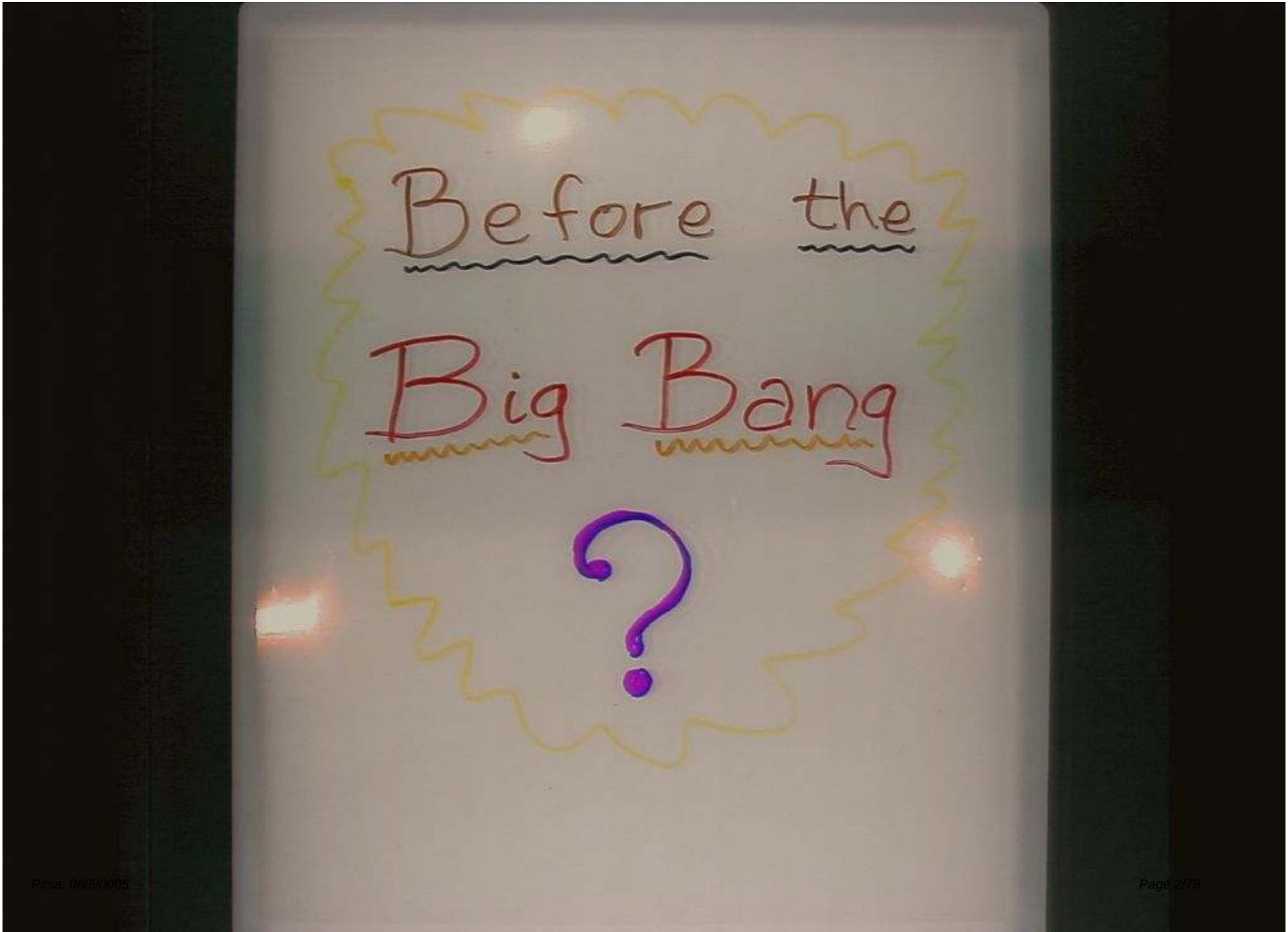
Title: Before the Big Bang: an Outrageous Solution to a Profound Cosmological Puzzle

Date: Sep 12, 2006 02:00 PM

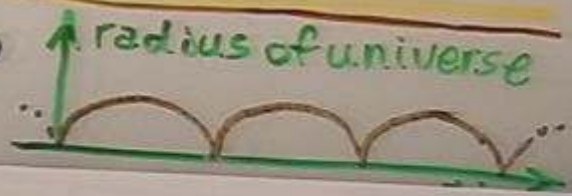
URL: http://pirsa.org/06090005

Abstract:


Before the
Big Bang
?

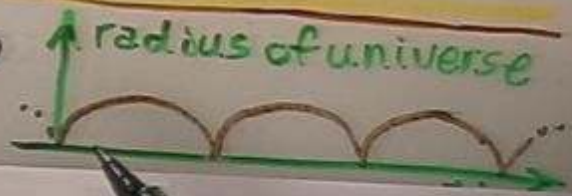
Before the Big Bang?
Some earlier (crazy?) ideas

Friedmann $k>0$
cyclic model



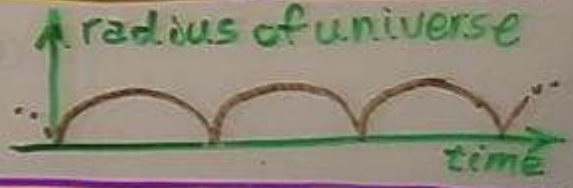
Before the Big Bang?
Some earlier (crazy?) ideas

Friedmann $k>0$
cyclic model



Before the Big Bang?
Some earlier (crazy?) ideas

Friedmann $K>0$
cyclic model

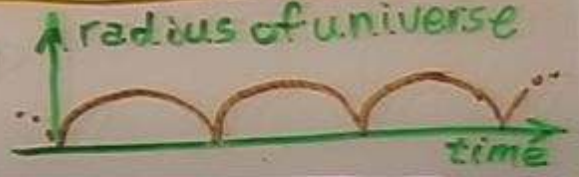


Modifications: Tolman – each cycle changed from previous
(greater max. radius) 2nd law?

Before the Big Bang?

Some earlier (crazy?) ideas

Friedmann $K>0$ cyclic model



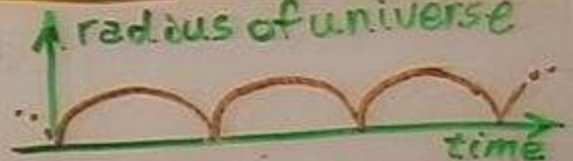
Modifications: Tolman – each cycle changed from previous (greater max. radius:

) 2nd law?

Wheeler: constants of Nature may change from one cycle to next?

Before the Big Bang?
Some earlier (crazy?) ideas

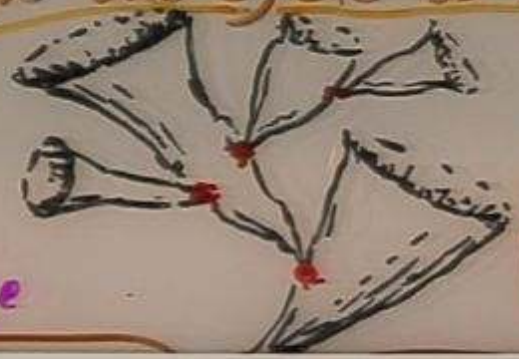
Friedmann $K>0$
cyclic model



Modifications: Tolman – each cycle changed from previous (greater max. radius) 2nd law?

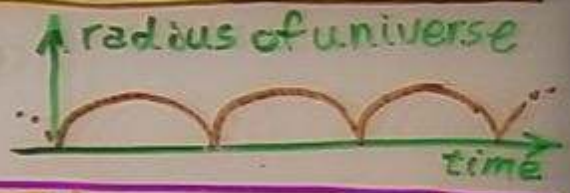
Wheeler: constants of Nature may change from one cycle to next

Smolin: each black-hole sing. is seed of next universe



(Geometry doesn't fit....)

Friedmann K>0
cyclic model



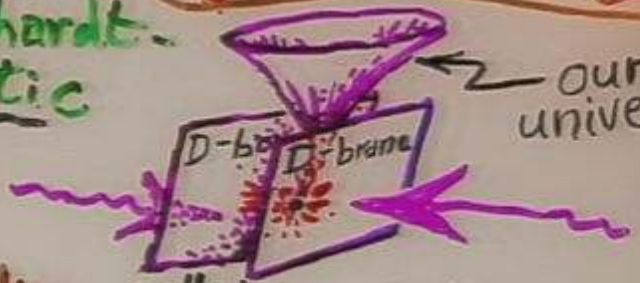
Modifications: Tolman – each cycle changed from previous (greater max. radius:) 2nd law?

Wheeler: constants of Nature may change from one cycle to next

Smolin: each black-hole sing. is seed of next universe

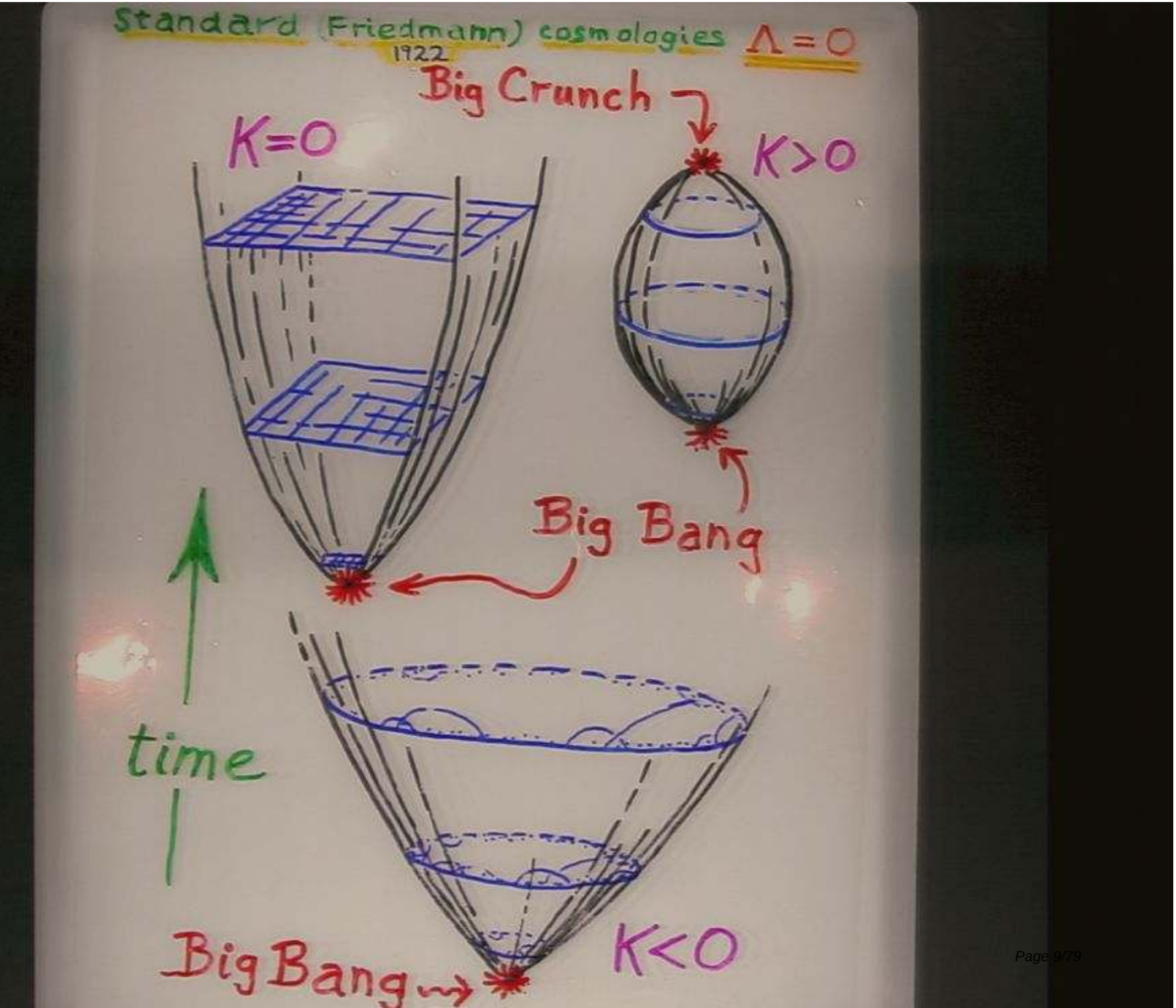
(Geometry doesn't Fit....)

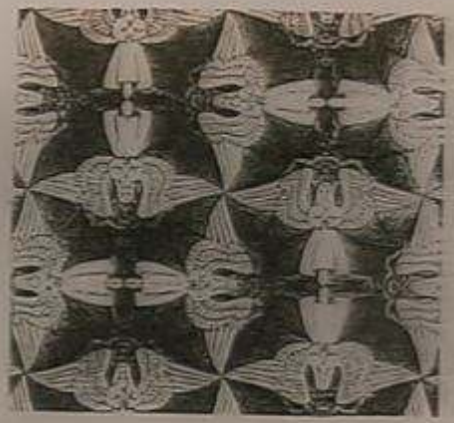
Turok-Steinhardt... Ekpyrotic

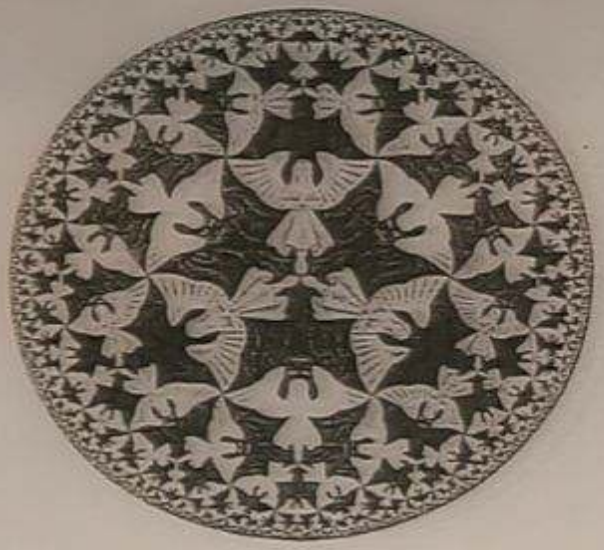


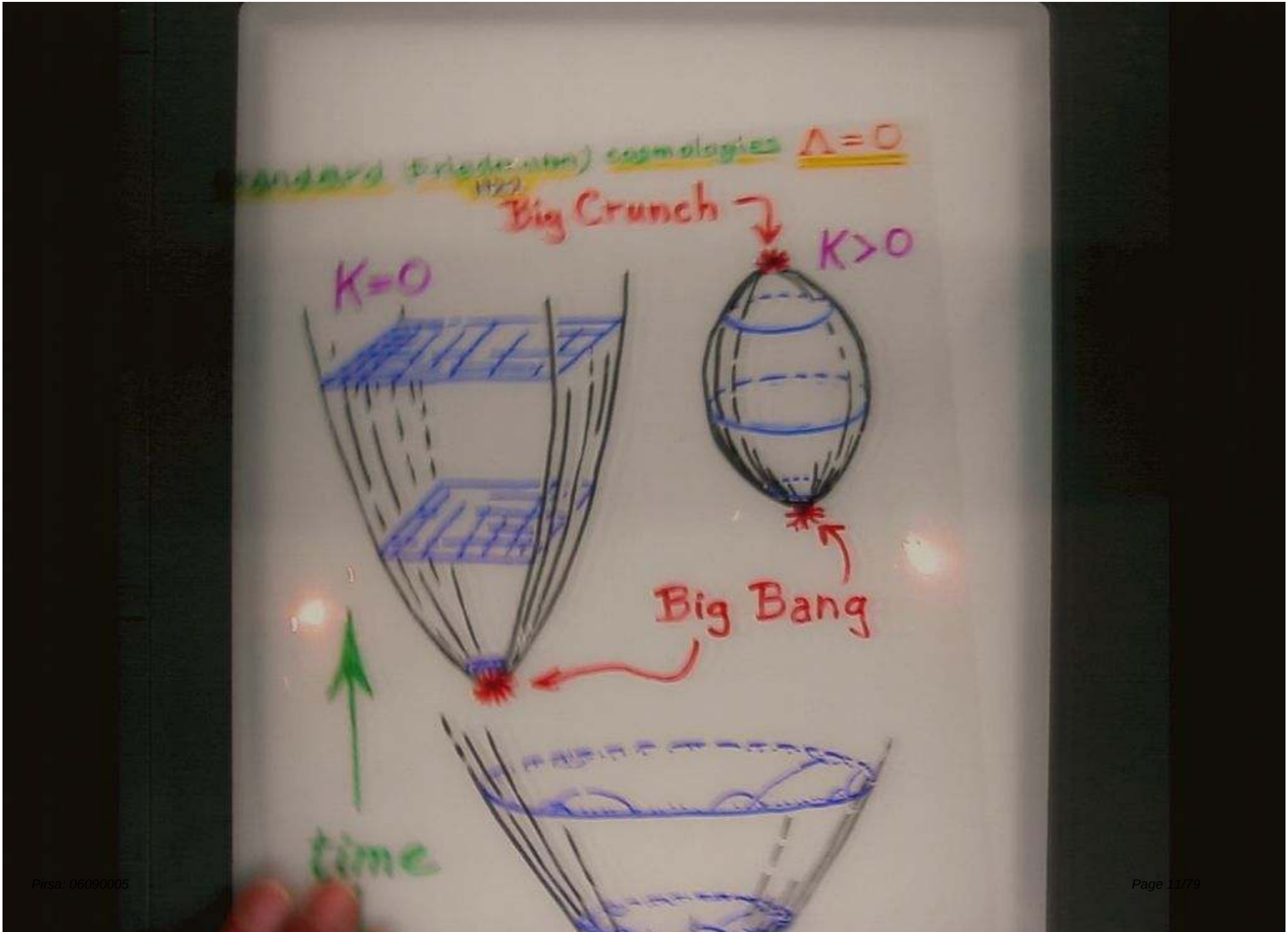
stringy... need to believe in extra (stringy) dims

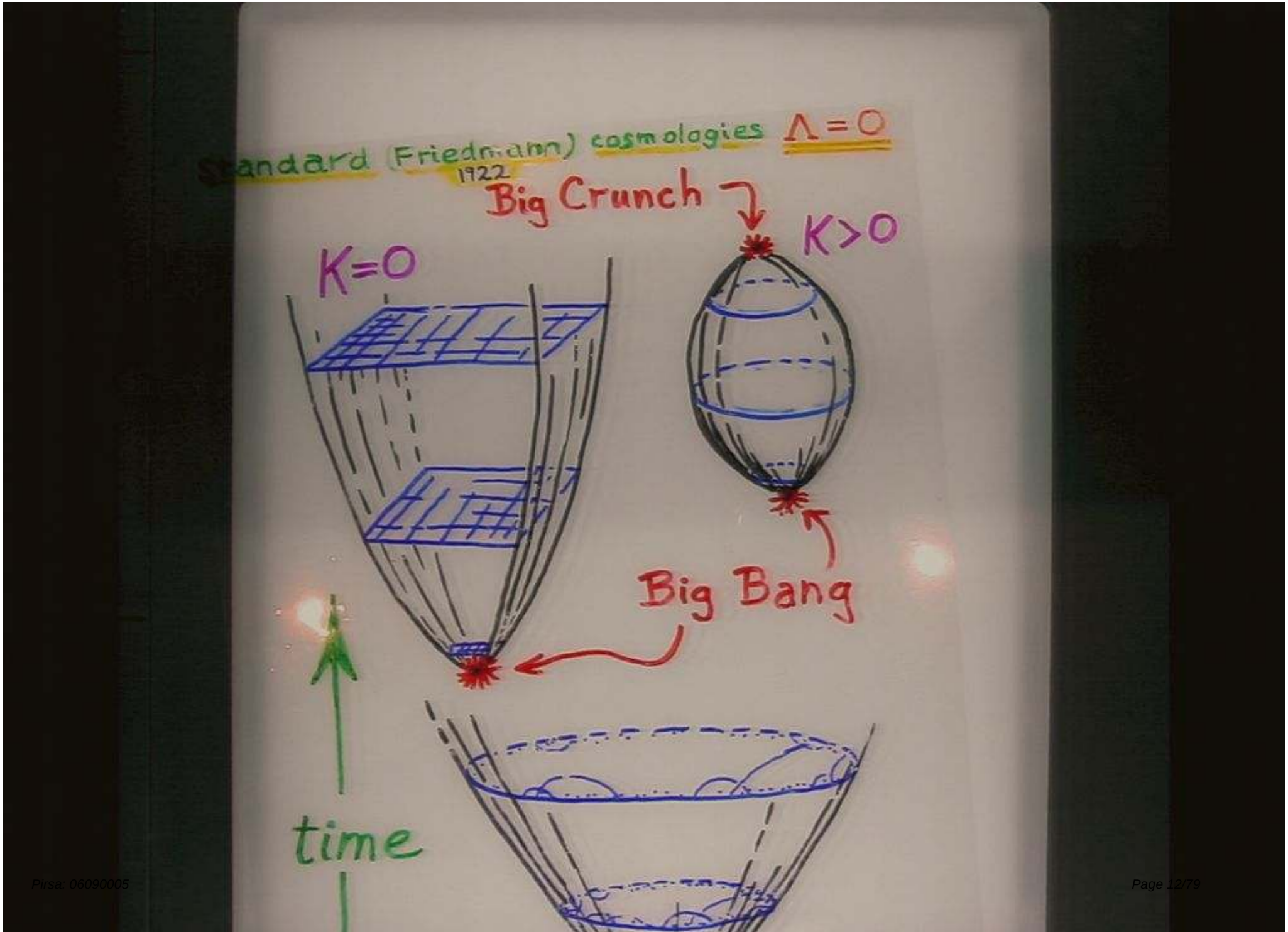
Veneziano ... (then Steinhardt-Turok) maybe closest to my idea?

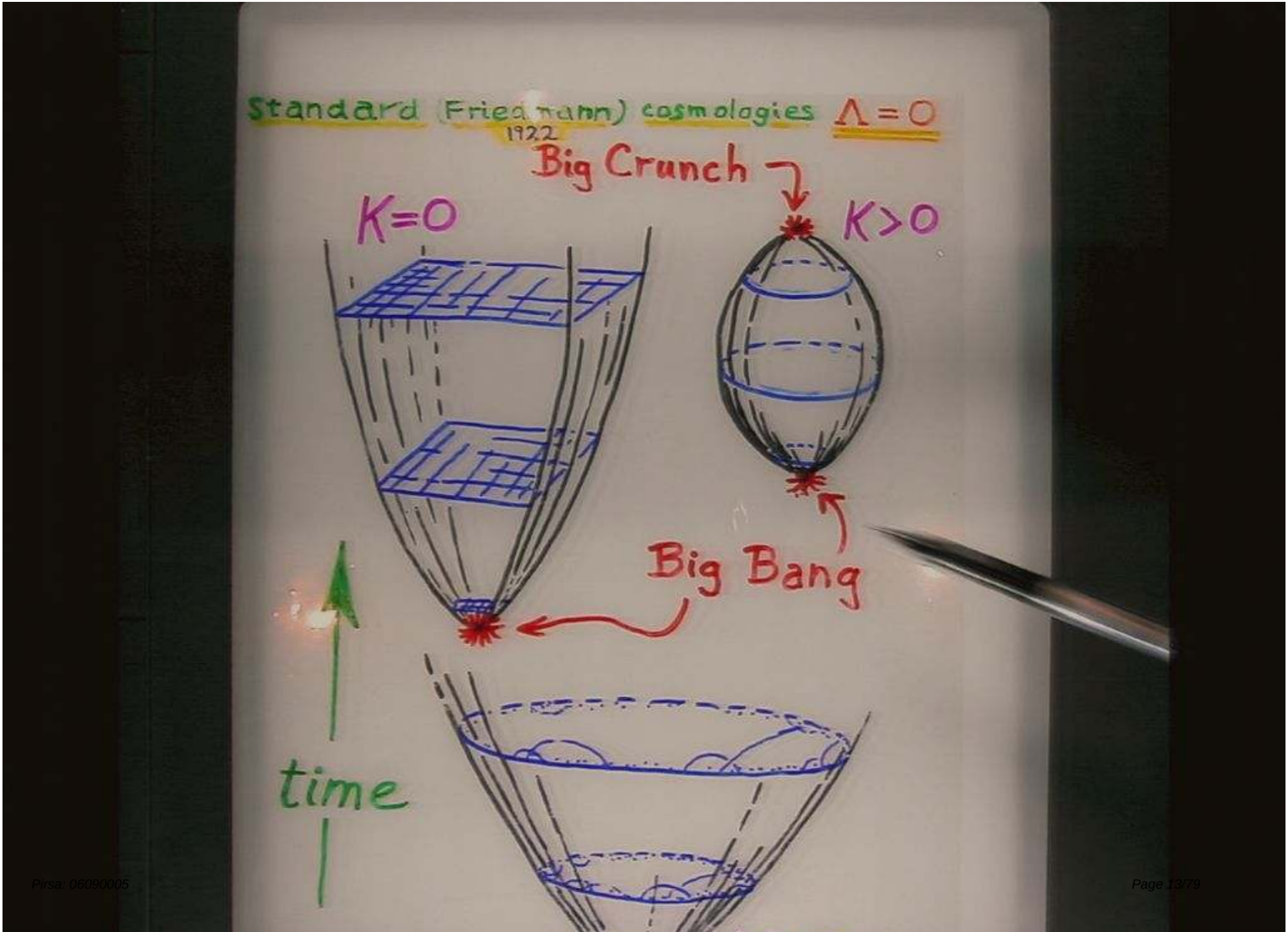

Standard (Friedmann) cosmologies Λ=0
1922
Big Crunch
K=0
K>0
Big Bang
time
Big Bang
K<0






Λ=0
Big Crunch
K>0
K=0
Big Bang
time


Standard (Friedmann) cosmologies Λ=0
1922
Big Crunch
K>0
K=0
Big Bang
time


Standard (Friedmann) cosmologies Λ=0
1922
Big Crunch
K=0
K>0
Big Bang
time

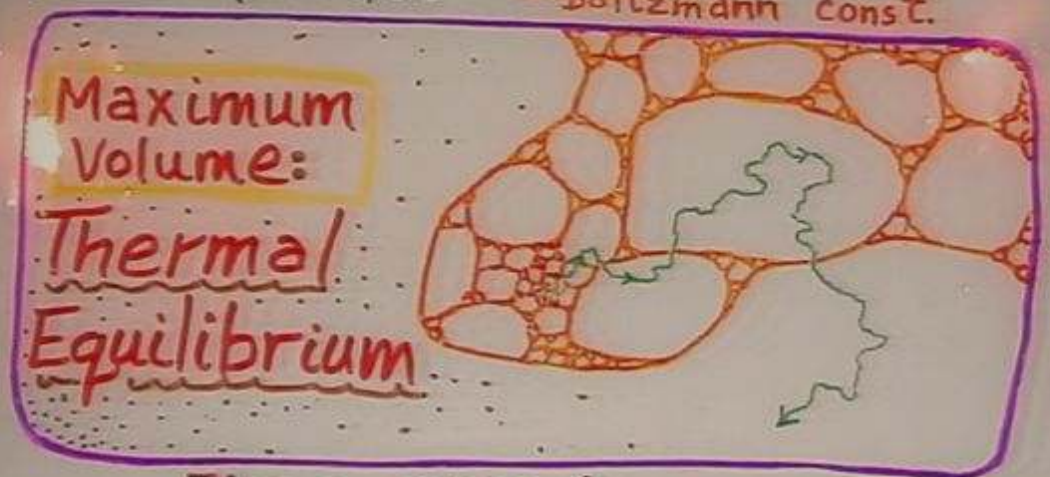
The 2nd law of thermodynamics

time

Entropy: $S = k \log V$ increases

V = vol. in phase space

Boltzmann const.



Phase space (coarse-grained)

S entropy

The 2nd law of thermodynamics

The 2nd law of thermodynamics

time

Entropy: $S = k \log V$ increases

V = vol. in phase space

Boltzmann const.

The 2nd law of thermodynamics

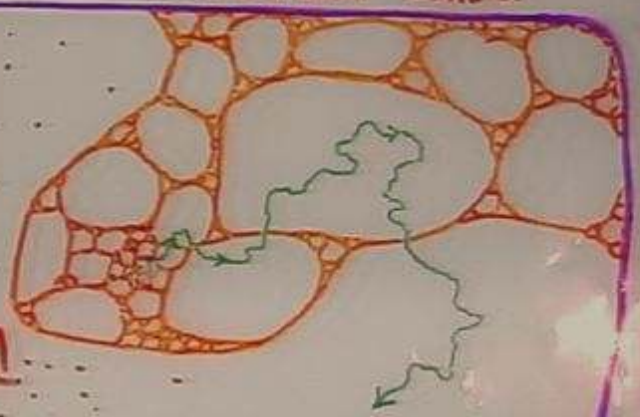
time

Entropy: $S = k \log V$ increases

V = vol. in phase space

Boltzmann const.

Maximum Volume: Thermal Equilibrium



Phase space (coarse-grained)

time

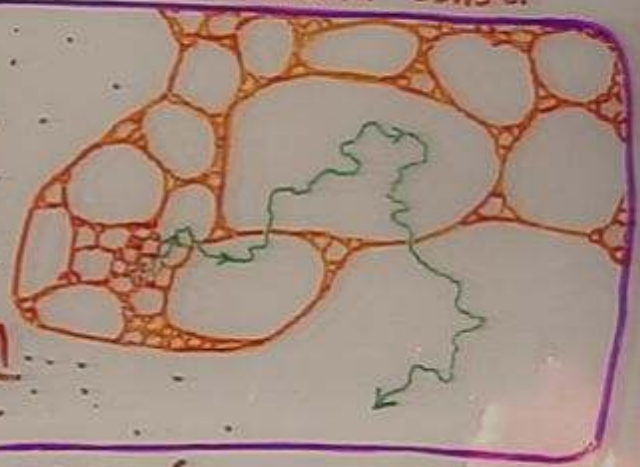
Entropy: $S = k \log V$ increases

V = vol. in phase space

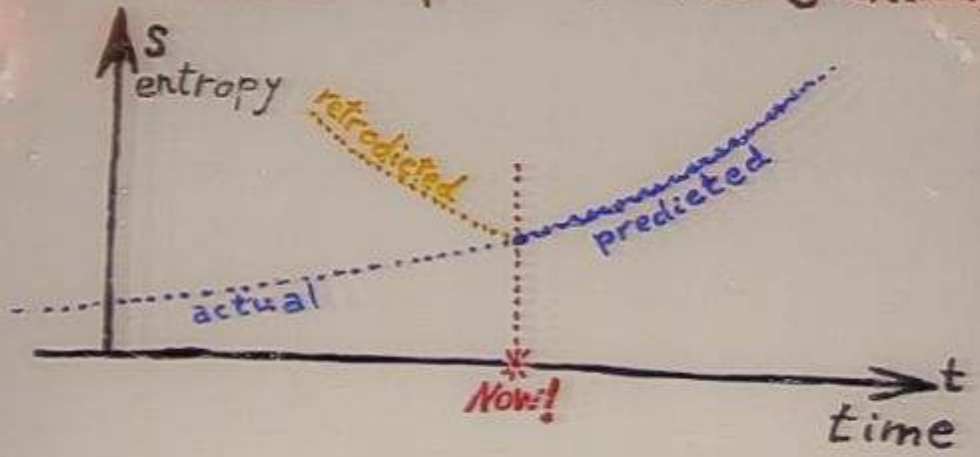
Boltzmann const.

Maximum Volume:

Thermal Equilibrium



Phase space (coarse-grained)



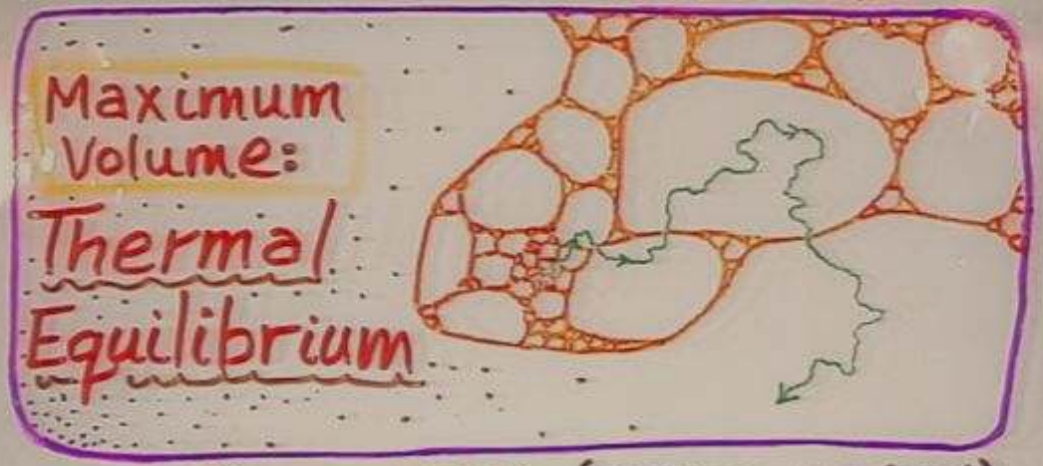
The 2nd law of thermodynamics

time

Entropy: $S = k \log V$ increases

V = vol. in phase space

Boltzmann const.



Phase space (coarse-grained)

time

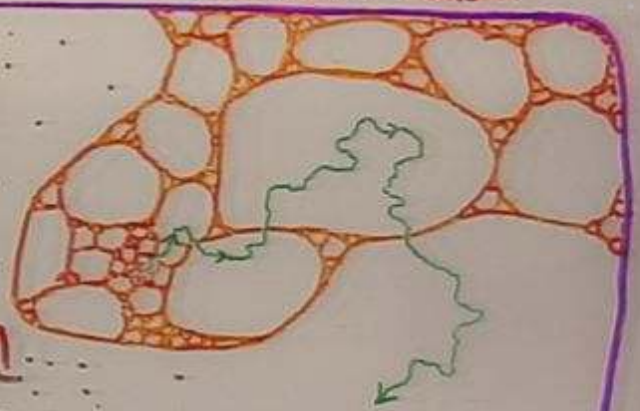
Entropy: $S = k \log V$ increases

V = vol. in phase space

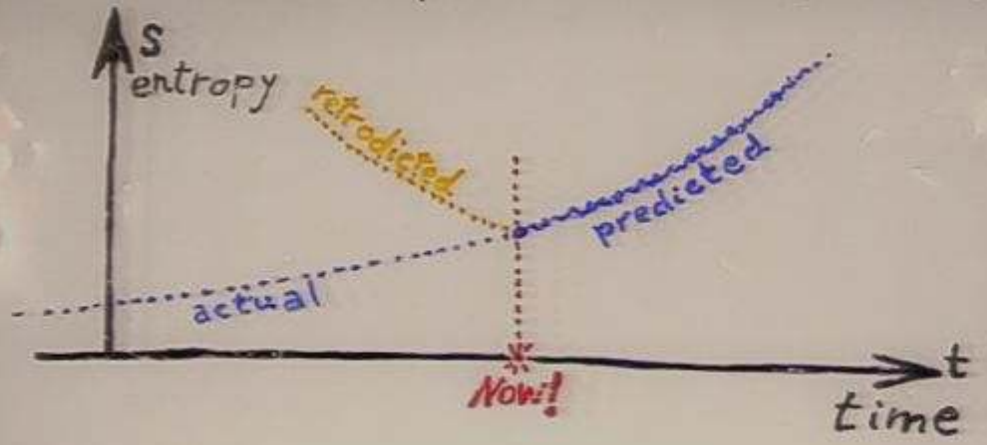
Boltzmann const.

Maximum Volume:

Thermal Equilibrium



Phase space (coarse-grained)



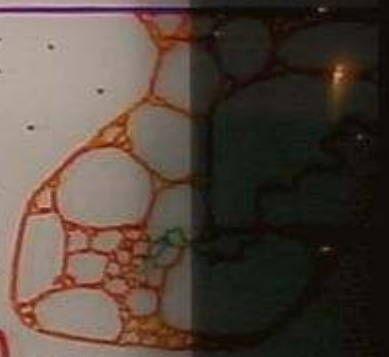
Entropy: $S = k \log V$

V = vol. in phase space

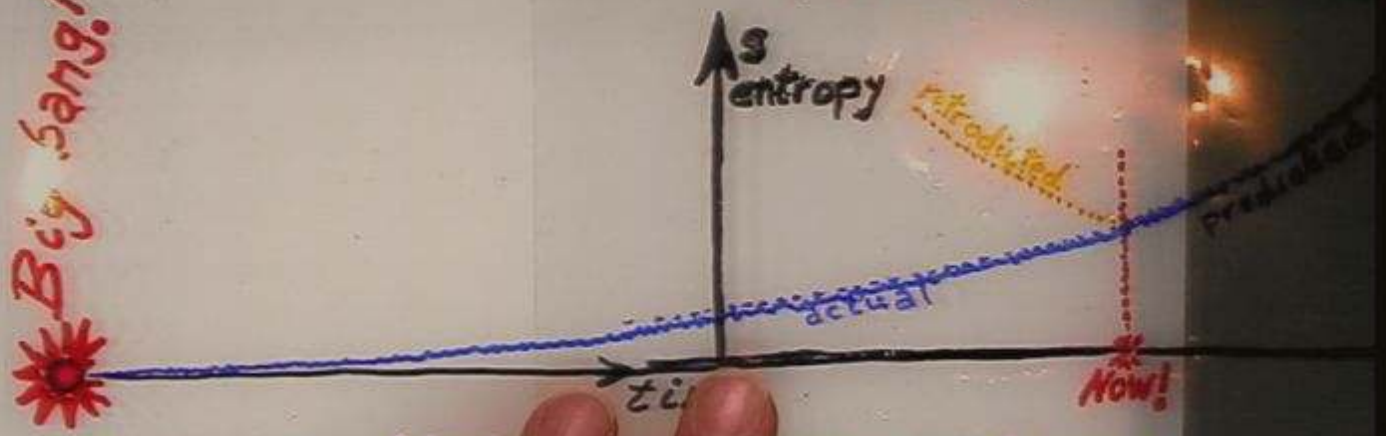
Boltzmann

Maximum Volume:

Thermal Equilibrium



Phase space



To ensure that the entropy continues to go down in the past we need an enormous compression of the space-time geometry

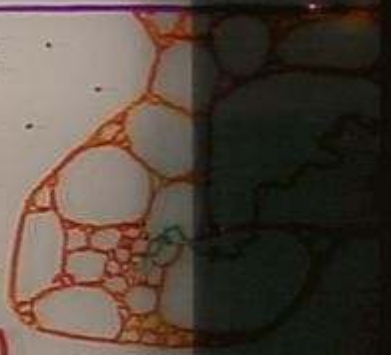
Entropy: $S = k \log V$

V = vol. in phase space

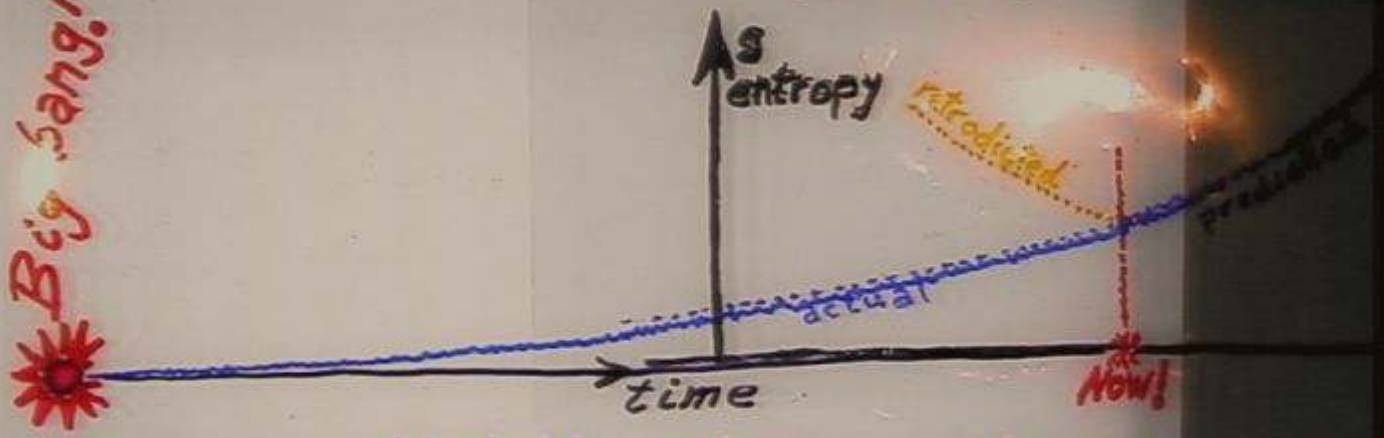
Boltzmann

Maximum Volume:

Thermal Equilibrium



Phase space



To ensure that the entropy continues to go down in the past, we need an enormous constraint on the space-time geometry at the Big Bang.

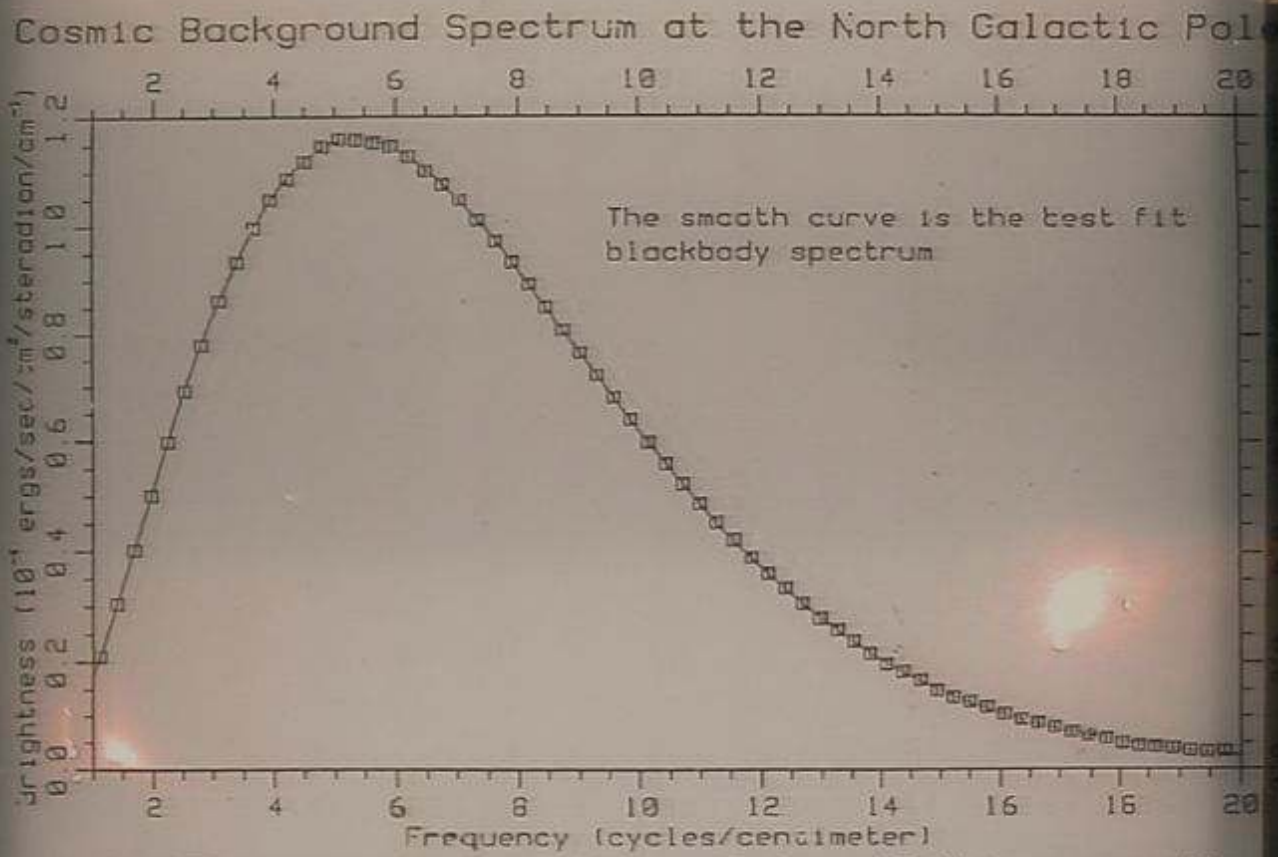


FIG. 9. The spectrum of the Cosmic Microwave Background Radiation as measured by the COBE satellite in the direction of the North Galactic Pole. Within the quoted errors, the spectrum is that of a perfect black body at radiation temperature 2·735 ± 0·06 K (Mather *et al.* 1990).

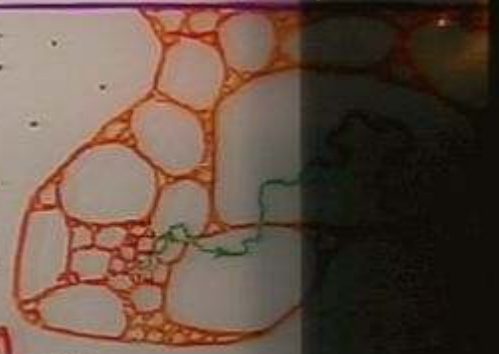
Entropy: $S = k \log V$

V = vol. in phase space

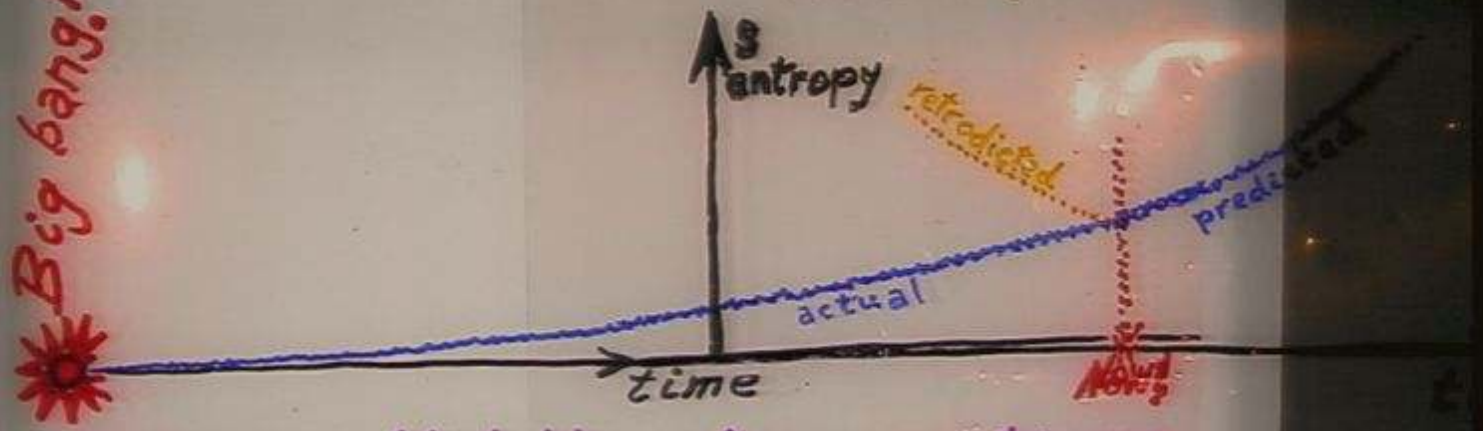
Boltzmann const

Maximum Volume:

Thermal Equilibrium



Phase space (coar



To ensure that the entropy continues to go down in the past, we need an enormous constraint on the space-time geometry at the Big Bang.

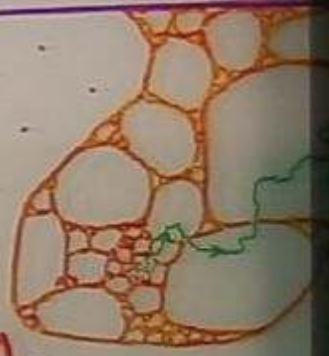
Entropy: $S = k \log V$

V = vol. in phase space

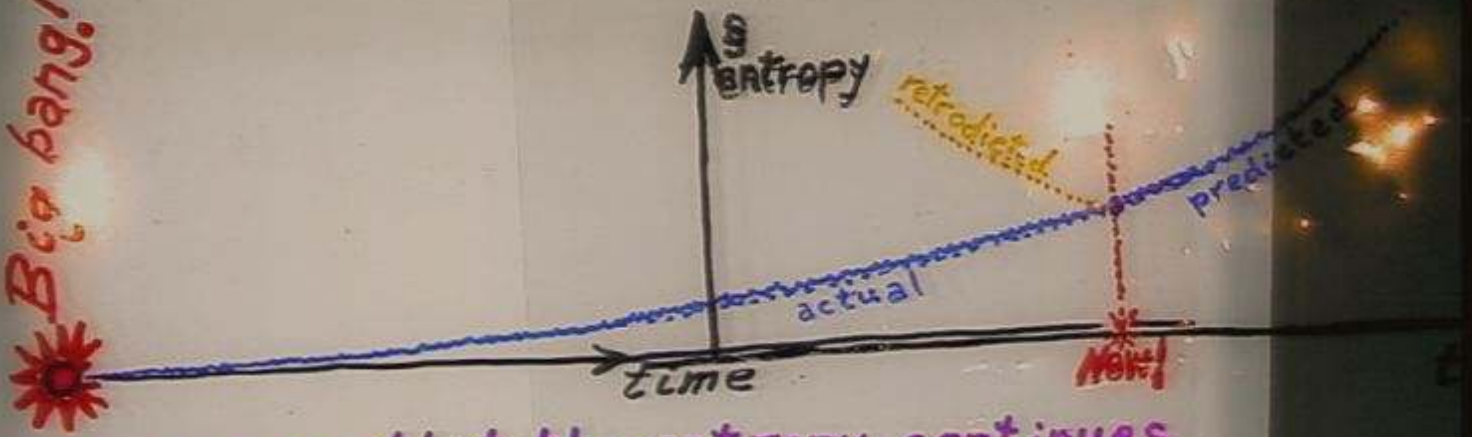
Boltzmann const

Maximum Volume:

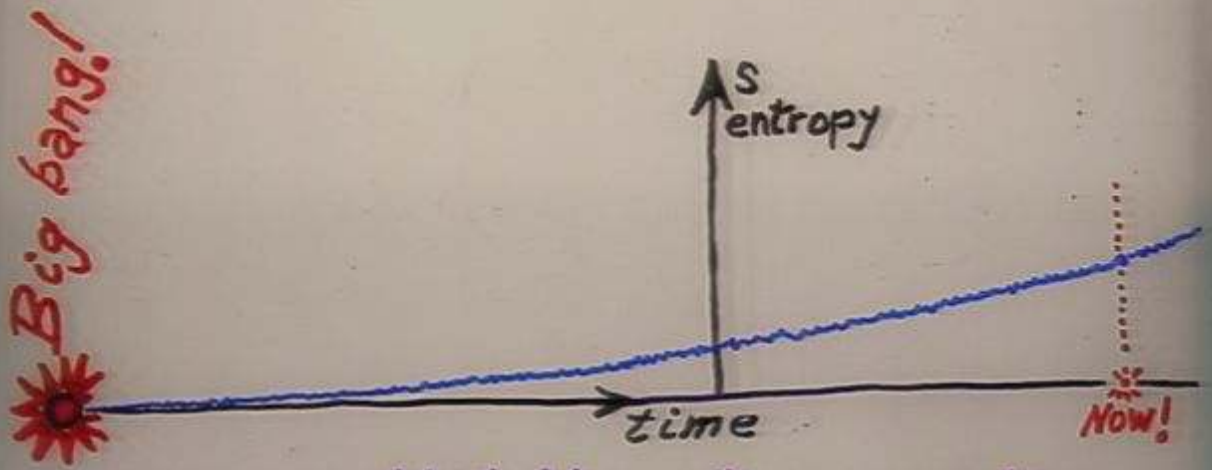
Thermal Equilibrium



Phase space (coar



To ensure that the entropy continues to go down in the past, we need an enormous constraint on the space-time geometry at the Big Bang.



To ensure that the entropy continues to go down in the past, we need an enormous constraint on the space-time geometry at the Big Bang.

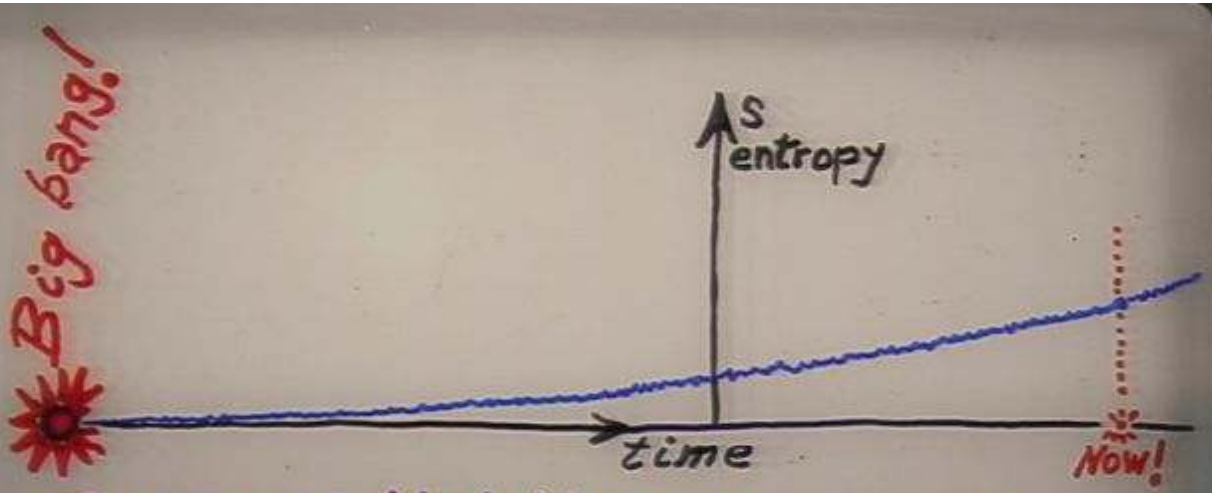
Conformal curvature ≈ 0

Why on the geometry?

Because the matter itself was apparently in a *thermal state* (= maximum entropy) to get agreement with observation.

How do we estimate the contribution of the geometry?

How enormous is (was!) this



To ensure that the entropy continues to go down in the past, we need an enormous constraint on the space-time geometry at the Big Bang.

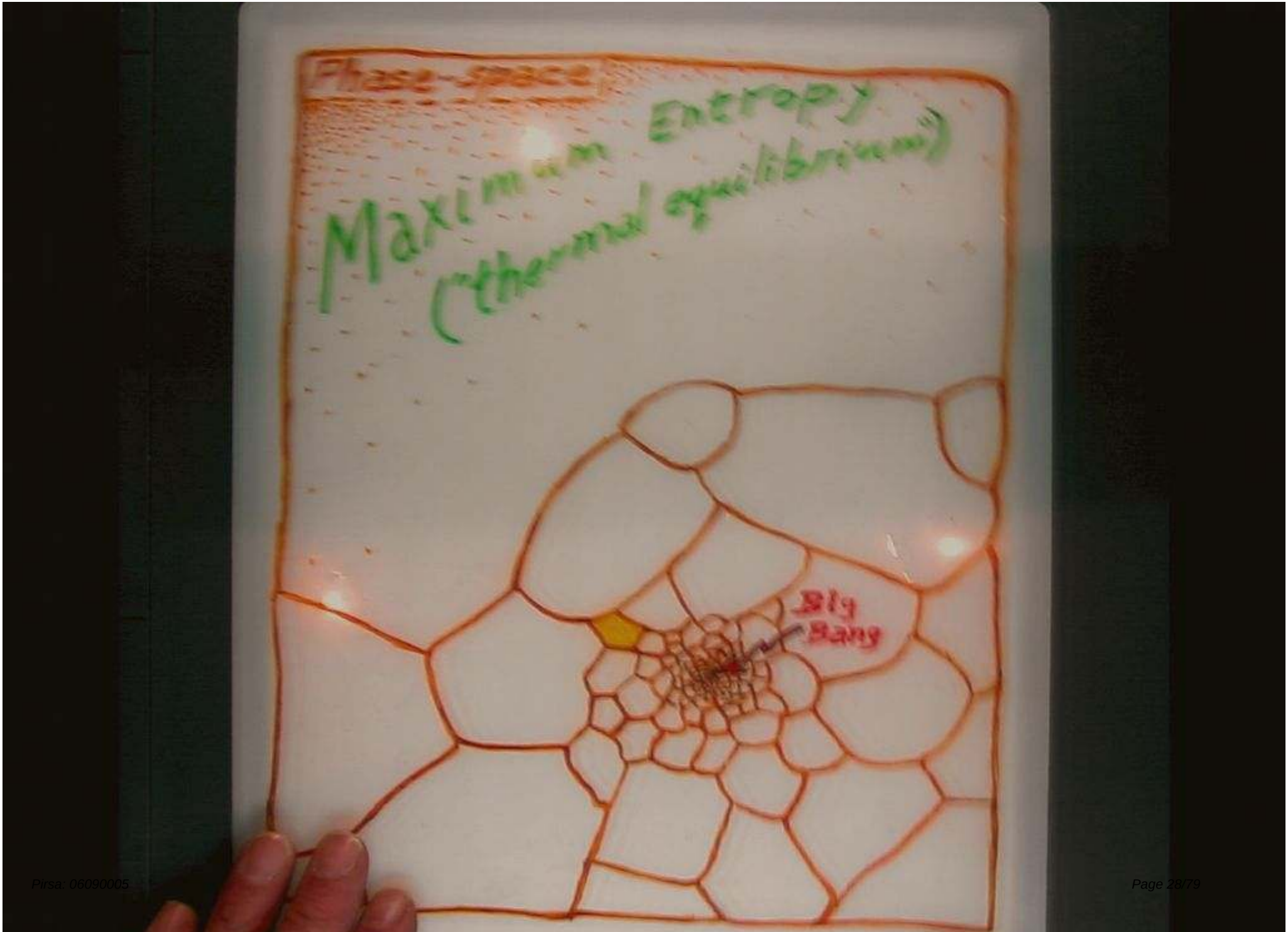
Why on the geometry?

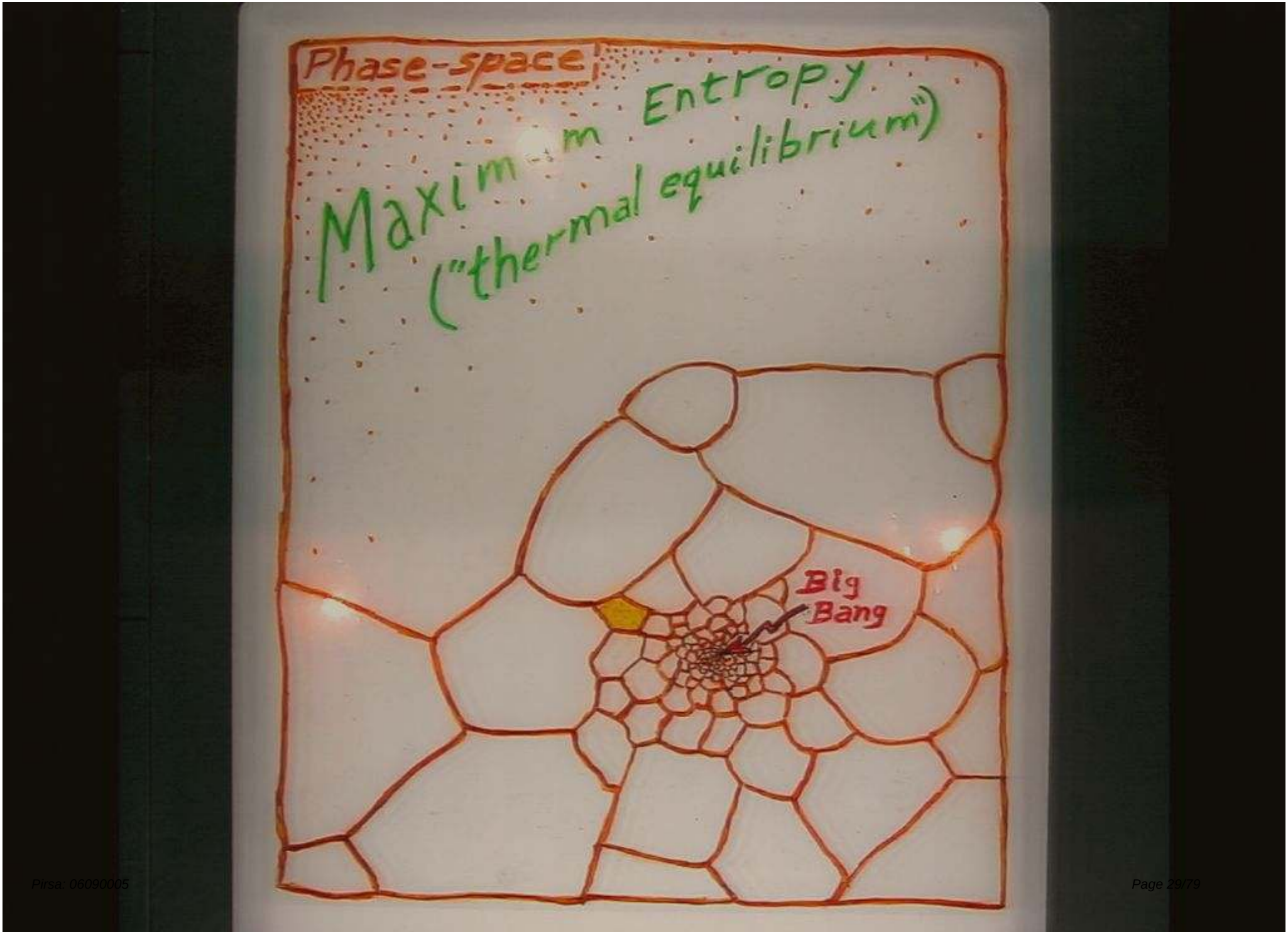
Conformal curvature ≈ 0

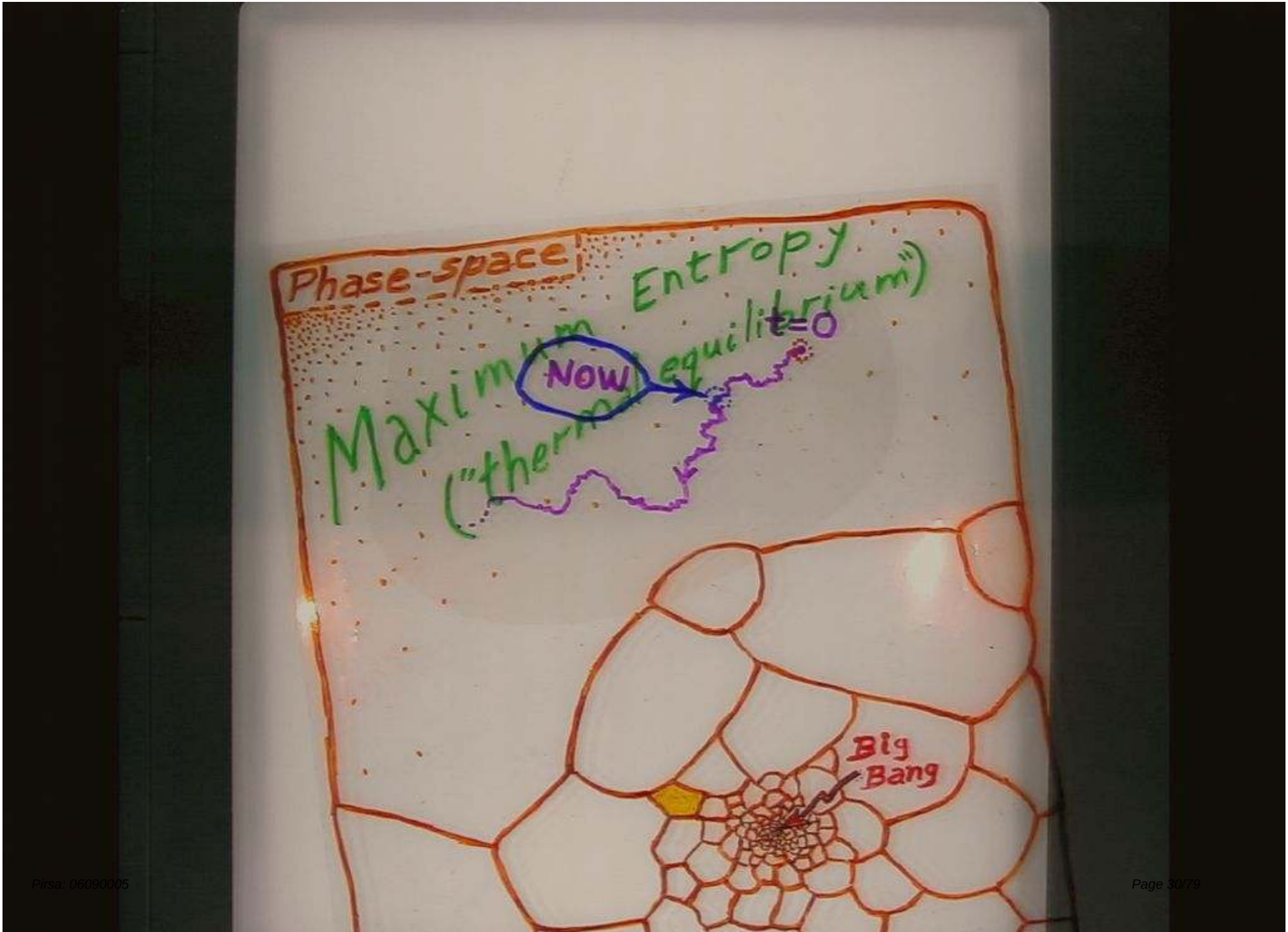
Because the matter itself was apparently in a *thermal state* (= maximum entropy) to get agreement with observation.

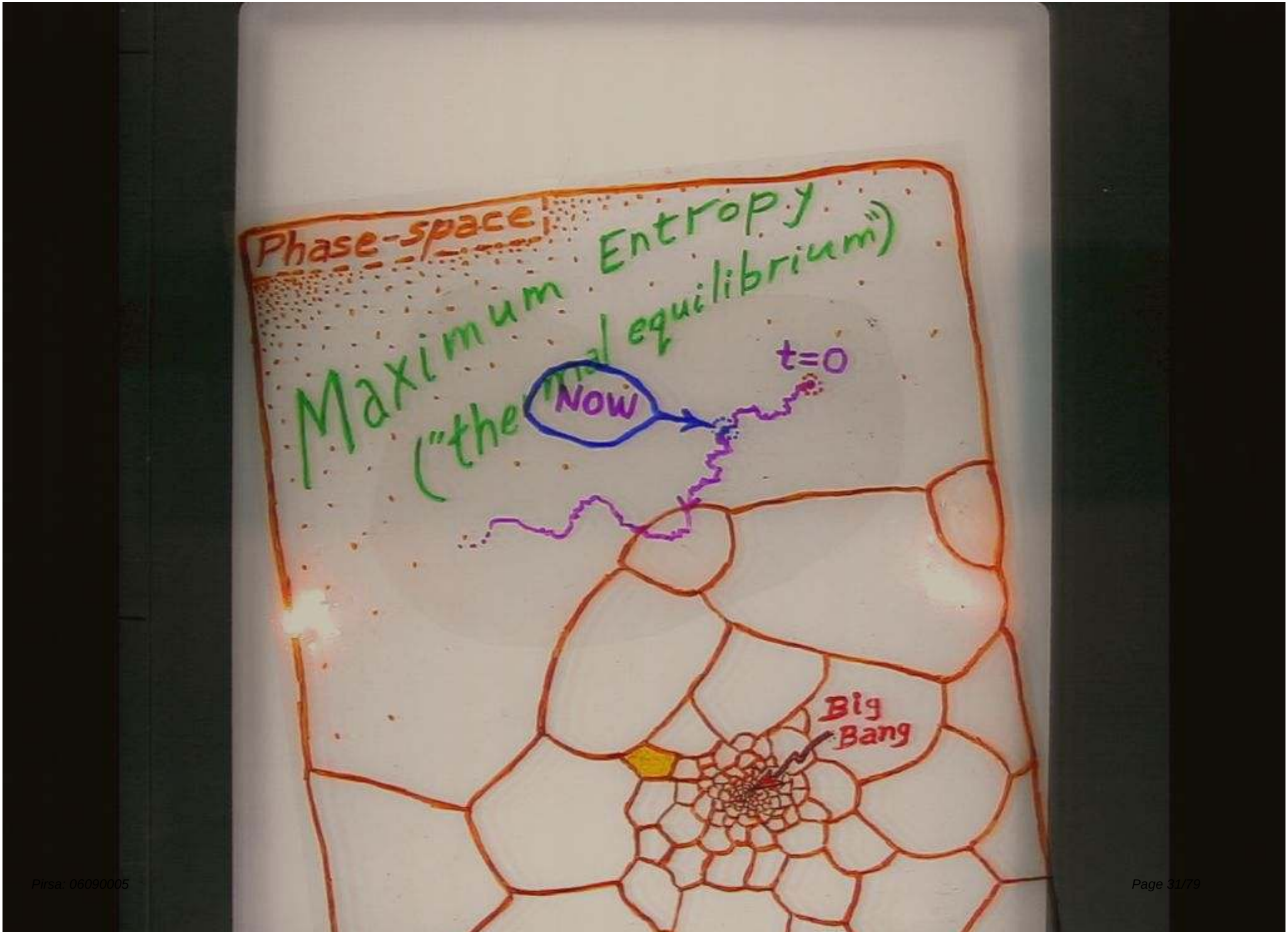
How do we estimate the contribution of the geometry?

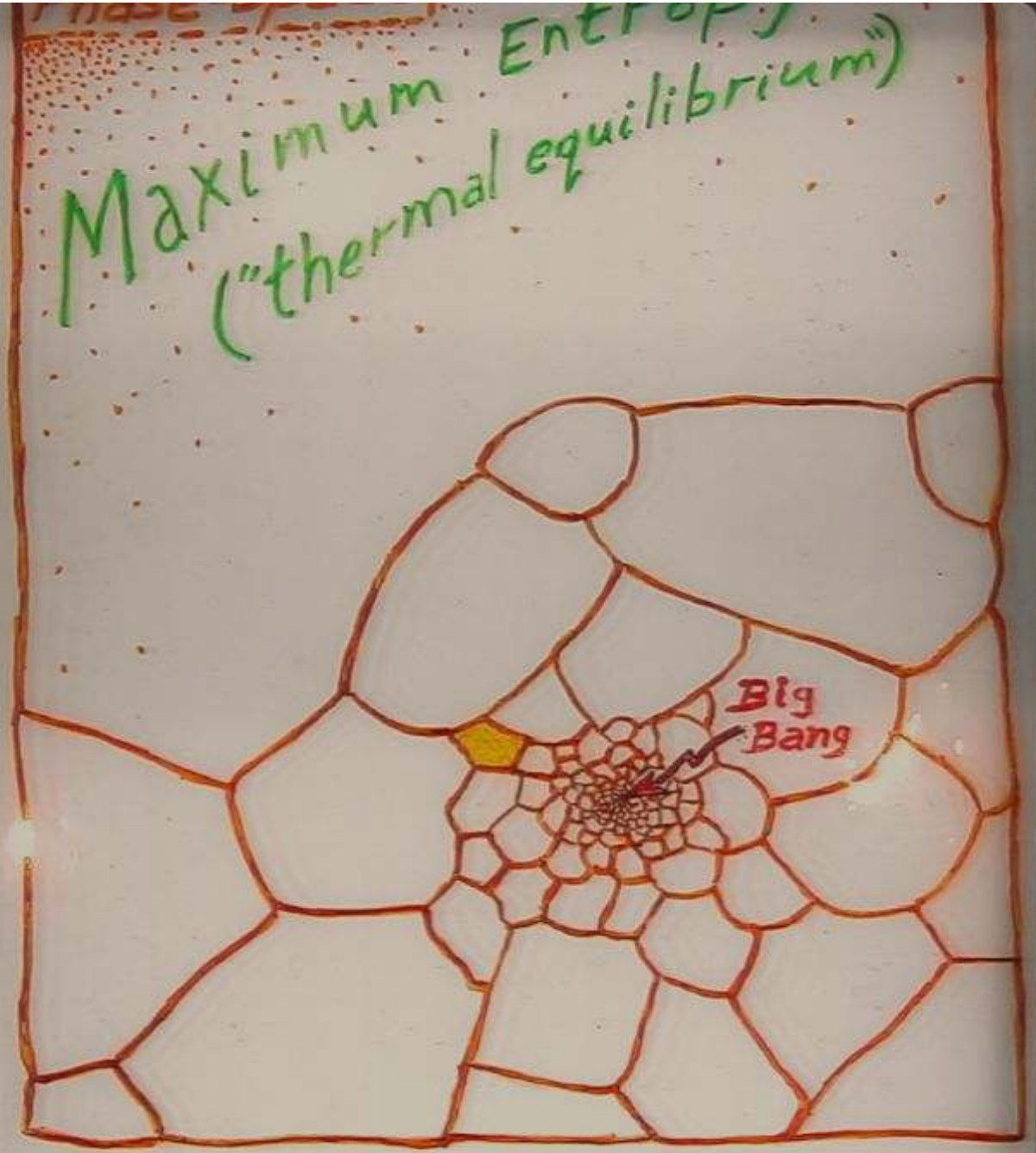
How enormous is (was!) this constraint?

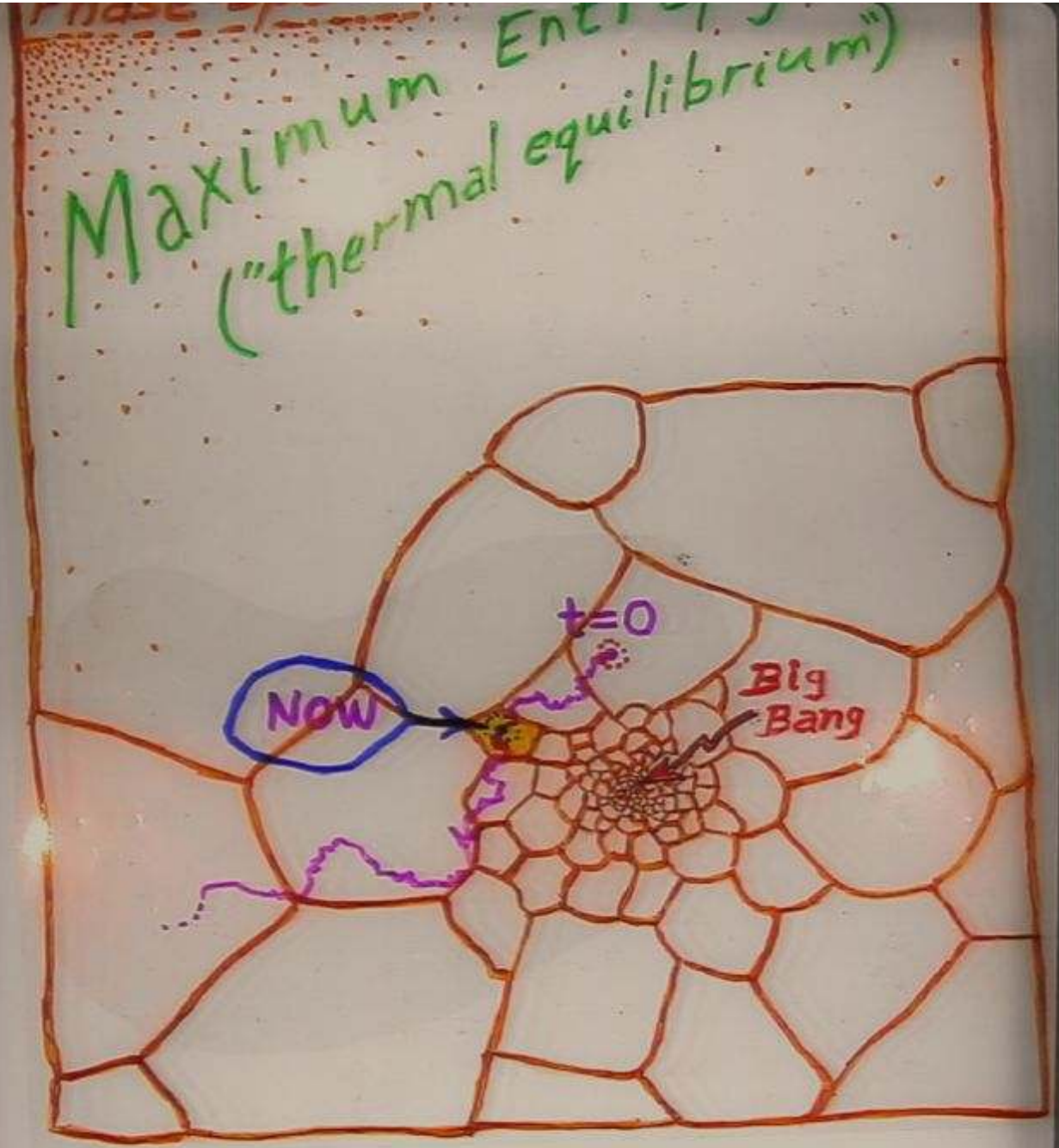

Phase-space
Maximum Entropy
("thermal equilibrium")
Big
Bang


Phase-space
Maximum Entropy
("thermal equilibrium")
Big
Bang

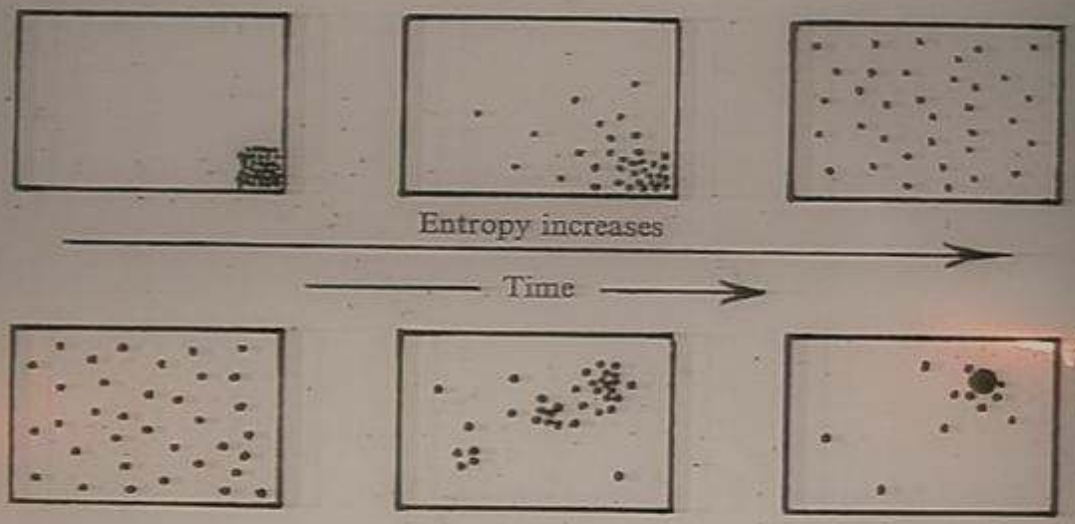

Phase-space
Maximum Entropy
("thermal equilibrium")
Now
t=0
Big Bang


Phase-space
Maximum Entropy
("thermal equilibrium")
Now
t=0
Big Bang


Maximum Entropy
("thermal equilibrium")
Big Bang


Maximum Entropy
("thermal equilibrium")
t=0
NOW
Big Bang

Entropy increase

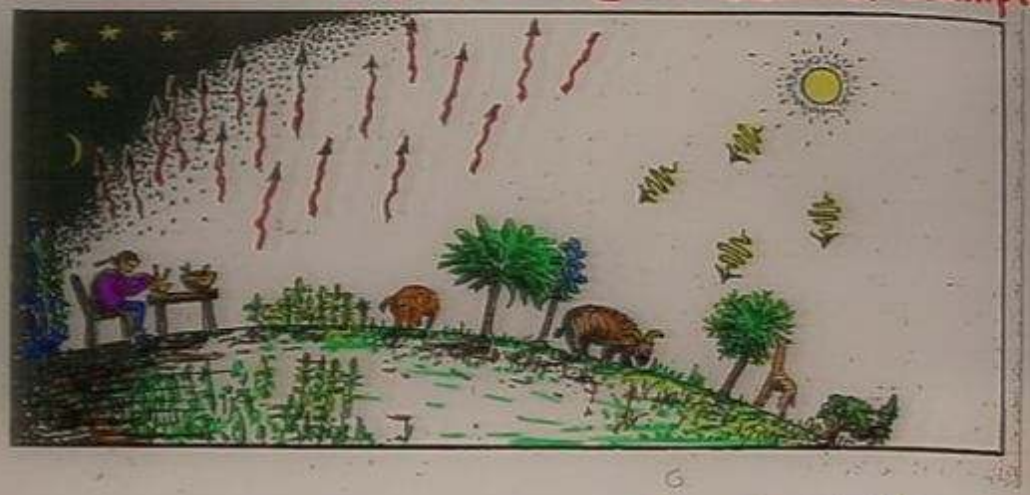


with gravity!

How we make use of the low-entropy resevoir available from gravitational clumping: The sun is a hot spot in a dark background sky. Its very existence results from gravitational clumping.

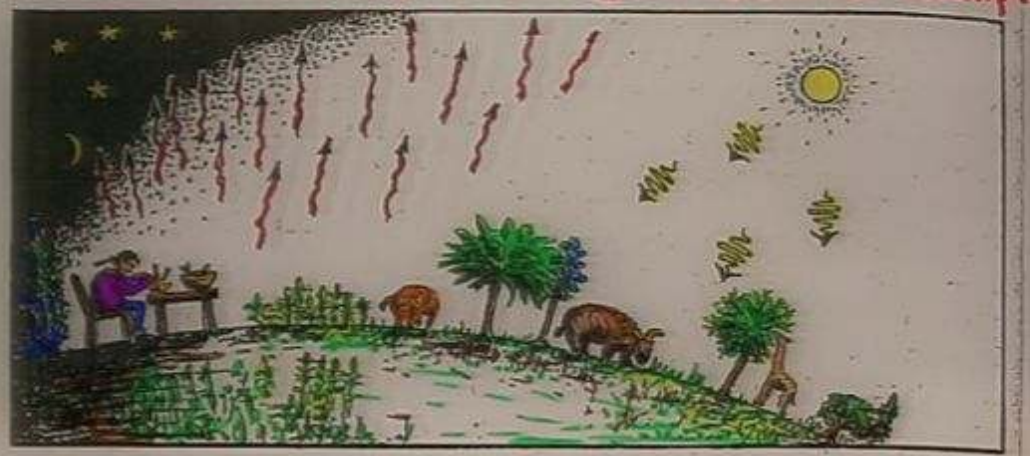
The Earth gives back all the energy it receives from the Sun. But the energy received is in a SMALL number of high-energy photons (yellow) and sent away in a LARGE number

How we make use of the low-entropy resevoir available from gravitational clumping: The sun is a hot spot in a dark background sky. Its very existence results from gravitational clumping.



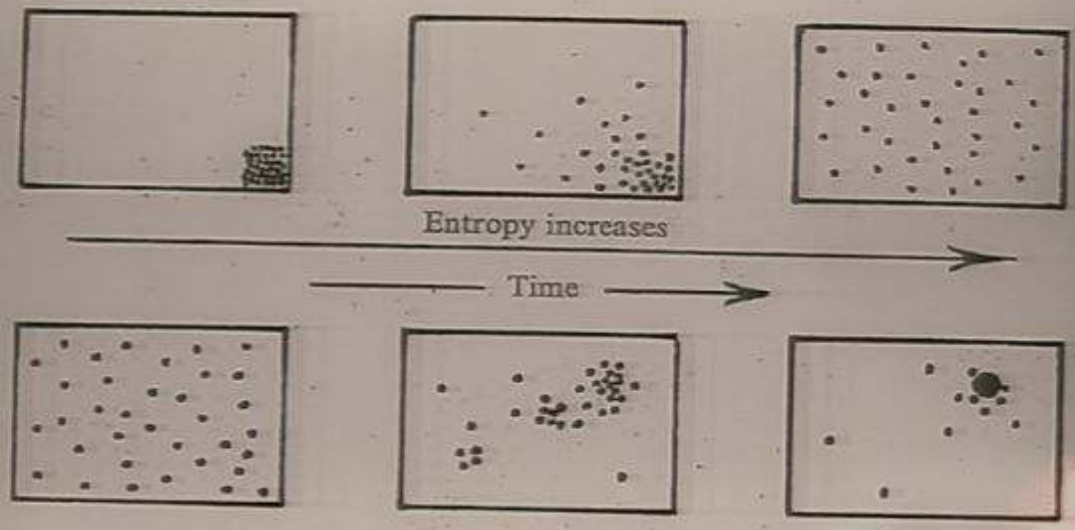
The Earth gives back all the energy it receives from the Sun. But the energy received is in a SMALL number of high-energy photons (yellow) and sent away in a LARGE number of low-energy photons (infra-red). Hence entropy on Earth is reduced.

How we make use of the low-entropy resevoir available from gravitational clumping: The sun is a hot spot in a dark background sky. Its very existence results from gravitational clumping.



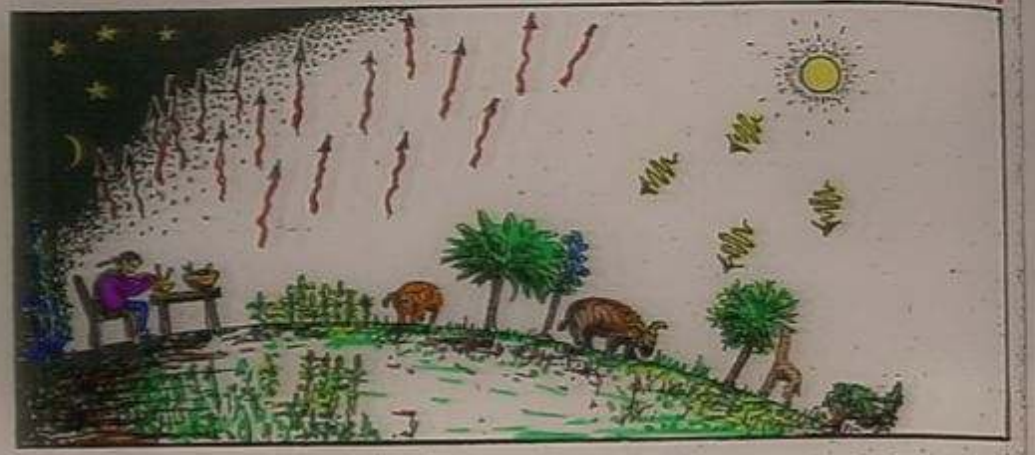
The Earth gives back all the energy it receives from the Sun. But the energy received is in a SMALL number of high-energy photons (yellow) and sent away in a LARGE number of low-energy photons (infra-red). Hence entropy on Earth is reduced.

Entropy increase



with gravity!

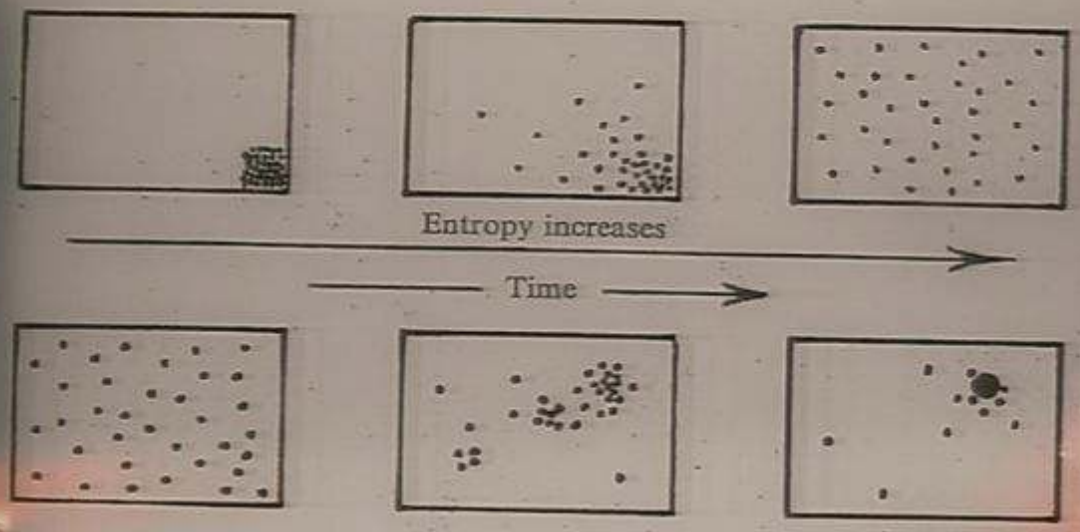
How we make use of the low-entropy resevoir available from gravitational clumping: The sun is a hot spot in a dark background sky. Its very existence results from gravitational clumping.



The Earth gives back all the energy it receives from the Sun. But the energy received is in a SMALL number of high-energy photons (yellow) and sent away in a LARGE number of low-energy photons (infra-red). Hence entropy on Earth is reduced.

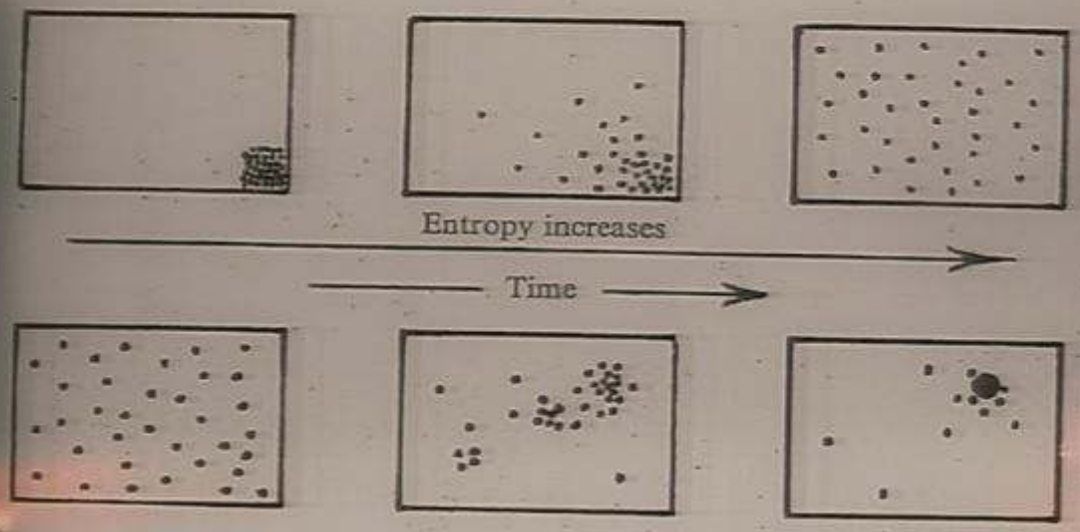
Standard (Friedmann) cosmologies Λ = 0
1922
Big Crunch
K>0
K=0
Big Bang
time
K<0
Big Bang

Entropy increase

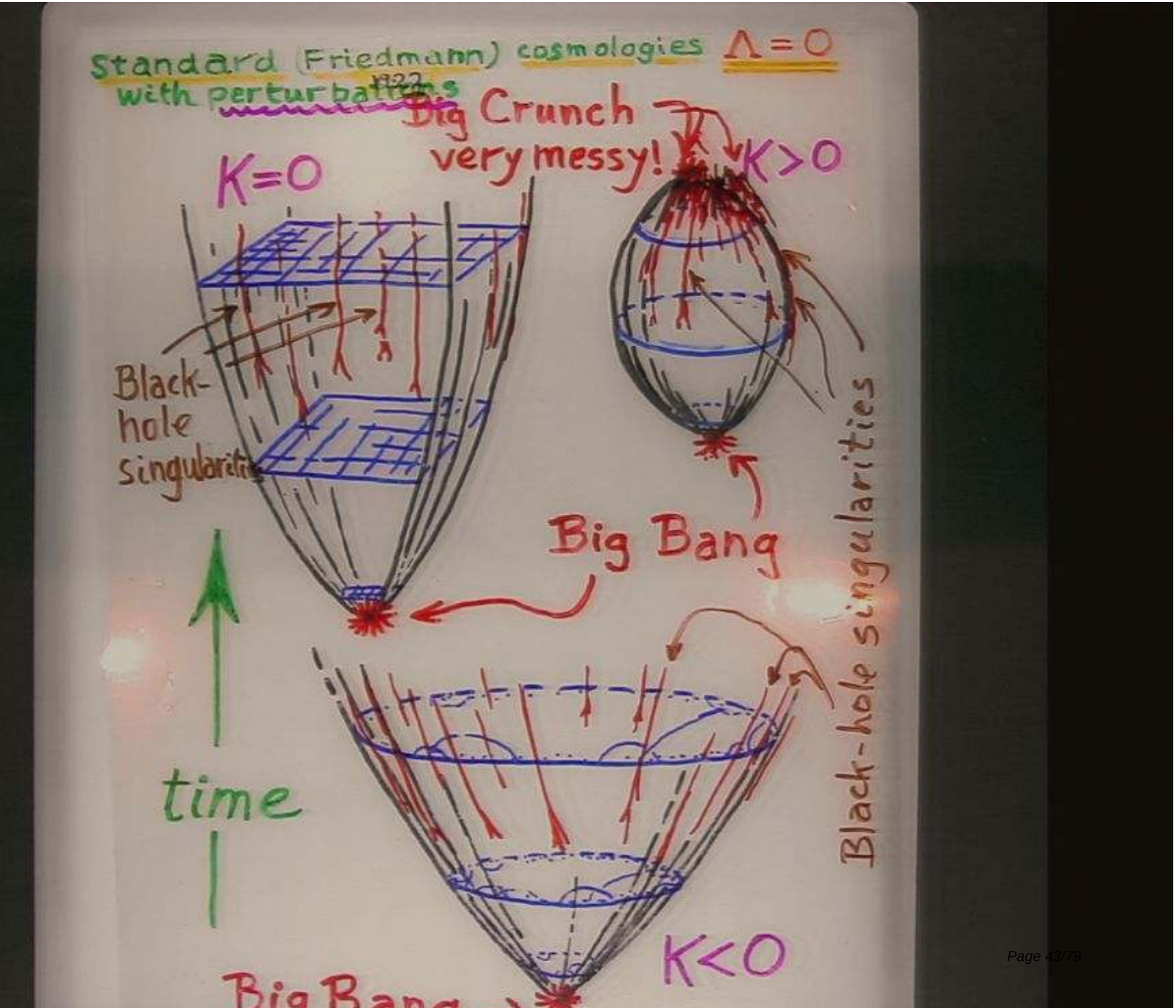


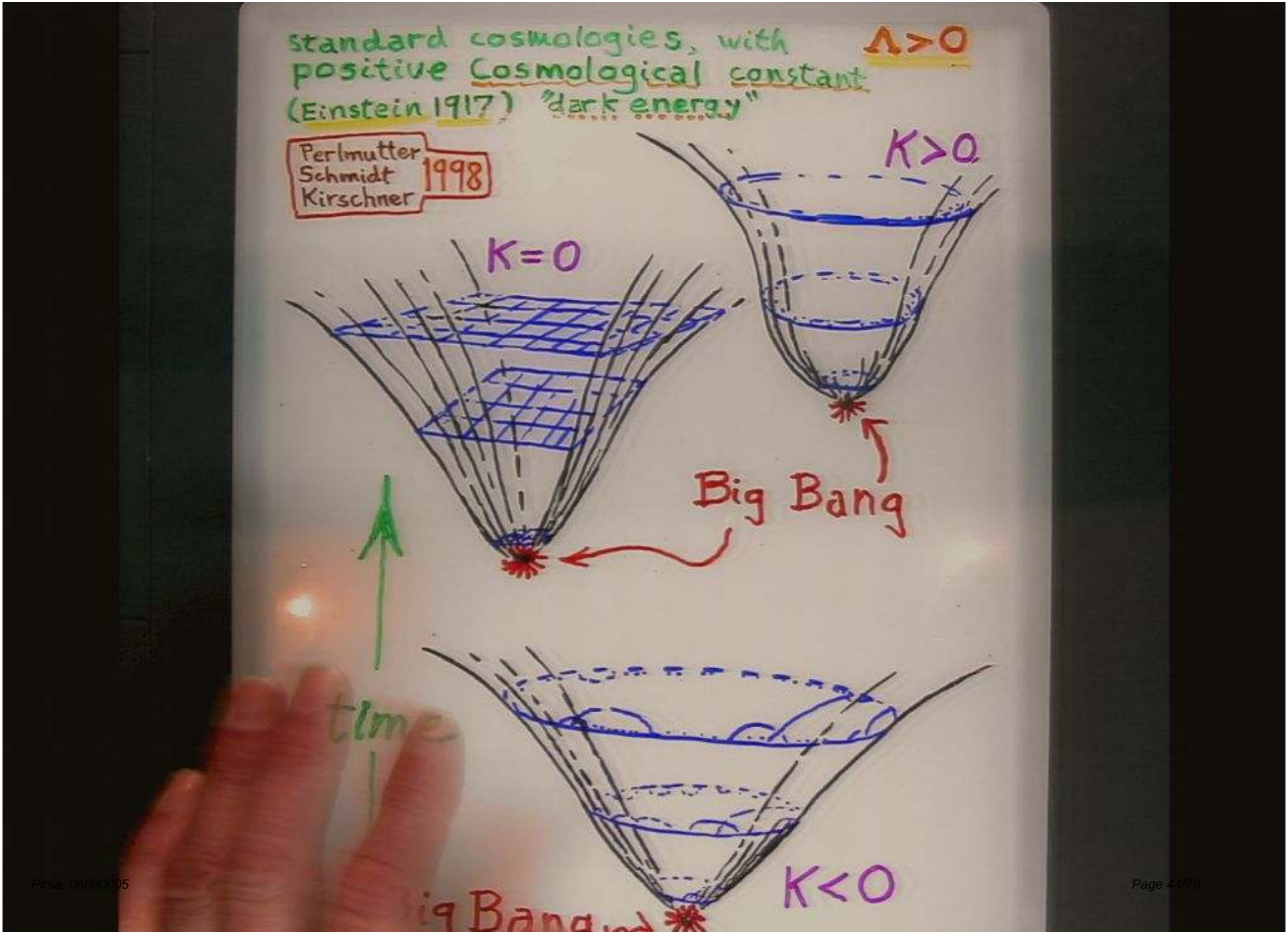
with gravity!

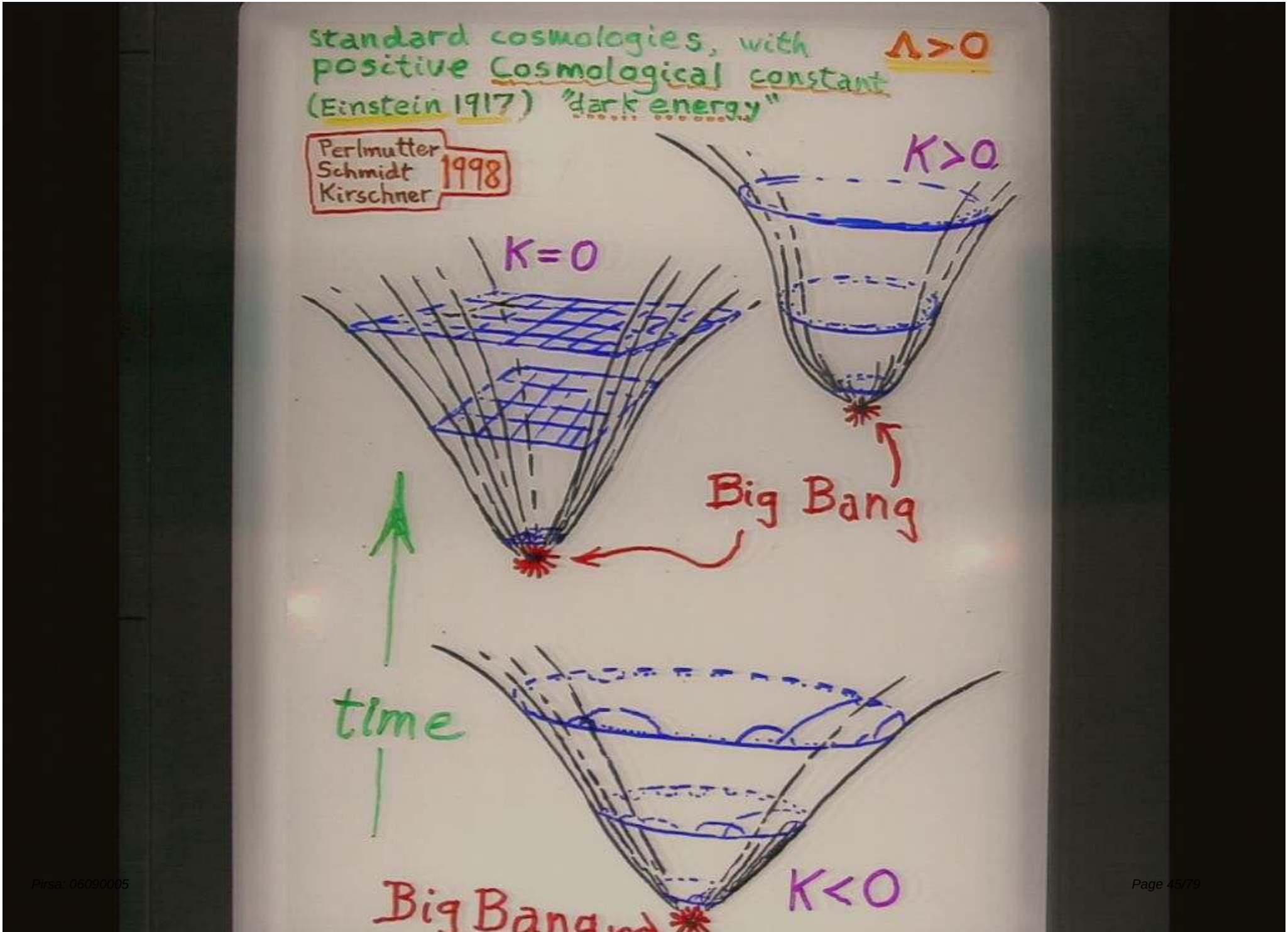
Entropy increase



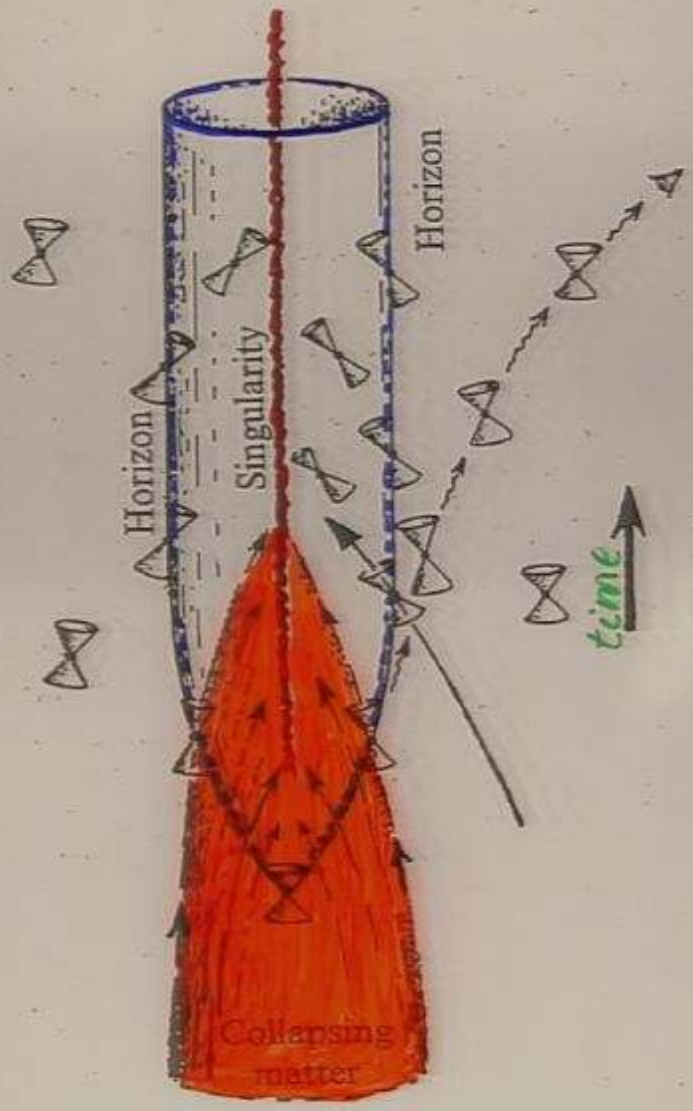
with gravity!


Standard (Friedmann) cosmologies Λ=0
with perturbations
Big Crunch
very messy!
K=0
K>0
Black-hole singularities
Big Bang
time
Black-hole singularities
K<0
Big Bang

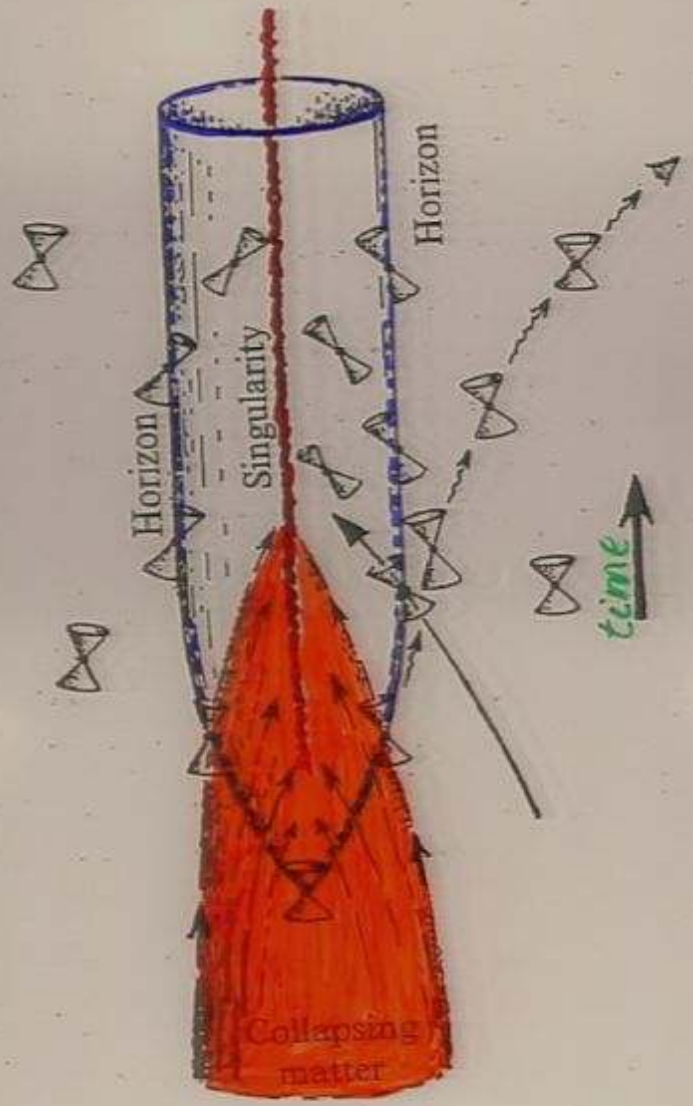

standard cosmologies, with positive Cosmological constant (Einstein 1917) "dark energy"
Λ>0
Perlmutter
Schmidt
Kirschner
1998
K>0
K=0
Big Bang
time
K<0

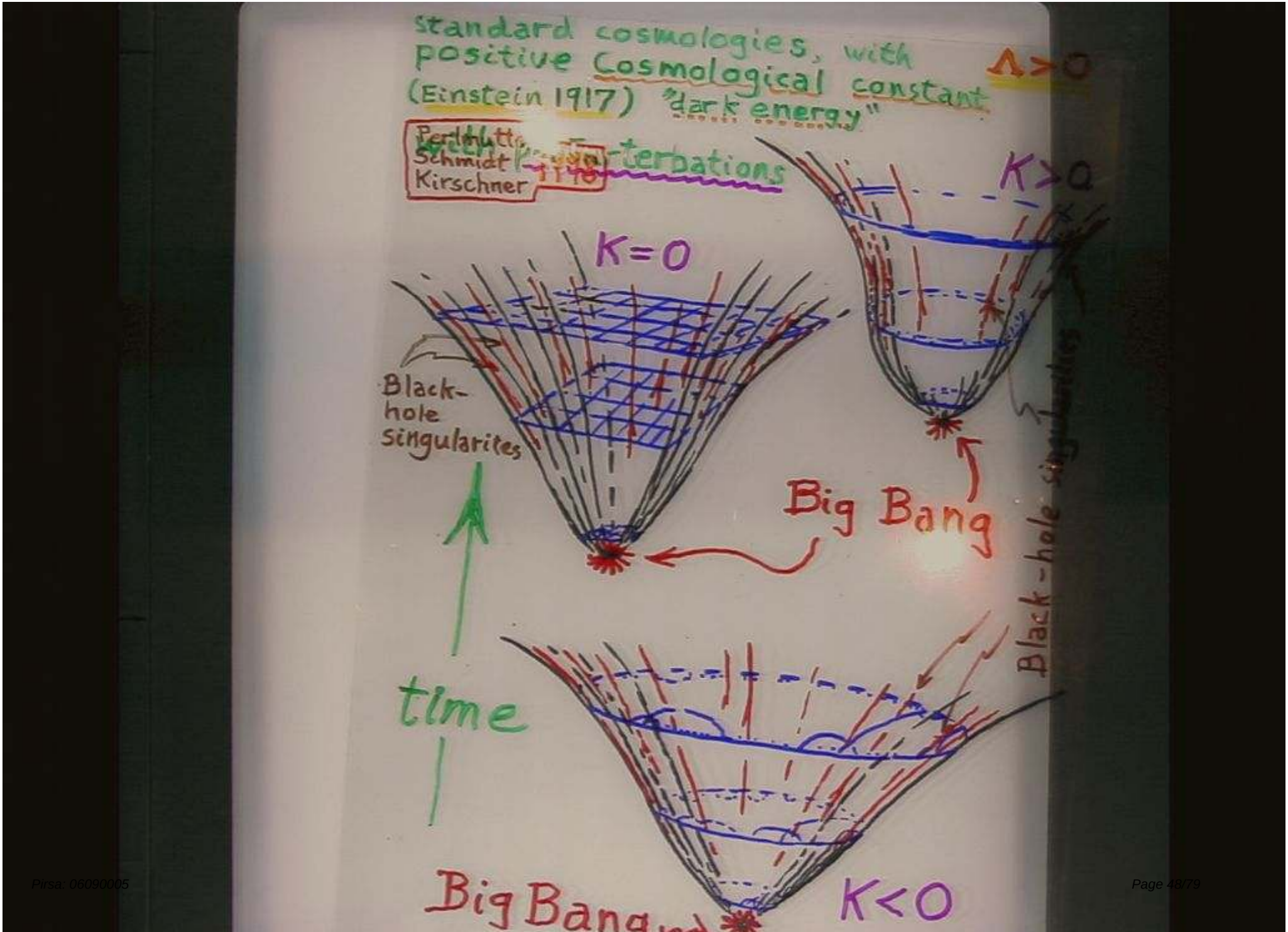

standard cosmologies, with positive Cosmological constant (Einstein 1917) "dark energy"
Λ>0
Perlmutter
Schmidt
Kirschner
1998
K>0
K=0
Big Bang
time
Big Bang
K<0

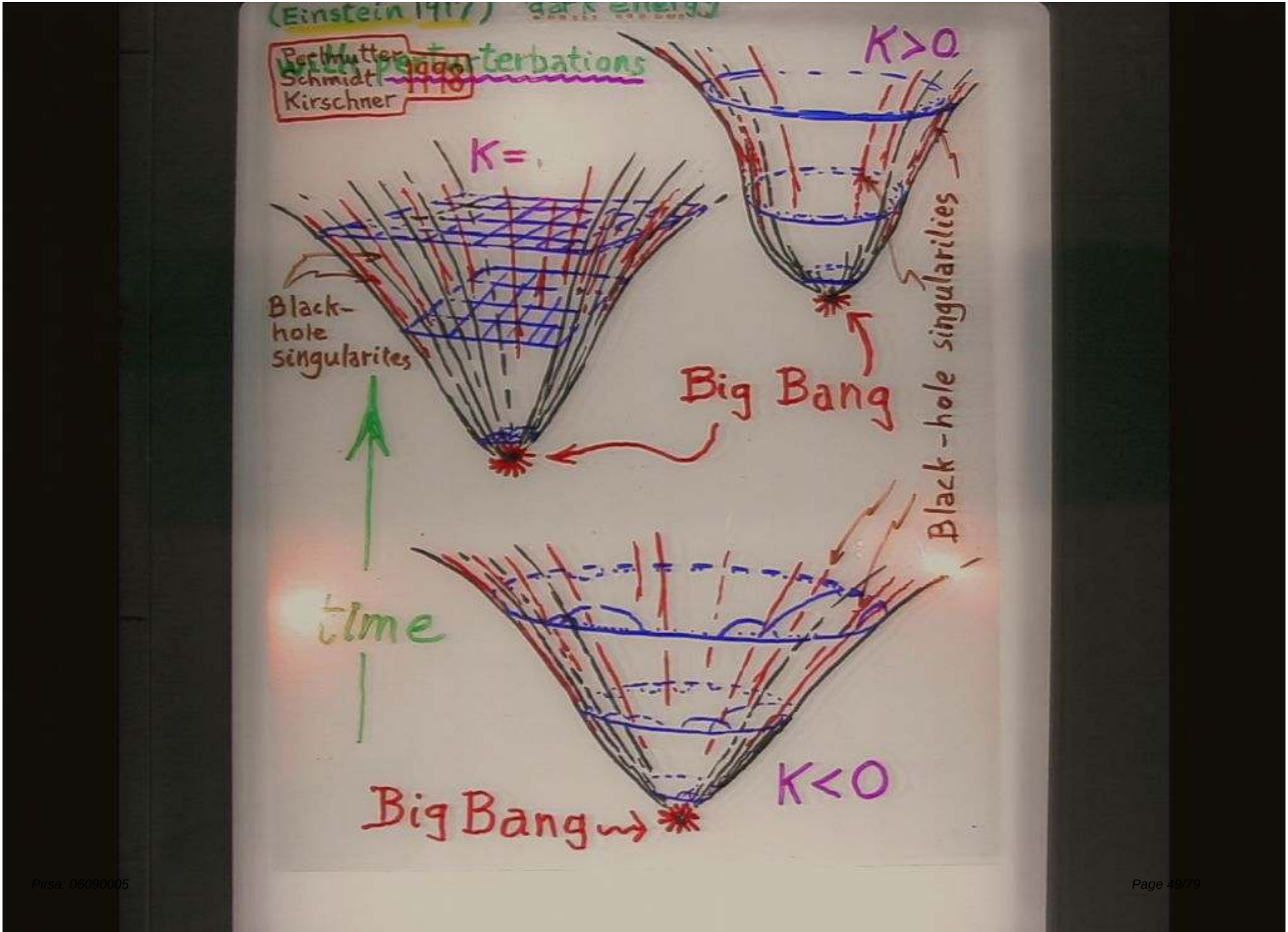
Collapse to a black hole

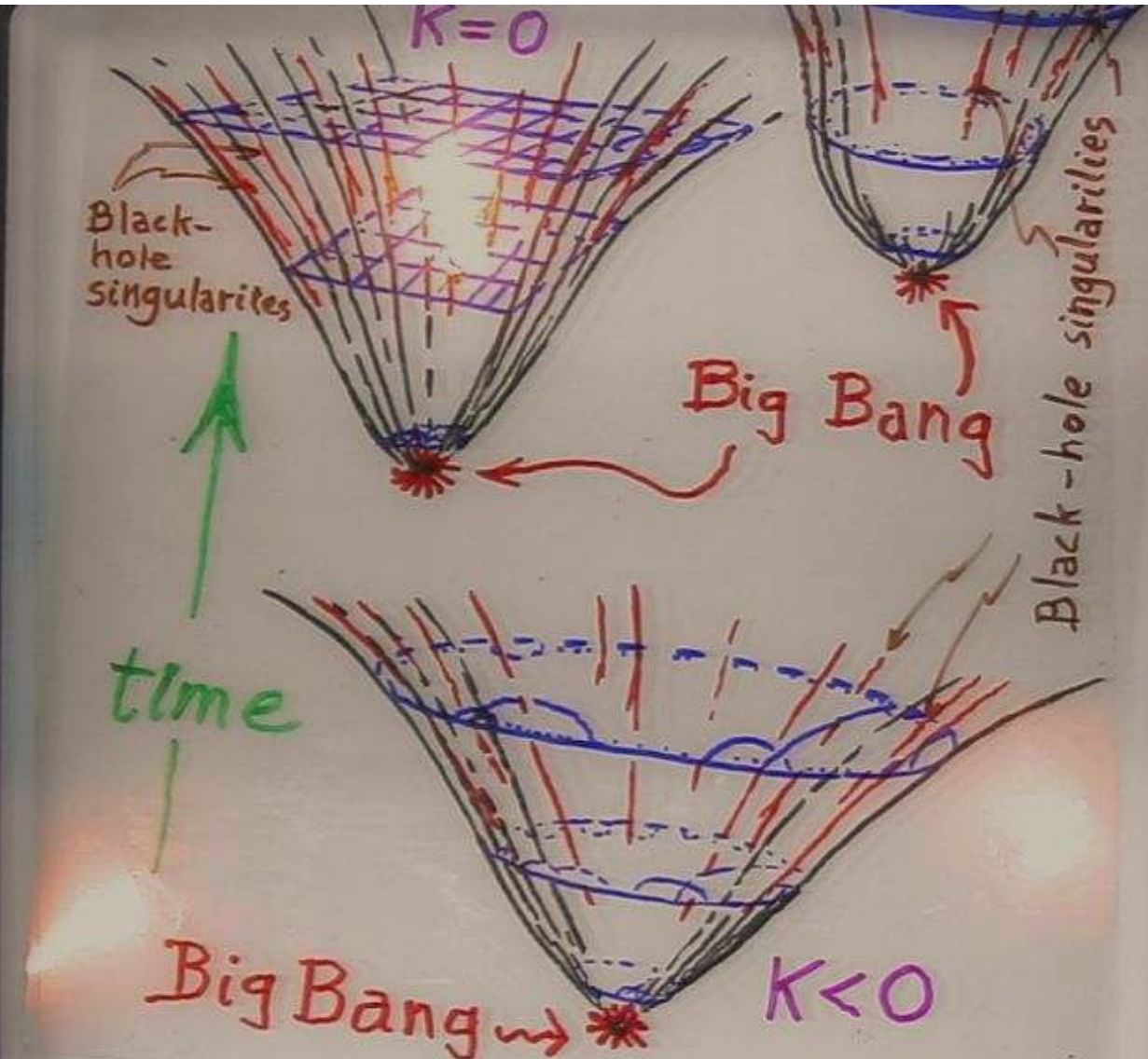


Collapse to a black hole

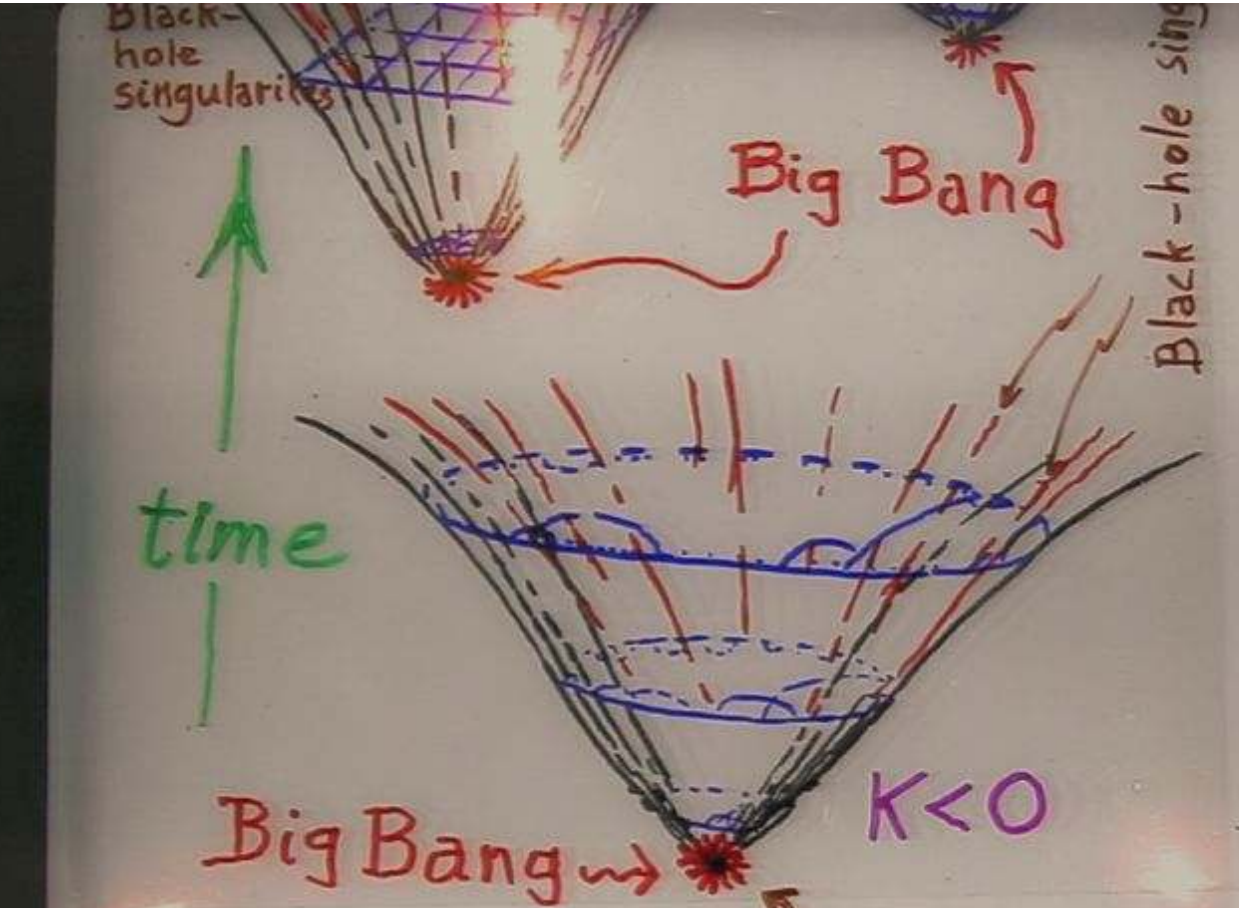



standard cosmologies, with
positive Cosmological constant
(Einstein 1917) "dark energy"
Λ>0
Perlmutter
Schmidt
Kirschner
1998
terbations
K>0
K=0
Black-
hole
singularites
Big Bang
Black-hole singularities
time
Big Bang
K<0


(Einstein 1917)
Perlmutter
Schmidt
Kirschner
1998
K>0
K=
Black-
hole
singularites
Big Bang
Black-hole singularities
time
K<0
Big Bang



1 chance in $\gg 10^{10^{123}}$

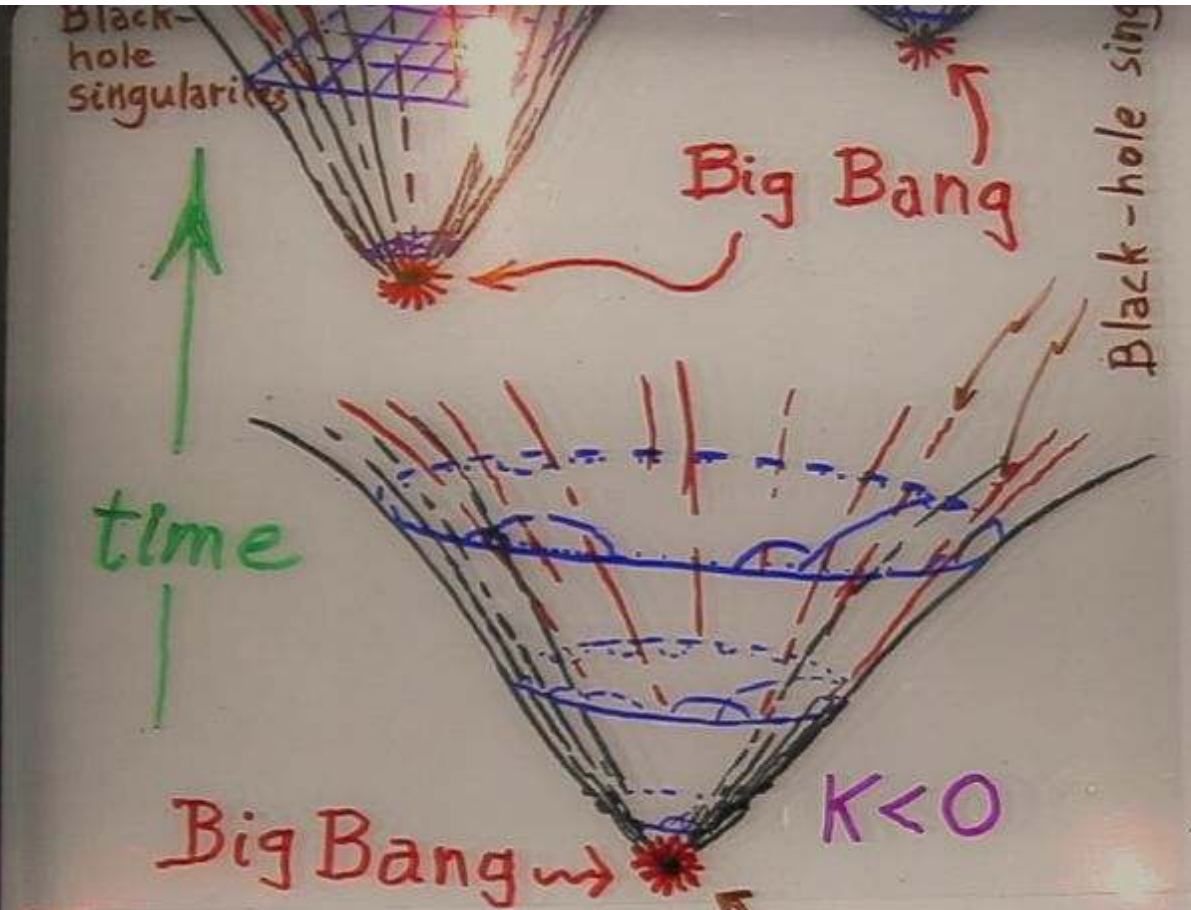


Big Bang singularity was enormously constrained → 1 part in $10^{10^{123}}$

Gravitational degrees of freedom seem not to have been excited

Weyl curvature hypothesis:

Initial-type singularities (but not final ones) are constrained to have Weyl curv. $\cong 0$



Big Bang singularity was enormously constrained → 1 part in $10^{10^{123}}$

Gravitational degrees of freedom seem not to have been excited

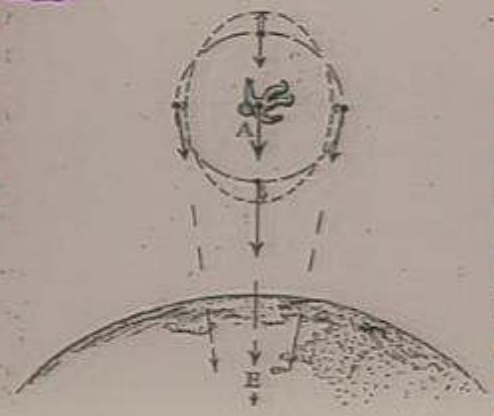
Weyl curvature hypothesis:

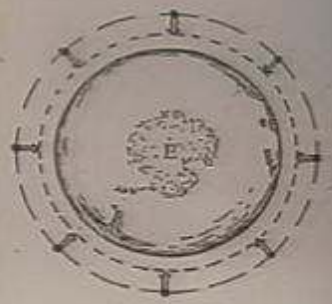
Initial-type singularities (but not final ones) are constrained to have Weyl curv. $\cong 0$

Space-time curvature: tidal distortion

Full Riemann curvature = Weyl curv. + Ricci curv.

Free gravity



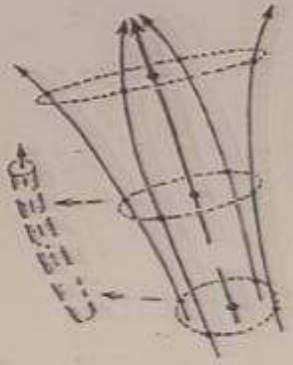


Matter source

spatial picture

(geodesic deviation in space-time)

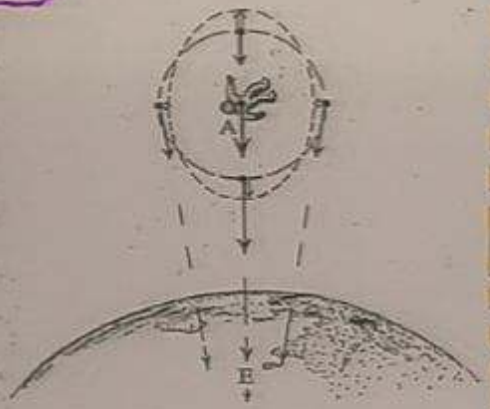
time

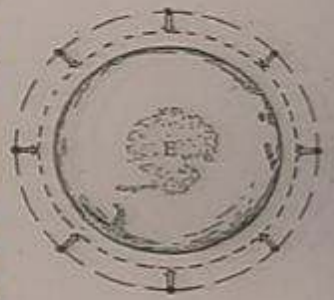


Space-time curvature: tidal distortion

Full Riemann curvature = Weyl curv. + Ricci curv.

Free gravity





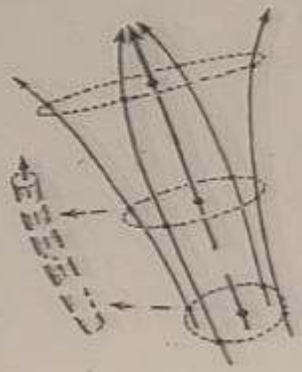
Matter source

spatial picture

(geodesic deviation in space-time)

time

Free gravity



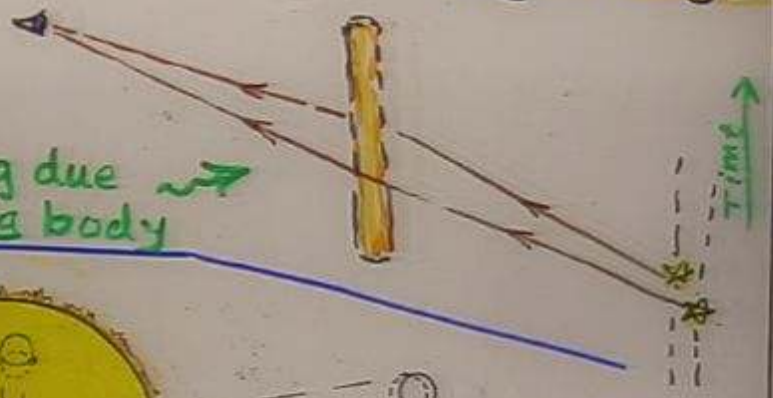
Matter source

time

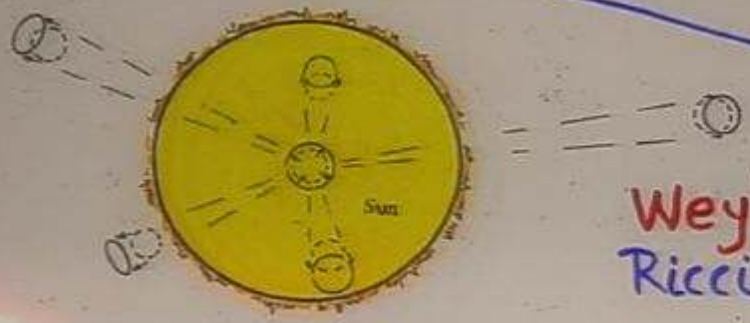
Weyl Ricci

space-time picture

Effects of Weyl & Ricci (trace-free) space-time curvature on light rays



light bending due to gravitating body



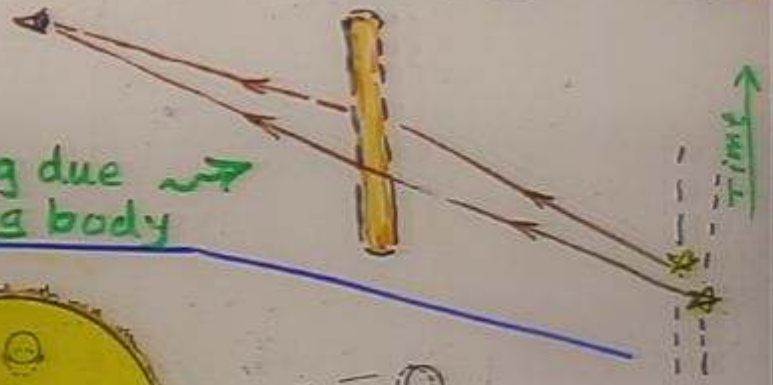
spatial picture

Weyl: distortion
Ricci: magnification

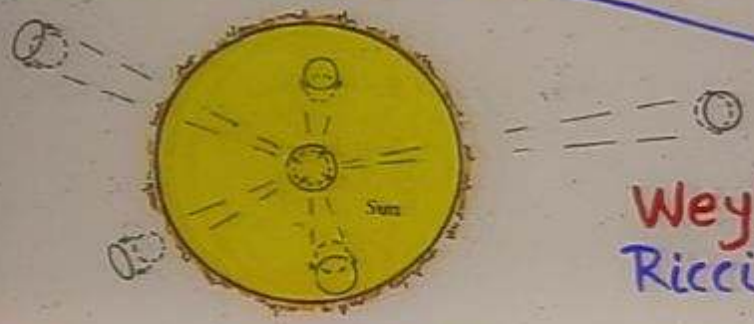
geodesic deviation of light rays

Weyl curvature = conformal curvature

Effects of Weyl & Ricci (trace-free) space-time curvature on light rays



light bending due to gravitating body



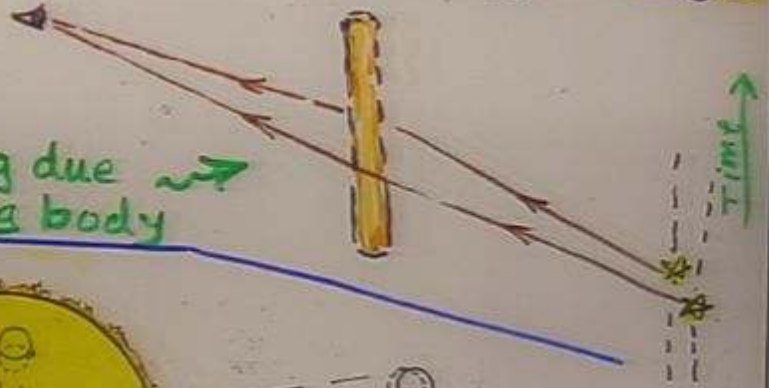
spatial picture

Weyl: distortion
Ricci: magnification

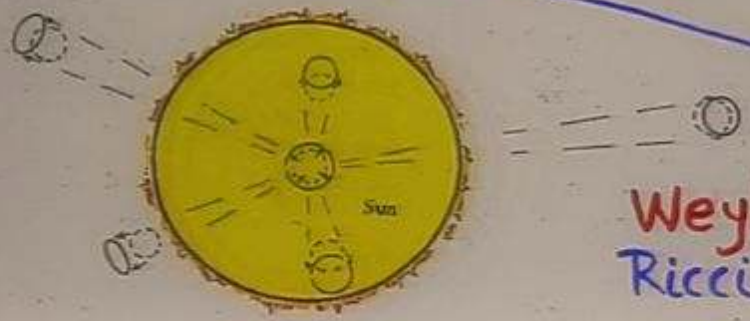
geodesic deviation of light rays

Weyl curvature = conformal curvature

Effects of Weyl & Ricci (trace-free) space-time curvature on light rays



light bending due to gravitating body



spatial picture

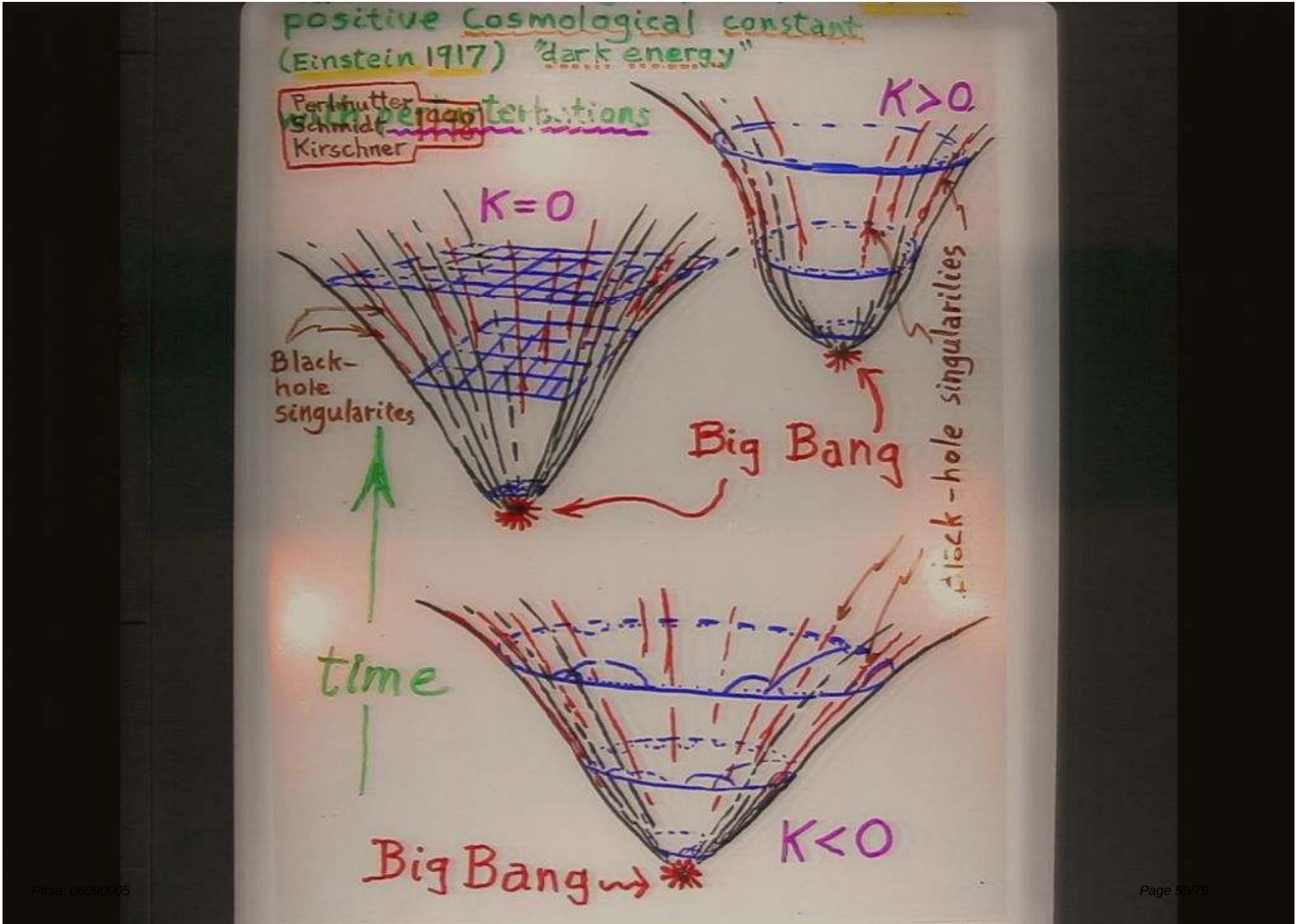
Weyl: distortion
Ricci: magnification

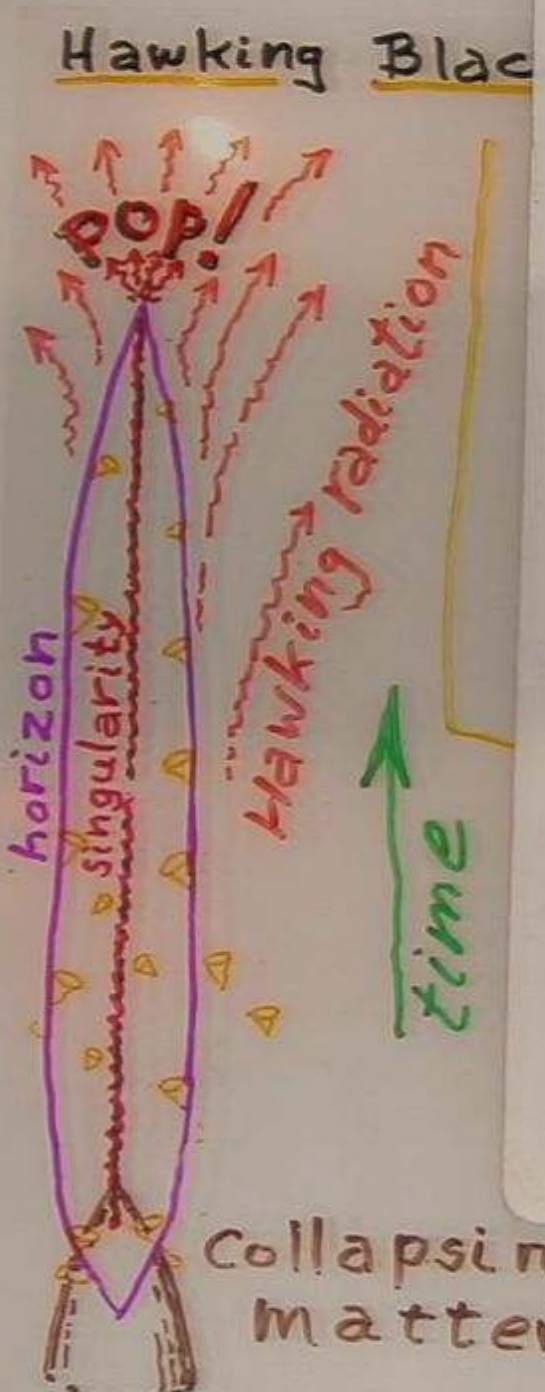
geodesic deviation of light rays

Weyl curvature = conformal curvature

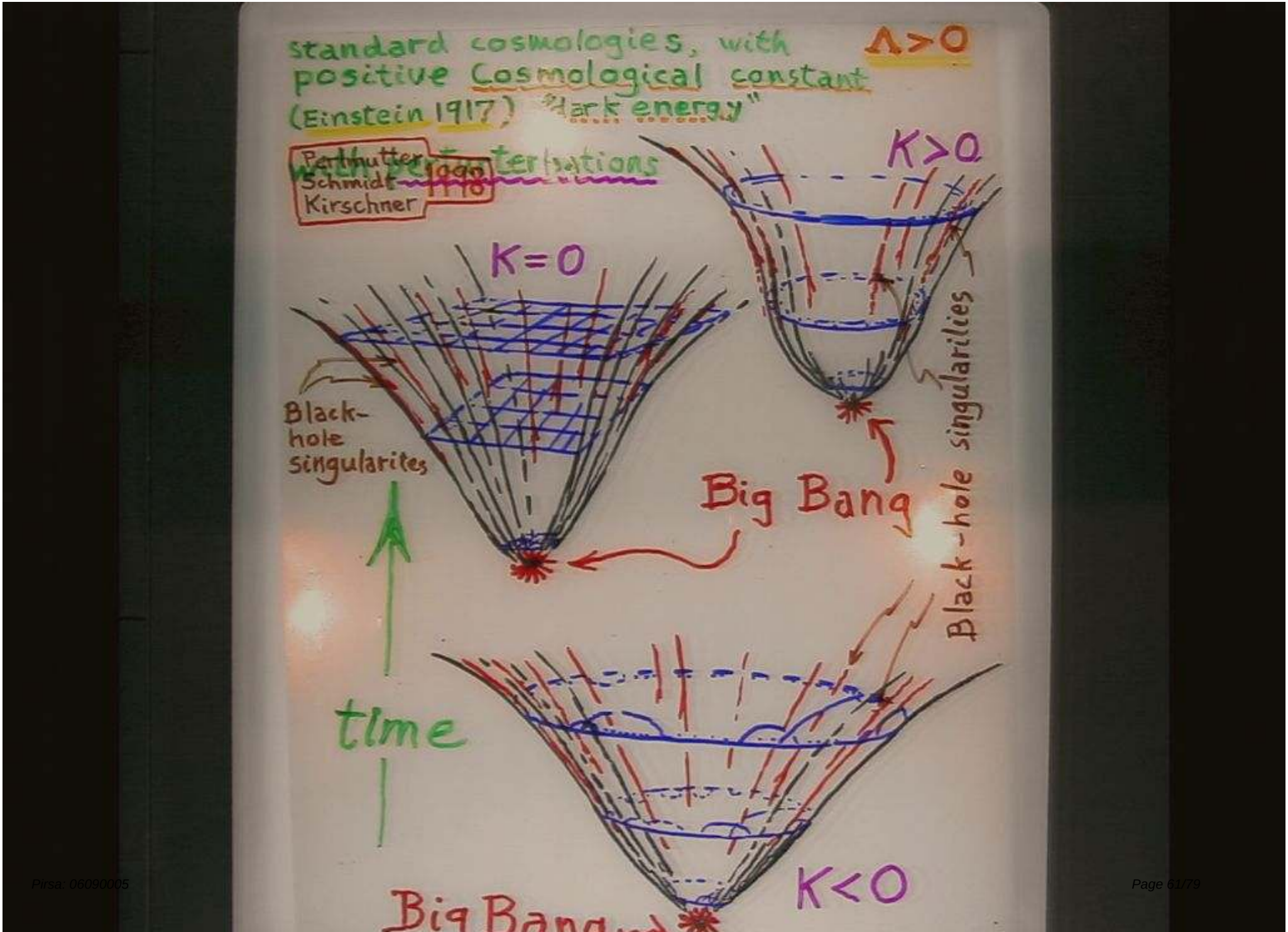
GRAVITATIONAL LENSES IN ABELL 2218

Pirsa: 06090005


positive Cosmological constant
(Einstein 1917) "dark energy"
Perlmutter
Schmidt
Kirschner
1998
with perturbations
K>0
K=0
Black-hole singularities
Big Bang
Black-hole singularities
time
Big Bang
K<0



of singular
TIPs


standard cosmologies, with positive Cosmological constant (Einstein 1917) "dark energy"
Λ>0
Perlmutter, Schmidt, Kirschner 1998
K>0
K=0
Black-hole singularities
Big Bang
Black-hole singularities
time
K<0
Big Bang

Conformal geometry

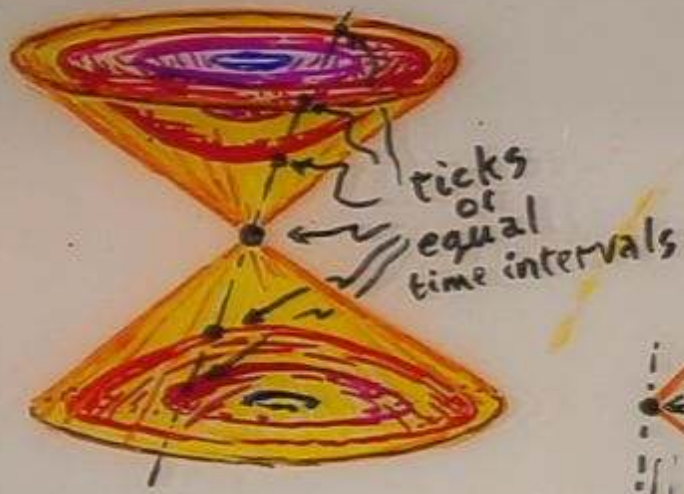
Metric up to local scale changes

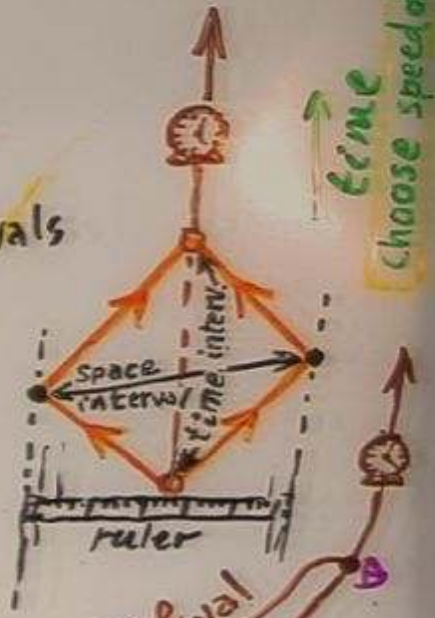
Angles and small shapes, not length

E.g. in Escher's circle limits, the hyperbolic geometry agrees with the Euclidean background

Beltrami
Poincaré

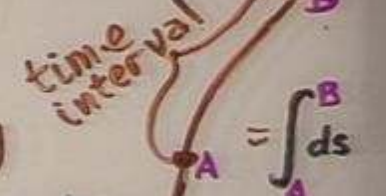
Space-time conformal geom.
= light-cone structure

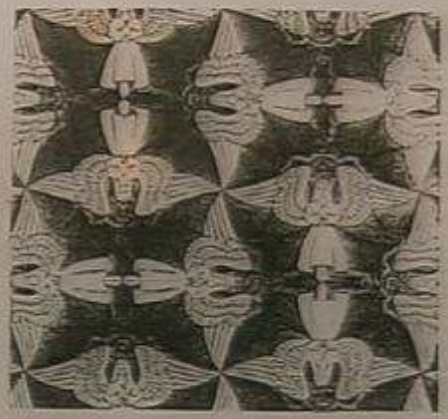




The metric $g_{..}$ is really a measure of time (not distance)

(signature ...)





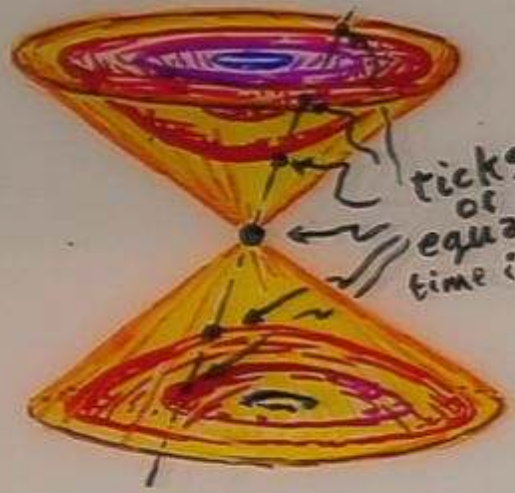
Metric up to local scale changes

Angles and small shapes, not length

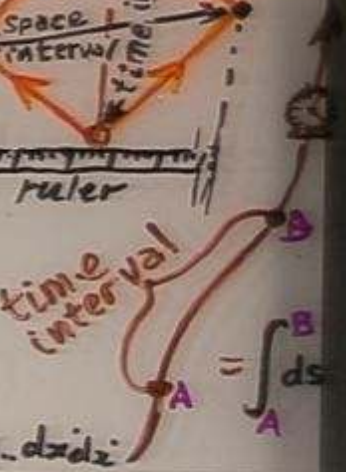
E.g. in Escher's circle limits, the hyperbolic geometry agrees with the Euclidean background

Beltrami Poincaré

Space-time conformal geom.
= light-cone structure



The metric g_{ij} is really a measure of time (not distance)
(signature +---)



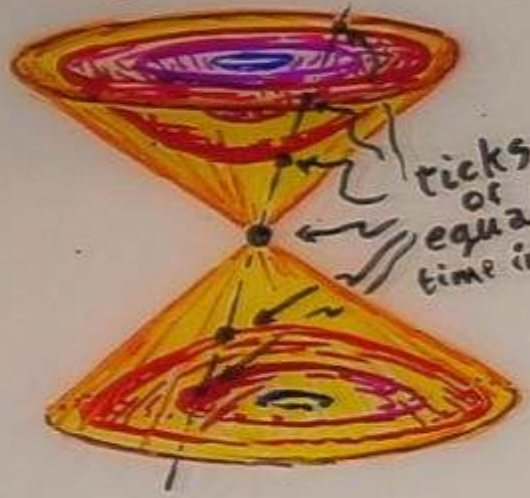
Conformal geometry

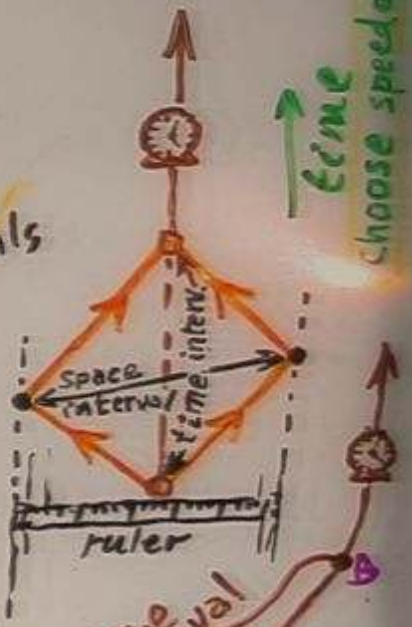
Metric up to local scale changes

Angles and small shapes, not length

E.g. in Escher's circle limits, the hyperbolic geometry agrees with the Euclidean background Beltrami Poincaré

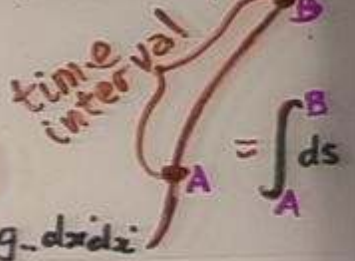
Space-time conformal geom. = light-cone structure





The metric $g_{..}$ is really a measure of time (not distance)

(signature $+---$)



Strict conformal diagrams

symmetry axis

point

sphere S^2

infinity ($\mathscr{I}$)

singularity

Key

each interior point describes S^2

Minkowski space

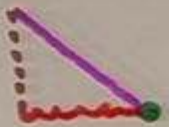
horizon

collapse to black hole

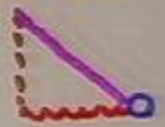
Cosmological models

$\Lambda = 0$

$k > 0$



$k = 0$



$k < 0$

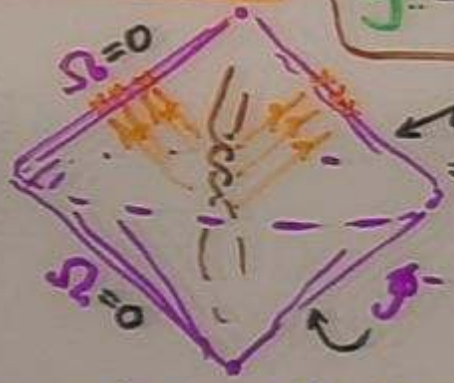
$\Lambda > 0$

2 Conformal "Mathematical Tricks"

Gravitational radiation

phys

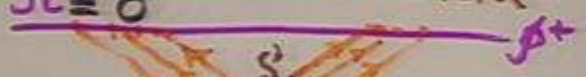
$\hat{g}_{ab} = \Omega^2 g_{ab}$



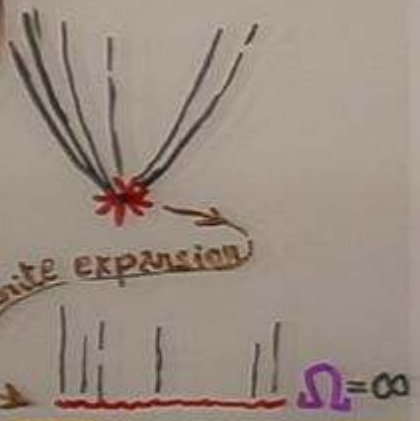
Asymptotically flat space-time $\Lambda = 0$

Trick: shrink ∞ to a finite place by taking $\Omega = 0$ there

When $\Lambda > 0$, this still works (in some sense better (RP Friedrich) – easier) but then $\mathscr{I}^+$ is spacelike rather than null



Cosmological singularities



Trick: expand out singularity to obtain a conformally smooth initial hypersurface

Tod's form of Weyl currature hypothesis: this works!

ysical metric

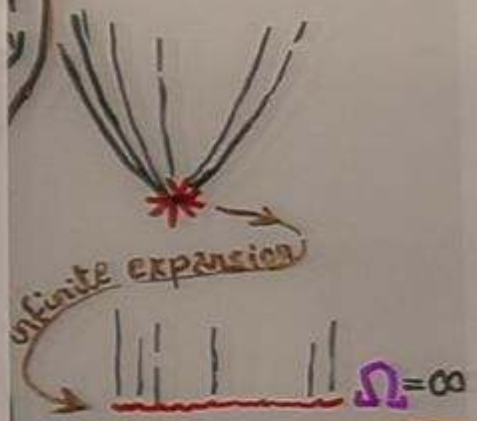
Cosmological singularities

Trick: expand out singularity to obtain a conformally smooth initial hypersurface

Tod's form of Weyl curvature hypothesis: this works!

ysical metric

Cosmological singularities



Trick: expand out singularity to obtain a conformally smooth initial hypersurface

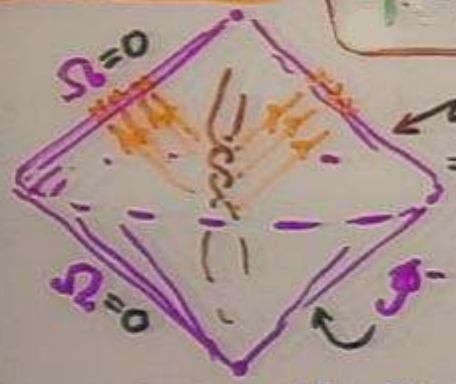
Tod's form of Weyl currature hypothesis: this works!

2 Conformal Mathematical Tricks

Gravitational radiation

$\hat{g} = \Omega^2 g$ ← physical metric

RP ~ 1962

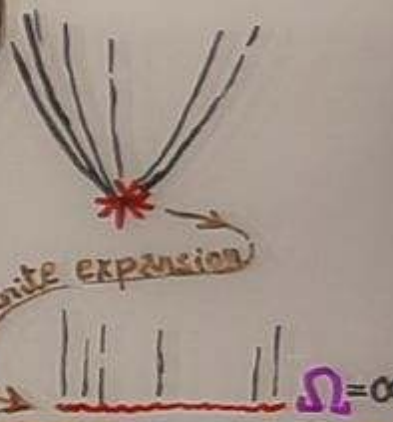


Asymptotically flat space-time $\Lambda = 0$

Trick: shrink ∞ to a finite place by taking $\Omega = 0$ there

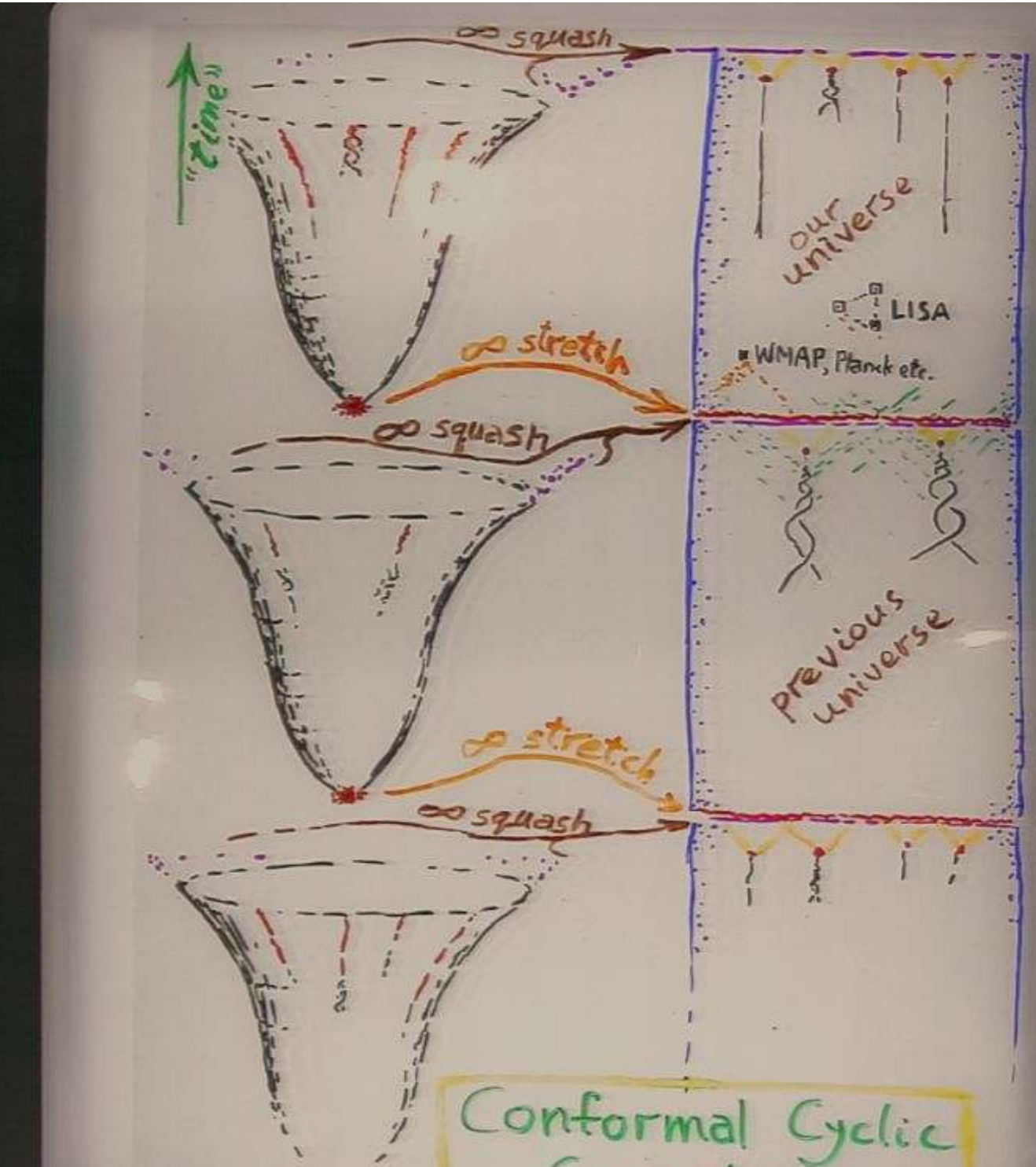
When $\Lambda > 0$, this still works (in some sense better (R.P. Friedrich) – easier) but then $\mathscr{I}^+$ is spacelike rather than null

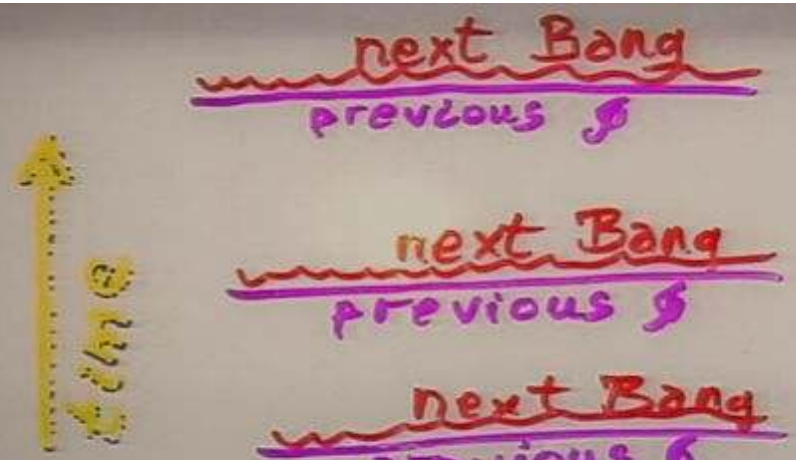
Cosmological singularities

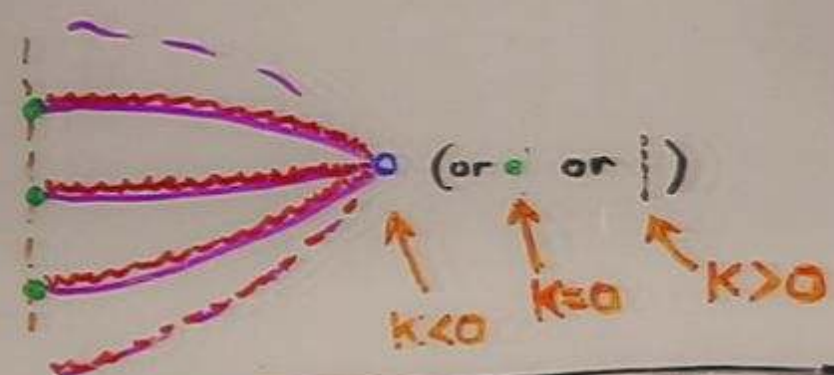


Trick: expand out singularity to obtain a conformally smooth initial hypersurface

Tod's form of Weyl currature hypothesis: this works!


∞ squash
"time"
our universe
LISA
WMAP, Planck etc.
∞ stretch
∞ squash
previous universe
∞ stretch
∞ squash
Conformal Cyclic





Requirements / predictions

Good → • Tod form of Weyl curvature hypothesis ∴ 2nd Law in form observed

Questionable → • Need electrons to lose their mass, ultimately (or some other possibility)

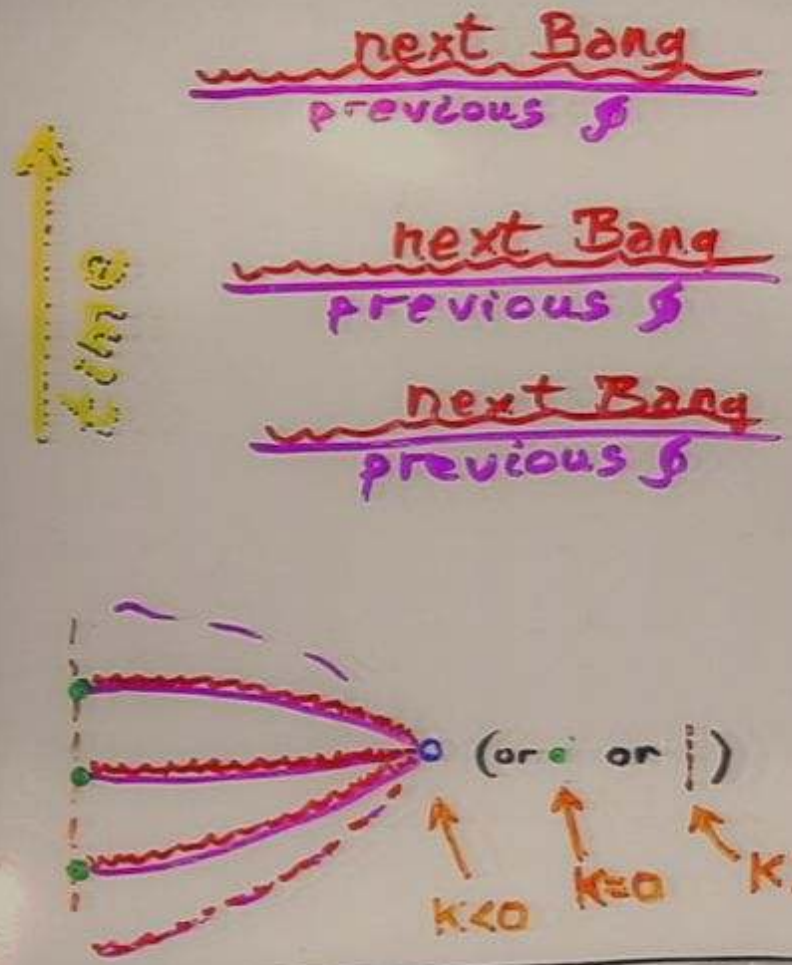
→ • Proton decay (or ultimately lose mass)

→ • All black holes ultimately decay away.

("ħ" renorm.) → • ~~Quantum aspects of fields eventually go.~~

→ • Conformal invariance at very high energies.

Observational? • Primordial grav. waves, density fluctn



Requirements / predictions

Good → • Tod form of Weyl curvature hypothesis ∴ 2nd Law in form observed

Questionable → • Need electrons to lose their mass, ultimately (or some other possibility).

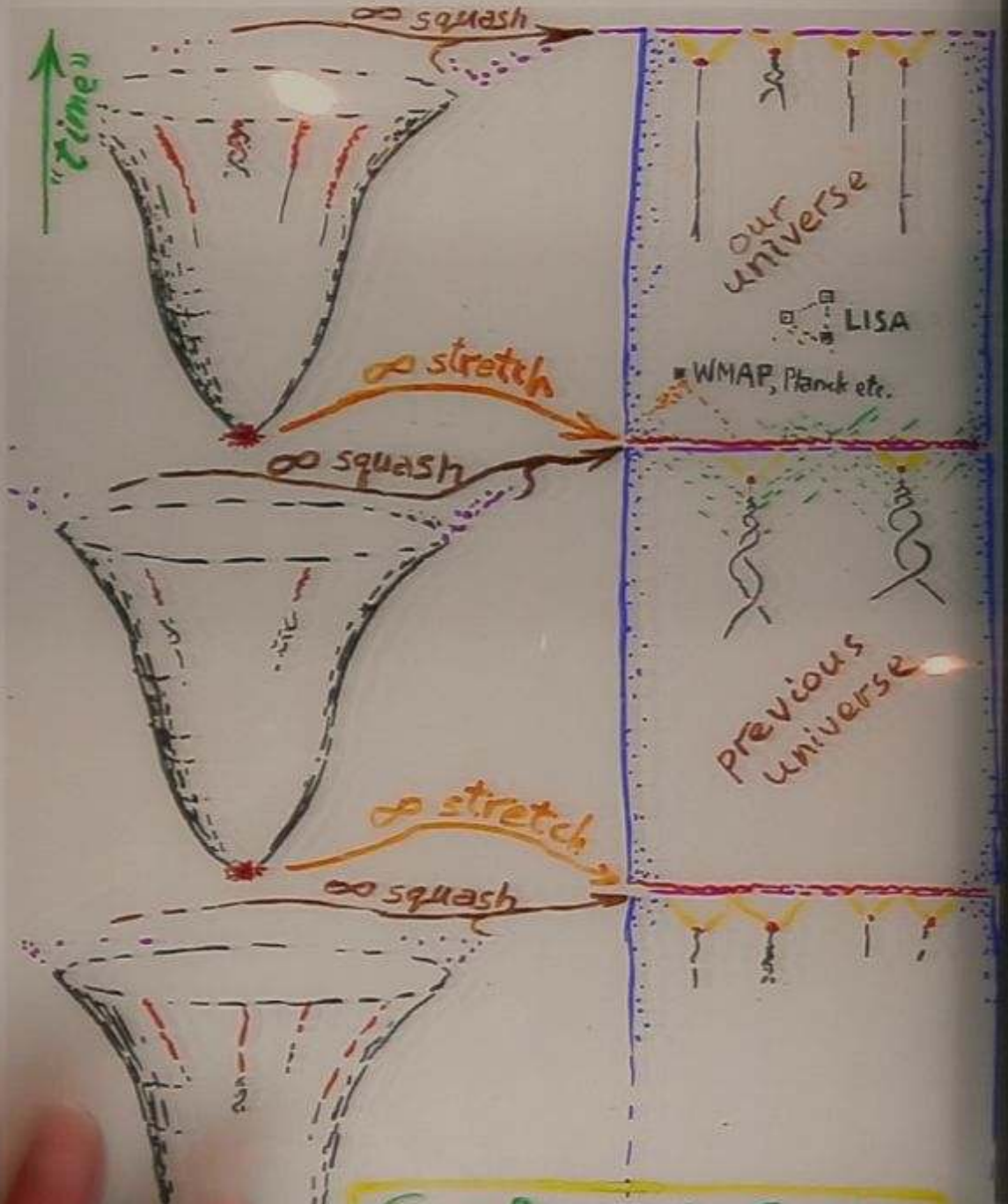
→ • Proton decay (or ultimately lose mass)

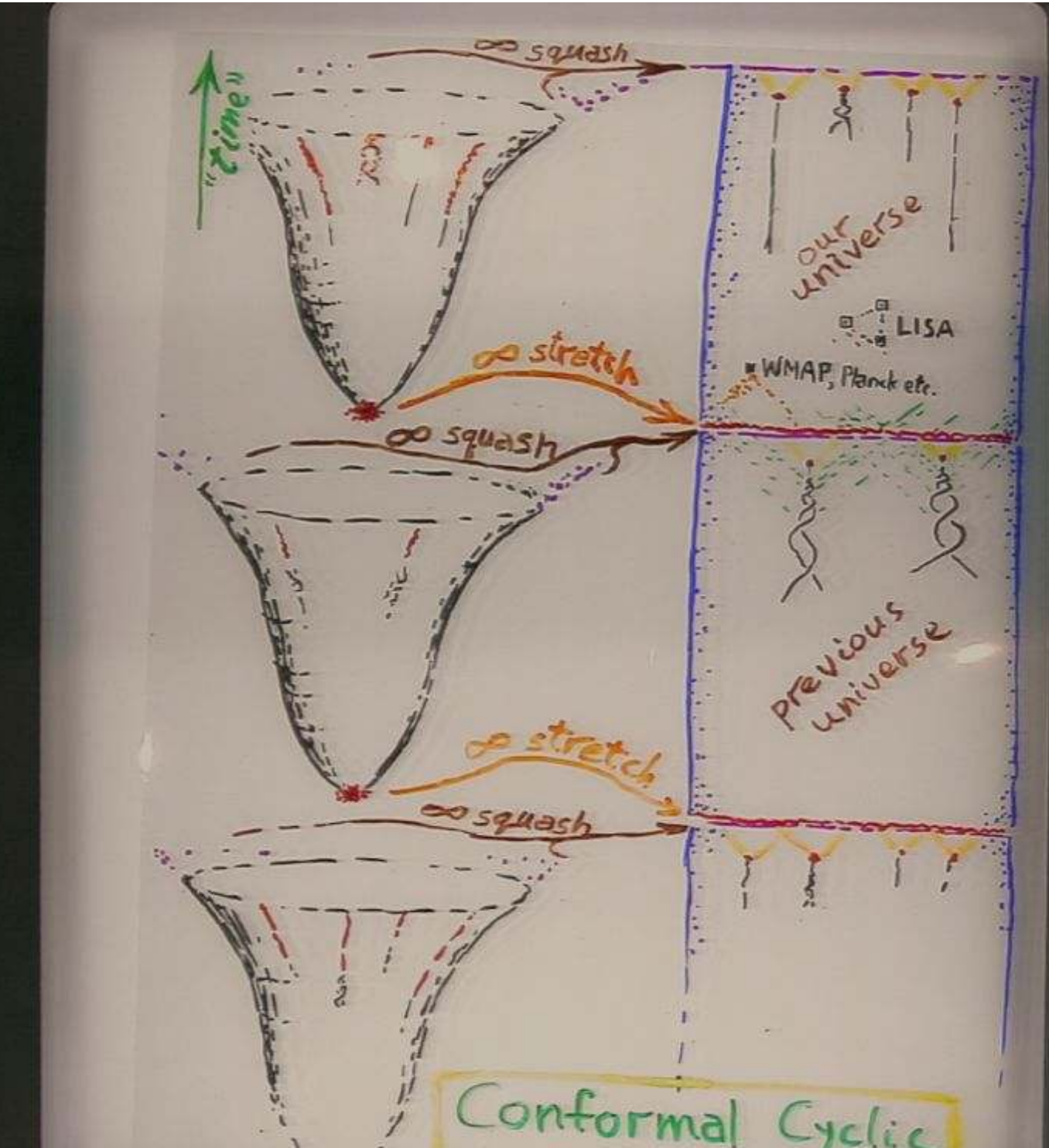
("Λ" renorm.) → • All black holes ultimately decay away.

→ • ~~Quantum aspects of fields eventually go.~~

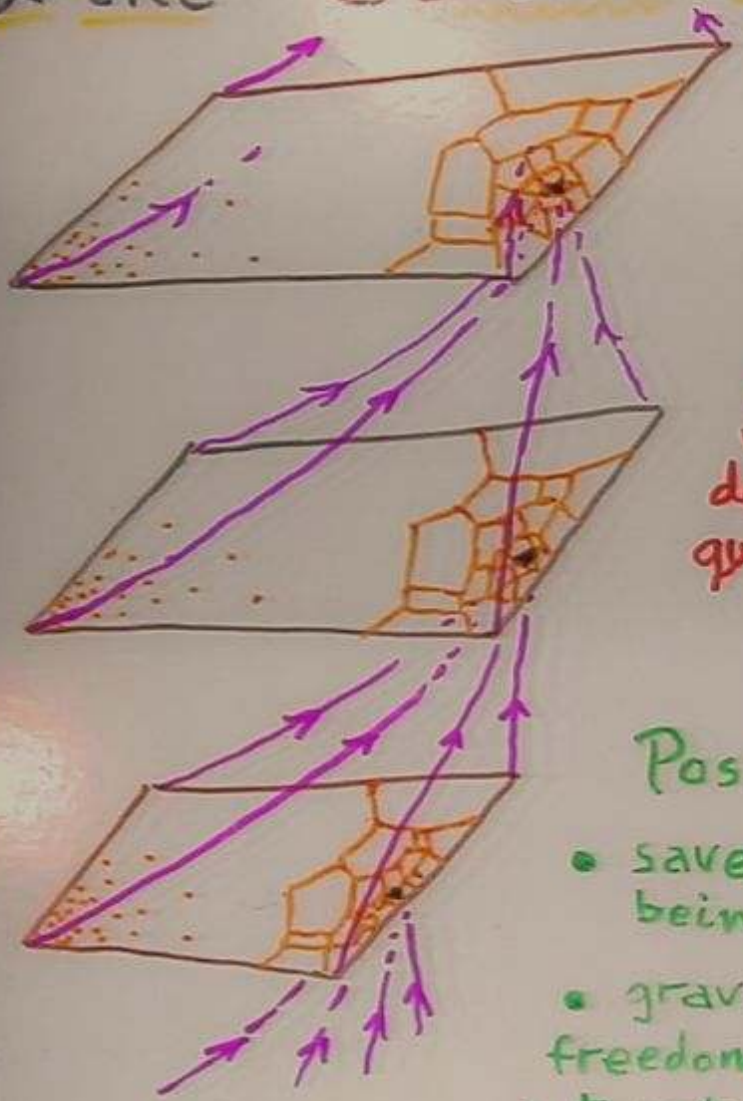
→ • Conformal invariance at very high energies.

Observational ? • Primordial gray waves


∞ squash
"time"
our universe
LISA
WMAP, Planck etc.
∞ stretch
∞ squash
previous universe
∞ stretch
∞ squash


∞ squash
"time"
our universe
LISA
WMAP, Planck etc.
∞ stretch
∞ squash
previous universe
∞ stretch
∞ squash
Conformal Cyclic

Phase-space Volume Loss & the Second Law



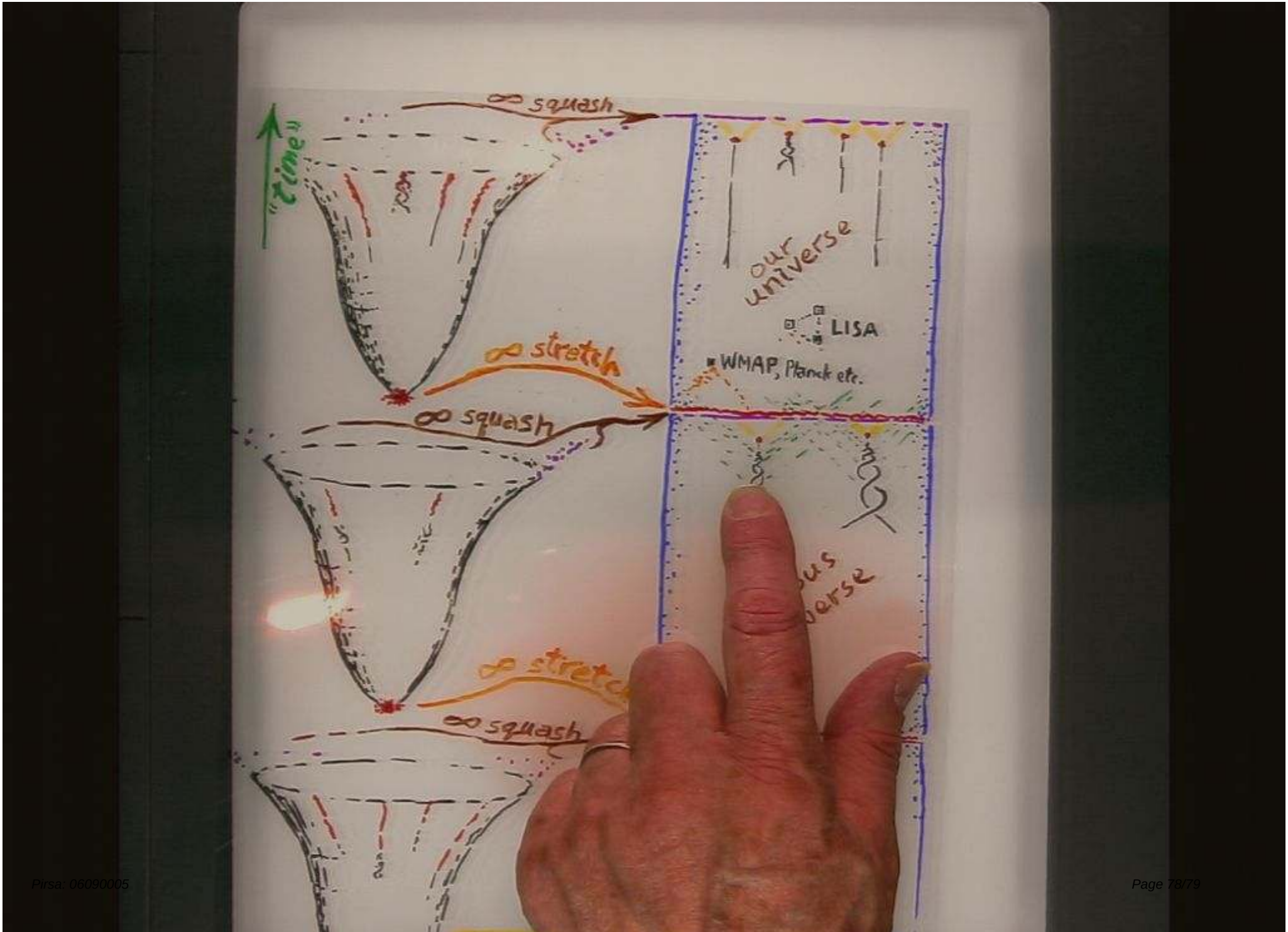
N.B. phase space has a natural volume measure determined by quantum theory

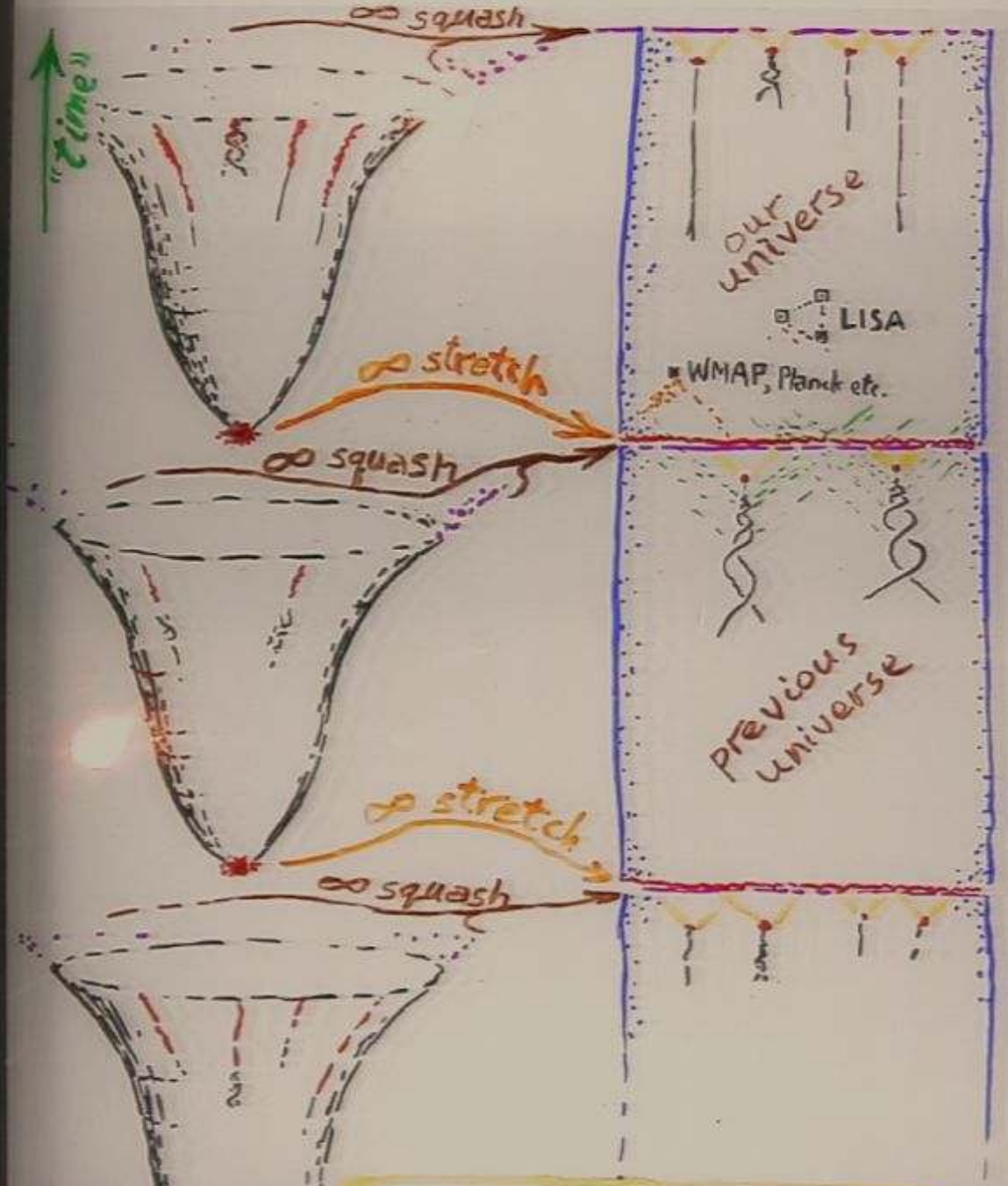
"$\left(\frac{dp_i dq_i}{\hbar}\right)^n$"

Possibilities:

- saved by volumes being infinite?
- grav. degrees of freedom "scale away"?
- $\hbar$ gets "renormalized"?
- balanced by "information loss paradox" in Hawking black-hole evaporation

Bestbet


∞ squash
"time"
our universe
LISA
WMAP, Planck etc.
∞ stretch
∞ squash
∞ stretch
∞ squash


∞ squash
"time"
our universe
LISA
WMAP, Planck etc.
∞ stretch
∞ squash
previous universe
∞ stretch
∞ squash