OUT OF THE WHITE HOLE:
A HOLOGRAPHIC ORIGIN FOR THE BIG BANG

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Cosmology After Planck
University of Michigan-Ann Arbor
24 Sep. 2013
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arXiv:1309.1487
COSMIC PYRAMID

Dark “Energy”: CC problem
“Missing” Baryons
“Big Bang”

Dark “Matter”
INVITATION:
DARK UNIVERSE VS HOLOGRAPHY

✧ **Fluid/Gravity duality:** “Fluids” on a boundary modeled with Einstein gravity in the bulk or vice versa

✧ **Dark “Fluids” in cosmology:** Dark Matter, Dark Energy, Inflaton, etc.

✧ Could these “fluids” be holographic duals of a higher-d gravity? ➞ **Braneworld scenario**

✧ Our brane has its own gravity; need another bulk gravity that kicks in at late times ➞ **DGP gravity** *(Dvali, Gabadadze, Porrati)*
HOLOGRAPHIC FLUID

- Bulk gravity as additional stress tensor on the brane:

\[ G_{\mu\nu} = 8\pi G_N (T_{\mu\nu} + \tilde{T}_{\mu\nu}) \]

- Brown-York stress tensor:

\[ \tilde{T}_{\mu\nu} \equiv \frac{1}{8\pi G_b} (K g_{\mu\nu} - K_{\mu\nu}) \]

- Eq. of State of holographic fluid, fixed by bulk Einstein eq’s

\[ \tilde{\rho} + \rho - 3(P + \tilde{P}) + \frac{8\pi G_b^2}{G_N} \left( \frac{2}{3} \tilde{\rho}^2 + 2\tilde{\rho}\tilde{P} \right) = 0, \]
5D BLACK HOLE

- Most generic cosmological solution, equivalent to a spherical brane in 5D Schwarzschild spacetime
- **Big-Bang** singularity is **White Hole** singularity
- Holographic pressure singularity (Gregory, et al. 2008) always inside horizon

\[
\tilde{\rho}_\pm = \tilde{\rho}_s \left(1 \pm \sqrt{1 - \frac{\mu^2}{12\pi G_N \tilde{\rho}_s a^4} + \frac{2\rho}{\tilde{\rho}_s}}\right)
\]

\[
\tilde{P} = \frac{\tilde{\rho}^2 + \tilde{\rho}_s (\tilde{\rho} - T)}{3(\tilde{\rho}_s - \tilde{\rho})},
\]
5D BLACK HOLE

- Most generic cosmological solution, equivalent to a spherical brane in 5D Schwarzschild spacetime

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\tilde{\rho}_\pm = \tilde{\rho}_s \left(1 \pm \sqrt{1 - \frac{\mu^2}{12\pi G_N \tilde{\rho}_s \alpha^4} + \frac{2\rho}{\tilde{\rho}_s}}\right)
\]

\[
\tilde{P} = \frac{\tilde{\rho}^2 + \tilde{\rho}_s(\tilde{\rho} - T)}{3(\tilde{\rho}_s - \tilde{\rho})}
\]
SINGULARITY VS WHITE HOLE HORIZON

BBN

now

Tuesday, 24 September, 13
White hole singularities are only artifacts of static approximation, and cannot form in our Universe.

Could the same be true for the big bang?

→ \textit{Collapse of 5D "star"}
BYE BYE BIG BANG!!

- White hole singularities are only artifacts of static approximation, and cannot form in our Universe.

- Could the same be true for the big bang?
  → *Collapse of 5D “star”*
SCALAR METRIC PERTURBATIONS

- Poisson/Thermal matter distribution (e.g. debris from the star) in 4+1d yield scale-invariant metric perturbations

\[
\langle \Phi_4(x^a)\Phi_4(y^a) \rangle_T \simeq \frac{5}{8} T^6 \left( \frac{8\pi G_b}{3} \right)^2 \int \frac{d^4k}{(2\pi)^4} \frac{\exp[ik_a(x^a - y^a)] M(k/T)}{k^4}
\]

\[
M(\kappa) \simeq \frac{15\zeta R(5)}{\pi^2} + \mathcal{O}(\kappa^2) \simeq 1.576 + \mathcal{O}(\kappa^2),
\]

- Imposing $Z_2$ reflects this onto the brane

\[
\frac{k^3}{2\pi^2} P_\zeta(k) \simeq \left[ 8.66 \times 10^{-5} + \mathcal{O} \left( \frac{k}{a_b T_b} \right)^2 \right] \left( \frac{T_b}{M_5} \right)^6
\]

\[
\frac{T_b}{M_5} = 0.17139 \pm 0.00077,
\]
CAN THIS REPLACE INFLATION?

- **Horizon problem**: no big bang, plenty of time to equilibrate
- **Flatness problem**: Big Star $\rightarrow M_{BH} \gg M_{5}$
- **Monopole problem**: $T \ll T_{GUT}$
HOMEWORK

- Tilt? ... gravitational backreaction $O(T/M)^3$
- Non-gaussianity? ... central limit theorem
- Gravitational Waves? ...
**Goodbye Big Bang, hello black hole? A new theory of the universe's creation**

Sep 19, 2013 by Elizabeth Howell, Universe Today

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Big Bang was mirage from collapsing higher-dimensional star, theorists propose.

Zeeva Merali

13 September 2013

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**Universe May Have Formed From Debris When Star Collapsed Into Black Hole, Cosmologists Say**

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**WATCH: How To Make Sense Of Dreaming**

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**Science May Have Formed From Debris When Star Collapsed Into Black Hole, Cosmologists Say**

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**PBS**

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Ready to have your mind blown? We might be living in a membrane around the event horizon of a collapsed hyperdimensional star that gave birth to the universe.

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John Swinburn I was afraid that might be the case, but I didn’t want to mention it and cause undue alarm...

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September 23, 2013
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New Concern Keeps Spacecraft From Docking With ISS

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LAST WORD!

✧ DGP cosmology: Our universe could have formed from collapse of a 4+1d star ➞

✧ No big bang singularity, No need for inflation, etc.

✧ 5D generation of scale-invariant perturbations

✧ Tilt? Non-gaussianity? Grav. waves?

✧ *Cosmology After Planck*: The burden is on theorists to make sense of our cosmic pyramid ...
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