Rethinking Time at the Big Bang

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Some References

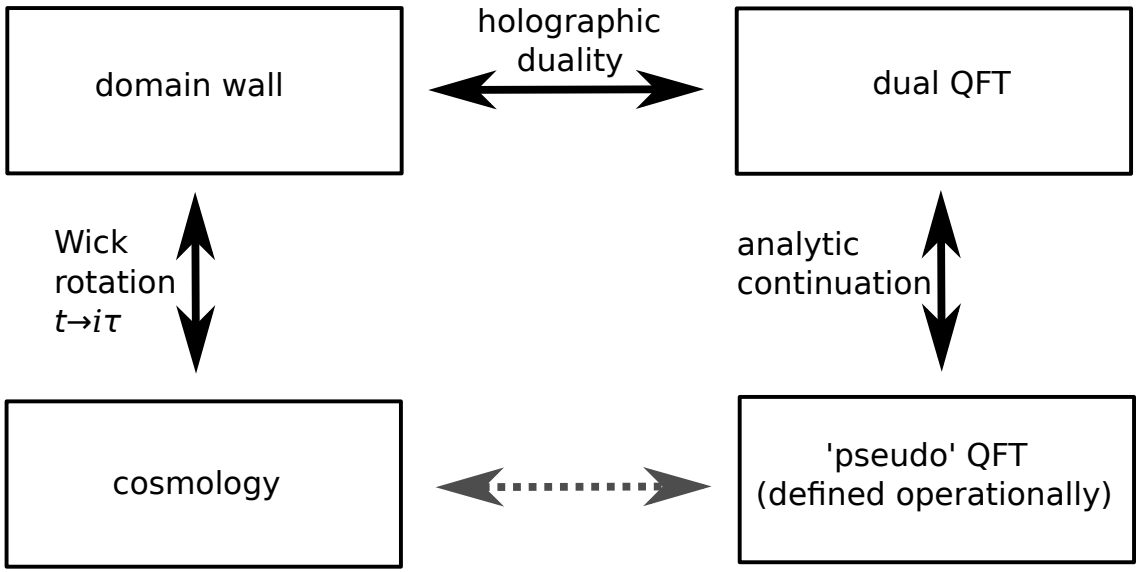

Niayesh Afshordi, Elizabeth Gould, and Kostas Skenderis.
Constraining holographic cosmology using Planck data.
arXiv:1703.05385 [astro-ph.CO].

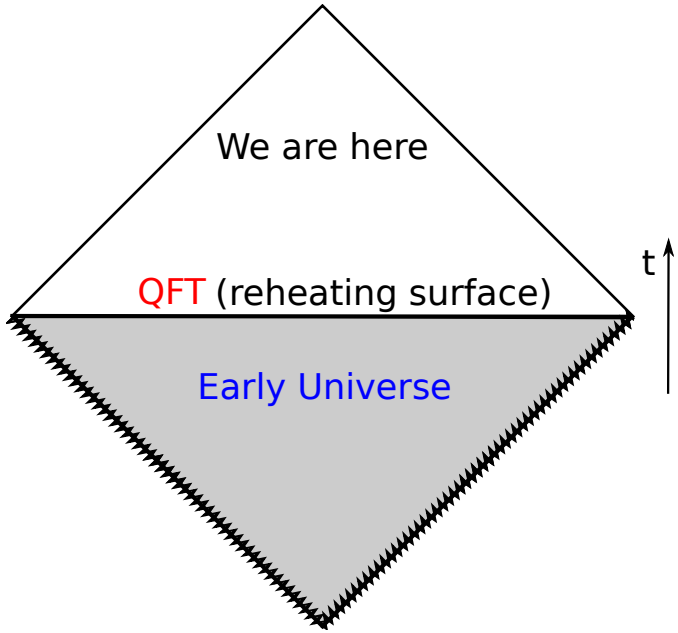

Niayesh Afshordi, Claudio Corianò, Luigi Delle Rose, Elizabeth Gould, and Kostas Skenderis.
From Planck data to Planck era: Observational tests of holographic cosmology.
Phys. Rev. Lett., 118:041301, Jan 2017.


Richard Easther, Raphael Flauger, Paul McFadden, and Kostas Skenderis.
Constraining holographic inflation with WMAP.
JCAP, 1109:030, 2011.


Paul McFadden and Kostas Skenderis.
The Holographic Universe.
J. Phys. Conf. Ser., 222:012007, 2010.

Model Description





Dual QFT Lagrangian (arXiv 1001.2007)

- models are defined by the dual QFT
- use a superrenormalizable (3D Euclidean) QFT

$$S = \frac{1}{g_{YM}} \int d^3x \, \mathrm{tr} \left[\frac{1}{2} F^I_{ij} F^{Iij} + \frac{1}{2} \left(D\phi^J \right)^2 + \frac{1}{2} \left(D\chi^K \right)^2 + \psi^L \not{D} \psi^L \right.$$
$$\left. + \lambda_{M_1 M_2 M_3 M_4} \Phi^{M_1} \Phi^{M_2} \Phi^{M_3} \Phi^{M_4} + \mu^{\alpha\beta}_{M L_1 L_2} \Phi^M \psi^{L_1}_\alpha \, \psi^{L_2}_\beta \right]$$

- dimensions: g^2_{YM}, ϕ, $A = 1$; $\psi = \frac{3}{2}$
- SU(N), $N \sim 10^4$; parameters are:
  - number of various fields: N, N_ϕ, N_χ, N_ψ
  - coupling constants: $\lambda_{M_1 M_2 M_3 M_4}$, $\mu^{\alpha\beta}_{M L_1 L_2}$, g_{YM}

Modified Spectrum

- difference between models given by primordial power spectra

$$A = A_0 \left(\frac{q}{q_*}\right)^{(n_s-1)+\frac{n_{run}}{2}\ln\left(\frac{q}{q_*}\right)} \rightarrow A = A_0 \frac{1}{1+(gq_*/q)\ln\left(q/\beta g q_*\right)}$$

- all parameters are the same except g and $\ln(\beta)$ instead of n_s (and n_{run}) define shape of power spectrum

The holographic cosmology perturbation expansion is expected to break down at low l values for large $|g|$, when $\left|\frac{gq^*}{q}\right|$ becomes large.

Best Fit Parameters

	HC		ΛCDM	
	best fit	68% range	best fit	68% range
$\Omega_b h^2$	0.02217	0.02215 ± 0.00021	0.02231	0.02229 ± 0.00022
$\Omega_c h^2$	0.1173	0.1172 ± 0.0012	0.1184	0.1186 ± 0.0012
100θ	1.04112	1.04115 ± 0.00042	1.04108	1.04105 ± 0.00041
τ	0.081	0.082 ± 0.013	0.069	0.068 ± 0.013
$10^9 \Delta_0^2$	2.126	2.126 ± 0.058	2.151	2.149 ± 0.054
n_s			0.9682	0.9671 ± 0.0045
α_s			-0.0027	-0.0030 ± 0.0074
g	-0.0070	$-0.0074^{+0.0014}_{-0.0013}$		
$\ln \beta$	0.88	$0.87^{+0.19}_{-0.24}$		
χ^2	11324.5		11319.6	

- $\Delta\chi^2 = 4.8$, difference in likelihood $\sim 2.2\,\sigma$
- $\left|\frac{gq^*}{q}\right| = 2.5$, so expansion expected to be invalid when $l < 35$

Best Fit Parameters for $l > 30$

	HC		ΛCDM	
	best fit	68% range	best fit	68% range
$\Omega_b h^2$	0.02204	0.02202 ± 0.00022	0.02217	0.02212 ± 0.00024
$\Omega_c h^2$	0.1187	0.1187 ± 0.0014	0.1186	0.1188 ± 0.0013
100θ	1.04097	1.04099 ± 0.00042	1.04101	1.04100 ± 0.00041
τ	0.067	0.066 ± 0.017	0.0695	0.067 ± 0.016
$10^9 \Delta_0^2$	2.044	2.043 ± 0.074	2.151	2.139 ± 0.066
n_s			0.9682	0.9666 ± 0.0047
α_s			0.0083	0.0090 ± 0.0094
g	-0.0130	$-0.0127^{+0.0042}_{-0.0038}$		
$\ln \beta$	1.01	$0.90^{+0.32}_{-0.16}$		
χ^2	824.0		823.5	

- Here, $\Delta\chi^2 = 0.5$, meaning the difference is negligible.

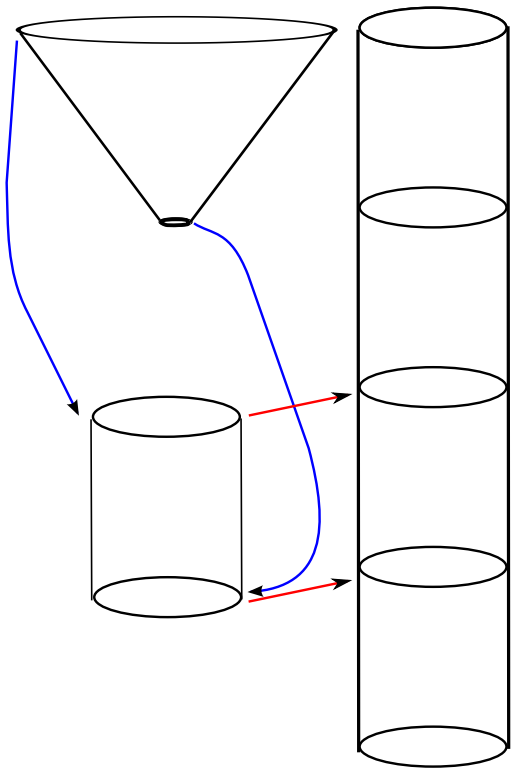
1. Holographic Cosmology
   - Description
   - Comparison of Models

2. Periodic Time Cosmology
   - Description
   - Results

3. Conclusion

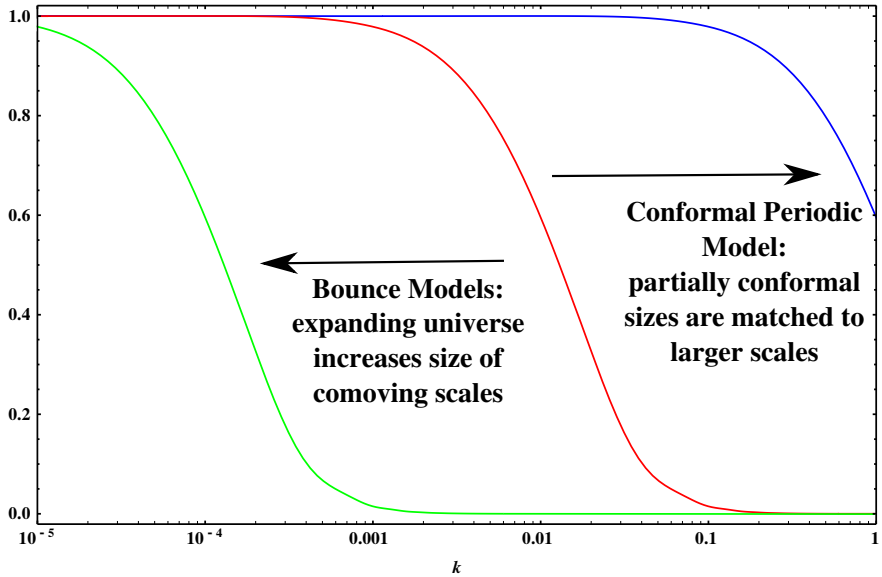
Cyclic Models

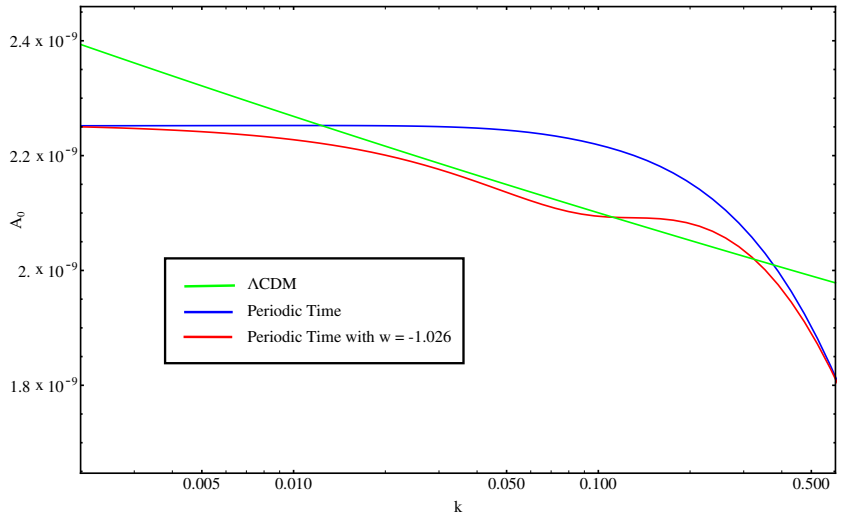
- conception - taking cyclic model and making it exactly periodic
- will use a conformal matching similar to Penrose's Conformal Cyclic Cosmology (CCC)



Transfer Function

- model matches large scales (with low k) of old spectrum to visible scales in new spectrum

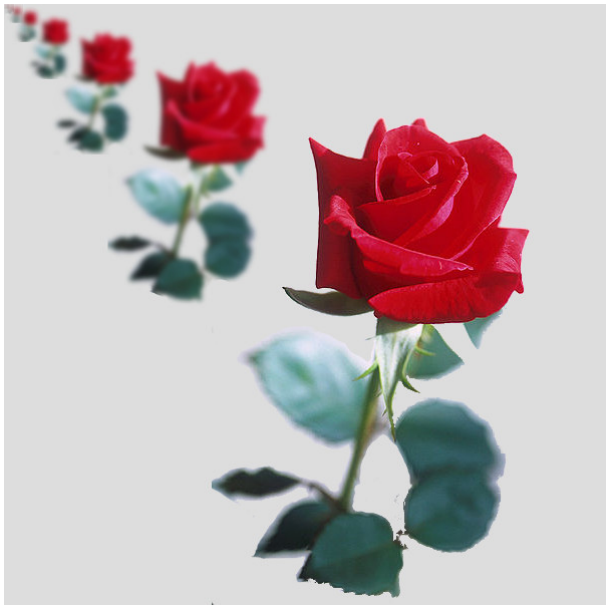




Penrose's CCC, like other cyclic models and inflation, match in the other direction, taking the portion of the transfer function with no power and reforming or constructing the primordial power spectrum at some time.

Description

- parameter α defines relative conformal rescaling of co-moving scales so $k_{old} = \alpha k_{new}$
- $\mathcal{P}(k)$ primordial power spectrum, $T(k) = \frac{\zeta_k(t=\infty)}{\zeta_k(t=0)}$ transfer function
- $\mathcal{P}(k) = A_0 |T(\alpha k)|^2 \left|T\left(\alpha^2 k\right)\right|^2$ ... invariant under evolution + rescaling
- producing repeating pattern, where each cycle shrinks previous and applies low-pass filter:



- $\alpha \ll 1$ so for observable k, $T(\alpha k) \sim 1$ and $\mathcal{P}(k)$ is approx. scale invariant with a red tilt

Preliminary Minimum χ^2

- model run in CosmoMC with present $T(k)$ used to determine $\mathcal{P}(k)$
- lowTEB+highl+lensing+BKP+BAO+highP+tau

	χ^2 for ΛCDM	χ^2 for PT	$\Delta\chi^2$	σ
6 params	12995.3	13021.1	25.8	5.1
+ $w \neq -1$	12995.1	12998.5	3.4	1.8
+ w, w_a	12994.7	12997.8	3.1	1.8

	ΛCDM	PT
$\Omega_b h^2$	0.02220	0.02225
$\Omega_c h^2$	0.1198	0.1184
100θ	1.04074	1.04094
τ	0.0527	0.0483
$10^9 \Delta_0^2$	2.0900	2.1779
w	-1.0364	-1.0238
n_s	0.9637	
α		0.01125

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Conclusion

- Holographic Cosmology
  - By constructing a holographic dual on the "reheating surface", a non-geometric alternative to inflation can be constructed.
  - This model was fit to data using CosmoMC and compared to ΛCDM.
  - Holographic cosmology can match observation as well as ΛCDM.
  - The model becomes non-perturbative for low l values or large angles.
- Periodic Time
  - model run in CosmoMC which relates cosmic history to initial conditions at the big bang
  - preliminary results indicate model is viable but disfavored
  - 6 parameter model disfavored by $\sim 5.1\sigma$
  - best results from $w \neq -1$, difference of $\sim 1.8\sigma$