Title: Conversations & controversies in the early universe

Speakers: Phillip Halper

Collection: Quantum Spacetime in the Cosmos: From Conception to Reality

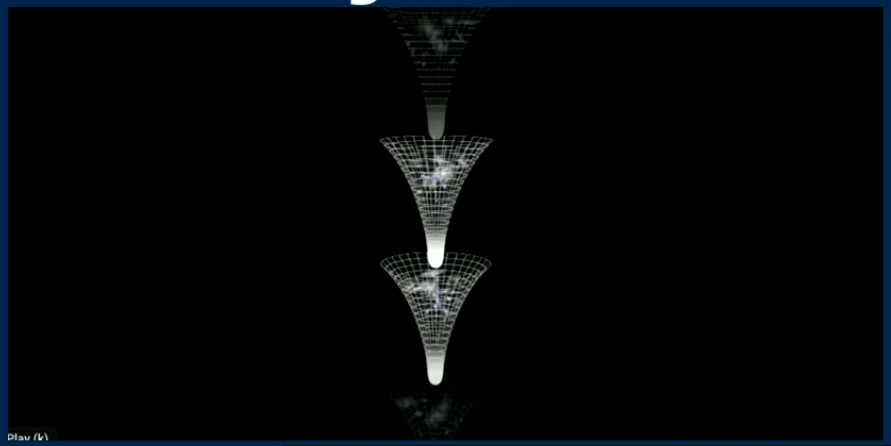
Date: May 09, 2023 - 2:45 PM

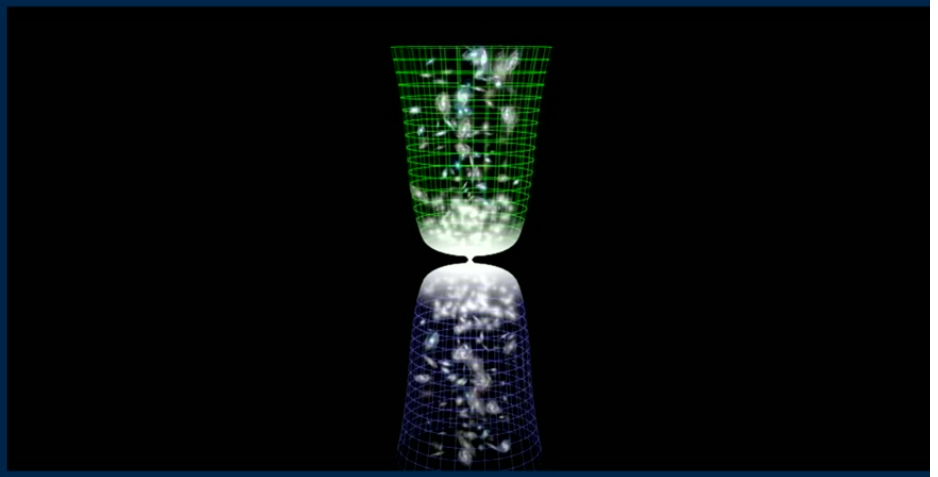
URL: https://pirsa.org/23050118

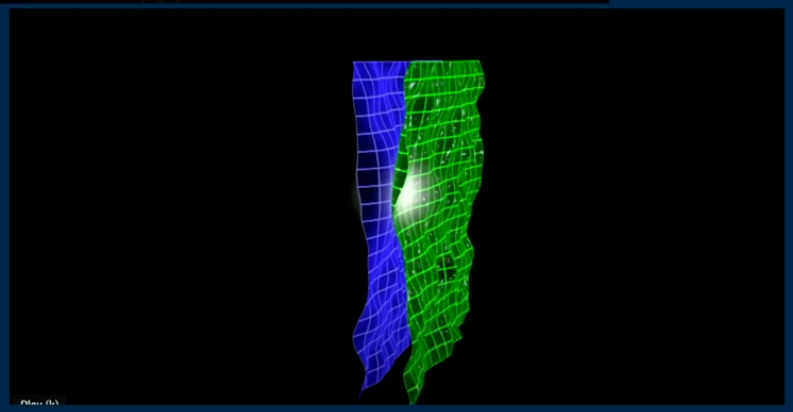
Abstract: Zoom Link: https://pitp.zoom.us/j/95721802052?pwd=TE1iTGxGLzNqeTFSZlNGRXRYMHBCZz09

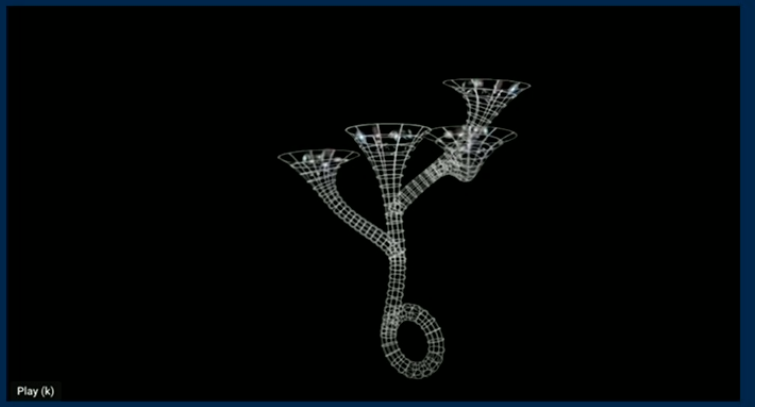
For the last ten years I have been documenting various scenarios for the early universe in a YouTube series called 'Before the Big Bang". Having interviewed many of the leader figures of the field including Stephen Hawking, Roger Penrose, Alan Guth (and hosted debates between them), this will be a broad survey of inflation, it's suggested prequels and alternatives. I shall highlight the strengths and weaknesses of the various proposals and give an inside track of the claims and counter claims in attempts to move beyond the standard Big Bang model.

Conversations & controversies in the early universe

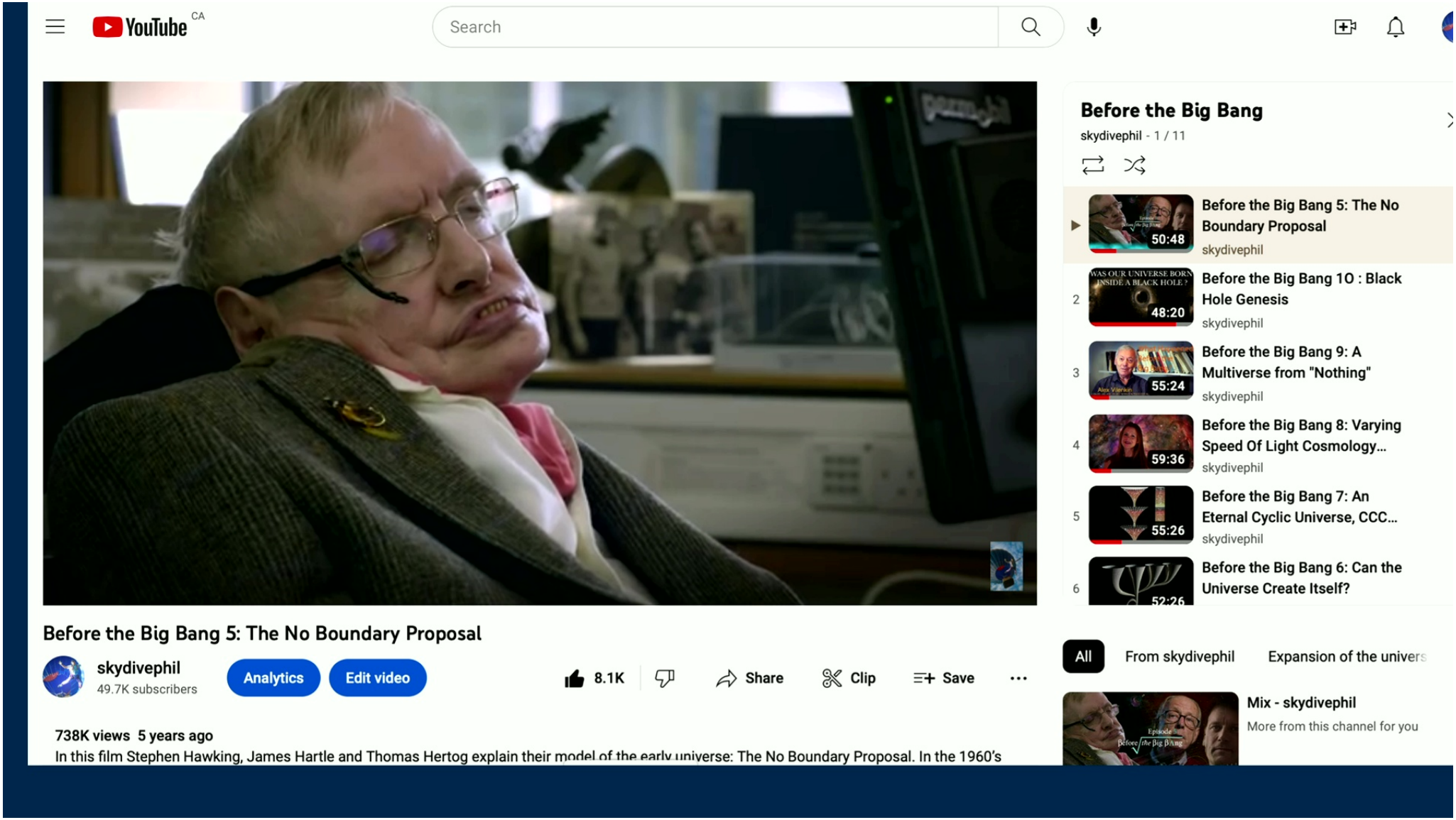








Phil Halper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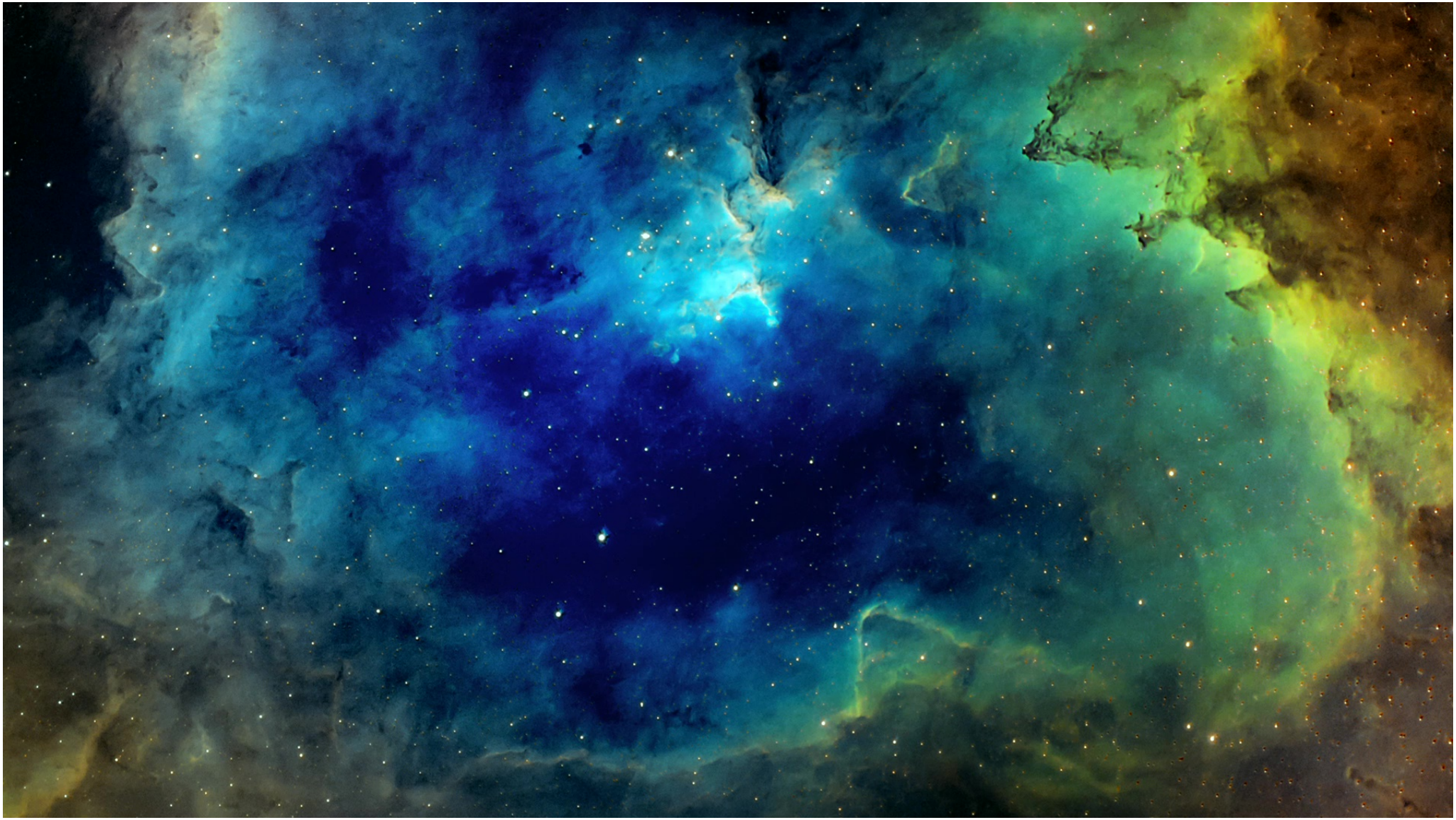
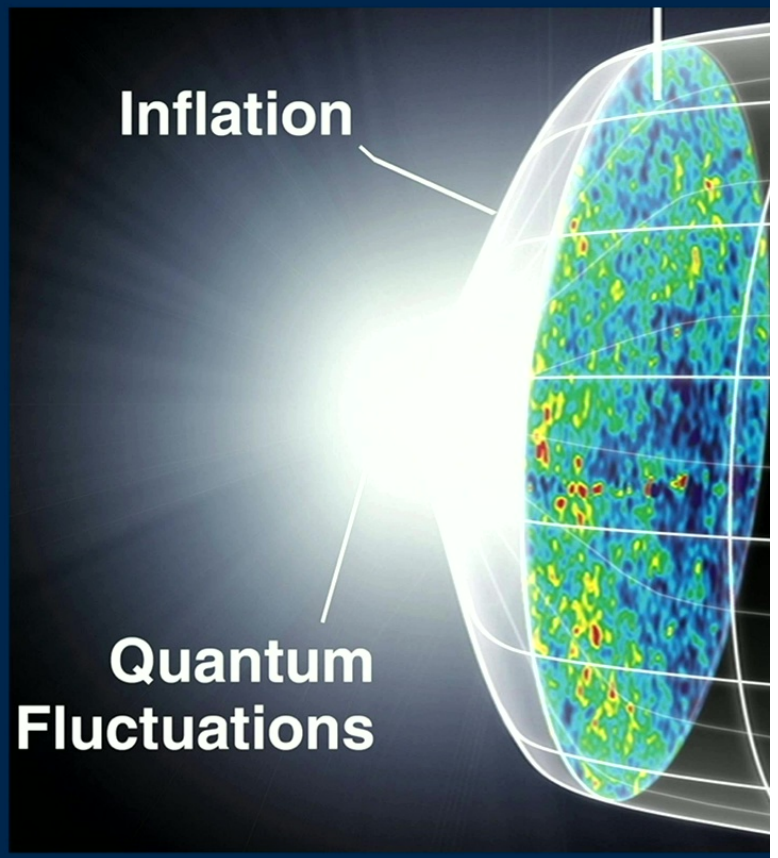


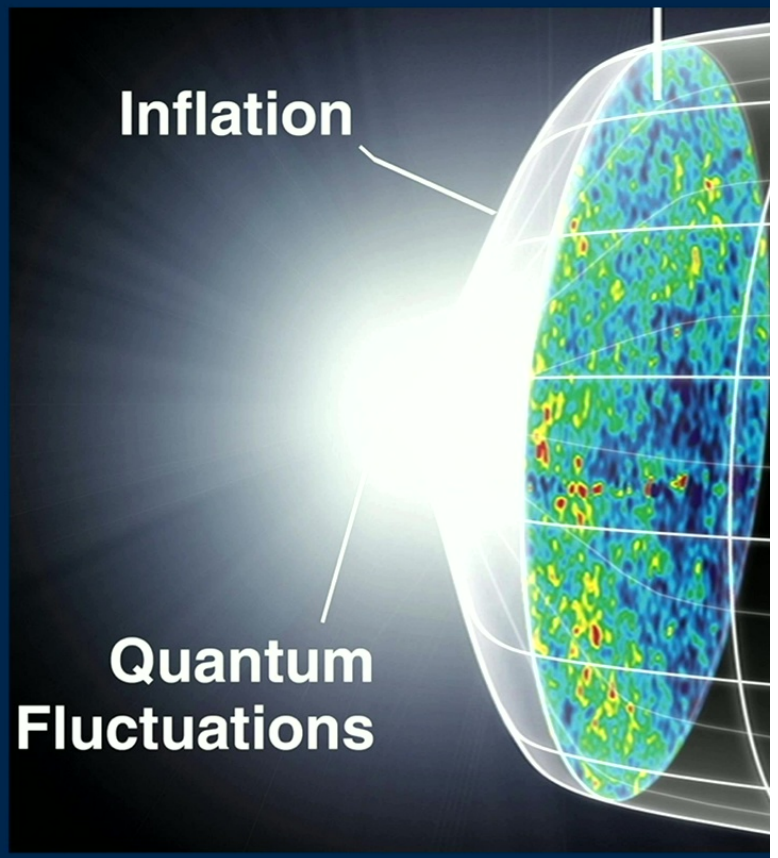
Inflation Claims to Solve:

- **Monopole Problem**



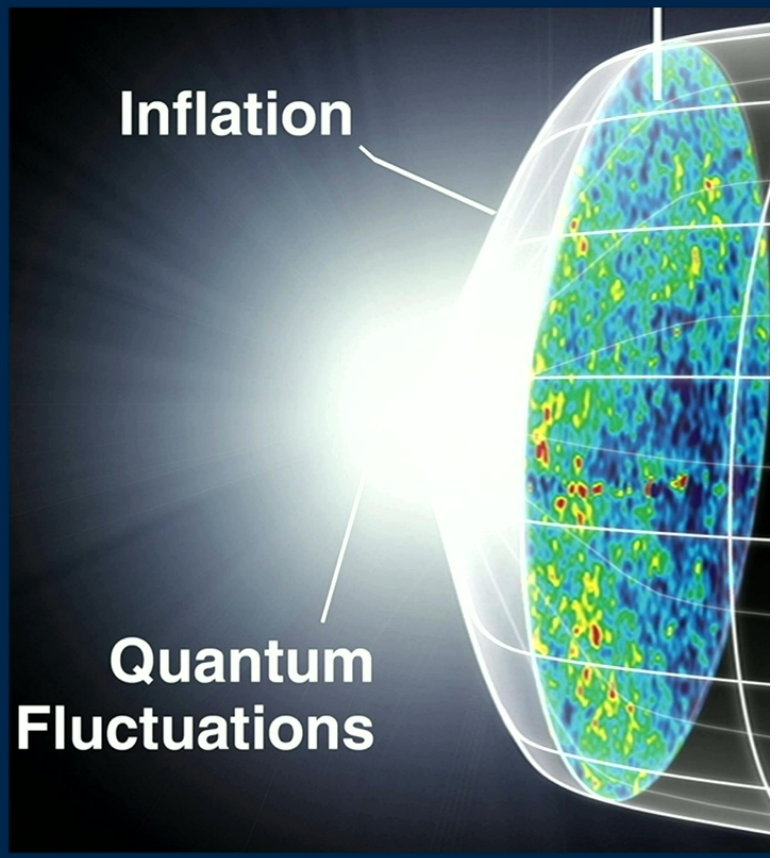
Inflation Claims to Solve:

- Monopole Problem
- Horizon Problem
- Flatness Problem



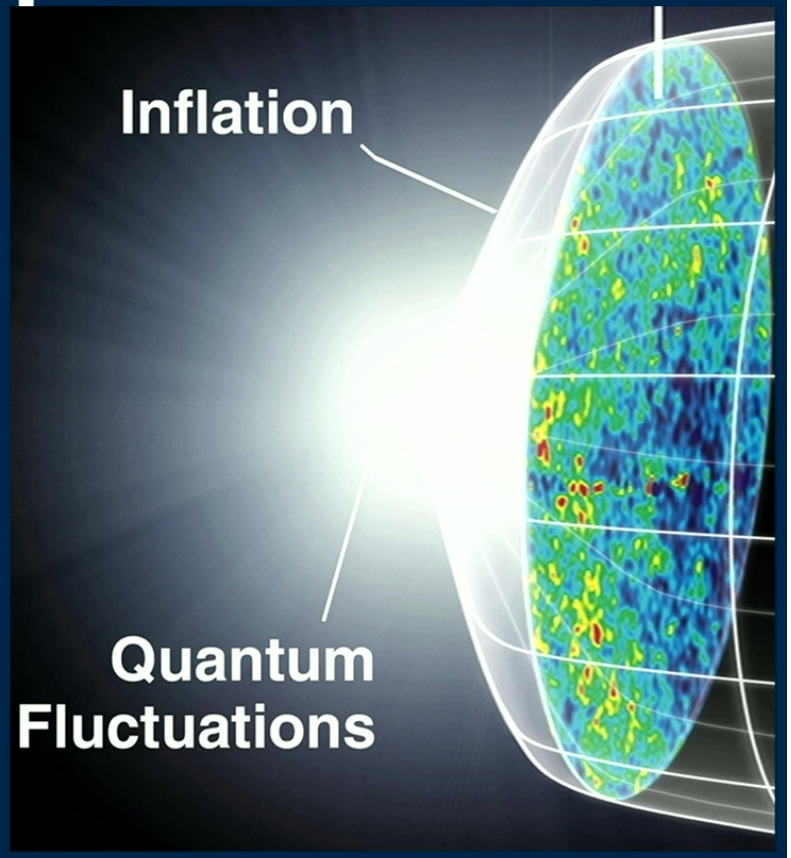
Inflation Claims to Solve:

- Monopole Problem
- Horizon Problem
- Flatness Problem
- Structure Problem



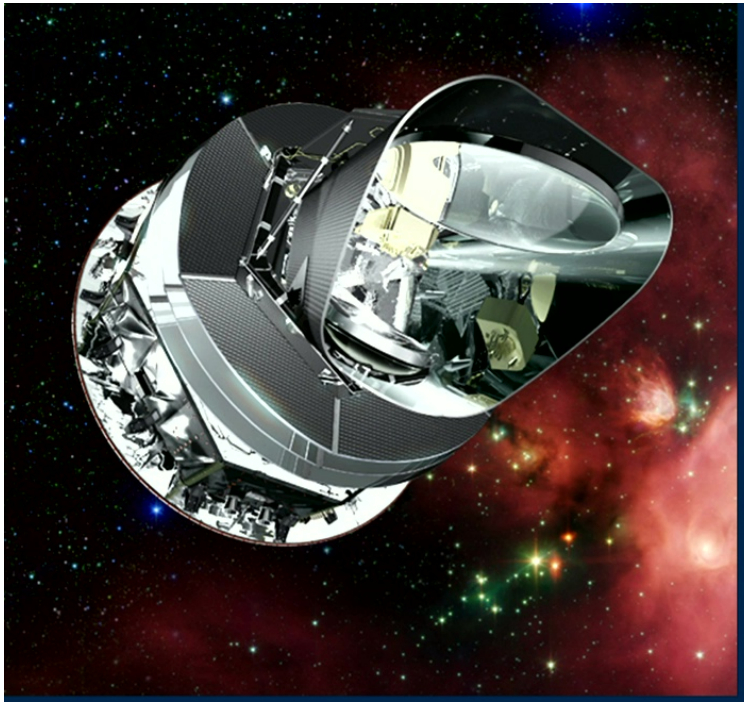
Inflationary cosmologists claim these as successful predictions

- the universe is nearly flat
- nearly scale invariant
- adiabatic fluctuations
- nearly Gaussian distribution
- red tilt in the power spectrum



Problems for inflation

- too many inflationary models
- probability of inflation is low
- no explanation of what came before inflation
- not connected to a theory of quantum gravity
- trans planckian problem
- swampland conjecture
- predictions predate inflation



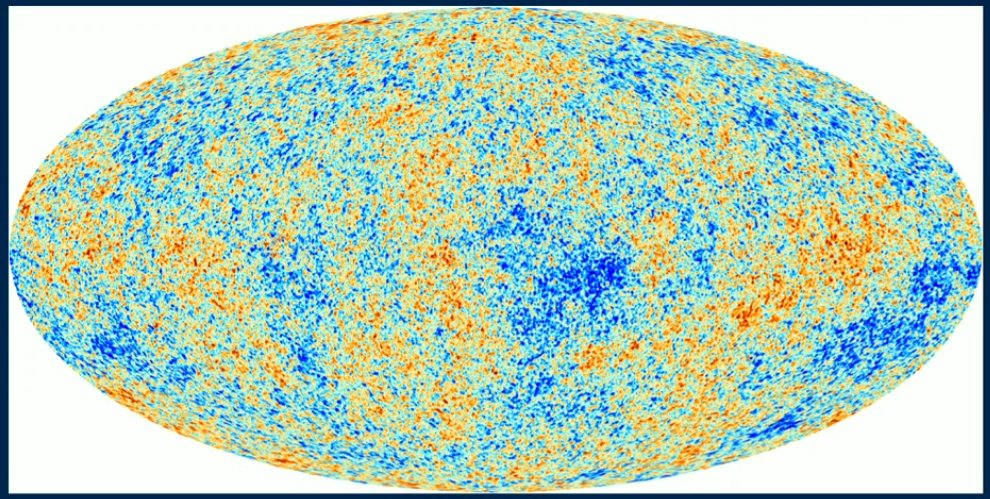
Planck 2013

Ijjas, Anna, Paul J. Steinhardt, and Abraham Loeb.
Inflationary paradigm in trouble after Planck2013
Physics Letters B 723, no. 4-5 (2013): 261-266.

VS

Guth, A. H., Kaiser, D. I., & Nomura, Y. (2014).
Inflationary paradigm after Planck 2013. Physics Letters B, 733, 112-119.

Planck & Inflation



- Generic predictions confirmed
- Too many models
- Standard model has the same problem
- For SM:more data than free parameters, not so in inflation
- no reason to expect correlations more than 2 degrees apart in a 1.16 billion pixel map

Case for the inflationary multiverse

- arises naturally from inflation
- Planck data favours Plateau models which are eternal
- Weinberg used it to predict small Cosmological Constant
- Landscape of string theory
- many worlds = multiverse (Susskind & Busso https://arxiv.org/abs/1105.3796 Nomura https://arxiv.org/pdf/1104.2324.pdf)
- multiplicity is the default in nature
- can help solve anthropic coincidences

eternal inflation

Figure 2. Evolution of the inflaton field during new inflation.

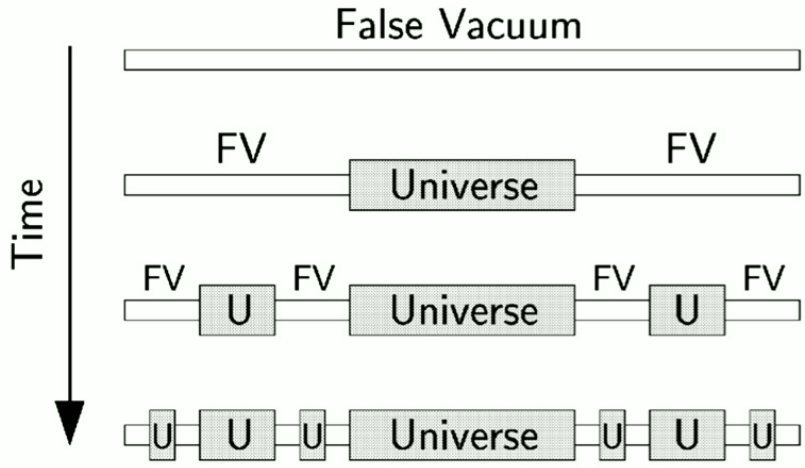


Figure 3. A schematic illustration of eternal inflation.

Case against the inflationary multiverse

- we have alternatives to inflation
- anthropics solved by Cosmological Natural Selection
- anthropics (fine tuning for life) is a pseudo problem
- Sorkin (1987) predicted dark energy without anthropics
- Inflation without a multiverse?

Case against the inflationary multiverse

- we have alternatives to inflation
- anthropics solved by Cosmological Natural Selection
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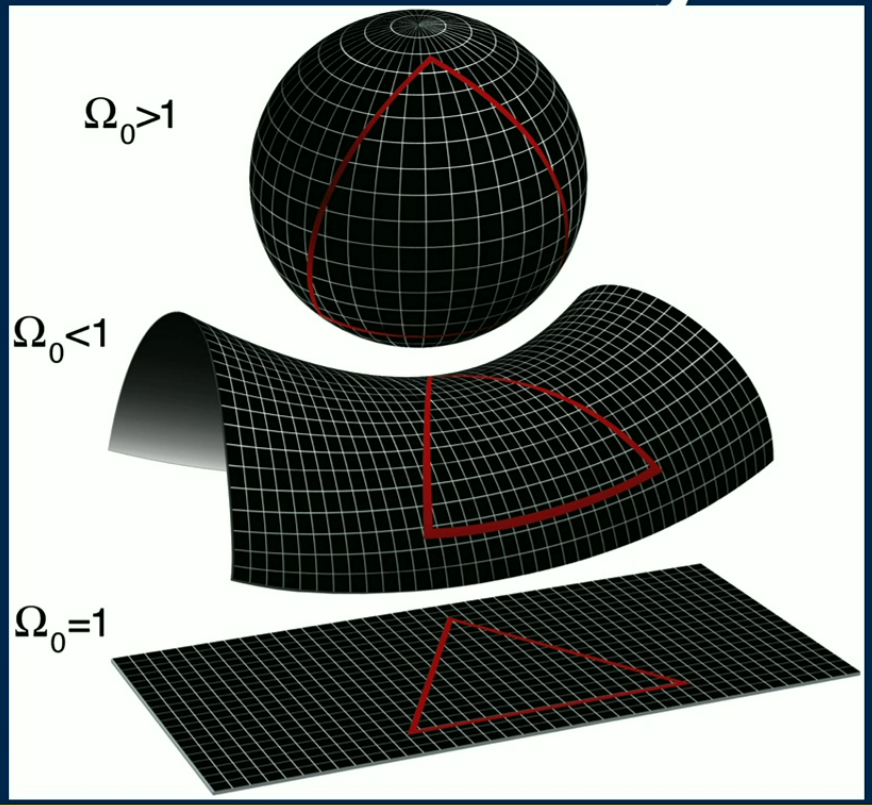
- Sorkin (1987) predicted dark energy without anthropics
- Inflation without a multiverse?
- extravagant
- not science as not falsifiable

Falsifiability?



Positive curvature: Ωk < −10⁻⁴, "then the framework of the eternally inflating multiverse, as currently understood, is excluded with high significance "(Guth Nomura 2012 https://arxiv.org/abs/1203.6876)

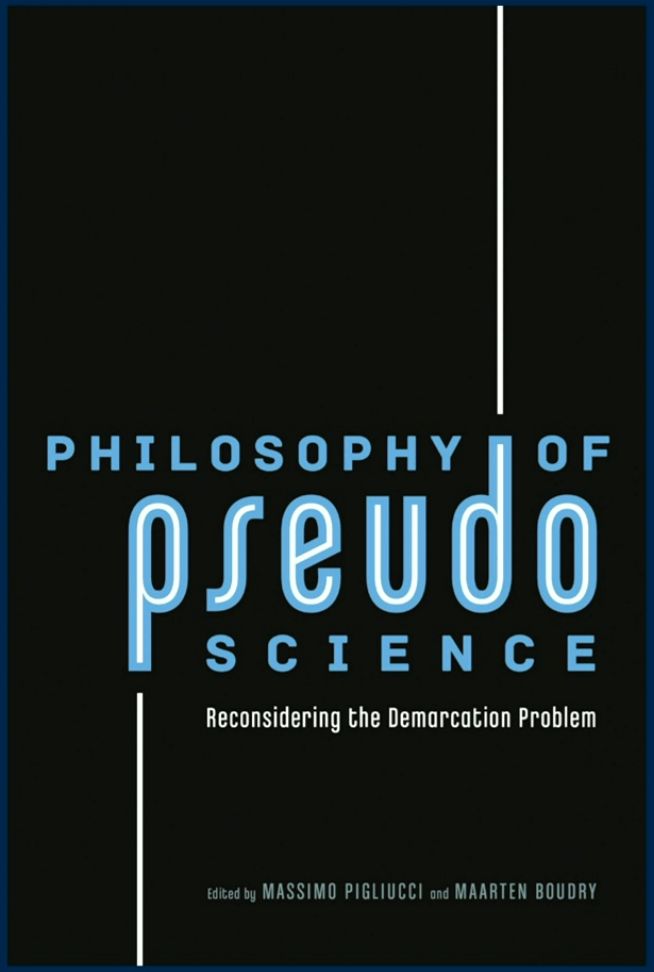
Falsification

Alters, Brian J. "Whose nature of science?" Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching 34, no. 1 (1997): 39-55.

Falsification

Alters, Brian J. "Whose nature of science?" Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching 34, no. 1 (1997): 39-55.

11% of philosophers supported single criteria for demarcation



"Contemporary philosophers of science, it seems, have no trouble with inherently fuzzy concepts… science is best considered as a family of related activities, with no fundamental essence to define it."
Massimo Pigliucci

Semi Eternal Eternal Inflation?

Borde, Arvind, Alan H. Guth, and Alexander Vilenkin.
"Inflationary spacetimes are not past-complete”arXiv01100122001.

Semi Eternal Eternal Inflation?

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"Inflationary spacetimes are not past-complete"arXiv01100122001.

Nomura, Yasunori. "Static quantum multiverse."arxiv1205.5550

Aguirre, Anthony. "Eternal Inflation, past and future."arxiv0712.0571

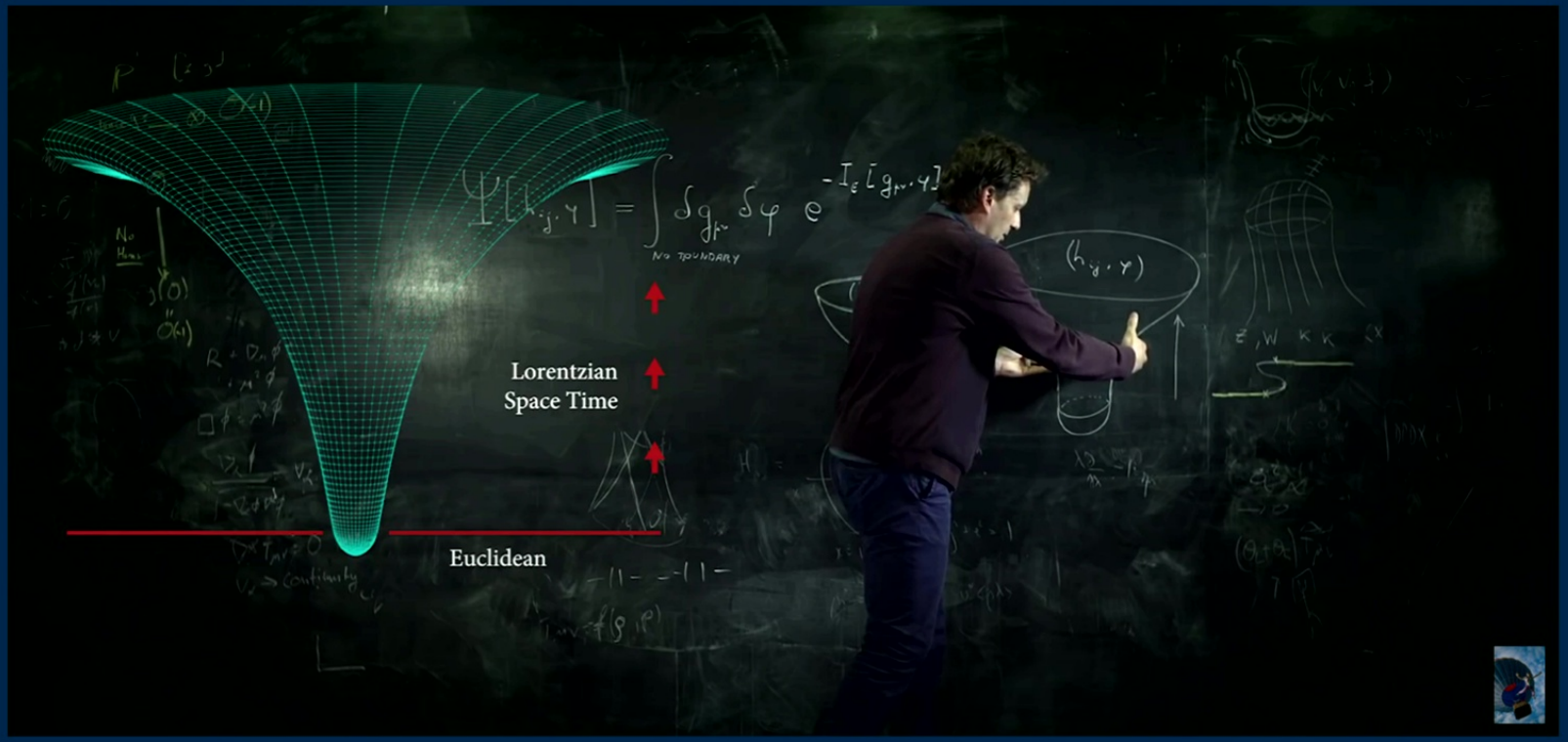
Susskind, Leonard. "Was there a beginning?" arXiv1204.5385

Tunneling from Nothing

Vilenkin 1982 https://doi.org/10.1016/0370-2693(82)90866-8

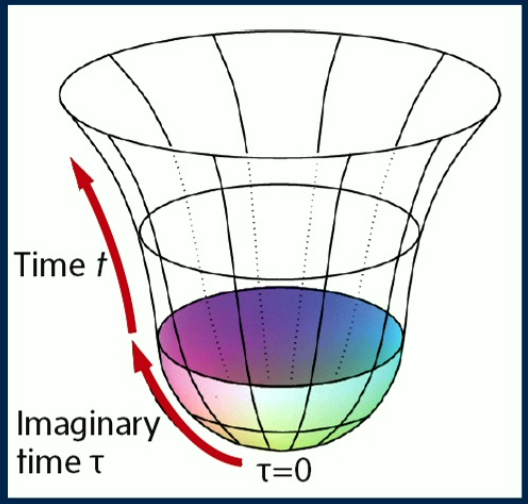
No Boundary Proposal

Hartle, Hawkng Phys. Rev. D 28, 2960 1983



Recent controversy

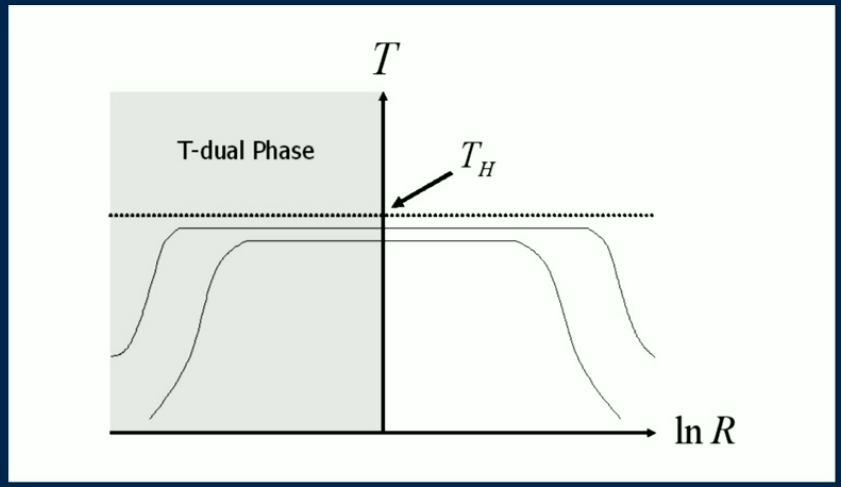
Feldbrugge, Job, Jean-Luc Lehners, and Neil Turok. "No smooth beginning for spacetime." Physical review letters 119, no. 17 (2017): 171301



vs

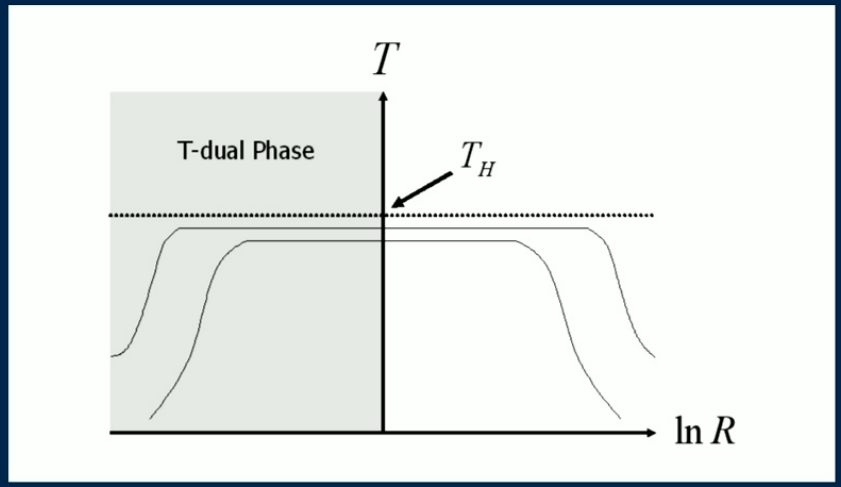
Halliwell, Jonathan J., James B. Hartle, and Thomas Hertog. "What is the no-boundary wave function of the Universe?" Physical Review D 99, no. 4 (2019): 043526

String Gas Cosmology



Brandenberger
2011 https://arxiv.org/pdf/1105.3247.pdf

String Gas Cosmology



Brandenberger
2011 https://arxiv.org/pdf/1105.3247.pdf

- Thermal origin of structure/scale invariant with primordial gravitational waves (Nayeri, Brandenberger, Vafa arxiv0511140)

Ekpyrotic/Cyclic Model

Khoury, Ovrut, Steinhardt, Turok arxiv0103239

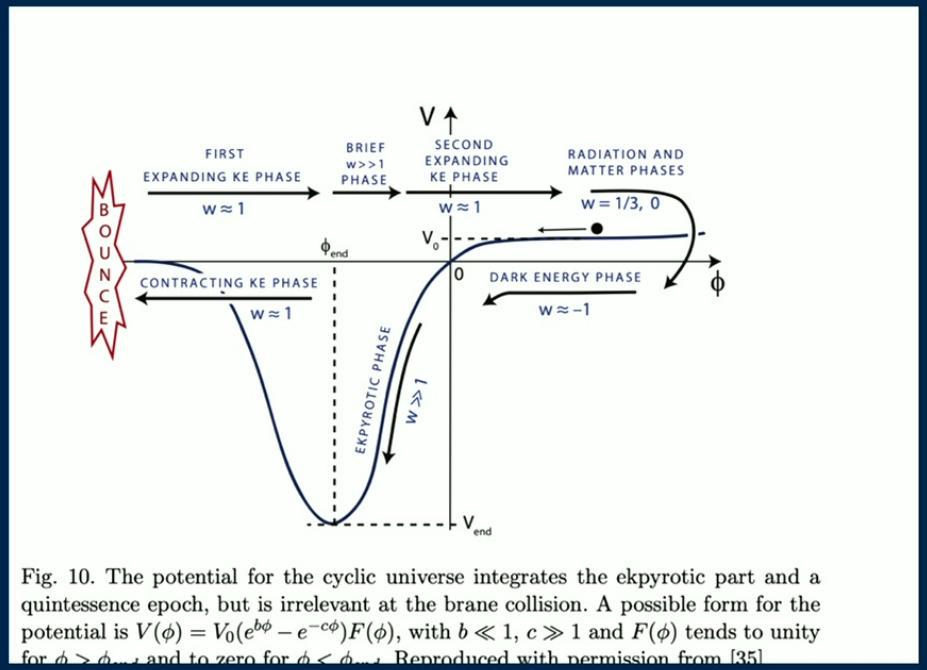
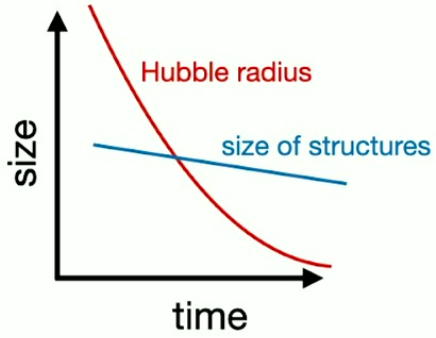


Fig. 10. The potential for the cyclic universe integrates the ekpyrotic part and a quintessence epoch, but is irrelevant at the brane collision. A possible form for the potential is $V(\phi) = V_0(e^{b\phi} - e^{-c\phi})F(\phi)$, with $b \ll 1$, $c \gg 1$ and $F(\phi)$ tends to unity for $\phi > \phi_{end}$ and to zero for $\phi < \phi_{end}$. Reproduced with permission from [35].

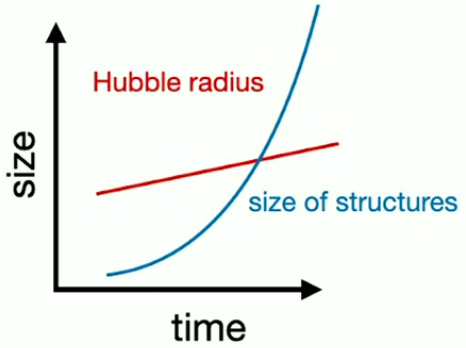
Inflation/contraction duality

Boyle, Steinhardt,Turok https://arxiv.org/abs/hep-th/0403026

Ekpyrotic contraction

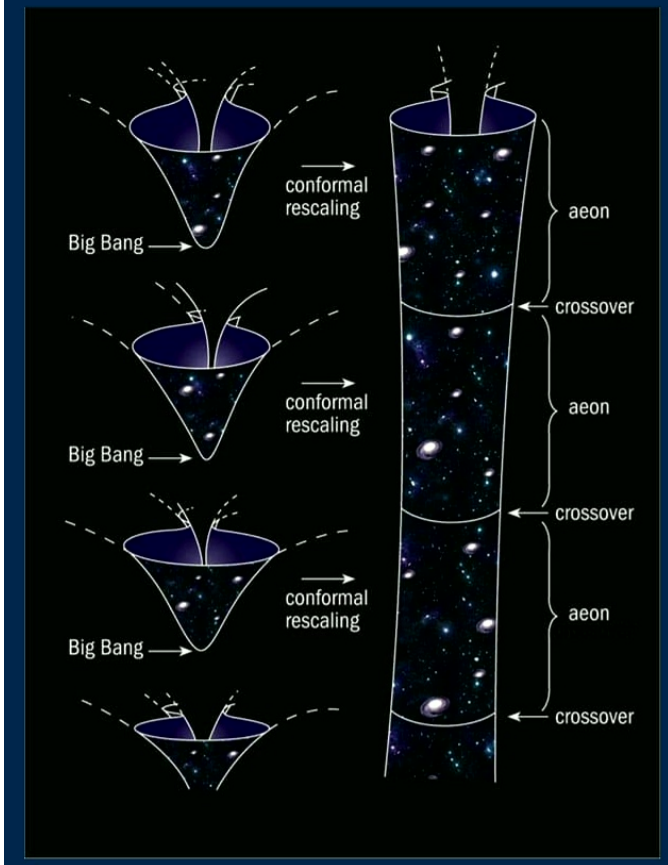


Inflation



Some criticisms of these string models

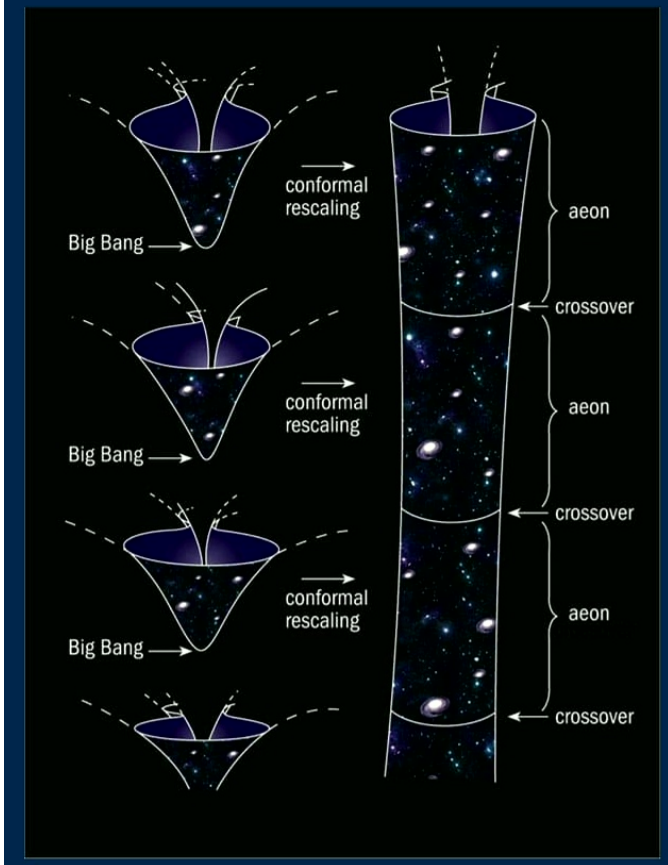
- relies on speculative physics vs known physics for inflation
- String Gas Cosmologists chose the wrong frame of reference for pertubations
- universe starts off flat but inflation makes it flat
- Ekpyrotic universe is just inflation placed at a different era
- no clear singularity resolution (although fuzzball Samir's talk)
- measure problem in cyclic models



CCC (Conformal Cyclic Cosmology)

Penrose, Proceedings of EPAC, pp. 2759-2763. 2006.

- conformal rescaling can remove the singularity

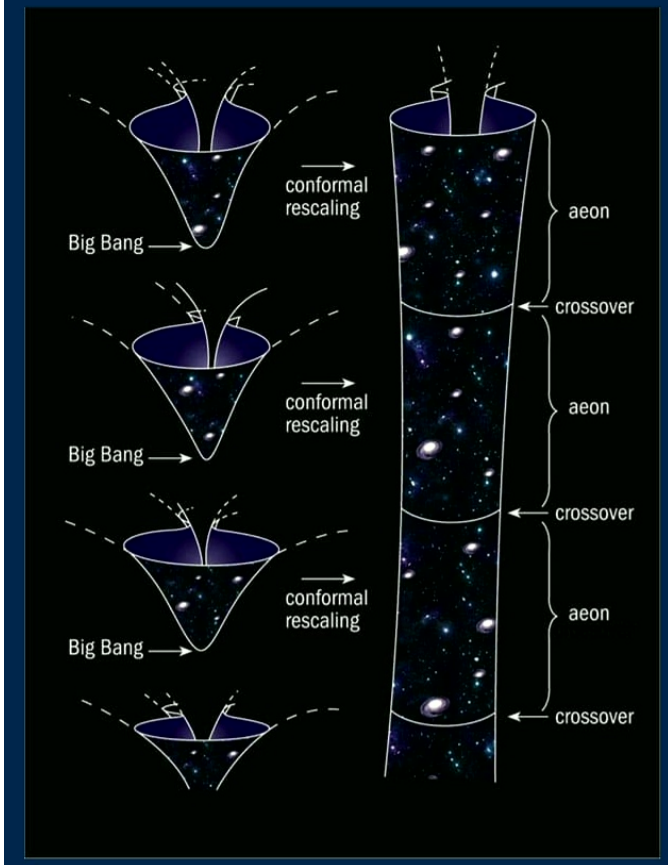


CCC (Conformal Cyclic Cosmology)

Penrose, Proceedings of EPAC, pp. 2759-2763. 2006.

- conformal rescaling can remove the singularity
- solve the low entropy paradox

CCC criticisms



- assumes all particles decay by cross over
- loss of unitarity

deSitter Equilibrium Cosmology

Albrecht, Andreas. "de Sitter equilibrium as a fundamental framework for cosmology." In Journal of Physics: Conference Series, vol. 174, 2009.

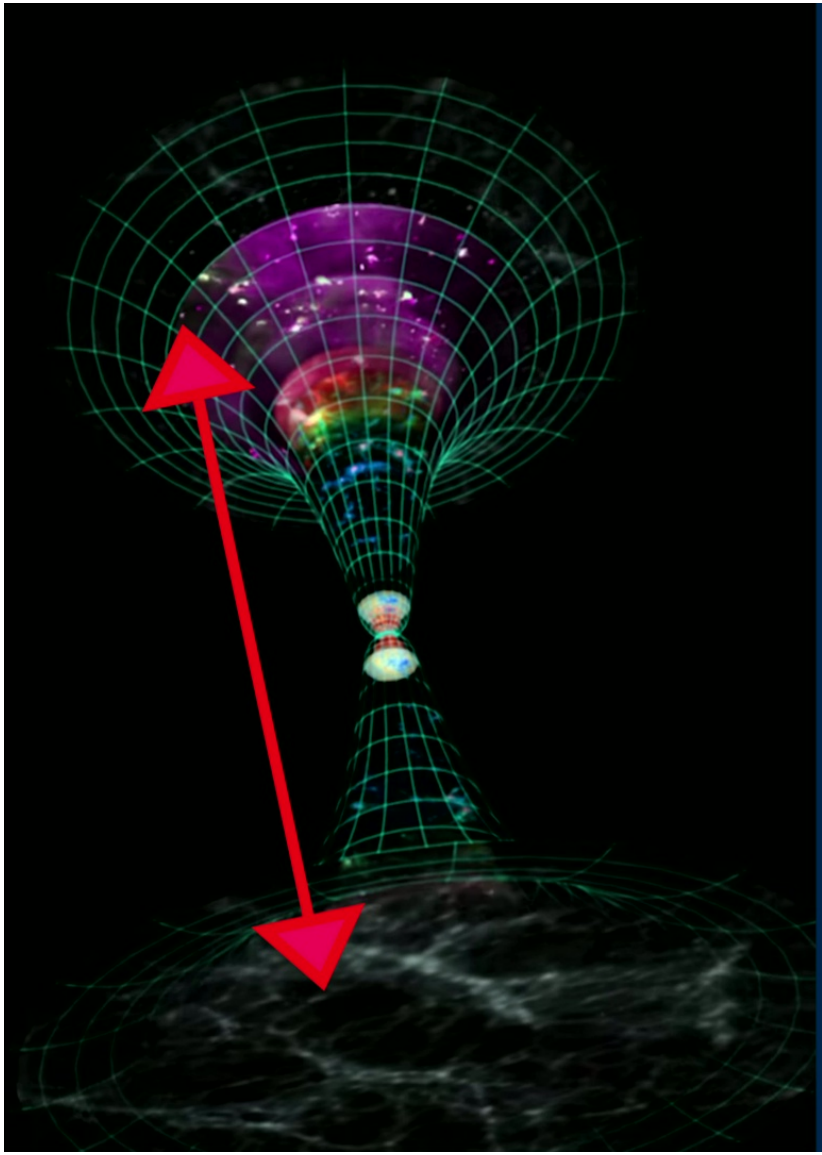
criticism

deSitter Equilibrium Cosmology

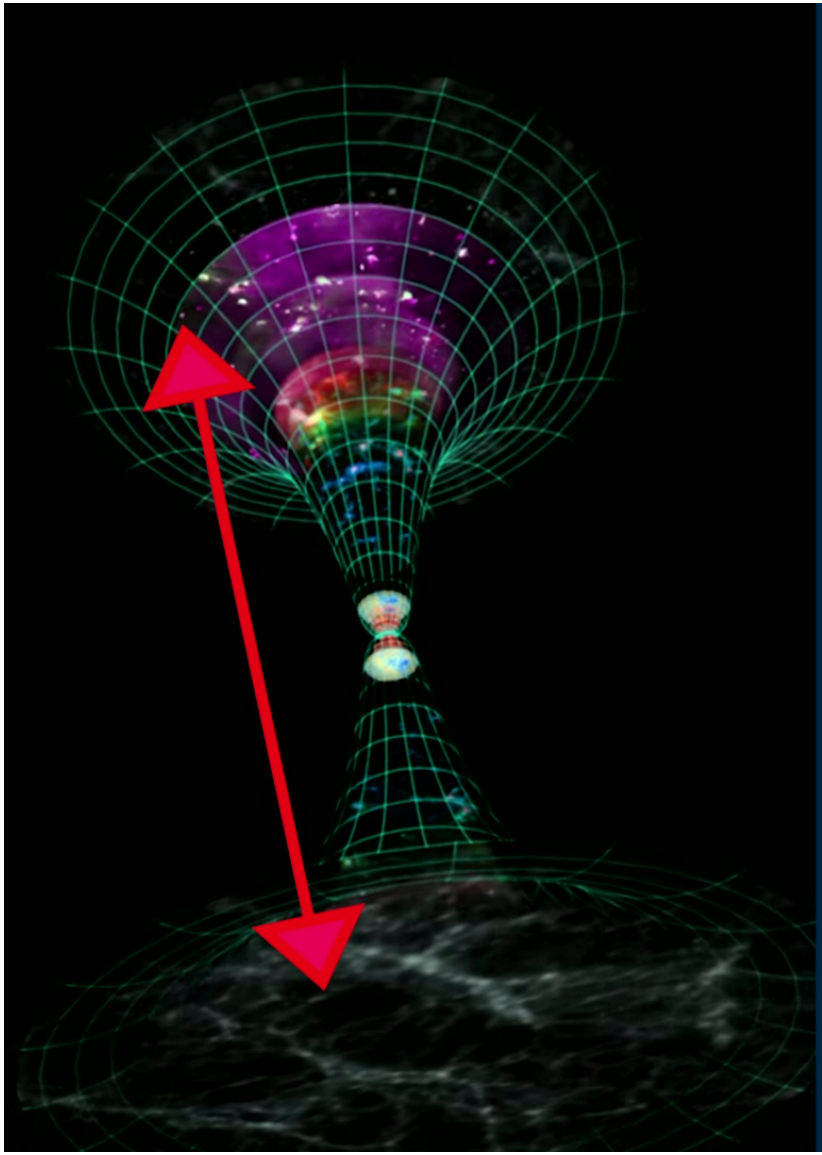
Albrecht, Andreas. "de Sitter equilibrium as a fundamental framework for cosmology." In Journal of Physics: Conference Series, vol. 174, 2009.

criticism

Requires Farhi Guth Guven



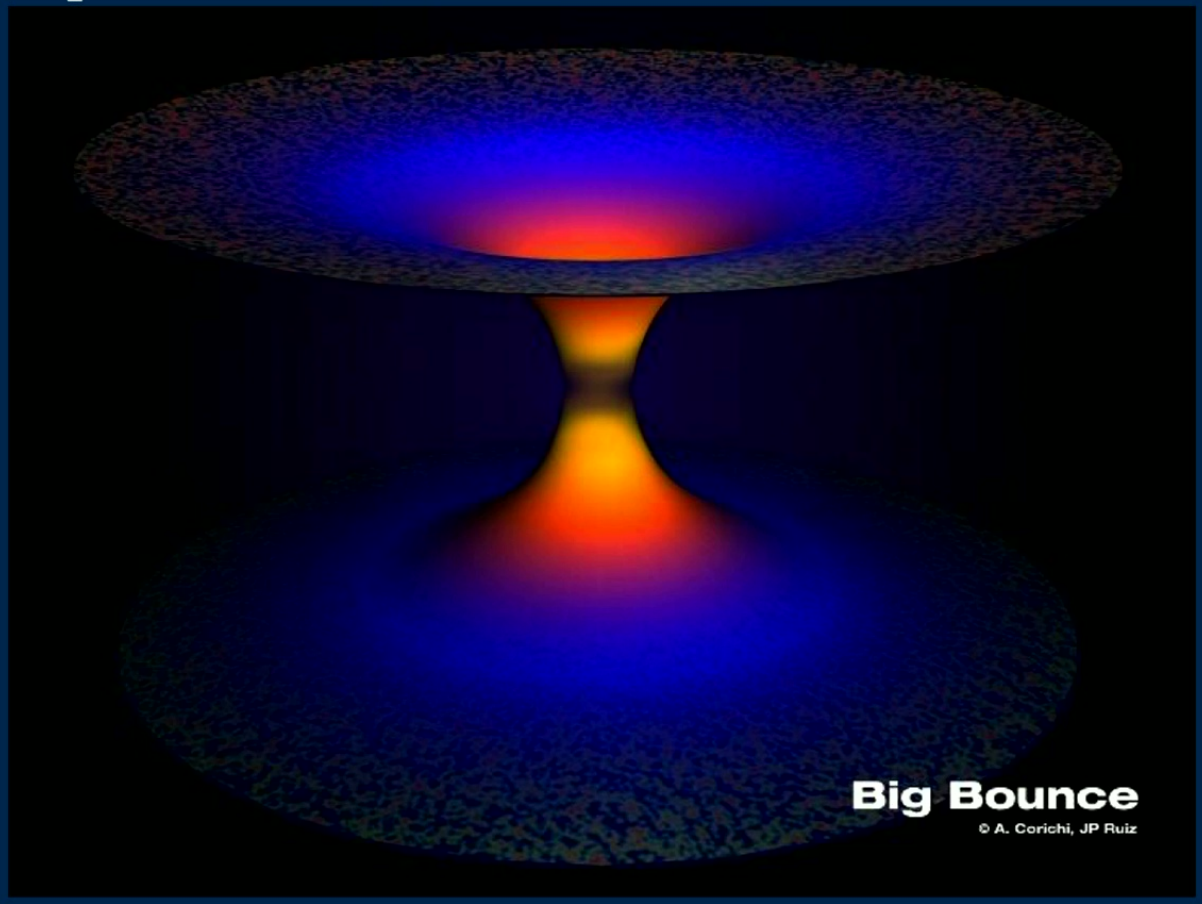
Reversal of the arrow of time



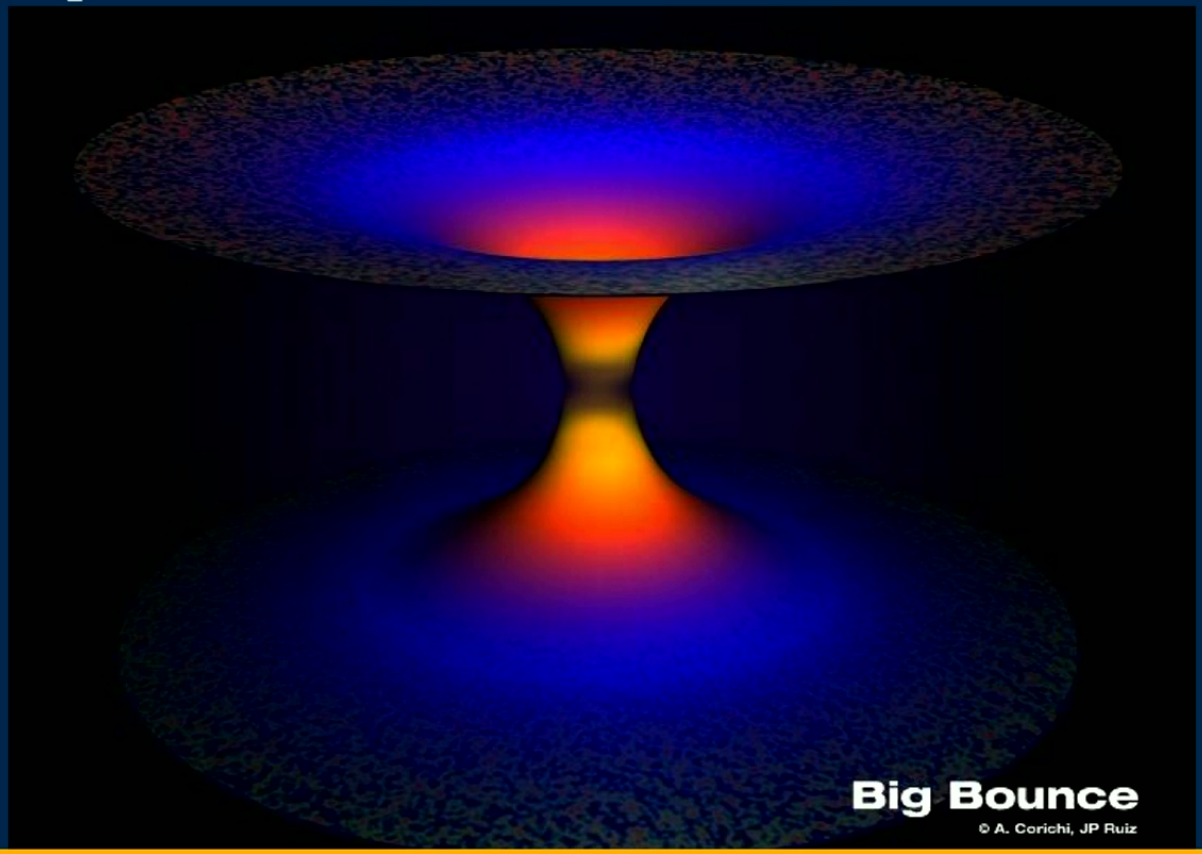
Reversal of the arrow of time

- CPT symmetric universe (arxiv 1803.08928)
- Janus Universe (arxiv1507.06498)
- Carroll Chen (arxiv.org 0410270)
- Steady-State Eternal Inflation (arXiv0111191)
- Hartle Hawking (?)

Loop Quantum Cosmology



Loop Quantum Cosmology

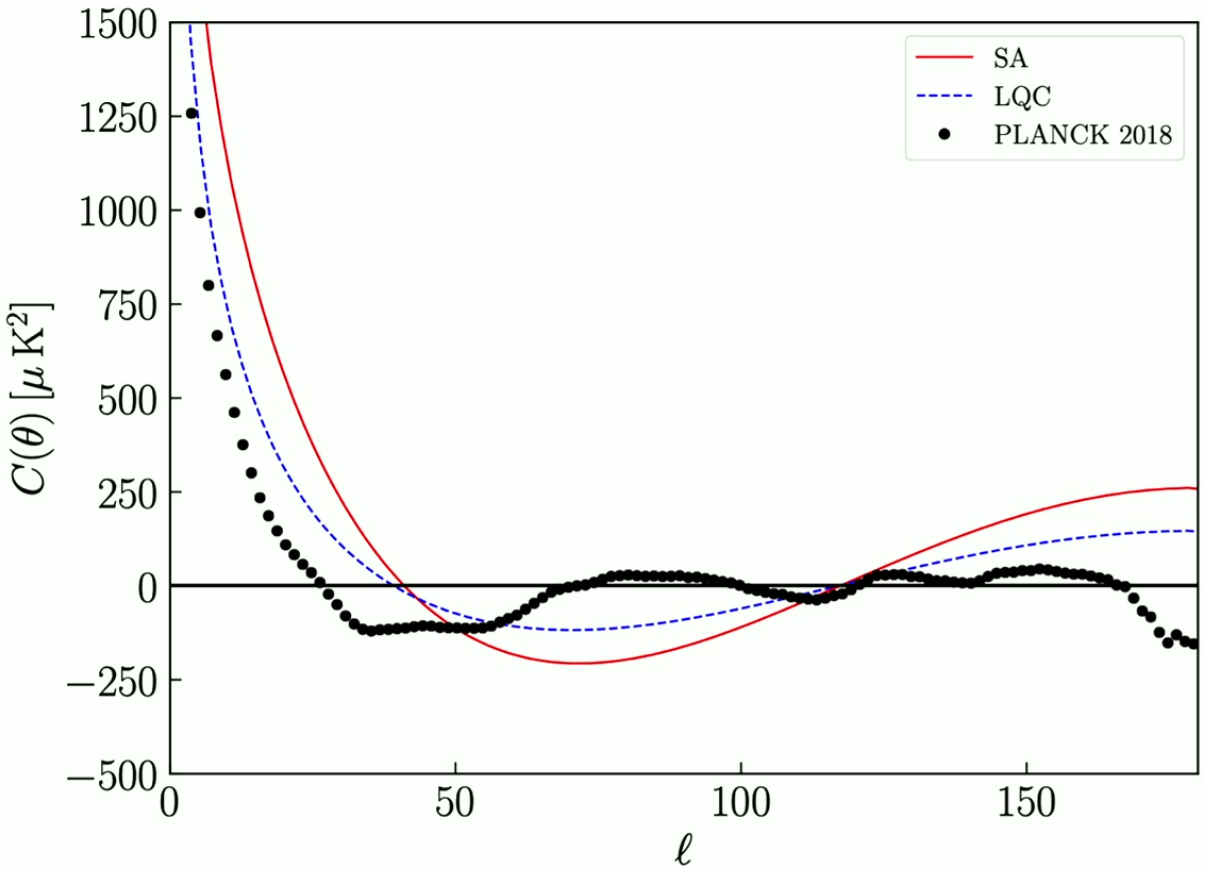


- Quantum repulsion force at 1% of the Planck density

Loop Quantum Cosmology

- original version (Bojowald 2001 arxiv0102069)
- improved dynamics (Ashtekar, Pawlowski, Singh 2006 arxiv0607039)
- high probability for inflation (Ashtekar, David Sloan 2011 arxiv1103.2475)
- explains CMB anomalies (Ashtekar, Gupt, Sreenath 2021 DOI: 10.1103/PhysRevLett.125.051302)

Predictions from LQC?



criticisms

- too simplistic mini superspace models (but Spin Foam, see Vidotto https://arxiv.org/abs/1011.4705)
- predictions depend on assumed matter field present

criticisms

- too simplistic mini superspace models (but Spin Foam, see Vidotto https://arxiv.org/abs/1011.4705)
- predictions depend on assumed matter field present
- not covariant (Bojowald),Hartle Hawking model (https://arxiv.org/abs/1810.09871

Hořava–Lifshitz gravity

- breaks Lorentz Invariance at high energies
- predicts c rises in quantum gravity regime

Hořava–Lifshitz gravity

- breaks Lorentz Invariance at high energies
- predicts c rises in quantum gravity regime
- connects to VSL (Moffat, arXiv 9211020)

criticisms

- no breaking of Lorentz invariance via LIGO/Fermi
- changes in c not meaningful
- multiple models of VSL
- more specualtive than inflation

Causal Set Theory

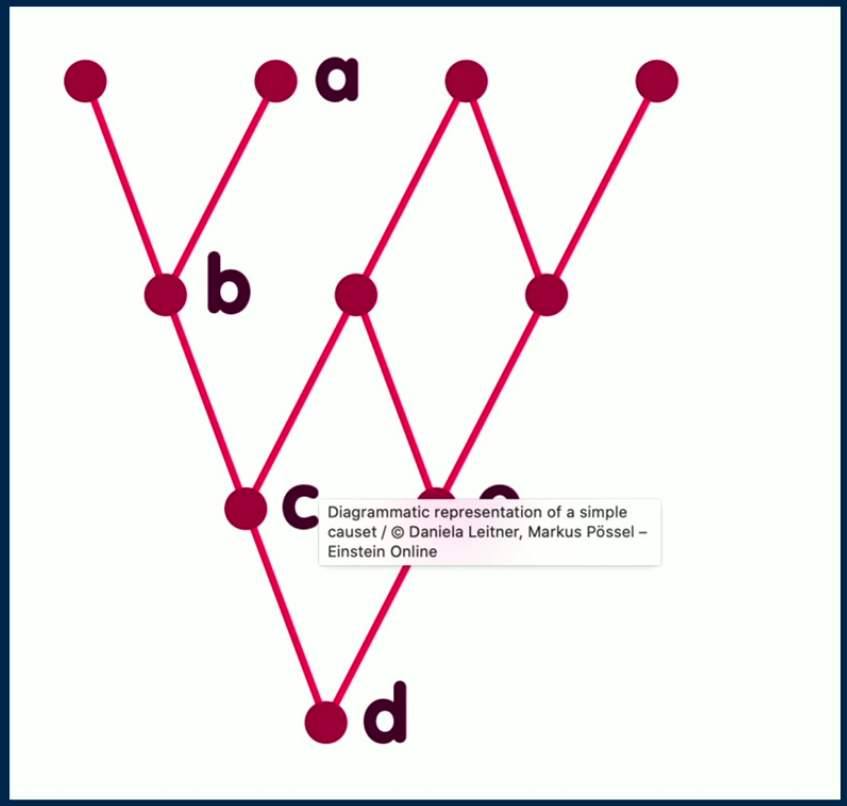


Image: Einstien Online

Pre Big Bang Causal Set

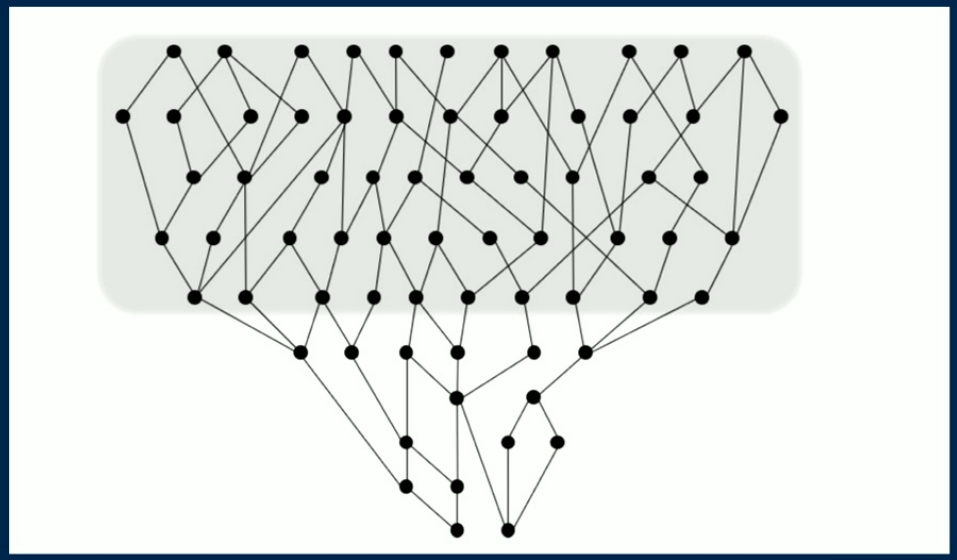


Image:Bruno Bento[1,1] and Stav Zalel[1,2]

Cosmological Natural Selection

Dowker, Fay, and Stav Zalel. "Evolution of universes in causal set cosmology." Comptes Rendus Physique 18, no. 3-4 (2017): 246-253

criticisms

- Ricci curvature at Big Bang vs Black Hole Weyl

criticisms

- Ricci curvature at Big Bang vs Black Hole Weyl
- Torsion Bounce does not include quantum gravity
- Braneworld inconsistent with observations
- LQG may imply a bounce into the future (Rovelli, Vidotto Int. J. M
  Phys. D23, 1442026 (2014)

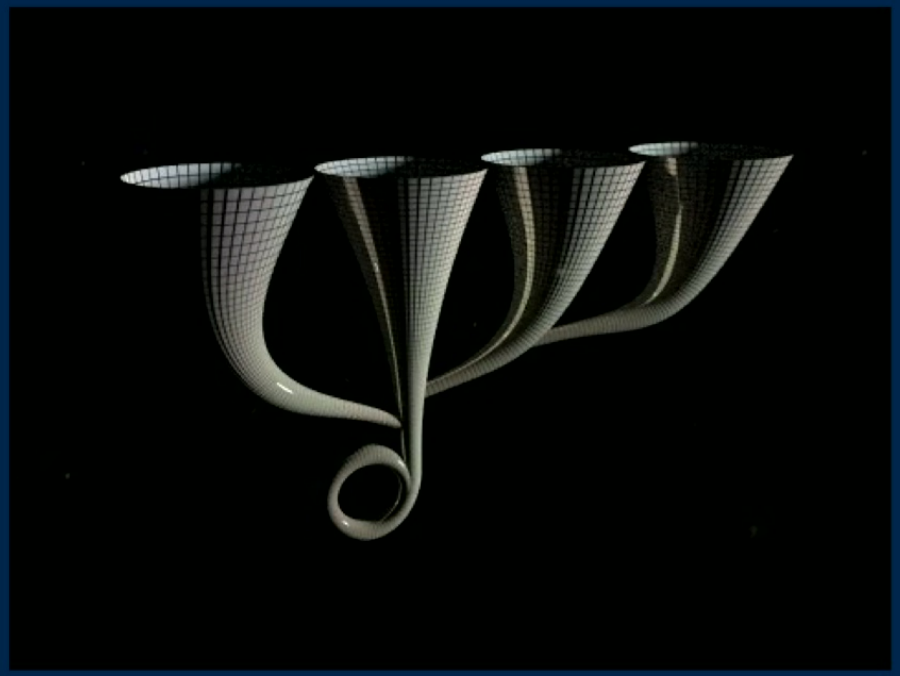
Emergent Spacetime

- “space time is doomed” Nima Arkani Hamed
- Emergent Metric Space-Time from Matrix Theory (Brahma, Brandenberger, Laliberte 2022 https://arxiv.org/abs/2206.12468)
- Holographic Cosmology (McFadden ,Skenderis 2015 https://arxiv.org/abs/0907.5542)
- Space from Hilbert Space (Cao, Carroll, Michalakis 2016 https://arxiv.org/abs/1606.08444)

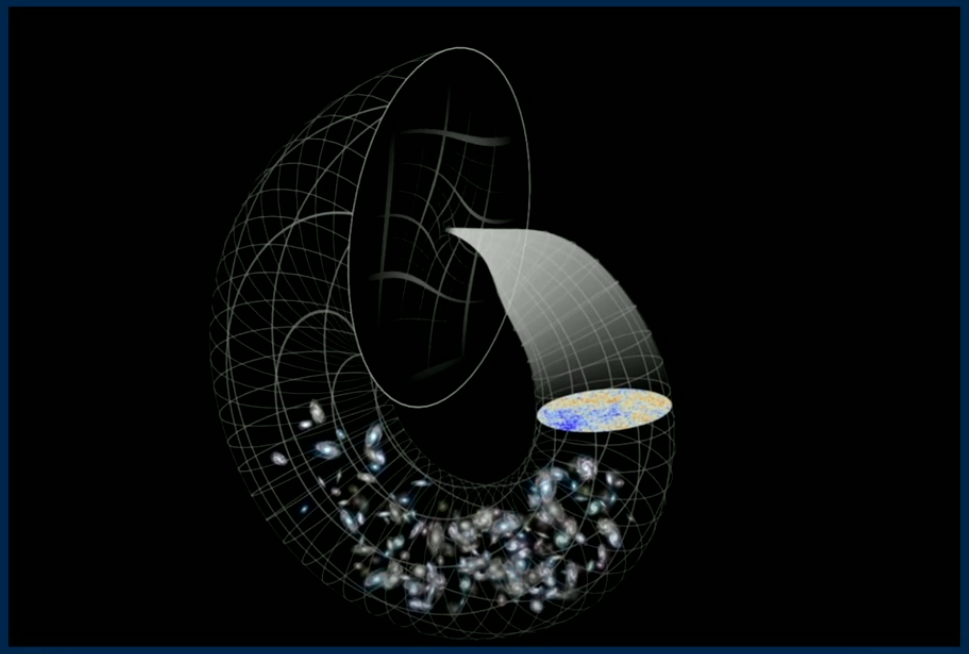
Criticisms

- AdS/CFT neither are our world
- Space from Hilbert Space too vague to make predictions

Closed Timelike Curves



Gott and Li Model (1997)
(https://arxiv.org/abs/astro-ph/9712344)



Periodic Time Cosmology
(Gould & Afshordi 2019)
https://arxiv.org/pdf/1903.09694.pdf

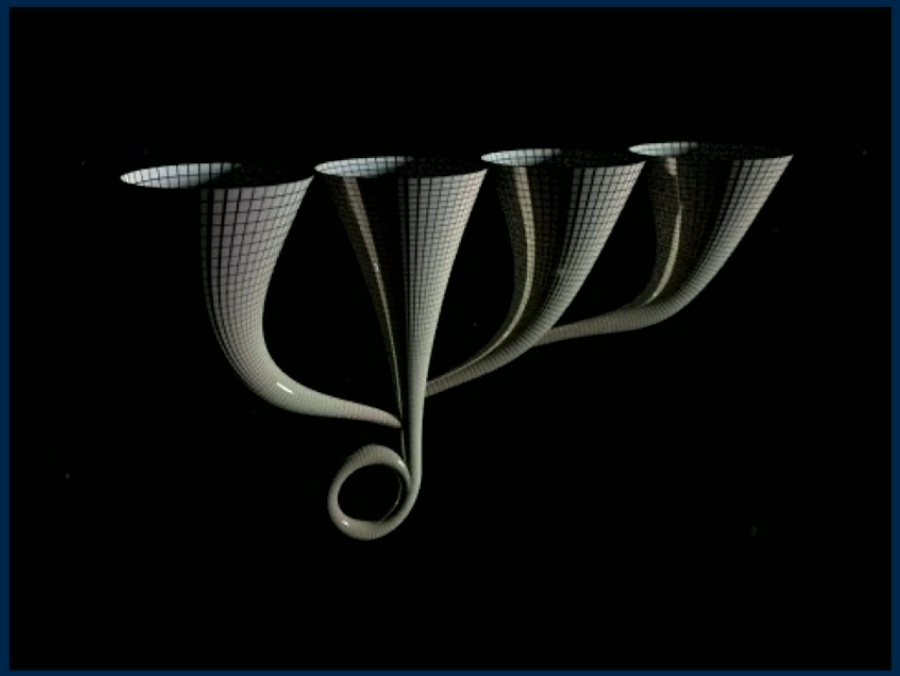
Criticisms

- chronology protection conjecture (Hawking Phys. Rev. D 46, 603 (1992)

Criticisms

- chronology protection conjecture (Hawking Phys. Rev. D 46, 603 (1992)
- unstable vacuum (Hiscock 2000 https://arxiv.org/pdf/gr-qc/0009061.pdf)
- Periodic Time Cosmology assumes dark energy increases

Closed Timelike Curves



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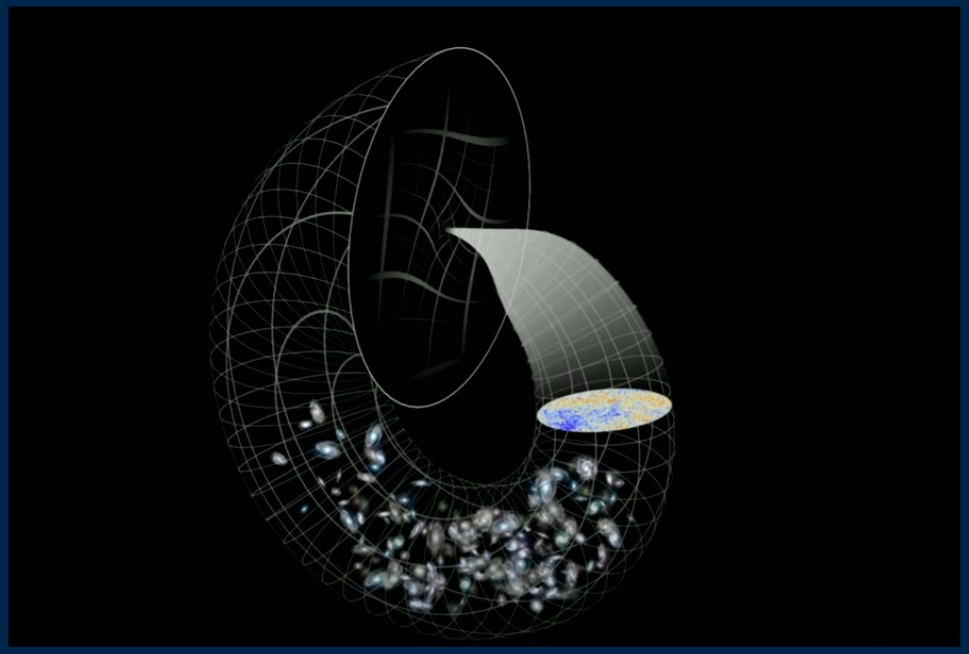


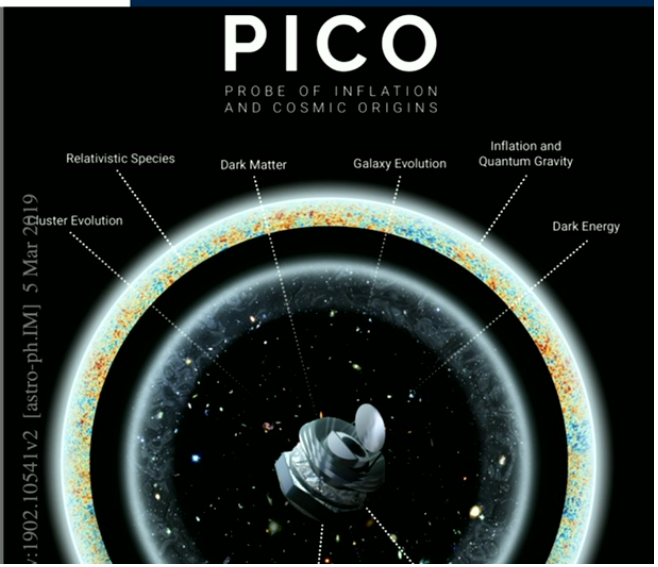
Periodic Time Cosmology
(Gould & Afshordi 2019)
https://arxiv.org/pdf/1903.09694.pdf

Ground Based CMB

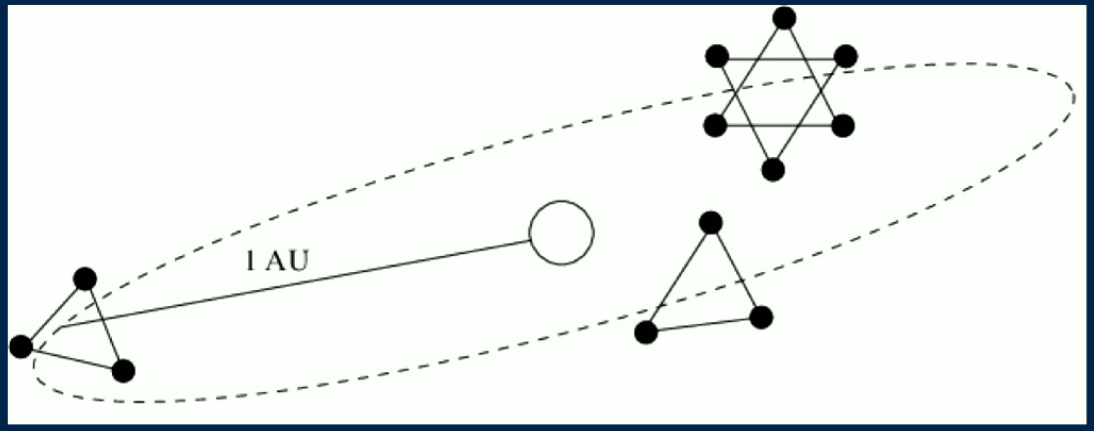
Space Based CMB

CMB BHARAT: AN INDIAN COSMOLOGY CONSORTIUM

LiteBIRD

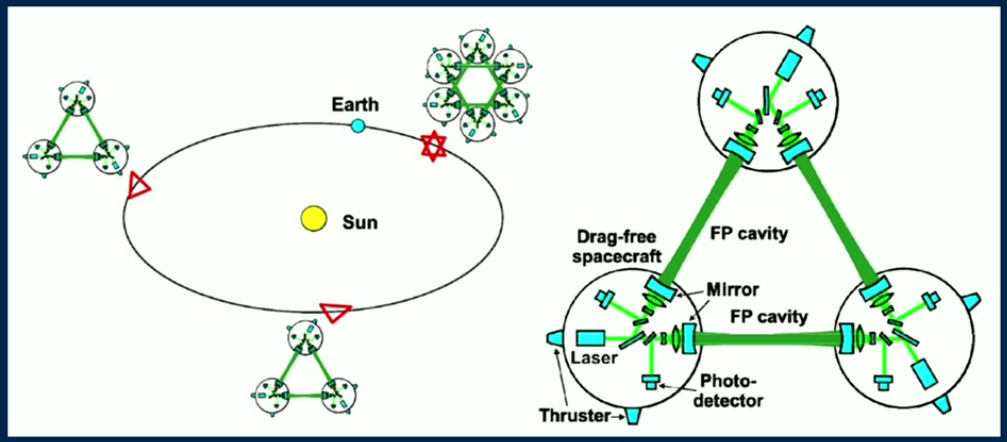


Space Based Primordial Gravitational Waves

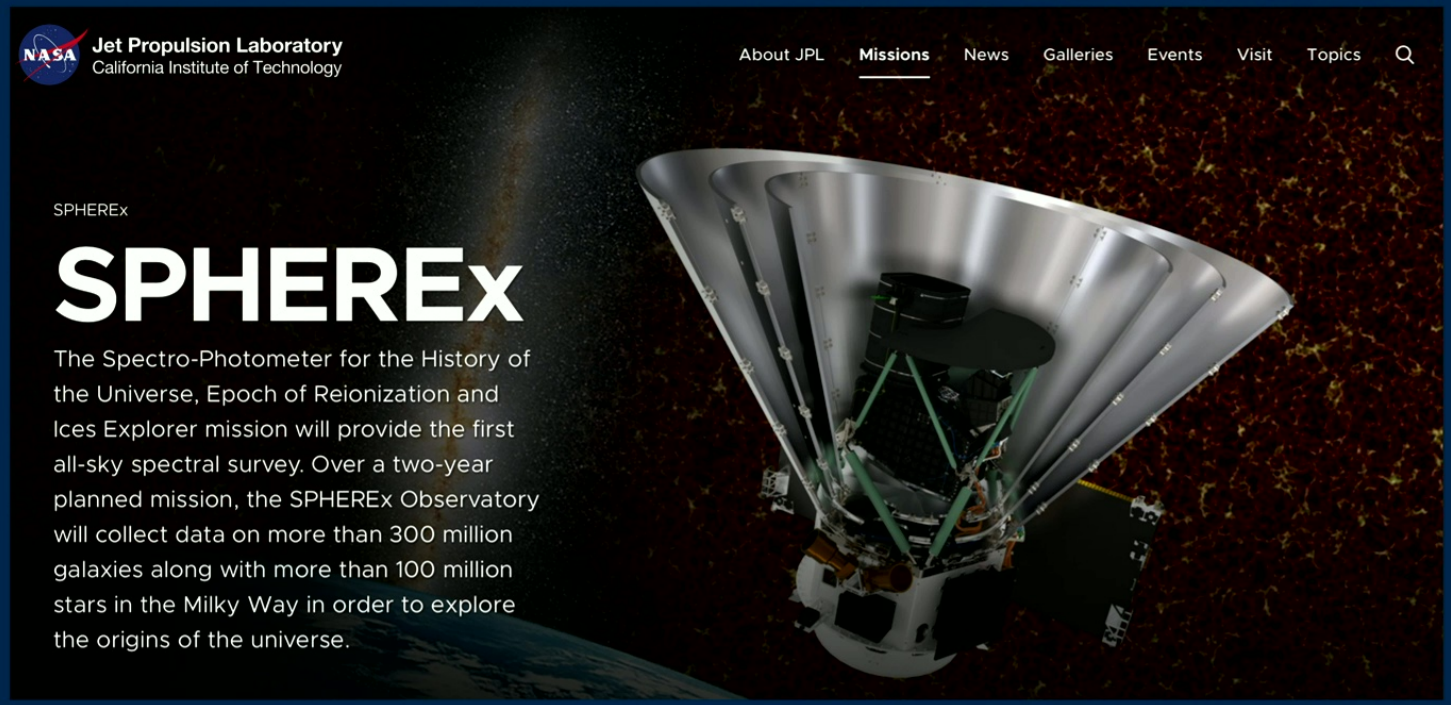


Big Bang Observer

DECIGO



Non Gaussianities



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- VSL: Ns = 0.96478
- Dark energy

New probes for inflation?

Chen, Loeb, and Xianyu. "Unique fingerprints of alternatives to inflation in the primordial power spectrum." Physical Review Letters 122, no. 12 (2019): 121301

Vagnozzi, and Loeb. "The challenge of ruling out inflation via the primordial graviton background." The Astrophysical Journal Letters 939, no. 2 (2022): L22.