S c i e n c e s

Across the Universe

S c i e n c e s

Some distance unites:

To show distances **within** the **Solar System**

Astronomical Unit (Au)

The average between the Earth and the Sun

150’000’000 km

To show distances **beyond** the **Solar System**

Light years (Ly)

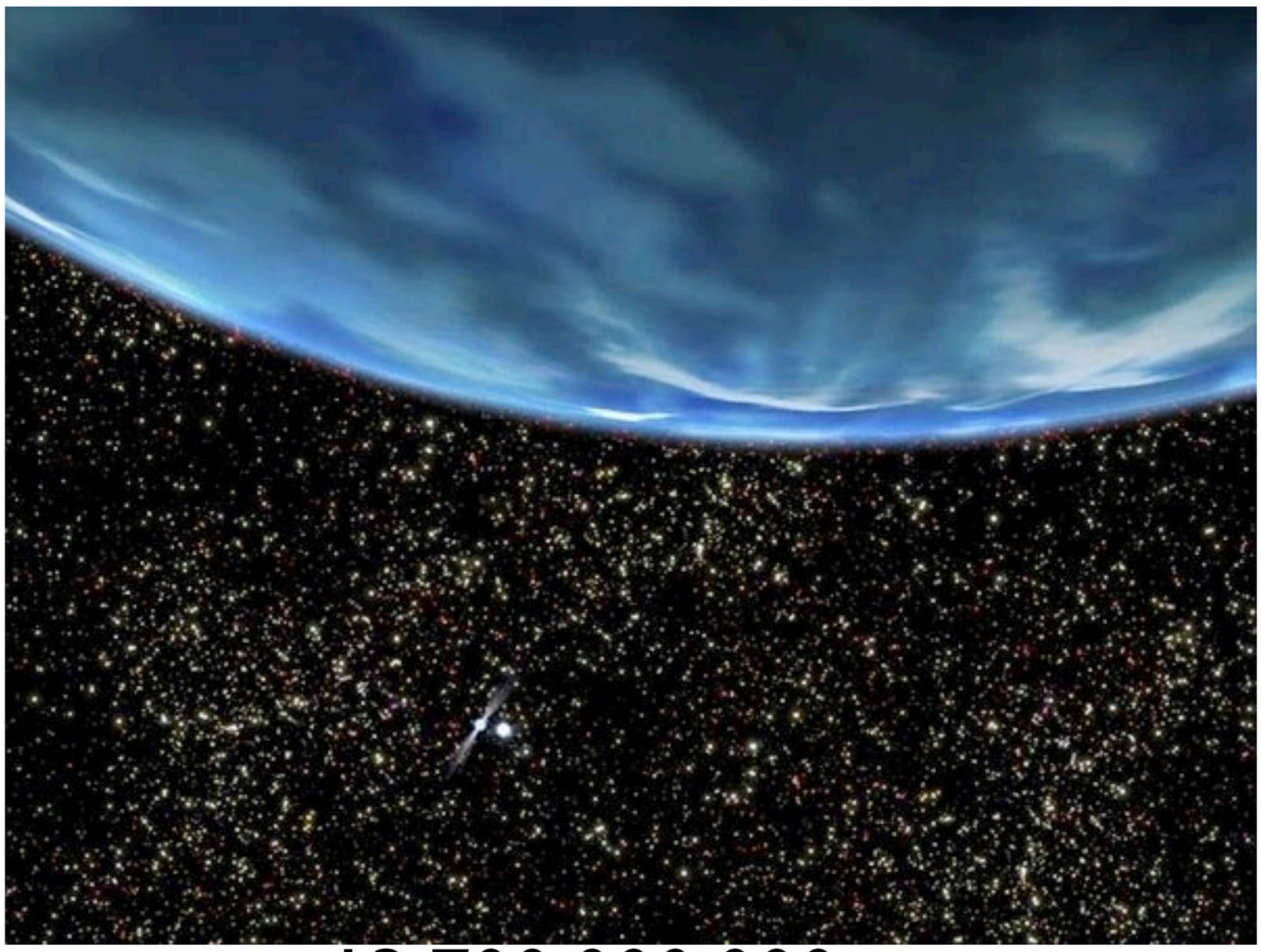
The distance that light travels in one year

9.46×10^{12} km

Across the Universe

The Origins of the Universe

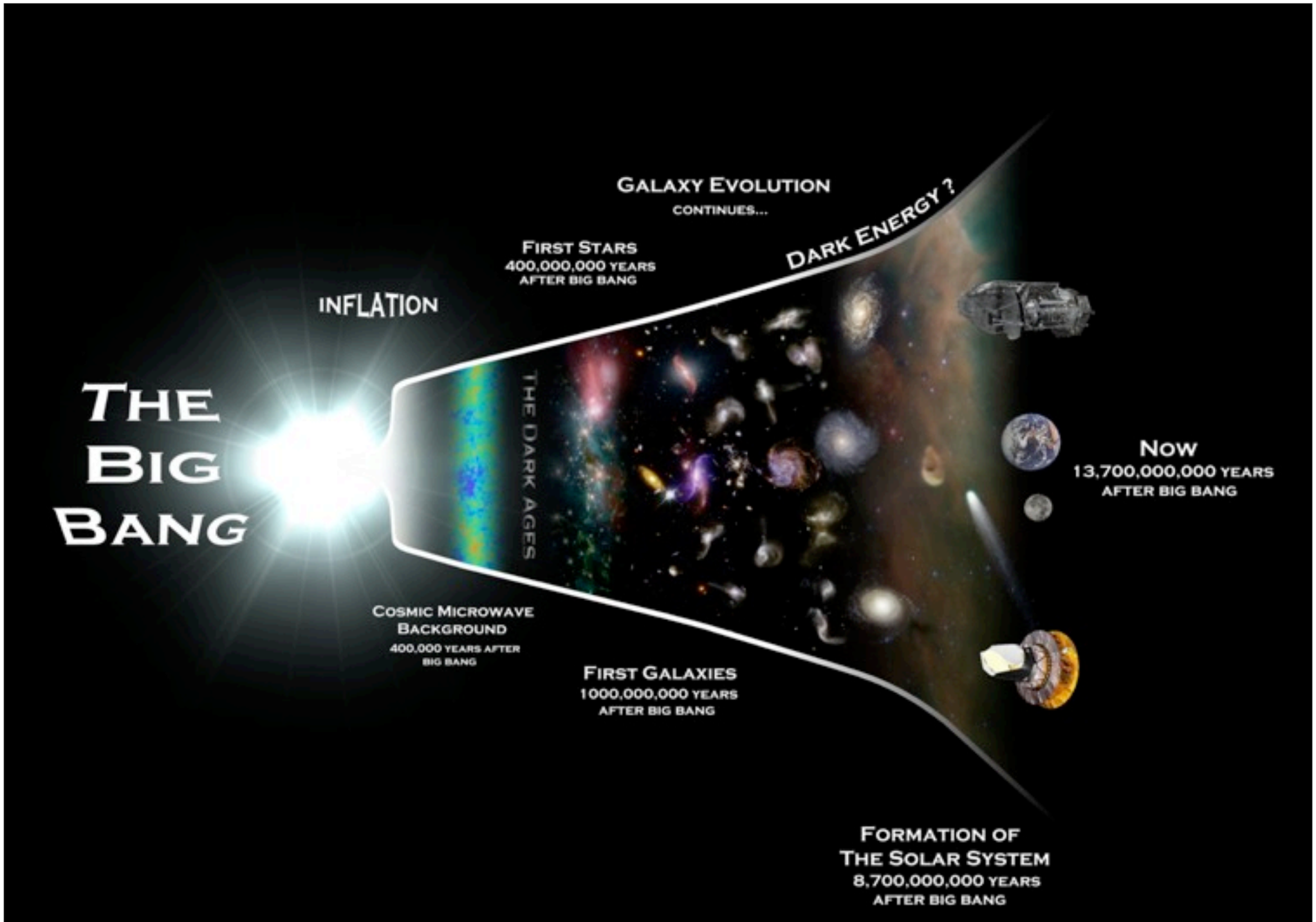
The events which led to the formation of the universe



13.700.000.000 ya

Across the Universe

The **Big Bang** model is the theory of the development of the universe. Following this theory, the whole universe was once (13.7 billion years ago) in an extremely small, hot and dense state, as big as an atom. This state is known as ***singularity***.
We still do not know why or how, but this dense nucleus suddenly exploded and rapidly expanded (a "Big Bang"), cooling down and creating the universe as we know it.



SINGULARITY
an extremely small and dense nucleus. Everything started from here

Across the Universe

What are the major evidences which support the Big Bang theory?

Galaxies appear to be moving away from us at speeds proportional to their distance. This is called "**Hubble's Law**," named after Edwin Hubble (1889-1953) who discovered this phenomenon in 1929. This observation supports the expansion of the universe and suggests that the universe was once compacted.

Hubble's law

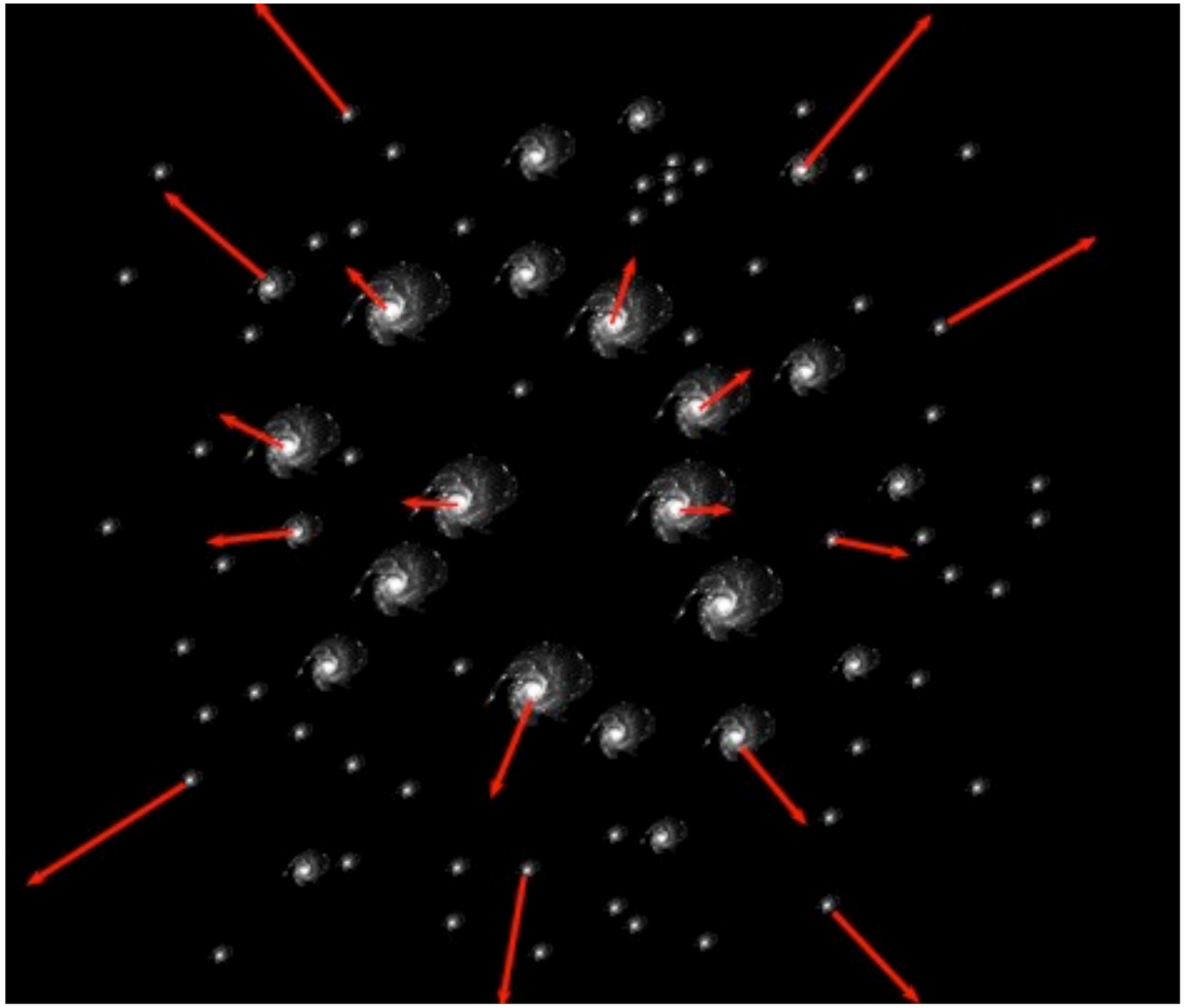
The velocity at which various galaxies move away from the Earth is proportional to their distance from us. It can be expressed by the equation

$$v = H_0 d$$

H_0= Hubble constant = 73.8 (km/s)/Mpc
d= Proper distance to a galaxy (which can change over time)
v= Velocity

Across the Universe

What are the major evidences which support the Big Bang theory?



Hubble's law: That the farther away a galaxy is from us, the faster it moves away from us

Across the Universe

What are the major evidences which support the Big Bang theory?

If the universe was initially very hot, we should find some residue of this heat (in the same way we find some hot ember the day after a camp fire).
In 1965, Radio-astronomers Arno **Penzias** and Robert **Wilson** (Fig. 1), using a radio telescope (Fig. 2), discovered a constant radiation.
They called this radiation **Cosmic Microwave Background Radiation** (CMB).
This background radiation was found, as a microwave radiation with the temperature of -270°C (-3°K), constant all around the observable universe.
This is believed to be the residual radiation of the Big Bang.

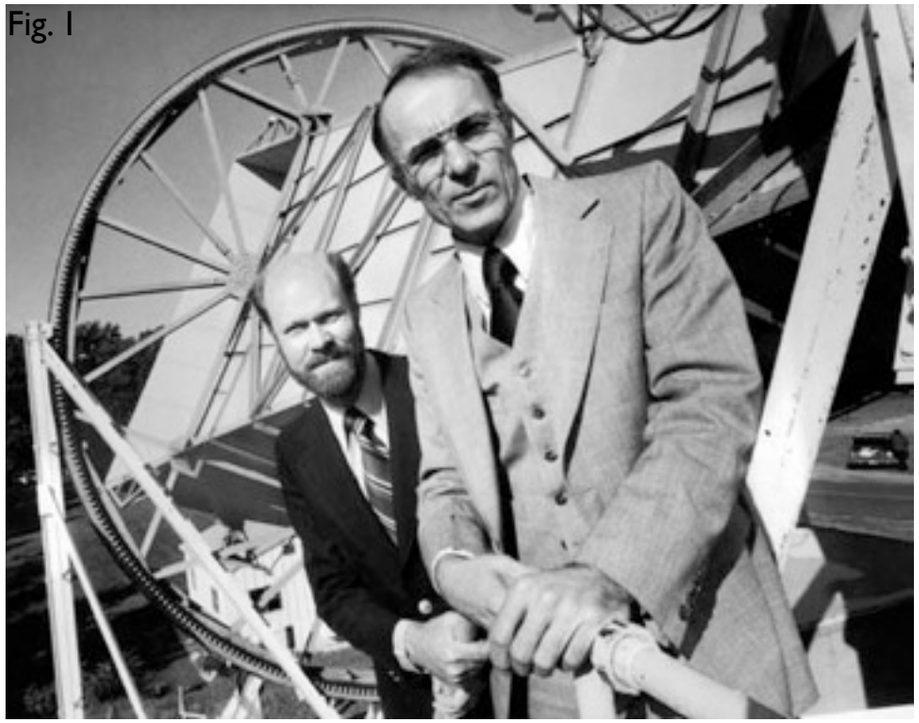


Fig. 1

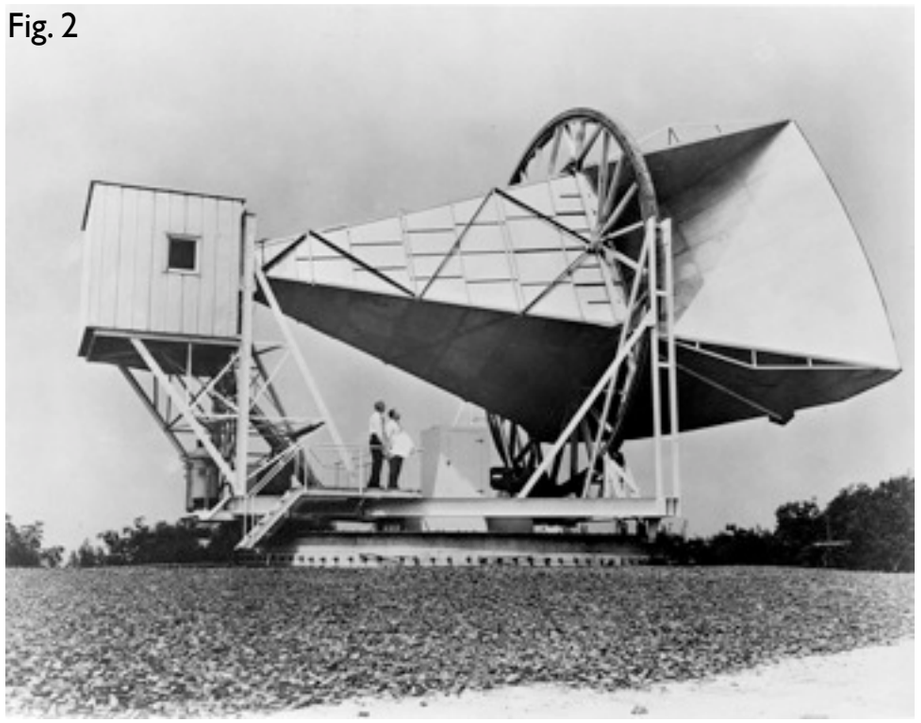


Fig. 2

Across the Universe

What are the major evidences which support the Big Bang theory?

Although with a traditional optical telescope the space between stars (called background) seems to be completely dark (see Fig.1), a radio telescope shows a background glow (Fig. 2), that is not associated with any star, galaxy, or other object. This glow is strongest in the microwave region of the radio spectrum and is the representation of the CMB.

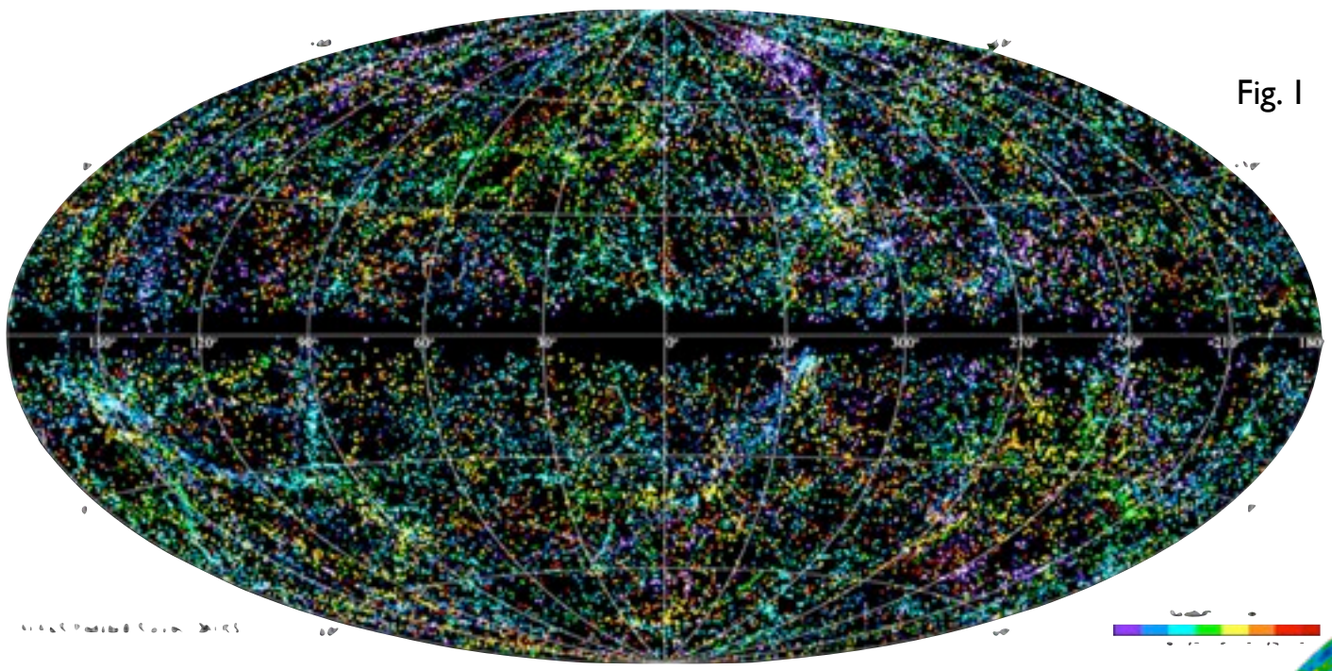


Fig. 1

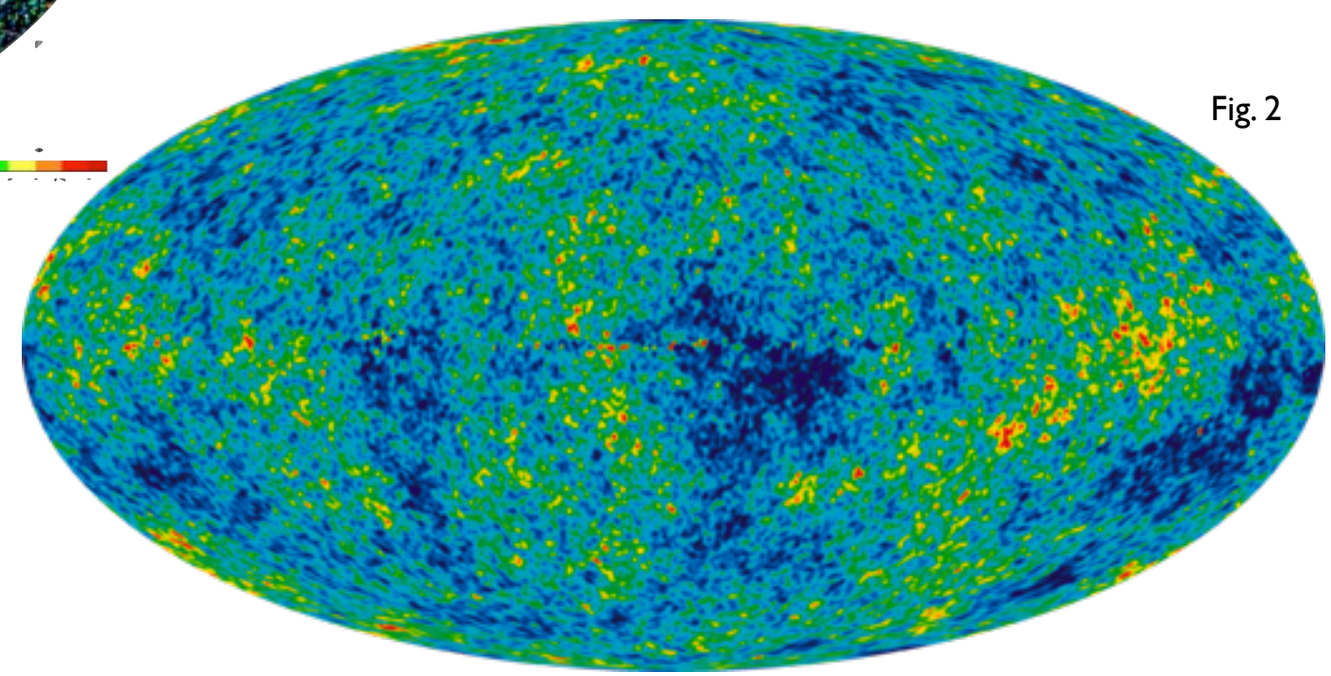


Fig. 2

time= 0

Temperature= 0

Diameter= 0

What happened at the very beginning?

0

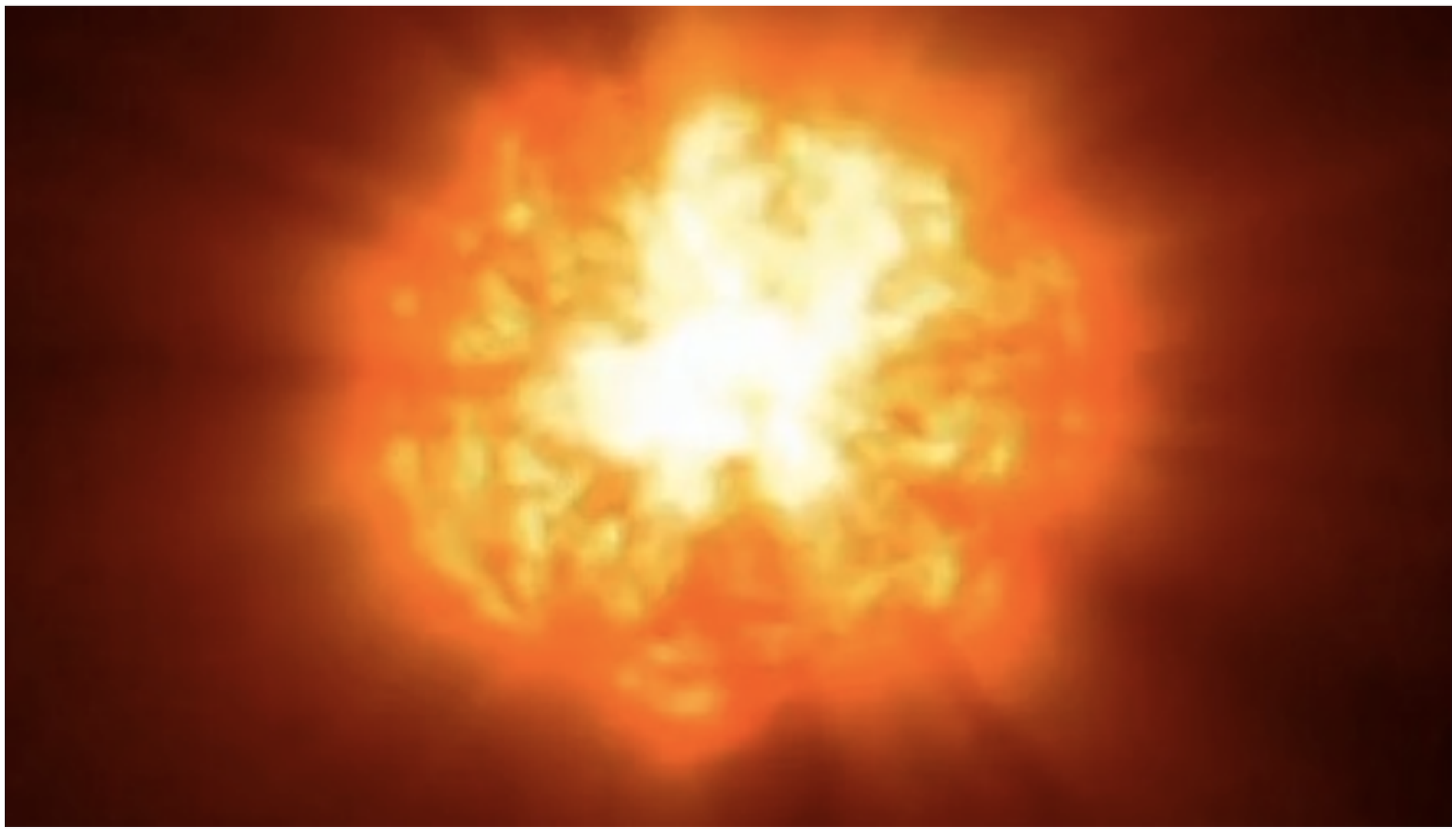
What is a "**singularity**" we don't know for sure.

There are zones in the Universe where our laws of physics have no value. They are believed to exist at the core of black holes where the pressure is so intense that matter is squished into infinite density. These zones of infinite density are called "singularities." Our universe is thought to have begun as an infinitely small, infinitely hot, infinitely dense singularity.

Where did it come from? We don't know. Why did it appear? We don't know

Time= 1/trillionth trillionth s
Temperature= infinitesimal
Diameter= infinitesimal

All the matter contained in the today's Universe was confined, under unbelievable forces, in a **super hot nucleus big as an atom**. This nucleus becomes unstable and grows with incredible velocity. It starts to cool and after 1 trillionth of trillionth of seconds is small enough to fit inside the palm of an hand



Time= 1/billionth s

Temperature= 2 million trillion °K

Diameter= 620000 km (48 times the Earth)

After a fraction of second the new born universe was 48 times the size of the Earth and is still expanding. But it didn't contain matter, it was **pure energy**.

Time= 1/billionth s
Temperature= 2 million trillion °K
Diameter= 620000 km (48 times the Earth)

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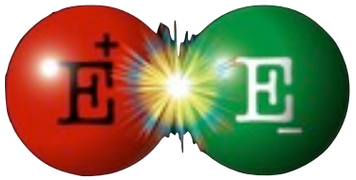
$$E=mc^2$$

Einstein gave us the relation between energy and matter. The Universe created the first matter converting the huge amount of pure energy into trillion and trillion and trillion of small particles.

But there was a problem!

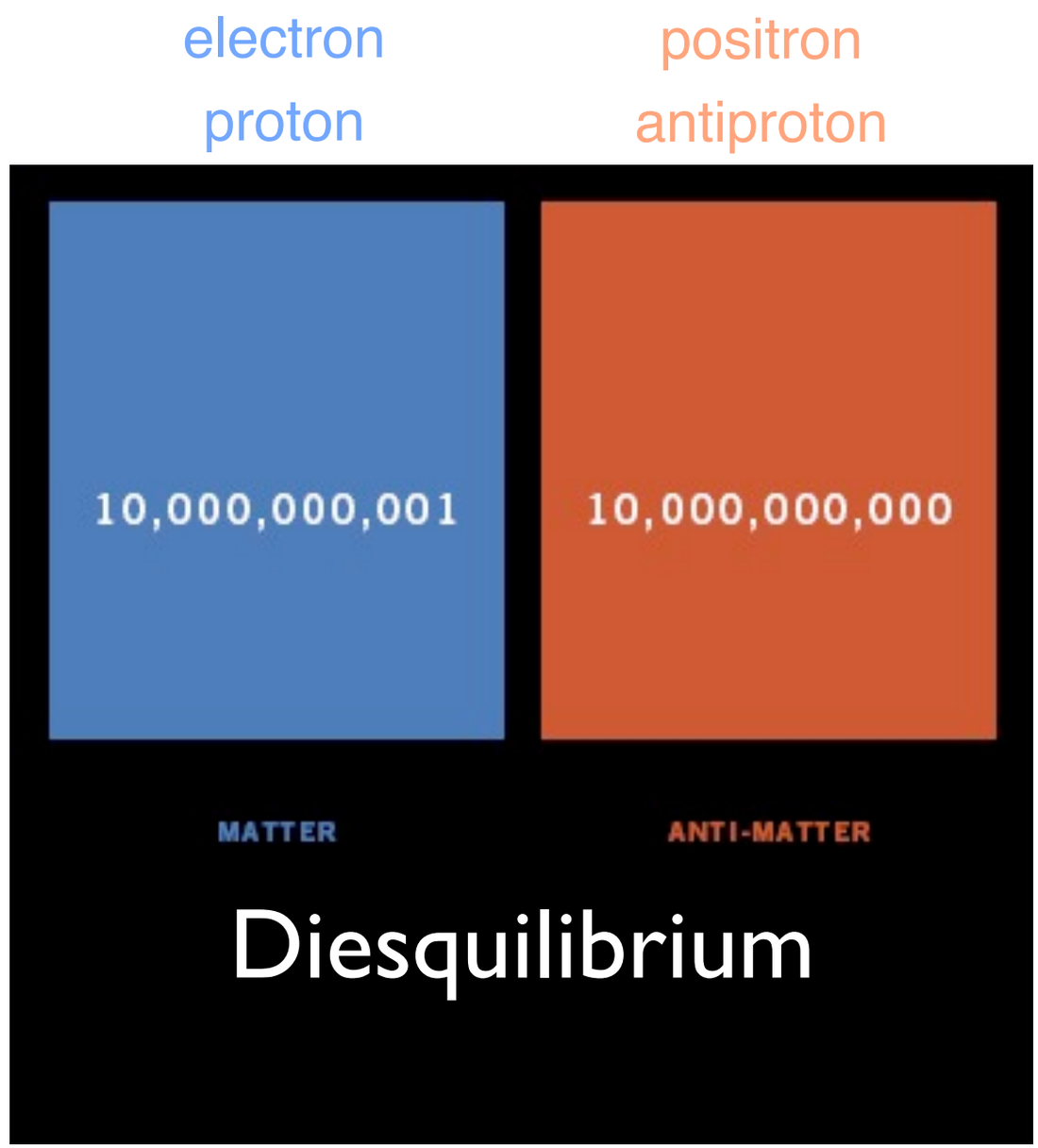
The baby Universe was creating both **MATTER** and its antagonist, the **ANTIMATTER**.



When these two met
they annihilate each other.

Time= 1/billionth s
Temperature= 2 million trillion °K
Diameter= 620000 km (48 times the Earth)

Matter vs Antimatter



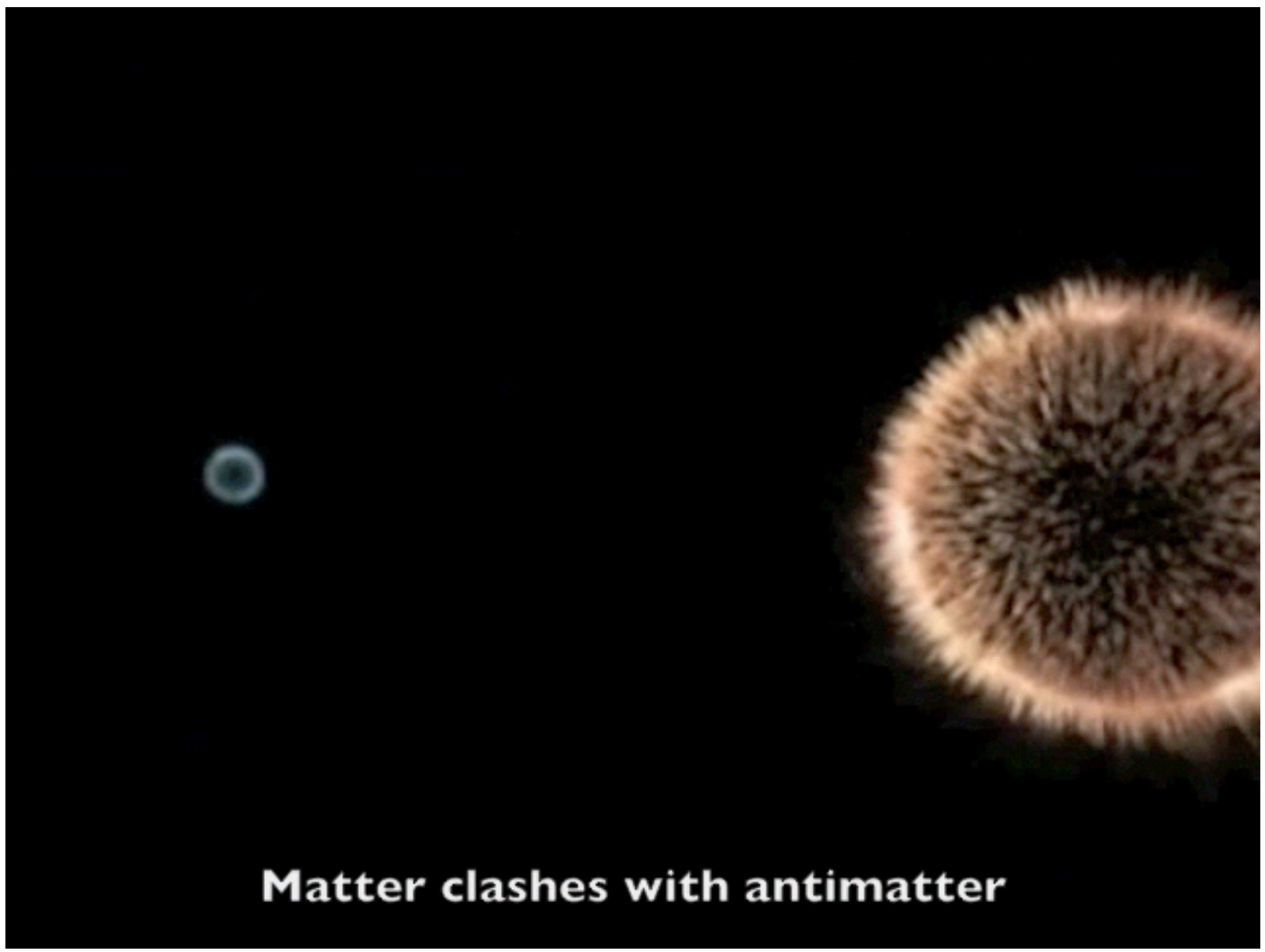
If they neutrally annihilated, the universe would have remained only full of energy, without matter.
with no galaxies, stars, planet and life

Time= 1/billionth s

Temperature= 2 million trillion °K

Diameter= 620000 km (48 times the Earth)

Matter vs Antimatter



Time= 1/billionth s
Temperature= 18 million °K
Diameter= 60 billion km (8 times Solar System)

Now in the universe there are Subatomic Particles

The huge energy generated by the matter vs antimatter fight does not allow particles to decelerate, making impossible the formation of bonds

The Universe has matter, energy, but is still missing a structure

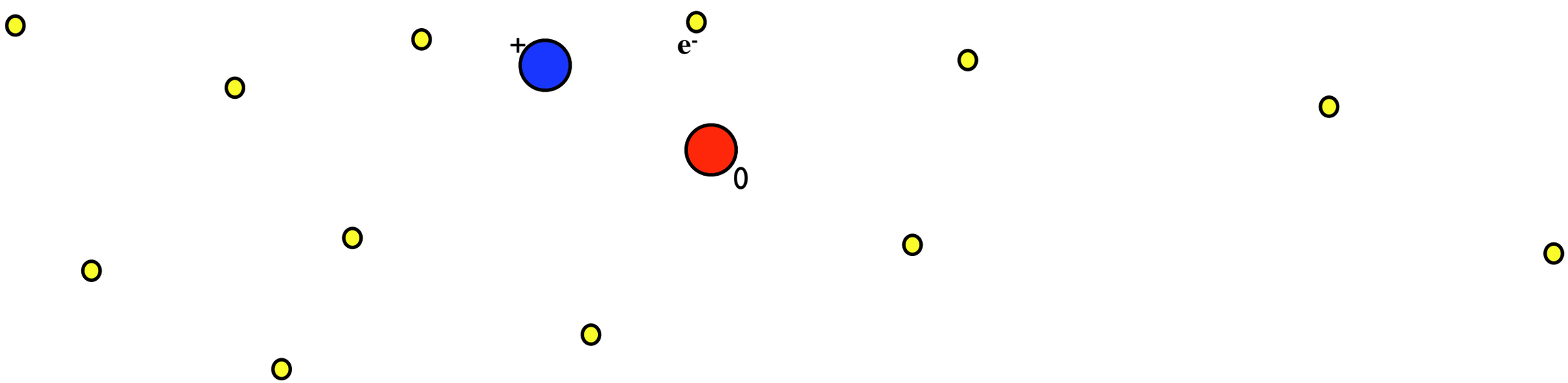
Time= 3’

Temperature= cooling down

Diameter= light years

The Universe start to cool down after the first three minutes life and goes on for the next 380000 years.

The Universe cools sufficiently for Protons and Neutrons to bind together. The first primordial atomic niclei are forming. These were not yet proper atoms. They were still missing electrons. In the hot baby Universe, there were plenty of electrons moving around, but because of the high energy, the electrons were still moving too fast to form bonds with the nuclei. It stayed in that way for over 380000 years.



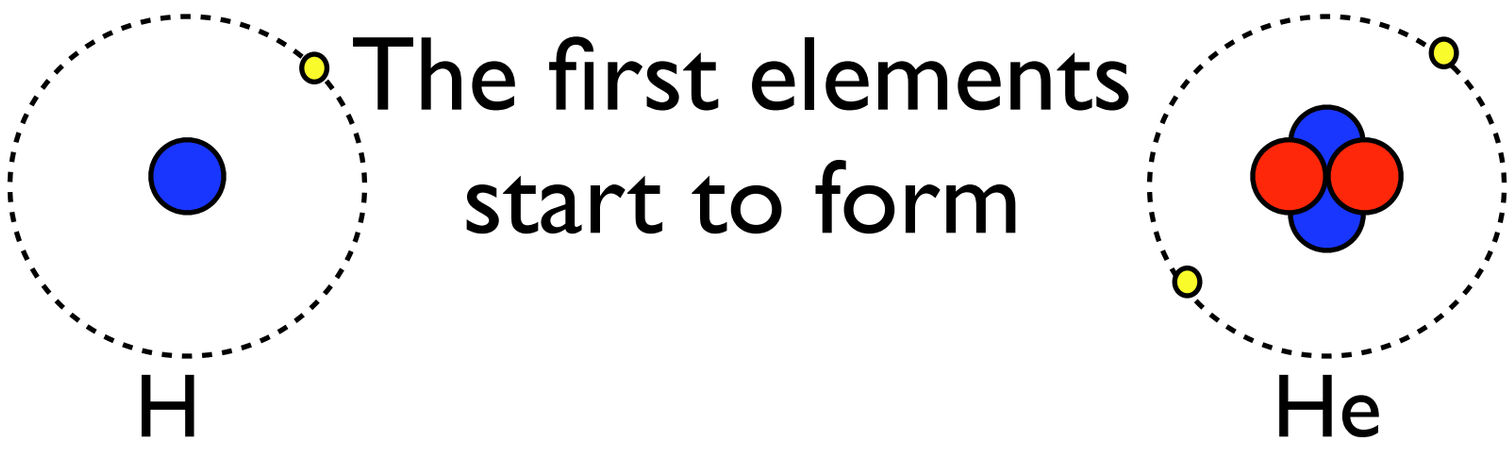
e^- =FREE RADIATIONS

Time= 380000 years
Temperature= 5000 °K
Diameter= 100×10^6 light years

e^- =FREE RADIATIONS

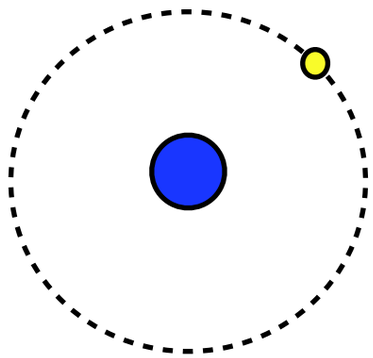
This radiation will remain forever as
COSMIC MICROWAVE BACKGROUND radiation
(Penzias & Wilson, 1964)

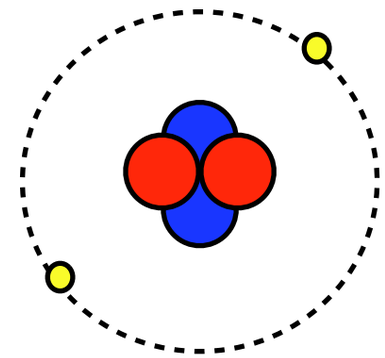
Now the Universe is cold enough to decelerate e^- and make them binding with nuclei.



GAS

Time= 380000 years
Temperature= 5000 °K
Diameter= 100×10^6 light years



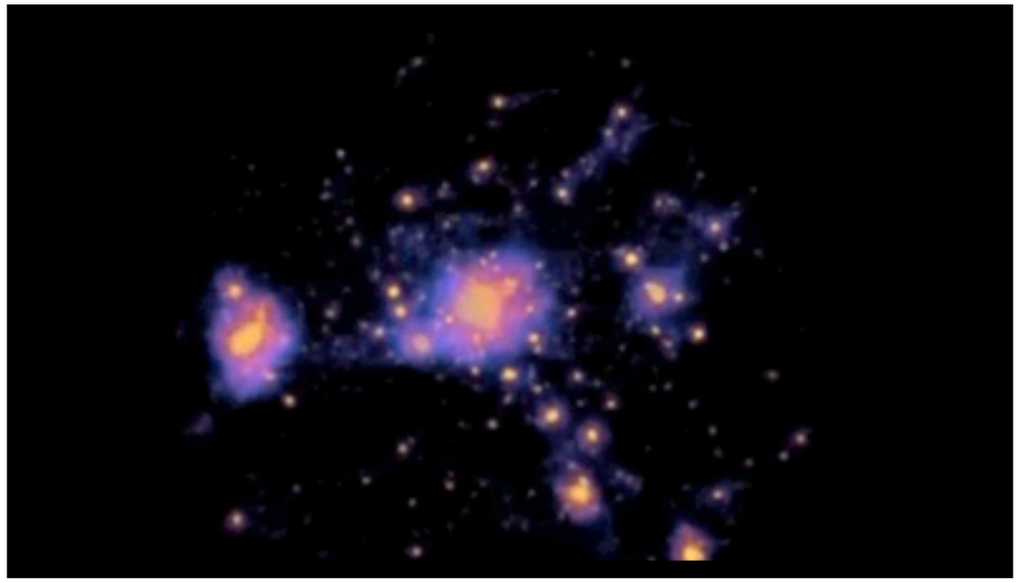


Now the Universe needs...

ELEMENTS

Time= 200 million years
Temperature= -200 °K
Diameter= 100×10^9 light years

After 200 million years, the space has now the dimension of a Galaxy and is composed of gases (H and He). But the distribution of the gases around is not uniform, in some regions there are higher concentrations of gas than in other areas. In those dense regions, the gases begin to thicken in nuclei, Hydrogen and Helium form clouds and warm up, atoms fuse together and release huge quantities of energy.



For million and million years, the gas nuclei will burs, releasing enormous quantities of energy and becoming stars.

While the high concentration regions will form the today's galaxies (with stars and planets), the less dense areas will form the empty regions of our Universe

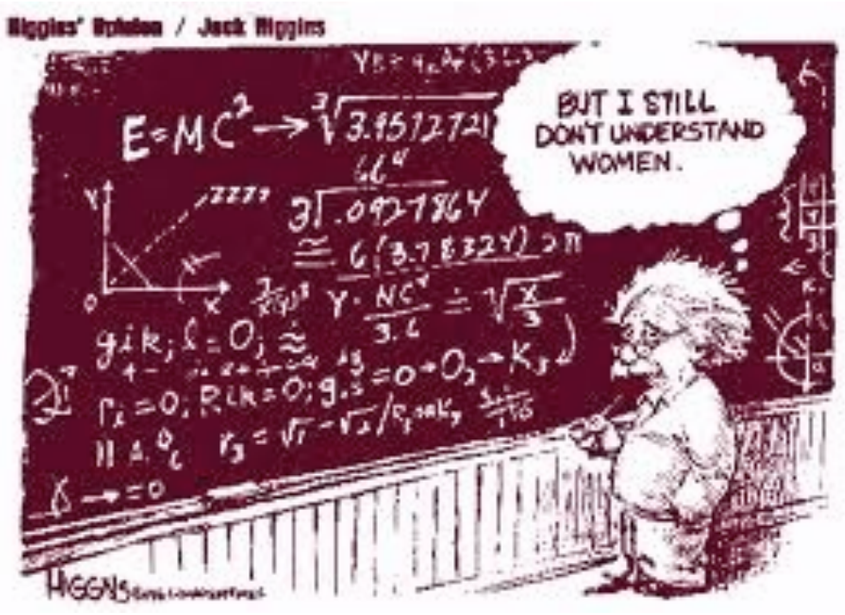
A star is born

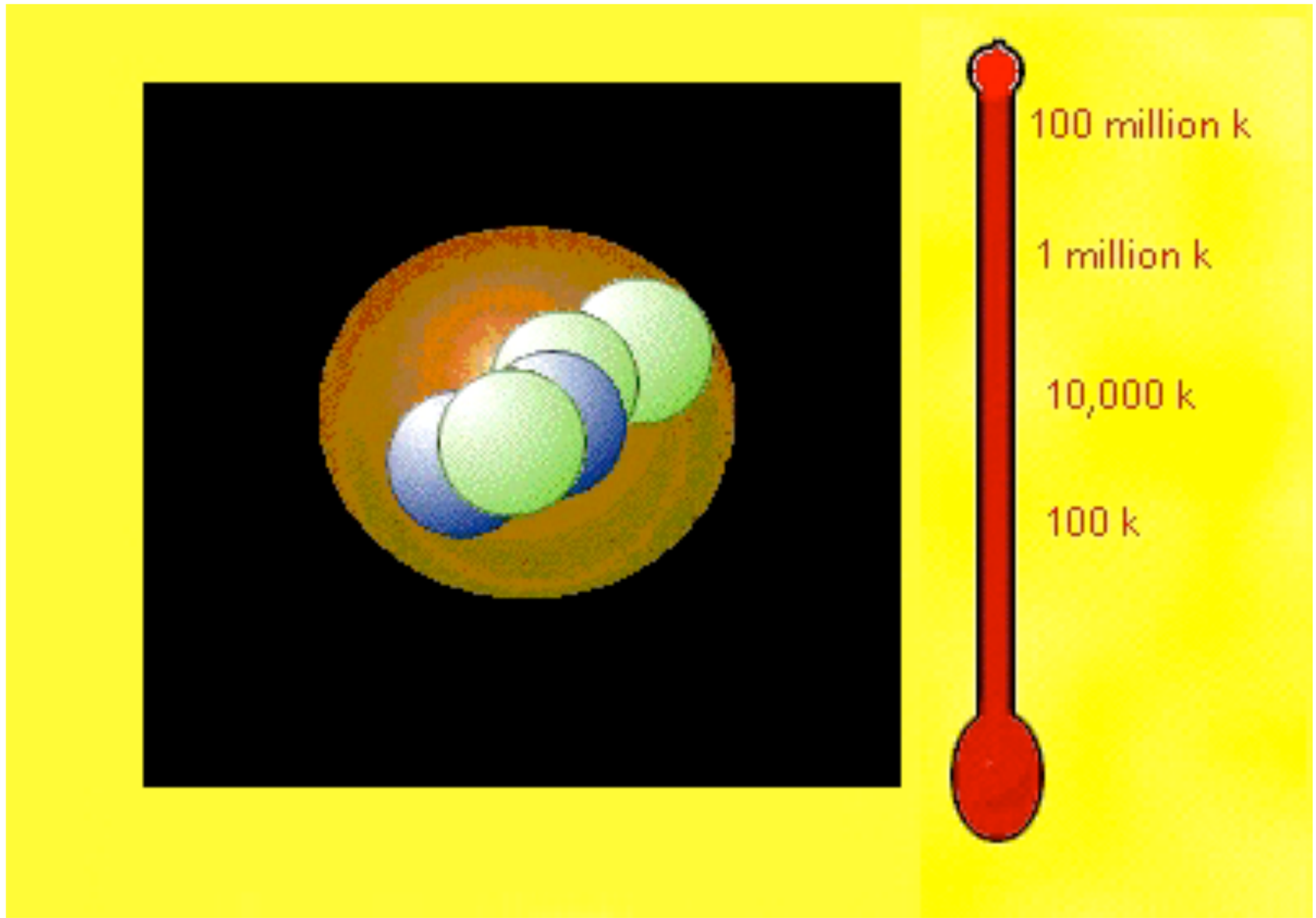
A star is born

To produce the elements we need now a furnace...
a **STAR FURNACE**
Stars acted as thermonuclear reactors

$$E=mc^2$$

E= kg · m²/s²
m= Kg
c= 300 000.000 m/s

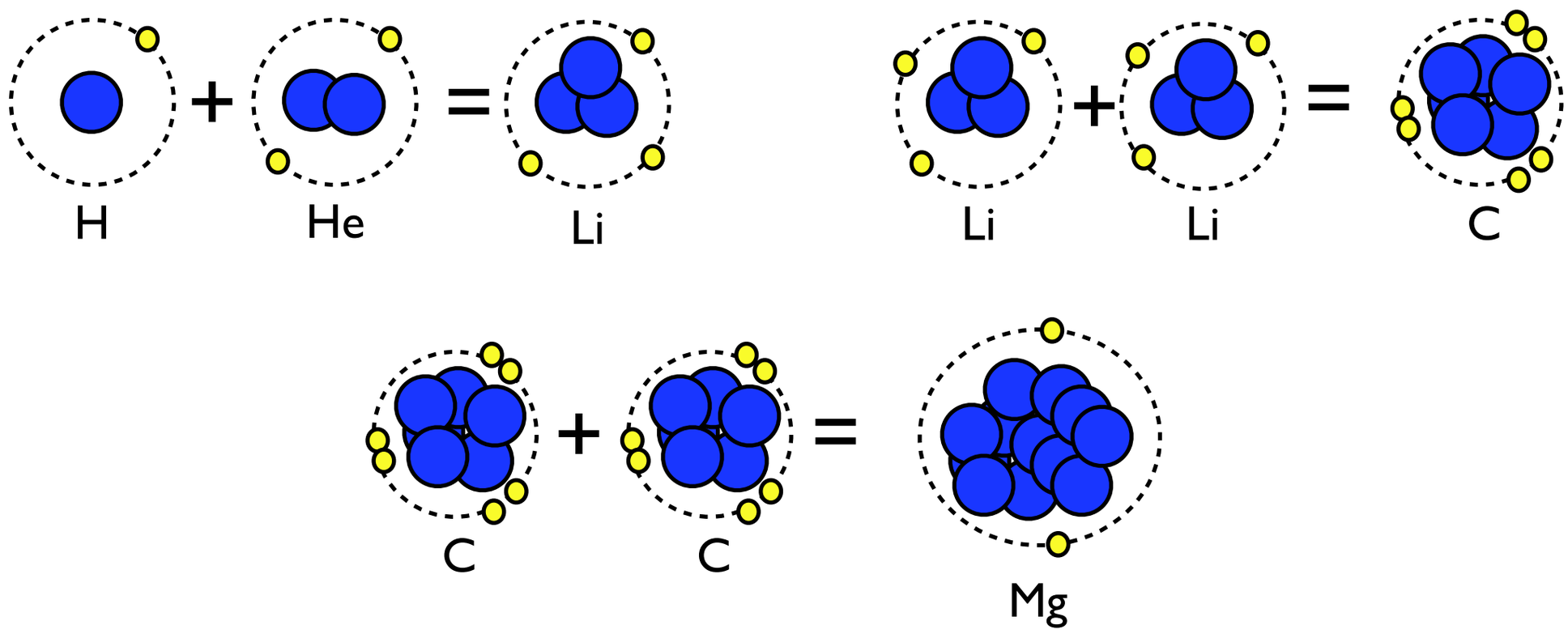




A star is borning

$$E=mc^2$$

The thermonuclear reactions happening inside the star furnace release **huge energies.** This energy make the atoms of H and He to fuse, creating heavier and **heavier elements**



Now in the space there are all the elements to build the rest of the Universe as we know it...

So How big is the Universe?!

So How big is the Universe?!

The Big Bang theory in 6 steps

1- There was a huge explosion (space started to expand, Physicists still do not know what happened before the "bang").

2- Energy are converted into matter and anti-matter. But the conversion produces a little more matter than anti-matter. Most anti-matter have annihilated with matter (procuding energy). The remaining matter is scattered in all directions and begins to cool (it will form the galaxies).

3- First, particles join together into protons and neutrons, then protons capture electrons to form Hydrogen atoms.

4- Later, Gravity pulls the Hydrogen atoms together to form Helium and Lithium, then stars, and galaxies.

5- Heavier elements (Carbon, Oxygen, etc) are formed inside stars (furnaces)

6- Stars burn out and explode expelling heavy metals (Iron, Copper etc) that formed planets