From Multiverse to Hologram

New Creation Myths

Roy Blake Nov. 2015

Typical Creation Story

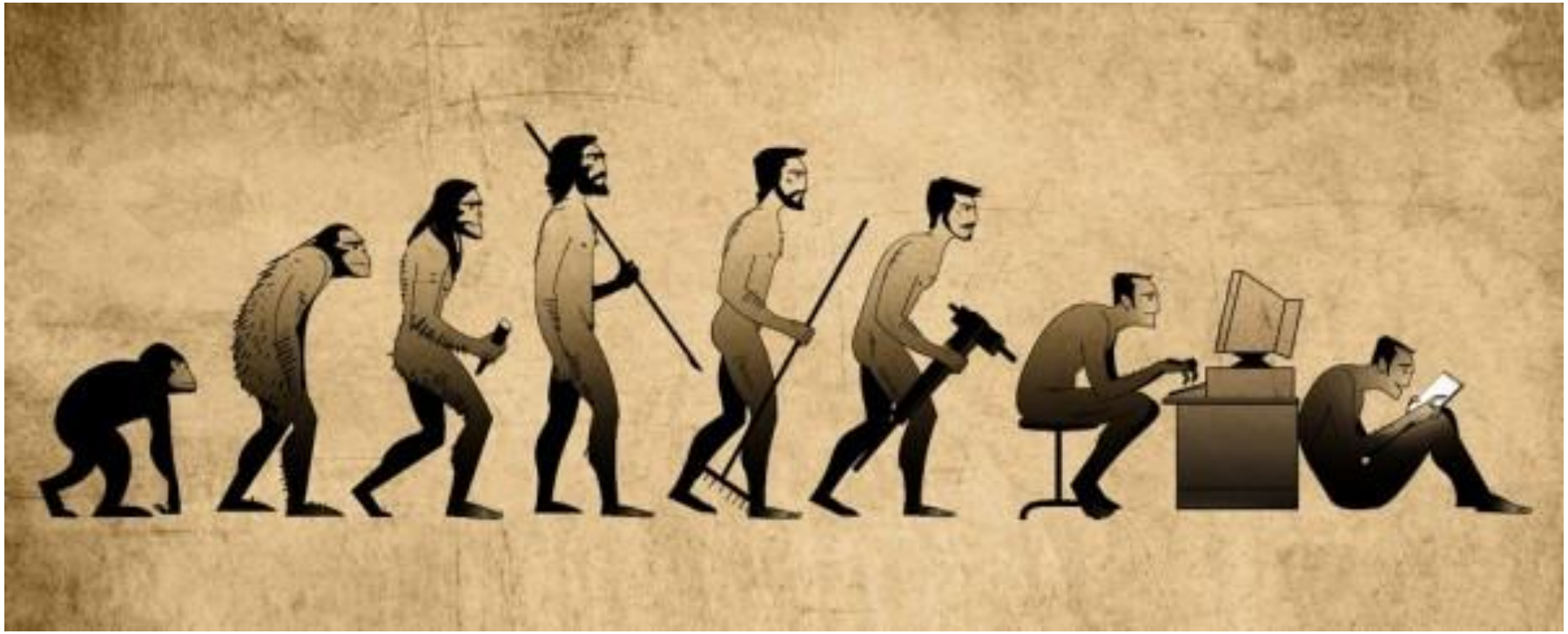
- **Creation of Universe**
  - Creation of Earth
  - Creation of Life
  - Creation of Humans

A Bit of Humility

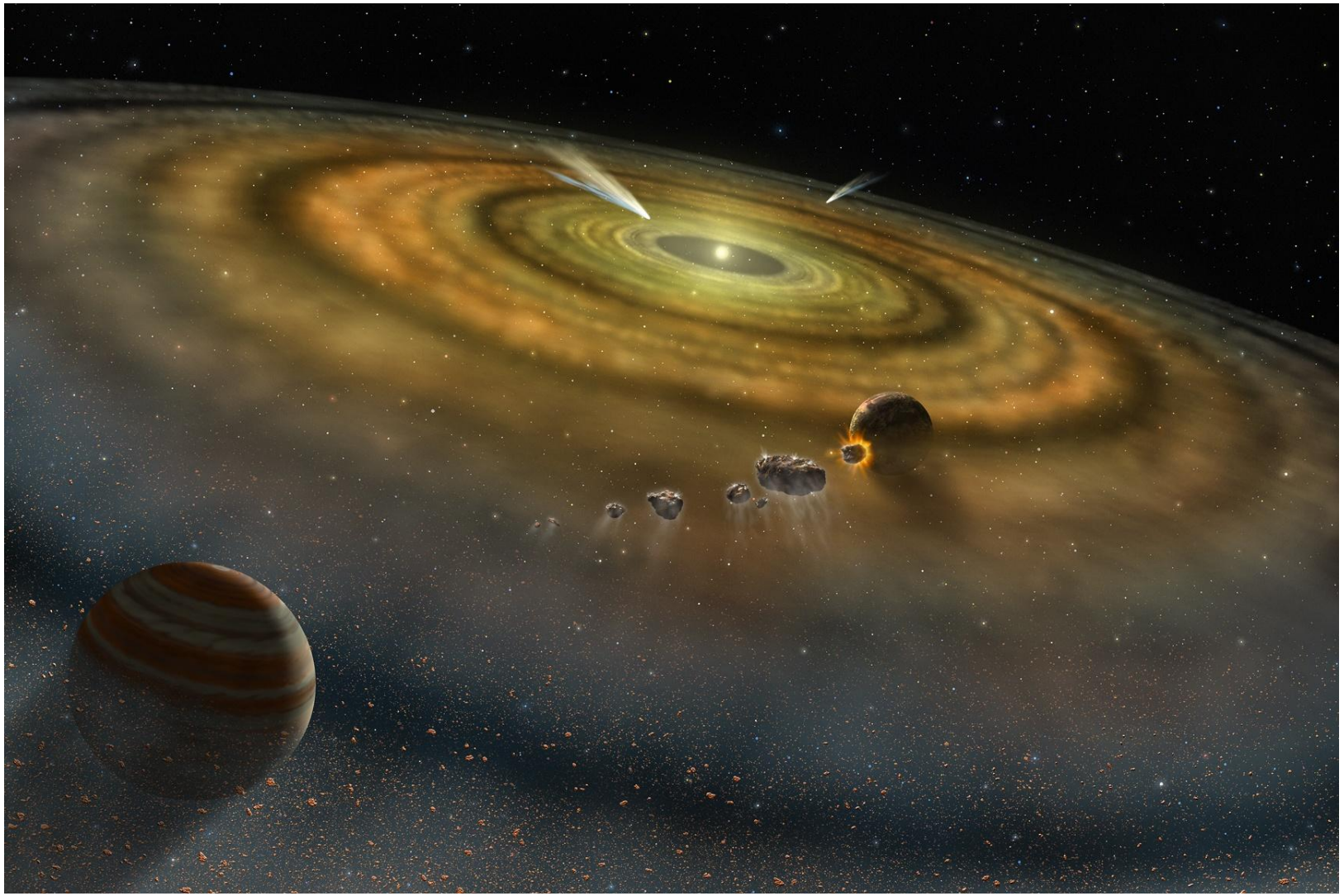
- Science never “proves” anything.
- All theories are models of reality that are useful in explaining it.
  - Not reality itself.
  - A better theory is more useful at explaining and predicting reality.
  - A really good theory is capable of being proven wrong by observations that conflict with it.

Science so Far

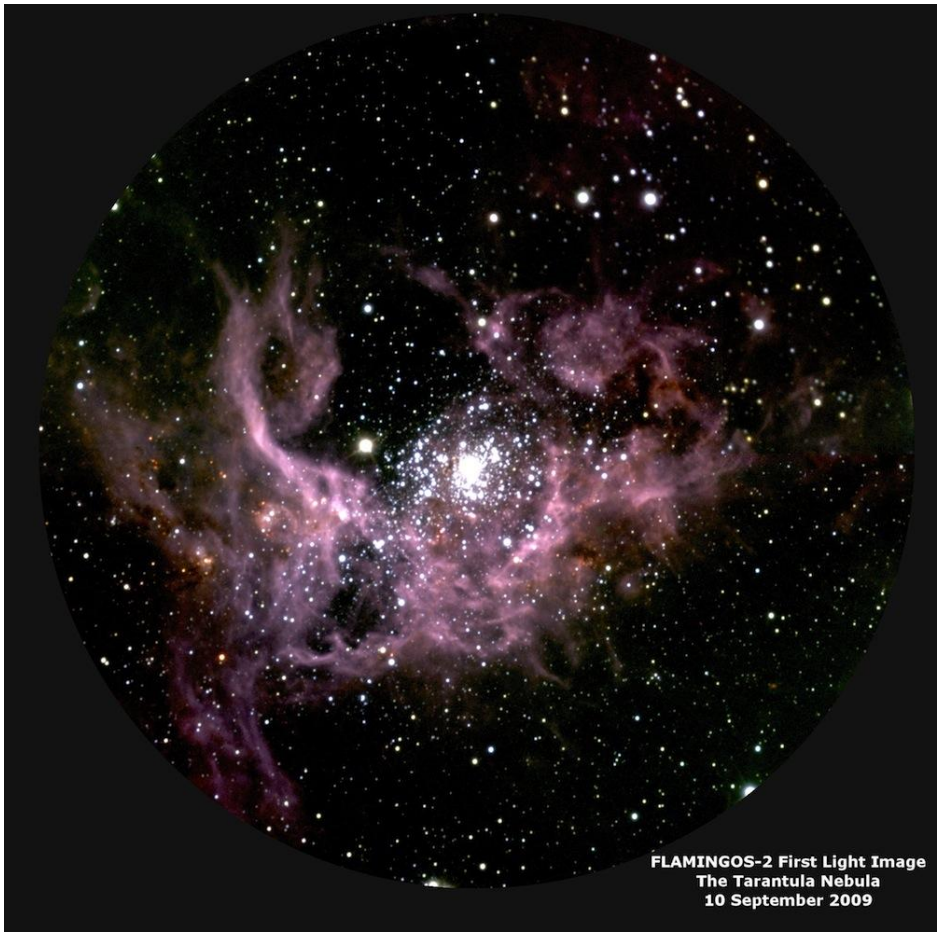
- Life on earth began around 3.5 billion years ago.
- Homo sapiens sapiens (us) evolved about 200,000 years ago.



- Earth --- Material from Exploded Stars.
- Formed around 4.5 billion years ago.

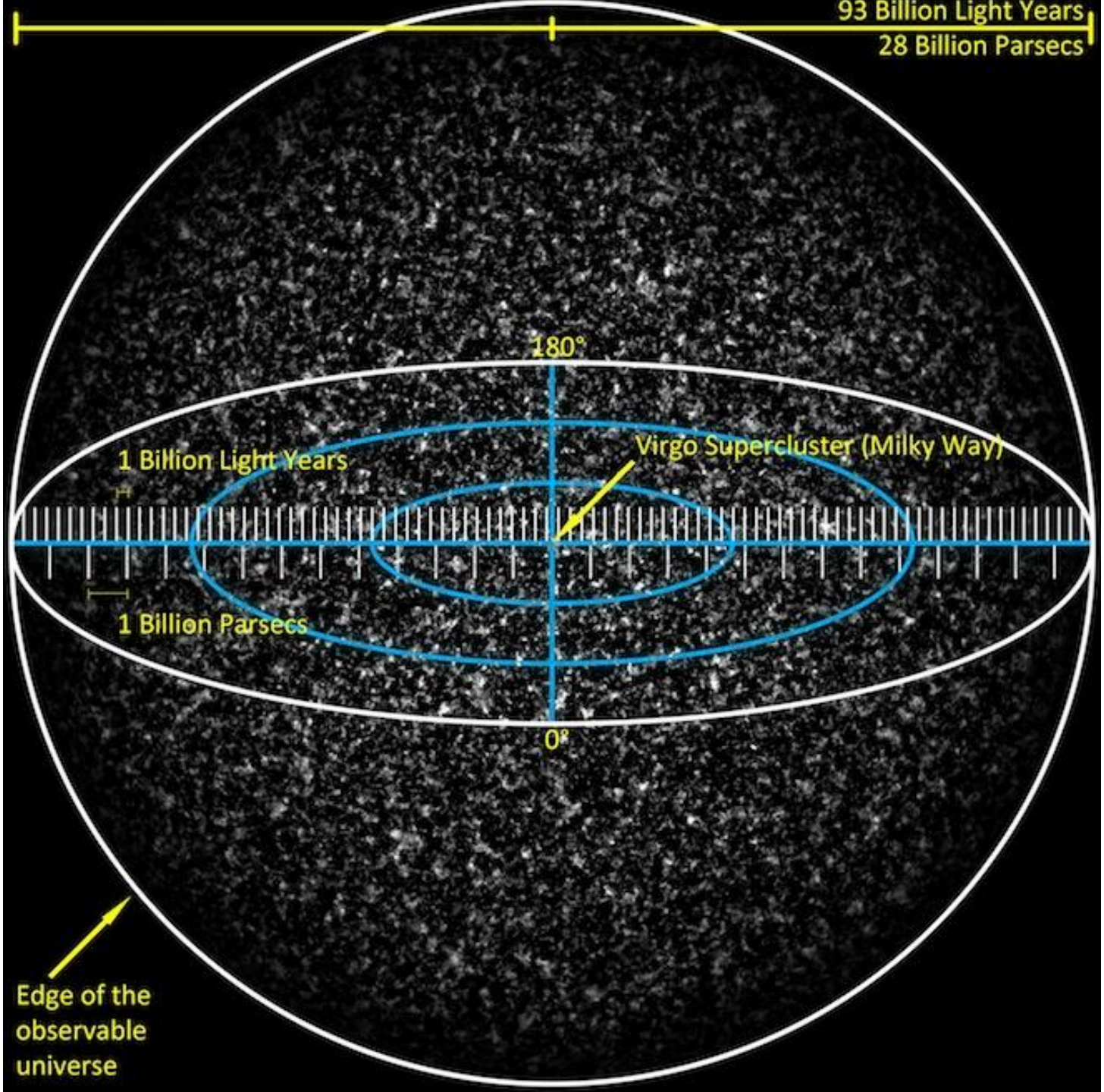


- Stars and Galaxies --- material compressed by gravity until atomic fusion starts.
  - About 200 billion galaxies, 200 billion stars each
- Sun is about 4.6 billion years old.

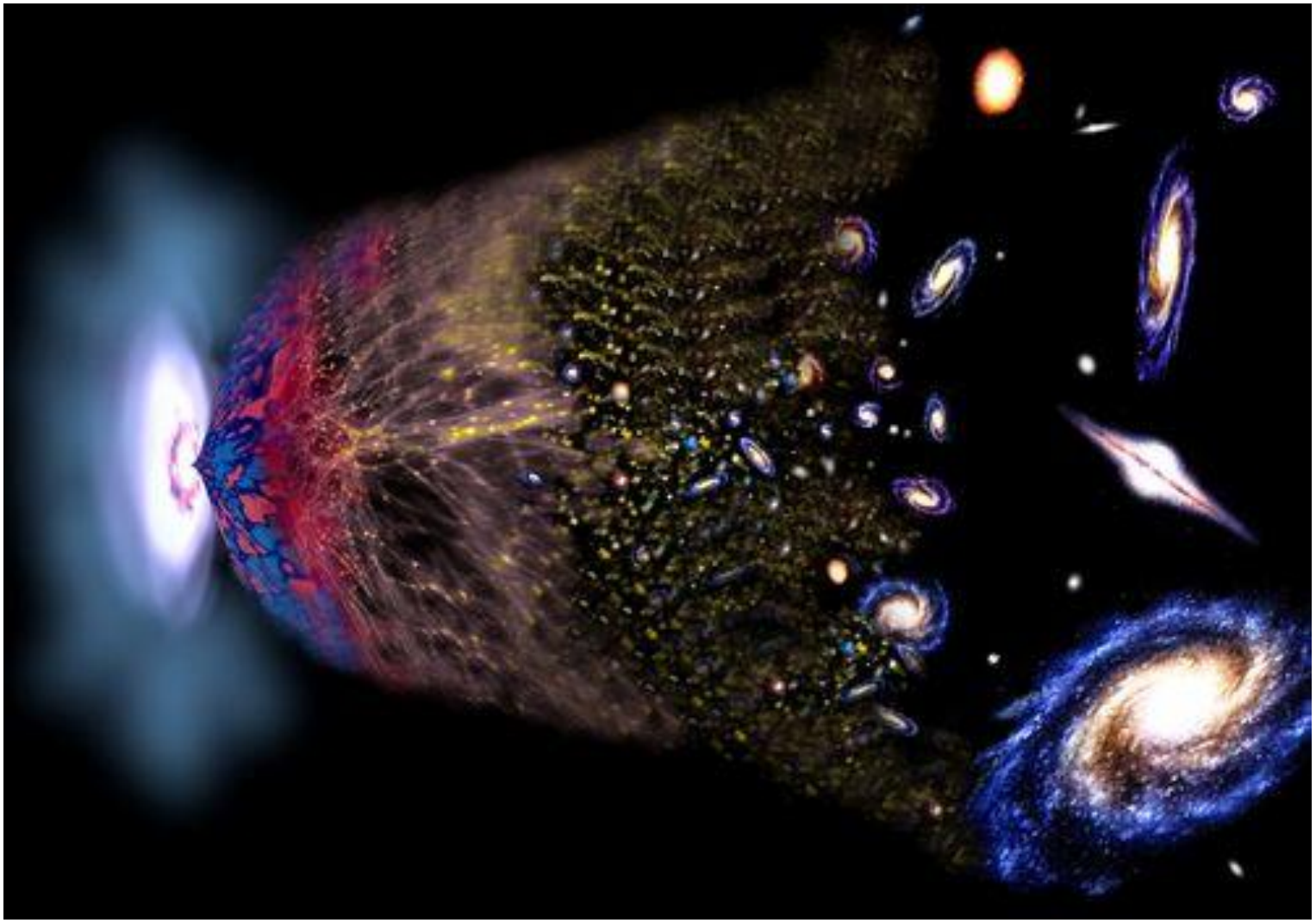


Galaxies

- 200 Billion galaxies, 200 billion stars each
- Our galaxy is about 100,000 light years across
- Known universe about 90 billion light years across

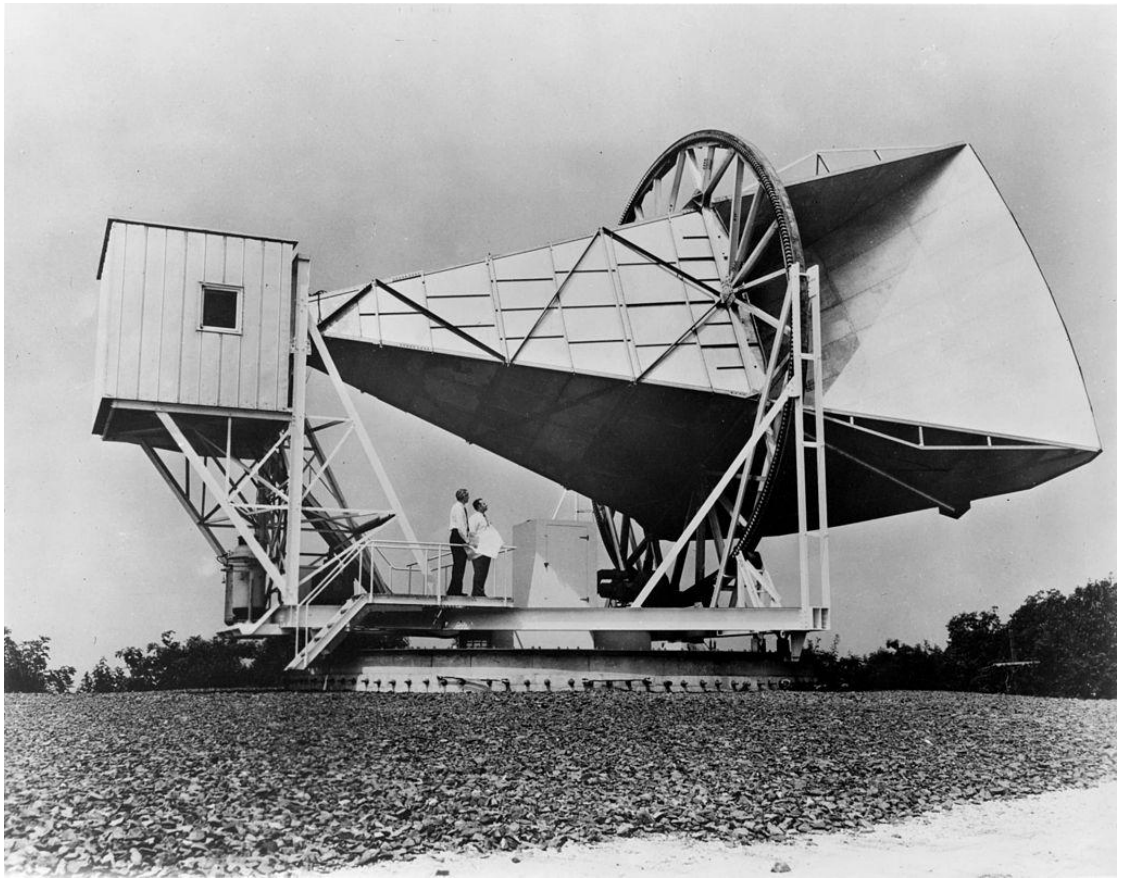

93 Billion Light Years
28 Billion Parsecs
180°
1 Billion Light Years
Virgo Supercluster (Milky Way)
1 Billion Parsecs
0°
Edge of the observable universe

- Universe: Big Bang
- About 13.8 billion years ago

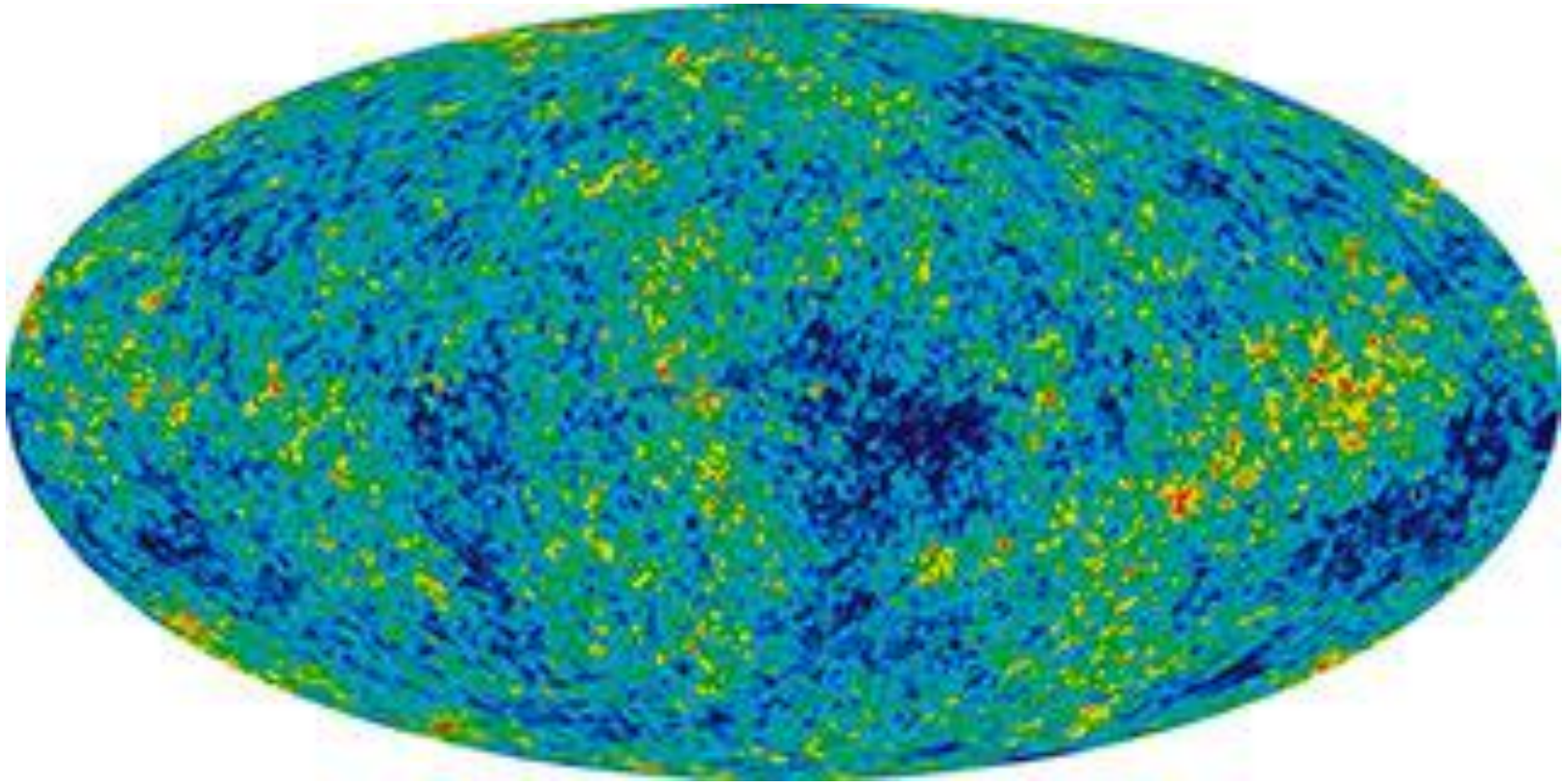


Cosmic Microwave Background

- Evidence for existence of big bang
- Discovered accidentally in 1964.



Microwave Background

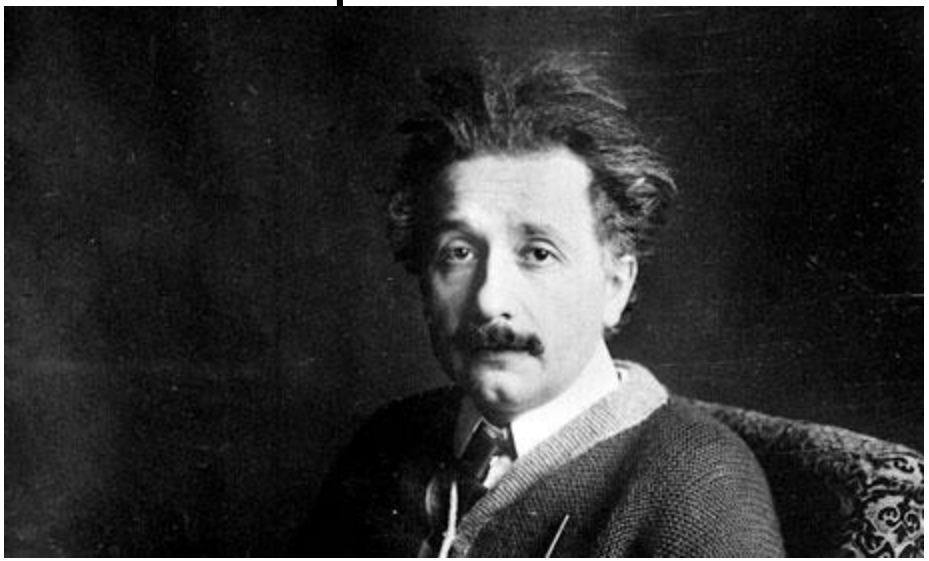


Big Bang Questions

- What happened before it?
  - If Big Bang created time, can we even ask this?
- Where did all the stuff and energy come from?
- How did the stuff form galaxies, stars, us?
- What happens now?
  - Expansion forever?
  - “Big Crunch”?
- What about dark matter, dark energy?

Basic Physics Models

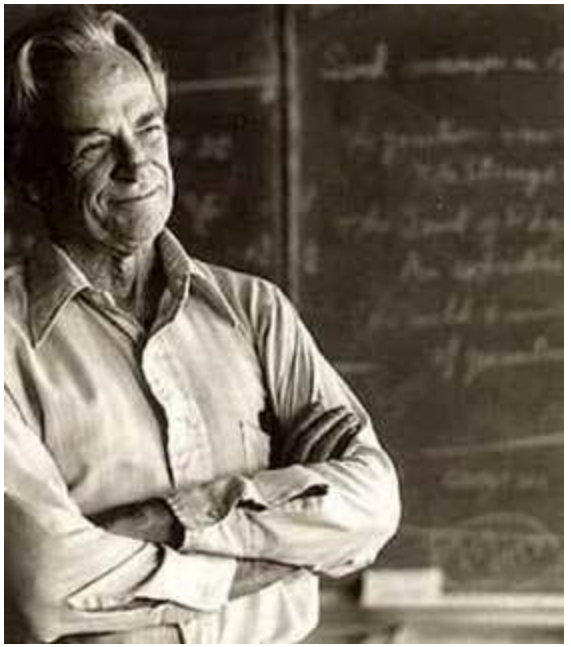
- General Relativity (Einstein, 1915)
  - Needed for large objects, large distances, high speeds.
  - Newtonian physics (1687) is a special case that works for low speeds.



Quantum Mechanics

- Needed at small scales (subatomic particles).
- Disagrees with relativity at small scales.

Neils Bohr 1885-1962



Richard Feynman 1918-1988

Problem at the Beginning of the Universe

- General Relativity fails because of small initial size.
  - Predicts a singularity (entire mass of universe in zero size.)
- Quantum mechanics required because entire universe at the beginning is very small, smaller than size of a subatomic particle
  - Probably about the Planck length (1.6×10^{-35} m)

Quantum Mechanics

- Hard to Understand
  - "If you think you understand quantum mechanics, you don't understand quantum mechanics."
    - Neils Bohr, one of the pioneers of quantum mechanics
  - "I think I can safely say that nobody understands quantum mechanics."
    - Richard Feynman, developer of quantum electrodynamics.
  - "God does not play dice with the universe."
    - Albert Einstein, who later admitted he was wrong.

But it Works!

- A few practical things that depend on quantum mechanics to work:
  - LEDs and Lasers
  - Transistors
  - Atomic energy
  - X-ray machines
  - Solar energy arrays
  - Photosynthesis in plants

Quantum Complications

- Probabilities – nothing is definite until observed.
  - Applies to every interaction between particles.
  - Even an elementary particle seems to have a “wave function” extending throughout the universe.
  - An alternative idea (Feynman) is that there is a different universe (“history”) for every possibility of every interaction. Sometimes called the “many worlds” theory.

Feynman's Van

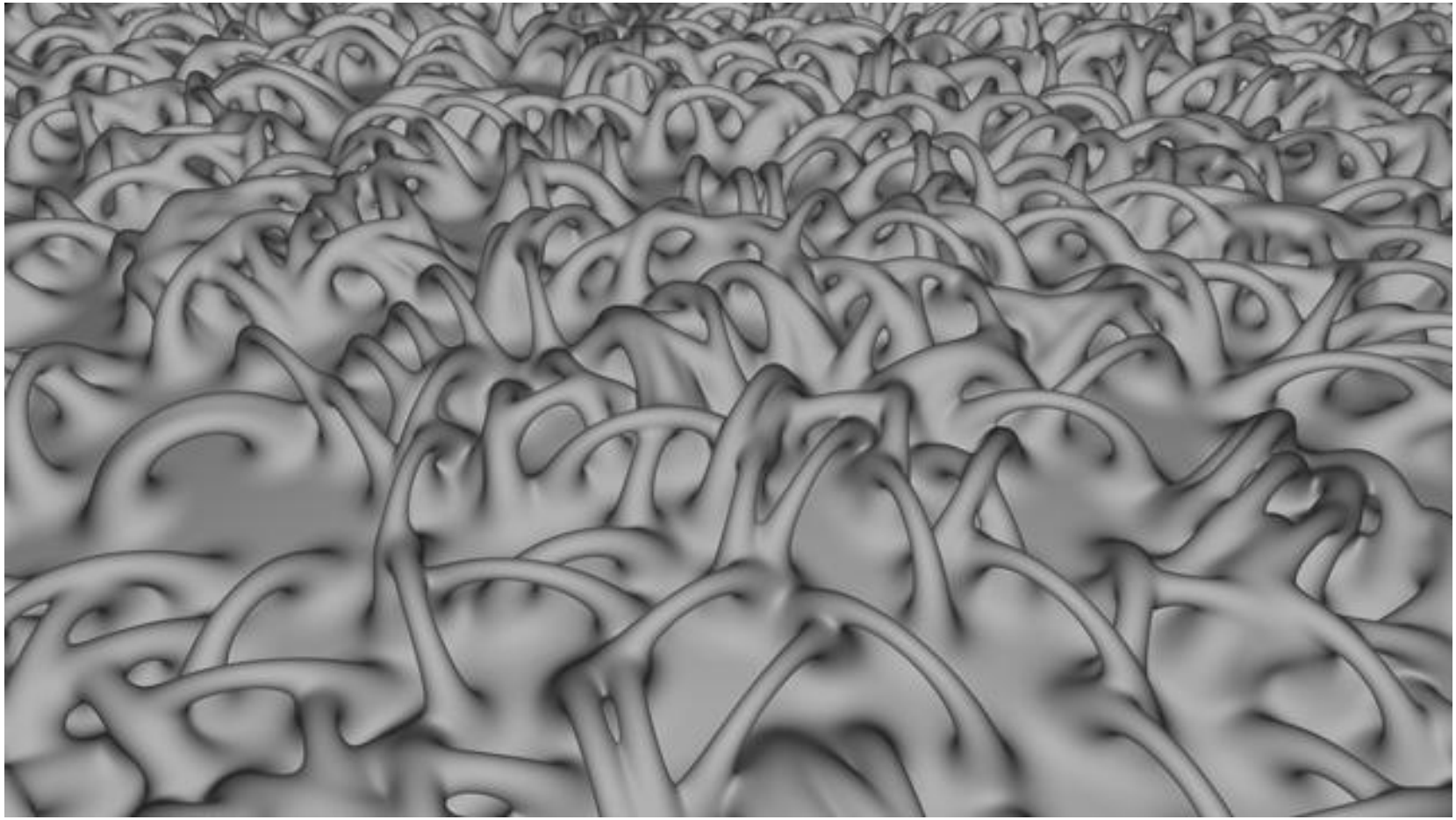
Uncertainty Principle

- We can’t know both speed and position exactly.
- We can’t know both the value of a field and its rate of change exactly.

Empty Space?

- We used to think a vacuum had nothing, no fields, no particles, never changing.
- That's not possible according to quantum mechanics!
- "Empty" space is full of rapidly changing energy fields.
- Particles constantly appear and disappear.
- Vacuum has "vacuum energy" in a "quantum foam."

Quantum Foam



What We Think we Know About the Big Bang

- Slow start at beginning
  - Small amount of matter to start
- Then very rapid expansion at first: “inflation” (1980)
  - Universe went from subatomic size to about the size of a galaxy in 10^{-30} second
  - (1/1000000000000000000000000000000 second)

After Inflation

- Most matter and energy produced at end of expansion by collapse of an “inflaton field.”
- At that point hydrogen and helium formed.
- Slower expansion, cooling, formation of stars and galaxies as gravity brings particles together.
- Expansion continues today and is accelerating.

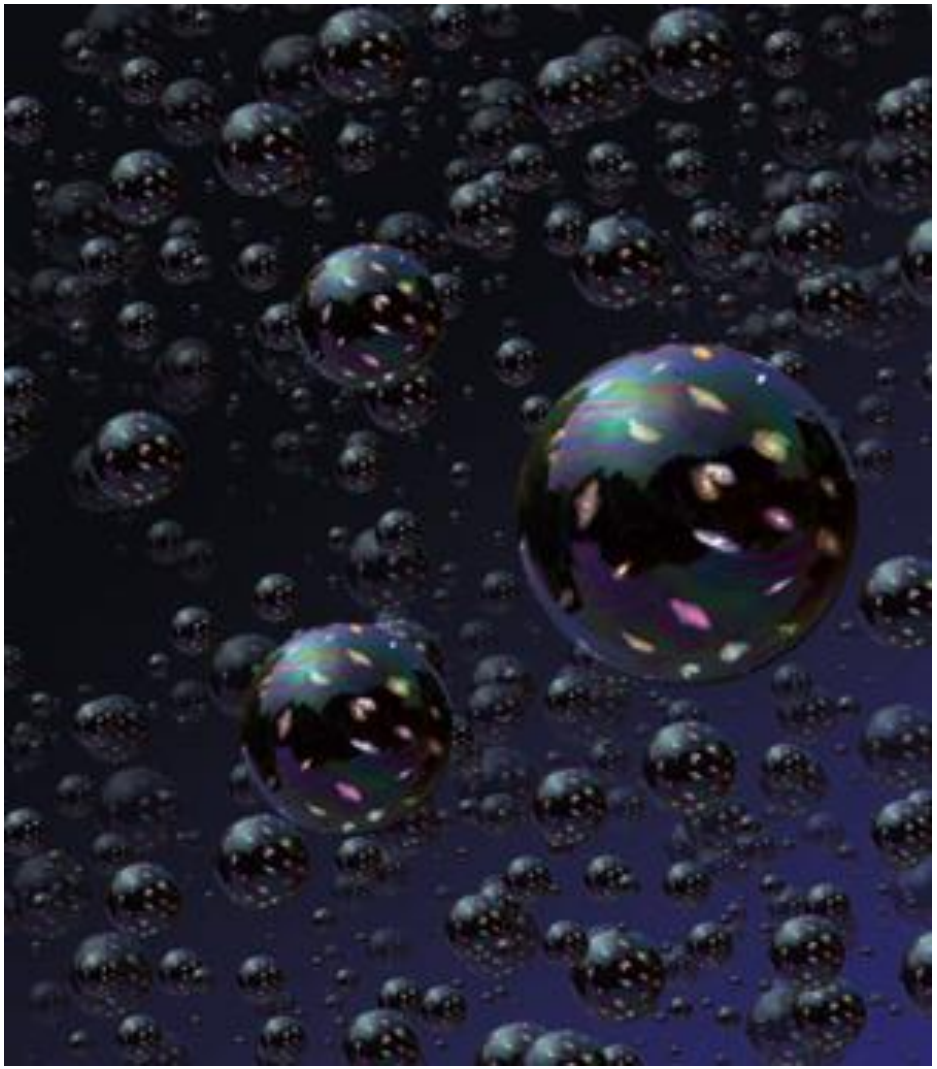
Free Lunch?

- Where did all the stuff and energy come from?
- Gravity can be considered to have negative energy, which balances the positive energy of the “stuff.”
- Result: a universe with zero net energy.
- “The ultimate free lunch” (Hawking).

Before the Big Bang?

- In one sense the question has no answer, as our space and time begin with the Bang.
  - Like asking what's south of the South Pole.
- In another sense, it seems the Bang may have resulted from a "bubble" in a pre-existing cosmic "foam."
- In that case there may be many such bubbles (multiverse).

Bubble Universes



Anthropic Principle

- Obviously our universe is organized to support life.
- Requires many physical constants to be just right.
- How come?

Strong Anthropic Principle

- Universe “designed” to support life.
- Or perhaps we just got lucky and the universe happens to support life for no particular reason.
- Or perhaps laws of physics yet to be determined only allow one type of universe.

Alternative View

- There may be many other universes that don't support life, but obviously we wouldn't be there to know about them.
- There may be a huge or infinite number of universes, and it's no surprise that we happen to occupy one that supports life!

“Standard Model” of Atomic Physics

- Deals with atomic structure, and all forces except gravity.
- Many types of subatomic particles.
- Physical constants seem to have arbitrary values.
- Works so far but doesn’t include gravity.
  - A major problem especially for early universe.
- Lacking in “elegance.”

Superstring Theory

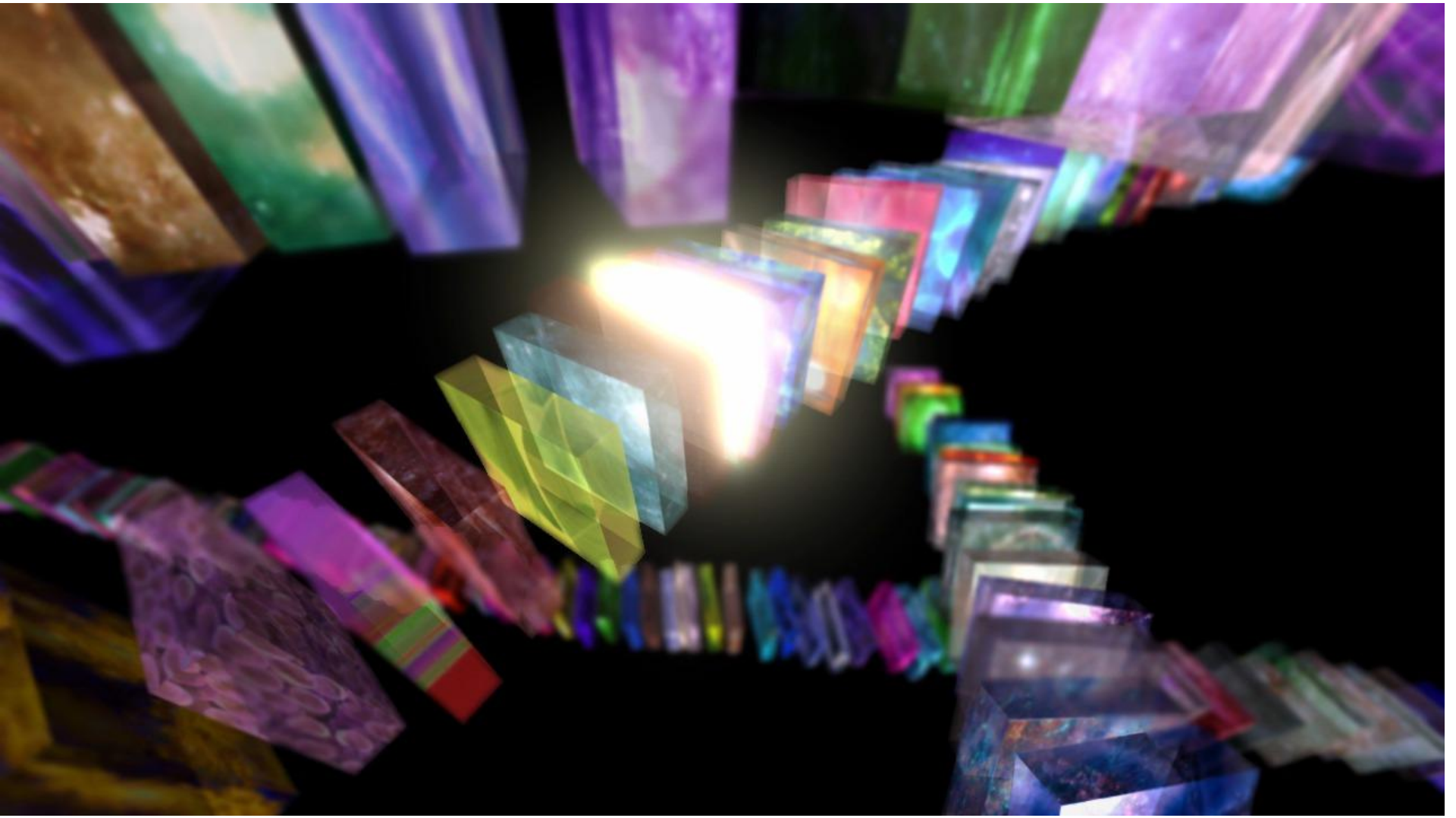
- Theory designed to explain the many different subatomic particles and include gravity.
- All particles considered to be very small one-dimensional vibrating “strings.” Different vibrations give different particles.
- Requires 7 extra “rolled-up” dimensions to the universe!
- Very complex mathematics, can describe our universe and many others.

Branes and M-Theory

- Extension of superstring theory into two or more dimensions, i.e. instead of a string we could have a 2-dimensional membrane.
- Our universe could be a “3-brane” in a higher dimension space (a p-brane).
- Some possibility of contacting other “braneworlds.”
- Multiple braneworlds could account for dark energy.
- No proof of this yet but if true, M-theory allows for about 10^{100} different universes.

Stephen Hawking

Edward Witten



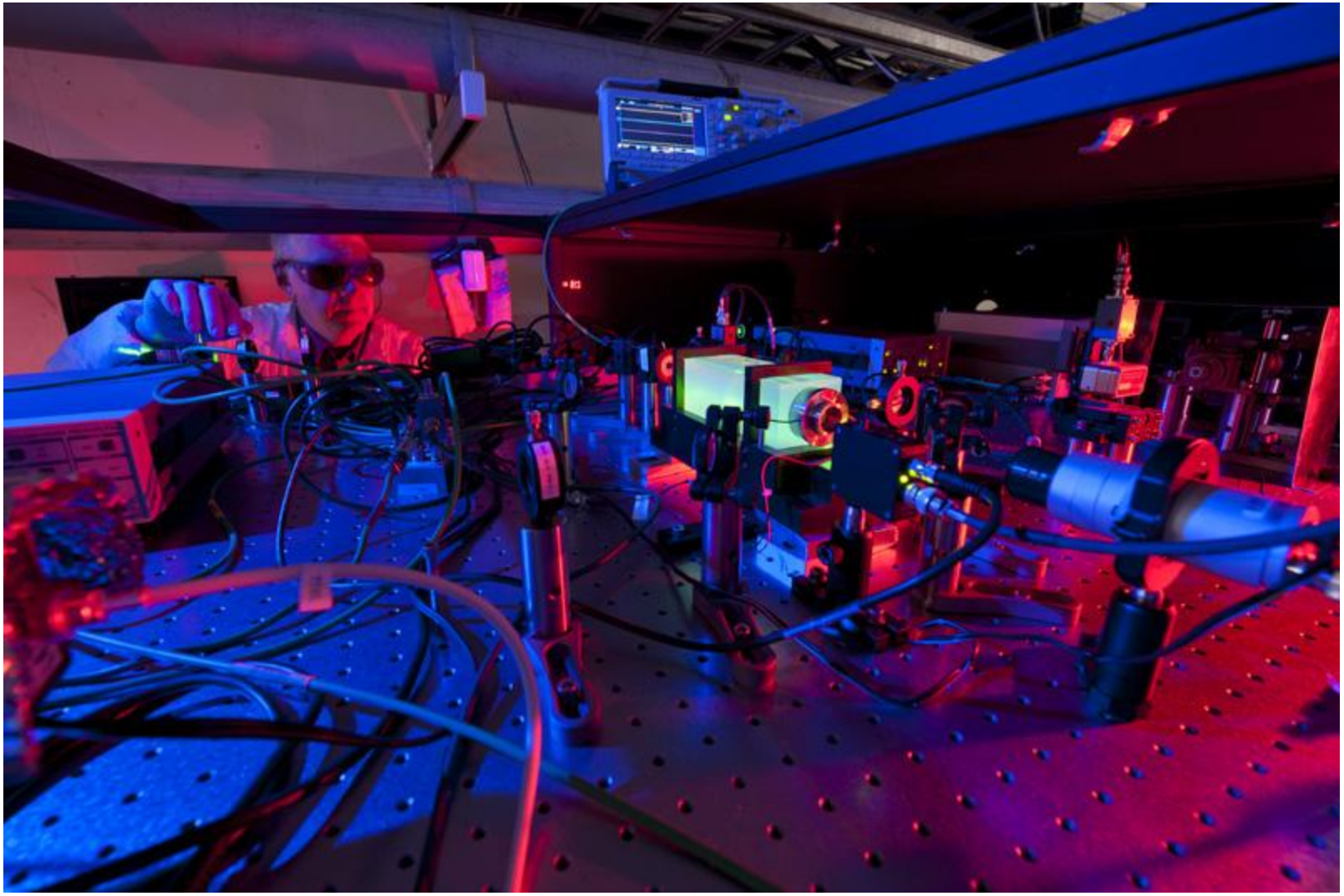
Are We a Hologram?

- Not the most popular theory, but is actually being worked on.
- Experiment to measure quantum jitter at Fermilab could indicate if this is possible.
- Idea is that all the information in a 3 dimensional space can be encoded on its boundary.
- So the entire universe could be a hologram.

Holographic Model

- Developed in conjunction with black holes.
- Could explain what happens to information when material is sucked into a black hole, then the black hole “evaporates.”
- Could also possibly explain quantum entanglement.

Fermilab Holometer



Summary

- The search for the Theory of Everything continues
- M - theory looks possible, needs more work
- Universe from nothing sounds strange but the math seems to work
- But what or who created the math and the laws?
- “Fiat lux” --- but how, we’re not sure.