internal relativity: a progress report

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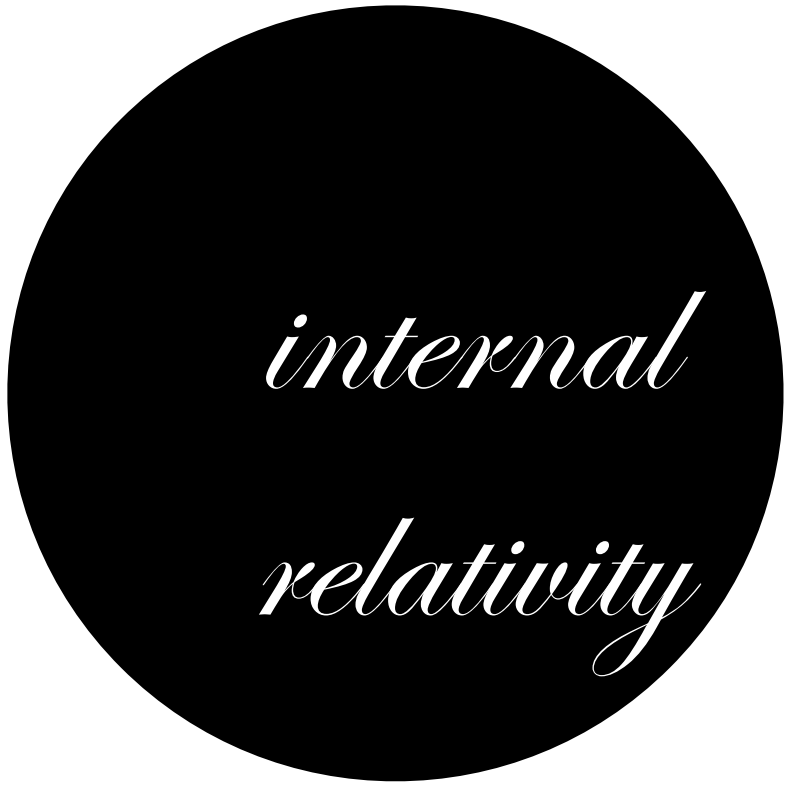
overview

- internal relativity
- the setup
- gravity
- discussion

one



internal relativity

lorentz, bell, ... : maxwell equations give minkowski space

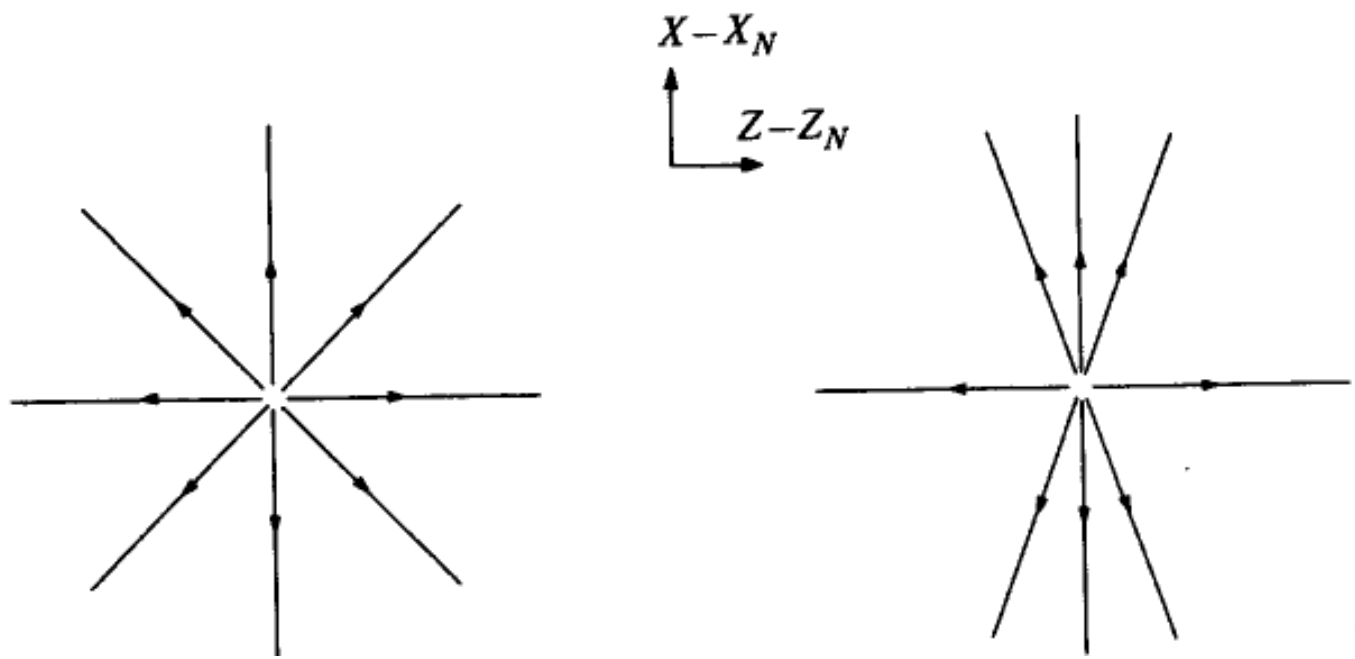
$$E_z = Zez'(x^2 + y^2 + z'^2)^{-3/2}$$

$$E_x = Zex(x^2 + y^2 + z'^2)^{-3/2}\left(1 - \frac{v^2}{c^2}\right)^{-1/2} \qquad z' = (z - z_N(t))\left(1 - \frac{v2}{c^2}\right)^{-1/2}$$

$$E_y = Zey(x^2 + y^2 + z'^2)^{-3/2}\left(1 - \frac{v^2}{c^2}\right)^{-1/2}$$

$$B_x = -\frac{v}{c}E_y$$

$$B_y = \frac{v}{c}E_x$$



from bell (1987)

internal relativity

how does the system look from the inside?

a conjecture

matter has a dual role:

define the geometry ⟷ matter

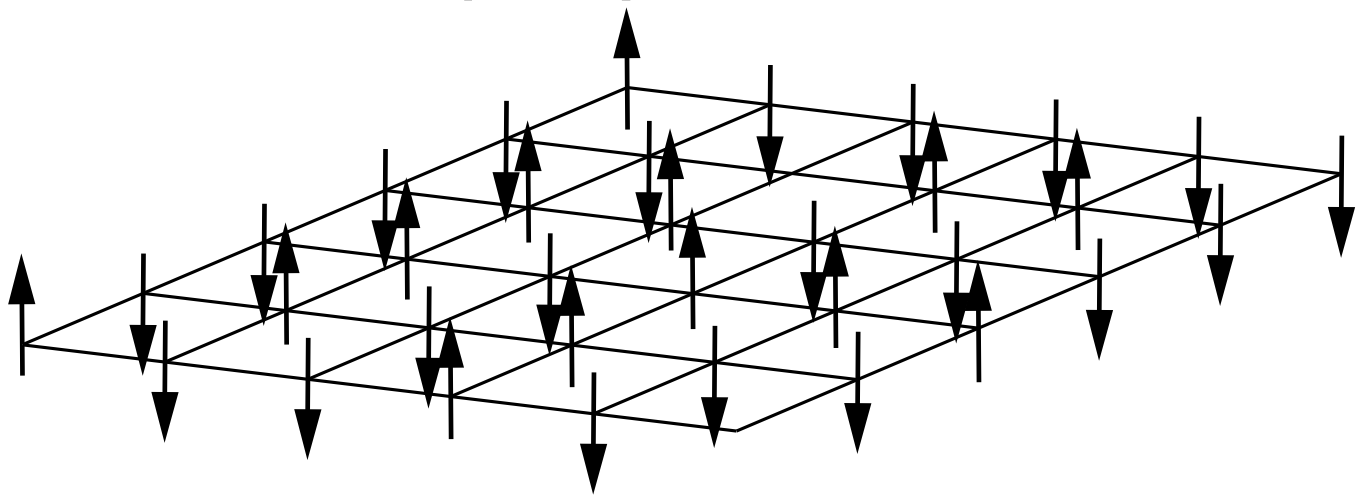
internal relativity → equivalence principle, Einstein equations

$$\mathbb{R}_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = 8\pi G T_{\mu\nu}$$

two

setup

three dimensional spin systems on a lattice



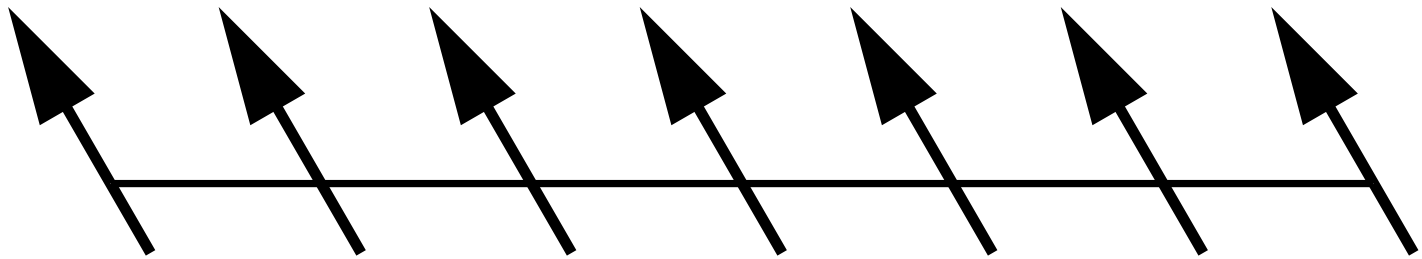
examples:

(i) ising model (+ modifications)

(ii) stringnet condensates
(a la wen, quantum graphity)

0th level

ground state



characterized by

$$\theta_0$$

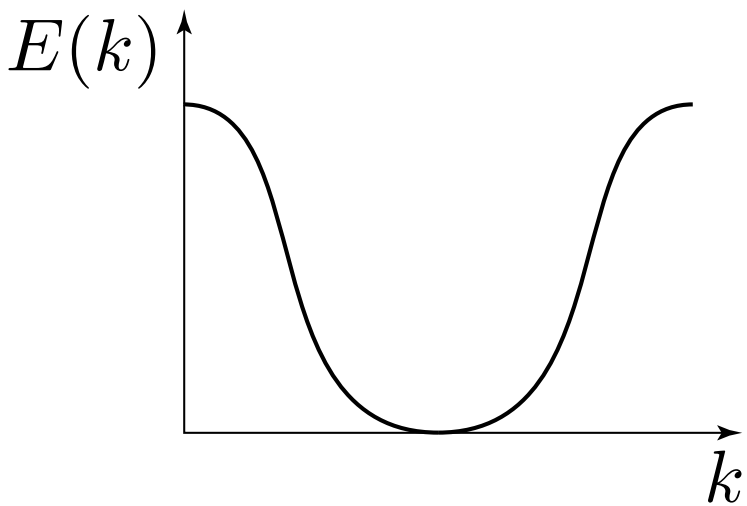
the vacuum

1st level

excitations

$$|k\rangle = \sum_n \exp\left(2\pi i \frac{nk}{N}\right) |0 \ \ldots 0\ 1\ 0\ \ldots\ 0\rangle$$

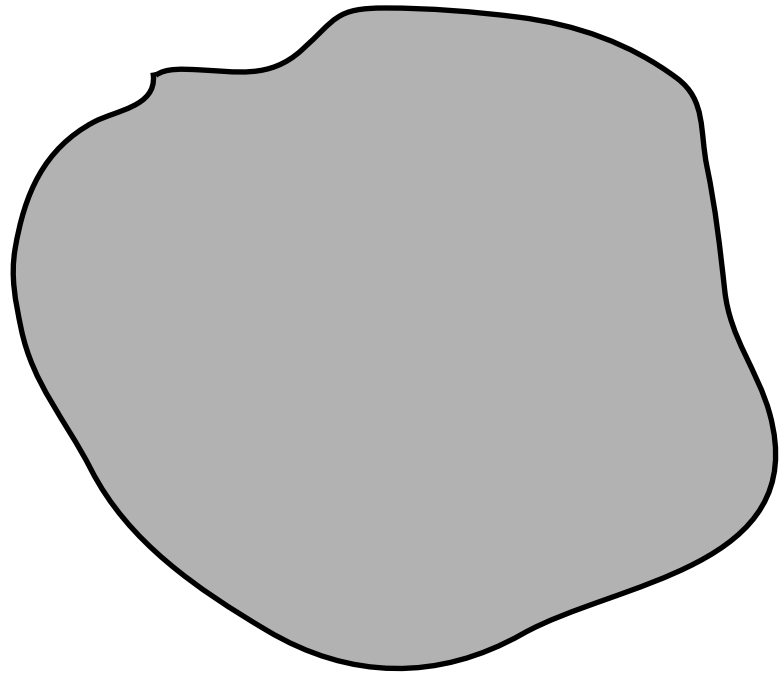
excitation implies
$\theta \neq \theta_0$



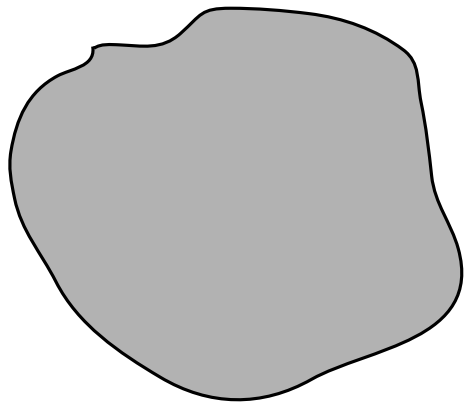
"elementary particles"

- 2nd level

bound state of excitations



overview



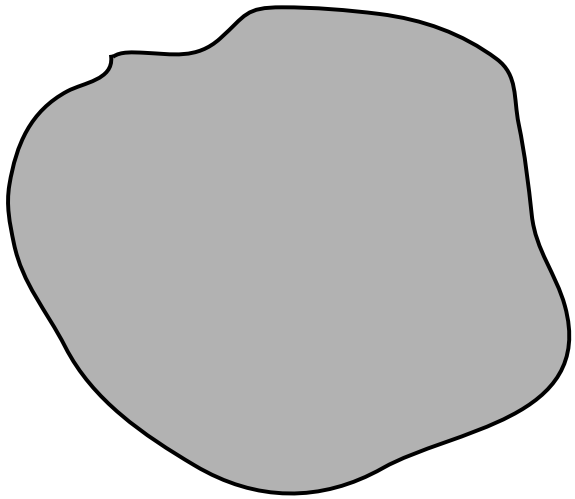
bound states level 2

$|k\rangle$ excitations level 1

θ_0 ground state level 0

three

- the argument

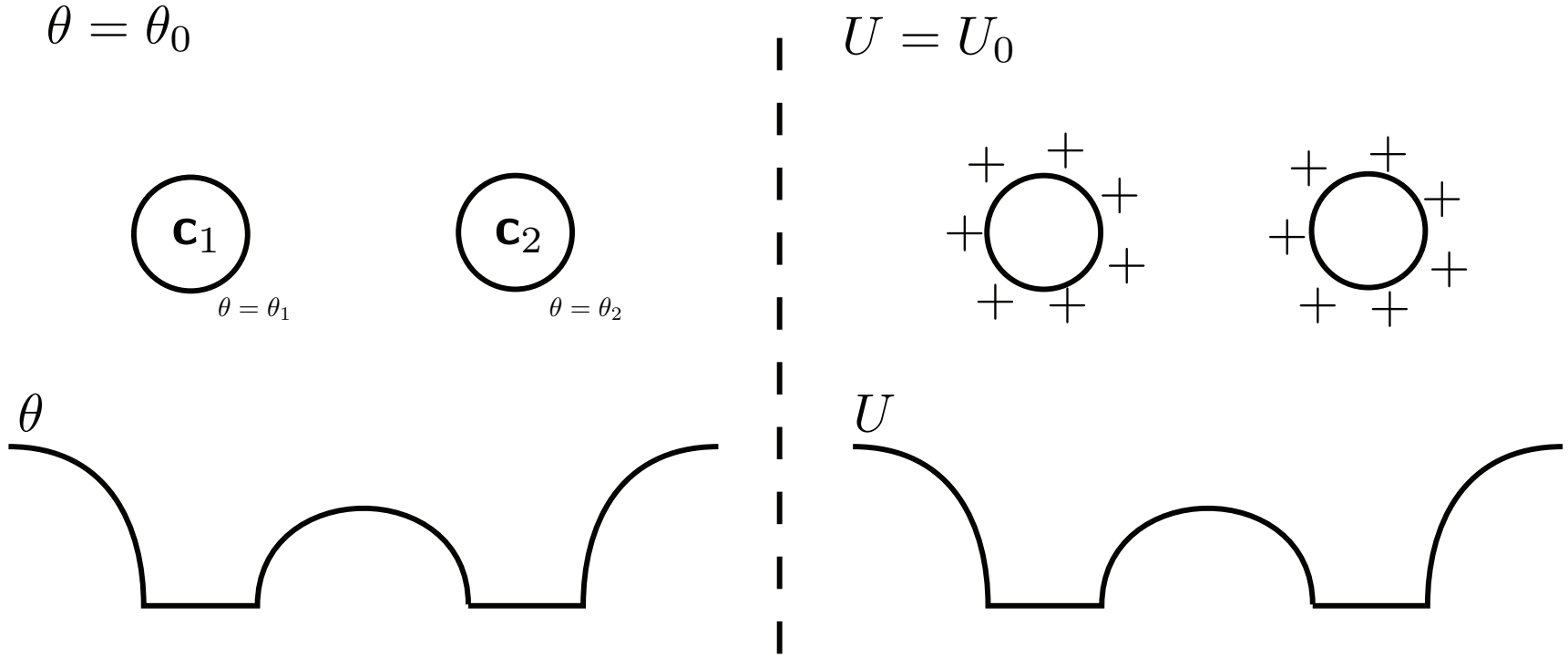


$\theta \neq \theta_0$

θ_0

newton's law

$$E \simeq \int d^3x \, (\nabla\theta)^2 \qquad \frac{\delta E}{\delta\theta} = \Delta\theta = 0$$



$$F \simeq \frac{m_1 m_2}{r^2} \qquad m_i \simeq \int_{\partial C_i} (\nabla\theta) d\sigma$$

■ internal relativity

how does the system look like from the inside?

- constant speed of light

  → lorentzian metric

- newtonian gravity in low speed limit

  → metric is curved

five

- two choices

■ matter on geometry

- spacetime fundamental
- einstein's equations fundamental
- L^2 (geometry)
- LQG, spin foams

- two choices

- matter & geometry emergent
  - spacetime emergent
  - matter emergent
  - derive einstein's equations
  - derive the equivalence principle
  - internal relativity

emergence

- because matter and geometry emerge together they are free to influence each other.
- gravity requires two levels of emergence.
- it is important to solve a model (i.e. to look at the emergent physics) see also D. Oriti

"problem of time" trap

problem of time: what to do with

$$H|\psi\rangle = 0 \ ?$$

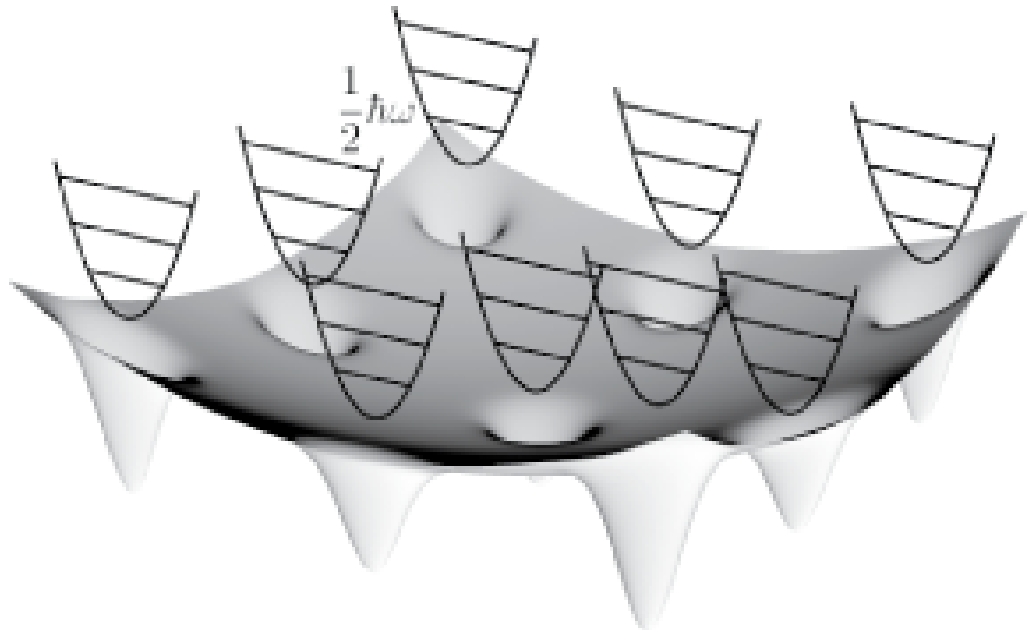
internal relativity:

- problem arises because of unphysical idealization
- matter and geometry arise together
- matter part is dropped

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = 8\pi G \cancel{T_{\mu\nu}}$$

- it is ok to have an external time

- cosmological constant problem



no matter on geometry

$\Longrightarrow$

no cosmological constant problem

od, hep-th/0409048

ether?

not your grandfathers ether

old ether:

- carried electromagnetic waves
- matter is an additional ingredient

new ether:

- carries all matter

the lorentz group

current understanding: lorentz group fundamental

e.g.: fundamental particles = irreducible representations of the lorentz group

internal relativity: particles define the symmetry

the lorentz group is not part of the setup.

quantum mechanics

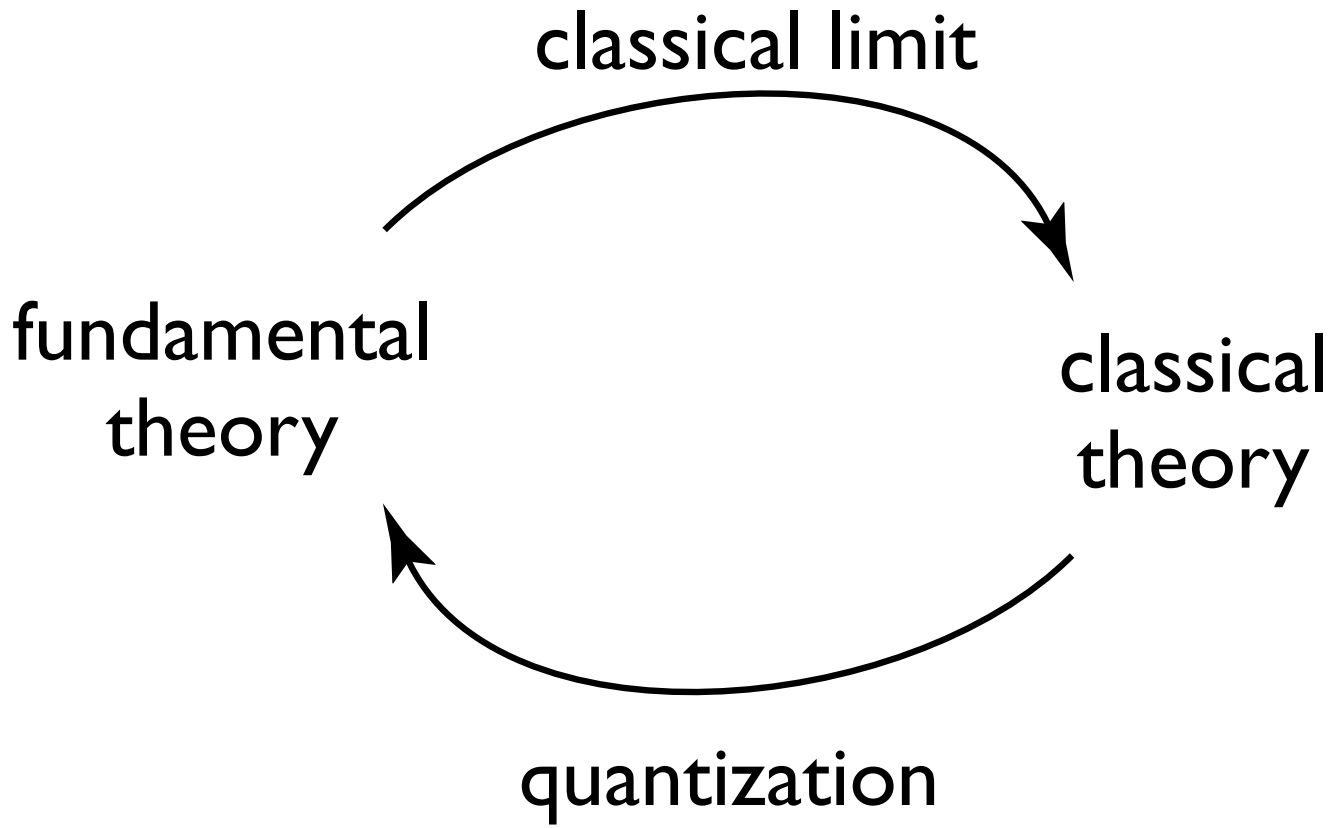
classical objects  bound states

have shown: **classicality** implies **curvature**

maxwell's equations imply minkowski space

quantum mechanics implies general relativity

■ don’t quantize



this circle does not close here.

start with a quantum theory

observable effects

- cosmology:
  how does the emergence of spacetime look like?
- fundamental constants:
  there should be relations between the fundamental constants.

G=1?

no units: G should naturally be 1

in fact: G is naturally small

$$\frac{F_{el}}{F_g} \leq N^{\alpha} \qquad\qquad \alpha = \mathcal{O}(1)$$

$N \gg 1$: number of constituents between the levels

internal relativity sheds light on the hierarchy problem