Vortrag im Working-Seminar 13.11.20

A mechanism for baryogenesis in CFS

How this project developed:

2015-2016 idea of dynamical gravitational coupling
unpublished paper on arXiv
I will outline this soon and explain why it is unpublished

2016-2017 with M. Kraus: regularized Hadamard expansion;
more systematic treatment of mathematical core of DGC idea

spring 2017 Claudio P. asked about baryogenesis
Noticed that related to regularized Hadamard expansion
first proposal for mechanism unpublished

Dec 2019 proposal 42: suggestion for cosmological model based on mechanism of baryogenesis

in the meantime Max' thesis, intended to making the mechanism for baryogenesis precise

This work has not yet been completed. But his preliminary results and joint discussions have led to a proposal for baryogenesis which is simple, mathematically clean and involves no free parameters.

Although it may not be the final answer, it seems a good starting point for further discussions and investigations.

1) What is baryogenesis?

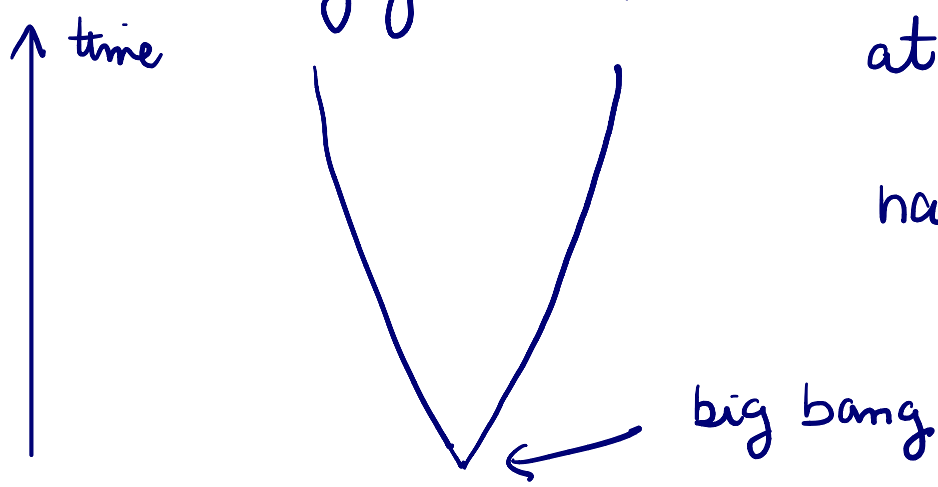
Creation of matter without antimatter

at big bang: symmetric configuration, no particles or antiparticles

now: abundance of matter

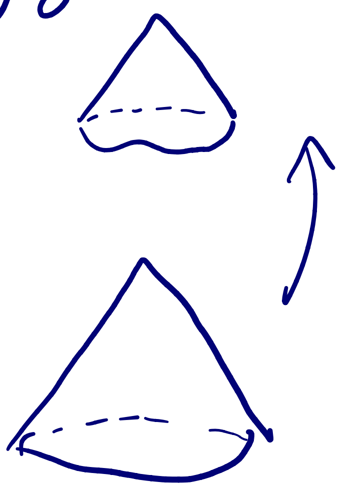
How does this come about?

Cannot be explained from present physics



In CFS theory, the Dirac sea is considered real.
More precisely, regularized Dirac sea as described by the fermionic projector

Thus changes of the regularization may give rise to baryogenesis.



time evolution

If the Dirac sea now involves less particles than in the early universe, then the particles which are no longer needed in the sea could form matter.

Clearly, in order to be consistent with observations, the effect must be tiny.

2) The Dirac dynamics of the regularization

Begin with simplest regularization : $i\varepsilon$-regularization

$\hat{P}(k) = (\not{k}+m)\,\delta(k^2-m^2)\,\Theta(-k^0)$ "completely filled Dirac sea"

$\hat{P}^\varepsilon(k) = (\not{k}+m)\,\delta(k^2-m^2)\,\Theta(-k^0)\; e^{\varepsilon k^0}$ ← convergence-generating factor

In position space

$$P(x,y) = \int \hat{P}^\varepsilon(k)\, e^{ik\xi}, \qquad \xi := y-x$$

$$e^{\varepsilon k^0}\, e^{ik^0\xi^0} = e^{ik^0(\xi^0 - i\varepsilon)}$$

$\xi^0 \to \xi^0 - i\varepsilon$; reason for name "$i\varepsilon$-regularization"

Note: - Dirac equation is preserved

$\Gamma(x,y) := \xi^2$ geodesic distance squared

$$\to \Gamma_\varepsilon = (\xi^0 - i\varepsilon)^2 - \vec{\xi}^{\,2}$$

$$= \Gamma - 2i\varepsilon\,\xi^0 + \mathcal{O}(\varepsilon^2)$$

error term

describes the regularization

As a consequence, the poles of $P(x,y)$ on the light cone disappear; $P^\varepsilon(x,y)$ is smooth.

In a gravitational field, the situation is more interesting.

$$(\mathcal{D}-m)\, P^{\varepsilon}(x,y)$$

$$P^{\varepsilon}(x,y) = (\mathcal{D}+m)\, T^{\varepsilon}(x,y)$$

[Zeige Formeln aus [reghadamard], (1.10)-(1.13)

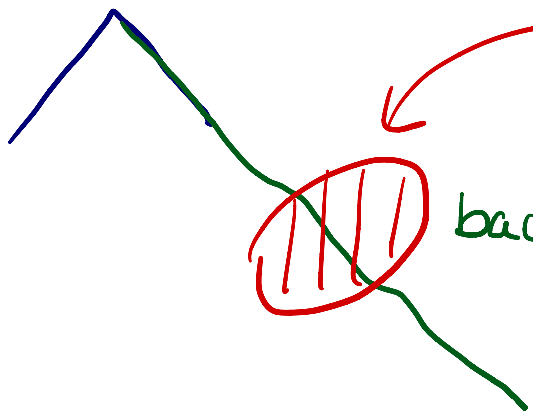
note: linear function ξ^0 now corresponds to $f(x,y)$ and f satisfies a transport eqn along light cone, (2.6)

$$\langle \nabla \Gamma, \nabla f \rangle = 2f,$$

which means that

$$f(x,y) = \tau(y) - \tau(x)$$

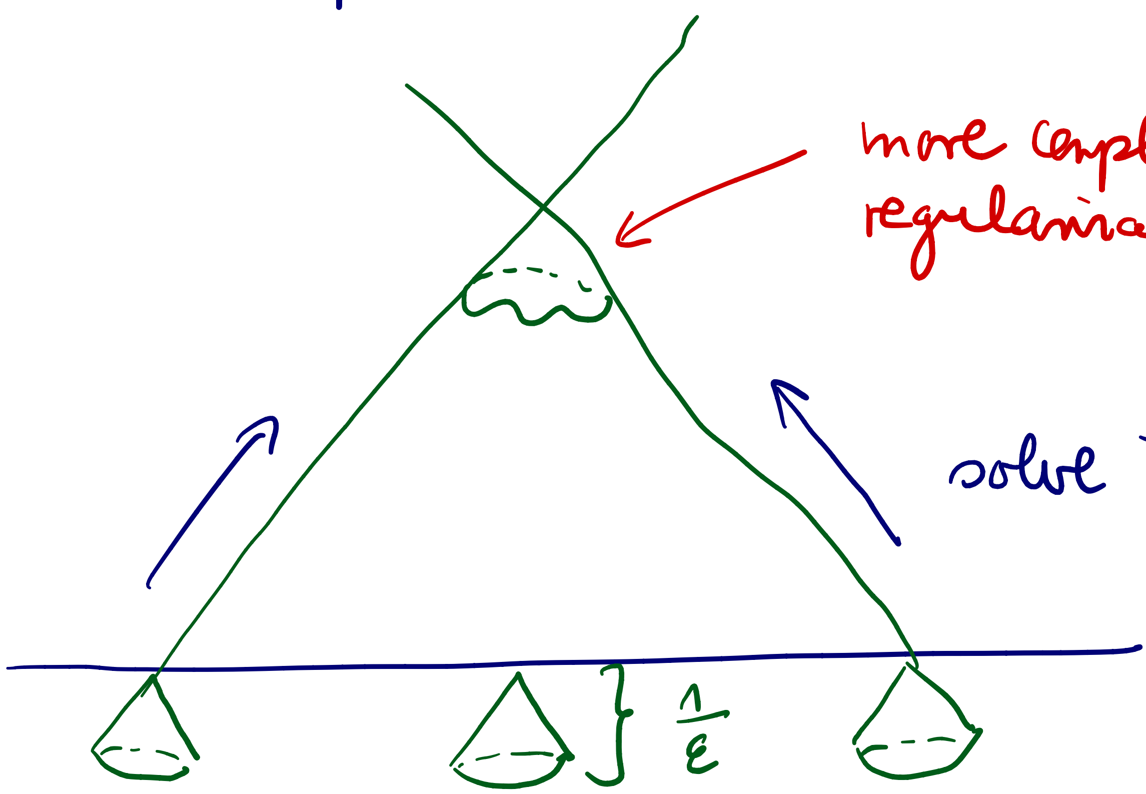
where τ is an affine parameter along null geodesic!



gravitational field can change the affine parameter!

backward null geodesic

Concrete example:



more complicated regularization

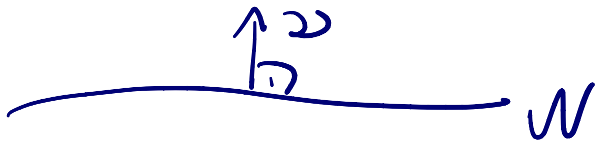
solve transport eqns

initial time

$i\varepsilon$-regularization

- How does particle number change?

  Not at all:



$$f = \int_N \mathrm{Tr}\left(\not\nu\, P(x,x)\right) d\mu_N$$

  is independent of choice of N due to current conservation

- But gravitational coupling constant changes

  $\kappa \sim \varepsilon^2$ (details would be separate talk)

- Is the resulting $P^\varepsilon(x,y)$ a minimizer of the causal action principle?

  No! For example,

  $\mathrm{Tr}\left(P^\varepsilon(x,x)\right)$ not constant,

  in contradiction to volume constraint

3) How does the causal action principle change the regularization?

This is precisely the subject of Max' thesis.

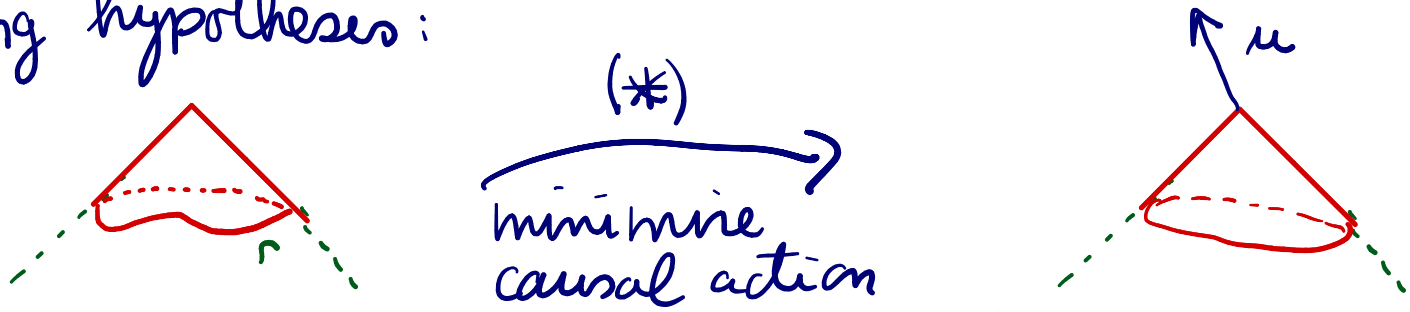
- work "locally" in Gaussian coordinates, gives problem in Minkowski space
- decomposition into angular modes
- computation of $\delta^2 S$, ..., ...

Not yet finished

A general conclusion:

- regularization is rather "rigid", except for Lorentz transformations

Therefore, let us make the working hypothesis:



$i\varepsilon$-regularization in boosted reference frame

Thus locally:

$$\hat{P}^{\varepsilon}(k) = (\not{k}+m)\,\delta(k^2-m^2)\,\Theta(-k^0)\,e^{\varepsilon k\cdot u}$$

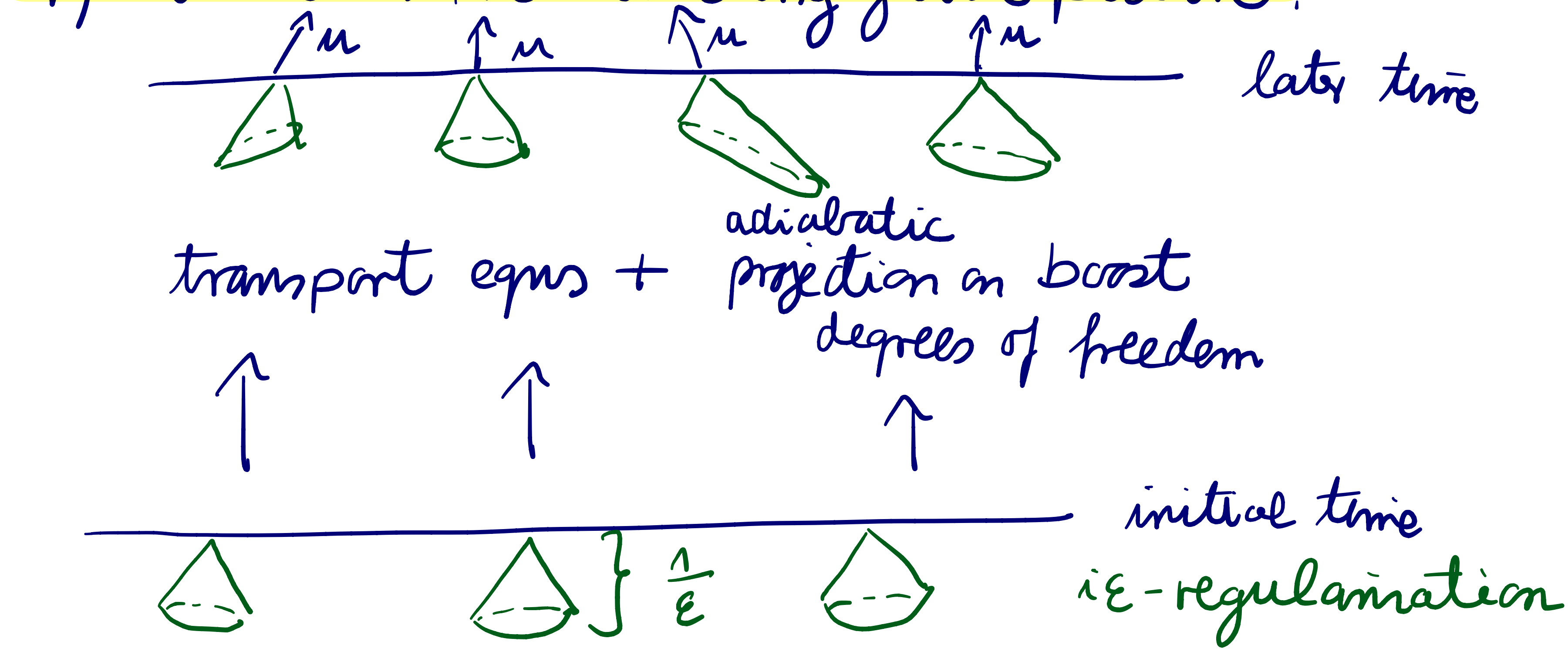
where u is a future-directed timelike unit vector.

<u>Benefits</u>: - simple, no free parameters

- trace constraint satisfied, because $\mathrm{Tr}(P^{\varepsilon}(x,x)) = \text{const}$ (Lorentz scalar)
- also $\int \mathcal{L}(x,y)\,d\rho(y)$ is constant

The above mapping (*) can be described more concretely by adiabatic projection to the $l=1$ angular momentum modes (which correspond to spatial vector fields generating the boosts).

4) What is the resulting global picture?



description with quasihomogeneous ansatz

$$P^\varepsilon(x,y) = \int \frac{d^4k}{(2\pi)^4} \, (\not{k}+m)\, \delta(k^2-m^2)\, \Theta(-k^0)\, e^{\varepsilon k u\left(\frac{x+y}{2}\right)} \times e^{-ik(x-y)}$$

(similar to Wigner function)

Note:

- Dirac equation is violated
  $\Rightarrow$ particle number no longer needs to be conserved

$\mathrm{Tr}(\not{u}\, P^\varepsilon(x,x))$ particle density of sea

$\int_W \mathrm{Tr}(\not{u}\, P^\varepsilon(x,x))\, d\mu_W$ total number of particles

The excess of particles triggers baryogenesis.

5) Discussion and outlook

→ "local rigidity of the regularization up to boosts"
is an assumption.
Needs to be verified and/or be modified

→ possible modifications:
- also mass ratios or coupling constants are changed
- the gravitational coupling constant changes
- " , "

→ all this needs to be put in the context of cosmology.
- does it fit together with "proposal 42"?
- what are consequences and predictions?

" " "