Events in the Life of a Star
A Self-Paced Workshop
(A)

How old is our Sun? Is that the question you really want to know? I don't! I'd much rather know how much longer the Sun will be around. Wouldn't it be nice to be able to tell that information just from looking at a star? Follow these steps to lifeline of stars and you will be able to construct a simple chart that will help you be able to tell how much longer a star is going to "live" based on how it looks.

These are some important events in the history of the universe. Using chapter 25 in your textbook, research each of them and answer the following information portions.

The Big Bang

When:

Average Universe Temperature:

What is it?

What supporting evidence do we have?

Cool factoid: 1% of the "snow" on a poorly tuned TV station is due to cosmic background radiation

Where did you find your information?

Only Plasma Exists

When:

Average Universe Temperature:

What is it?

Where did you find your information?

Primordial Nucleosynthesis

When:

Average Universe Temperature:

What is it?

What supporting evidence do we have?

Where did you find your information?

(B)

Now we are going to create a timeline for the important events in the history of the universe. Our timeline is fourteen Ms.Lunits long. Since the beginning, or the big bang, took place (1)__________________[1] billion years ago, that means that each Ms.Lunit is equal to (2)__________________ billion years.

How do we find the information to fill in blank number two? Well, we divide the information from blank number 1 by 14.

Place the Following on the Timeline:

(1) Mark all vertical lines with their appropriate time measurements.
(2) Mark locations for the events from part A.
(3) Mark locations for these additional events --
    10,000 years after the big bang – Radiation Era
    300,000 years after the big bang – Matter Domination Era
    300 million years after the big bang – Stars and Galaxies Form
    5 billion years ago – Birth of the Sun
    3.8 billion years ago – Earliest Life Forms
    700 million years ago – Primitive Animals Appear
    200 million years ago – Mammals Evolve
    65 million years ago – Dinosaurs are Extinct
    600,000 years ago – Homo Sapiens[2] Evolve
    170,000 years ago – Supernova 1987A Explodes
    952 years ago – Crab Supernova Appears
    397 years ago – Galileo Builds First Telescope
    341 years ago – Newton Describes Gravity
    101 years ago – Einstein Publishes Relativity
    77 years ago – Hubble Discovers Universe Expansion
    46 years ago – Quasars Discovered
    42 years ago – Microwave Radiation Discovered
    39 years ago – Pulsars Discovered
    19 years ago – Supernova 1987A Reaches Earth
    16 years ago – Hubble Telescope Launched
    16 years ago – Big Bang Theory Confirmed
    13 years ago – Hubble Telescope Repaired
(4) Mark the temperatures for the universe from part A.
(5) Mark the absolute right-most portion of the time line "present day".

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[1] Fill in this blank with the answer from part A to "The Big Bang: When".
[2] That is in reference to humans. *Homo sapiens* is the Latin name for "person".

The next step is to, as a workshop, assemble a long timeline paper strip and place these events on the paper strip at an appropriate scale.

We now have a universe-sized cloud made up of mostly hydrogen with a bit of helium (aka interstellar gas and dust), what is another word for this?

What trend (aka relationship) do we see in between the age of the universe and the temperature of the universe?

USEFUL RESEARCH INFORMATION

From Earth Science and the Environment (third edition) by Graham R. Thompson and Jonathan Turk

24.1 In the Beginning: The Big Bang

In our search for the origin and history of the Earth, we have looked back more than 4.6 billion years to the time when a diffuse cloud of dust and gas coalesced to form the Solar System. But now, as we look into our galaxy and beyond, we ask, "How did that cloud of dust and gas form?" As our search for answer deepens, we finally ask, "How and when did the Universe begin?"

Before we explore the origin of the Universe, we must ask an even more fundamental question: "Did it begin at all?" One possibility is that the Universe has always existed and there was no beginning, no start of time. An alternative hypothesis is that the Universe began at a specific time and has been evolving ever since.

In 1929, Edwin Hubble observed that all galaxies are moving away from each other. By projecting the galactic motion backward in time, he reasoned that they must have started moving outward from a common center, and at the same time. Therefore, scientists calculated that in the beginning, the entire Universe was compressed into a single infinitely dense point. This point was so small that we cannot compare it with anything we know or can even imagine. According to modern theory, this point exploded. But it was no ordinary explosion. It cannot even be compared with a hydrogen bomb or supernova explosion. This explosion, called the **big bang**, instantaneously created the Universe. Matter, energy, and space came into existence with this single event. It was the start of space and time.

Astronomers calculate the timing of the big bang by measuring speeds of galaxies and the distances among them. They then calculate backward in time to determine when they were all joined together in a single point. In 2003, astronomers combined a variety of techniques to determine that the Universe is 13.7 billion years old.

Scientists generally start their discussions of the origin of the Universe when it was a trillionth of a trillionth of a billionth of a second old. How can we reach that far back in time with any degree of certainty? In one series of experiments, scientists studied the collision behavior of particles at very high velocities in modern particle accelerators. These results are then compared with observations of deep space. In the 75 years since Hubble's pioneering work, the experiments, observations, and calculations have led to disagreements, paradoxes, and unsolved mysteries. Yet the preponderance of evidence is so persuasive that almost all astronomers agree with the fundamental premise of the big bang theory. The first is the expansion of the Universe, discussed above. To understand the second two, we must study the first 300,000 years in the life of the Universe.

Let us go back to that unimaginably distant time when the Universe was a trillionth of a trillionth of a billionth of a second old. At that time, the Universe was only about as big as a grapefruit and the temperature was about 100 billion degrees Kelvin (written 100 billion K)[3]. But this primordial Universe was expanding rapidly as it was propelled outward by the force of the explosion that formed it. As the Universe expanded, it cooled. During the first second, the Universe cooled to about 10 billion degrees, 1000 times the temperature in the center of the modern Sun. At such high temperatures, atoms do not exist. Instead, the Universe consisted of a plasma of radiant energy, electrons, protons, neutrons, and extremely light particles called neutrinos.

Over the next few minutes, the most exciting action came from the behavior of protons and neutrons. Recall that protons are positively charged particles. At large distances (by subatomic standards) two positive protons repel each other, like two north poles of a magnet. However, if protons are hot enough, they collide with sufficient energy to overcome the repulsion. At very close distances, two protons attract and bond together. This bonding is called **fusion**. Hot protons also fuse with hot neutrons.

A hydrogen nucleus consists of a lone proton. At the right temperature, 4 protons (hydrogen nuclei) fuse together to form a nucleus of the next heavier element: helium. This nuclear fusion is identical to reactions that occur in a star or in a hydrogen bomb.

When the universe was less than 1.5 minutes old, it was so hot that the helium nuclei were blasted apart almost as soon as they formed. After 10 minutes, the Universe was so cool that fusion could no longer occur. Thus, the formation of helium nuclei, called **primordial nucleosynthesis** occurred over a time span of 8.5 minutes. Enough fusion had occurred during this time so 6 percent of the total nuclei in the Universe were helium, while 94 percent remained as hydrogen nuclei. Although primordial nucleosynthesis created a trace of lithium (the next heavier element after helium) it did not produce any heavier elements. There was no carbon, nitrogen, or oxygen, so life could not have evolved, no silicon or metals, so solid planets could not have evolved. The Universe was still in its infancy.

When scientists calculate the expected ratio of hydrogen to helium in the modern Universe from the conditions of the primordial Universe, they arrive at a number almost exactly in agreement with the observed abundances. This agreement provides the second line of evidence and logic to support the

[3] Astronomers generally report temperature on the Kelvin scale which is based on fundamental thermodynamic properties. 0˚C = 273Kelvin (no degrees symbol for K). At high temperatures, the 273 degree difference between the two is negligible.

big bang theory. It is also a testimonial to human genius.

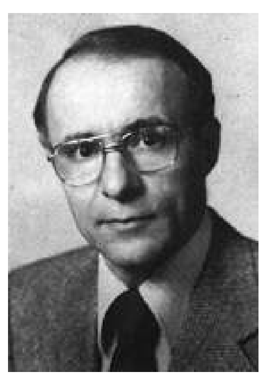
As the Universe continued to expand, it finally cooled to a few thousand degrees by about 300,000 years after the big bang. At this crucial temperature, electrons became attached to the hydrogen and helium nuclei. Thus the first atoms formed and, in a sense, the modern Universe was born.

Before atoms existed, the Universe was a chaotic plasma that scattered and absorbed photons. As a result, photons could never move far in any direction. The Universe was fog-like or opaque. But when electrons combined with nuclei to form hydrogen and helium atoms, conditions changed radically. An atom absorbs light in only a relatively few specific wavelengths. All the rest of the light passes through unhindered. Thus a hydrogen and helium-filled Universe is ore like a pair of sunglasses. Sunglasses filter out certain wavelengths of light, but permit other wavelengths to pass through.

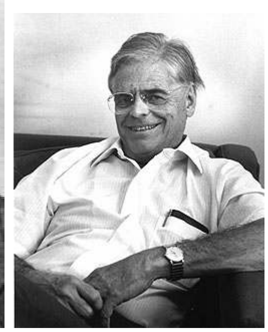
In the 1960s, an astrophysicist at Princeton named Robert Dicke predicted that we should be able to detect the primordial photons that began moving in a straight line as soon as atoms formed. He calculated that the continued expansion of the Universe would have cooled the primordial photons to about 2.7K (2.7°C above absolute zero.) In 1964, Arno Penzias and Robert Wilson at Bell Laboratories detected a very faint photon radiation that was 2.7K and was uniformly distributed throughout space. Thus experimental observation agreed with Dicke's calculation.

Walk outside at any time of day at any place on Earth and turn your palm to the sky. Every second, a million billion low energy photons will strike your palm. These photons are in the microwave band of the electromagnetic spectrum. The energy is so faint and weak that you could never feel it. Yet, this **cosmic background radiation** began traveling through space when the Universe was only 300,000 years old. Today, the cosmic background radiation is called the echo of the big bang. The prediction and discovery of the cosmic background radiation provides the third convincing line of evidence to support the big bang theory.

Robert Dicke



Arno Penzias



Robert Wilson