A Big Bang Occurred... Then What?
The Story of the Universe since the Beginning

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First Things First

This is a talk about one of the most interesting topics known to human kind: **Our Universe**

It’s also a talk about how it came to be the way it is

The story in a nutshell: A Big Bang occurred ~15 billion years ago and EVOLVED into what we have today
Genesis, 1:1

"In the beginning, G-D created the Heavens and the Earth"
Is the world 5769 Years Old?

• Most non-creationist Torah scholars see Genesis 1-11 (from Creation to the "generations of Terah") as theology or metaphor rather than history

• Most, however, like the idea of scientific evidence for “moment of creation”
Answer to Questions

What is the scientific evidence that a Big Bang occurred 15 billion years ago?
Standing on the Shoulders of Giants

Edwin Hubble

Albert Einstein

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What did Hubble See?

Hubble observed lots of galaxies

He noticed that all the far away ones are moving away from us very quickly.
So What?

All the galaxies will come from a single point in space ~15 billion years ago.

What happened in the past?

Run the clock backward in time.

Name this time the Big Bang.

→ A moment of Creation.
The Big Bang occurred, then what?
In the Beginning...

• As best as we understand the Universe began with a Big Bang
  – A REALLY Big Bang
• Then what?
• How did we get from the bang to the Universe we have today?
A Brief History of Time

- Zero
- One millionth of one second after the Bang
- A few minutes
- A few hundred thousand years
- 100 million to 1 billion years
- 9 billion years
- ~15 billion years

- The Big Bang produces lots of particles
- Quarks combine to form protons and neutrons
- Protons and Neutrons combine to form the nucleus of an atom
- A nucleus and electrons combine to form atoms
- Atoms combine to form Stars and Galaxies
- The Earth and our solar system forms
- You listen to this lecture
Artists Conception of the Big Bang
The very early Universe

Lots of free particles just hanging around...

Universe is so hot that quarks can’t combine to make protons/neutrons
Later, Quarks Combine to Form Nucleons

\[ qqq \Rightarrow \text{Proton} \]
A Millionth of a Second after the Big Bang

The quarks have combined to form Protons and Neutrons
Nuclei in the Early Universe

Proton + Proton $\rightarrow$ Deuterium

Nuclear Reaction $\rightarrow$ Deuterium
Even Heavier Nuclei

Proton + Deuterium $\rightarrow$ Helium$_3$ + Photon

Nuclear Reaction

Photon

Helium$_3$

Proton

Deuterium

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Creating Stable Helium

Helium\textsubscript{3} + Helium\textsubscript{3} \rightarrow Helium\textsubscript{4} + 2 Protons
A couple hundred thousand years later: Atoms

Proton

Electromagnetic Reaction → Hydrogen Atom

Electron

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Wait a Billion Years

After about a billion years, atoms combine to form the first stars and galaxies.
After about 9 billion years our solar system, and the Earth form
Recent History: Life on Earth

• Earth is about 4 or 5 billion years old

• Evidence that microbial tracings existed on Earth about 3.5 billion years ago

• Humanoids, like Lucy existed a mere 3 million years ago

• Homo-sapiens at around 100,000 years ago
Interested in learning more?

- Physics department now offers a course entitled “Big Bang, Black Holes, No Math”
  - Covers Stephen Hawking’s “Brief History of Time”
- More about what you heard today, plus much more!
  - Cosmology
  - How do Stars form?
  - Black Holes
  - General Relativity
  - Quantum Mechanics
  - Particle Physics
  - Etc....

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Astronomy/Physics 109
Where in the world is the LHC?

Geneva

Jura Mountains

France

Switzerland

CERN

Actually... It's down here

100 yards Underground!

The accelerator
Another view of the LHC

27 km in Circumference!

One of the largest and the most complex scientific instrument ever conceived & built by humankind

Lake Leman

Geneva Airport

ATLAS
What does it DO?
Accelerates protons to REALLY high energies, then bashes them together.
So... The LHC makes really high energy collisions that can be studied

- Lots of high energy collisions between protons in the Early Universe
- LHC is creating the conditions like they were RIGHT AFTER the Big Bang so we can understand the Origin of the Universe better
Inside the Accelerator
Overview

Then, we’ll move to the questions we’ll use it to help answer:

• What are the fundamental things in the Universe?
• The universe started with a really Big Bang, then what?
Won't have much to say about the Bang itself. Even less to say about what came "before" the bang
What’s the Matter in The Universe?

Start with a size we know: The nose in front of your face.

Next we’ll look at smaller sizes: 10 centimeters, or 0.1 meters, or $10^{-1}$ meters. About 3 inches.
Getting smaller... Your eye

Something smaller you can see with your eyes

0.01 meters, (10^{-2} m) or 1 cm, or about a 1/3 of an inch
Using microscopes

The blood vessels in the surface of the retina

Into the realm of biology

10^{-3} meters or 1 millimeter
Really good microscopes...

The rods and cones in the retina

10^{-4} meters
Closer still...

A close up view of a few rod cells

\[ 10^{-5} \text{ meters} \]
Further inside the cell...

Strands of DNA

$10^{-6}$ meters
More on DNA

A close up of some DNA deposited on a graphite substrate

10^{-7} meters
The Double Helix

A close up of the helical structure of DNA

Starting to get into Chemistry

10^{-8} meters
Atoms!

What atoms “look” like

What we're seeing is the electron “cloud” in a crystal

The realm of Physics

Single atom

$3 \times 10^{-10} \text{ m}$

$10^{-9}$ meters or 1 nanometer
Inside a carbon atom in your eye

- 6 electrons "orbiting" the nucleus
- More are clustered nearer the nucleus
- Ignore the "size" of the dots

Artist's conception

10^{-10} meters
The central part of the atom

- Only the inner two electrons are visible
  - Others outside the box
  - Again, ignore the “size” of the dots

10^{-11} meters
Homing in on the nucleus

- Finally see the nucleus at its full size
- The electrons are outsize our field of view

10^{-12} meters
The structure of the nucleus

Can just start to see the “stuff” inside the nucleus

10^{-13} \text{ meters}
Protons and Neutrons

- A carbon atom has 6 protons (blue) and 6 neutrons (grey)
- VERY tightly packed

$10^{-14}$ meters
Inside the proton

Three quarks inside the proton

Again ignore the size of the dots

$10^{-15}$ meters
Inside an Atom

If an atom were the size of a large city, then the neutrons and protons would be the size of a person, and the electrons and quarks would be smaller than a small freckle.