
THE BIRTH, LIFE AND DEATH OF OUR STAR
Newbury Beginners
19th January 2022
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The Birth of our STAR the Sun

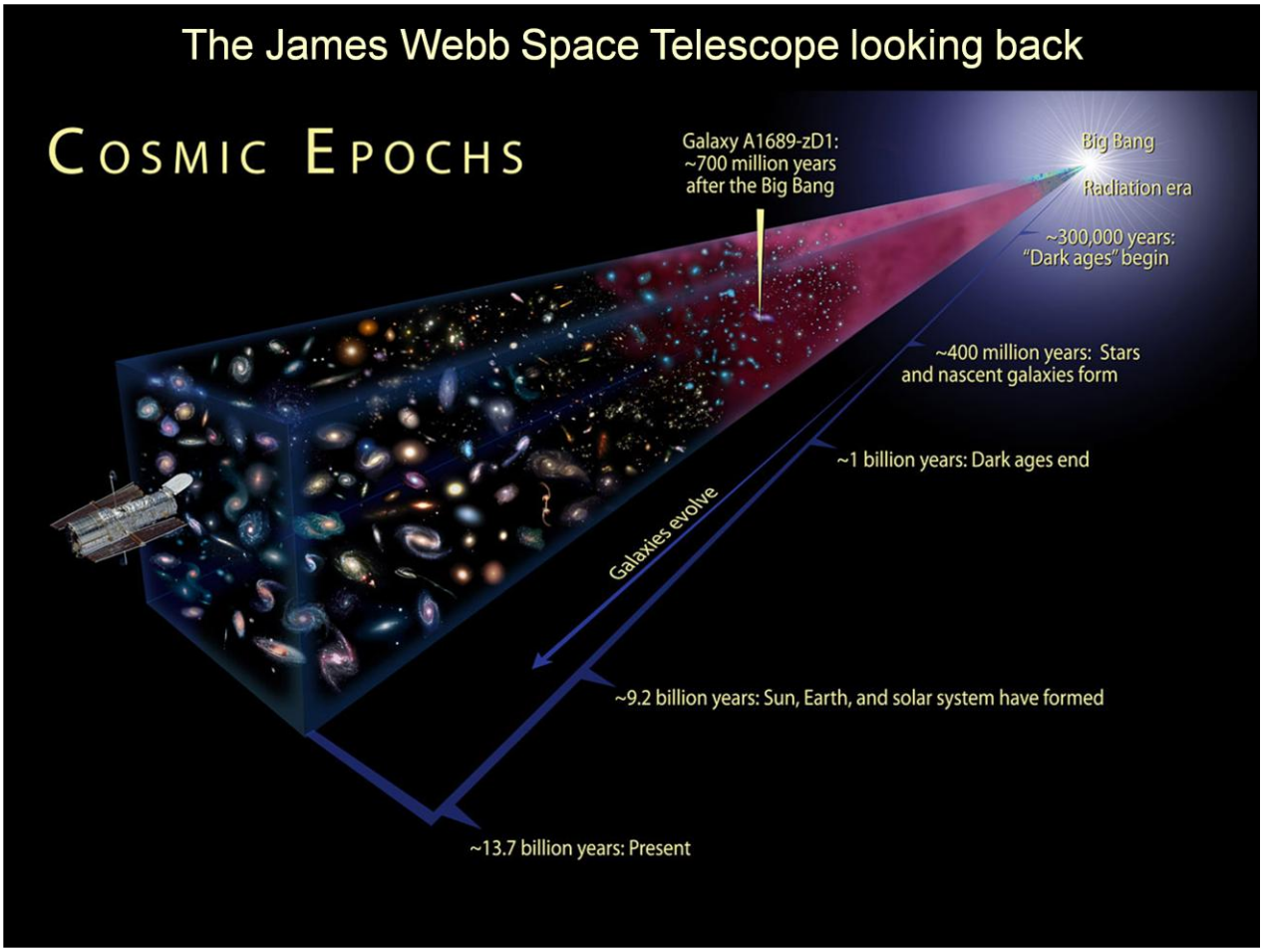
Before considering where our Sun came from

We must consider where the ‘building blocks’ came from

To do this we must start at the very beginning

THE BIG BANG is where our Universe began

So let us go back to the very beginning



The diagram above shows a slice of the Universe.

The Hubble space telescope is shown looking back towards the big Bang.

We refer to the moment of creation of the Universe as the ‘Big Bang’.

The event that we call the ‘Big Bang’ occurred about 13.8 billion ‘Earth’ years ago.

This is when time began for us and everything in our Universe was created.

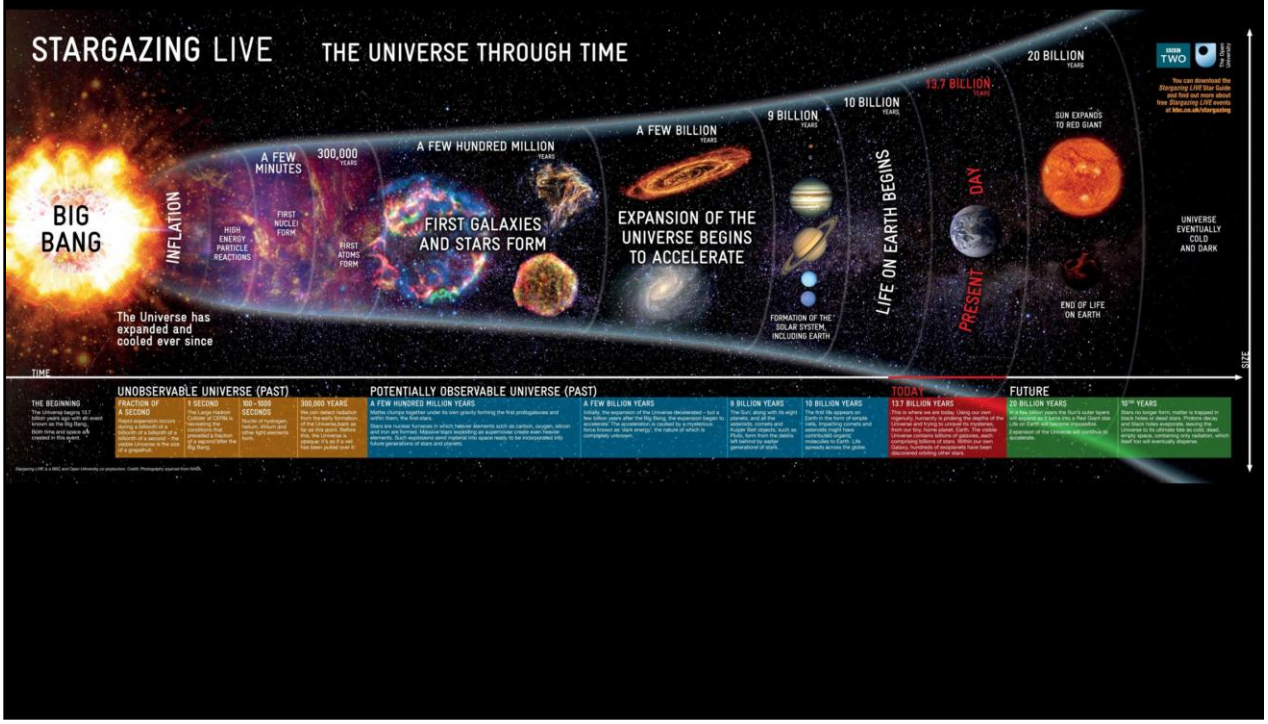
For us anything that happened or was there before the Big Bang has no meaning to us because we can never see out beyond our Universe.

It is now too big and it is too far for us to see to outer the edges.

We have already mentioned how the Universe began with the ‘Big Bang’ 13.8 billion years ago.

Now we can consider how the unbelievably small, dense and hot fireball expanded and cooled into the complex Universe we can observe today.

The JWST will be able to see back to the first stars



The diagram above shows how the Universe developed over the 13.8 billion years.

Things began to develop very fast immediately after the Big Bang. If we look at the horizontal scales at the bottom of the diagram above the time scale begins on the left using very small decimal fractions of a second.

In the first sub-second phase on the diagram the pure energy from the Big Bang expanded and cooled enabling sub-atomic particles (proto-matter) to form.

Then the sub-atomic particles combined to create atoms.

The first atoms were Hydrogen (89%), Helium (10%) and a tiny amount of Lithium.

The next slide shows the first part (left side) of the diagram above expanded.

In the next 1000 years the sub-atomic particles were forced together by the pressure and heat and started to create Protons (the positive (+) nucleus of an atom) and Electrons (the negative (-) particles orbiting a Proton).

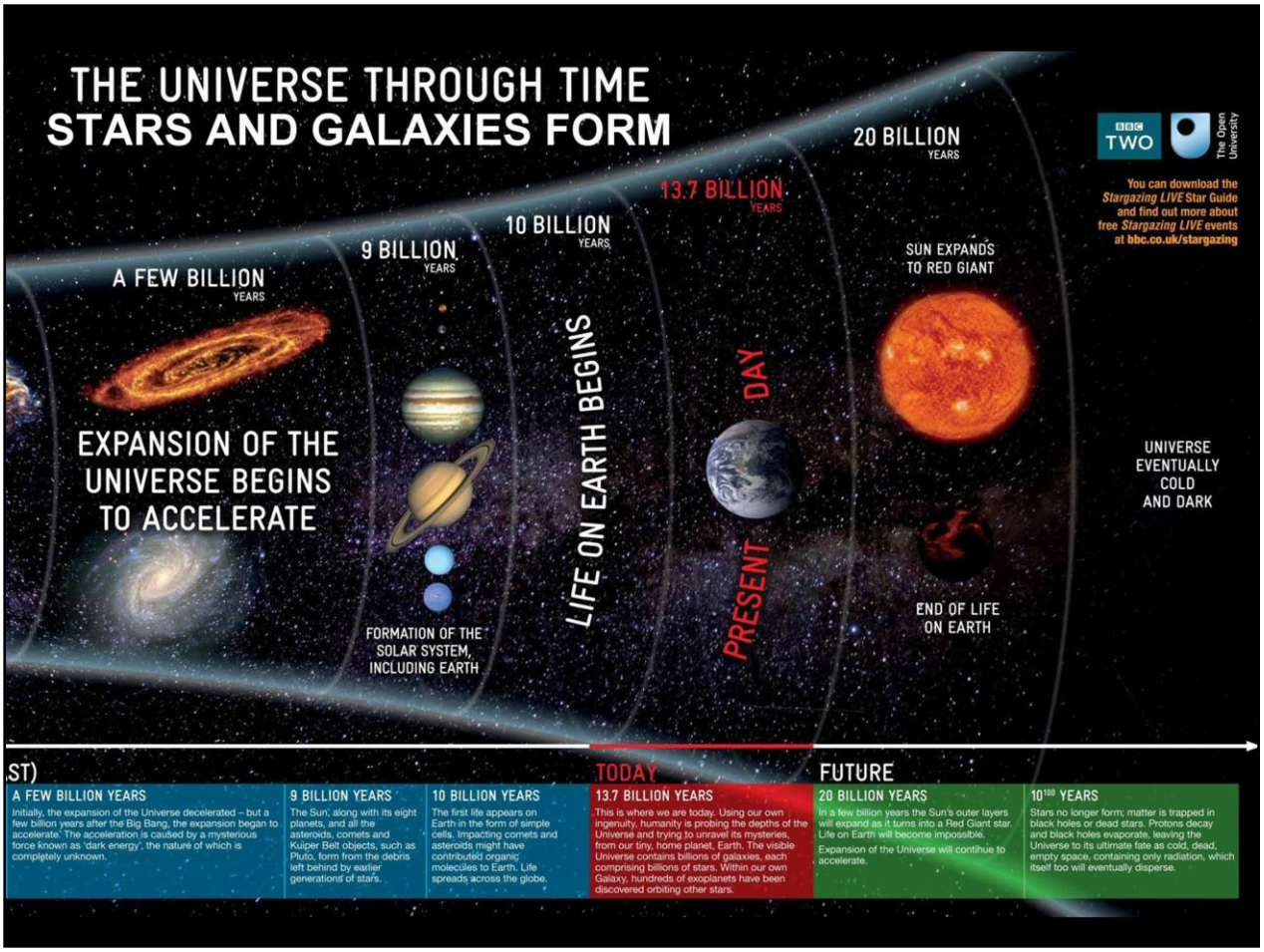
As a Proton and Electron fuse together they create an atom of Hydrogen gas.

There were some fusion events that joined two Protons and two Electrons together to create an atom of Helium gas.

Some sub atomic particles called Neutrons (similar to Protons but with no electrical charge (neither + or -) but were able to be combined into the forming atoms to create stable isotopes of these atoms.

The Nuclear Fusion process also produced sub-atomic energy packets called photons that are the carrier of what will become light. However these photons could not leave the expanding fireball because it was too dense and opaque.

After about 300,000 years most of the subatomic particles had been converted into atoms and the universe became transparent. The photons could then be released as electromagnetic waves (light).



After 300,000 to 400,000 years the first stars began to form as atoms were drawn together by gravity.
On a largest scale, the clouds of gas (Nebulae [single Nebula]) formed and were pulled into denser areas that formed into vast filaments (like a gigantic spider web). As the gas was pulled into filaments huge voids developed where there were virtually no atoms left.

At the largest scale, within these filaments galaxies began to form.

At the smallest scale, within these developing galaxies, stars formed.

This star and galaxy formation began within the first 500 million years.

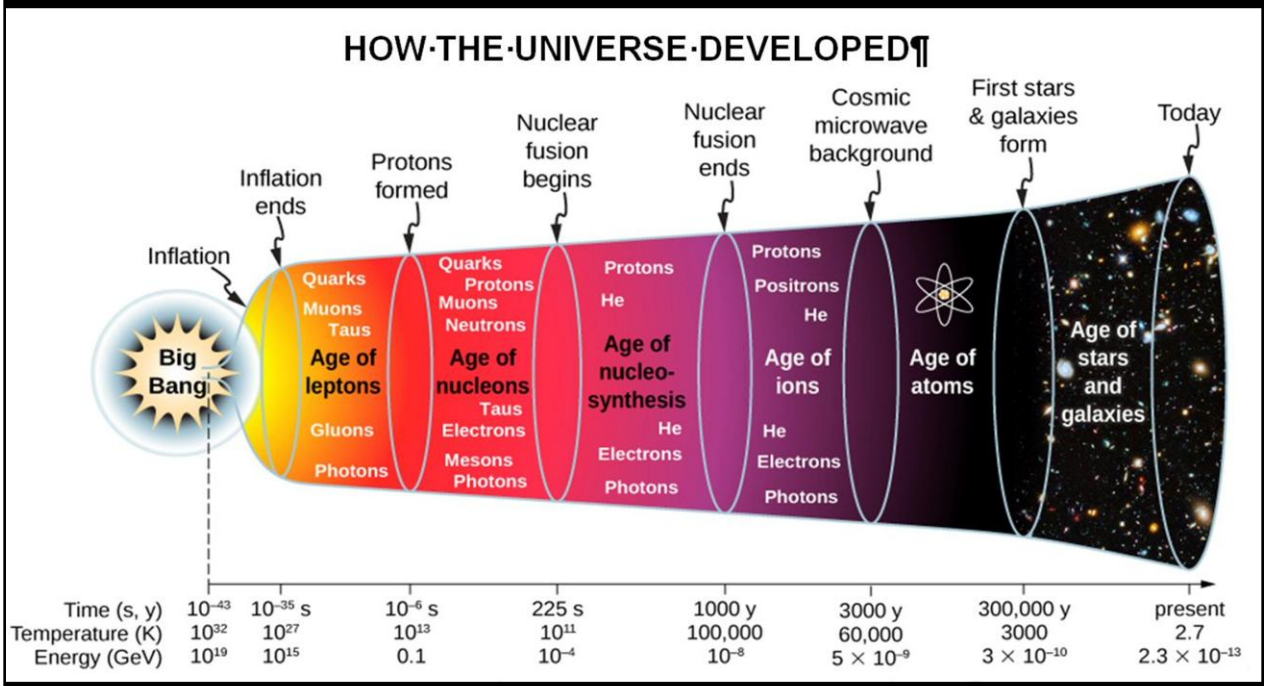
At this early stage all the matter (mainly Hydrogen atoms with 10% Helium) was still close together but expanding.

As there was so much matter packed into a relatively small volume, the very first stars were able to grow very large, very powerful but lived very short 'lives'.

Some stars had Planets form in orbit around them and our Earth formed.

But we must ask, where did the stuff to make planets come from?

The creation of atoms and photons



Quarks, Muons, Taus, Mesons, Gluons and Photons began to form
Then Protons, Neutrons, Electrons Positrons and Ions were created
Finally atoms of Hydrogen, Helium and some Lithium were created

In the first sub-second phase on the diagram above the pure energy expanded and cooled enabling sub-atomic particles (proto-matter) to form.

It seems very strange that matter can be created from energy but Albert Einstein's famous equation $E = mc^2$ shows us it is possible.

If we mathematically transpose ($E = mc^2$) into ($m = E \div c^2$) then we have Mass (matter) was created from Energy (E) divided by the speed of light squared (c x c).

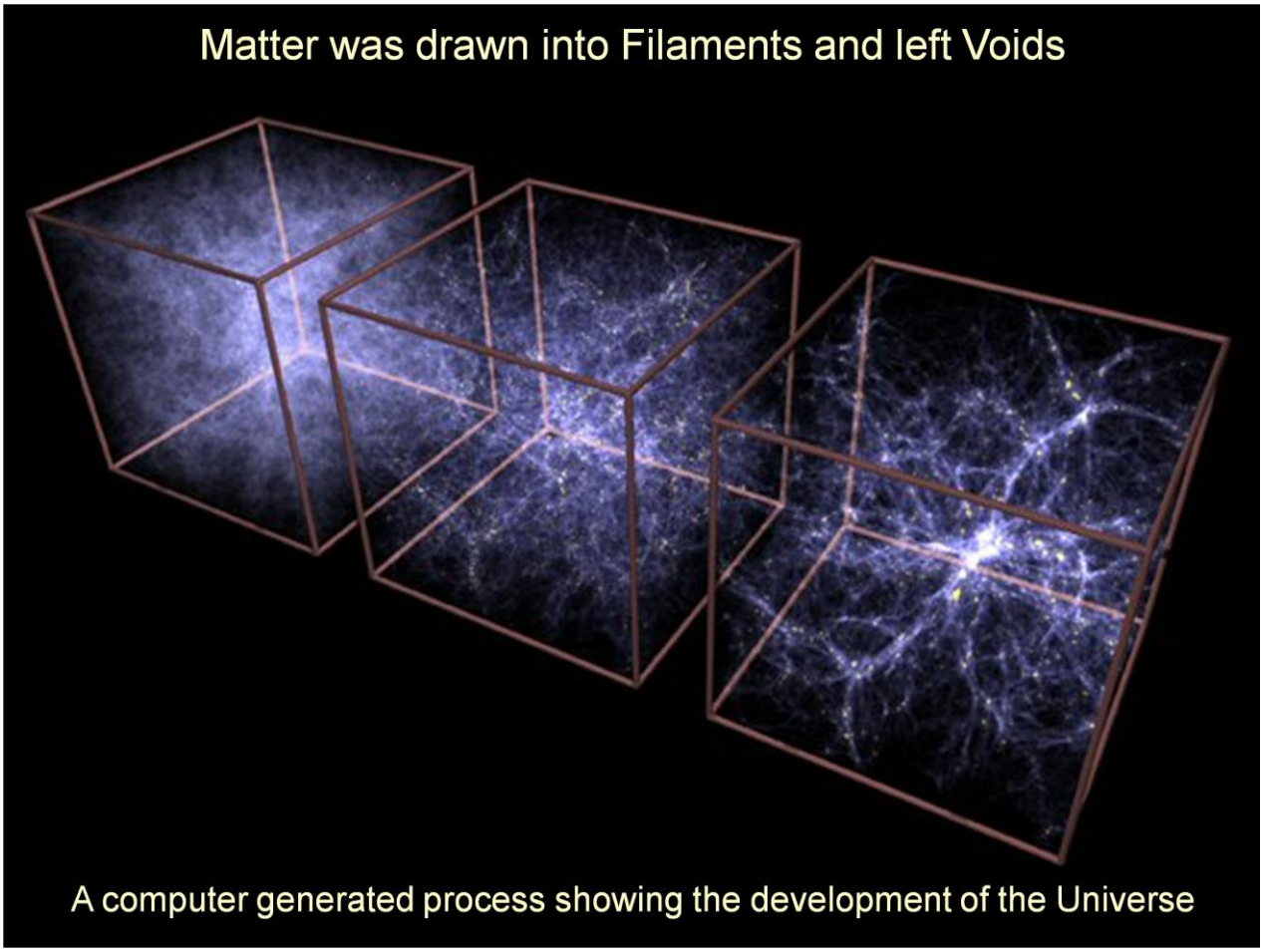
The sub-atomic particles are listed on the diagram above (these became the building blocks of atoms).

First to be created are: Quarks, Muons, Taus, Gluons and Photons.

These went on to create: Protons, Neutrons, Electrons then Positrons and Ions.

In the time from 3000 to 300,000 years after the Big Bang atoms began to form and when the sub-atomic particles were used up the universe became transparent.

Photons could then travel through space as electromagnetic waves (light).



After about 300,000 years the Universe became transparent so the flash could travel through space.

Gravity started to exert its effect on the matter that had been created.

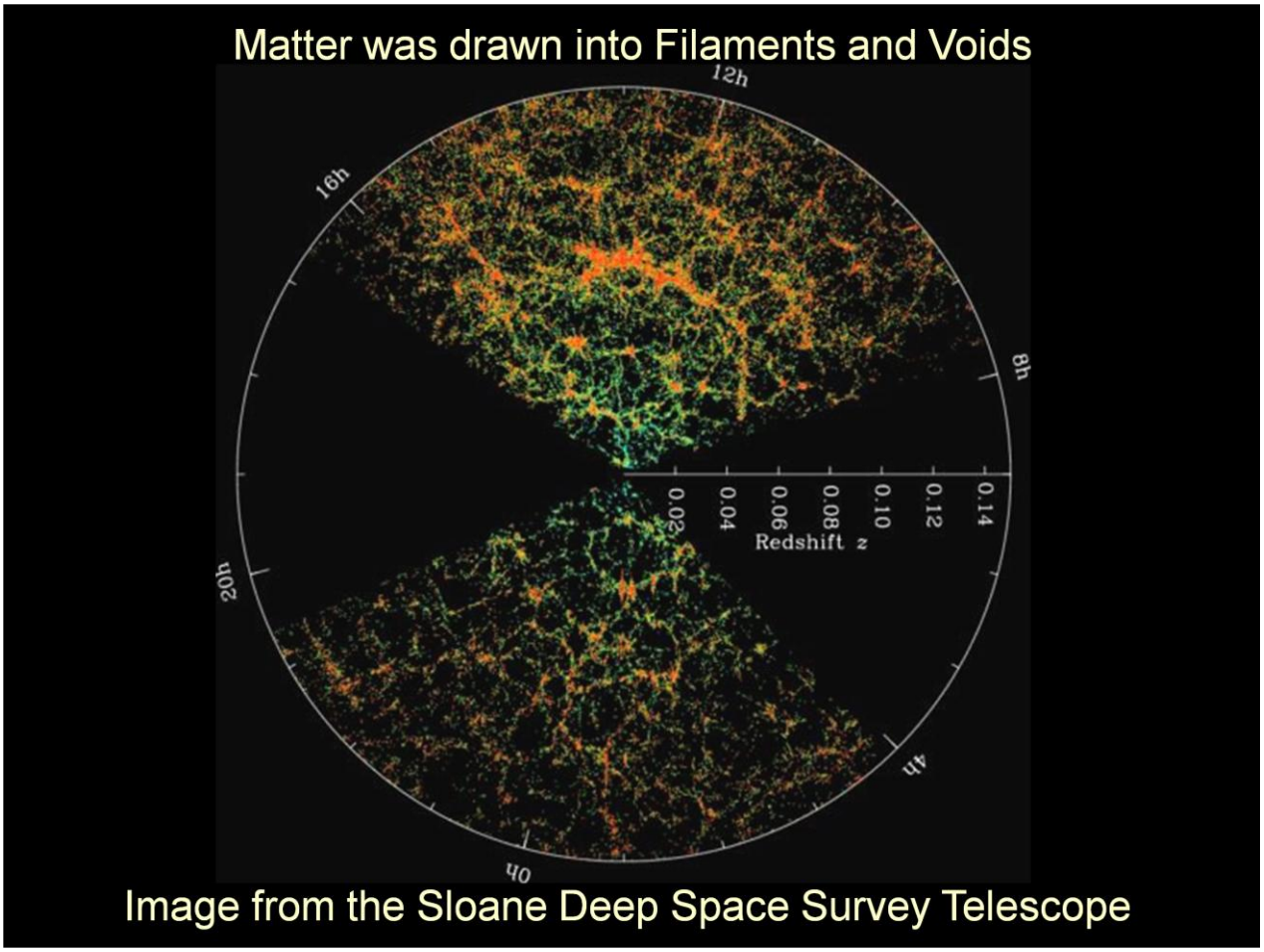
Atoms that were already moving due to the Big Bang were drawn together by their mutual gravity.

As more atoms were drawn together their mutual gravity increased and pulled even more atoms together.

At the largest scales the atoms of Hydrogen and about 11% Helium were drawn into vast filaments stretching across the expanding Universe.

As gas was pulled into the filaments by gravity vast Voids of empty space were left behind.

At a smaller scale the atoms, by virtue of their velocity (movement through space), began to form into great swirling clouds and eventually created spinning Spiral Galaxies.



The Sloan Digital Sky Survey has created the most detailed three-dimensional maps of the Universe ever made.

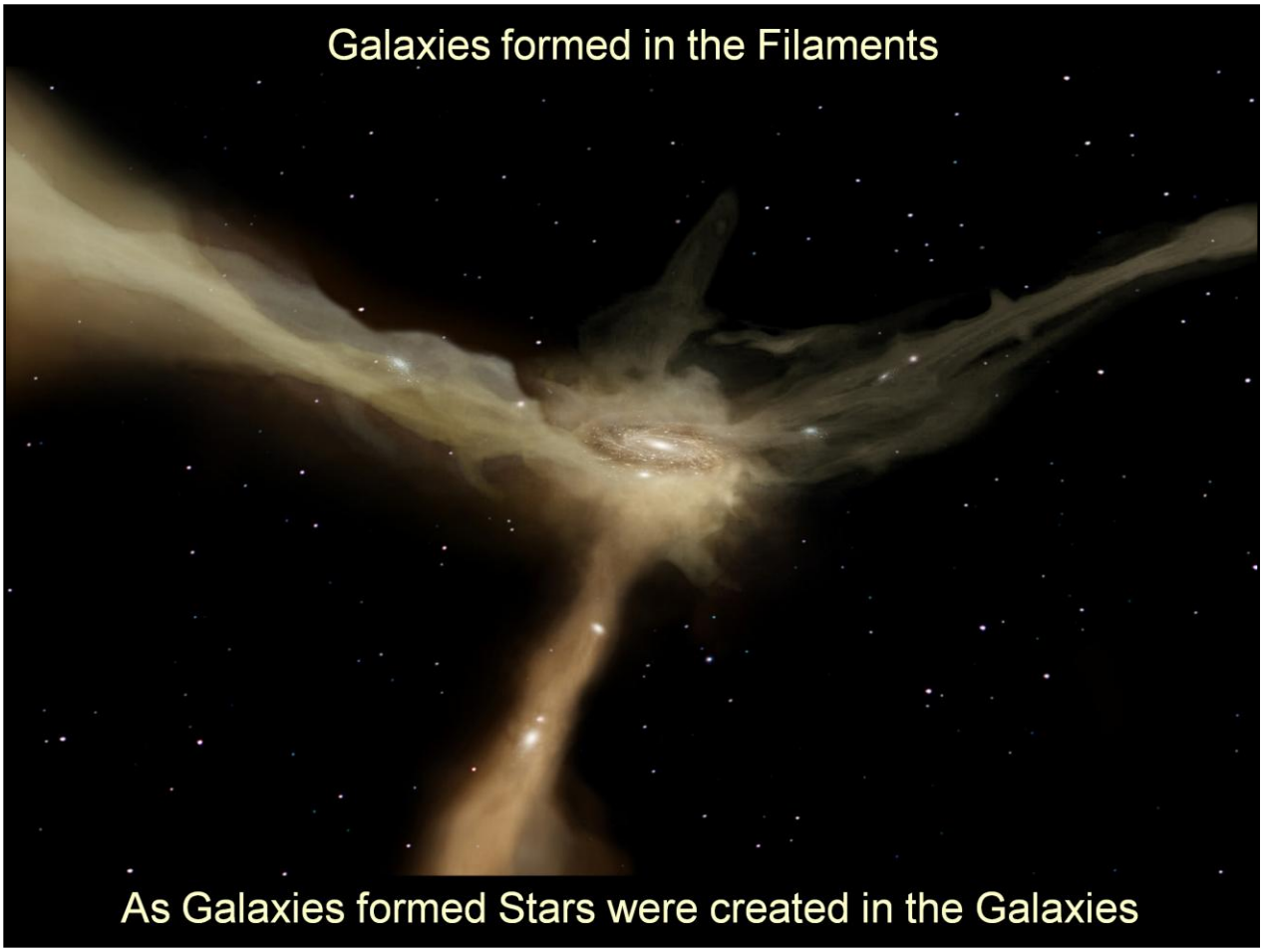
It created deep multi-colour images of one third of the sky, and spectra for more than three million astronomical objects.

The Sloan Digital Sky Survey (SDSS) is one of the most ambitious and influential surveys in the history of astronomy.

Over eight years of operations it obtained deep, multi-colour images covering more than a quarter of the sky.

It created 3-dimensional maps containing more than 930,000 galaxies and more than 120,000 quasars.

With its upgrades it was also able to determine how galaxies were moving in relation to us and how fast they are moving.



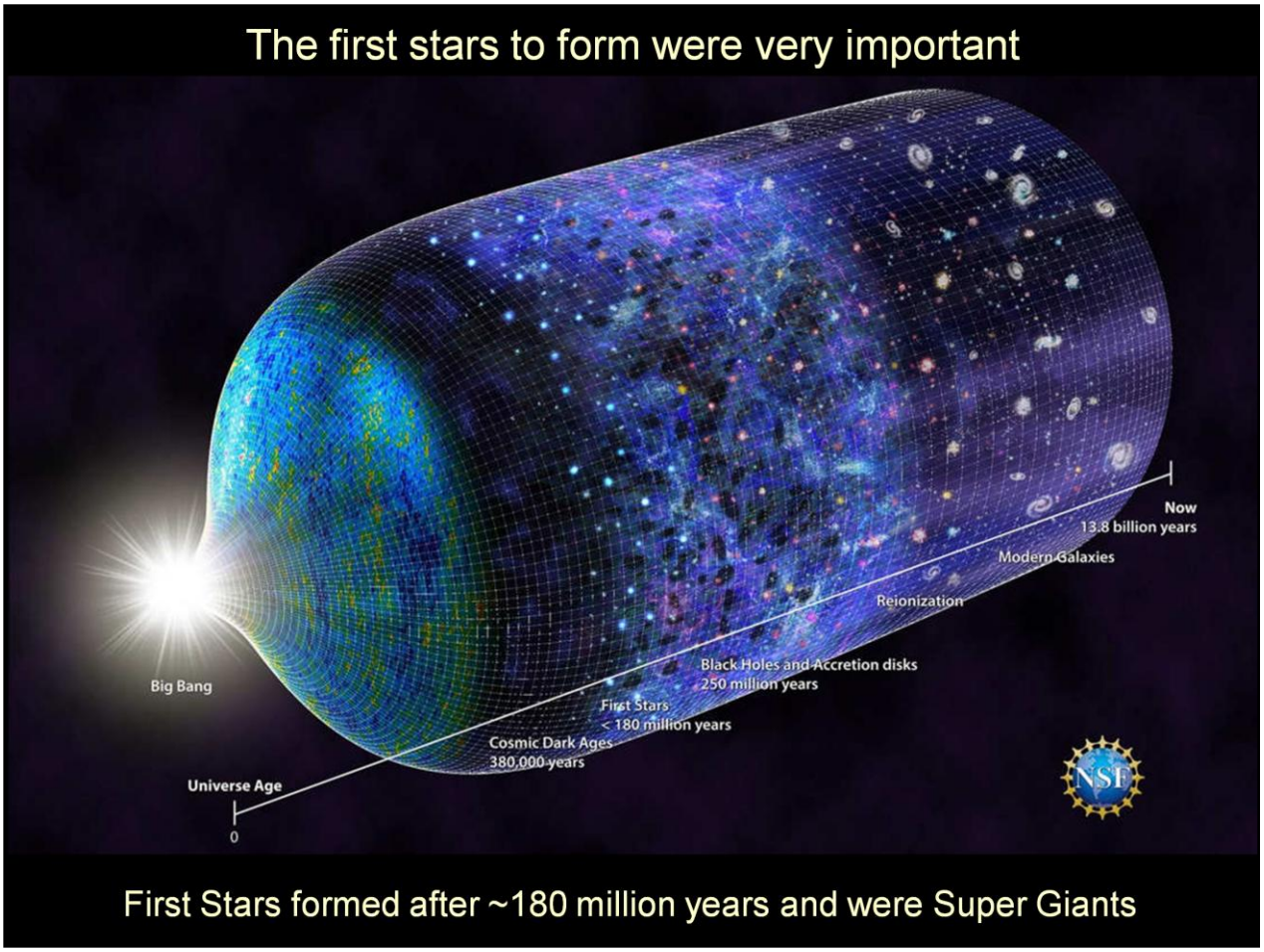
The original gas Hydrogen (89%) and Helium (10%) was drawn into denser filaments by gravity.

As gas was pulled into the filaments by gravity vast Voids of empty space were left behind.

As the gas was drawn into the filaments, its motion caused huge eddies and swirls to form.

These swirls developed into spinning discs that created Spiral Galaxies.

Within the flat rotating discs of these Galaxies stars formed from the gas.



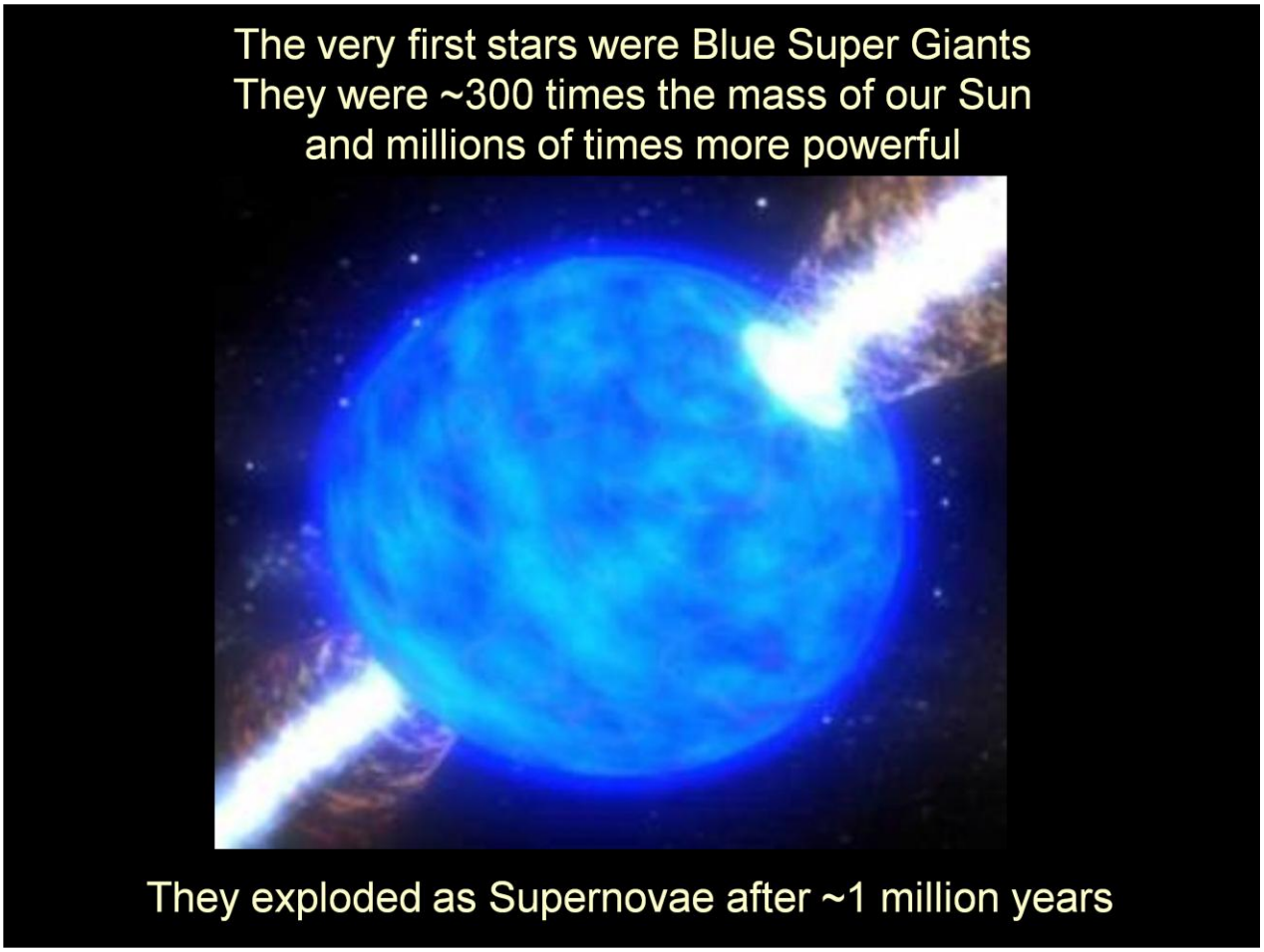
At this phase of the development of Galaxies they were comprised of just Hydrogen and 10% Helium created by the Big Bang.

Everything was much closer together and very hot as the Universe continued to expand it started to cool.

As the atoms cooled they were able to group together due to their gravity.

So the first stars were created from pure Hydrogen and Helium gas.

The conditions in these early galaxies allowed the forming stars to be Super Giants.



The first stars to be created were Super Giant stars containing up to 300 times the mass of our Sun.

Being to massive their cores had an enormous pressure and very high temperature.

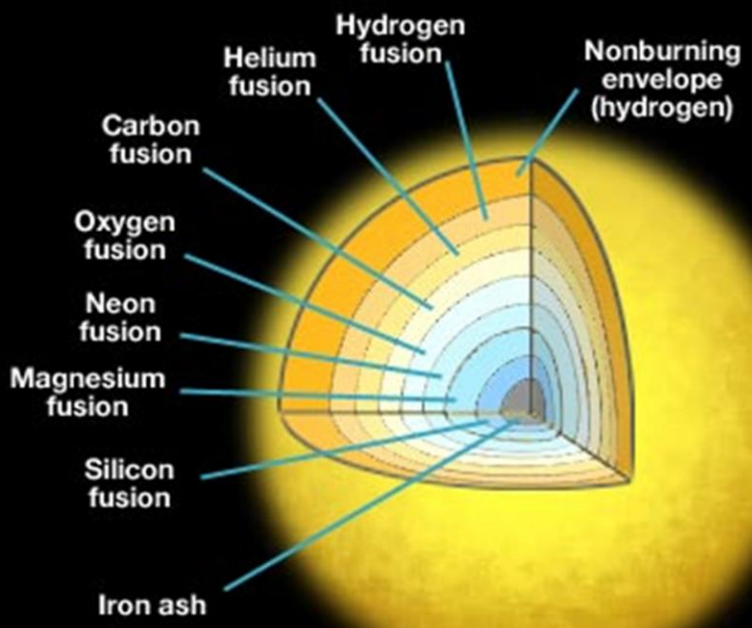
The Hydrogen atoms were compressed together by the enormous gravity and were moving around very fast due to the heat.

Hydrogen atoms were forced together and combined (fused) together to create more Helium atoms.

This Nuclear Fusion process released X-Rays that heated the core to even higher temperatures.

Nuclear Fusion in these giant stars produced huge amounts of energy and consumed enormous amounts of Hydrogen gas.

Giant stars can fuse heavier and heavier elements



Giant Stars can fuse Silicon into Iron in the core
There is a problem creating Iron it does not produce energy

These enormous blue stars were able to continue the Nuclear Fusion process.

Helium gas was fused into heavier elements with a bias towards certain elements.

First the Helium was fused into Carbon which was in turn fused into Oxygen atoms.

The fusion process continued to produce Neon, Magnesium, Silicon and finally Iron.

With each stage the heavier atoms sunk to the centre if the core as shown above.

All these fusion stages added more energy to the star it became hotter and the increased radiation pushed outwards to increase the diameter of the star.

However the final Iron production stage did not produce energy and caused the stars to become unstable.

Giant stars destroy themselves as Supernovae

The final moments leading up to the death of a Super Giant Star happen very quickly.

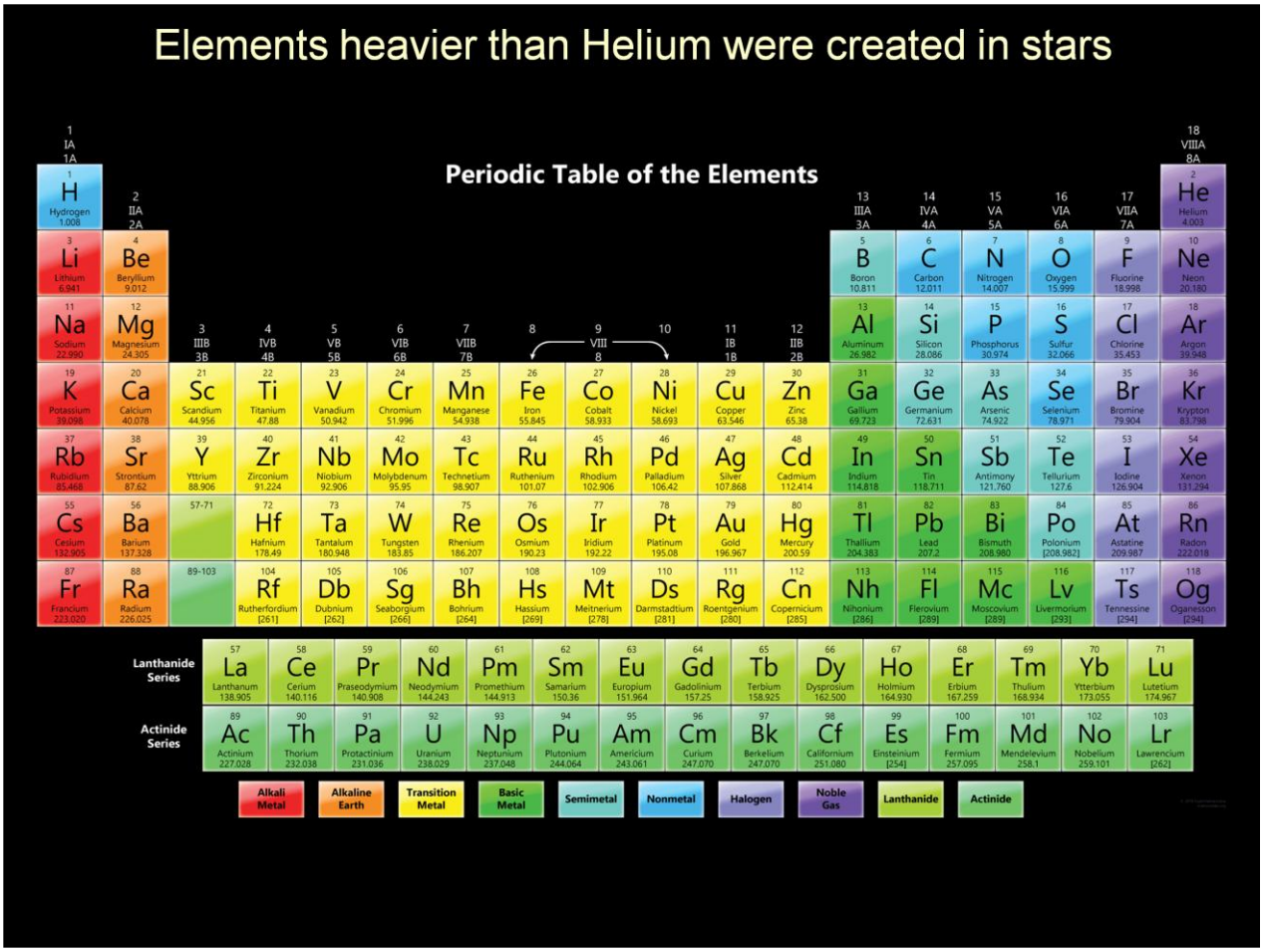
When Iron begins to form in the core the star it is destined to die within a couple of our days.

Iron rapidly fills the centre of the core until the Iron sphere reaches a mass of 1.4 times the mass of the Sun.

At this point the Iron in the core suffers a catastrophic collapse and briefly exists like an Iron white Dwarf about the diameter of Earth (12,756 km).

Almost immediately the rest of the star collapses at enormous speed on to the super compressed Iron sphere and starts a run away Nuclear Fusion Explosion.

The explosion rips through the star as a Supernova. All the elements already present and new ones created in the Supernova are blow out into space at enormous speed.



During the short life of these Super Giant Stars elements up to Iron (Element 26) are manufactured.

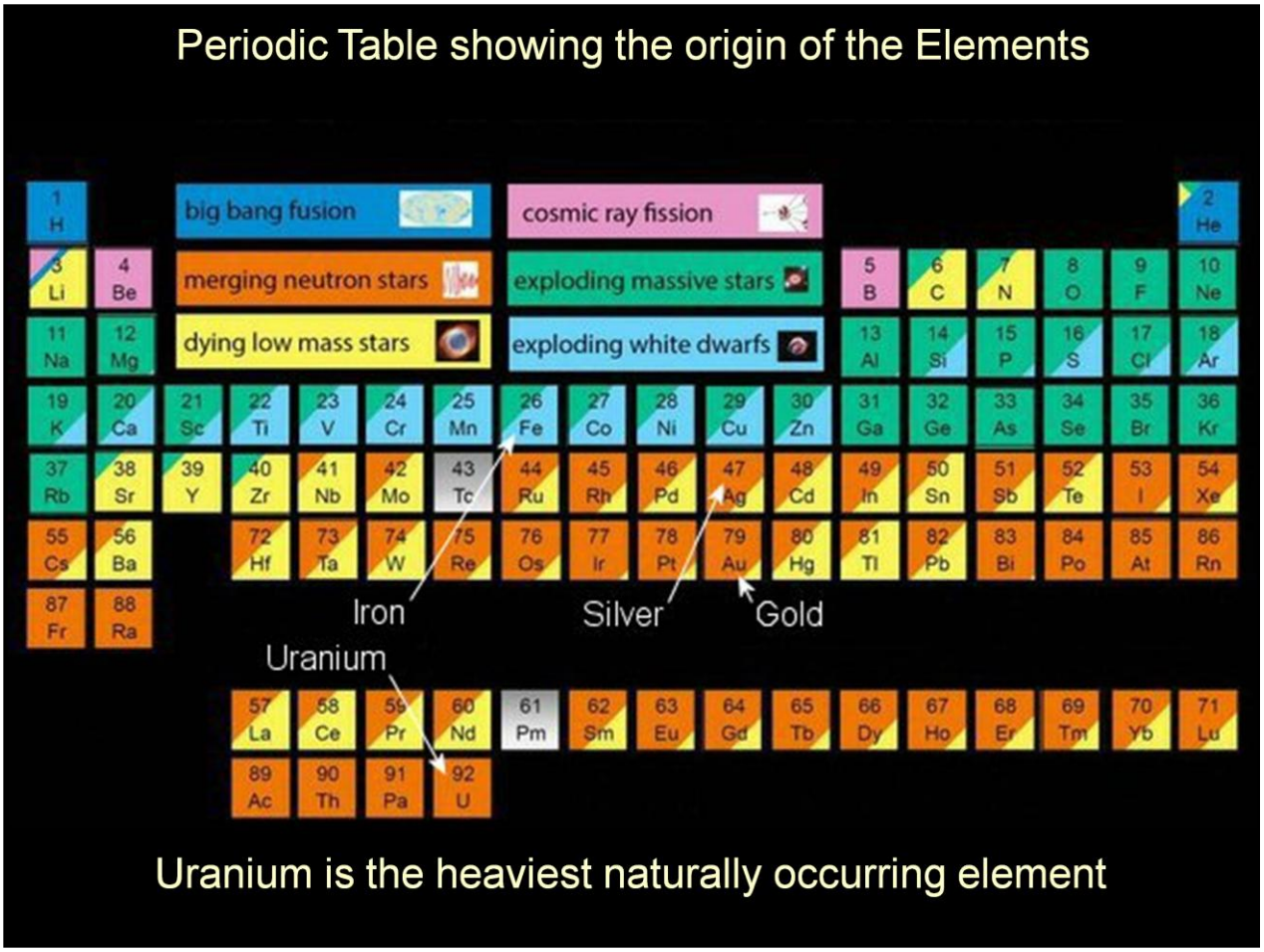
In the short time that the supernova Nuclear Fusion explosion rips through the star all the elements in the table can be forged.

Some elements are short lived and rapidly decay into other elements and add to the energy output.

All these Elements are scattered into the Clouds of Hydrogen around the Supernova.

With millions of these early and short lived Supergiant stars exploding the Nebula becomes contaminated with these heavier elements.

As new stars form in the Nebula they contain more and more of the heavier elements with each subsequent generation.



The Periodic Table of Elements above has been specially drawn to show the origin of each element.

At the top of the table a colour code shows where the proportions of each element were formed.

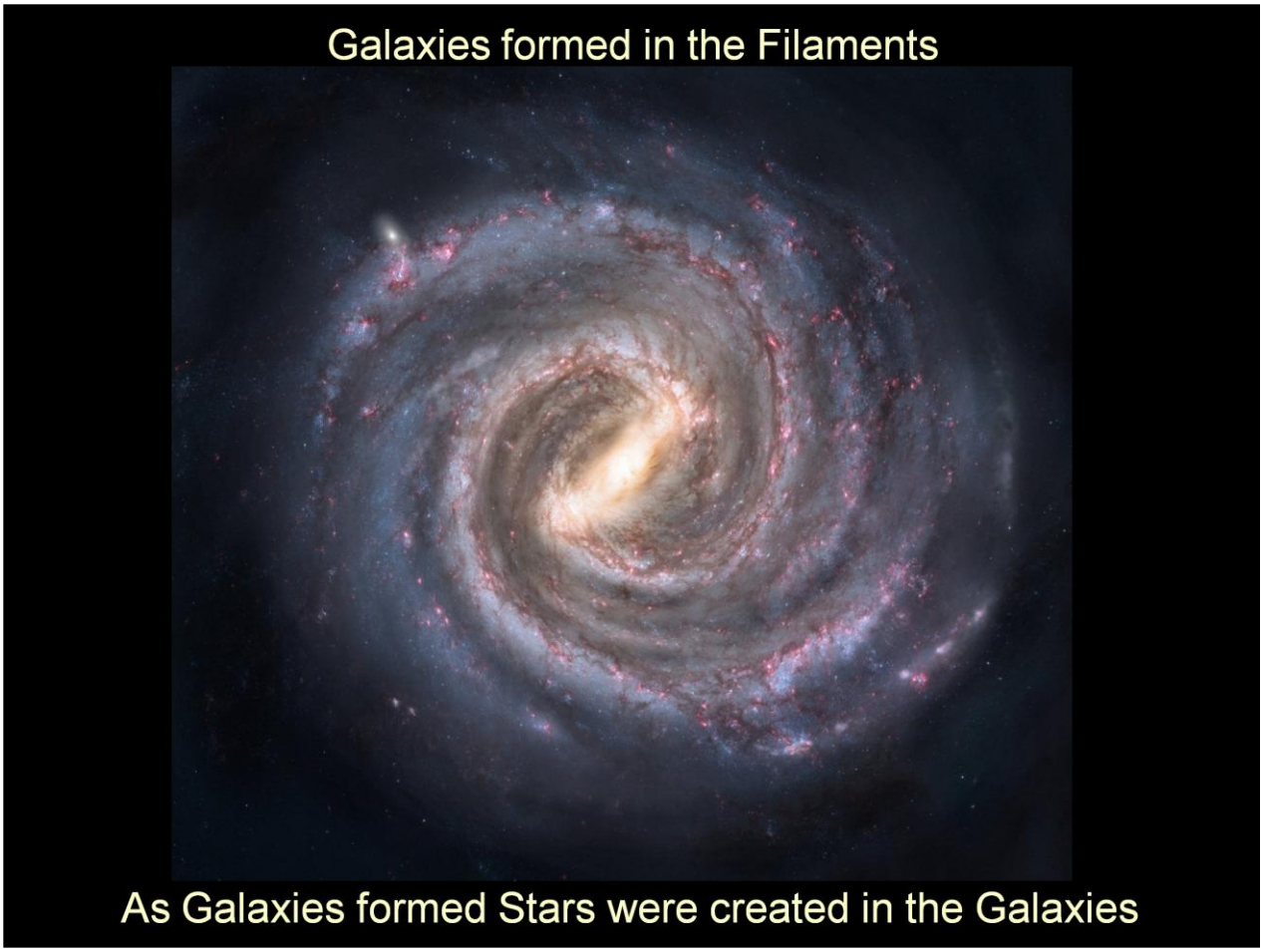
Hydrogen, Helium (light blue) was created in the Big Bang with a small amount of Lithium.

Green shows the elements created in Supernovae either prior or during the Supernova.

Orange and yellow elements were created later by Neutron Stars or by dying low mass stars.

Uranium (92) is the heaviest naturally occurring element all the other heavier elements have decayed over millions of years.

Elements like Neptunium (93) and Plutonium (94) and the other heavier elements are created by humans but naturally occurring atoms of these heavier elements have decade into lower elements over the billions of years.



The picture above shows what we think our Galaxy ‘the Milky Way’ looks like.

The red and pink in the spiral arms is areas where stars are forming in Nebulae.

Spiral Arms are created as shock waves from forming and dying stars move around the disc.

Shock waves stir up the nebulae create more star formation that moves through the disc in waves that create the curved spiral arms.

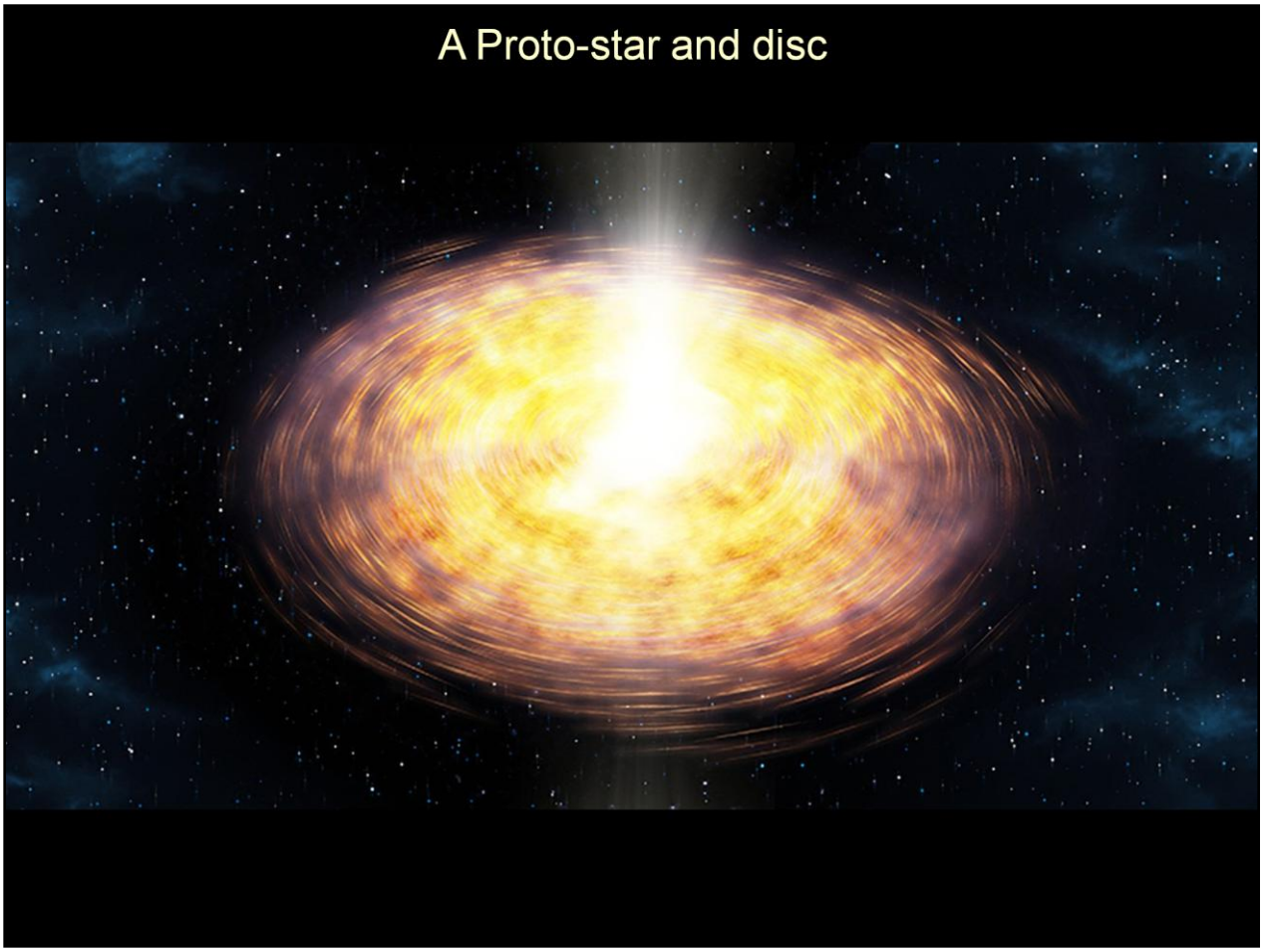
As the shock wave passes through a quiet nebula the atoms are disturbed and begin to be attracted to each other.

Gravity pulls the atoms together and new stars are formed.

The image above shows a star forming area in one of the arms of our galaxy.

As intense ultraviolet radiation from new stars hits Hydrogen atoms of the surrounding nebula they glow red the natural colour emitted by excited Hydrogen atoms.

In the centre we can see where stars are driving the Nebula to form what looks like pillars of gas and dust.



Gas and dust in the nebula begins to create denser areas due to the attraction between atoms.

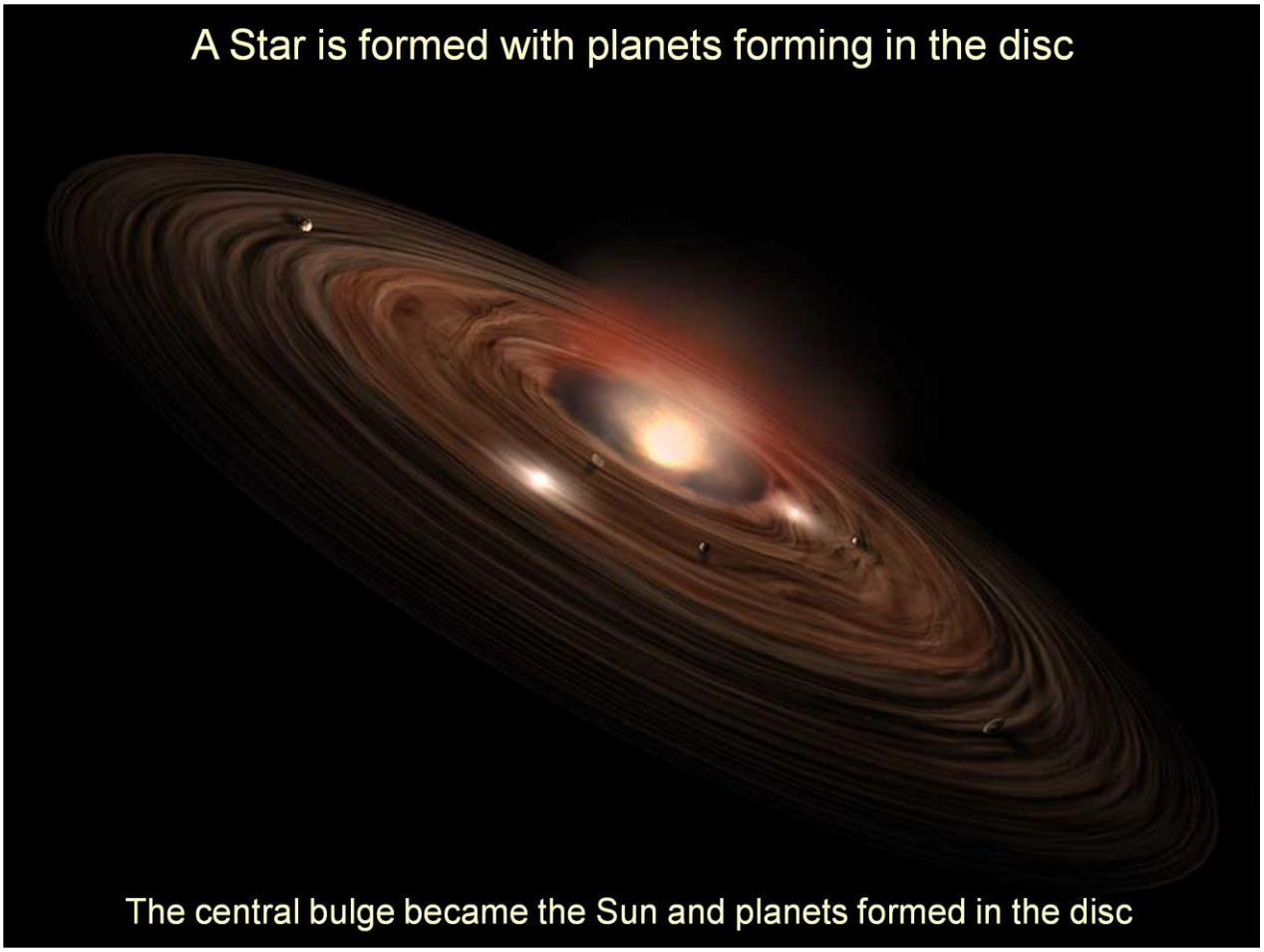
More mass creates more gravity and the dense regions grow.

As more material is pulled in, its velocity is added to the area and a rotating disc forms.

Material is drawn to the centre of the disc and a dense sphere of material is created there.

As this central sphere grows the increasing gravity compresses the sphere so the pressure and temperature in the centre increases.

As the pressure rises the temperature rises until Nuclear Fusion can begin and a new star is born.



Our Sun began to form about 4.5 billion years ago in a Nebula in the Galaxy we call the Milky Way.

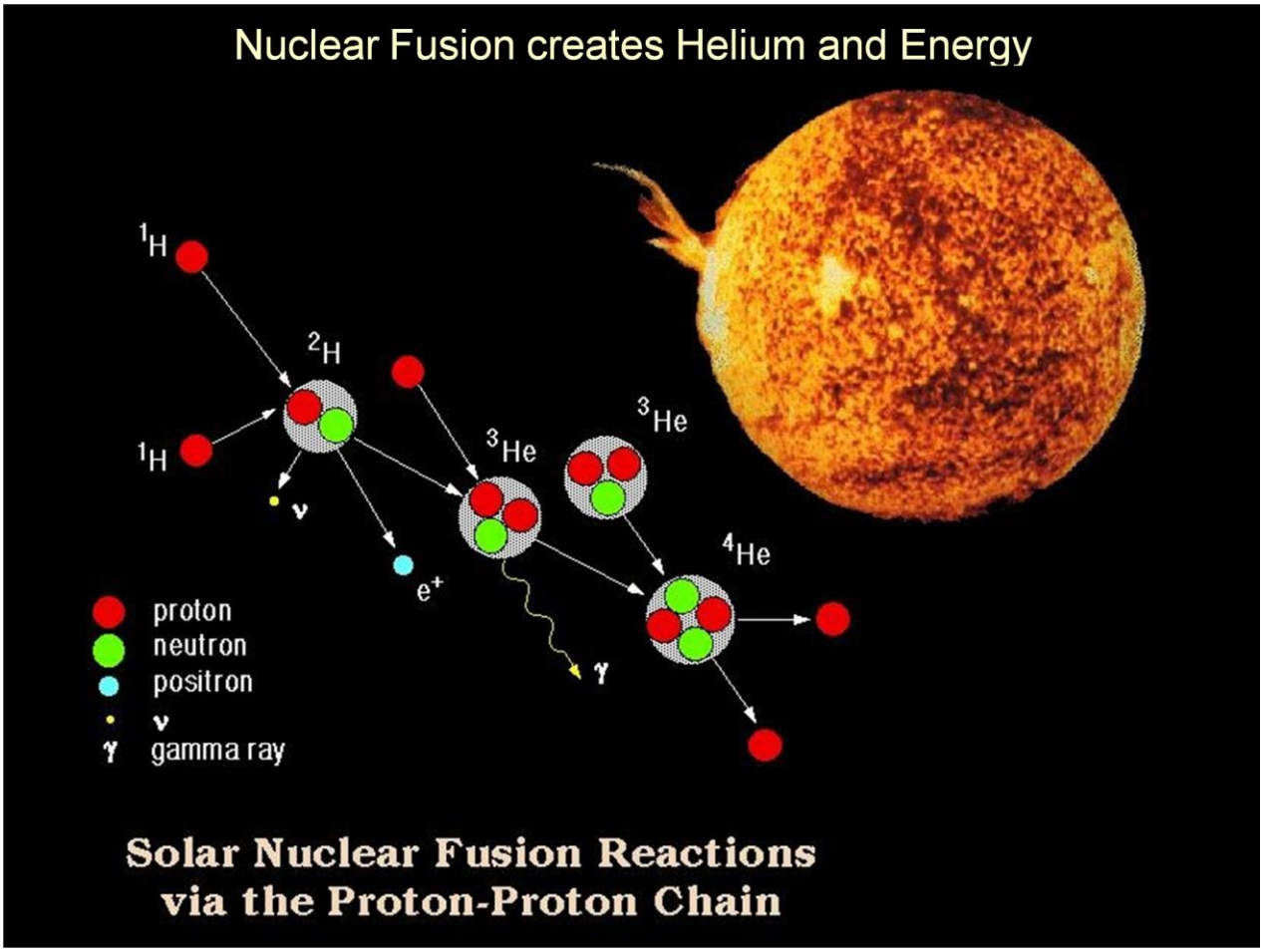
The original Hydrogen and Helium in our galaxy was contaminated with dust and gas produced by many generations of exploding stars.

As the new proto-star pulled in more and more gas and dust a rotating disc of material formed.

The dense central bulge became highly compressed and Nuclear Fusion began and our star ‘the Sun’ began to shine.

Material in the rotating disc began to form denser clumps that developed into planets.

Some planets had close encounters and were thrown into the Sun or out into space others planets had collisions.



Nuclear Fusion is a natural process that occurs in stars where pressure and heat compresses atoms tightly together.

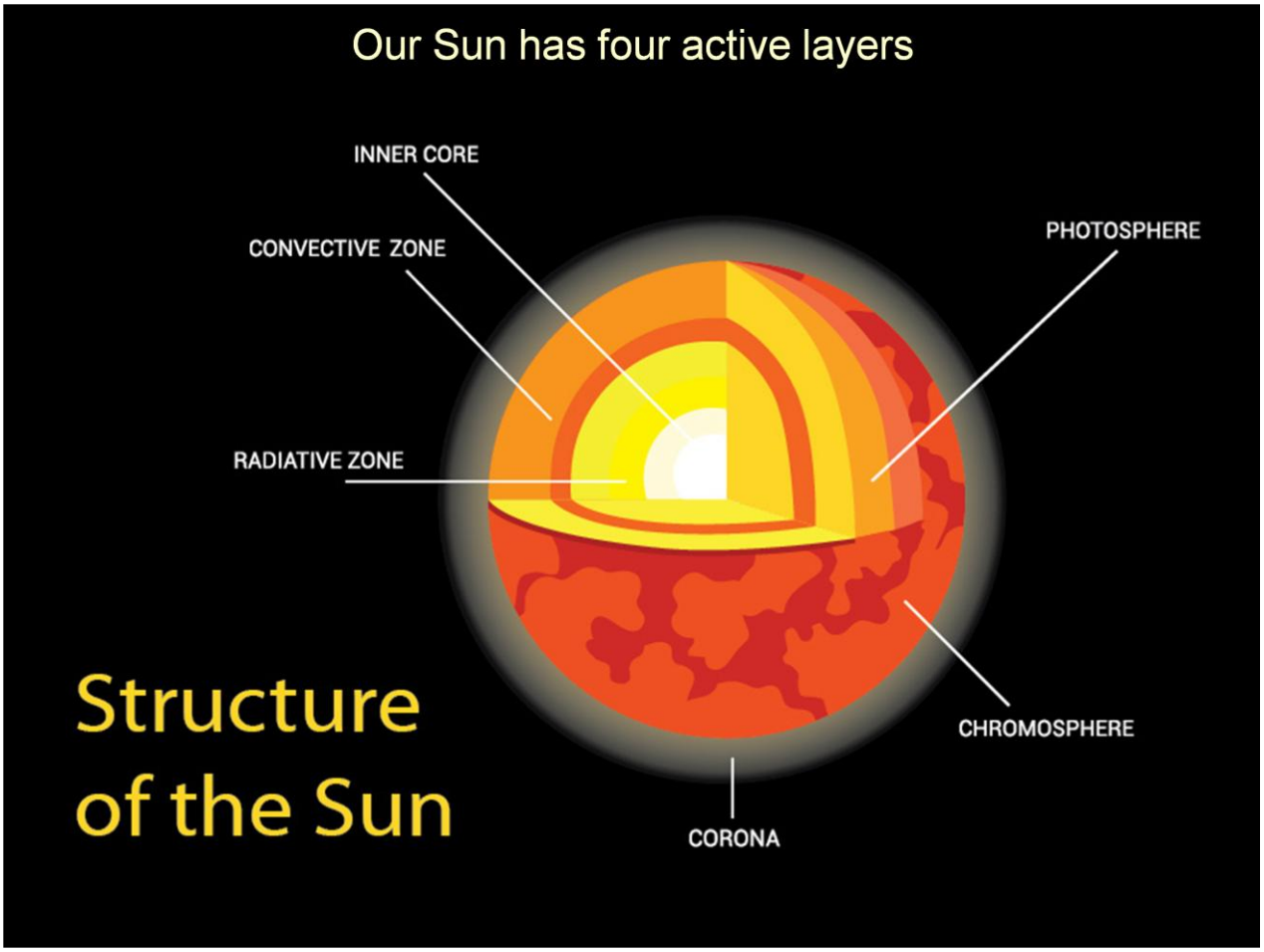
When the pressure rises to millions of times the pressure of Earth's atmosphere and temperature of millions of degrees the Nuclear Fusion can Begin.

In the diagram above a red Proton and a green Neutron join to become an atom of Hydrogen.

In the high pressure and temperature a second proton can be forced into the Hydrogen atom to create an atom of Helium (^3He).

In this Fusion process a Gamma ray (γ) is released that provides additional heat to the core.

After this reaction two Helium atoms can also be fused into a single helium (^4He) and two Protons are released to form another (^3He) atom.



The Fusing of two Hydrogen Atoms into one Helium atom produces a Gamma Ray (Υ) to heat the Sun.

One Helium atom weighs less than the two Hydrogen atoms that created it so where did the mass go?

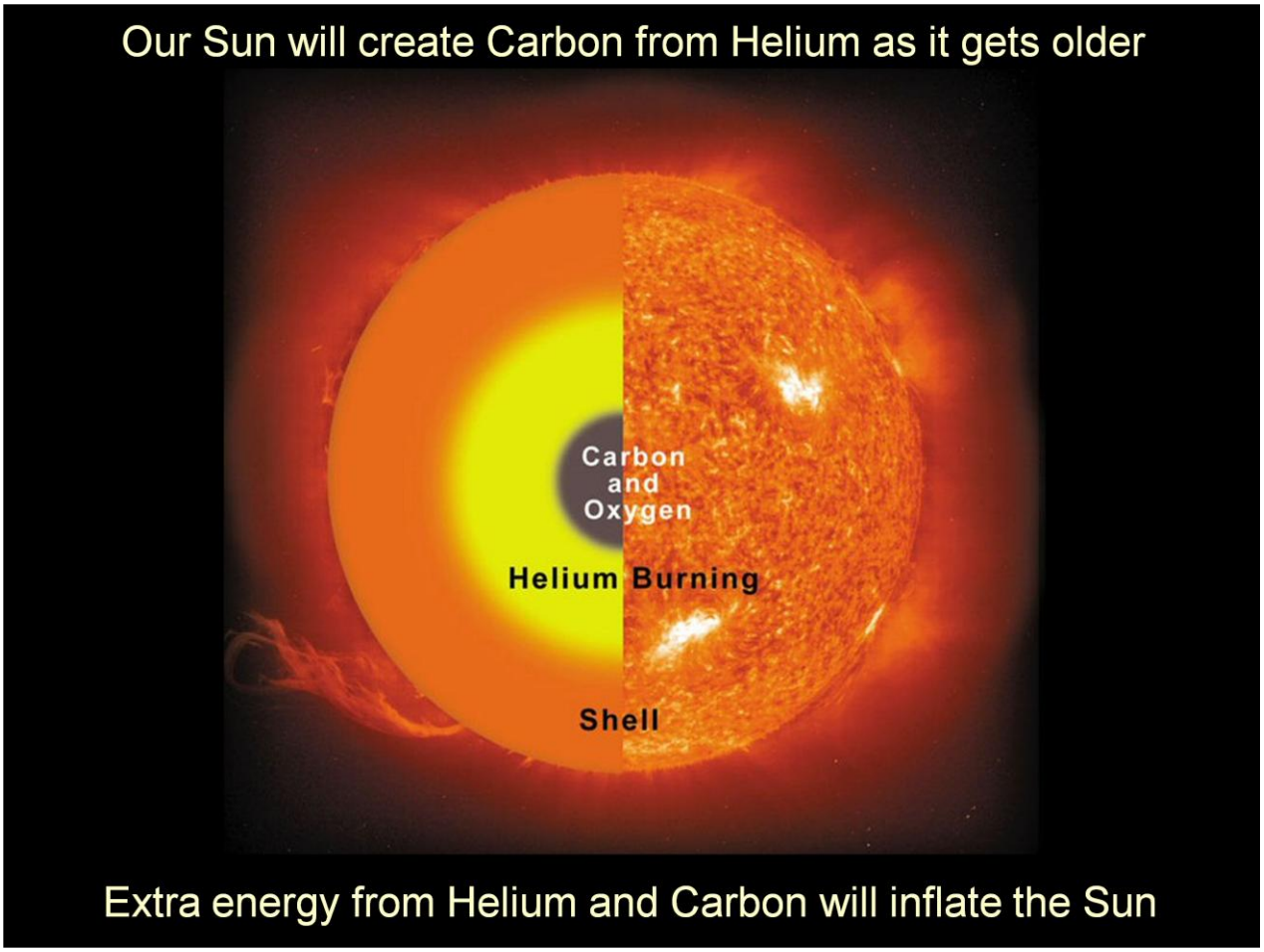
The mass was converted into energy as seen in Einstein's famous equation $E = mc^2$ where E = Energy, m is Mass and c is the speed of light.

The lost mass has been converted into a Gamma Ray that quickly hits another atom and is absorbed.

To stabilise, the excited atom quickly releases the unwanted Gamma Ray energy as an X-Ray that then continuously hits other atoms and is absorbed and then released again and again.

X-Rays gradually travel away from the core through a 'Radiative Zone' until they reach the 'Convective Zone'.

The less dense Convective Zone absorbs the heat and is convected (boils) up to the surface (Photosphere) where the energy is radiated away from the Sun as white light.



Our Sun has been processing Hydrogen into Helium for about 4.5 billion years.

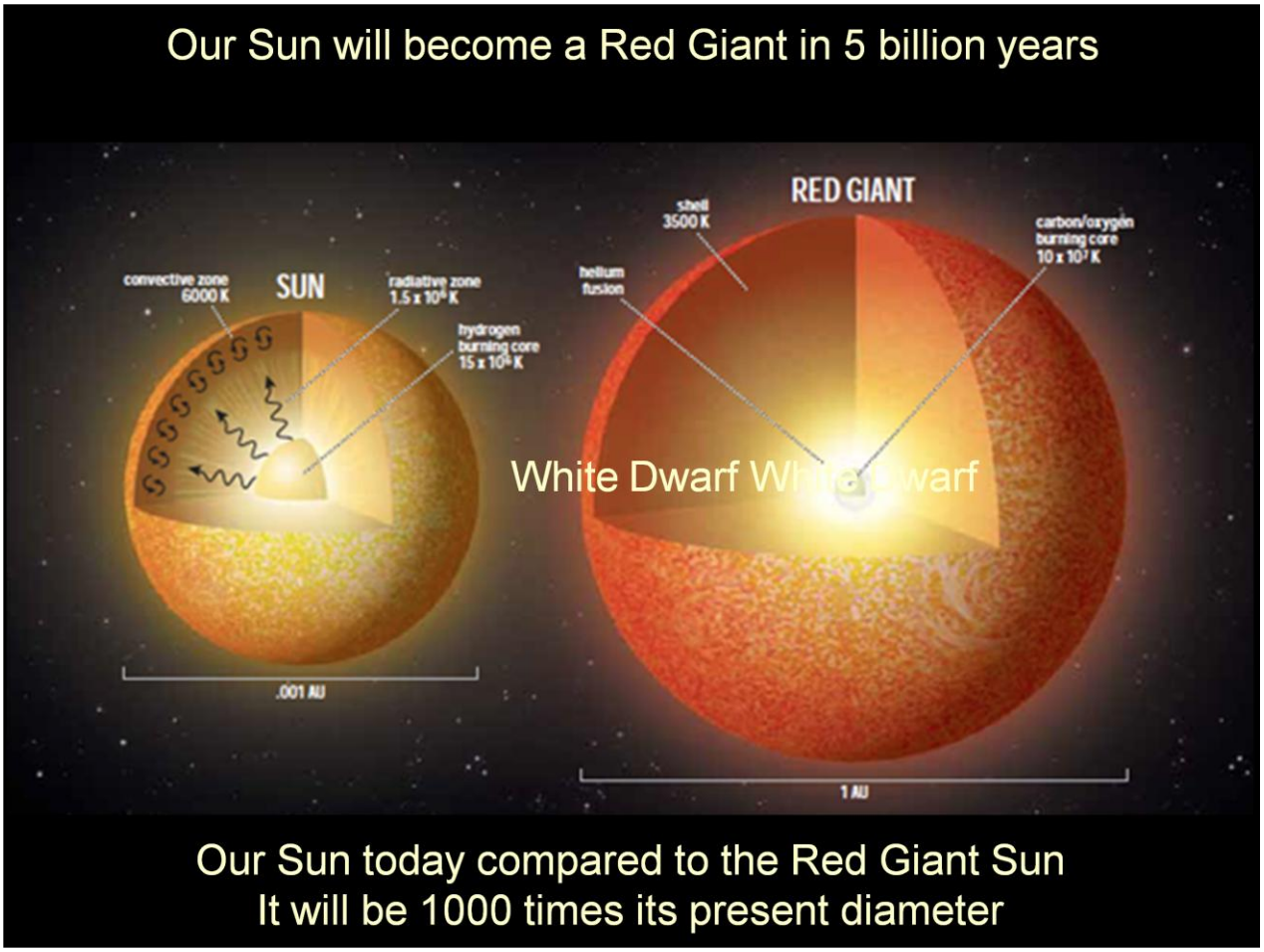
It has enough Hydrogen to last about another 4.5 billion years.

Helium builds up in the centre of the core so the Nuclear Fusion zone occurs on the outside of the developing Helium inner core.

In about 3 to 4 billion years time the Helium Nuclear Fusion will begin to fuse Helium into Carbon.

This Helium / Carbon fusion will produce additional energy and radiation that will push outwards and the Sun will begin to expand.

The diameter of the Sun will increase to beyond the orbit of Earth so Mercury, Venus and Earth will be consumed by the Sun.

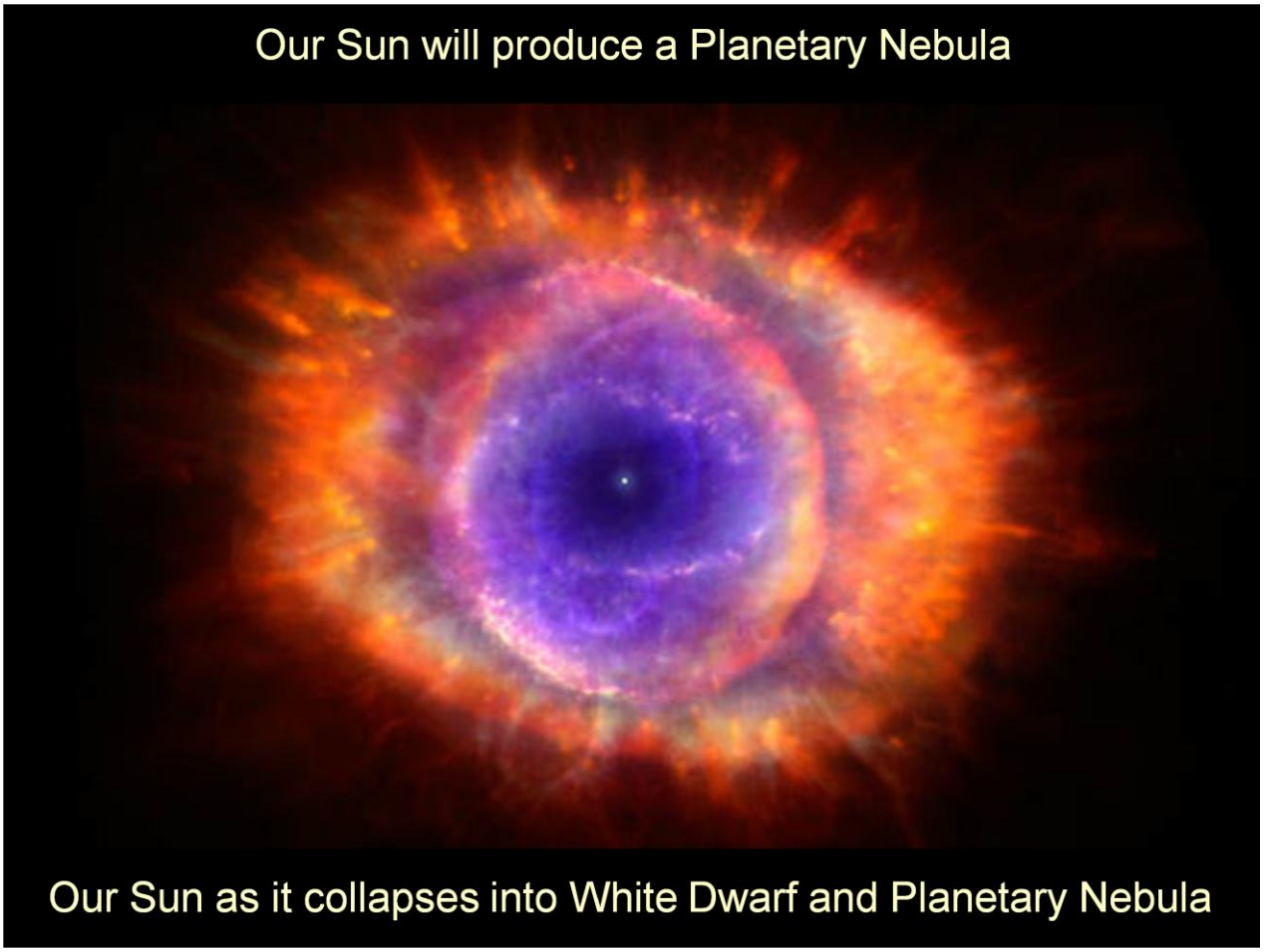


As the Sun expands the heat produced in the core will be distributed over the much larger surface.

Receiving less heat the surface will be cooler so will become yellow then orange and finally red.

Our Sun is currently 1.4 million kilometres in diameter but as develops into a Red Giant it will expand in diameter to between 300 million to 400 million kilometres.

Eventually as the Hydrogen and Helium fuel runs out gravity will start to take over and the Sun will slowly collapse.



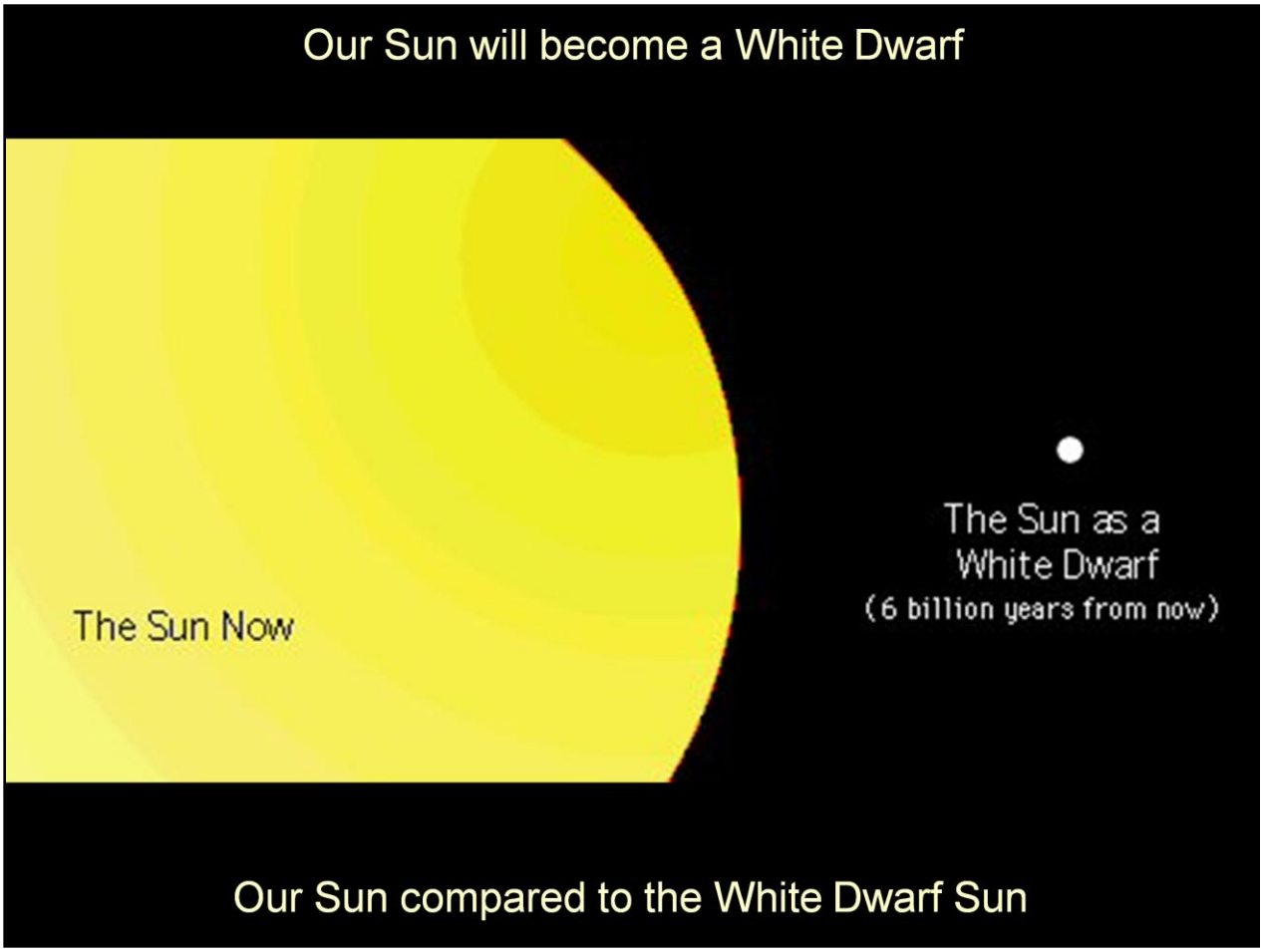
With the Nuclear Fusion reducing the outward force provided by the radiation starts to lessen.

Gravity begins to pull the gas in towards the core and the Sun will eventually be compressed to about the size of Earth (12,756 kilometres).

The enormous pressure compresses what remains into white hot Carbon sphere known as a White Dwarf Star.

The outer layers of the Red Giant will be left behind to form a halo that will continue to expand and dissipate.

So our Sun may develop into a Planetary Nebula (like the one shown above) with a central White Dwarf that was formerly our Sun.



After the Planetary Nebula Halo has dissipated our Sun will spend billions of years as a White Dwarf.

White Dwarfs slowly cool down from their original temperature of ~50,000ºC until they become cold Black Dwarfs.

White Dwarfs can exist up to 1.4 times the mass of our Sun (today).

The larger White Dwarfs can compress to transform their Carbon into Diamond and become a planet sized diamond.

If the created White Dwarf exceeds the 1.4 Sun size its structure will collapse further and form into a Neutron Star.

A Neutron Star it about 25 km in diameter, will weigh more than our Sun and will be rotating very fast.

White Dwarfs can be between 0.5 to 1.4 times the mass of our Sun when their star collapses.

A White Dwarf Star typically has a temperature of between 50,000ºC and 100,000ºC when they form.

So although they are very small the do shine very brightly.

They are incredibly dense with an average density of about 1 billion tonnes per cubic metre.

White Dwarfs are cooling down but they are expected to take trillions of years to cool completely.

When they have completely cooled the will not emit any light and will become a Black Dwarf Star.

Beginner's Website:

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