The Big Bang
& its dark matter content
whence, whither & wherefore

Vatican City (~Rome)

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Oxford U.K.
2017
Cosmological constant \( \Lambda \)

Inflation? 
Not visible on this scale

Big Bang

..... & not there??
Big Crunch

Mess of Congealing Black Holes
Two Mathematical Tricks

1. Squash down future infinity to get smooth future boundary

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

Conformal map

Expansion
Planck: $E = h\nu$
Einstein: $E = mc^2$
\[ \therefore \nu = m \times \left( \frac{c^2}{\hbar} \right) \]
Light cones & conformal space-time geometry

Maxwell's equations for electromagnetism depend only on the light cones.
Mass needed to define Clocks & Einstein's general relativity
Hawking evaporating black hole

pop!

Hawking radiation

decay in: 10^10 years

time
infinite Compression

The extremely remote future

Much matter collapses to black holes which eventually evaporate away by Hawking’s process. ~10^100 years Mainly photons left; remaining massive particles (e.g. electrons) lose their mass eventually through a proposed “anti-Higgs process” with only massless ingredients left, there is no way to build a clock! Eternity is as nothing for a massless particle like a photon Conformal geometry!

Note: infinity is spacelike for \( \Lambda > 0 \)
• Works under very general circumstances (H. Friedrich) (positive)

• Extremely strong restriction suppressing gravitational degrees of freedom (K.R. Tod)
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.
2nd Law of Thermodynamics

Entropy increases with time

\(\Rightarrow \) "disorder" (roughly speaking)

Gas in a box

Time increases

Entropy increases

Gravitating bodies

Maximum entropy: **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 $10^{124}$.

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 BE BEFORE

Infinite expansion

Just a mathematical trick! .....? Temperatures become so large at the Big Bang that rest masses become ignorable .....
Conformal cyclic cosmology (cyc)
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 wedge:

\[ \hat{\mathcal{C}}_{abcd} = \Omega^2 \mathcal{C}_{abcd} \]
\[ \hat{\mathcal{R}}_{abcd} = \Omega \mathcal{R}_{abcd} \]

Define

but

since this gives a conformally invariant wave eqn:

\[ \therefore \mathcal{R}_{abcd} \text{ finite at future infinity} \]
\[ \mathcal{C}_{abcd} = 0 \text{ at future infinity} \]
\[ \therefore \mathcal{C}_{abcd} = 0 \text{ at Big Bang of current aeon} \]

We find that degrees of freedom are NOT lost but go into \{ electric part → Dark Matter, magnetic part → Cotton conf. curv. of crossover \}
Outline of CCC equations

\[ \omega^2 g_{ab} = \hat{g}_{ab} \]
\[ \nu^2 g_{ab} = \hat{\nu}_{ab} \]

\[ \omega = -\Omega^{-1} \] [reciprocal hypothesis]

Pre-crossover \( \Omega \) is a phantom field put in only to allow Einstein equations to be written in the conformally invariant form

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

where the conformally invariant operator

\[ D_{\mu\nu} = \nabla_\mu \nabla_\nu - \frac{1}{4} g_{\mu\nu} \Box - \frac{1}{2} R_{\mu\nu} + \frac{1}{8} g_{\mu\nu} R \]

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

(1) \( \Omega \) picks up the gravitational degrees of freedom

(2) The \( \Omega \)-field must eventually decay away

(3) Mass value? Planch mass??!

(4) Mass value to gravitons?

(5) CMB temperature fluctu...
What is Dark Matter according to CCC?

Pre-crossover $\Omega$ is a "phantom field", with no physical content. Post-crossover, $\Omega$ acts as a real physical field, where $T_{\text{lab}}[\Omega]$ 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 $K_{\text{lab}}$ (magnetic part becomes Cotton tensor of crossover).

- $\Omega$-field interacts only gravitationally.
- $\Omega$-particle has $\sim$Planck mass.
- Must decay away completely by aem's end.
- Provides $\sim$scale invariant CMB temp. fluctuations of NEXT aeon! Spectral index?
Can we "see" through into the aeon prior to ours?

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Crossover 3-surface

Supermassive black holes in same galactic cluster

Black hole encounters

Us, now

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Atypical temperature
Better diagnostic
Low variance
Concentric rings

V. Gurzadyan
The Sky-Twist Test

(\(\theta, \phi\)) spherical polar angles

Area preserving

\[ \theta' = \theta \]
\[ \phi' = \phi + s\theta \]

(in degrees)

Infinitesimally:

\[ \rho_{\text{minor axis}} = \frac{\text{minor axis}}{\text{major axis}} = (\sqrt{1+s^2} - s)^2 \]

where \( s = \frac{1}{180} |\sin \theta| \)

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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 evaporative
- 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.