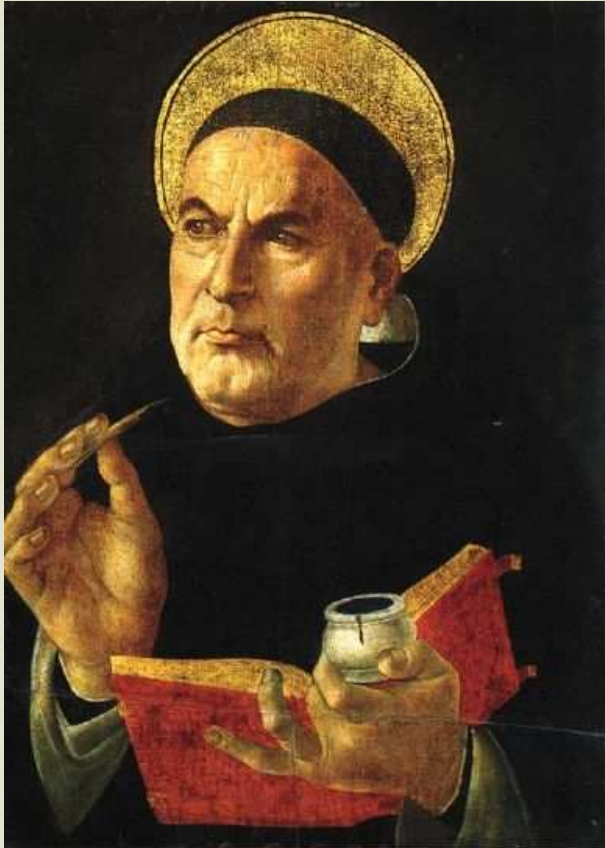


Testability and Epistemic Shifts in Modern Cosmology



The scholastic heritage



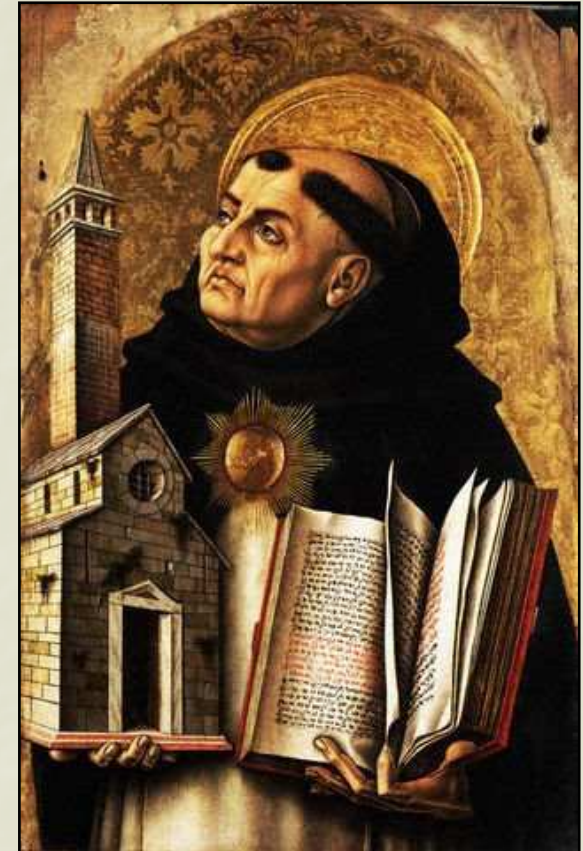
Thomas Aquinas (1224-1274)

Concepts of creation

Temporal infinity?



Albert the Great (ca. 1200-1280)



Bonaventura (1217-1274)

Allgemeine
Naturgeschichte

und

Theorie des Himmels,

oder

Versuch

von der Verfassung und dem mecha-
nischen Ursprunge

des ganzen Weltgebäudes

nach

Newtonischen Grundsätzen
abgehandelt.

* * * * *  * * * * *

Königsberg und Leipzig,

bey **Johann Friederich Petersen, 1755.**



Critik
der
reinen Vernunft

von

Immanuel Kant

Professor in Königsberg.



Riga,
verlegt Johann Friedrich Hartnoch
1781.



The Principle of Plenitude

"From the fact that a thing can exist, I infer readily enough that it does exist."

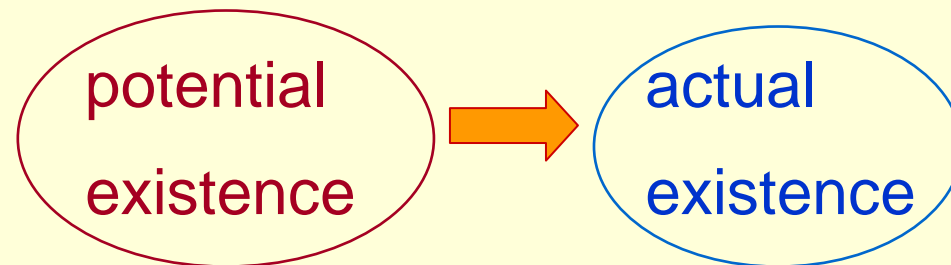
(J. Robinet, 1767)

"Anything which is not prohibited is compulsory."

(E. Sudarshan, 1972)

Has been used as an argument for a variety of objects, e.g. neutrinos, black holes, tachyons, magnetic monopoles, chemical elements, other universes, etc.

The principle postulates a necessary connection between potential and actual existence.





David Hilbert (1862-1943)

"The infinite is nowhere to be found in reality; it neither exists in nature, nor does it provide a basis for rational thought."

"Über das unendliche," *Mathematische Annalen* 95 (1925), 161-190.

Über das Unendliche¹⁾.

Von

David Hilbert in Göttingen.

Das Gesamtergebnis ist dann: **das Unendliche findet sich nirgends realisiert; es ist weder in der Natur vorhanden, noch als Grundlage in unserem verstandesmäßigen Denken zulässig — eine bemerkenswerte Harmonie zwischen Sein und Denken.** Im Gegensatz zu den früheren Bestrebungen

Lessons from the steady-state controversy

A chapter in the history of cosmology including instructive discussions of philosophical aspects, and involving scientists (H. Bondi, T. Gold, G.C. McVittie), philosophers (R. Harré, A. Grünbaum, N. Russell Hanson), as well as scientist-philosophers (G.J. Whitrow, H. Dingle, M. Bunge, R. Schlegel).



THE PROBLEM OF INFINITE MATTER IN STEADY-STATE COSMOLOGY*
RICHARD SCHLEGEL
Michigan State University

The British Journal for the
Philosophy of Science

VOLUME IV

FEBRUARY, 1954

No. 16

IS PHYSICAL COSMOLOGY A SCIENCE?

A Discussion

G. J. WHITROW and H. BONDI

Rationalism versus
Empiricism in Cosmology

The temptation to substitute logic for observation
is peculiarly hard to resist in astronomy.

G. C. McVittie

The "cosmological" nature of the laws & parameters of nature

P: "the charge of the electron is $e = 1.6 \times 10^{-19} \text{ C}$ "

Q: "electrical charges are multiples of $\pm e$ "

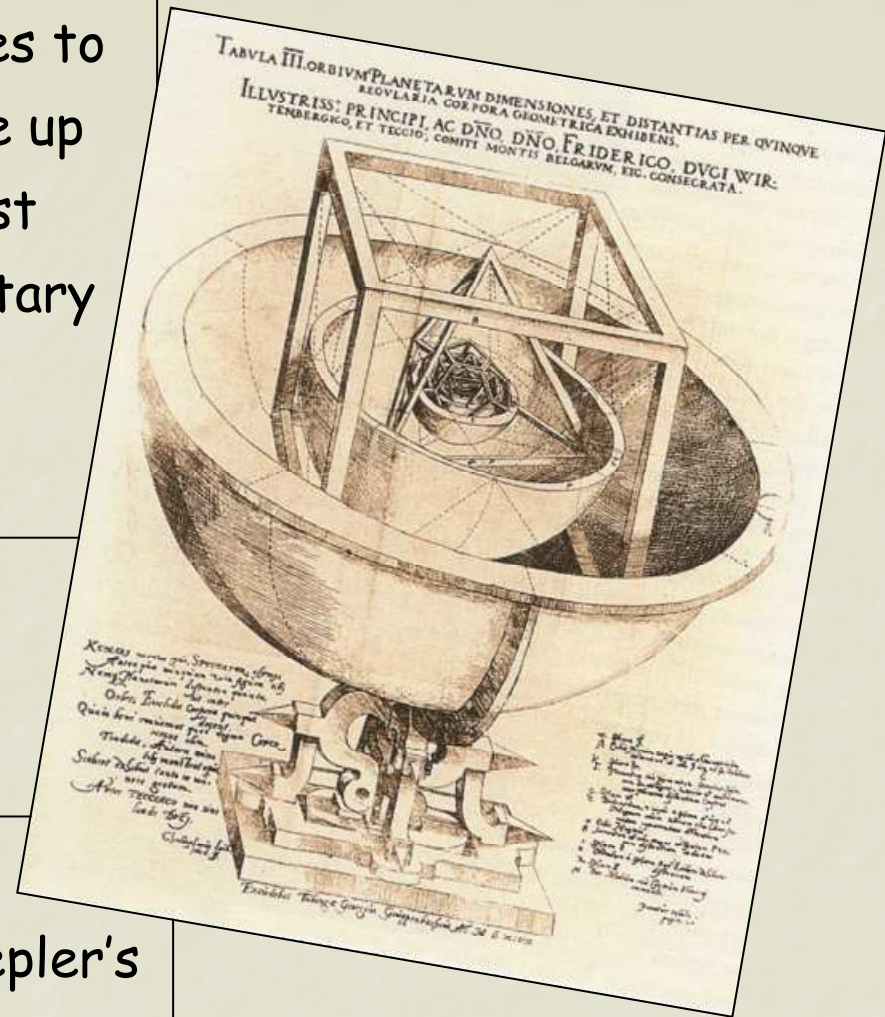
-- means that: *all* electrons (in the universe) have the charge e ; *all* electrical charges (in the universe) are multiples of $\pm e$

R: "energy is conserved"

-- means that: *all* processes (in the universe) satisfy energy conservation

"We may just have to resign ourselves to a retreat, just as Newton had to give up Kepler's hope of calculating from first principles the relative sizes of planetary orbits."

S. Weinberg, 2007



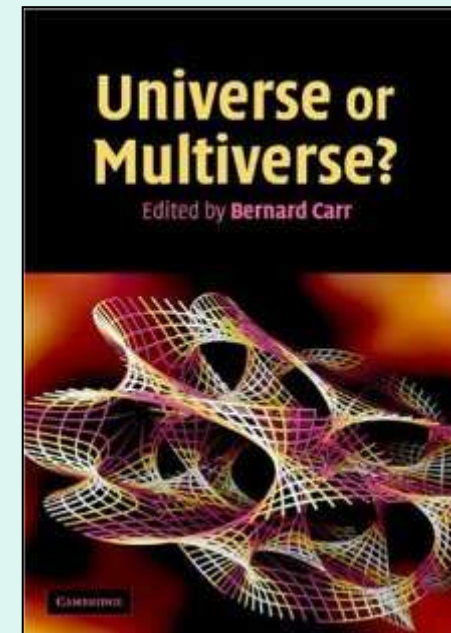
"The quest for first-principle explanations may prove as vain as Kepler's quest for a beautiful mathematical formula that described the solar system."

M. Livio & M. Rees, 2005

"Throughout the history of science, the universe has always gotten bigger. We've gone from geocentric to heliocentric to galactocentric. Then in the 1920s there was this huge shift when we realized that our galaxy wasn't the universe. I just see this as one more step in the progression. Every time this expansion has occurred, the more conservative scientists have said, 'This isn't science'. This is the same process repeating itself."

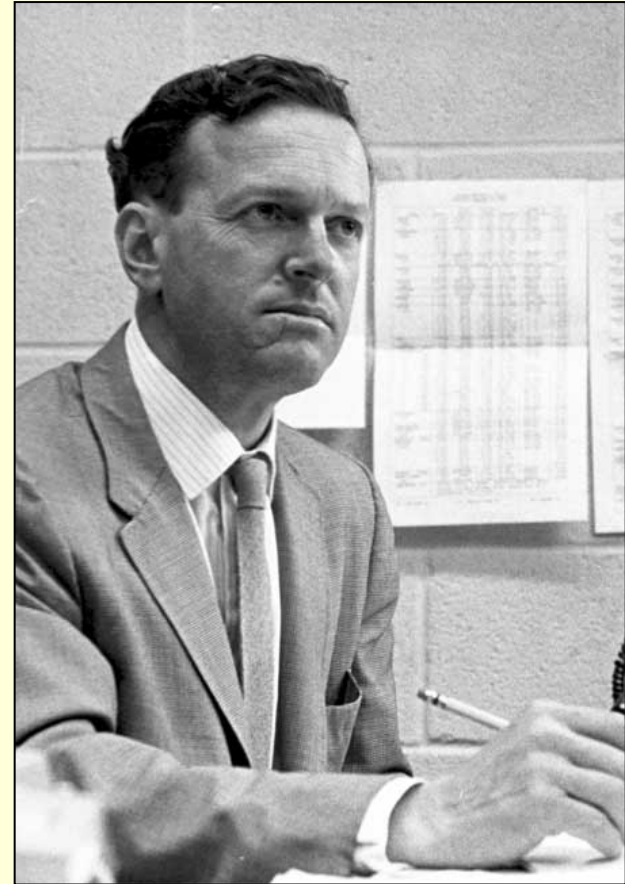


B. Carr

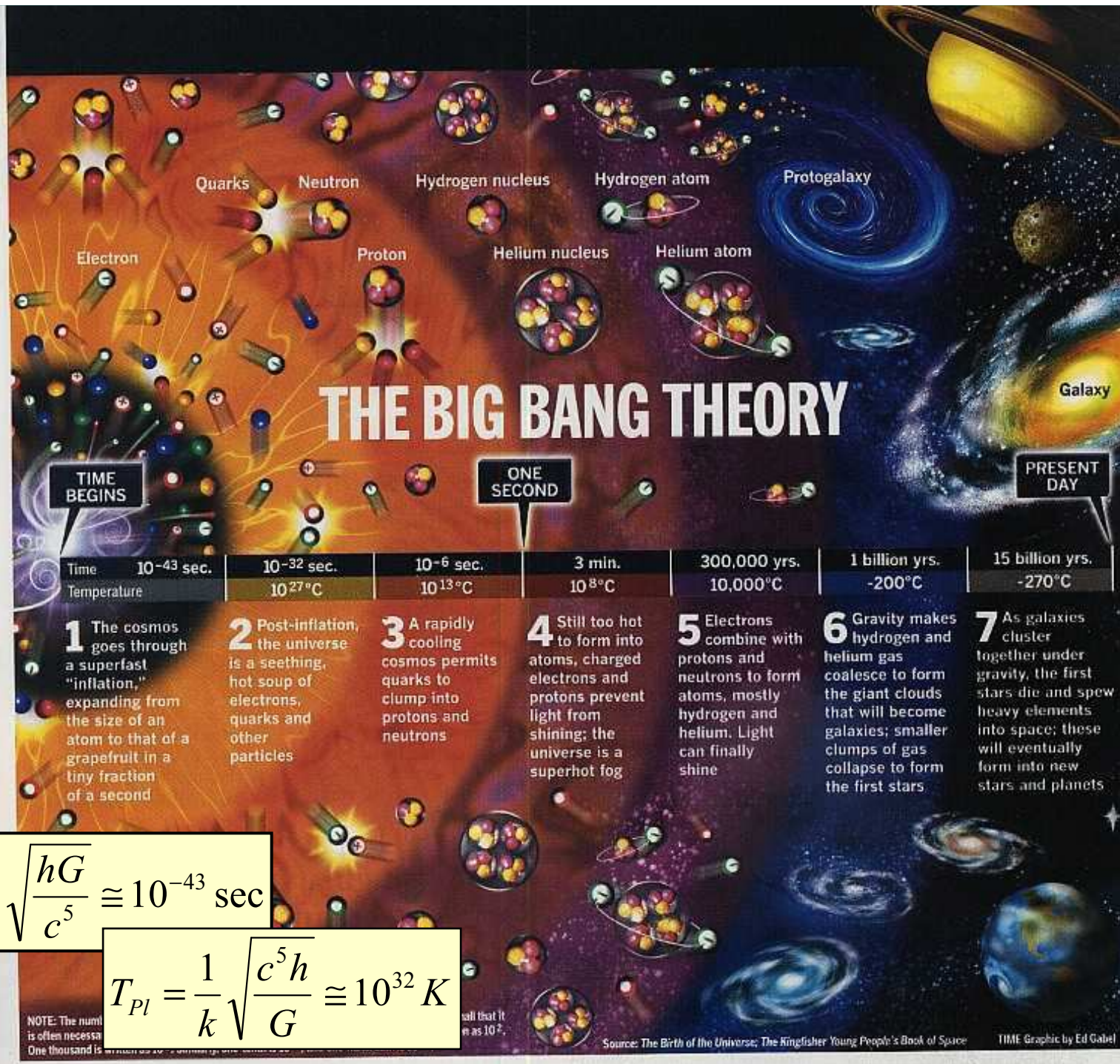


"Analogies drawn from the history of science are often claimed to be a guide [to progress] in science; but, as with forecasting the next game of roulette, the existence of the best analogy to the present is no guide whatever to the future.

The most valuable lesson to be learned from the history of scientific progress is how misleading and strangling such analogies have been, and how success has come to those who ignored them."



T. Gold, 1956



$$t_{Planck} = \sqrt{\frac{hG}{c^5}} \cong 10^{-43} \text{ sec}$$

$$T_{Pl} = \frac{1}{k} \sqrt{\frac{c^5 h}{G}} \cong 10^{32} \text{ K}$$

NOTE: The number is often necessary. One thousand is

all that it is as 10^2 .

Source: *The Birth of the Universe*; *The Kingfisher Young People's Book of Space*

TIME Graphic by Ed Gabel

"ultimate questions" in cosmology: do they have a scientific answer?



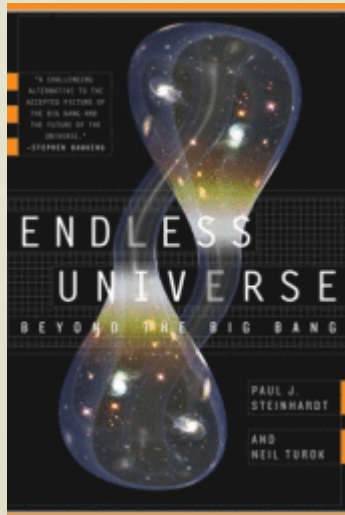
Cosmology marches on

A big-bang universe of infinite age?

A Cyclic Model of the Universe

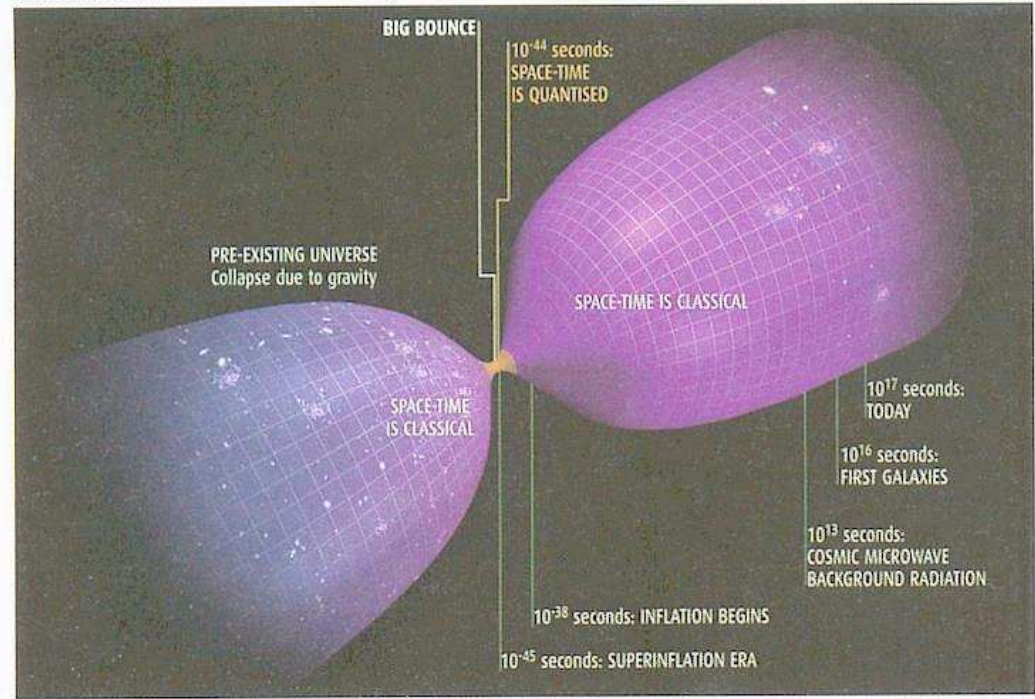
Paul J. Steinhardt^{1*} and Neil Turok²

We propose a cosmological model in which the universe undergoes an endless sequence of cosmic epochs that begin with a "bang" and end in a "crunch." Temperature and density at the transition remain finite. Instead of having an inflationary epoch, each cycle includes a period of slow accelerated expansion (as recently observed) followed by contraction that produces the homogeneity, flatness, and energy needed for the next cycle.



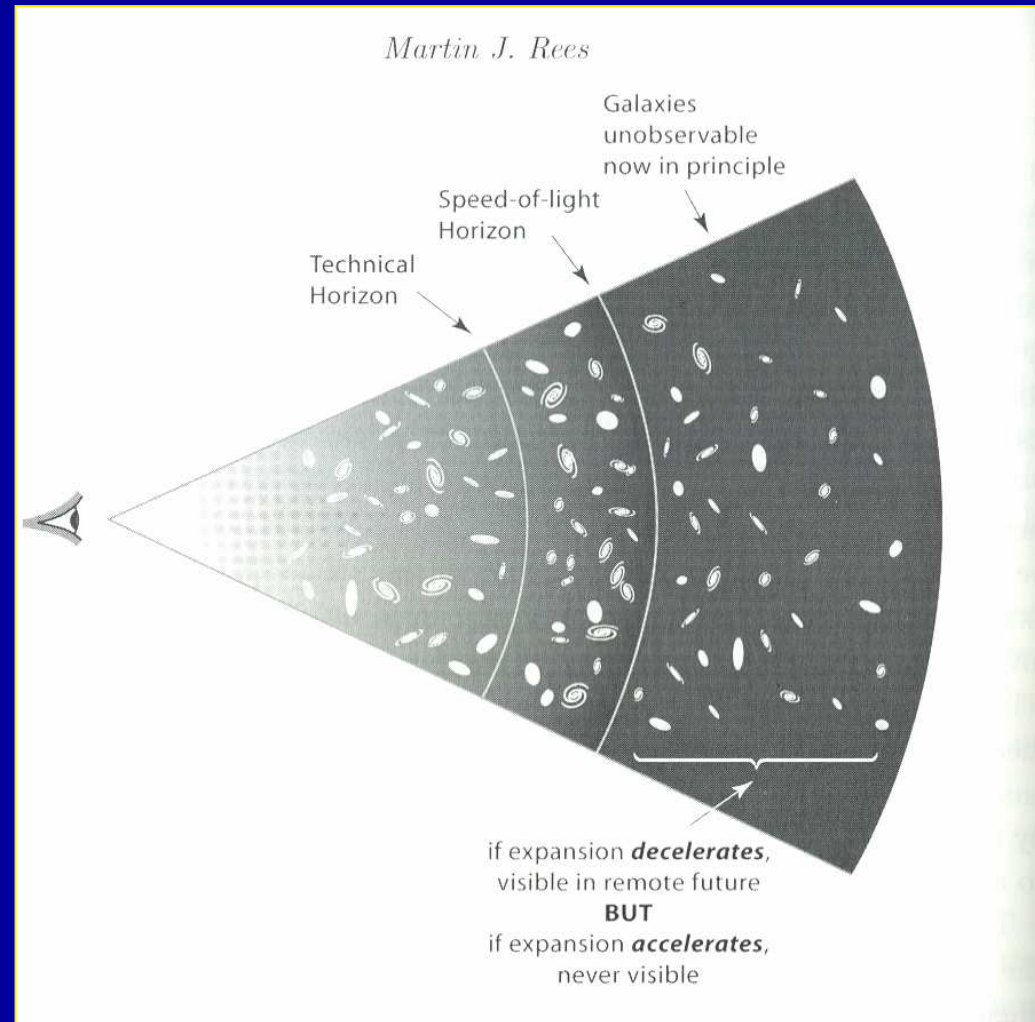
THE BIG BOUNCE

Loop quantum cosmology predicts that the universe did not arise from nothing in a big bang. Instead it grew from the collapse of a pre-existing universe that bounced back from oblivion.



Concepts of the universe

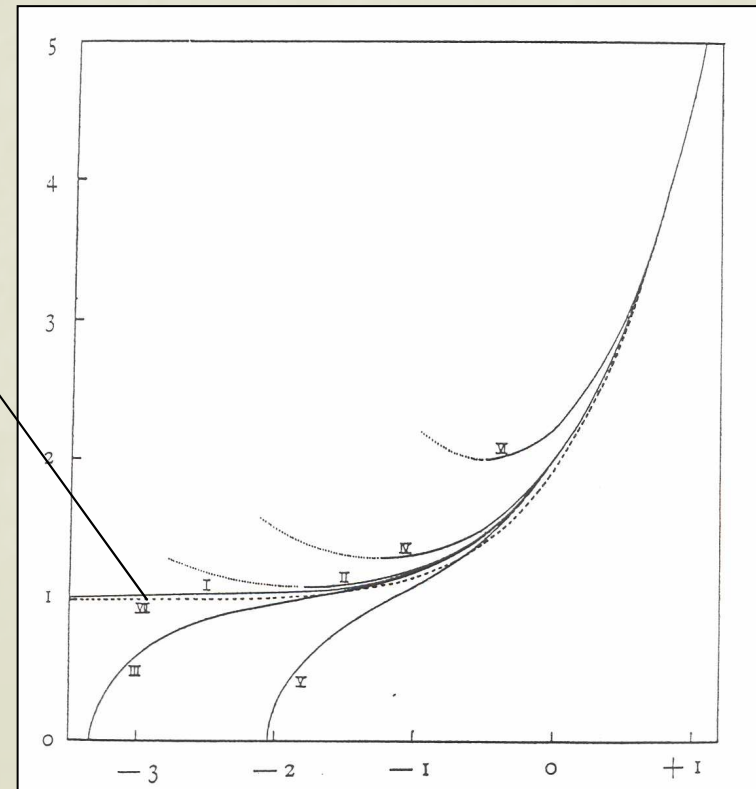
- The observed universe
- The in principle observable universe
- The universe that is, has been, or will be causally connected with us
- The totality of things about which knowledge can in principle be obtained



“Objects separating faster than the velocity of light are cut off from any causal inference on one another, so that in time the universe will become virtually a number of disconnected universes no longer bearing any physical relation to one another.” (A.S. Eddington 1931).



Lemaître-Eddington model (1927/1930):
expanding, closed,
no big bang



Epistemic and ontological shifts

What does it mean that something exists?
Should we ask nature, or the equations?

"What physicists ... mean by the term *exists* is that the object in question can exist *theoretically*. The object exists as a solution to the equations of the theory. By that criterion perfectly cut diamonds a hundred miles in diameter exist. So do planets made of pure gold. They may or may not actually be found somewhere, but they are possible objects consistent with the Laws of Physics."



Leonard Susskind,
cofounder of string theory
and leading multiverse
physicist.

"I believe that soon any cosmological theory that does not lead to eternal reproduction of universes will be considered as unimaginable as a species of bacteria that cannot reproduce."

"The combination of inflationary cosmology and the landscape of string theory leads to the multiverse and gives the anthropic principle a scientifically viable framework."

Alan Guth on the eternal-inflation multiverse



A. Guth, leading physicist and cosmologist who proposed the inflationary model of the early universe in a landmark paper of 1981.

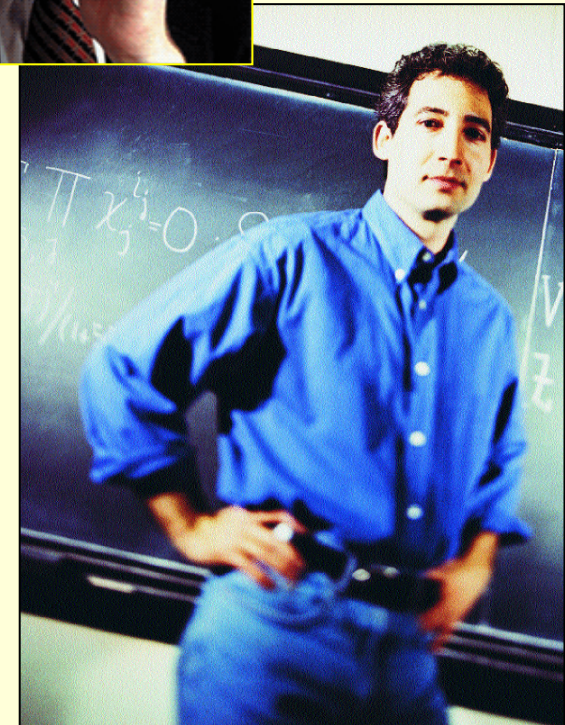
R. Matthews, "Do we need to change the definition of science?" *New Scientist*, 7 May 2008.

"The multiverse may be a turning point, a radical change in *what we accept as a legitimate foundation for physical theory.*"

Steven Weinberg

"The smart money will remain with the multiverse and string theory. I have personally undergone a sort of transformation, where I am very warm to the possibility of there being many universes, and that we are in the one where we can survive."

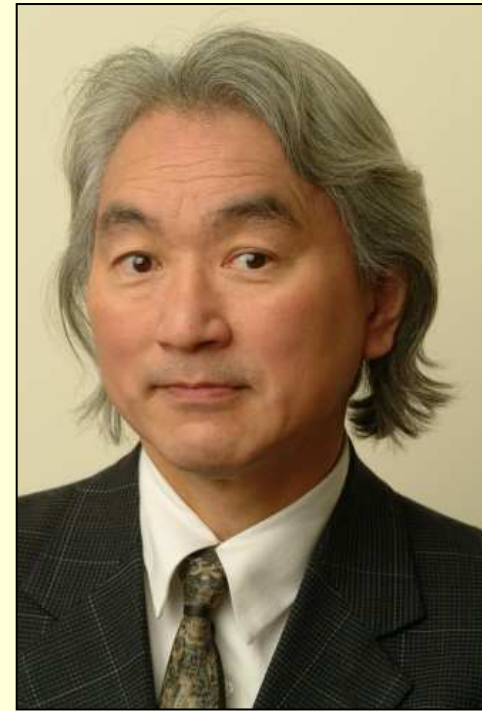
Brian Greene



Testability: A stable epistemic value

But,

- Does a theory need to be actually testable, or will testability in principle do?
- Should a theory result in precise and testable predictions, or will indirect testability based on probabilistic predictions do?
- Do tests have to be empirical, or can they also - and perhaps only - be mathematical?
- When should a theory be testable?



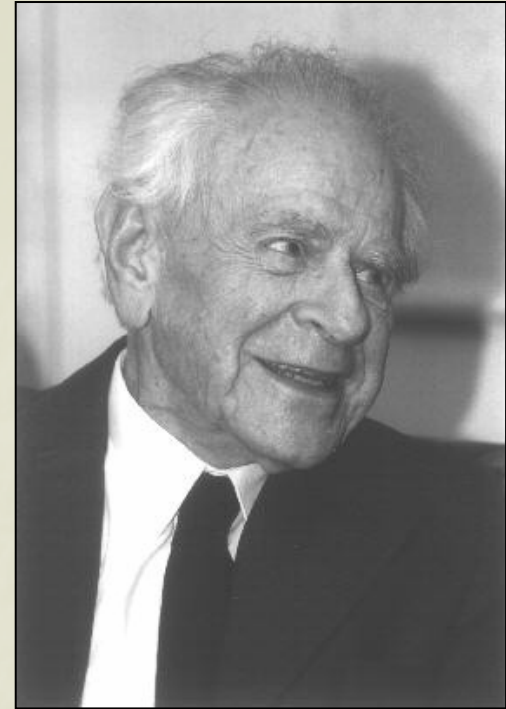
"Verification of string theory may come entirely from pure mathematics rather than from experiment."

Michio Kaku

Popper under fire?

"If scientists need to change the borders of their own field of research, it would be hard to justify a philosophical prescription preventing them from doing so."

A. Barrau, 2004



"As for rigid philosophical rules it would be the height of stupidity to dismiss the possibility [of the multiverse] just because it breaks some philosopher's dictum about falsifiability. It would be very foolish to throw away the right answer on the basis that it doesn't conform to some criteria for what is or isn't science."

L. Susskind, 2006

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DOI 10.1007/s00016-005-0279-6

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Physics in Perspective

Perspectives on Current Issues

What Makes a Theory Testable, or Is Intelligent Design Less Scientific Than String Theory?



Robert Ehrlich, US physicist

"Decisions as to what constitutes a legitimate scientific theory are simply too important to be left to the practitioners of that field, who obviously have a vested interest in it, such as a desire to keep the funding coming."

"Physics is in fact approaching, or perhaps has reached, the stage where we can proceed without the need to subject our further theories to empirical tests. ... Could empirical enquiry, which has guided science up to a certain point in history, lead at that point to a new stage wherein empiricism itself is transcended, outgrown?"

Dudley Shapere, 2001

"Ironic science is science that is not experimentally testable or resolvable even in principle and therefore not science in the traditional sense at all."

John Horgan, 1997

Postmodern Science?

