From Nothing to the Universe

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The efforts to understand the universe is one of the very few things that lifts human life a little above the level of farce...
S. Weinberg, 1977
\[ \Delta q \times \Delta p \geq \frac{1}{2} \hbar \]
Before 1990

Notre concitoyen, disaient-ils en pleurant,
Perd l'esprit : la lecture a gâté Démocrite.
Nous l'estimerions plus s'il était ignorant.
Aucun nombre, dit-il, les mondes ne limite :
   Peut-être même ils sont remplis
   De Démocrites infinis.
La Fontaine

“Our fellow citizen,” they said, “has lost his mind”
Reading has ruined Democritus.
If he knew less he’d have more sympathy from us.
There are more worlds, he claims, in number infinite,
   And each of them may have in it
   Another Democritus.
La Fontaine

“Only by their breaking could the divine configurations be perfected”

Kabbalistic text; Ta’alumoth Chokhmah (The Channels of Wisdom)
1629, Joseph Samomon del Medigo of Crete
The Universe expands

Hubble law

\[ V = Hr \]

\[ t \sim \frac{r}{v} = \frac{1}{H} \sim 13,7 \text{ bil. years} \]
There is baryonic matter:
about 25% of $^4\text{He}$, D....heavy elements

Dark Matter???? baryonic origin???

Large Scale Structure: clusters of galaxies!
Filaments, Voids??????????????
There exists background radiation with the temperature \( T \approx 3K \)

Penzias, Wilson 1965
When the Universe was 1000 times smaller
its temperature was about \(2725\,^\circ K\)
Big Bang

Nucleosynthesis

Recombination

Zeit \( T = 3 \text{ Minuten} \)

Zeit \( T = 300 \, 000 \text{ Jahre} \)
Millennium Simulation
10,077,696,000 particles
Very homogeneous

Inhomogeneous
\[
\frac{\text{female}}{\text{male}} = 0.96
\]
Quantum fluctuations and a nonsingular Universe

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Adopting a perturbation of the curvature scalar as a physical variable, we find the corresponding action in the form [6]

$$\delta S_b = \frac{1}{2} \int d^4x \left[ \phi^2 - \nabla^2 \phi \nabla^2 \phi + \left( \frac{a''}{a} + M^2 a^2 \right) \phi^2 \right],$$

where $\phi = 1/\sqrt{18(4H^2 - M^2)} a\delta R/M\ell$, and $\ell = (8\pi G/3)^{1/2} = 4.37 \times 10^{-33} \text{ cm}$ is the Planck length.

A finite duration of the de Sitter stage does not by itself rule out the possibility that this stage may exist as an intermediate stage in the evolution of the universe. An interesting question arises here: Might not perturbations of the metric, which would be sufficient for the formation of galaxies and galactic clusters, arise in this stage? To answer this question, we need to calculate the correlation function for the fluctuations of the metric after the universe goes from the de Sitter stage to the hydrodynamic stage. By analogy with (6) we find

$$\langle 0 | \hat{h}(x) \hat{h}(x + r) | 0 \rangle = \frac{1}{2\pi^2} \int Q^2(k) \frac{\sin kr}{kr} \frac{dk}{k},$$

where $h = h_0^2$ and where, for the most interesting region, $H > k > H \exp (-3H^2/M^2) (M^2 \ll H^2)$,

$$Q(k) \approx 3\ell M \left( 1 + \frac{1}{2} \ln \frac{H}{k} \right).$$

The fluctuation spectrum is thus nearly flat. The quantity $Q(k)$ is the measure of the amplitude of perturbations with scale dimensions $1/k$ at the time the universe begins the ordinary Friedmann expansion. With $\ell M \sim 10^{-9} - 10^{-5}$ and $M/H \lesssim 0.1$—these values are consistent with modern theories of elementary particles—the amplitude of the perturbations of the metric on the
$n_s = 0.96$
\( \Delta x \, m \, \Delta v \geq h \)
\[ \Delta p \Delta x \geq h \]

There always exist unavoidable Quantum Fluctuations

Quantum fluctuations in the density distribution are large (\(10^{-5}\)) only in extremely small scales (\(~10^{-33}\) cm), but very small (\(~10^{-58}\)) on galactic scales (\(~10^{25}\) cm).

Can we transfer the large fluctuations from extremely small scales to large scales???
decelerated Friedmann Expansion
The space and time had both one beginning. The space was made not in time but simultaneously with time.

Saint Augustin of Hipo

God creates new worlds constantly

Zohar

If the world has begun with a single quantum, the notions of space and time would altogether fail to have any sense at the beginning and would only begin to get some sensible meaning when the original quantum would have been divided in a sufficient number of quanta.

G. Lemaître,

The beginning of the world from the point of view of quantum theory, Nature 127, 706 (1931)

The Creation of the Universe as a Quantum Phenomenon

R. Brout, F. Englert, and F. Gunzig

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

Received July 7, 1977
\[ \dot{a} \approx \exp(Ht) \]
Predictions!!!

1) Does space have a shape?

- **Euclidian Space**
  - Zero Curvature

- **Elliptical Space**
  - Positive Curvature

- **Hyperbolic Space**
  - Negative Curvature

\[ \Omega = 1 \]
Perturbations (inhomogeneities) are:

2) Adiabatic (MC 1981)
3) Gaussian (MC 1981)

\[ \Phi = \Phi_g + f_{NL} \Phi_g^2, \text{ where } f_{NL} = \mathcal{O}(1) \text{ (MC, 81)} \]
4) have log spectrum (MC 1981)

\[ \Phi \propto \ln \left( \frac{\lambda}{\lambda_\gamma} \right) \propto \lambda^{1 - n_s} \] with \( n_S = 0.96 \) (MC, 1981)
L.P. 9/6/2003:
We are writing a proposal to get money to do our small angular scale CMB experiment. If I say that simple models of inflation require \( n_s = 0.95 \pm 0.03 \) (95\% c.l) is it correct? I'm especially interested in the error. Specifically, if \( n_s = 0.99 \) would you throw in the towel on inflation?

V.M. 9/8/2003
The "robust" estimate for spectral index for inflation is \( 0.92 < n_s < 0.97 \). The upper bound is more robust than lower. The physical reason for the deviation of spectrum from the flat one is the necessity to finish inflation.... If you find \( n_s = 0.99 \pm 0.01 \) (3 sigma) I would throw in the towel on inflation.
After 90 - present
COBE 1992

2.725 K Blackbody Spectrum of the CMB
1965 | Penzias and Wilson
---|---
1992 | COBE
---|---
2003 | WMAP
---|---
2009 | Planck
---|---

End 2012
the Planck Collaboration, including individuals from more than 100 scientific institutes in Europe, the USA and Canada.

Planck is a project of the European Space Agency, with instruments provided by two scientific Consortia funded by ESA member states (in particular the lead countries: France and Italy) with contributions from NASA (USA), and telescope reflectors provided in a collaboration between ESA and a scientific Consortium led and funded by Denmark.
PREDICTIONS

1) flat Universe

Perturbations are:

2) adiabatic (MC, 81)

3) gaussian: $\Phi = \Phi_g + f_{NL} \Phi_g^2$, where $f_{NL} = O(1)$ (MC, 81)

4) spectrum: $\Phi \propto \ln (\lambda/\lambda_\gamma) \propto \lambda^{1-n_s}$ with $n_s = 0.96$ (MC, 81)
with $\Omega_{\text{tot}} = 1$ (prediction) and $H_0$, $\Omega_\Lambda$, $\Omega_{\text{bar}}$ from supernova, deuterium et.cet. we get
Planck 2014 - TE & EE

Frequency averaged spectrum reduced $^2 = 1.04$

Frequency averaged spectrum reduced $^2 = 1.01$
Before Planck:
- Dark Matter: 22.7%
- Ordinary Matter: 4.5%
- Dark Energy: 72.8%

After Planck:
- Dark Matter: 26.8%
- Ordinary Matter: 4.9%
- Dark Energy: 68.3%
$-\Omega_{tot} = 1 \pm 0.005$

- Perturbations are adiabatic
- Gaussian: $f_{NL} = 2 \pm 5$

$n_s = 0.96 \pm 0.005$!!!
CONCLUSIONS

– General Relativity is valid up to the scales $10^{-27}$ cm
– We all originated from quantum fluctuations
- Theory is right
- Planck is right
- BICEP2 is right

\[ T + P \checkmark T + B \checkmark \]

\[ P + B \checkmark \]

But

\[ T + P + B \times \]

Therefore, \( P + B \Rightarrow \) catastrophe for theory
Risse in der Urknall-Theorie


Von Marlene Weiß

Wer meint, die Welt erklären zu können, indem er am kleinen n schraubt, bekommt es mit Wladyslaw Mukhanov zu tun. "Vollkommenes Unatlas", schimpft der an der Uni München aktive russische Physiker, "die Zirkschriften sind voll davon, aber es bleibt trotzdem Unatlas!"

Auch wer sonst nichts von seinem Vortrag kürzlich am Max-Planck-Institut für Astrophysik in Garching bei München verstanden hat, eines dürfte jedem Zuhörer klar geworden sein: Das kleine n in den Formeln über den Beginn des Universums, auch "spektakularer Index" genannt, sollte man in Ruhe lassen, wenn man sich nicht mit Mukhanov anlegen möchte.

Das sind schlechte Nachrichten für all die Fachleute, die Mitte März jubelten, als es hieß, man habe mit einem Teleskop am Südpol Signale aus den ersten Sekundenbruchteilen nach dem Urknall gemessen: Vielleicht war der Jubel verfrüht, das Ergebnis widerspricht anderen Messungen.

Stellen von Gravitationswellen, die vor 13,8 Gist Jahren entstanden sein