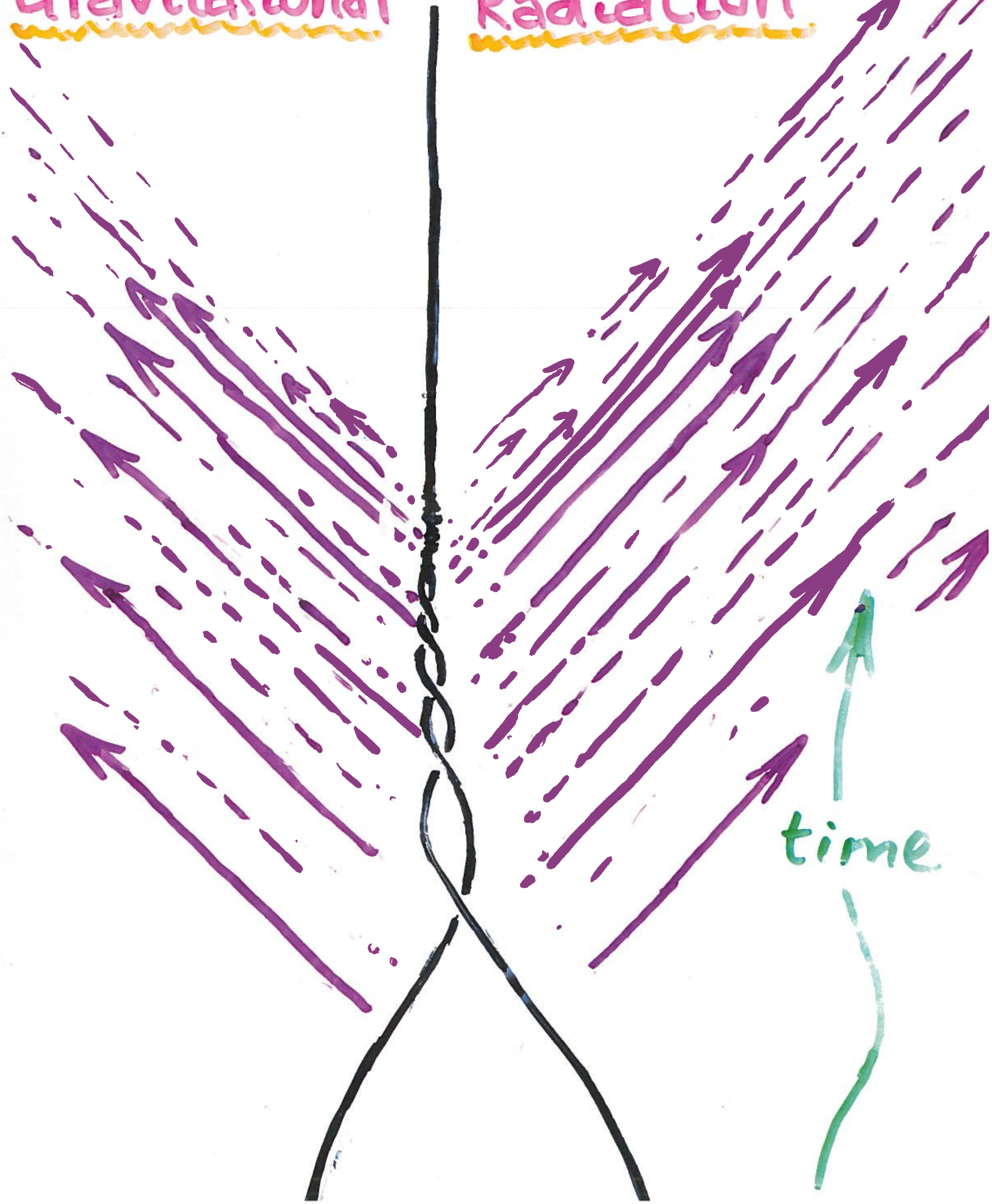
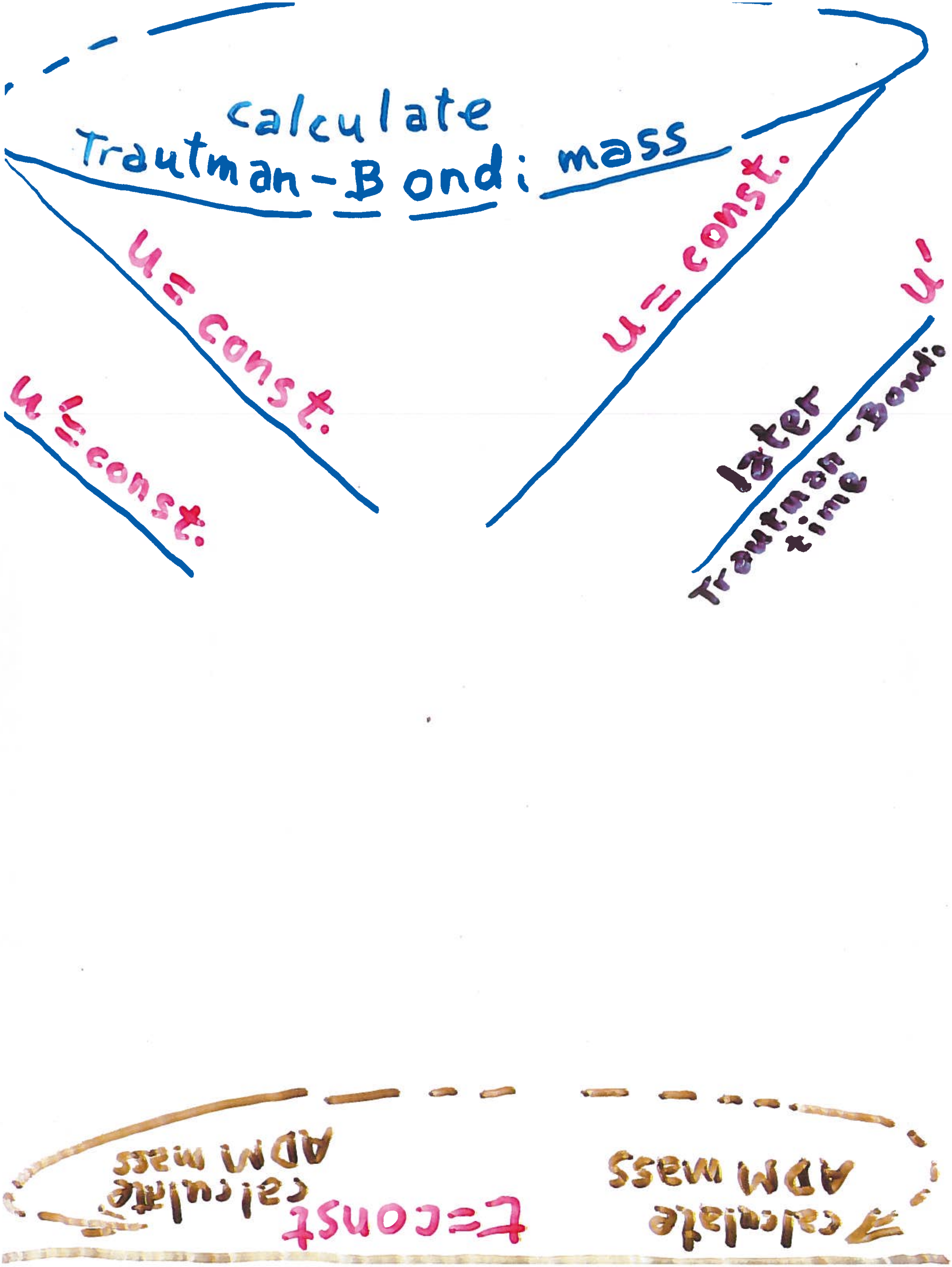
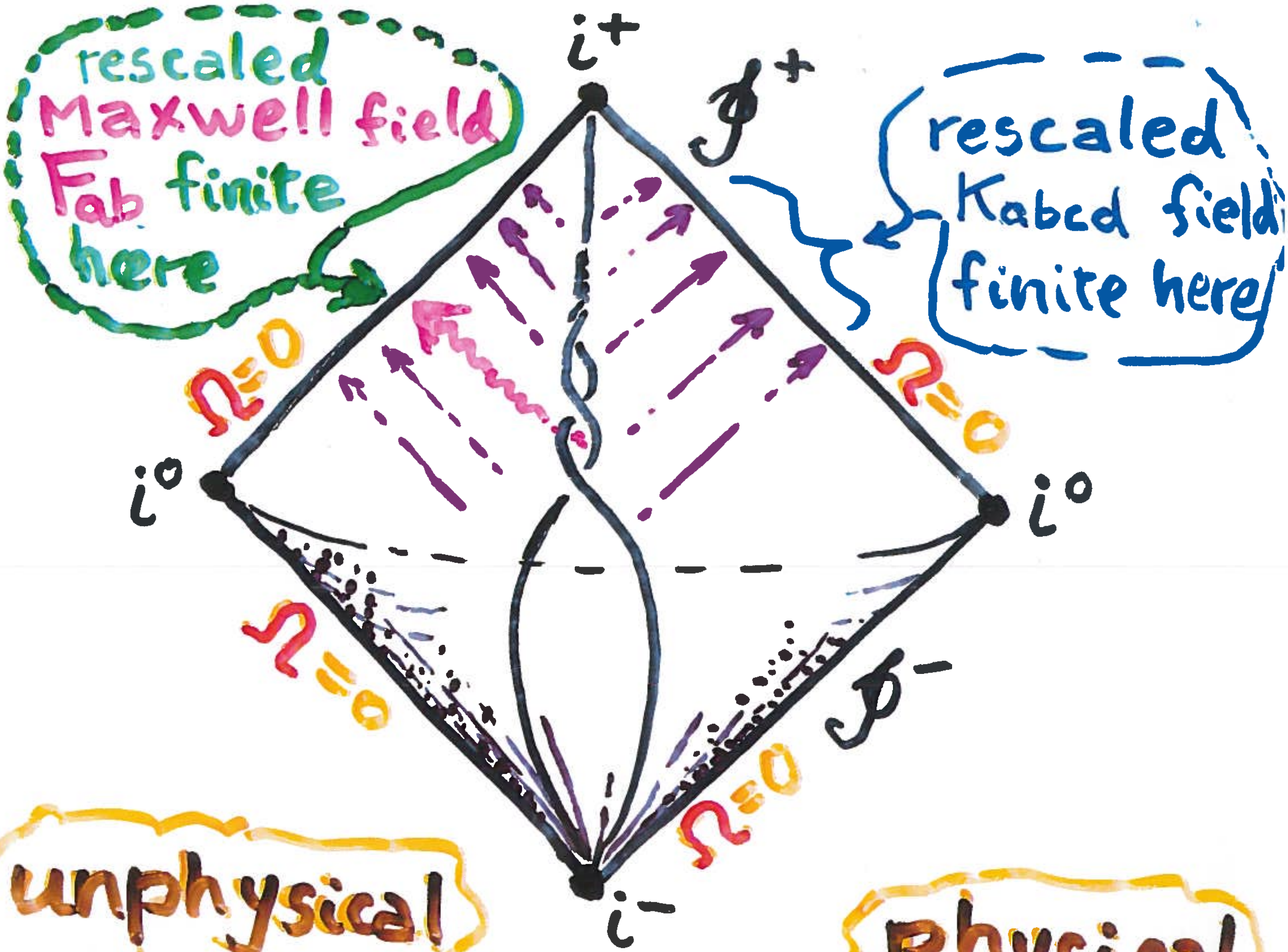
The Mass-Energy of Gravitational Radiation




calculate
Trautman-Bondi mass
u = const.
u = const.
u = const.
u'
later
Trautman-Bondi
time
t=const
calculate
ADM mass
calculate
ADM mass



unphysical metric

$$g_{ab} = \Omega^2 \tilde{g}_{ab}$$

physical metric

Maxwell tensor

$$F_{ab} = \tilde{F}_{ab}$$

Weyl conformal tensor

$$C_{abcd} = \Omega^2 \tilde{C}_{abcd}$$

gravitational tensor

$$K_{abcd} = \Omega \tilde{K}_{abcd}$$

these are equal

How/why do gravitational degrees of freedom get killed off as gravitational degrees of freedom & where do they go?

Under conformal rescaling $\hat{g}_{ab} = \Omega^2 g_{ab}$ the Weyl conformal curvature undergoes

$$\hat{C}_{abcd} = \Omega^2 C_{abcd}$$

Define $\hat{K}_{abcd} = \hat{C}_{abcd}$

but $\hat{K}_{abcd} = \Omega K_{abcd}$

since this gives a conformally invariant wave eqn.

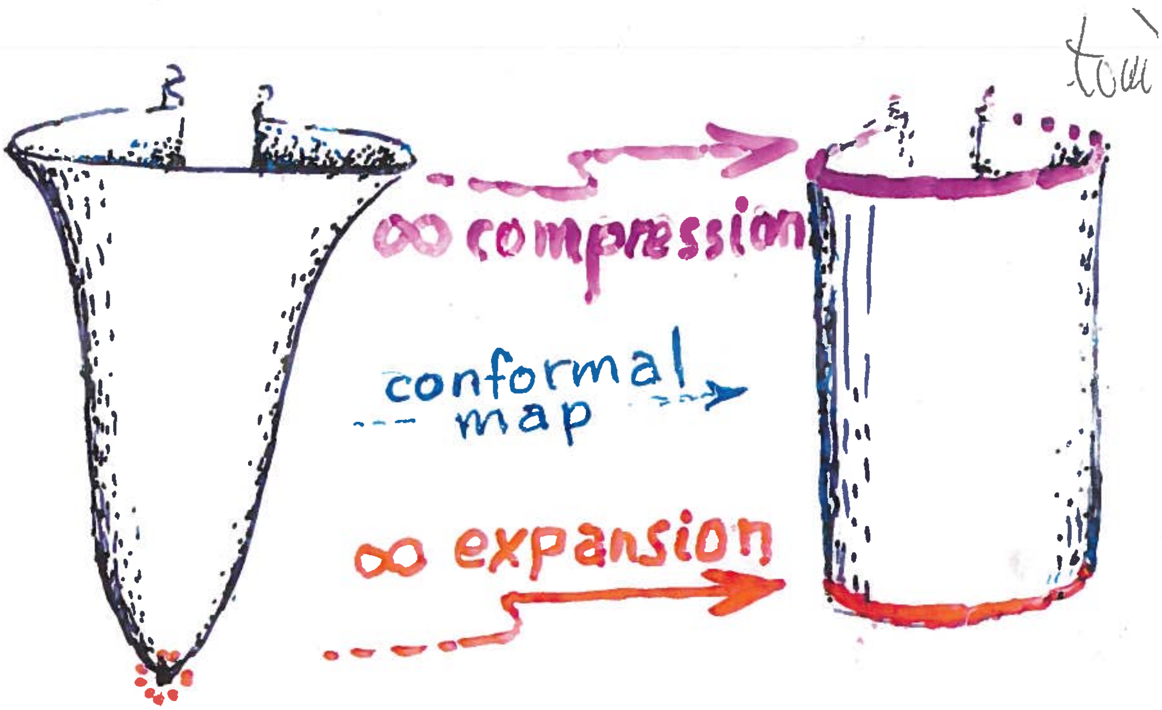
$\therefore K_{abcd}$ finite at future infinity } of previous aeon

$C_{abcd} = 0$ at future infinity }

$\therefore C_{abcd} = 0$ at Big Bang of current aeon

We find that degrees of freedom are NOT lost

but go into { electric part → DARK Matter
magnetic part → Cotton conf. curv. of crossover



toui
∞ compression
conformal map
∞ expansion

Two Mathematical Tricks

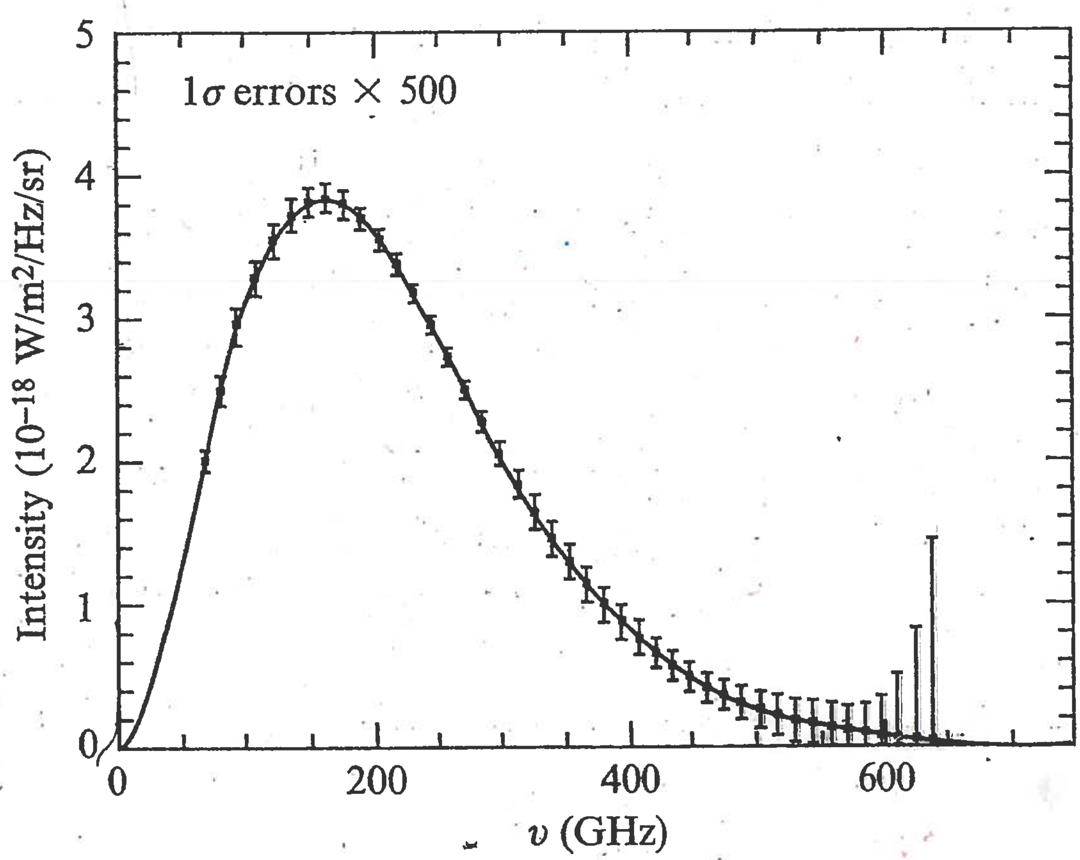
1. Squash down future infinity to get smooth future boundary

toui

2. Stretch out Big Bang singularity to get smooth initial boundary

Spectrum of the Cosmic Microwave Background

CMB



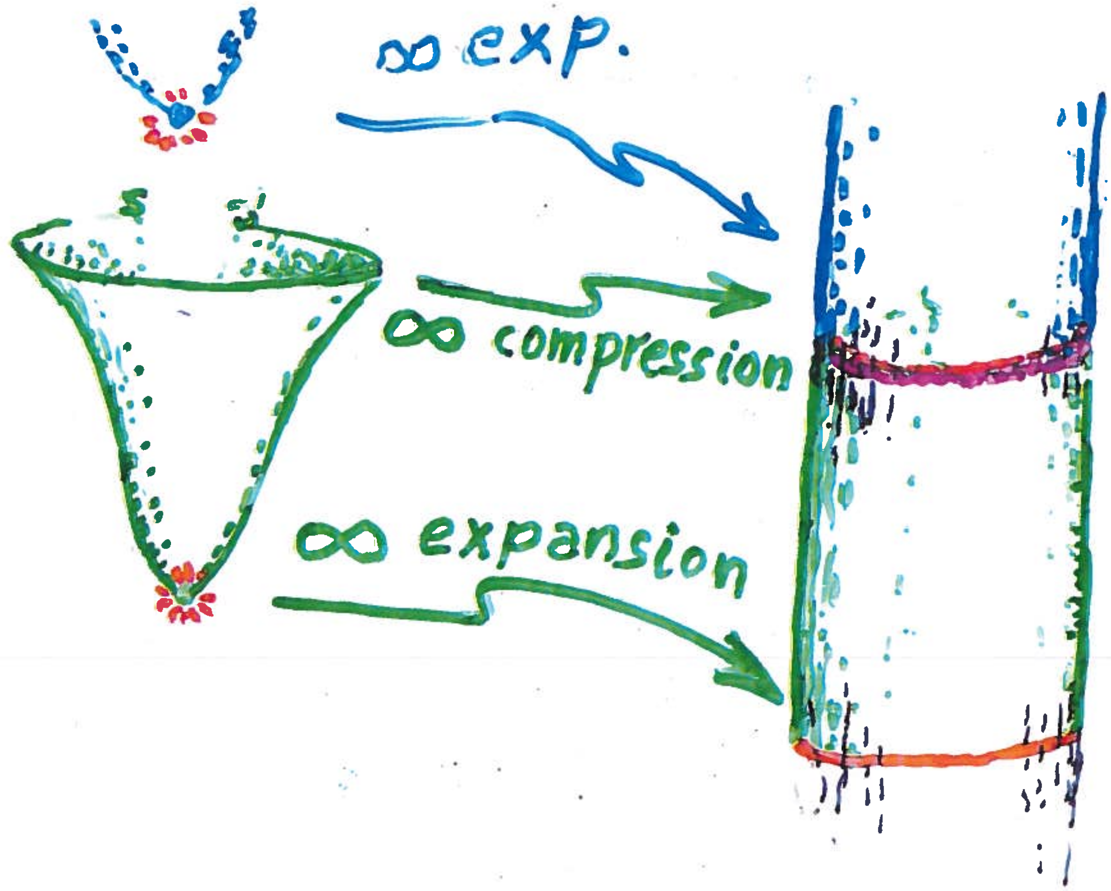
Note: error bars are exaggerated by a factor of 500.

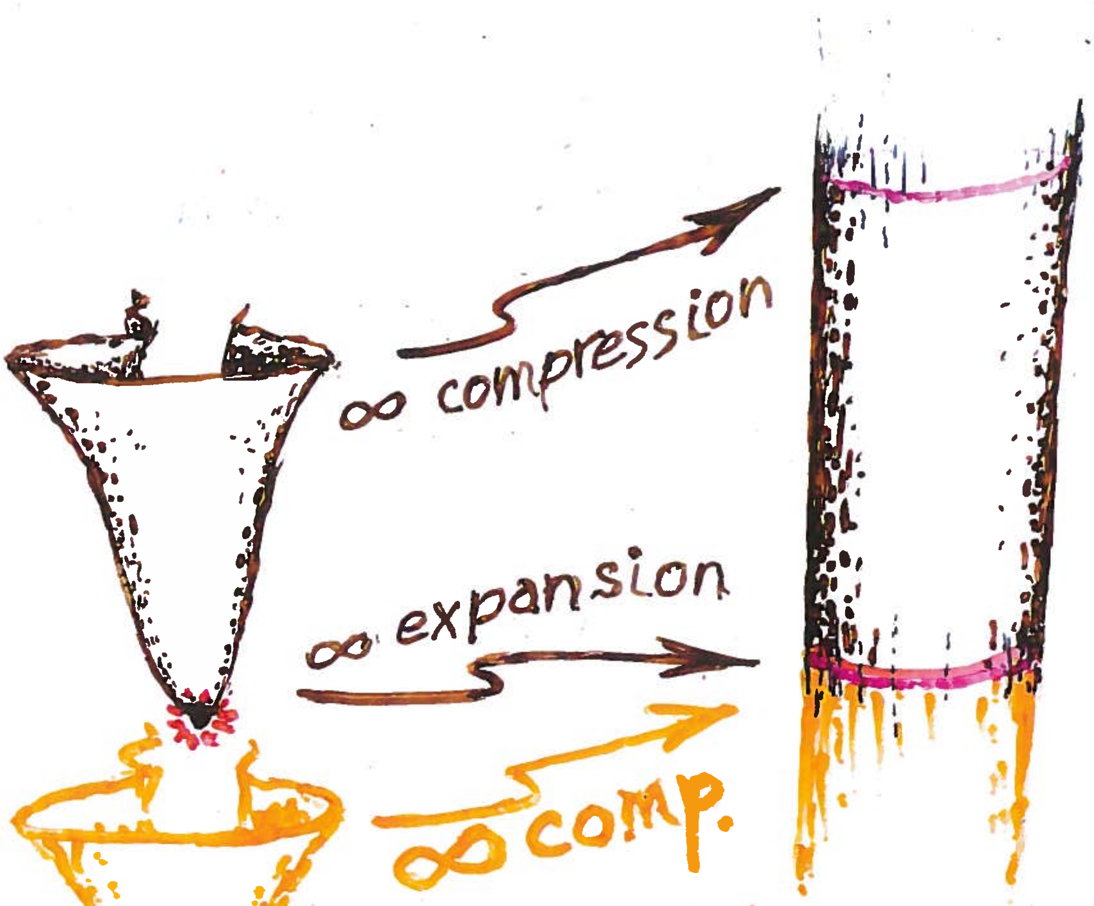
The solid curve displays the Planck black body spectrum of thermal equilibrium.

• Works under very general circumstances (H. Friedrich)
(positive Λ)

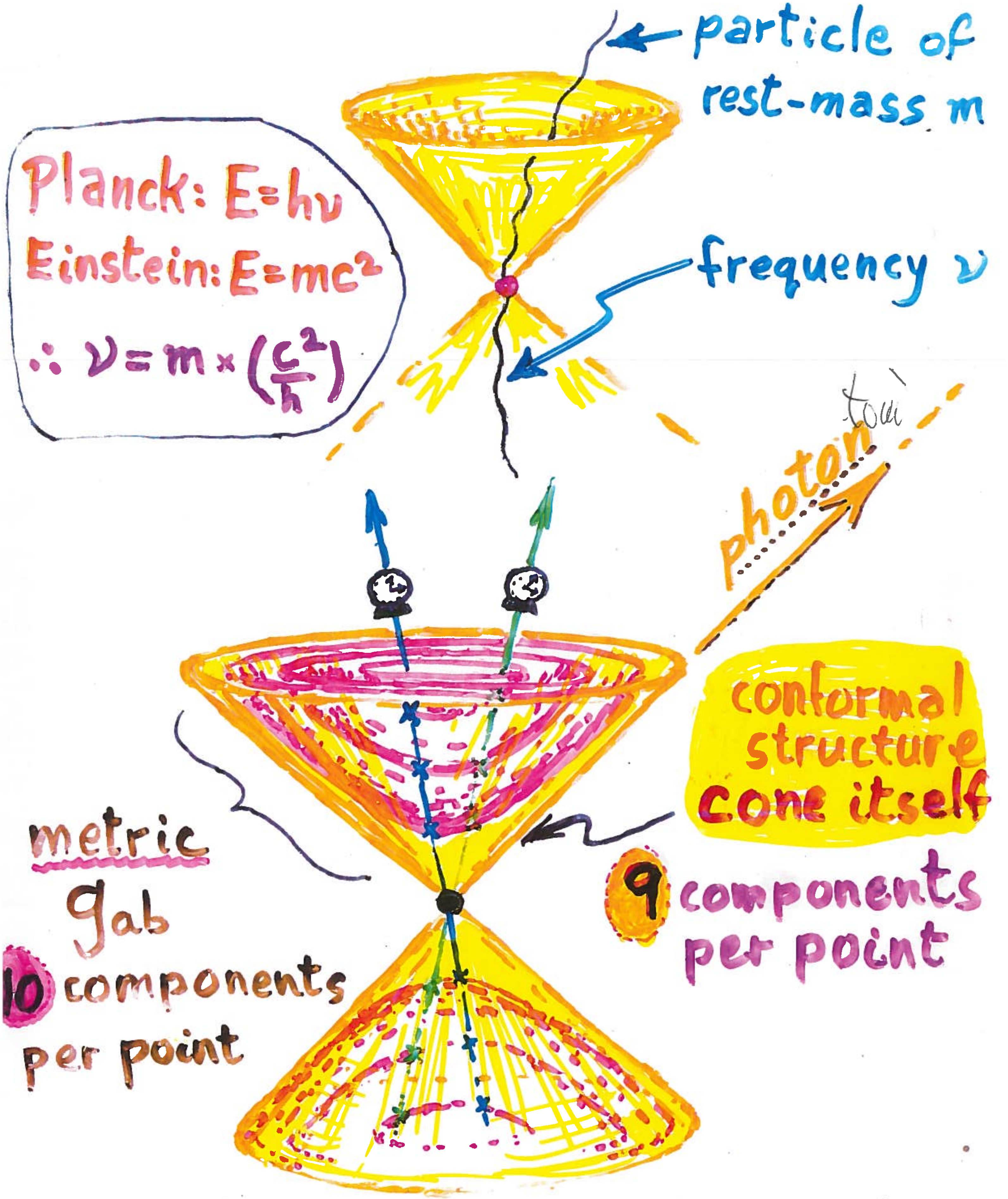
tout

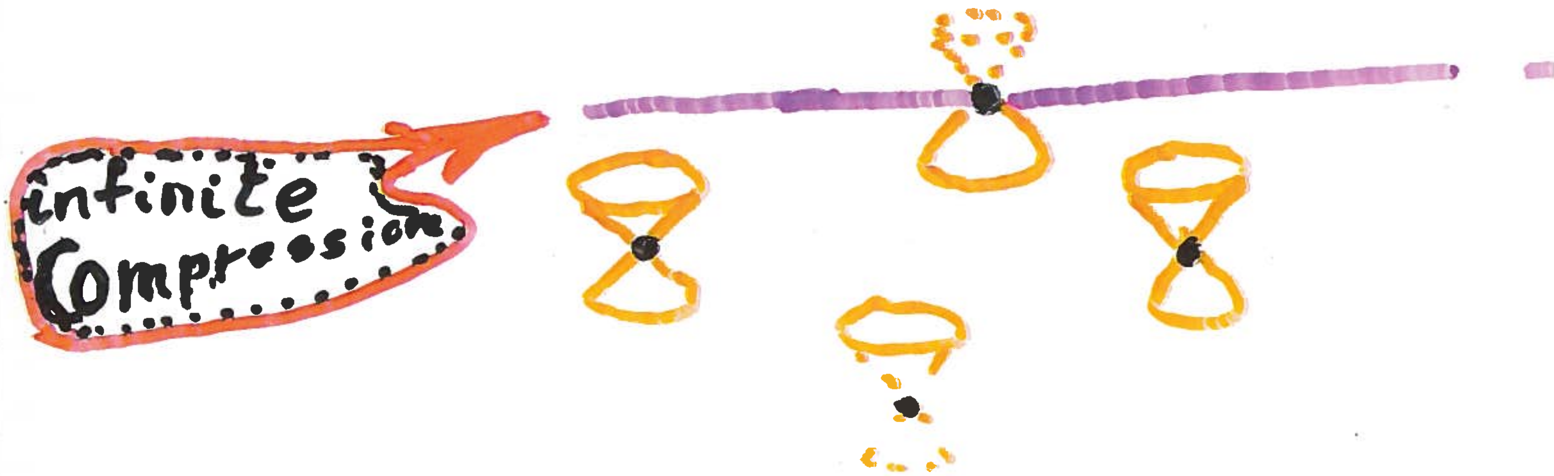
• Extremely strong restriction suppressing gravitational degrees of freedom (K.P. Tod)





Conformal cyclic cosmology (ccc)


particle of
rest-mass m
Planck: E=hν
Einstein: E=mc²
∴ ν=m×(c²/h)
frequency ν
photon
metric
gab
10 components
per point
conformal
structure
cone itself
9 components
per point

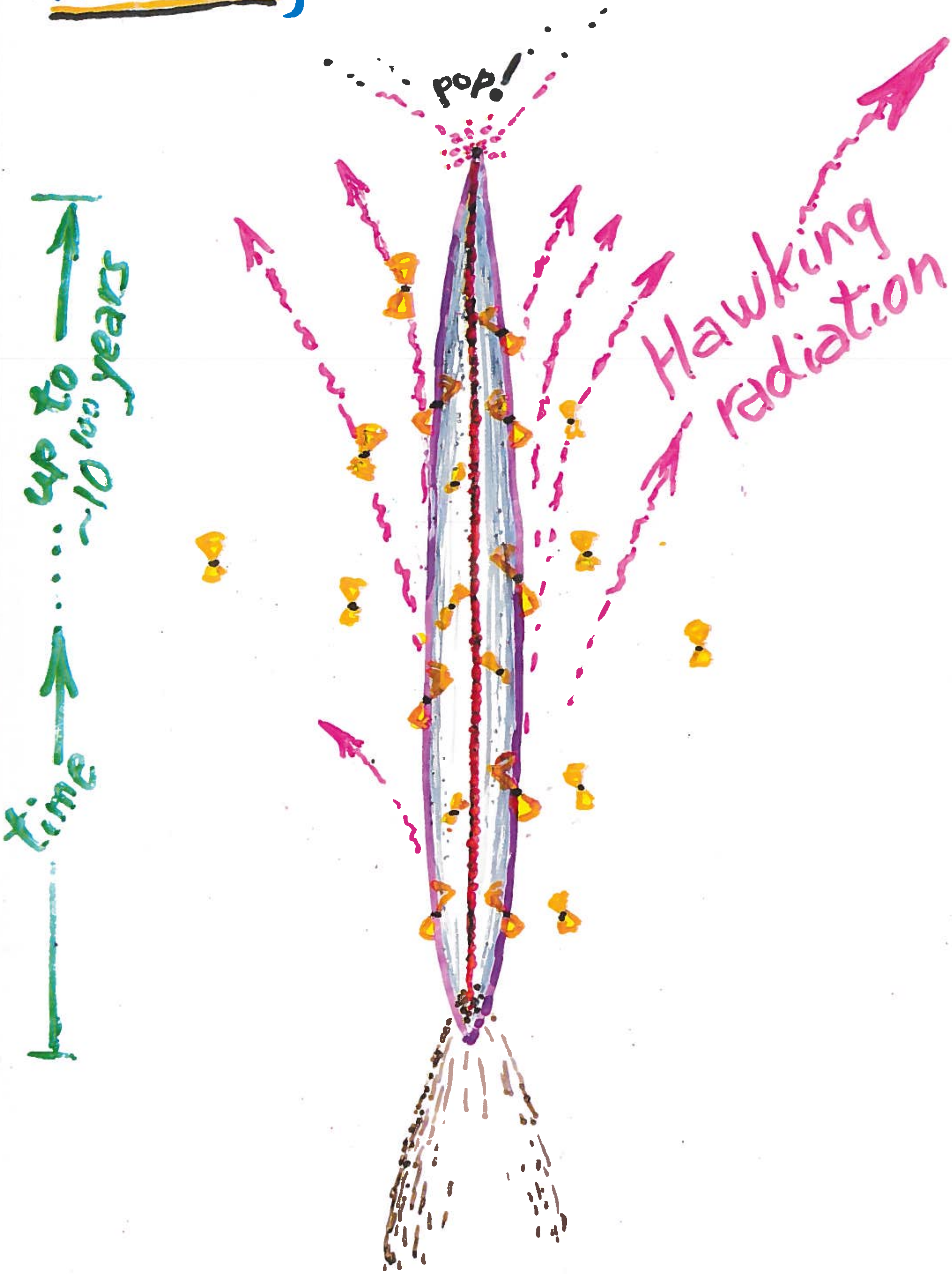


In the very remote future (after ~ 10^{100} years) almost all that will be left will be photons — massless, conformally invariant, so light-cone geometry is the relevant structure

But what about rogue electrons, positrons .... protons? .....

CCC-conjecture: in very remote an "inverse Higgs" proces takes over & rest-mass eventually disappears

Hawking evaporating black hole



Weyl Curvature Hypothesis

The Big Bang must have been subject to a HUGE constraint — to a region of phase space no larger than 1 part in $10^{10^{123}}$

The specialness in the Big Bang appears to be only in Gravitation i.e. the Weyl curvature appears to have been = 0 at the Big Bang whereas it diverges wildly in black holes

But an awkward condition to state mathematically. Tod's proposal: space-time extendible conformally (i.e. as light-cone structure) to BEFORE

Just a mathematical trick! ..... ? Temperatures become so large at the Big Bang that rest masses become ignorable .....

(x, t)

Lab. coordinates

acceleration

a

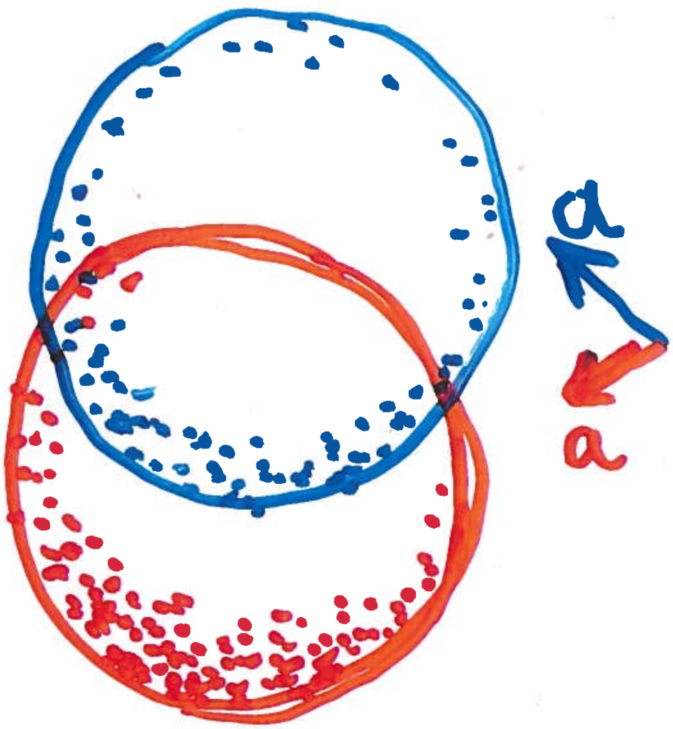
free-fall coordinates

(X, T)

$x = X + \frac{1}{2}T^2 a$

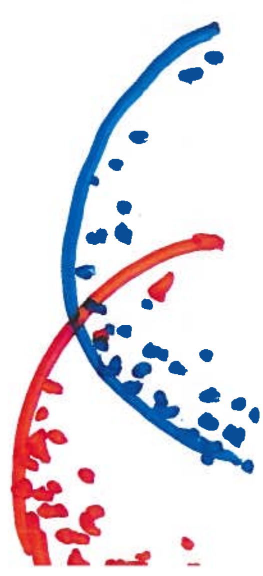
$t = T$

$$\Psi_E = e^{i\left(\frac{t^3}{6}a\cdot a - t\,\bar{x}\cdot a\right)\frac{M}{\hbar}}\Psi$$



different vacua

$$e^{\frac{iM}{\hbar}\left(\frac{t^3}{6}(a-a)^2\right)}$$



error term

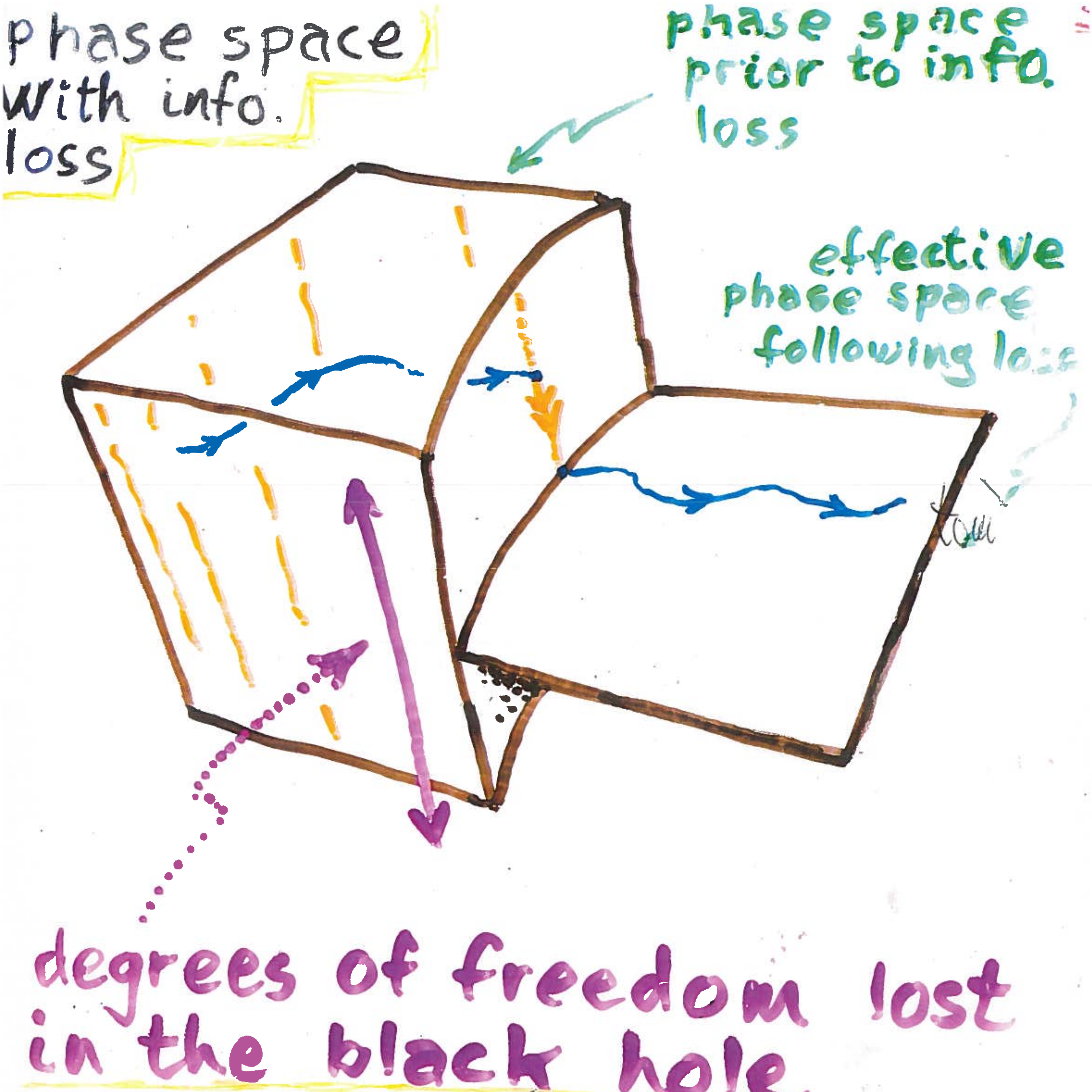
$s\text{-}sp]\int (a-a)^2 M \quad \cdots = t_e$

How can the 2nd Law be maintained in this cyclic universe model?

- By far, the major contribution to the entropy of our universe is, even now, in black holes, and this will surely increase in the future
- These black holes will eventually disappear by Hawking radiation
- Hawking originally argued that information (i.e. degrees of freedom) must be lost in black-hole evaporation
- Although Hawking later changed his mind, I argue that he was right the first time, and these degrees of freedom are indeed lost

"information paradox"

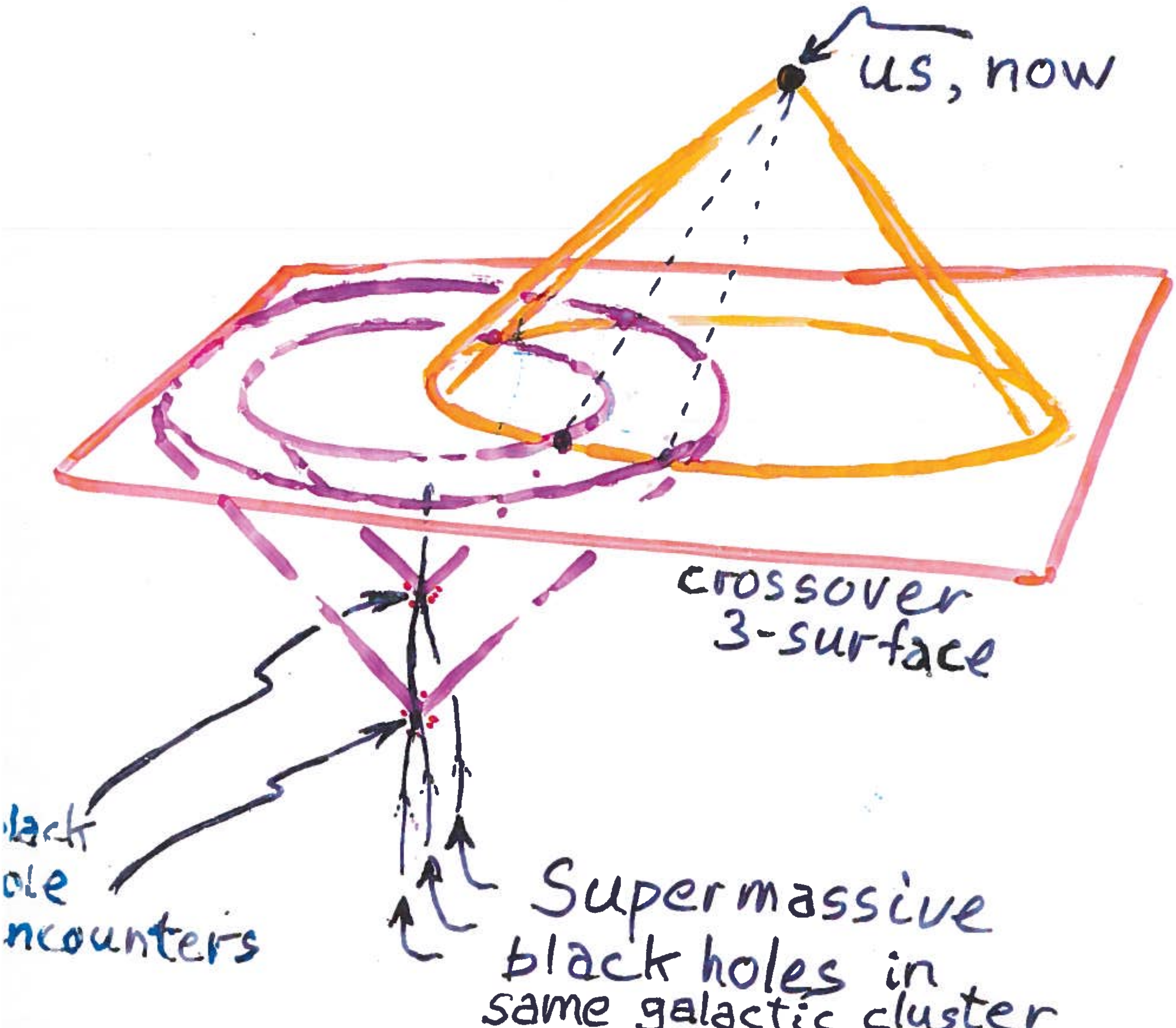
- Consequently, one must "renormalize" one's entropy definition after black holes evaporate away, and the new entropy value is drastically reduced
- The 2nd Law is TRANSCENDED, not violated



phase space with info. loss
phase space prior to info. loss
effective phase space following loss
degrees of freedom lost in the black hole

pop!
space like
time shift

Can we "see" through into the aeon prior to ours?



- atypical temperature

better diagnosti

- low variance

concentric rings

/. Gurzadyan

What is Dark Matter according to CCC?

Pre-crossover Ω is a "phantom field", with no physical content. Post-crossover, Ω acts as a real physical field, where $T_{ab}[\Omega]$ now contributes positively to the total energy-momentum tensor, owing to the reciprocal hypothesis

This new field provides the dominant matter contribution to the new big bang, and is interpreted as newly created dark matter, as it picks up mass. Its second derivatives pick up the electric part of K_{abcd} (magnetic part becomes Cotton tensor of crossover)

- Ω-field interacts only gravitationally
- suggests Ω-particle has ~Planck mass
- must decay away completely by aeon's end
- provides ~scale invariant CMB temp. flucts. of NEXT aeon! Spectral index?

Outline of CCC equations

$$\omega^2 g_{ab} = \check{g}_{ab} \qquad \omega = -\Omega^{-1}$$ [reciprocal hypothesis]

crossover →

$$\Omega^2 g_{ab} = \hat{g}_{ab}$$

Pre-crossover Ω is a "phantom field" put in only to allow Einstein equations to be written in the conformally invariant form

$$T_{ab}[\Omega] = \frac{1}{4\pi G}\Omega^3 D_{ab}\Omega^{-1}$$

$$= T_{ab}$$ ← EM of matter fields

where the conformall invariant operator

$$D_{ab} = \nabla_a\nabla_b - \frac{1}{4}g_{ab}\Box - \frac{1}{2}R_{ab} + \frac{1}{8}R g_{ab}$$

Post-crossover $\Omega (= -\omega^{-1})$ becomes a real field conjectured to be the initial form of dark matter - soon to acquire a mass

(1) Ω picks up (elec.) gravitational degrees of freedom

(2) The Ω-field must eventually decay away

(3) Mass value? Planck mass ??!

(4) gravitons? (5) CMB temperature fluctu

Dark Matter Particles

EREBONS (Erebosons?)

after Erebos (Egyption God of Darkness)

Conformal (spinless) partner of gravity

∴ only interacts gravitationally

Suggests: ~Planck mass $\sim 10^{-5}$g

Must decay over history of the aeon

D-P quantum state reduction

⇒ behaves as classical particle

(NOT Planck-mass black hole)

Lifetime from Λ

Decays to classical "gravitons"

~Planck frequency ∝ Ricci impulse

Gravitational Lenses

Weyl: purely astigmatic

Ricci: anastigmatic
(positive energy: positive len

Power $p = \frac{1}{\text{focal length}}$

2 lenses:

Total power: $p_1 + p_2 - \ell p_1 p_2$

∴ 

astig. −astig. ⇝ positive anastig

High freq. Weyl ≈ Ricci

Could LIGO, or other grav wave detectors see erebon decay?

Some *very* rough figures

Assume erebon mass $\approx$ Planck mass $\approx 10^{-5}$ g

$\therefore$ decay energy $\approx E_P \approx 2 \times 10^9$ J

Use Planck units

Mass of Sun $\approx 2 \times 10^{33}$ g $\approx 10^{38}$

$\therefore$ Energy of LIGO BH encounters $\sim 10^{38}$

galaxy $\approx 10^{11}$ suns $\therefore \sim 10^{41}$ erebons

LIGO galaxies $\sim 10^9$ ly away

Close by, maybe individual events?

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can we assume erebon lifetime ? $\gtrsim 10^{11}$ yrs $\approx 10^{18}$ s $\therefore 10^{23}$ decays/sec in a galaxy

Maybe Hanbury Brown-Twiss gives identifyable signal

Erebons BOSONIC! (compare 10^{45} ...)