Help! What is the universe?

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What do we know?

We can see less than 4% of the stuff that the universe is made of!!!

- We know lots about the stuff we can see: galaxies, stars, and the clouds of gas between them.
- We know a lot about the history of the universe.
What do we think Happened?

13.7 Billion Years: the present.

?????????? (we’ll talk about this later)
What do we think Happened?

13.7 Billion Years: the present.

1 second: atomic nuclei form.

$10^{-6}$ seconds: protons and neutrons form.

$10^{-11}$ seconds: Electricity and magnetism.

?
Before the first second

Electricity and Magnetism did not exist as a separate force.

There were no atoms or atomic nuclei.

Even the protons and neutrons that make up nuclei were nonexistent!
What do we think Happened?

→ 13.7 Billion Years: the present.

→ 70,000 years: matter starts to clump

→ 1 second: atomic nuclei form.

→ $10^{-6}$ seconds: protons and neutrons form.

→ $10^{-11}$ seconds: Electricity and magnetism.

→ ?
Gravity is attractive, and very greedy. Regions with more matter attract even more matter. Matter clumps!
What do we think Happened?

13.7 Billion Years: the present.

400,000 years: atoms form.

70,000 years: matter starts to clump

1 second: atomic nuclei form.

$10^{-6}$ seconds: protons and neutrons form.

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?
Atoms form

We can actually see this: the cosmic microwave background (we’ll talk about this later)!
What do we think Happened?

- 13.7 Billion Years: the present.
- 100 million years galaxy, first stars form.
- 400,000 years: atoms form.
- 70,000 years: matter starts to clump
- 1 second: atomic nuclei form.
- $10^{-6}$ seconds: protons and neutrons form.
- $10^{-11}$ seconds: Electricity and magnetism.
- ?
Galaxy and stars form
What do we think Happened?

→ 13.7 Billion Years: the present.
→ 9.2 Billion Years: the Earth forms.
→ 9.1 Billion Years: our sun forms.
→ 100 million years galaxy, first stars form.
→ 400,000 years: atoms form.
→ 70,000 years: matter starts to clump
→ 1 second: atomic nuclei form.
→ $10^{-6}$ seconds: protons and neutrons form.
→ $10^{-11}$ seconds: Electricity and magnetism.
→ ?
Our sun and Earth form

Humans appeared 250,000 years ago, this is one millionth of a percent of the age of the universe!
How do we know this?

- A map of the galaxies in our universe.
- The cosmic microwave background.
- The abundance of each element.
- The rotation of galaxies in our universe.
Light travels at a constant speed.

The light we see from distant galaxies was emitted a long time ago!

1 light year = the distance light travels in 1 year.

The nearest galaxy is 2 million light years away!
Far away = back in time.

He needs to wait 2 million years to see the collision happening right now!
Far away = back in time.

He needs to wait 2 million years to see the collision happening right now!
Far away = back in time.

He needs to wait 2 million years to see the collision happening right now!
A map of the universe.

This picture is 2D, how do we know how far away the galaxies are?
Standard Candles

- Type Ia supernova: constant total luminosity. The explosion dims with distance, so it is possible to infer the distance by measuring how bright it is!

- Also other objects whose luminosity we know....
Doppler Shift

Sound waves get stretched out as the truck recedes.

The same thing happens to the light from a galaxy as it recedes. It gets more red!
There is a direct relation between distance and velocity for galaxies!

Easy to measure velocities, so we can now make a 3D map!
Map of the universe

2dF Galaxy Redshift Survey

3° slice
62559 galaxies
220929 total
But, a mystery....

Further out, the galaxies ACCELERATE!

This implies some weird stuff!

The universe must be filled with stuff that does not dilute!

DARK ENERGY
In 1965, Penzias and Wilson were listening to the radio, and heard some fuzz. This came from everywhere in the sky, with equal volume. It turned out to be light from the early universe! Called the CMB (Cosmic Microwave Background)
An Opaque Universe.

Nuclei ➕ + charges

Electrons ➖ − charges
An Opaque Universe.

Nuclei \( + \) charges
Electrons \( - \) charges
An Opaque Universe.

Nuclei + charges

Electrons - charges
An Opaque Universe.

Nuclei + charges

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Nuclei  + charges
Electrons  − charges
An Opaque Universe.

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Diagram showing the distribution of nuclei and electrons with arrows indicating movement or interaction.
An Opaque Universe.

Nuclei  + charges
Electrons  - charges
An Opaque Universe.

Nuclei + charges
Electrons - charges
An Opaque Universe.

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Diagram showing the interaction of nuclei and electrons.
An Opaque Universe.

Nuclei + charges
Electrons - charges
A transparent Universe!

Nuclei + charges
Electrons - charges
A transparent Universe!

Nuclei $\bigcirc$ $+$ charges

Electrons $\cdot$ $-$ charges
A transparent Universe!

Nuclei + charges

Electrons - charges
A transparent Universe!

Nuclei + charges
Electrons - charges
The CMB

The state of the universe when it became transparent is imprinted in the light!
Abundance of Elements.

- How do we know what happened before the CMB?
- We can’t see this.....the universe was opaque!
- When universe was hot, nuclei fused to make heavier elements.
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Abundance of Elements.

Models predict how much of each element there should be, and we can observe the light from galaxies to see what they are made of!

The pattern of spectral lines identify the element that emitted the light.
Dark Matter

Measure the velocity of stars in a galaxy (using red shift) at different radii.

M33 rotation curve

(expected from luminous disk)

(observed)

(fig. 1)
Another Mystery...

- We have no idea what the Dark Matter is!
- Using the galaxy surveys and the CMB, if matter clumps the way we see it, then we have no idea what 96% of the universe is made of!
LHC: You could go to Switzerland!

May help us figure out what the other 96% of the universe is!
An International Effort

- 25 countries are collaborating on the LHC.
- Science brings together people from all over the world.
- In Santa Cruz, people are working on the ATLAS detector.
My Beginning
What do Scientists do?
Why should you care about science?

- It's a way of thinking!
- A way to critically evaluate situations and solve problems.
- Global warming, technology, the world is changing!
The “Beginning”
The future of the universe

- Eternal inflation, recollapse, heat death.
The future of me (hopefully less depressing)

postdoc and then faculty. Talk about other career options...