} = F_\perp + F_\parallel$

$\|\bar{u}\|^2 = c^2$

$A_i u^i = 0$

$$\frac{d\overline{\boldsymbol{p}}}{d\tau} = m\frac{d\overline{\boldsymbol{u}}}{d\tau} + \overline{\boldsymbol{u}}\frac{dm}{d\tau}$$



$m(x) = m_0 + \phi(\boldsymbol{x}?)$

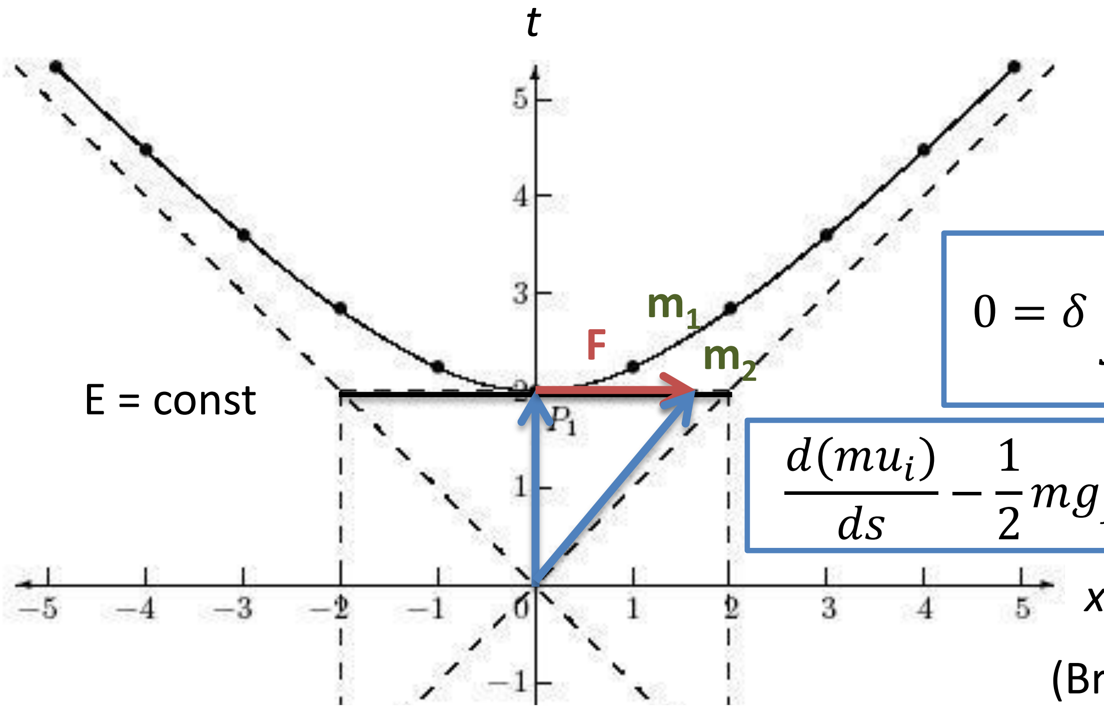
Rest mass might change

Conservative force field

$$E = \frac{m_0 c^2 \sqrt{g_{00}}}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$E = \frac{m(x) c^2}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$m(x) = m_0 \sqrt{g_{00}}$$



$$0 = \delta \int m \sqrt{(g_{ij} u^i u^j)} ds$$

$$\frac{d(m u_i)}{ds} - \frac{1}{2} m g_{jk,i} u^j u^k - m_{,i} = 0$$

(Brans & Dicke 1961)

$$m(x) = f(x) m_0$$

Scalar-tensor gravity

What is this scalar function?

$$m(x) = m_0\sqrt{g_{00}}$$

$$g_{00} = 1 - \frac{r_s}{r} \qquad r_s = \frac{2GM}{c^2}$$

$$m_0\sqrt{g_{00}} = m_0\sqrt{1 - \frac{2GM}{rc^2}} \approx m_0(1 - \frac{GM}{rc^2})$$

(First members of Taylor series)

$$E = m_0c^2\sqrt{g_{00}} \approx m_0c^2 - \frac{GMm_0}{r}$$

$$F = m_{,r}c^2 \approx \frac{GMm_0}{r^2}$$

Newtonian gravitational potential

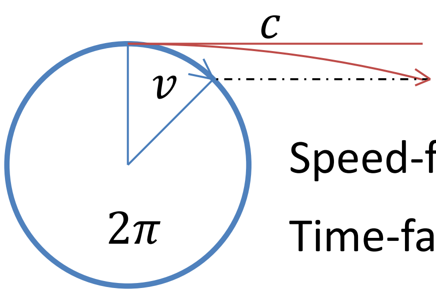
Perihelion advance of Mercure

$$\frac{d(mu_i)}{ds} - \frac{1}{2} m g_{jk,i} u^j u^k - m_{,i} = 0$$

General Relativity: $\Delta\varphi_{GR} = 6\pi \frac{v^2}{c^2}$

„Speed-effect”: $\Delta\varphi_{SR} = 2\pi \frac{v^2}{c^2}$

Light-deflection: $\Delta\varphi_{Light} = 4\pi \frac{v^2}{c^2}$



Speed-factor: $\frac{v}{c}$

Time-factor: $\frac{v}{c}$

Light-factor: 2

Relation of Scalar-Tensor theory and General Relativity

Scalar-Tensor theory: $m(x) = f(x)m_0$

Conformal transformation: $\bar{g}_{ij} = f^2 \mathrm{g}_{ij}$

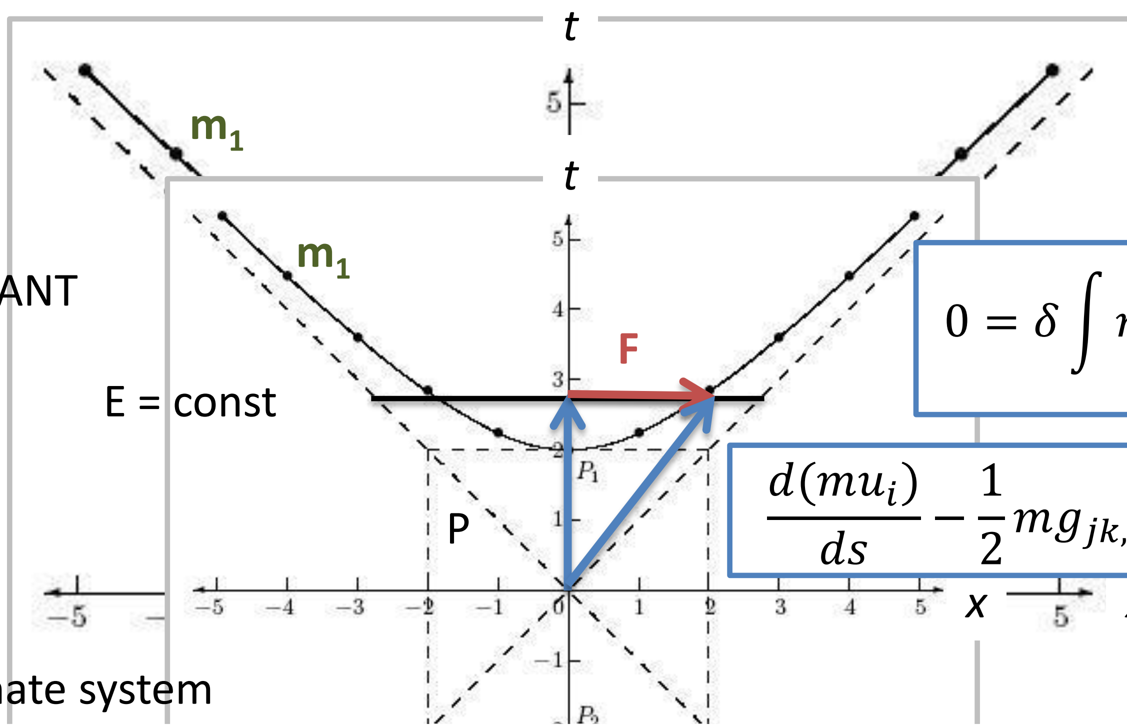
$d\bar{s}^2 = f^2 ds^2, \qquad \bar{u}^i = f^{-1} u^i$

We will get back the General Relativistic equation of motion: $m = const$

Gravitation force field in GR

Rest mass is CONSTANT

$m(x) = m_0$



$$0 = \delta \int m \sqrt{(g_{ij} u^i u^j)} ds$$

$$\frac{d(mu_i)}{ds} - \frac{1}{2} m g_{jk,i} u^j u^k - \cancel{m_{,i}} = 0$$

Change of coordinate system

Rescale + mass defect

Constant or variable rest mass?

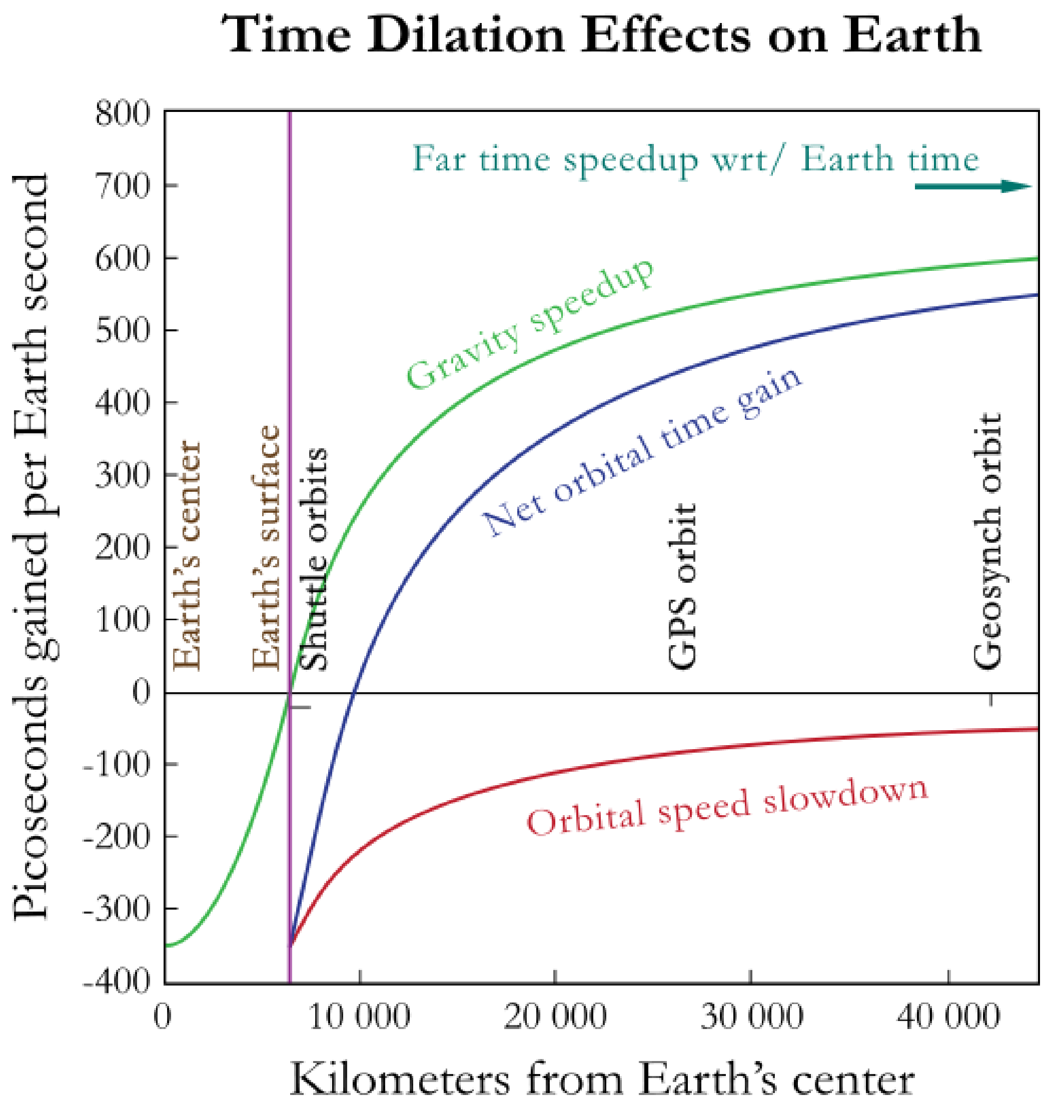
above. Imagine, if you will, that you are told by a space traveller that a hydrogen atom on Siruis has the same diameter as one on the earth. A few moments' thought will convince you that the statement is either a definition or else meaningless. It is evident that two rods side

theoretical structure appears to be simpler if one defines the inertial masses of elementary particles to be constant and permits the gravitational constant to vary. It should be noted that this is possible only if the mass ratios of elementary particles are constant. There may be reasonable doubt about this.[9,10] On the other hand,

[9] R. H. Dicke, Science **129**, 621 (1959).

[10] R. H. Dicke, Am. J. Phys. **29**, 344 (1960).

What satellite navigation (GPS) says?



Relation of scalar field and metric

Brans and Dicke (1961):

With the assumption that only the gravitational "constant" (or active gravitational masses) vary with position,

$$m_0(1 - \frac{GM}{rc^2})$$

a function of some scalar field variable. The contracted metric tensor is a constant and devoid of interest. The scalar curvature and the other scalars formed from the curvature tensor are also devoid of interest as they contain gradients of the metric tensor components, and fall off more rapidly than r^{-1} from a mass source. Thus such scalars are determined primarily by nearby mass distributions rather than by distant matter.

As the scalars of general relativity are not suitable, a new scalar field is introduced. The primary function of this field is the determination of the local value of the gravitational constant.

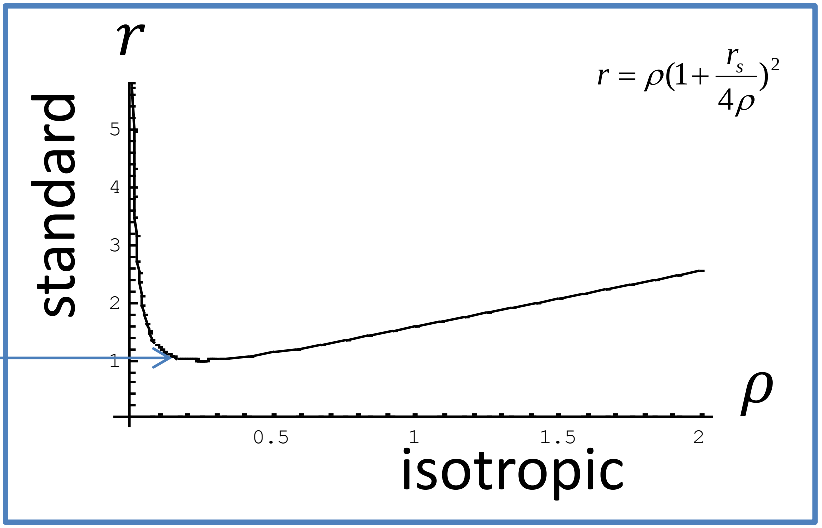
Change of coordinate-system

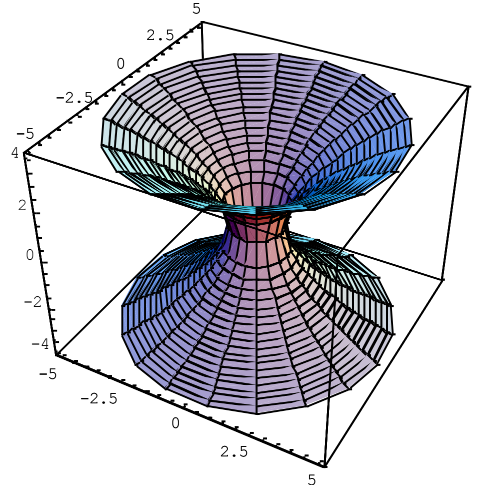
…to support conform transformation

Standard **Isotropic**

$$ds^2 = A(r)dt^2 + B(r)dr^2 + r^2(d\theta^2 + \sin^2\theta d\varphi^2) \Rightarrow ds^2 = A'(\rho)dt^2 + B'(\rho)(d\rho^2 + \rho^2 d\theta^2 + \rho^2 \sin^2\theta d\varphi^2)$$

Event horizon



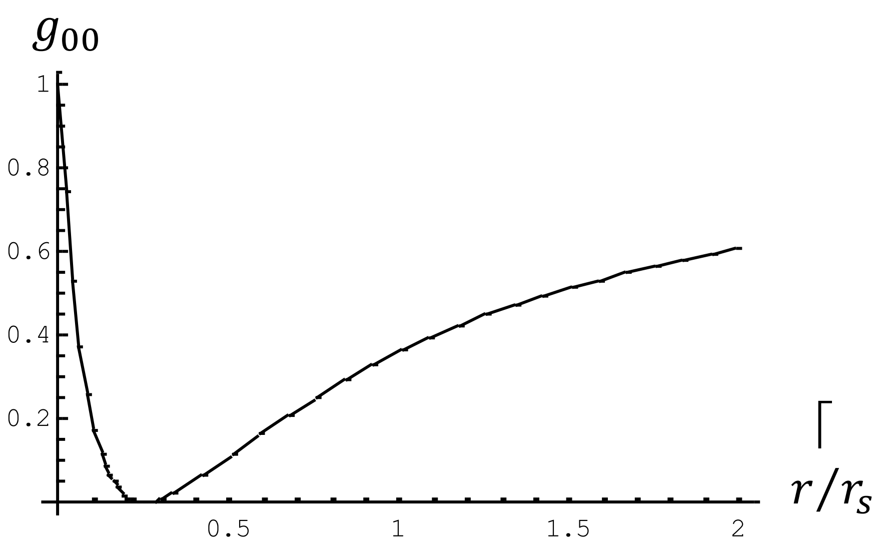


Einstein-Rosen bridge

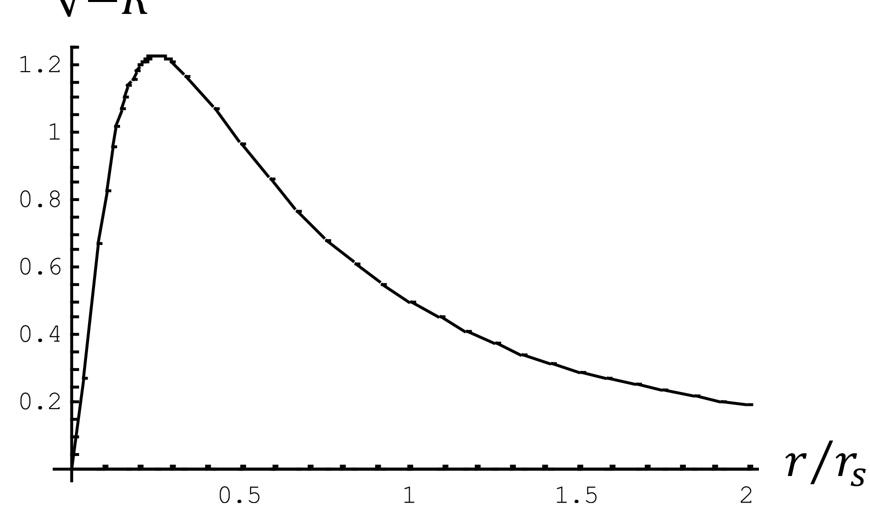
$$ds^2 = \left(\frac{1-\frac{r_g}{4\rho}}{1+\frac{r_g}{4\rho}}\right)^2 dt^2 + \left(1+\frac{r_g}{4\rho}\right)^4 (d\rho^2 + \rho^2 d\theta^2 + \rho^2 \sin^2\theta d\varphi^2)$$

Relation of scalar field and metric

g_{00} in isotropic coordinates



Ricci scalar in isotropic coords (after synchronization)



$$g_{00} = 1 - \sqrt[4]{\frac{2}{3}(-R)}$$

$$m(x) = m_0 \sqrt{g_{00}}$$

$$m(x) = m_0 \sqrt{1 - \sqrt[4]{\frac{2}{3}(-R(x))}}$$

Rest mass depends on Ricci scalar

How can curvature effect Rest-Mass?

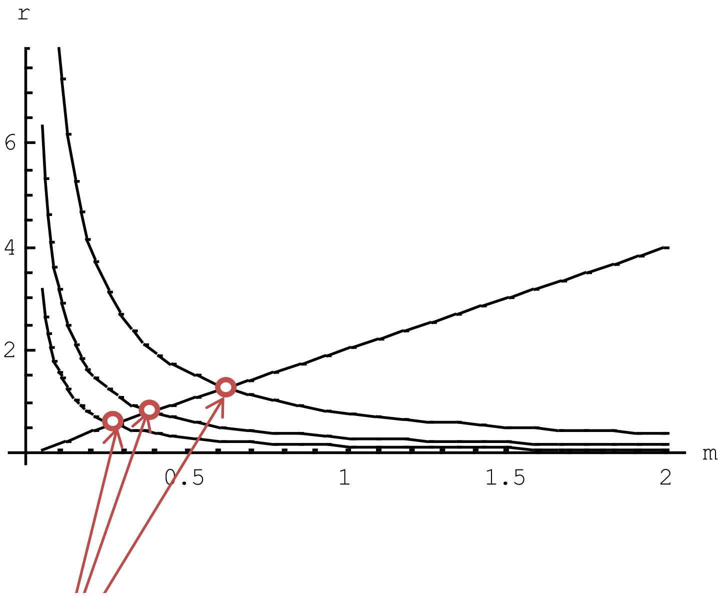
Theoretic quantum particle

Schwarzschild-radius

$$r_s = \frac{2Gm}{c^2}$$

Quantum-radius

$$r_Q = \frac{k}{2\pi}\lambda_{Compton} = \frac{hk}{2\pi mc}$$



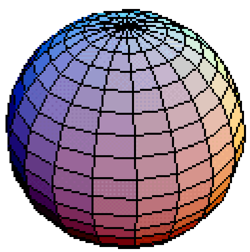
Rest-mass and size depends on ‚k' quantum number

Different posible particles

How can background-curvature effect Rest-Mass?

Theoretic quantum particle

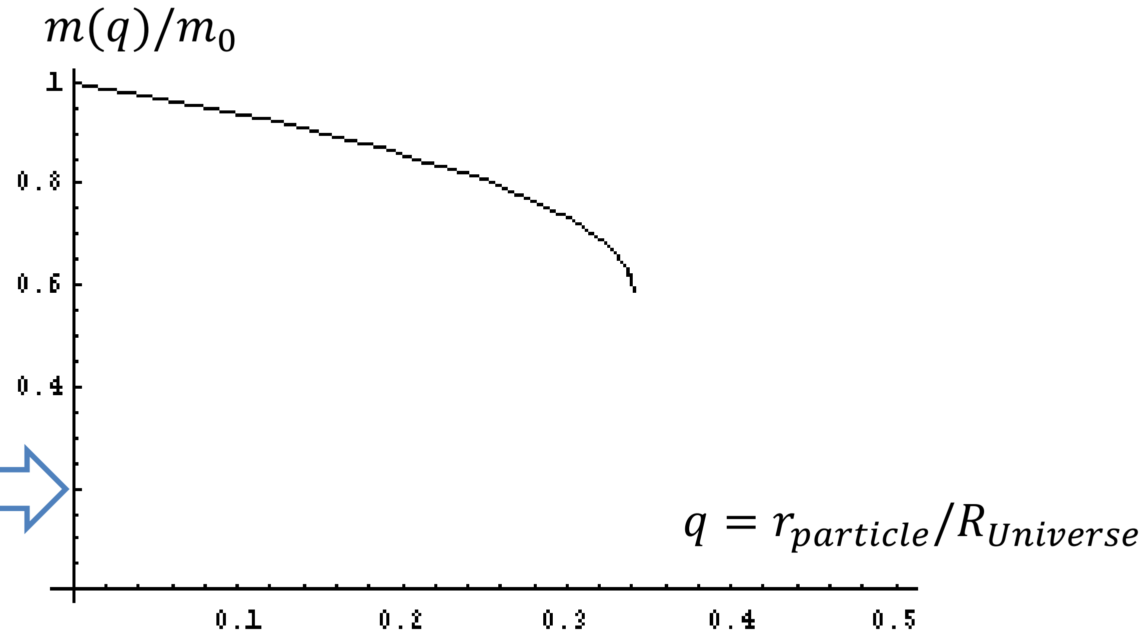
Background curvature



$$q = r_{particle}/R_{Universe}$$

Modified Schwarzschild-radius

$$r_s(q) = \frac{1 - \sqrt{1 - \frac{16Gmq}{c^2}}}{4q}$$



$$m = m_0 s(r_p, R)$$

r_p is different for p^+ and e^-

Is EEP hold for e^- ?

Conclusion

- General force can change restmass
- EEP does not necessarily hold
- Gravity is not an inertial force
- Scalar-tensor gravity is a more suitable approach (also fits GPS)
- …

There is a lot to do

References

1. Gy. Szondy, *A Pure Geometric Approach to Derive Quantum Gravity from General Relativity*; viXra:1312.0222 (2013)
2. Gy. David, Lecture 2011.04.27, https://www.youtube.com
3. C. Brans and R. H. Dicke, *Mach's Principle and a Relativistic Theory of Gravitation*, Phys. Rev. D 124 925-935 1961
4. Gy. Szondy, Linear Relativity as a Result of Unit Transformation, arXiv:physics/0109038 (2001)

Thank you for your attention!

Questions?