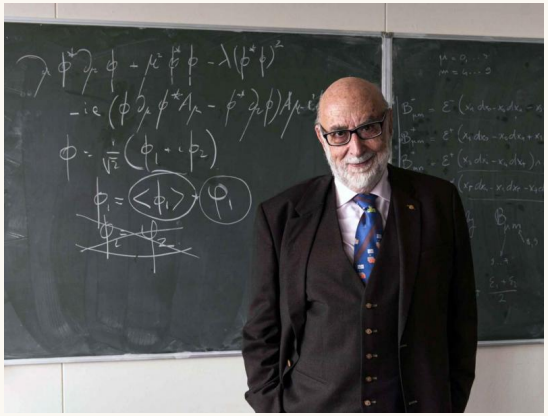
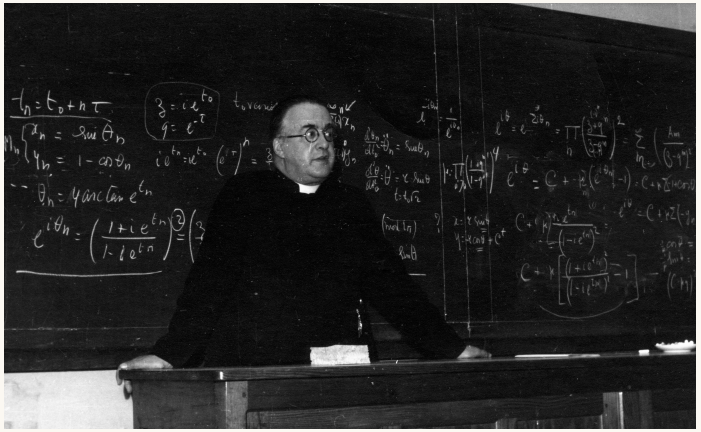
Brout and Englert's vision on Lemaître's primeval atom in today's fundamental physics

Thomas Hertog
BEL – Center





History of Modern Cosmology

- ***Initial*** (1917 – 1927): first models, lack observations
- ***Development*** (1927 – 1939): cosmic evolution
- ***Consolidation*** (1945 – 1965): nucleosynthesis, microwave background,…
- ***Acceptance*** (1965 – 1978): big bang model triumphs over steady state theory
- ***Extension*** (1978 – 1998): high-energy physics, early universe
- ***Precision cosmology***: cosmological parameters to a few %, new observables

G. Lemaître: From priest to astronomer

- **1923,** seminary St Rombaut, Malines
- **1923 – 1924**, University of Cambridge

  "*A truly brilliant student, wonderfully quick and clear-sighted, and of great mathematical ability.*"
  (A. Eddington to T. De Donder, 1924)

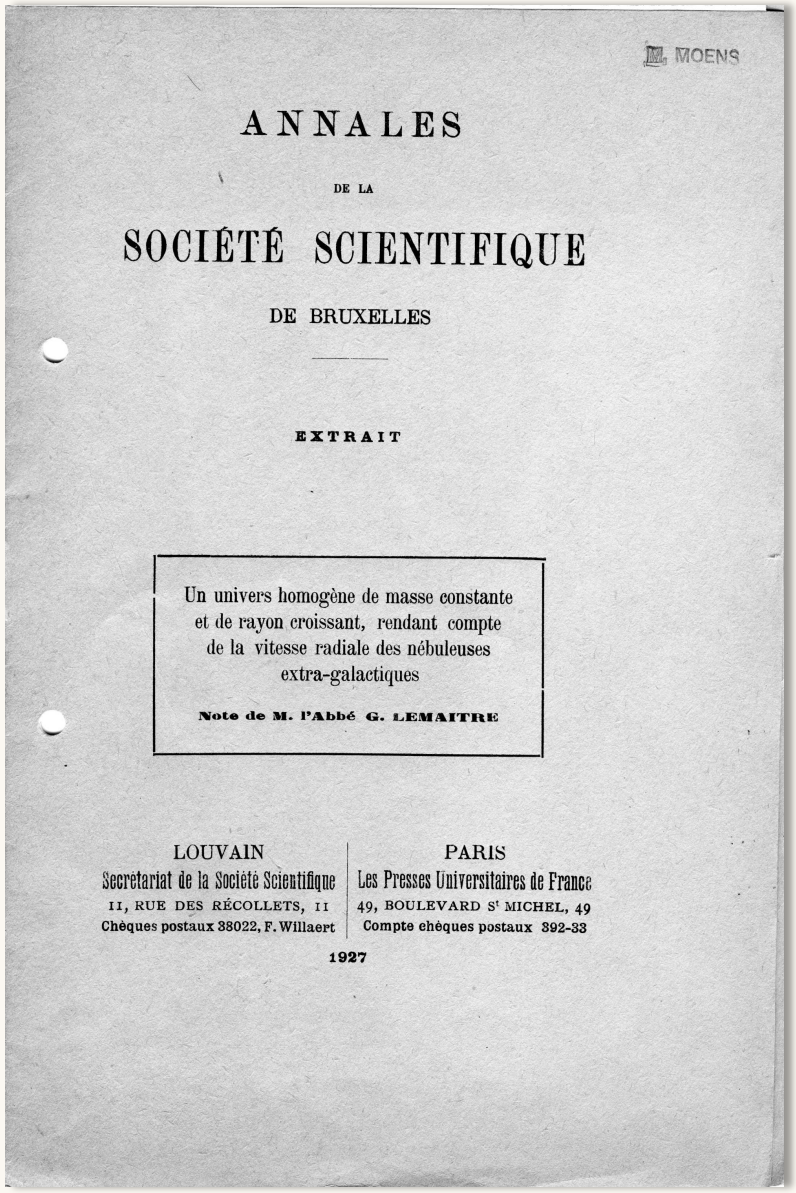
- **1924 – 1925**, Harvard College Observatory

  attends AAS meeting in Dec 1924 where Russell announces `great spiral nebulae' are other galaxies

  proves linear distance – redshift relation in the empty universe of the Dutch astronomer Willem de Sitter

- **1925**, Catholic University of Louvain

1927: discovery expanding universe



ANNALES

DE LA

SOCIÉTÉ SCIENTIFIQUE

DE BRUXELLES

EXTRAIT

Un univers homogène de masse constante
et de rayon croissant, rendant compte
de la vitesse radiale des nébuleuses
extra-galactiques

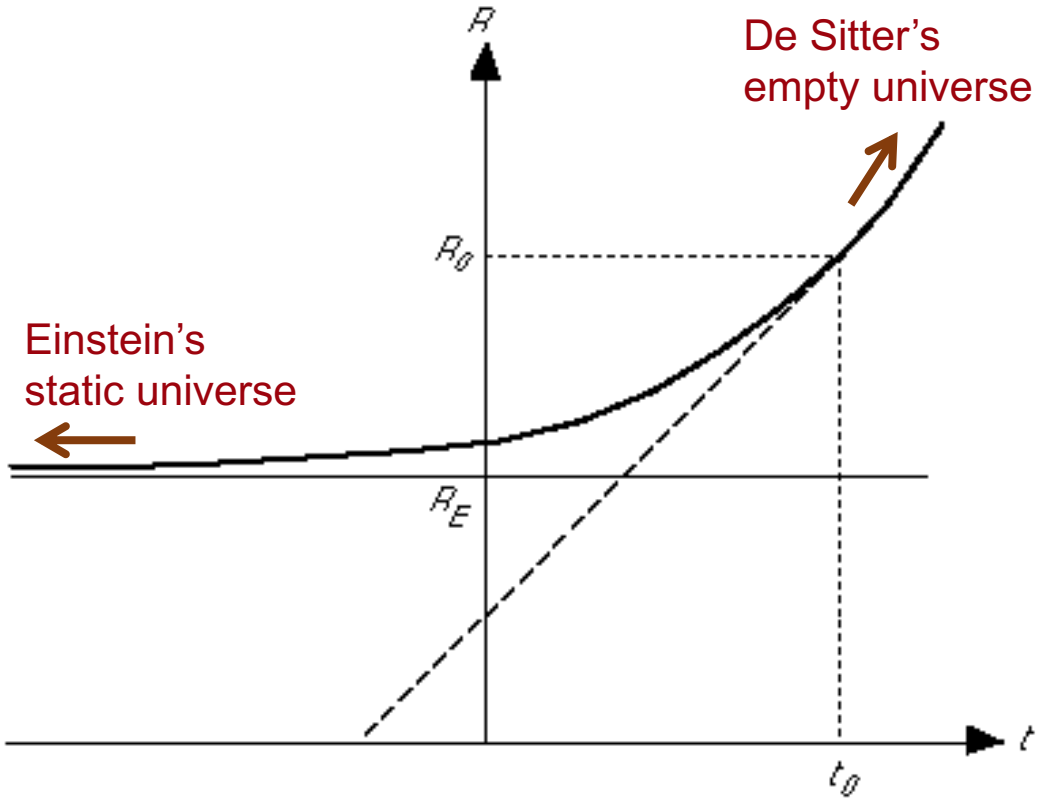
Note de M. l'Abbé G. LEMAITRE

LOUVAIN
Secrétariat de la Société Scientifique
11, RUE DES RÉCOLLETS, 11
Chèques postaux 38022, F. Willaert

PARIS
Les Presses Universitaires de France
49, BOULEVARD St MICHEL, 49
Compte chèques postaux 392-33

1927

1927: discovery expanding universe



Utilisant les 42 nébuleuses figurant dans les listes de Hubble et de Strömberg (1), et tenant compte de la vitesse propre du soleil (300 Km. dans la direction $\alpha = 315°$, $\delta = 62°$), on trouve une distance moyenne de 0,95 millions de parsecs et une vitesse radiale de 600 Km./sec, soit 625 Km./sec à 10^6 parsecs (2).

Nous adopterons donc

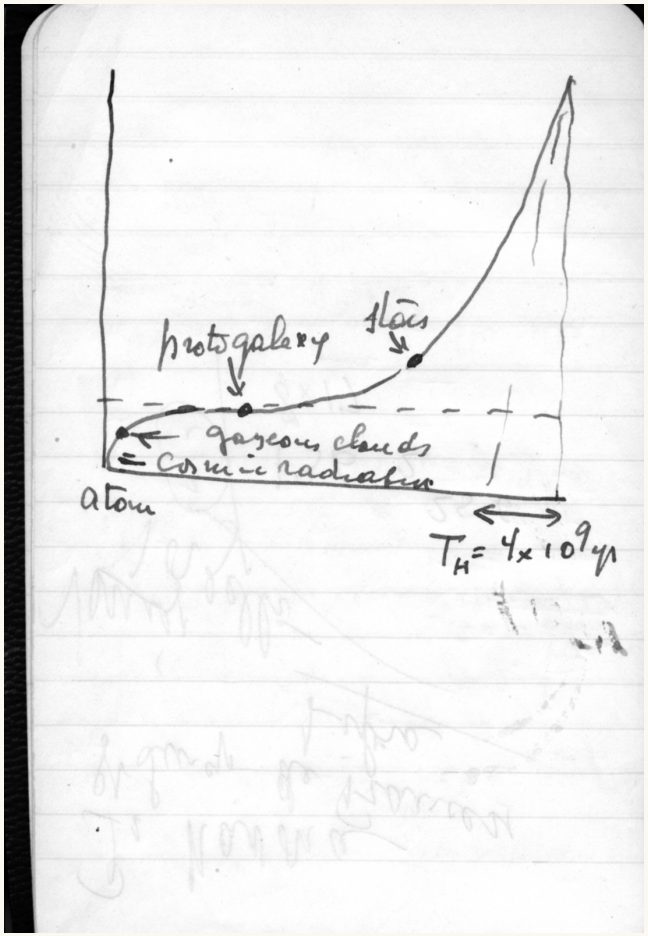
$$\frac{R'}{R} = \frac{v}{rc} = \frac{625 \times 10^5}{10^6 \times 3{,}08 \times 10^{18} \times 3 \times 10^{10}} = 0{,}68 \times 10^{-27}\ \text{cm}^{-1} \qquad (24)$$

"Hubble" law

H = 575 km/s/Mpc

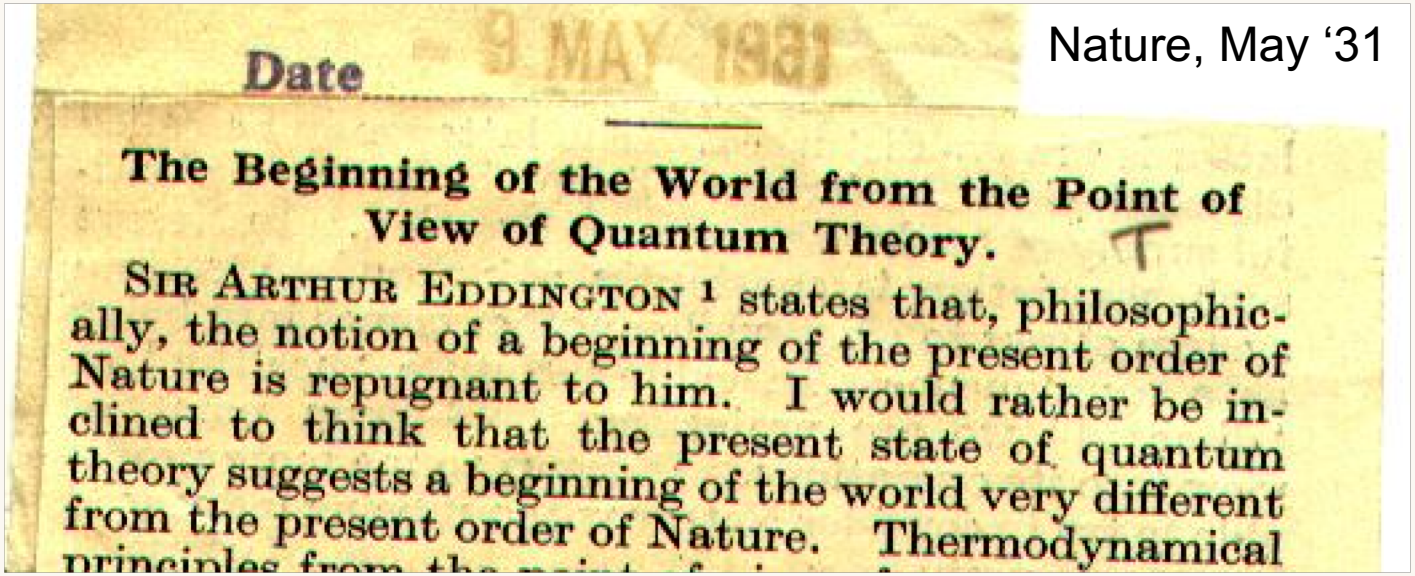
Lemaître's `hesitating' universe

- An evolving universe
- initially rapidly expanding
- with a cosmological constant
- and a quantum origin
- that comes with relic radiation



"λ is a bridge between Relativity and quantum physics."

A Quantum Origin – primeval atom



Nature, May '31

Date 9 MAY 1931

The Beginning of the World from the Point of View of Quantum Theory.

SIR ARTHUR EDDINGTON [1] states that, philosophically, the notion of a beginning of the present order of Nature is repugnant to him. I would rather be inclined to think that the present state of quantum theory suggests a beginning of the world very different from the present order of Nature. Thermodynamical

"If we go back in the course of time … the notions of space and time would altogether fail to have any meaning ...

Clearly the initial quantum could not conceal in itself the whole course of evolution.. Instead from the same beginning widely different universe could have evolved."

ANNALS OF PHYSICS **115**, 78–106 (1978)

The Creation of the Universe as a Quantum Phenomenon

R. BROUT, F. ENGLERT, AND E. GUNZIG

Faculté des Sciences, Université Libre de Bruxelles, Bruxelles, Belgium

Received July 7, 1977

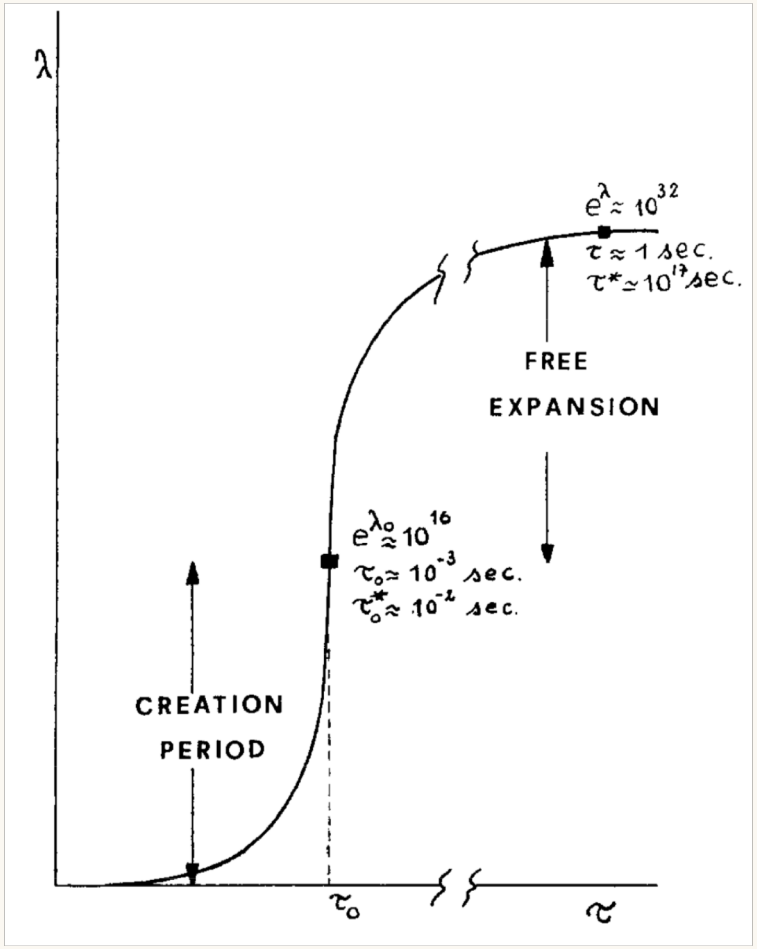
Quantum creation of massy particles can occur in the cosmological context without cost of energy. This fact is seized upon to construct a causal open homogeneous isotropic cosmology. The universe is conceived as the response of matter and the gravitational field to a spontaneous pointlike disturbance. Its history unfolds in two stages, creation and free expansion. The first stage gives rise to a "fireball." The free expansion is extrapolated back to the "fireball." The latter thus replaces the "big-bang," thereby avoiding an initial singularity. Though not intrinsic to the theory it does suggest the interpretation of the cosmological part of the gravitational field as the scalar dilaton that is encountered in the dynamical generation of mass in conformally invariant theory.

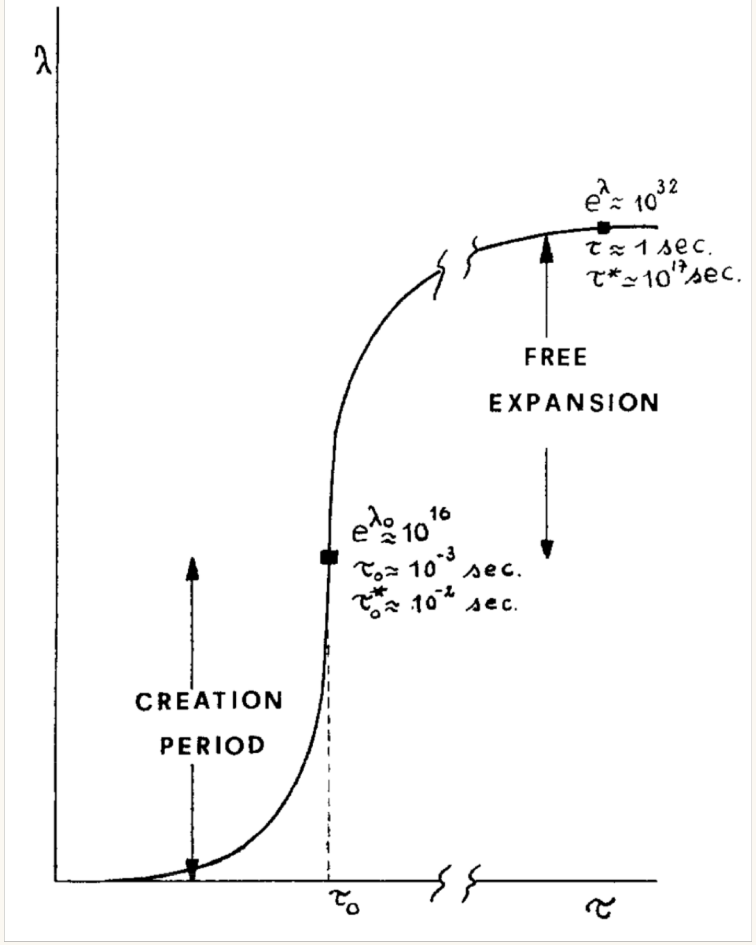
Brout and Englert's quantum creation

"The singularity means the "big-bang" hypothesis of creation is more a confession of desperation and bewilderment than the outcome of logical argumentation rooted in the known (or even unknown!) laws of physics. It is our endeavor to repair this situation."

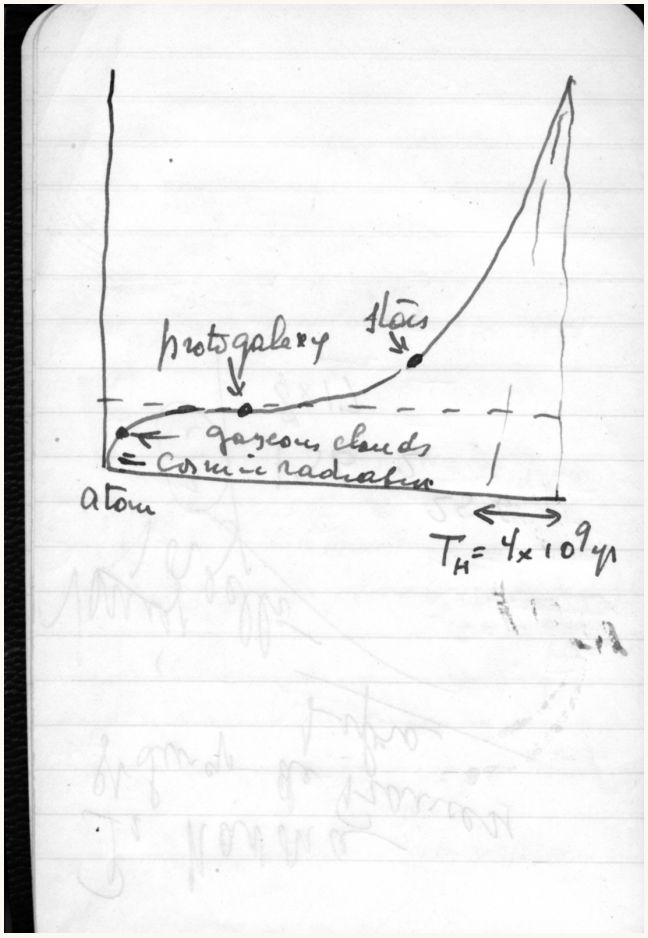
Brout and Englert's quantum creation

- A quantum origin
- leading to `de Sitter'-like expansion
- simultaneously creating matter and spacetime,
- transitioning into slow `free expansion'.





[Brout, Englert, Gunzig, 1978]



[Lemaître, 1933]

Brout and Englert's homework questions:

- "What is the nature of the initial nucleation?... We must not make too many universes! What is the criterion that selects this universe?"

How does inflation start?

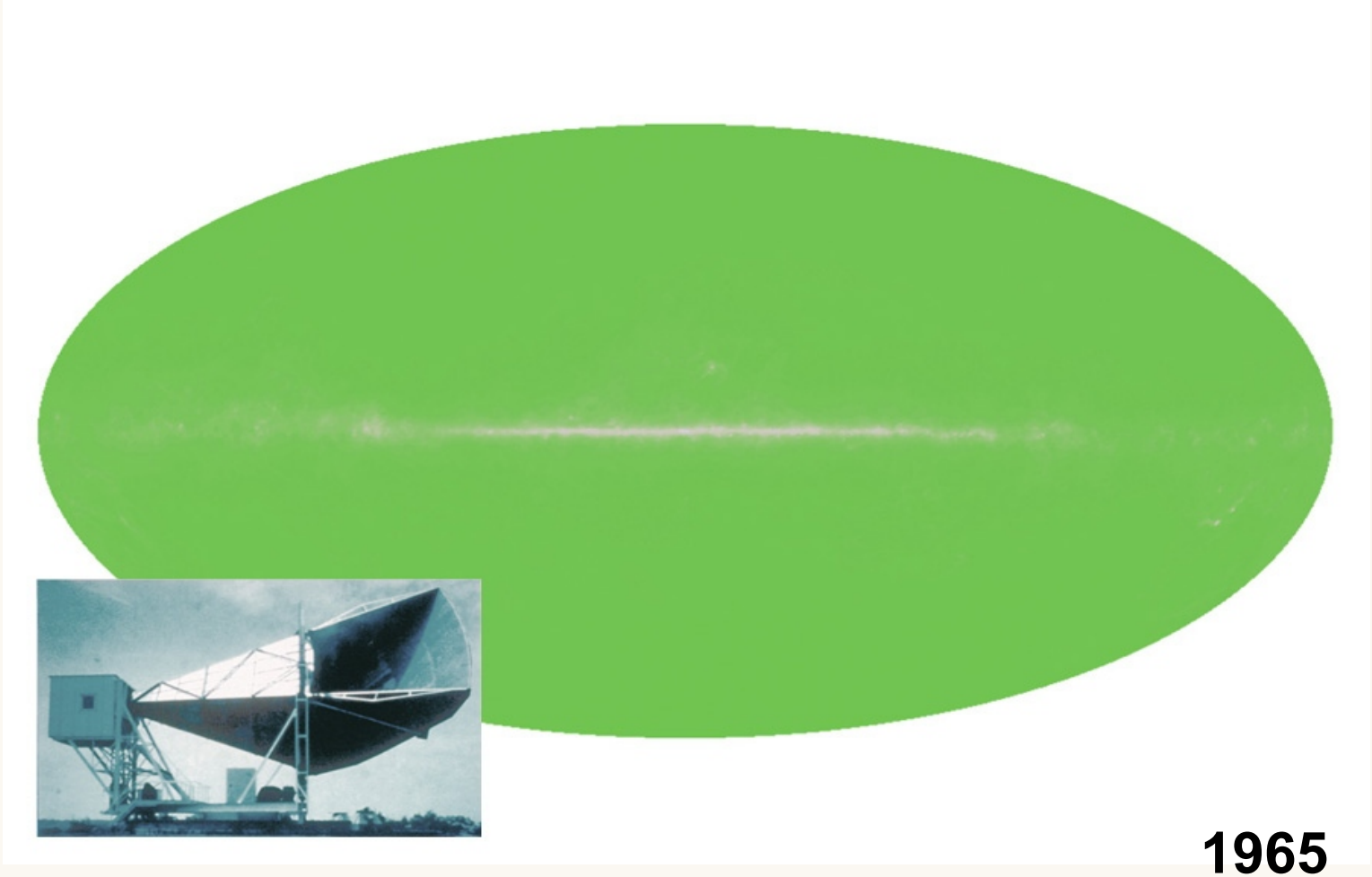
- "What justifies the quantum coherence which we have appealed to? Our scalar field is a highly oversimplified representation of the elementary particle world.."

What drives inflation?

- "What is the physics at the interesting period around the inflection point? It must be around this period that hadrons as we know them are formed and then the stars."

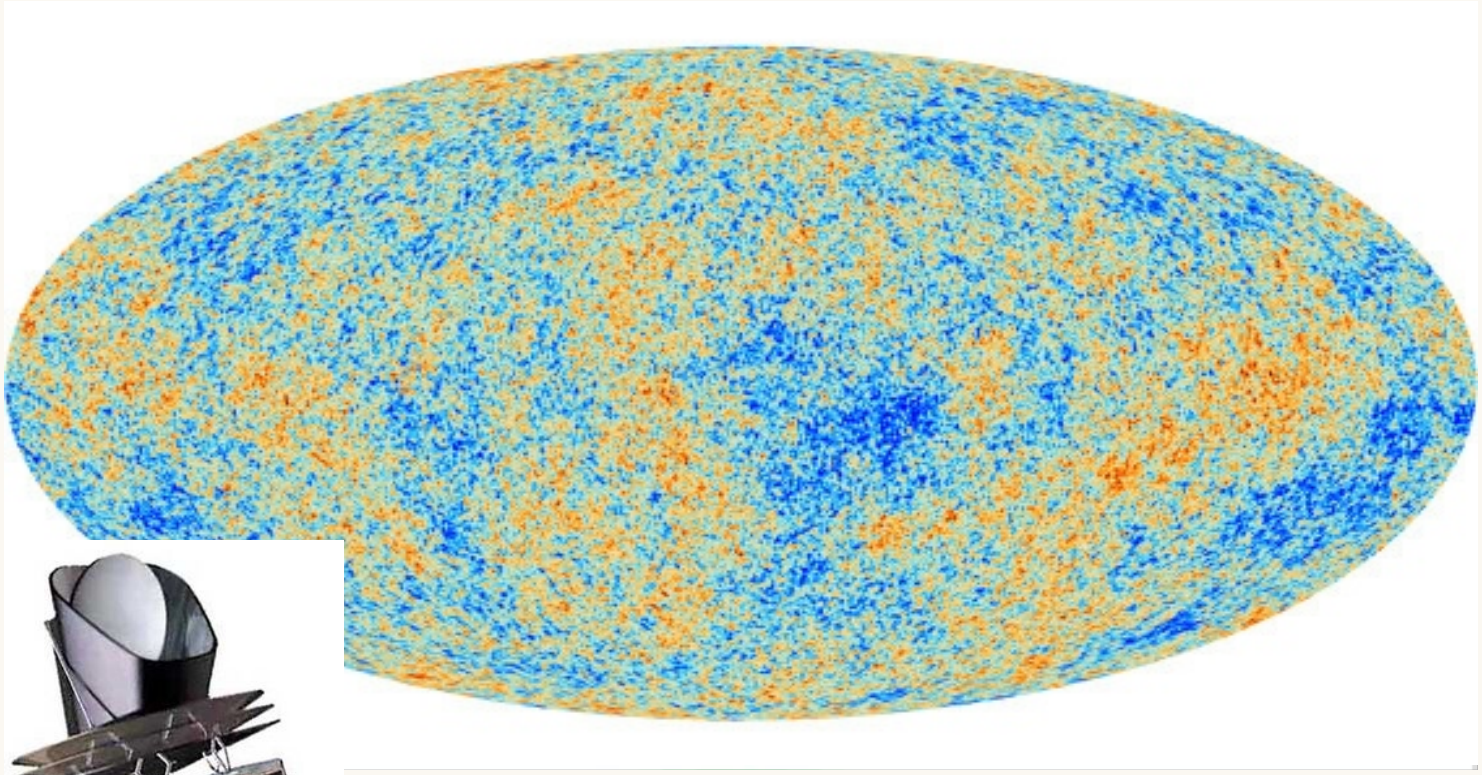
How does inflation end?

Cosmic Background Radiation



1965

Cosmic Background Radiation



2010

Of Inflation and the Inflaton

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The International Solvay Institutes

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29 March 2010

Brout and Englert's homework questions:

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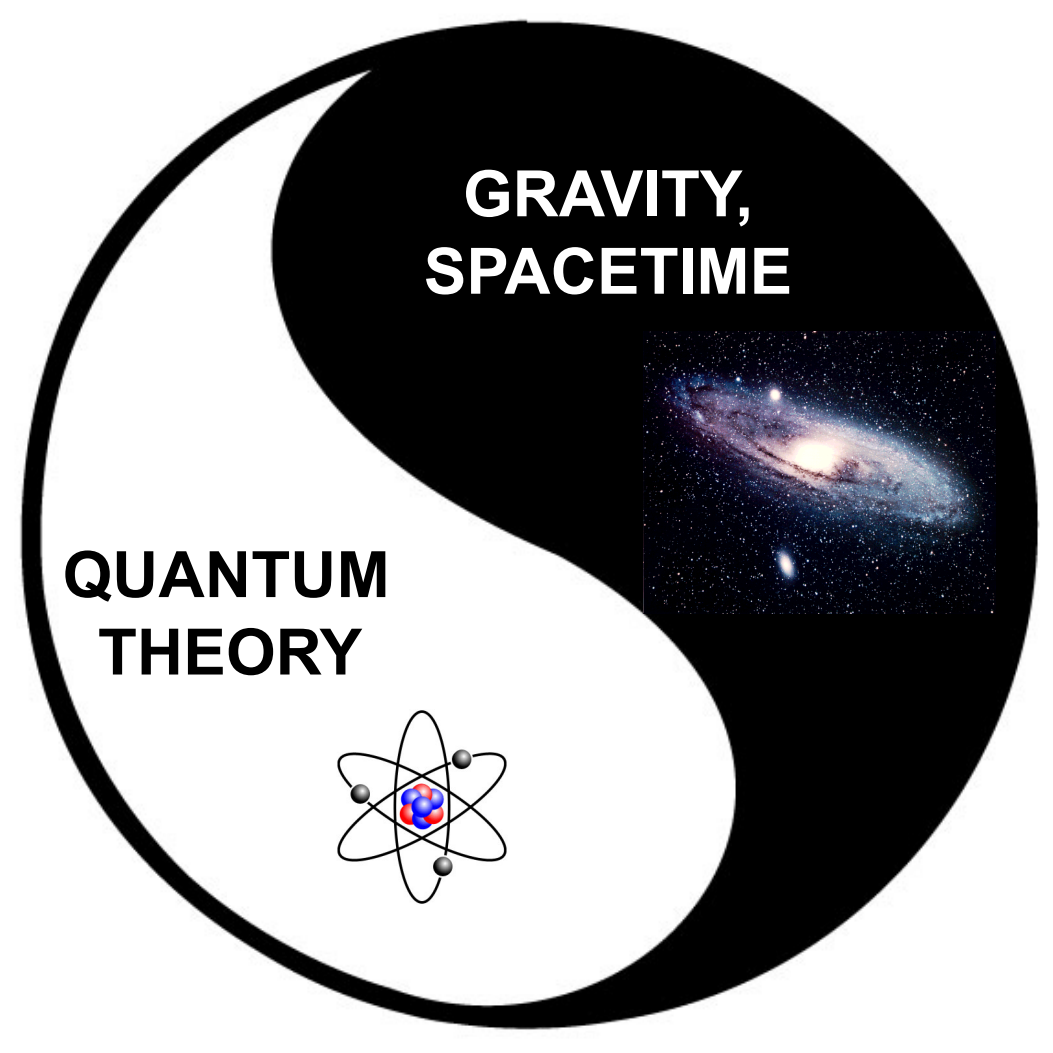
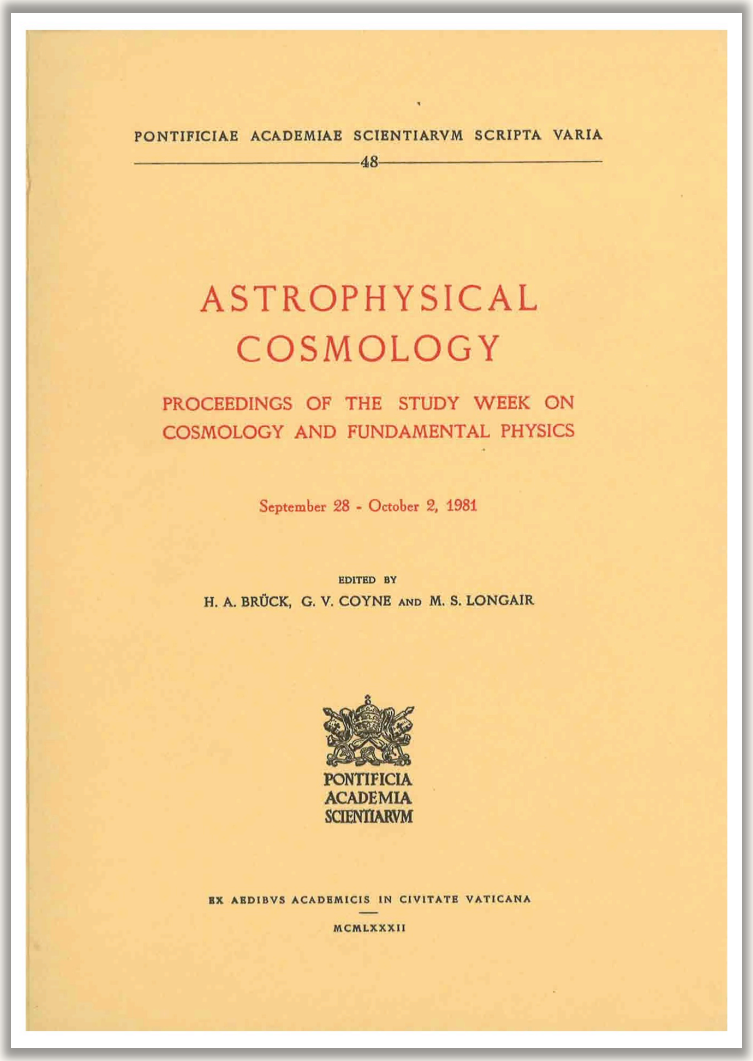
How does inflation end?

BEL's vision



1981, at the Vatican..



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48

ASTROPHYSICAL COSMOLOGY

PROCEEDINGS OF THE STUDY WEEK ON COSMOLOGY AND FUNDAMENTAL PHYSICS

September 28 - October 2, 1981

EDITED BY

H. A. BRÜCK, G. V. COYNE AND M. S. LONGAIR

PONTIFICIA ACADEMIA SCIENTIARVM

EX AEDIBVS ACADEMICIS IN CIVITATE VATICANA

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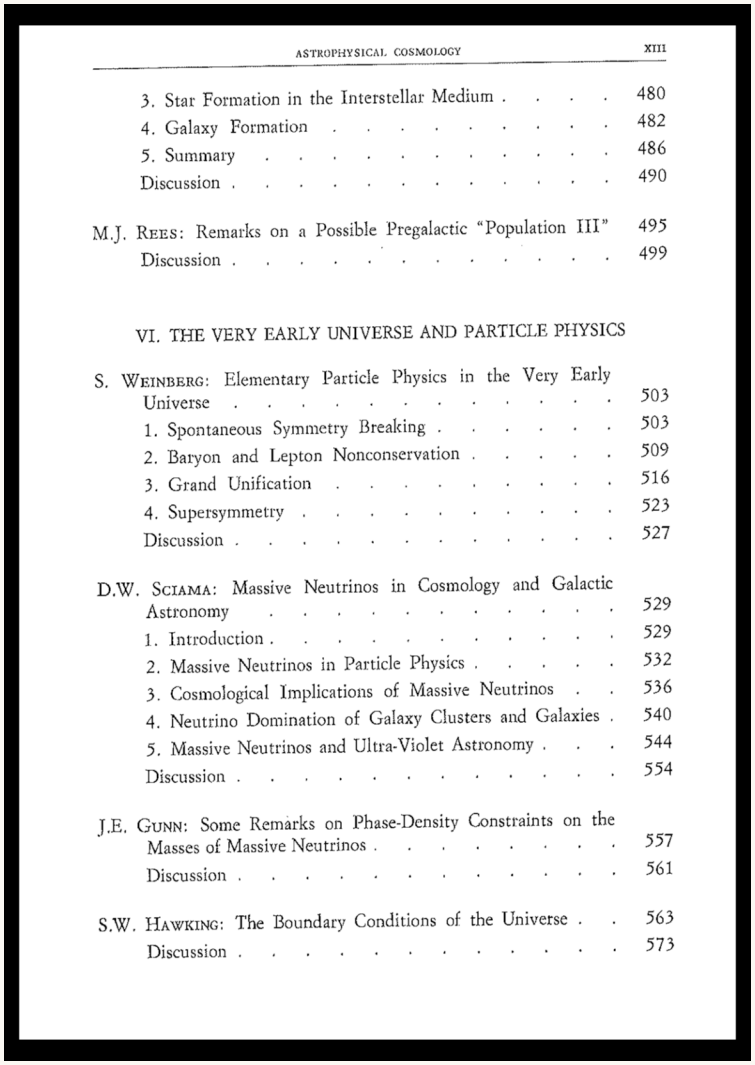
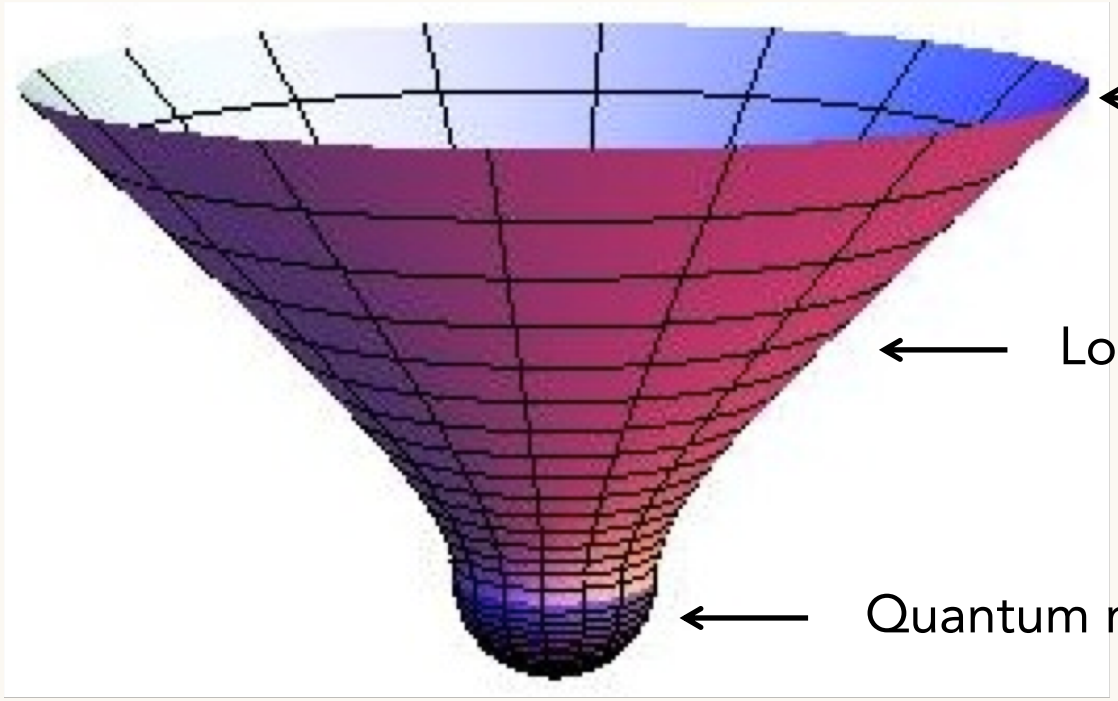


No-Boundary `ground state' Wave Function

[Hartle & Hawking, 1983]

Time



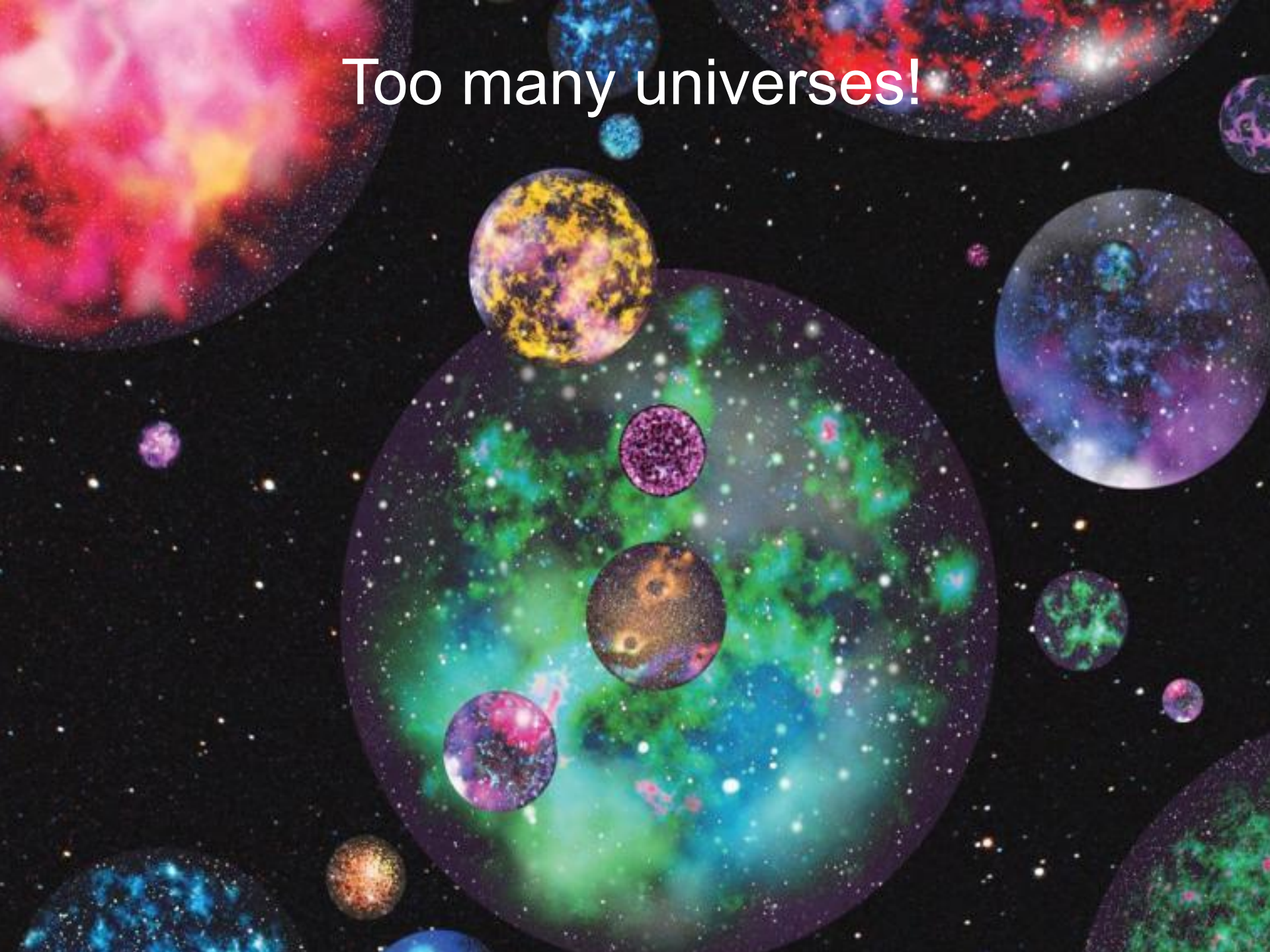
$({}^3g, \phi)$

Lorentzian, inflating

Quantum nucleation

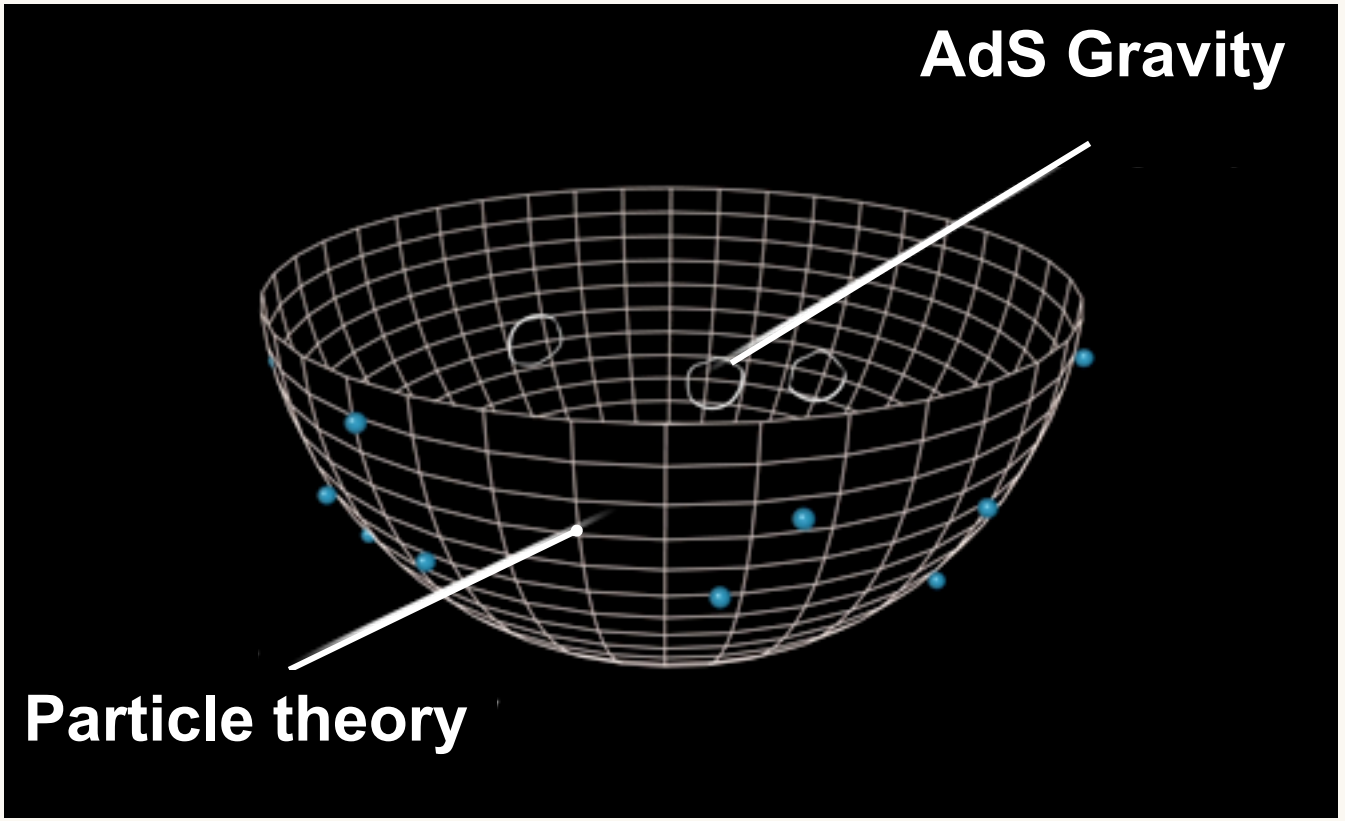
$$\Psi[{}^3g, \phi] \sim \exp[-I_E({}^3g, \phi)]$$

→ *Predicts* inflation!


Too many universes!

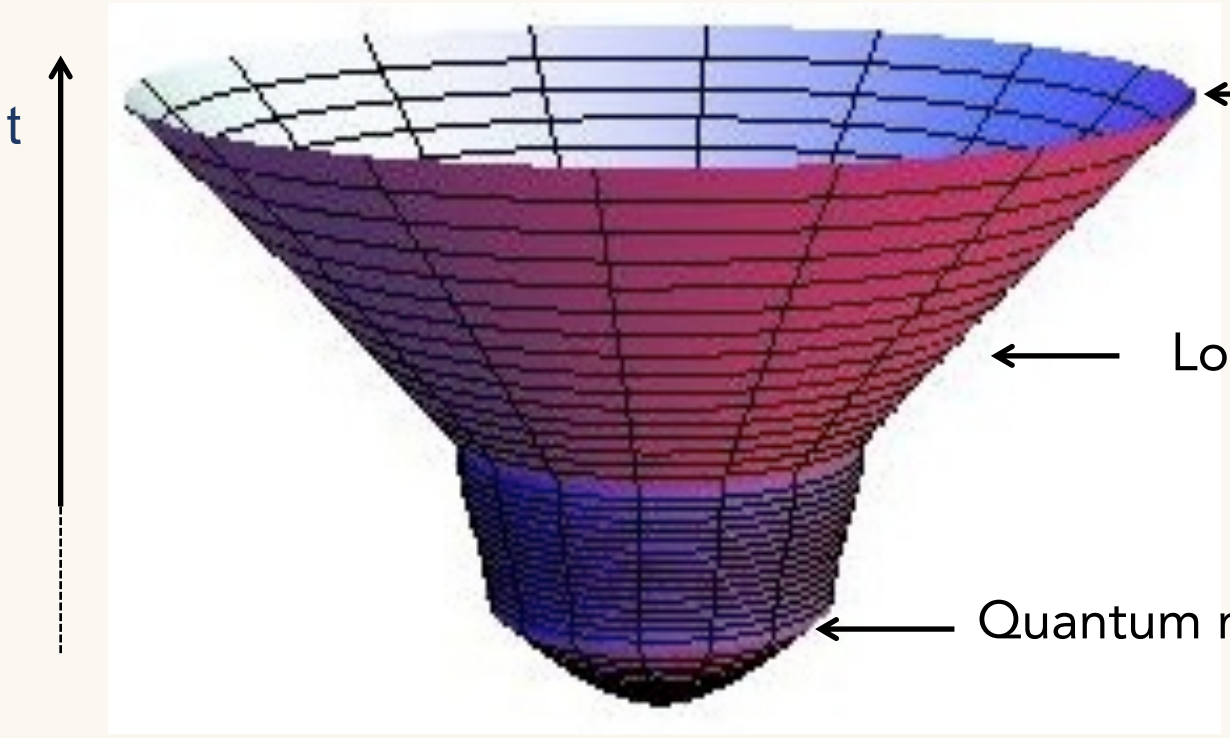
Holography

[Maldacena 1997; Witten 1998]



A holographic Origin

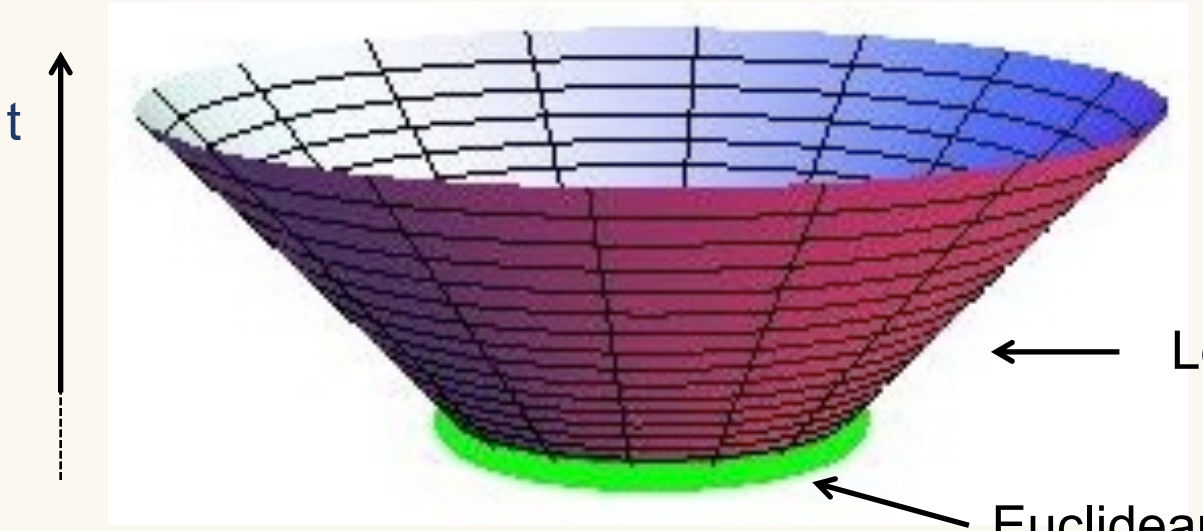
[Hartle, Hawking, TH, 2014]



$$\Psi[{}^3g, \phi] \sim \exp[-I_E({}^3g, \phi)]$$

A holographic Origin

[Hawking & TH, JHEP 2018]



$$Z_{QFT}[{}^3\tilde{g}, \tilde{\phi}] \to \Psi\Psi^*$$

A smooth exit from eternal inflation?

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[b] *Institute for Theoretical Physics, University of Leuven,*
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Abstract: The usual theory of inflation breaks down in eternal inflation. We derive a dual description of eternal inflation in terms of a deformed Euclidean CFT located at the threshold of eternal inflation. The partition function gives the amplitude of different geometries of the threshold surface in the no-boundary state. Its local and global behavior in dual toy models shows that the amplitude is low for surfaces which are not nearly conformal to the round three-sphere and essentially zero for surfaces with negative curvature. Based on this we conjecture that the exit from eternal inflation does not produce an infinite fractal-like multiverse, but is finite and reasonably smooth.

JHEP04(2018)147

Brout and Englert's vision on Lemaître's primeval atom is alive and well

Thank you!

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