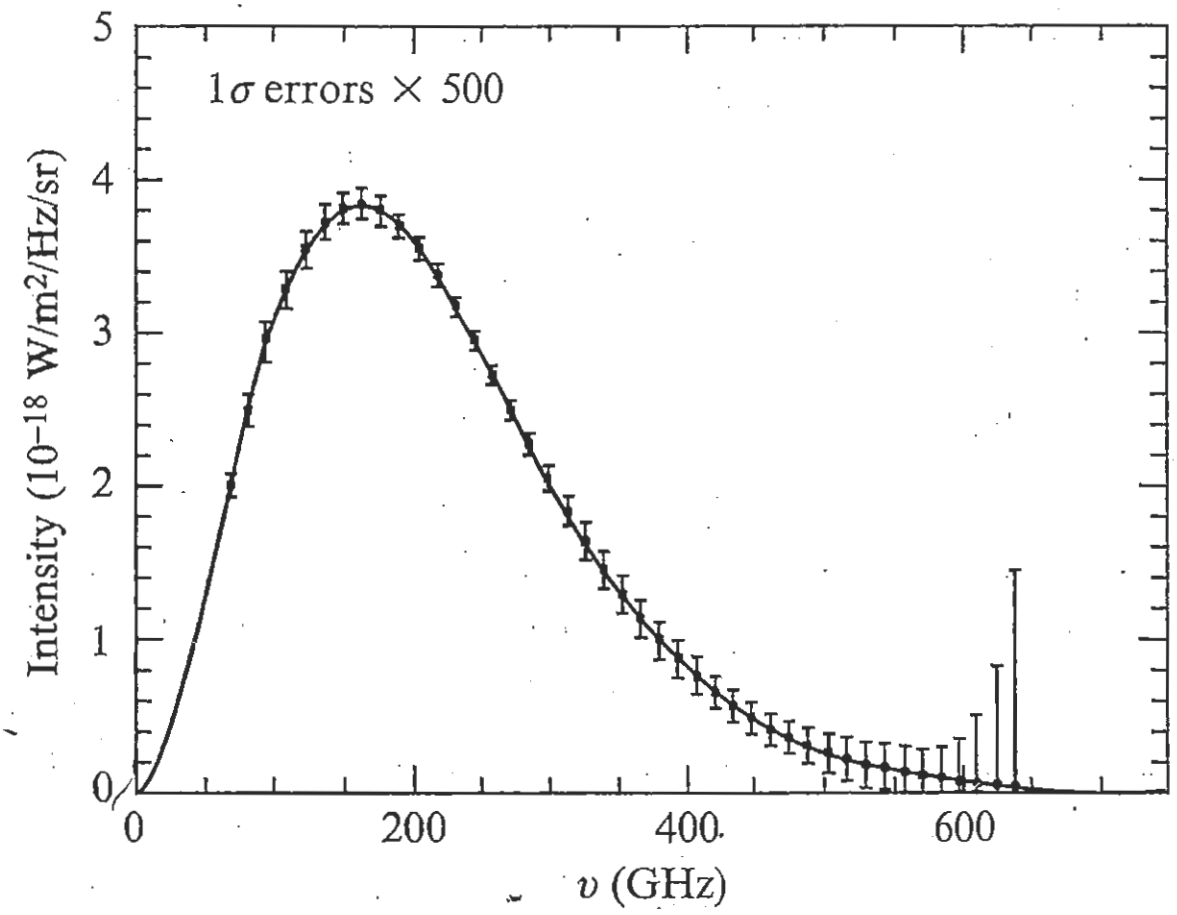
Fundamental problem raised by the 2nd law of thermodynamics & the nature of the Big Bang:

Why did the BB not involve any white holes (time-reversed black holes)?

Not answered by inflation or by any (current) theory of quantum gravity.

Spectrum of the Cosmic Microwave Background

CMB



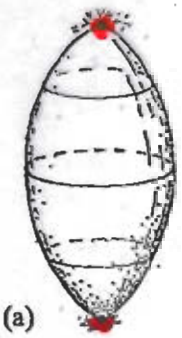
Note: error bars are exaggerated by a factor of 500.

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

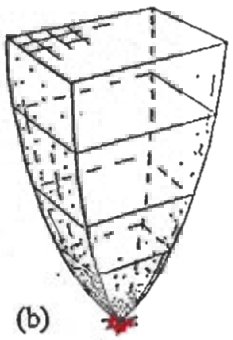
Standard Cosmological models

A. Friedmann 1922, 1924

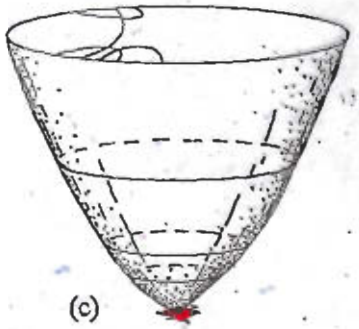
Time



$K > 0$



$K = 0$

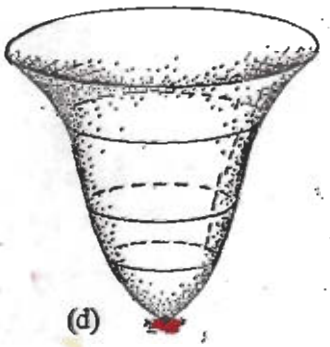


$K < 0$

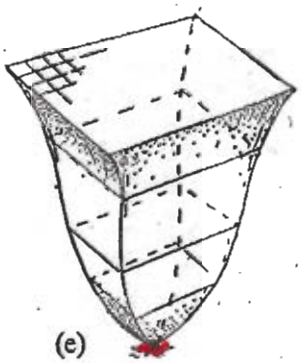
$\Lambda = 0$

cosmological const. (Einstein 1917)
"dark energy" (Perlmutter, Schmidt 1998)

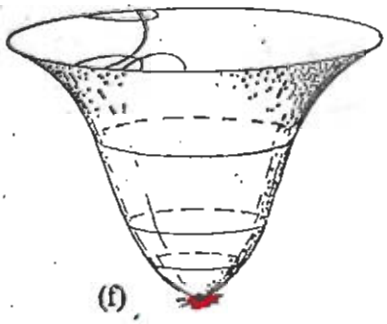
Time



$K > 0$



$K = 0$

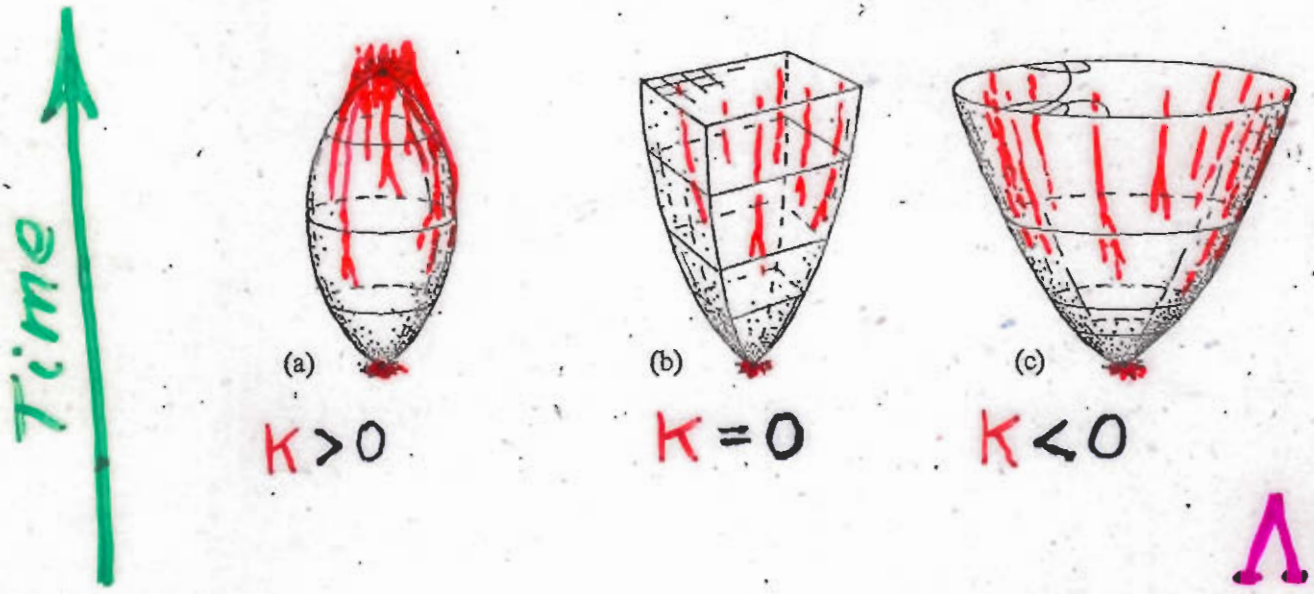


$K < 0$

$\Lambda > 0$

Standard Cosmological models with black holes

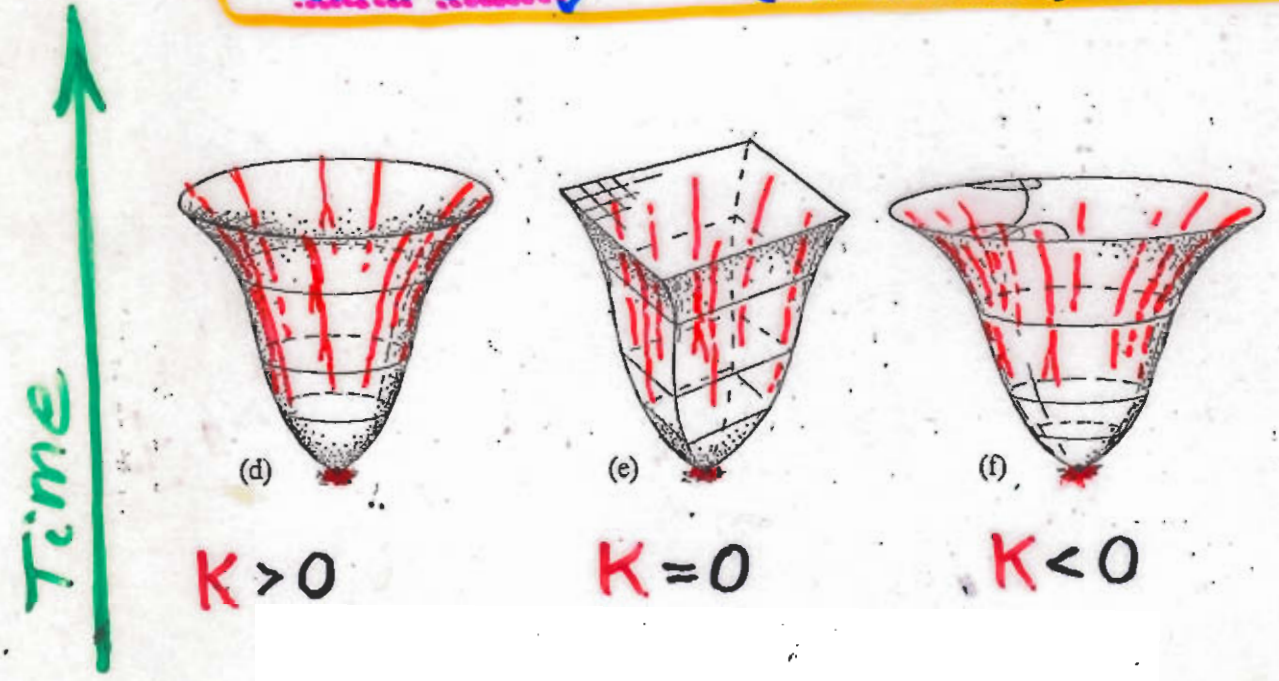
A. Friedmann 1922, 1924



$K>0$ $K=0$ $K<0$

$\Lambda = 0$

cosmological const. (Einstein 1917)
"dark energy" (Perlmutter, Schmidt 1998)

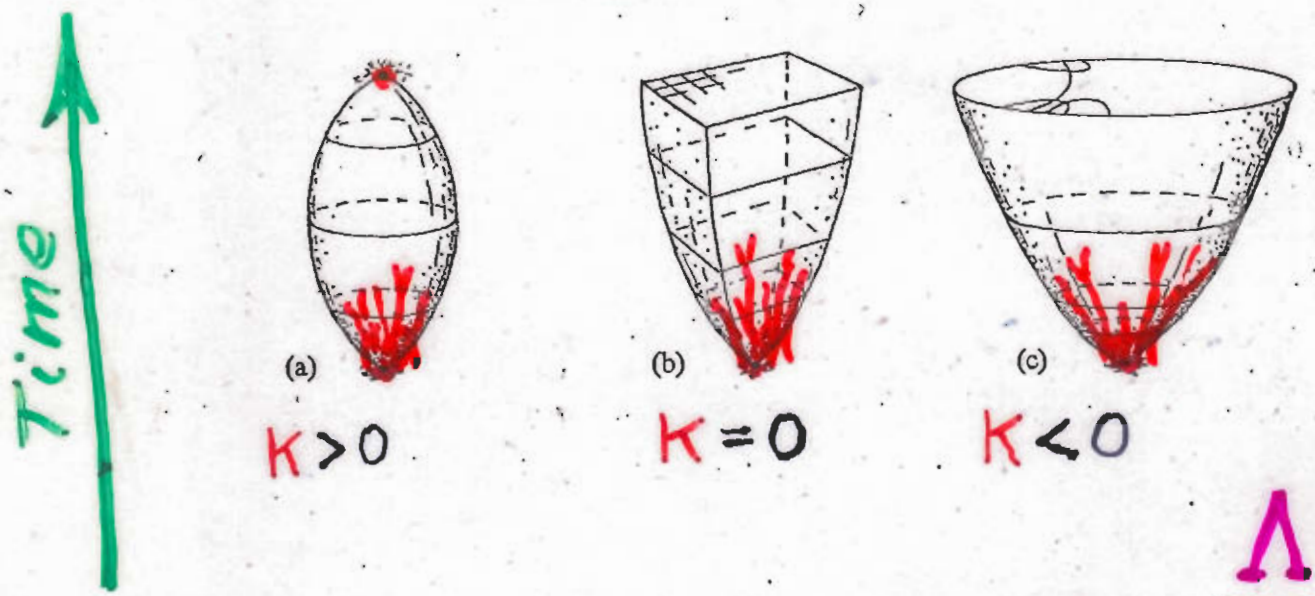


$K>0$ $K=0$ $K<0$

$\Lambda > 0$

Standard Cosmological models

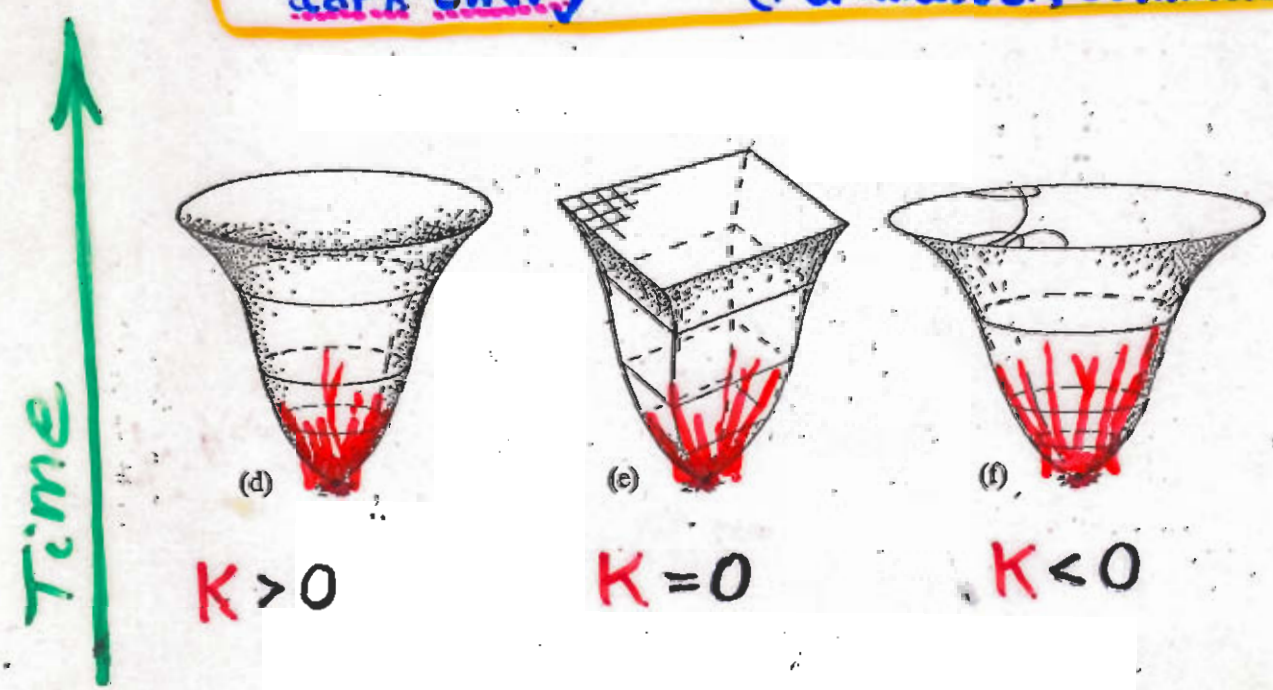
A. Friedmann 1922, 1924



$K>0$ $K=0$ $K<0$

$\Lambda = 0$

cosmological const. (Einstein 1917)
"dark energy" (Perlmutter, Schmidt 1998)



$K>0$ $K=0$ $K<0$

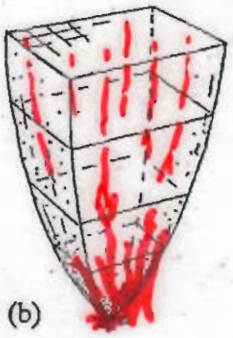
$\Lambda > 0$

Standard Cosmological models with black holes

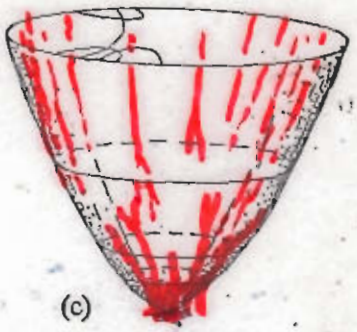
A. Friedmann 1922, 1924

Time

$K > 0$



$K = 0$

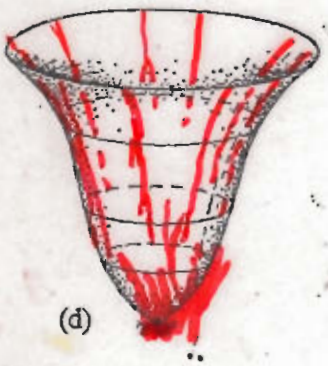


$K < 0$

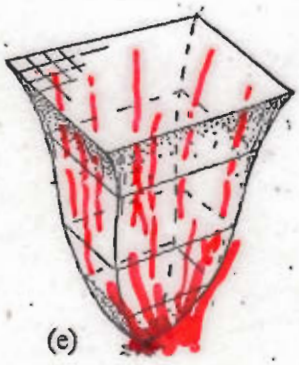
$\Lambda = 0$

cosmological const. (Einstein 1917)
"dark energy" (Perlmutter, Schmidt 1998)

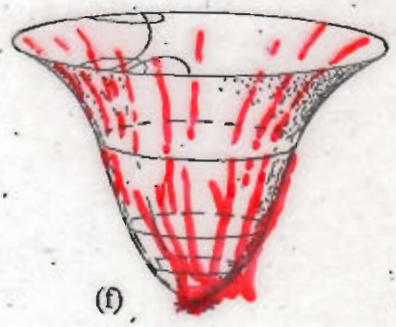
Time



$K > 0$



$K = 0$



$K < 0$

$\Lambda > 0$

Weyl curvature hypothesis

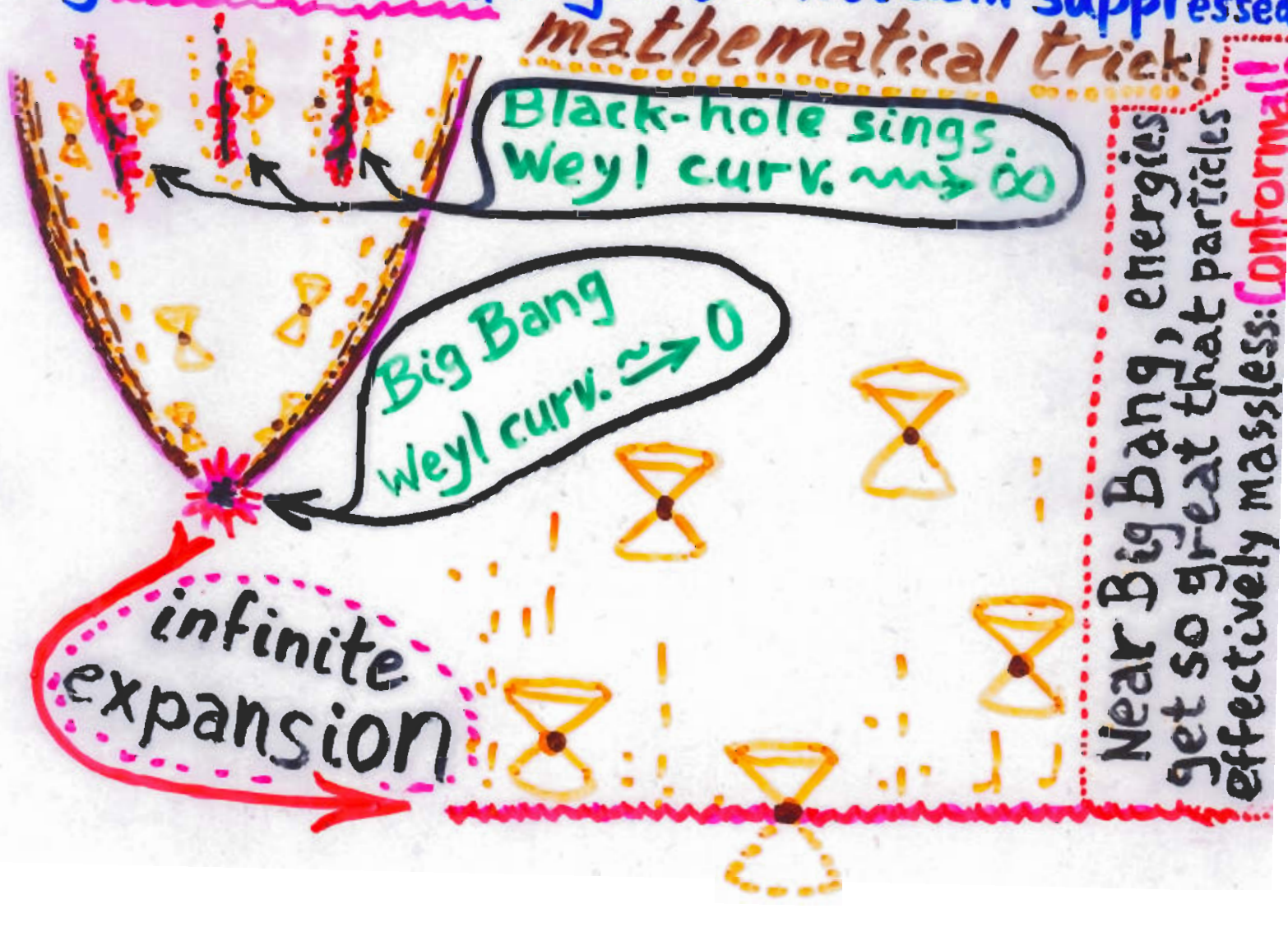
Tod's conformal formulation

Constraint on Big Bang: 1 part in $10^{10^{124}}$

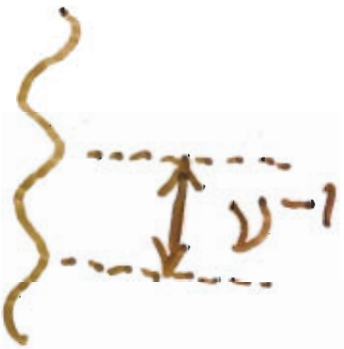
- from Bekenstein-Hawking black-hole entropy for hole from 10^{80} baryons (protons, neutrons, ...) + some dark matter.

$\Rightarrow$ 2nd Law – in the form we know it, with great spatial uniformity, so gravitational degrees of freedom suppressed

mathematical trick!



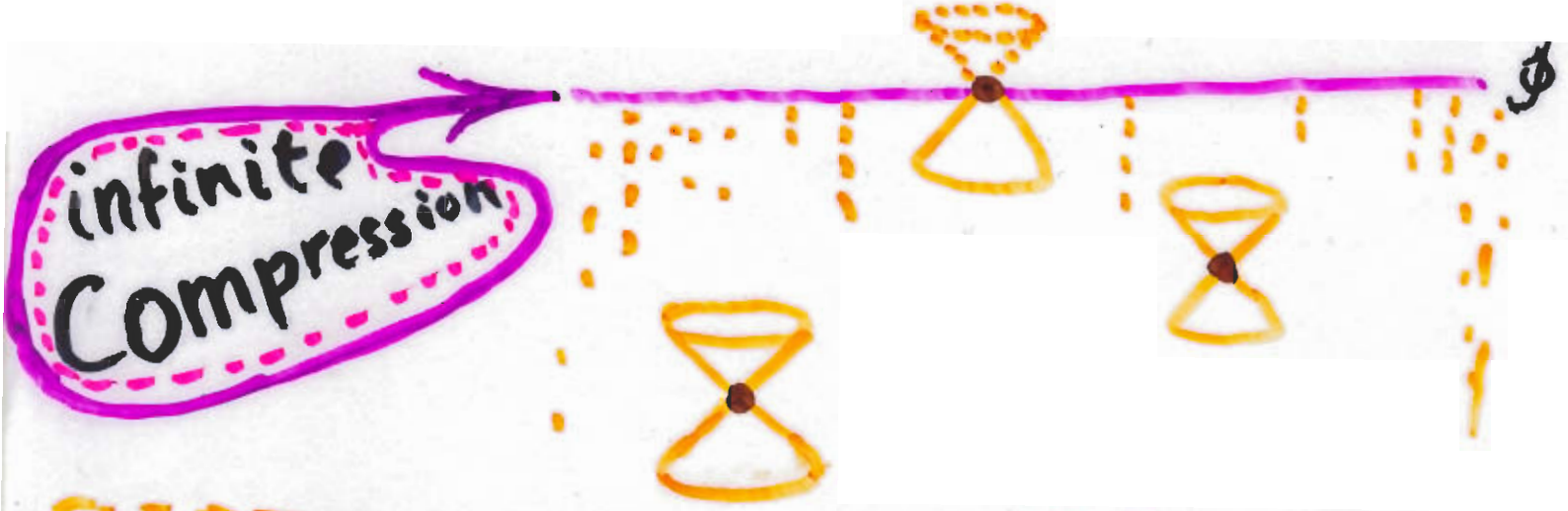
It's **MASS** (rest-mass) that determines clock rates



Planck: $E = h\nu$

Einstein: $E = mc^2$

$$\nu = m\left(\frac{c^2}{h}\right)$$



The extemely remote future

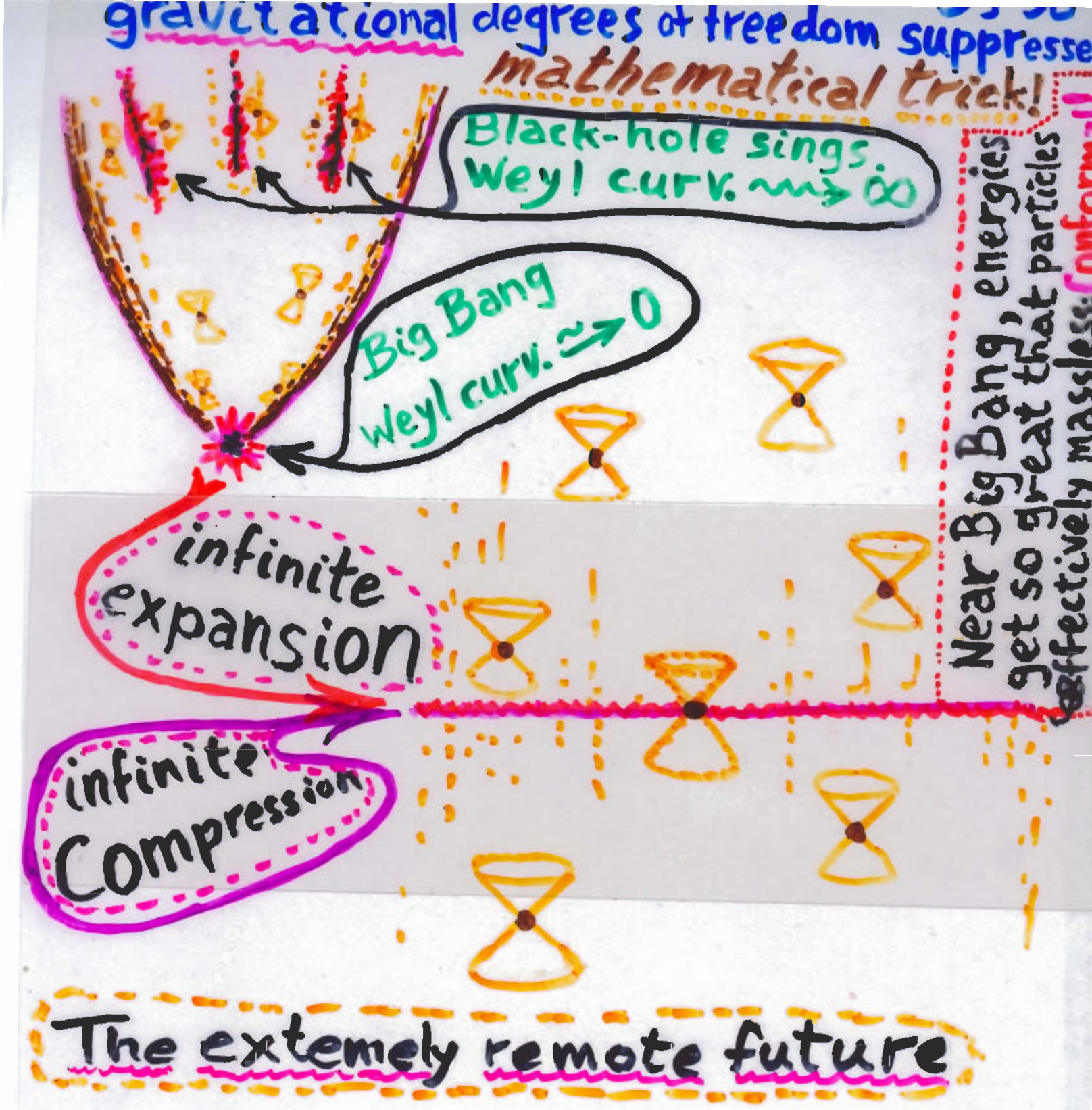
Much matter collapses to black holes. Eventually expanding universe cools to lower than black-holes' Hawking temperature. Then, the hole gradually evaporates away, very slowly $\sim 10^{64}$ yrs for $M_\odot$, $\sim 10^{90}$ yrs. for galactic until pop! it disappears. With only massless ingredients left, the universe loses track of time. No way to build a clock!

Eternity is no time at all, for a photon!

Conformal geometry

Conformal $\infty(\mathcal{I})$ is spacelike if $\Lambda > 0$. Mathematical trick!

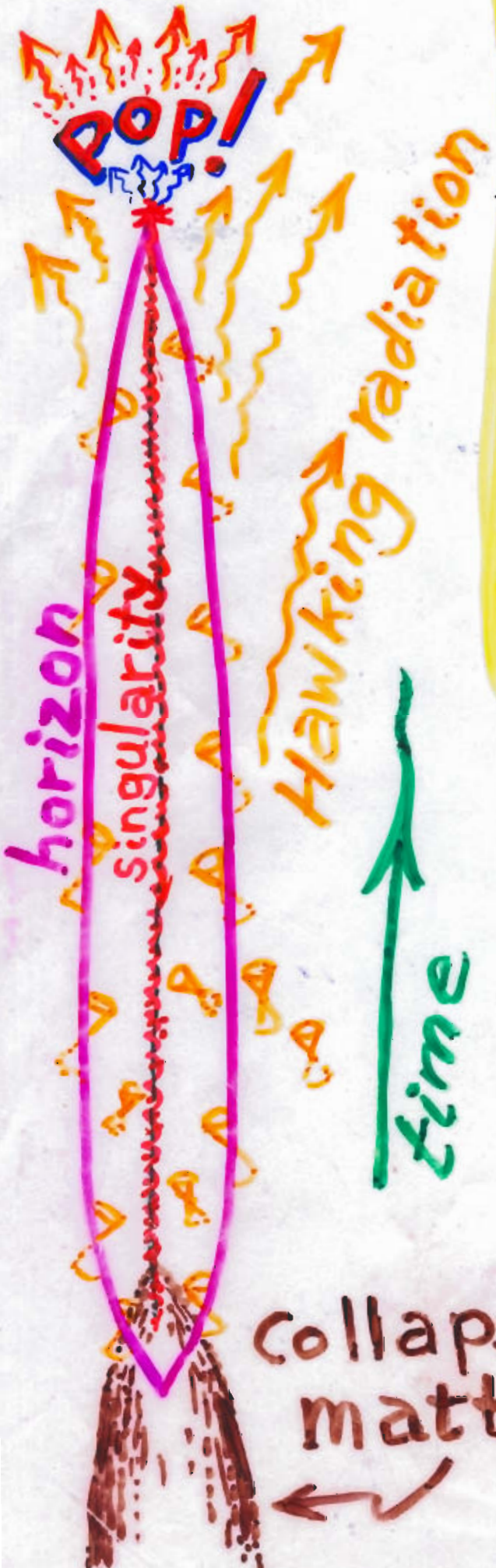
rogue electrons? mass evaporation?



Much matter collapses to black holes. Eventually expanding universe cools to lower than black-holes' Hawking temperature. Then, the hole gradually evaporates away, very slowly

$\sim 10^{64}$ yrs for $M_\odot$, $\sim 10^{90}$ yrs for galactic

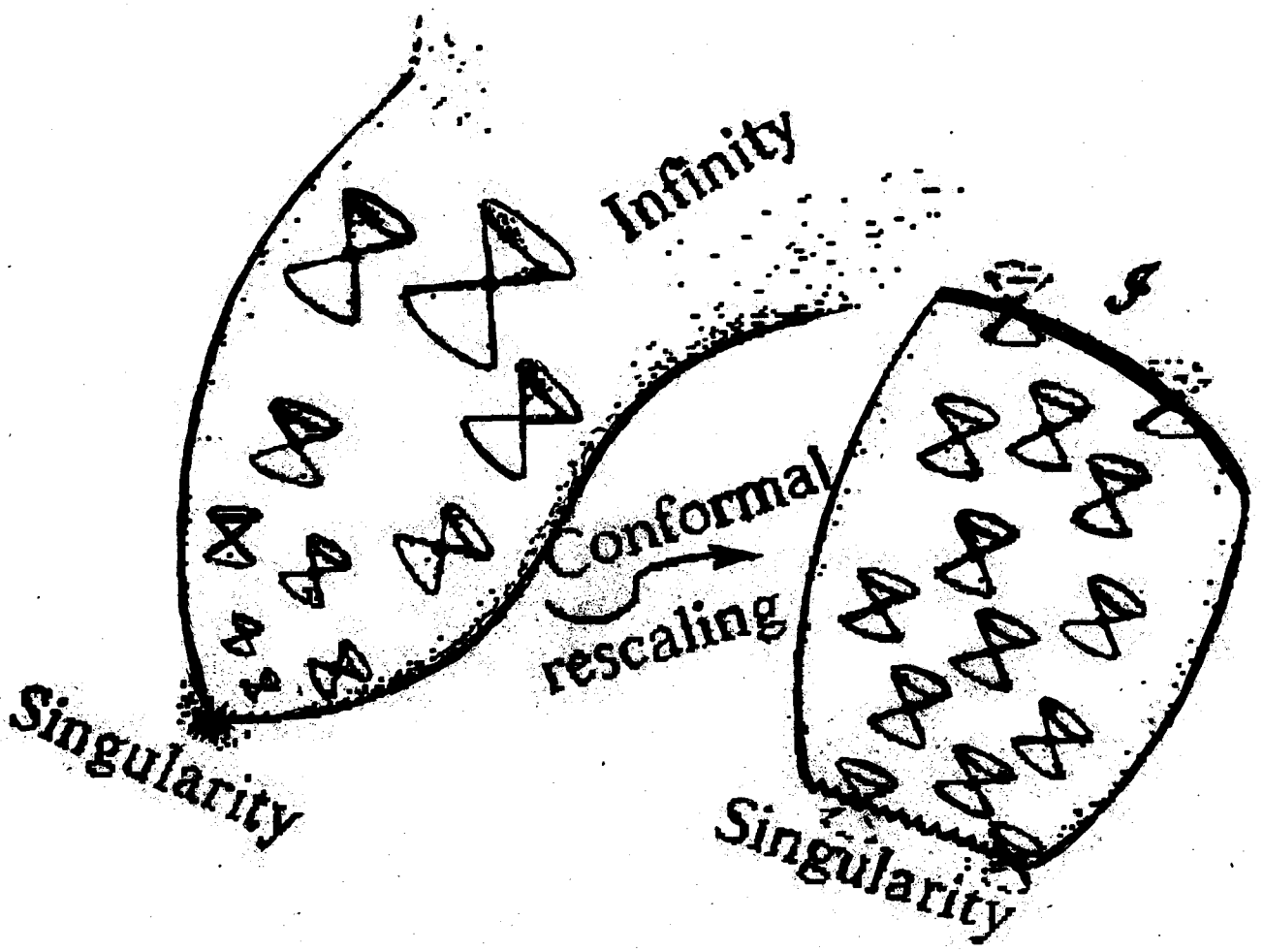
Hawking Black-Hole evaporation



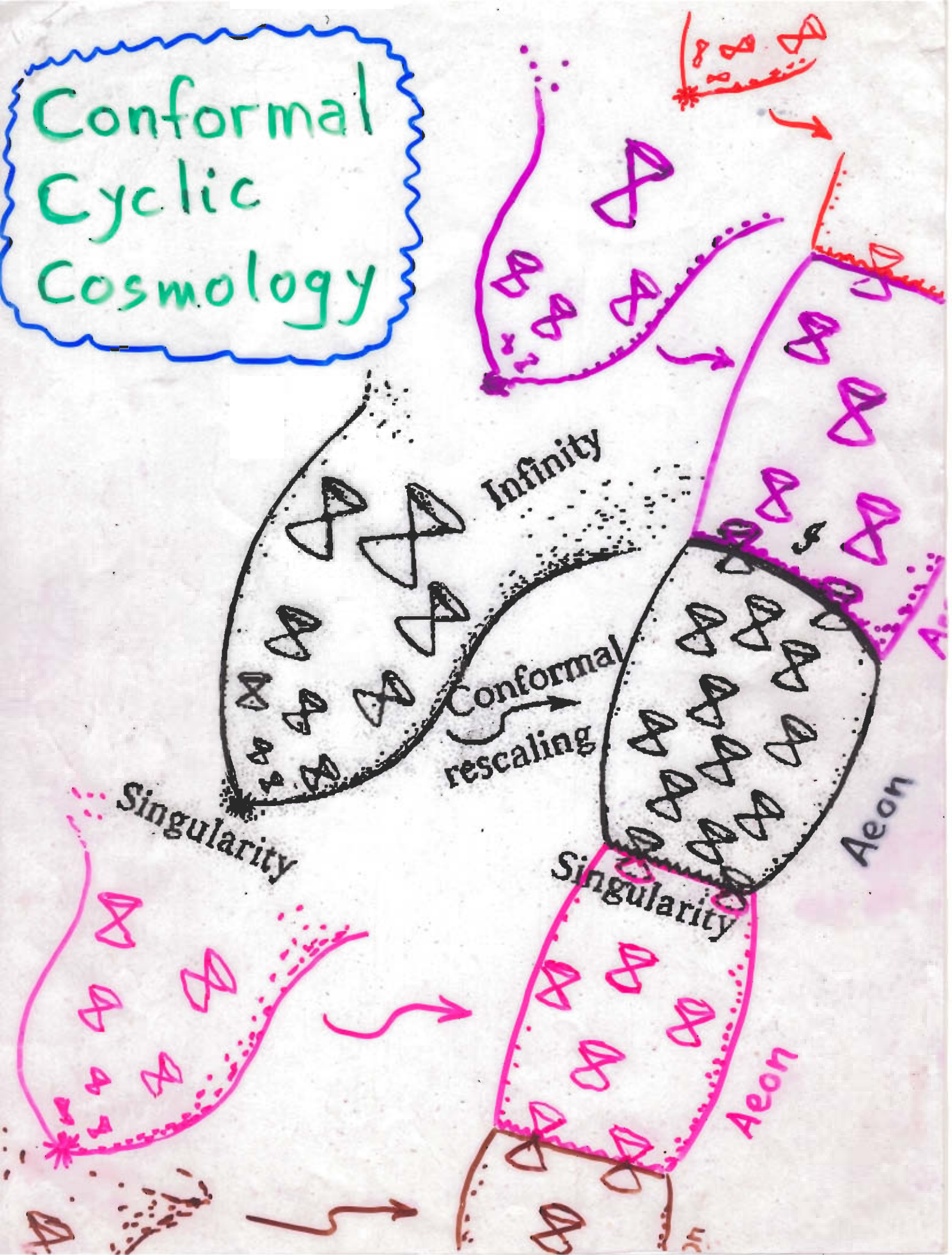
"INFORMATION PARADOX"

Problem: What happens to the information (in the sense of phase-space volume) in the collapsing material?

- lost?
  - weakly [orig. Hawking]
  - strongly (RP) (violates unitarity)
- retrieved in final Pop or in subtle correlations
- retained in final "nugget" (remnant)


Infinity
Conformal
rescaling
Singularity
Singularity

Conformal Cyclic Cosmology



$$d\tau = \Omega\, ds$$

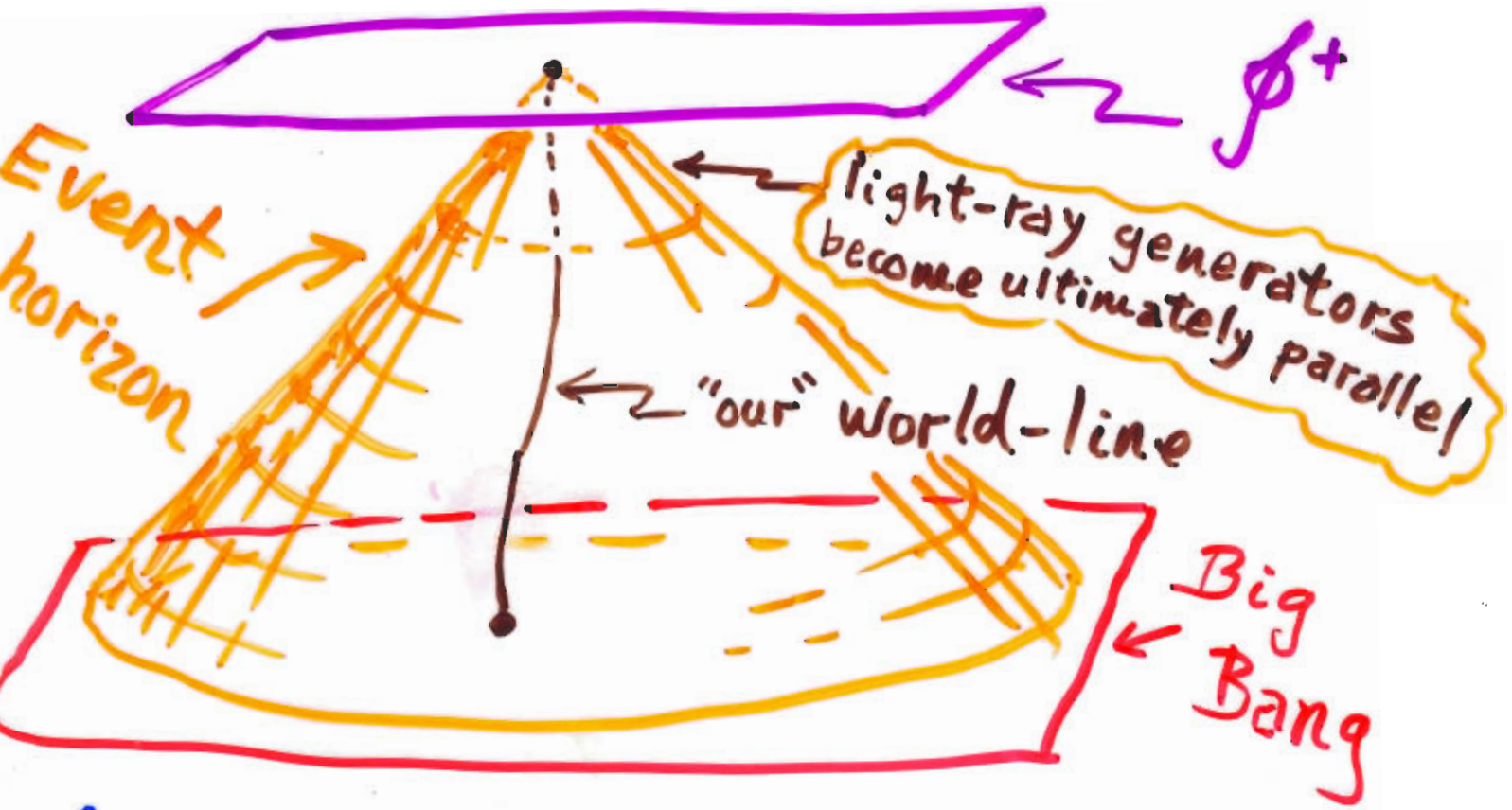
at $\mathscr{I}^+$, $\Omega \sim 1-\tau$

$1-\tau \propto e^{-t}$

at Bang, $\Omega \sim \tau^{-1}$

$$\tau = \sqrt{2t}$$

Cosmological entropy ?

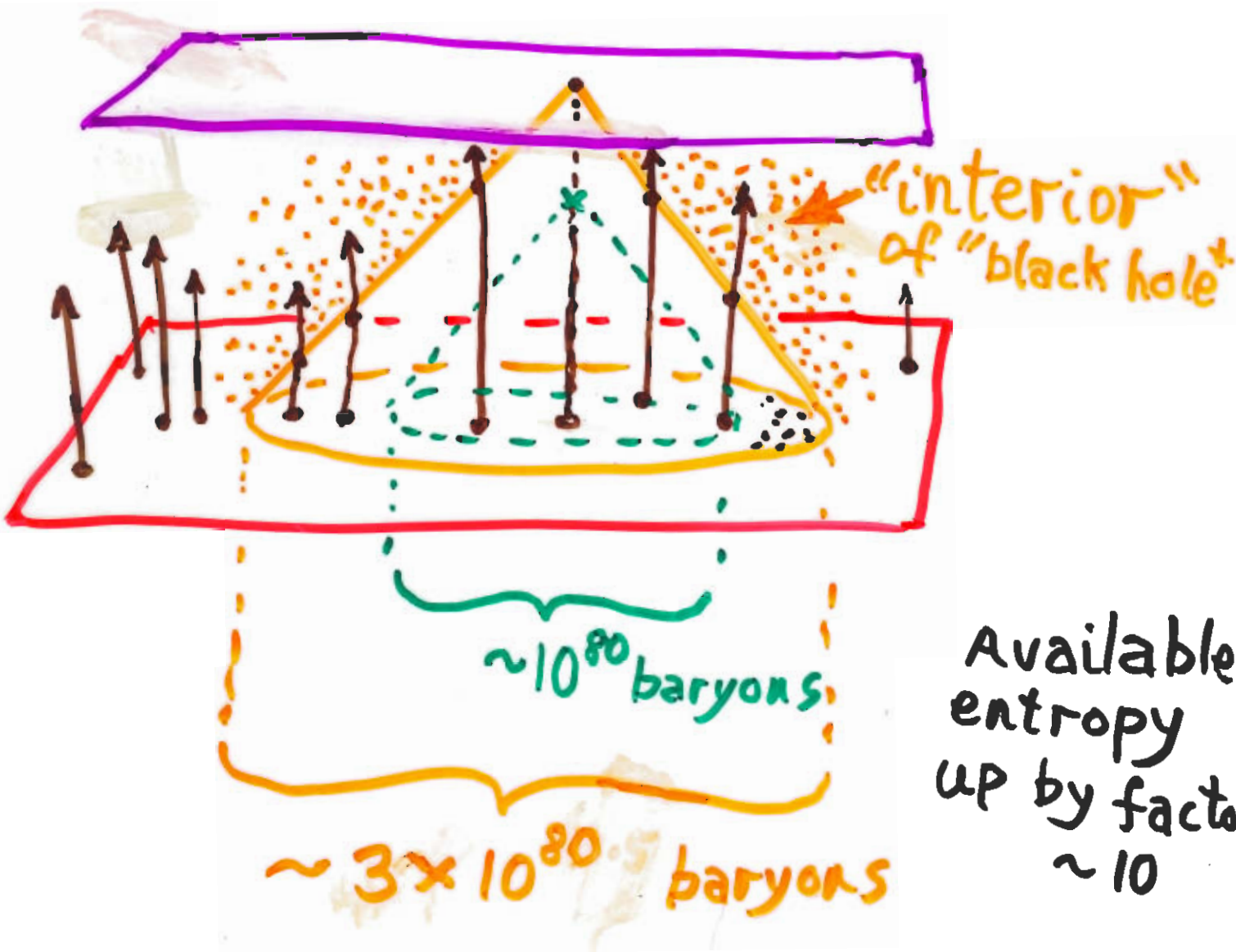


Area of cosmological horizon (deSitter) $= \frac{12\pi}{\Lambda}$.

If we believe Bekenstein-Hawking formula applies, we get

$$S_{cosm} = \frac{3\pi}{\Lambda} \approx 3 \times 10^{122}$$

Should we believe it? Unruh temp.=0 (free fall)



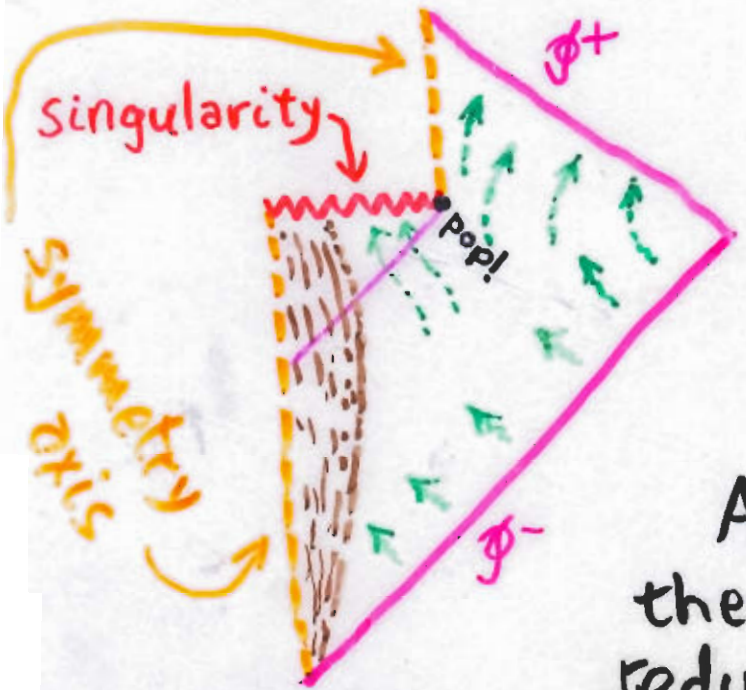
Available entropy up by factor ~10

$S \sim 10^{123} \rightsquigarrow S \sim 10^{124}$

with dark matter $S \sim 10^{125}$ or 10^{126}

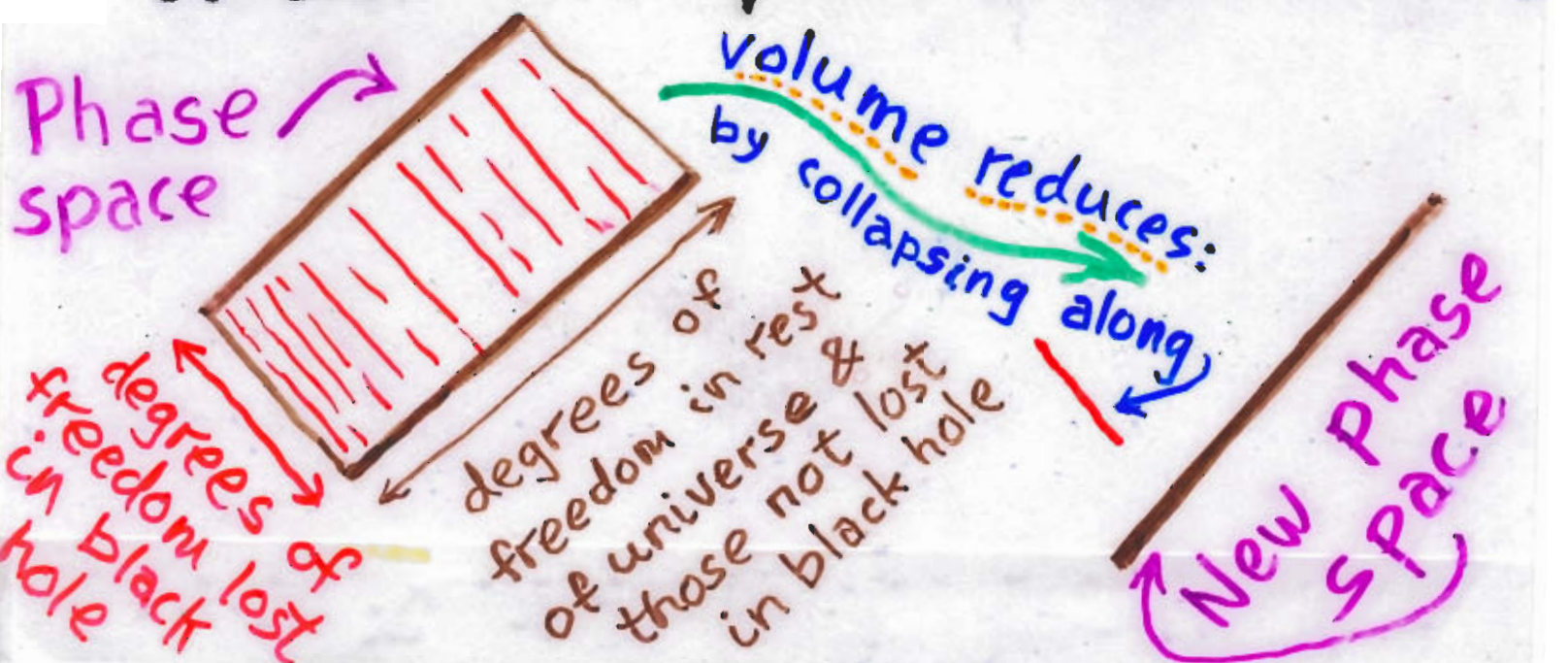
Black-hole information loss – essential for 2nd Law

N.B. original Hawking argument (still the only really convincing one) required information loss: in my opinion



Bogoljubov transf. from sharing initial data on $\mathscr{I}^-$ between that on $\mathscr{I}^+$ and that lost on singularity

After the "pop" occurs, the phase space is accordingly reduced in size. This certainly violates unitarity (but so also does quantum state reduction)



Creation of scalar field from conformal factor at crossover from one aeon to the next.

New "dark matter"?

Scalar field φ subject to:

$$\left(\Box + \frac{R}{6}\right)\varphi + \alpha\varphi^3 + \mu\varphi = 0$$

(α: consts.)

μ: mass term assumed small enough to be ignored at Bang [from Conformal Anomaly?]

if μ ignored, conformally invariant with

$$\varphi \rightsquigarrow \hat{\varphi} = \Omega^{-1}\varphi$$

and "new improved" energy-momentum tensor = const. × (trace-free part of)

$$\left[\nabla_a\varphi\nabla_b\varphi - \tfrac{1}{2}\varphi\nabla_a\nabla_b\varphi - \tfrac{1}{4}\varphi^2 R_{ab}\right]$$

Newman-RP-Coleman-Callan-Jackiw 1968/1970

This is just the term that arises from what must be added to the (trace-free) Ricci tensor when a conformal rescaling is made, with $\varphi = \Omega$.

$$\left(\Box + \frac{R}{6}\right)\Omega - \frac{\hat{R}}{6}\Omega^3 = 0$$

$$\text{trace-free } \hat{R}_{ab} = -\frac{4}{\Omega^2}\left(\begin{matrix}\text{trace-free}\\ \text{part of}\end{matrix}\right)\left(\nabla_a\Omega\nabla_b\Omega - \tfrac{1}{2}\Omega\nabla_a\nabla_b\Omega - \tfrac{1}{4}\Omega^2 R_{ab}\right)$$

Creation of scalar field from conformal factor at crossover from one aeon to the next.

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(consts.)

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mass term assumed small enough to be ignored at Bang [from Conformal Anomaly?]

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Newman-RP-Coleman-Callan-Jackiw 1968/1970

$$\left\{\nabla_a\varphi\nabla_b\varphi - \tfrac{1}{2}\varphi\nabla_a\nabla_b\varphi - \tfrac{1}{4}\varphi^2 R_{ab}\right\}$$

$$\left(\nabla_a\Omega\nabla_b\Omega - \tfrac{1}{2}\Omega\nabla_a\nabla_b\Omega - \tfrac{1}{4}\Omega^2 R_{ab}\right)$$

trace-free $\hat{R}_{ab} = -\frac{4}{\Omega^2}$ (trace-free part of)

This is just the term that arises from what must be added to the (trace-free) Ricci tensor when a conformal rescaling is made, with $\varphi = \Omega$.

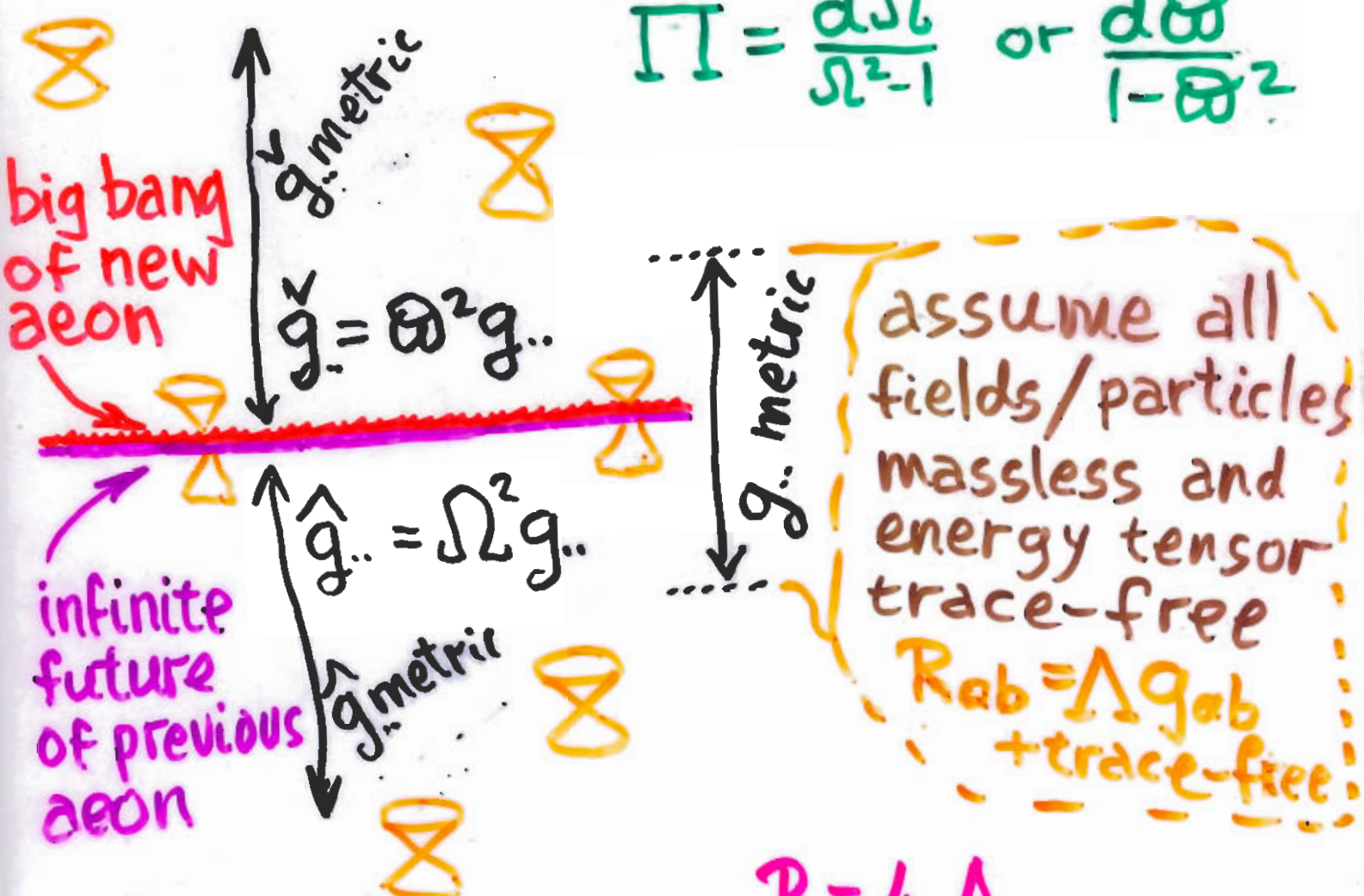
Appropriate structure at the aeon-to-aeon cross-over region

1. Time-oriented conformal (ie. null-cone) structure

2. Space-like cross-over hypersurface (with certain e.g. smoothness properties)

3. A smooth 1-form Π, where

$$\Pi = \frac{d\Omega}{\Omega^2 - 1} \quad \text{or} \quad \frac{d\varpi}{1-\varpi^2}$$



$R = 4\Lambda$

Conformal scalings which preserve this satisfy $\Box\Omega + \frac{R}{6}\Omega - \frac{R}{6}\Omega^3 = 0$

For convenience, we can scale things so that $R=12$ i.e. $\Lambda=3$.

Then the equation on Ω becomes

$$\tfrac{1}{2}\nabla_a\nabla^a\Omega+\Omega-\Omega^3=0$$

We find that this equation is equivalent to

$$2\Omega(1-\Pi_a\Pi^a)=\nabla^a\Pi_a$$

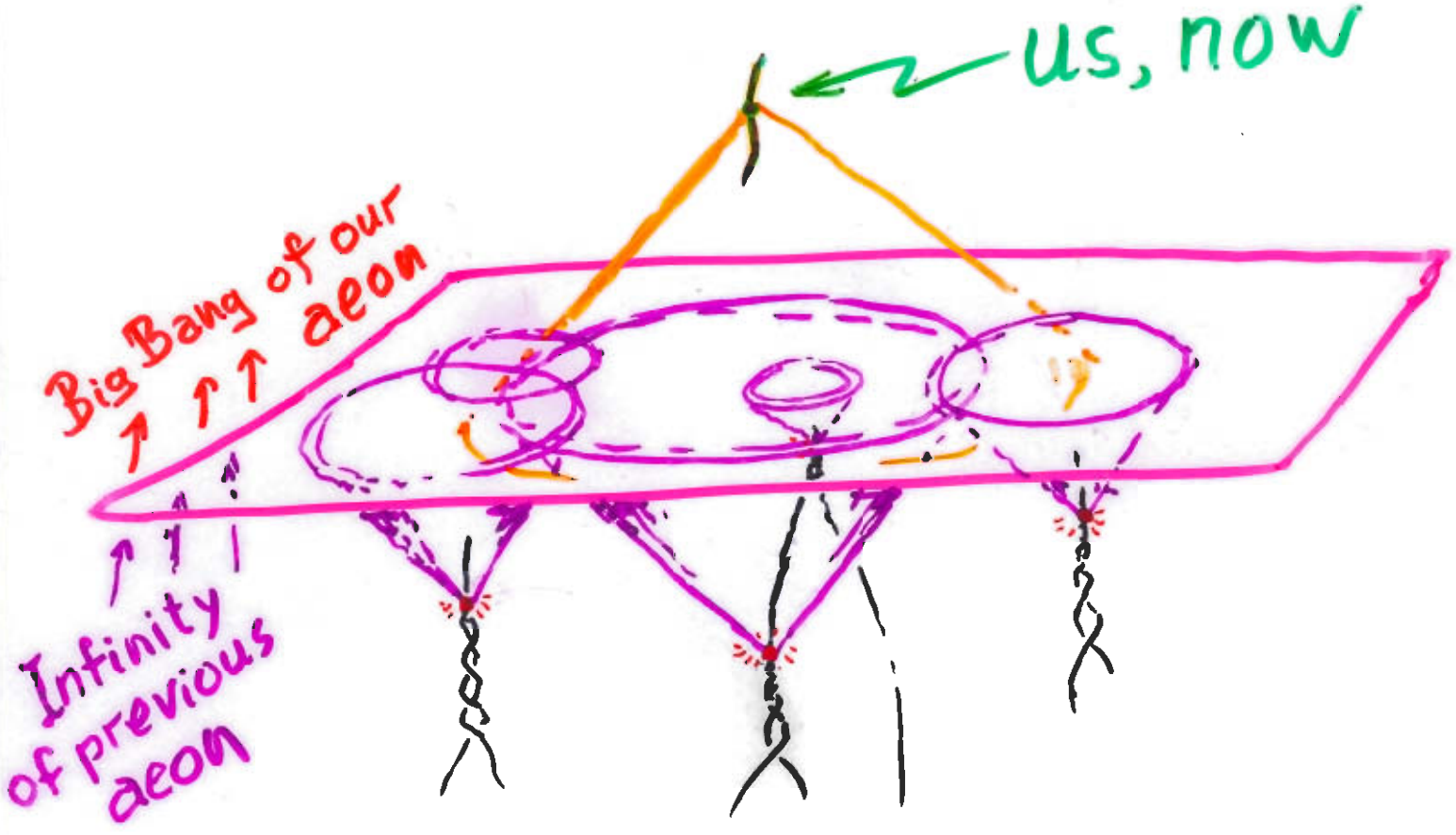
so we can find Ω by

$$\Omega=\frac{\tfrac{1}{2}\nabla^a\Pi_a}{1-\Pi_b\Pi^b}$$

$$\Pi_a=\frac{\nabla_a\Omega}{\Omega^2-1}=\frac{\nabla_a(\Omega^{-1})}{\Omega^{-2}-1}$$

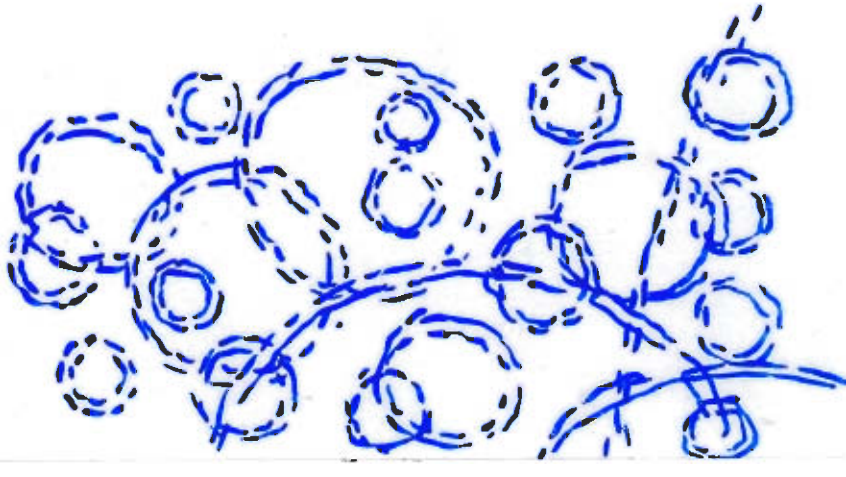
Note: If Ω^{-1} were also a solution ($\tfrac{1}{2}\nabla_a\nabla^a\Omega^{-1}+\Omega^{-1}-\Omega^{-3}=0$), then $\Omega^{-1}=\frac{\tfrac{1}{2}\nabla^a\Pi_a}{1-\Pi_b\Pi^b}$ also, so $1-\Pi_b\Pi^b=0=\nabla^a\Pi_a$, which is indeed necessarily true at the cross-over, but not everywhere else.

Observational consequence concerning temperature/density variations in Cosmic Microwave Background

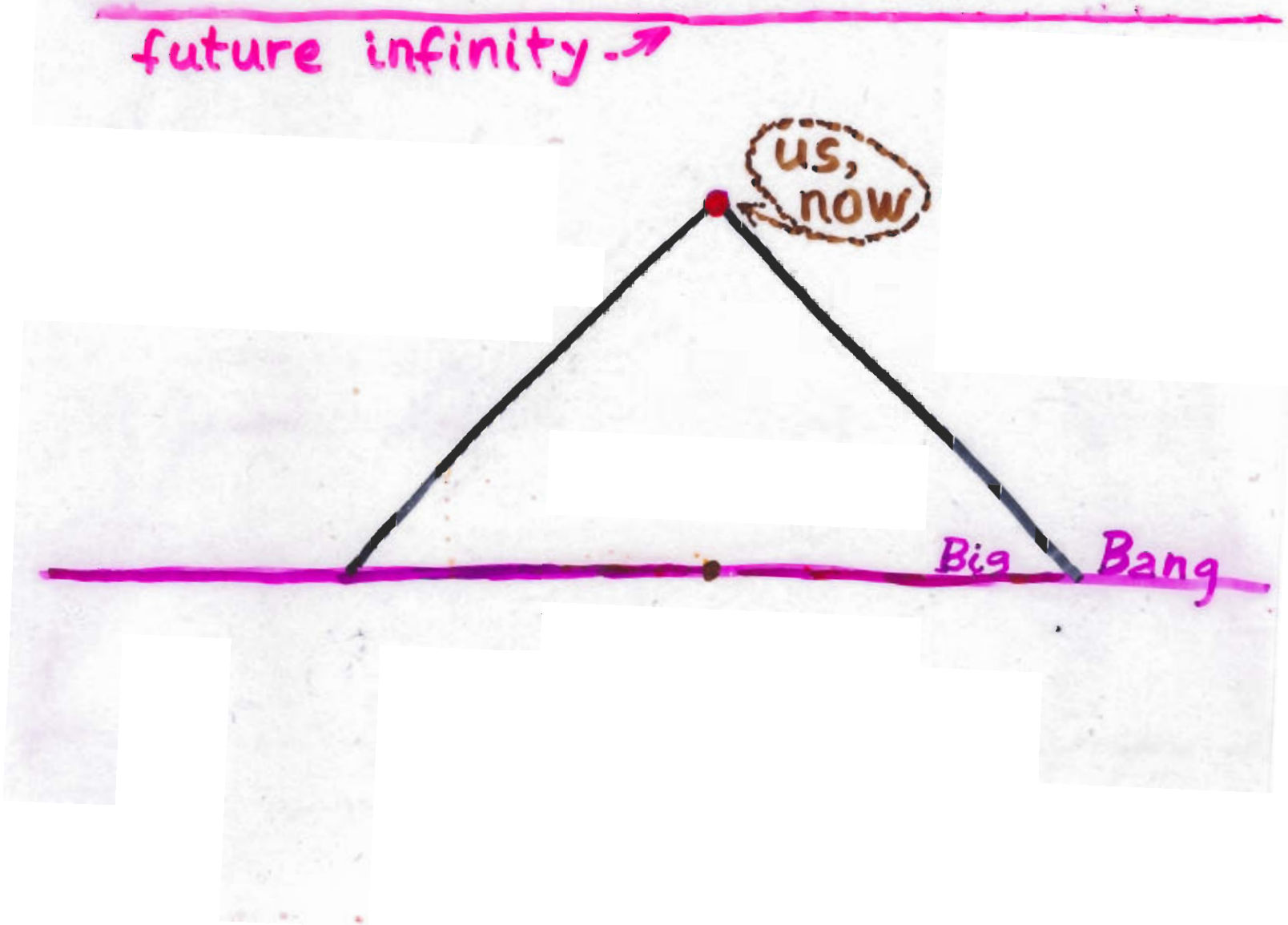


Think of ripples on a pond, caused by raindrops which have recently stopped falling.

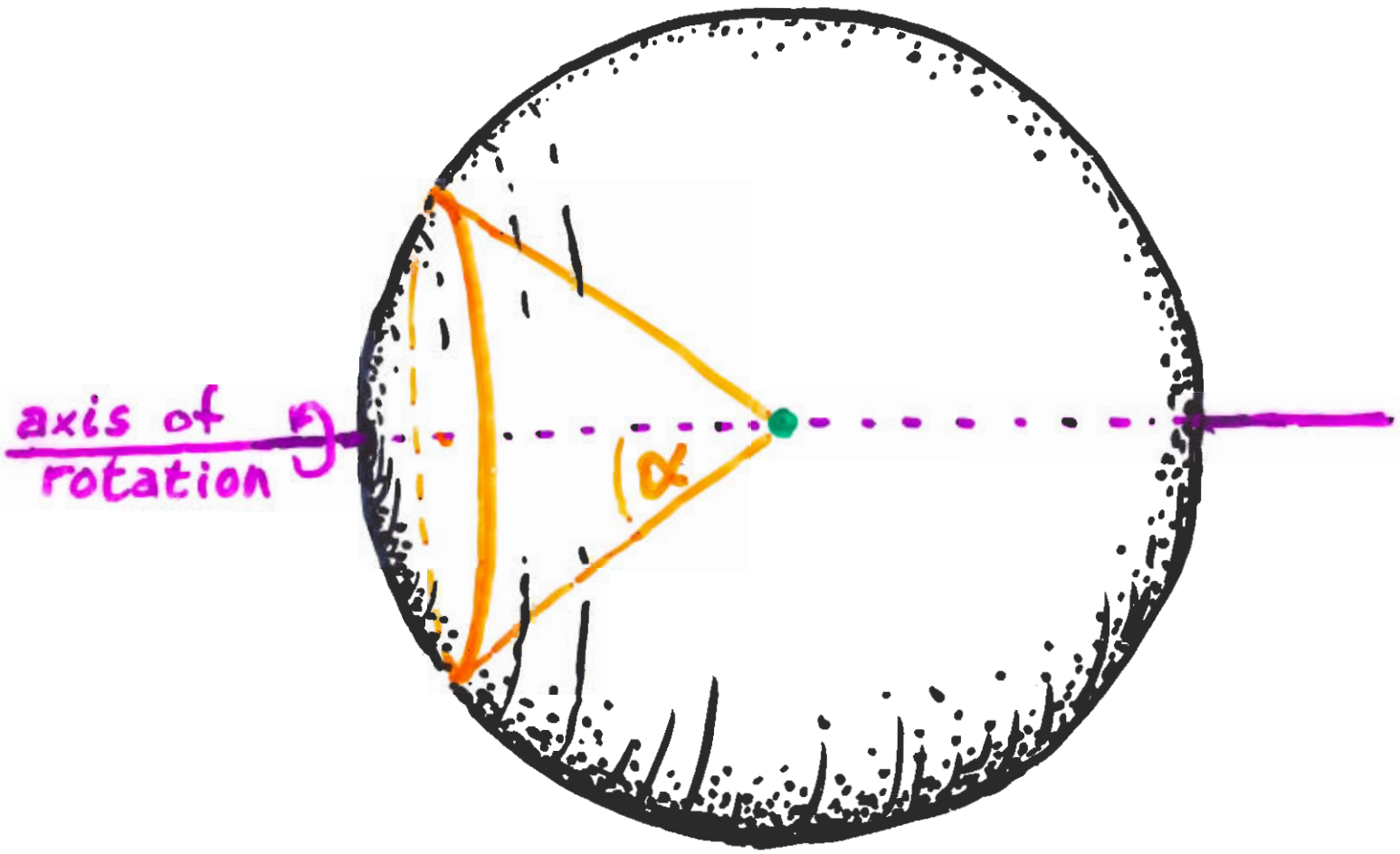
Pattern of ripples looks random at first, but can be analysed into circles by statistical analysis.

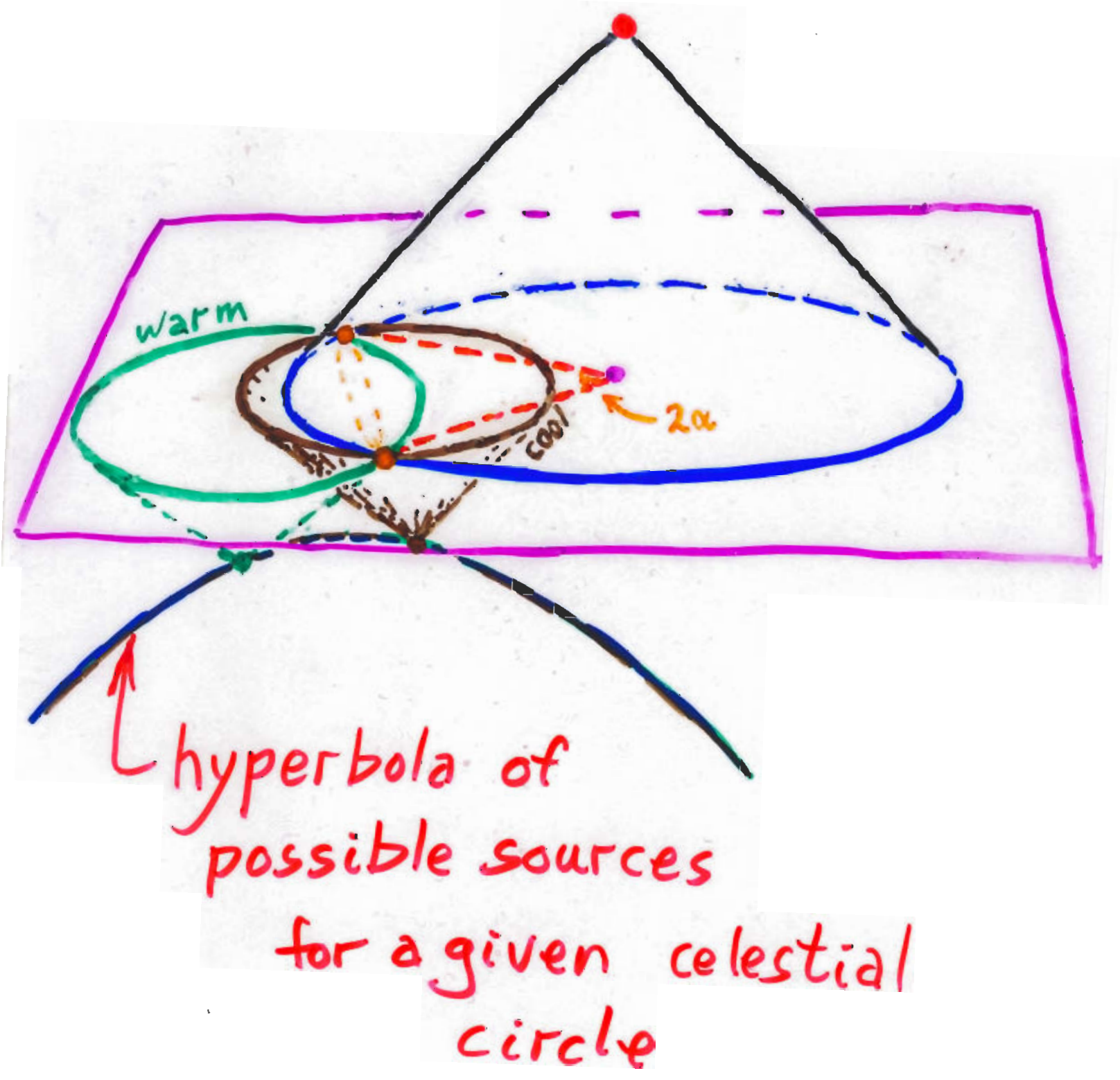


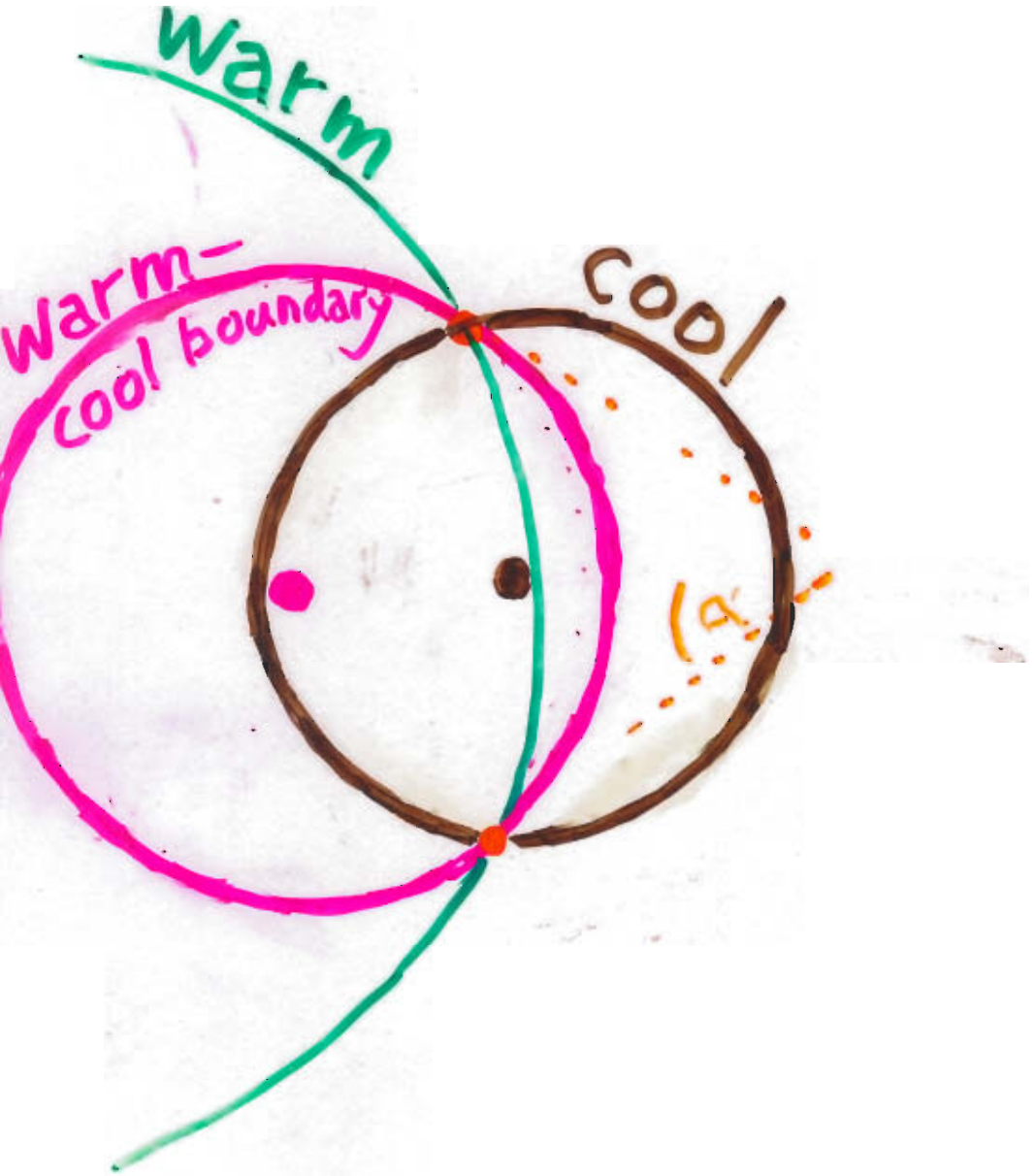
Black-Hole Encounters in the Previous Aeon to Our Own

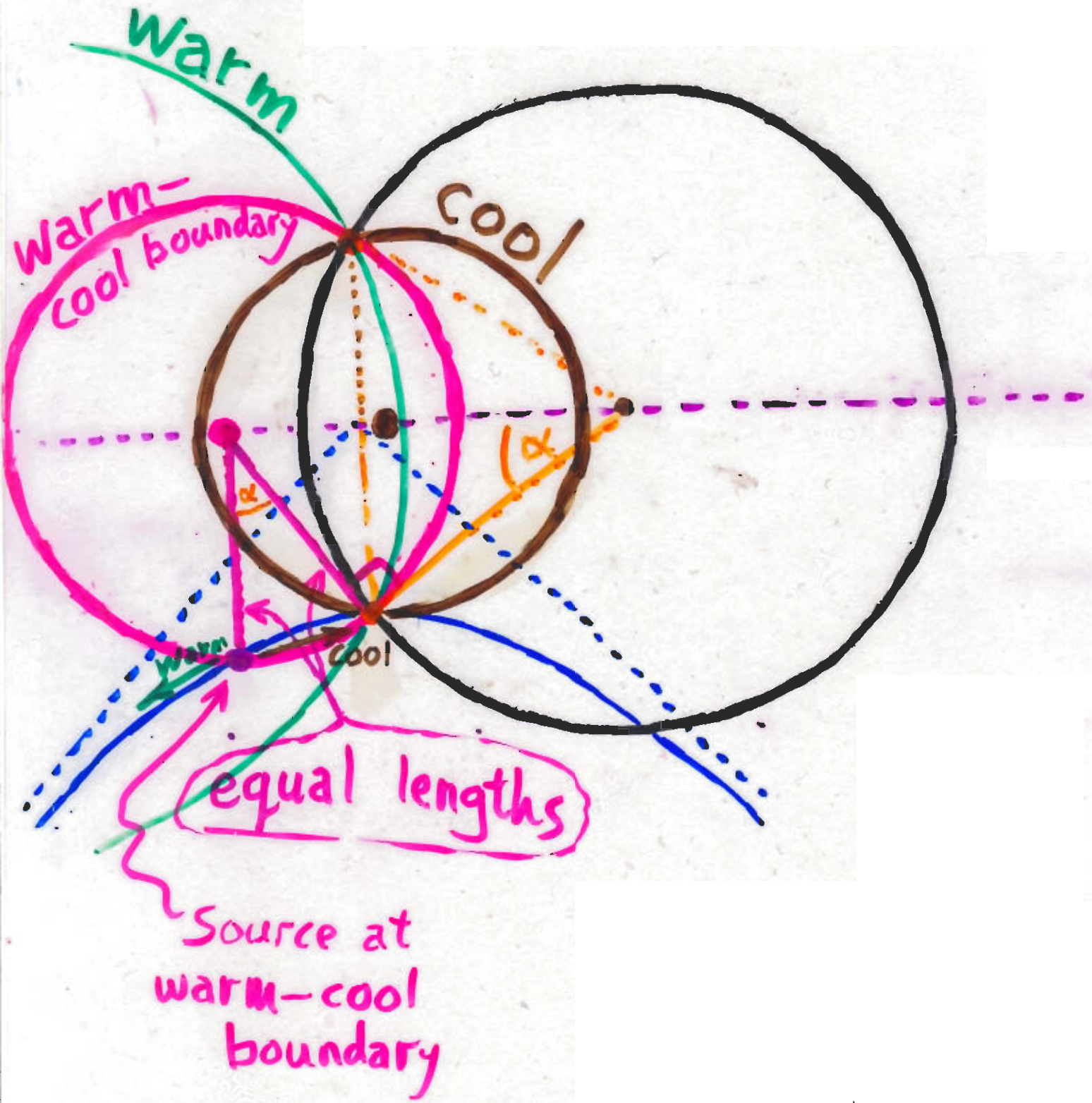


Big Bang of previous aeon if like our own

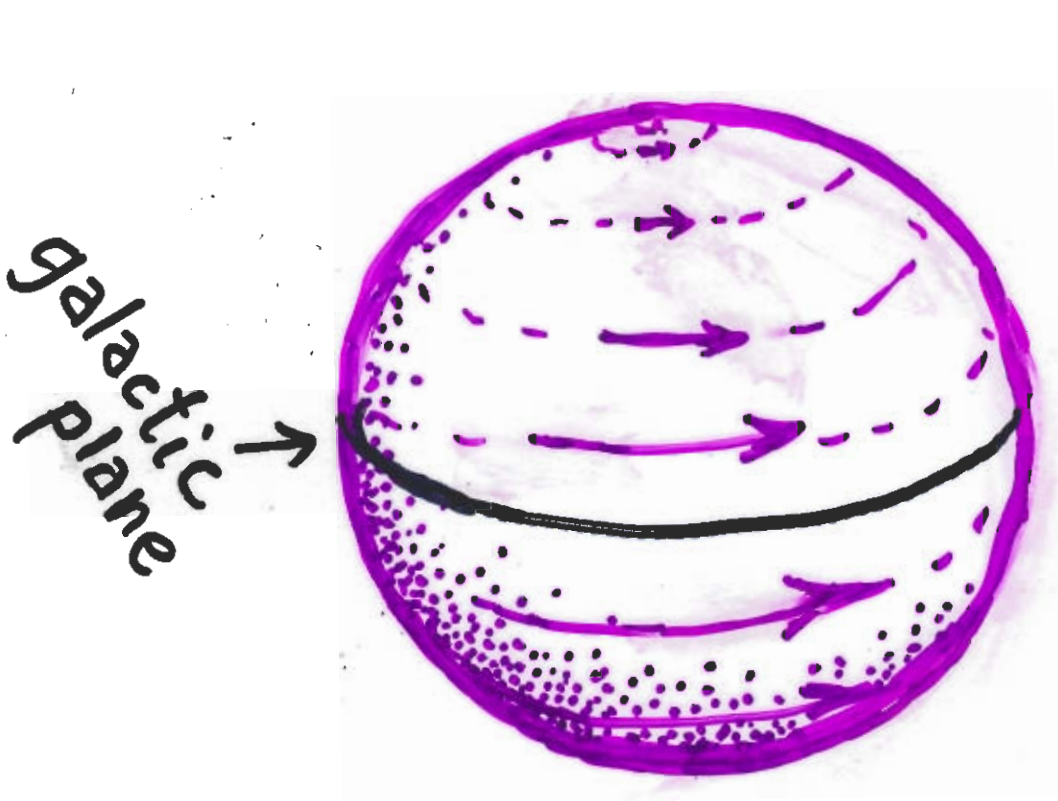

axis of
rotation
α

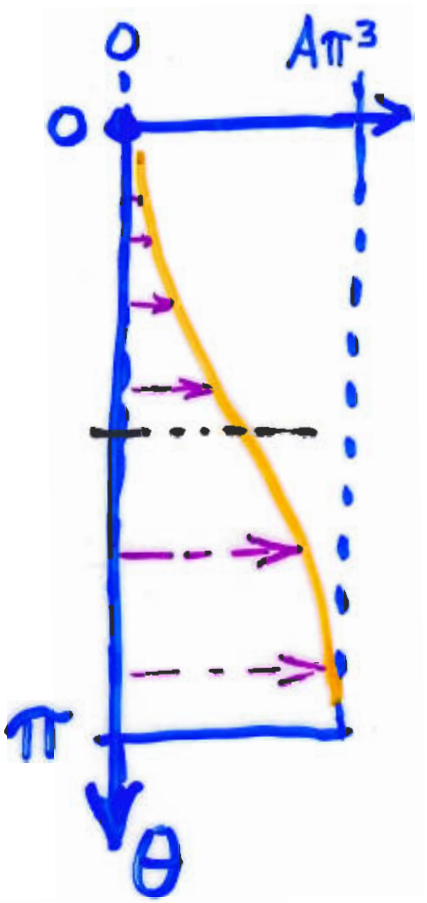

warm
cool
2α
hyperbola of
possible sources
for a given celestial
circle


Warm
warm-
cool boundary
cool


Warm
Warm-
Cool boundary
Cool
α
α
Warm
Cool
equal lengths
Source at
warm-cool
boundary

Twisting the CMB sky





$$\theta' = \theta$$

$$\phi' = \phi + 3A\pi\theta^2 - 2A\theta^3$$

Red: $A = 0$

Green: $A = 0.02$

Blue: $A = 0.05$

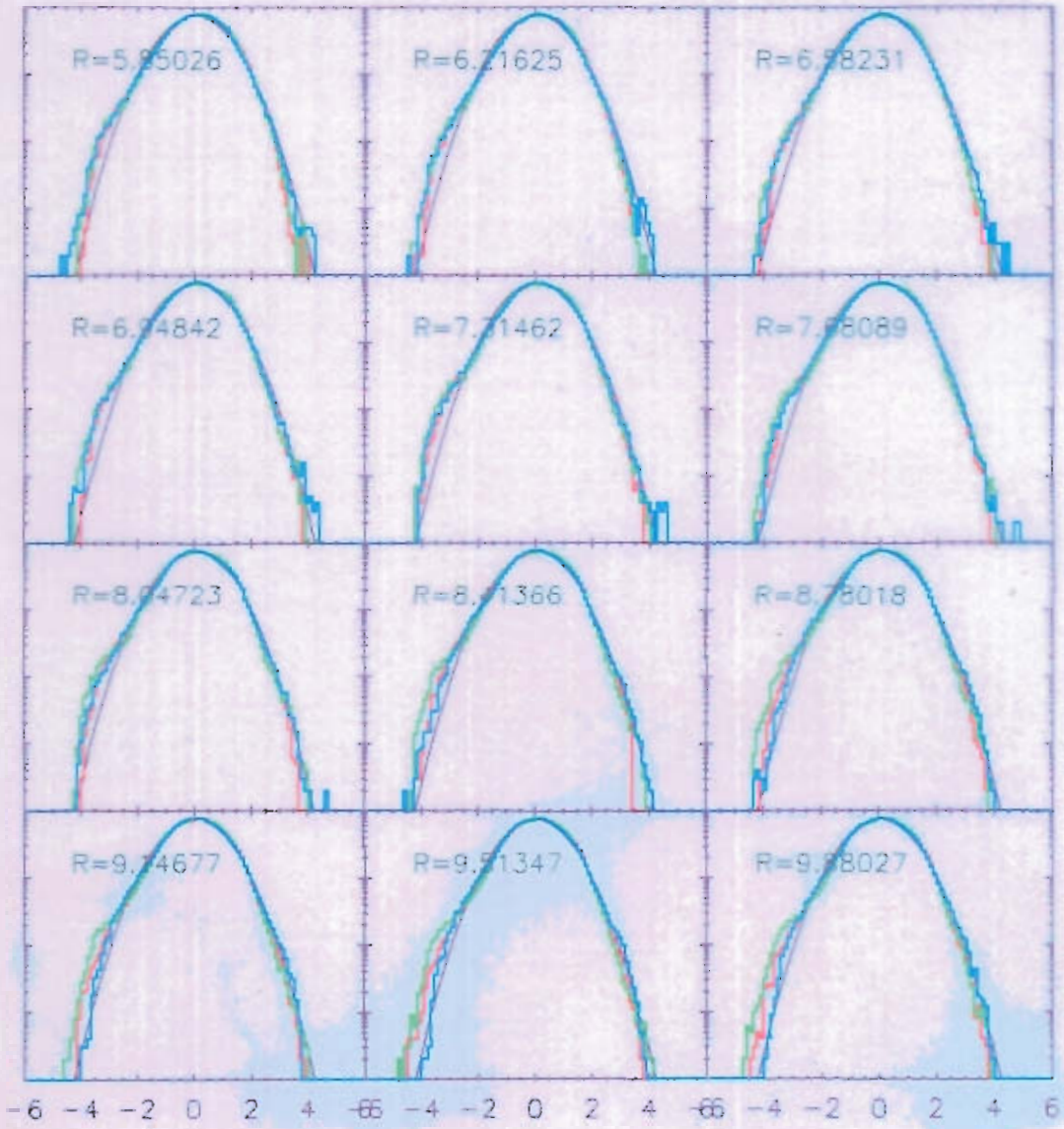


FIG. 33: Red: A = 0, Green: A = 0.02, Blue: A = 0.05, Black: Gaussian Curve.

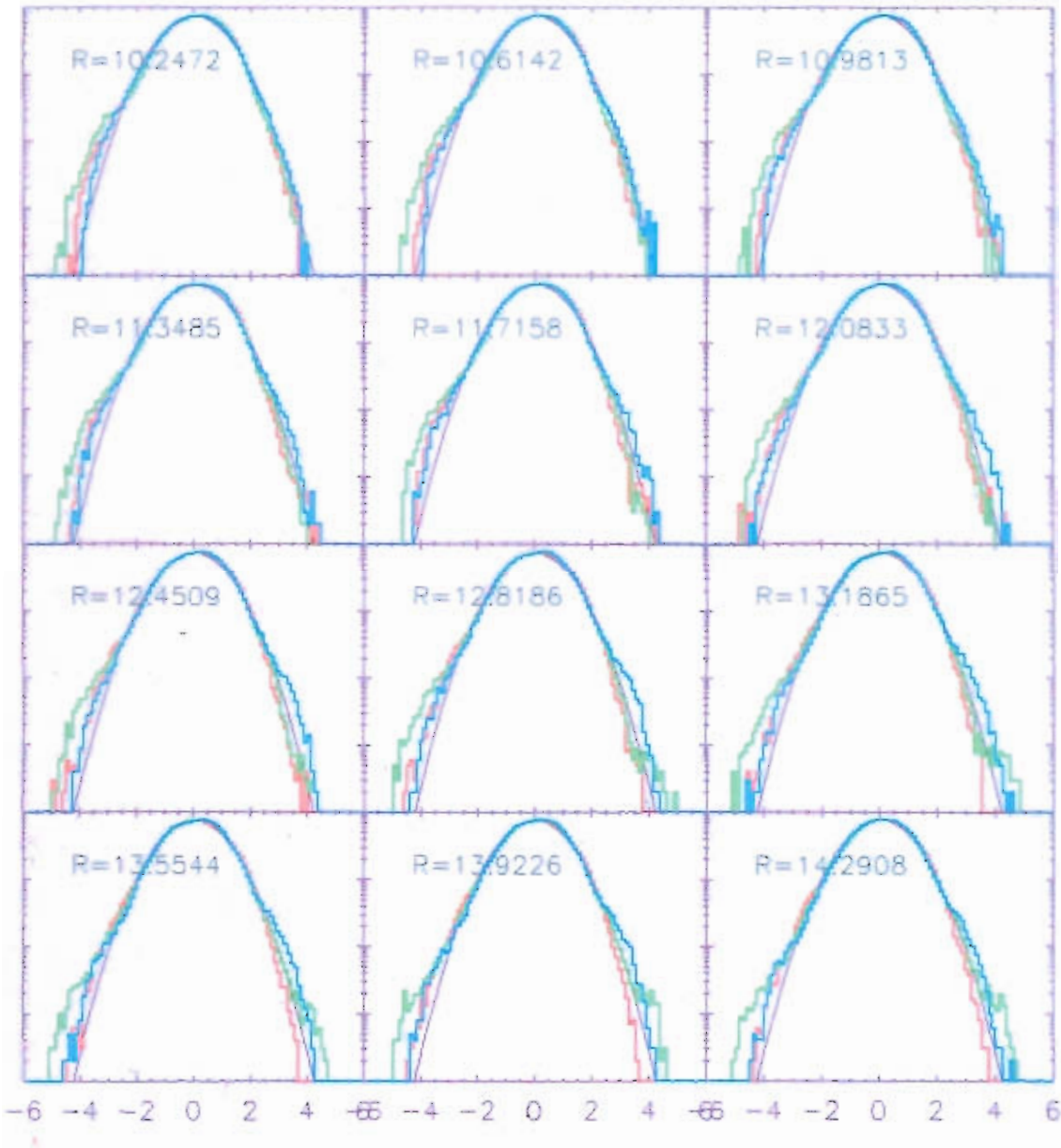
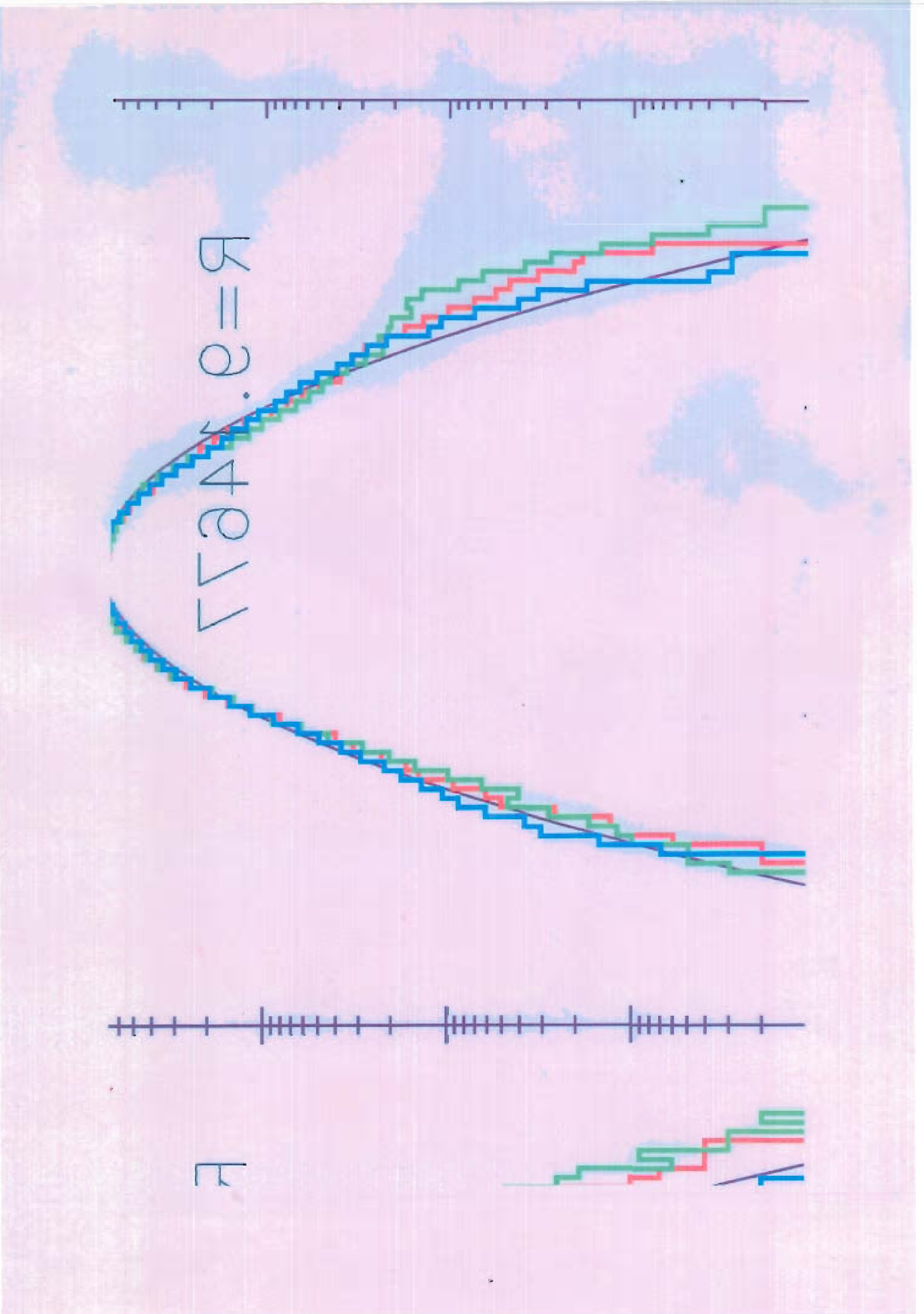
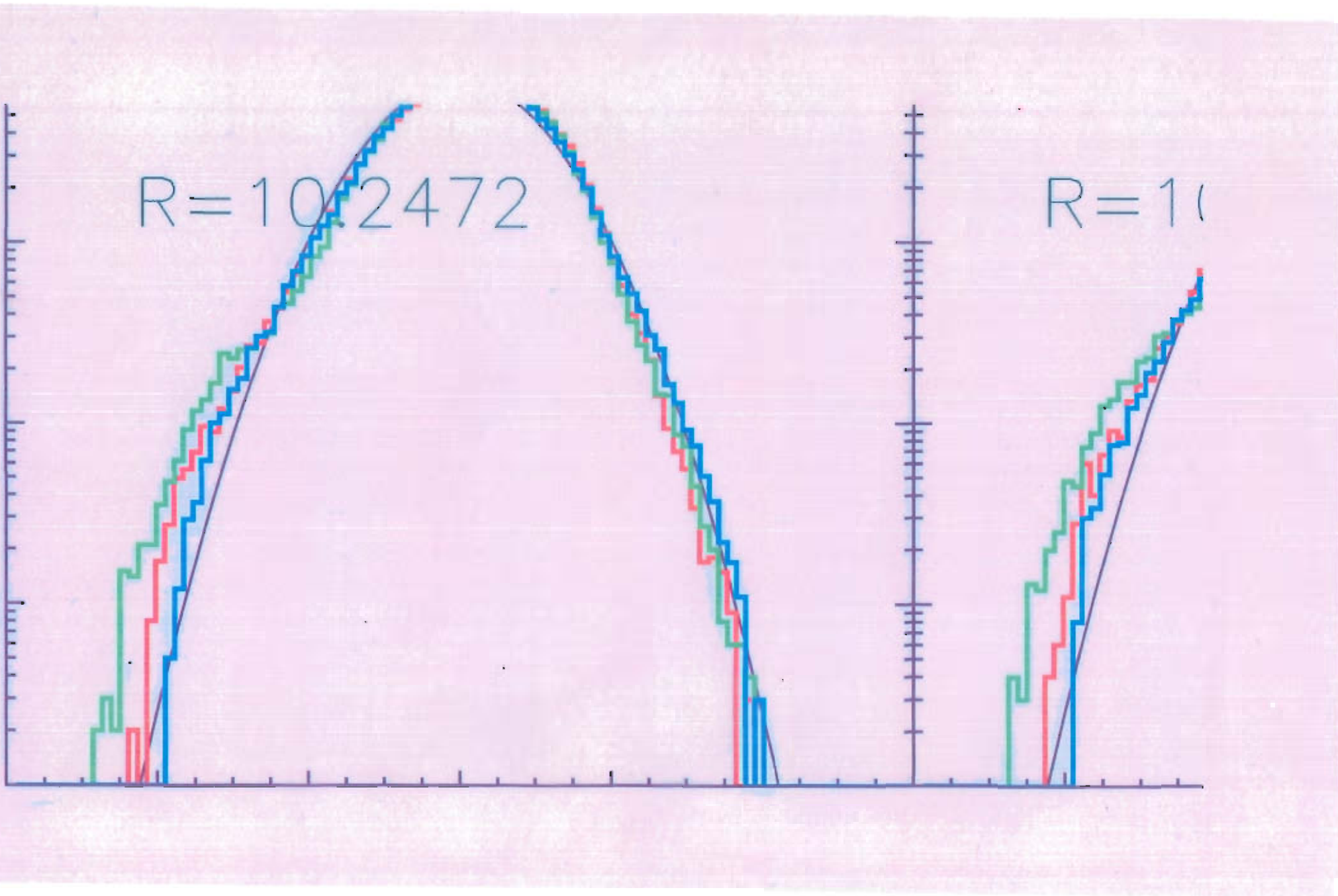


FIG. 34: Red: A = 0, Green: A= 0.02, Blue: A = 0.05, Black: Gaussian Curve.


R=9.14677
F


R=10
2472
R=1(


HAPPY
BIRTHDAY
ADHAV


HAPPY
BIRTHDAY
ADELAY
Whenever it is
next month!

CCC Cyclic Conformal Cosmology

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