College Guild
PO Box 6448 Brunswick, Maine 04011

~ SCIENCE SAMPLER ~

Unit 1 of 5

Astronomy

Greeting from College Guild! Welcome to the amazing world of science. Volunteer readers will be giving you feedback on your answers. Here are some guidelines for all CG courses:

1 - Answer all the questions that are in bold print. When we receive a completed Unit back, you'll be sent the next one, along with your original work and feedback from your reader. You don't need to return the questions – it saves us both postage.

2 - Take the time to read the questions thoroughly and find the most creative way to word your answers. There is no specific deadline to complete any Unit, but we would get concerned if we hadn't heard back from you in 2-3 months. You can ask for an extension if your own circumstances make that necessary. Remember how often the mail service loses things and if you don't hear back from us after a month, write to make sure your Unit was received and the next Unit sent out.

3 - Let us know if you need a dictionary, free to CG students who complete the first Unit.

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Introduction

Did you ever ask, Where did we come from? Why are we here? What is out there in the universe? It turns out that those simple questions do not have simple answers. For some of those questions we do not even have answers…YET! The universe is beautiful and mysterious. In this course we will uncover some of those mysteries.

This is a general science course, which means that it will cover different branches of science. The course is divided into five units: astronomy, geology, physics, chemistry and biology. Each unit will address different questions, but at the core they all try to uncover the same mysteries: *Where do we come from? Who are we?* There are many different answers to that question, coming from disciplines ranging from religion to science. But how will we know the right answer? So far we don't know anything for sure; we are still looking!

1. Where do <u>you</u> think we come from?

Now, let's take a tour of the cosmos![1]

Astronomy

In this unit we will study the birth of the universe, some celestial objects, and properties of light. Let's start from the very beginning, around 13.8 billion years ago!

Part 1 - The Big Bang Model

2. List five things astronomers might study. Which is the one that interests you the most and why?

Scientists believe that before 13.8 billion years ago, nothing existed: no space, no time, and no matter. But doesn't that sound impossible? How did we get from nothing to all the beautiful phenomena in the universe? The night sky is filled with billions of stars. Our planet Earth is filled with life. If there was nothing, how come there is something now? How could the universe provide the perfect conditions for the beginning of life, including intelligent life? Yes, the universe is unquestionably beautiful yet mysterious!

3. The universe seems to have emerged from nothing. Give another example of something that has emerged from nothing, (even if you have to make it up).

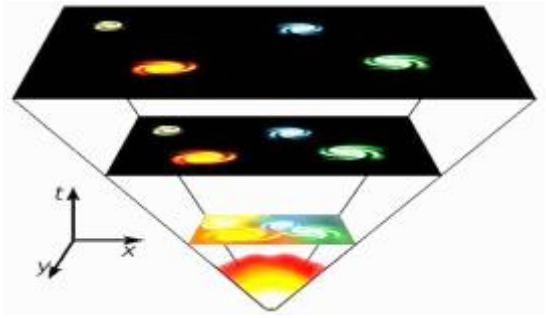
We human beings are curious. Since our Greek ancestors' period, we have been trying to uncover the underlying rhythm of the cosmos.

4. How does curiosity hurt and help our species? Has that changed from early mankind to today?

At the time of the ancient Greeks, we believed that the universe had always existed. There was never a beginning, and there would never be an end. Then a great astronomer named Edward Hubble (1889-1953) made an astounding observation: the expansion of the universe. Hubble observed that the Galaxies were shifting apart, moving away from each other. The logic goes as follows: if the galaxies are moving away from each other, then there must have been a time in which all the galaxies were bunched tightly together. That observation implies that there was a beginning, a time in which the universe was denser and hotter. When and how the universe was born are the tricky questions. But with Hubble's observation, we were closer to uncovering the truth. This evidence (along with some other, such as the existence of the cosmic microwave background) favored the Big Bang model.

5. In detail, what do you imagine when you think of "The Big Bang Theory"?

For most people, the first picture that comes to mind is a huge explosion. That's what the name implies. But that is one of the big misconceptions of the Big Bang theory. Instead, scientists encourage us to think of the Big Bang, not as an explosion in space, but rather as an expansion of space. We have a universe in which space itself is becoming bigger and bigger. To understand this, let's travel back in time. Instead of expanding outwardly, we will imagine everything in our universe shrinking down to a single point. Look at the image below:[2]



Starting from the bottom of the picture, the universe began from a point, but moving upward (going forward in time), it got bigger and bigger. For now, just focus at the bottom of the picture, at that single point. The Big Bang theory explains what happened during and after that moment. What happened before then? We don't know! Scientists believe that nothing existed before the Big Bang.

6. If you were a writer or poet, how would you describe "nothing"? If you were an astronomer, how would you describe it?

According to the Big Bang Theory, our universe jumped into existence as a singularity. What is a singularity? In physics, a singularity is a point, an infinitely small place, where gravity is so powerful that everything is crushed into one point of infinite density. From that very hot and dense point, the universe was born. When that point started to expand, it released an unbelievable amount of energy. It started to expand even faster than the speed of light. The universe was unstable during that time; it was so hot and dense that not even matter was stable. But as the universe expanded, it cooled down. As it started to cool, matter started to form from all the energy released from the singularity. You might wonder how it is possible for energy to convert into matter. That question was answered by Albert Einstein (1879-1955), a physics genius, who developed a formula to show how energy is converted into matter, and vise-versa: $E= mc^2$, where "E" is energy, "m" is mass and "c" is the speed of light.

Protons and neutrons were formed during this time. Protons and neutrons are subatomic particles which make up atoms. (We will talk more about them in Unit 3: Chemistry). Protons are positively charged, and neutrons have no electric charge. When neutrons combined with a proton, they formed the nucleus (center) of a hydrogen atom. When neutrons combined with two protons, they formed the nucleus of a helium atom.

7. What do you imagine the centers of hydrogen and helium atoms look like? Draw sketches of hydrogen and helium nuclei.

One would think that it would take years for all these processes to happen, but no! They all happened a minute after the universe was born! Then, electrons (subatomic particles with a negative electrical charge) were formed. Even after the electrons were formed, the universe was too hot for the electrons to combine with other particles. While the universe grew and cooled down, electrons, neutrons and protons were the only thing that existed in the universe for three hundred thousand years after the Big Bang. After that, it was cool enough for electrons to join the hydrogen and helium nuclei—the first atoms to be formed in the universe.

8. What is the difference between a hydrogen <u>nucleus</u> and a hydrogen <u>atom</u>?

During that time, the universe was made mostly of hydrogen and helium gas. Over a period of 10 million years, matter started to cluster together in denser clouds. After 1,000 million years, the center of those dense clouds became stars. Within those stars, helium and hydrogen were converted into heavier elements; eventually, these first stars collapsed into themselves and exploded, sending all those heavier elements out into the universe. After those big explosions, referred to as *supernovas*, it took around five hundred years for new stars to be born. At that time, we had thousands of billions of stars. Those new stars started to cluster into small groups, creating galaxies. Our home, the solar system, started to form 4.6 billion years ago. Our sun, our planet Earth, and many other planets were formed. Our sweet home was born!

9. Given the time scale of the formation of the universe, do you feel that humans are lucky to exist, or were we meant to exist? Do you believe human-like creatures exist in other places in the universe? Explain your reasons.

10. Pick one of your answers to #9. Pretend you are debating someone with the opposite viewpoint from yours. Try to convince that person that your view is more valid.

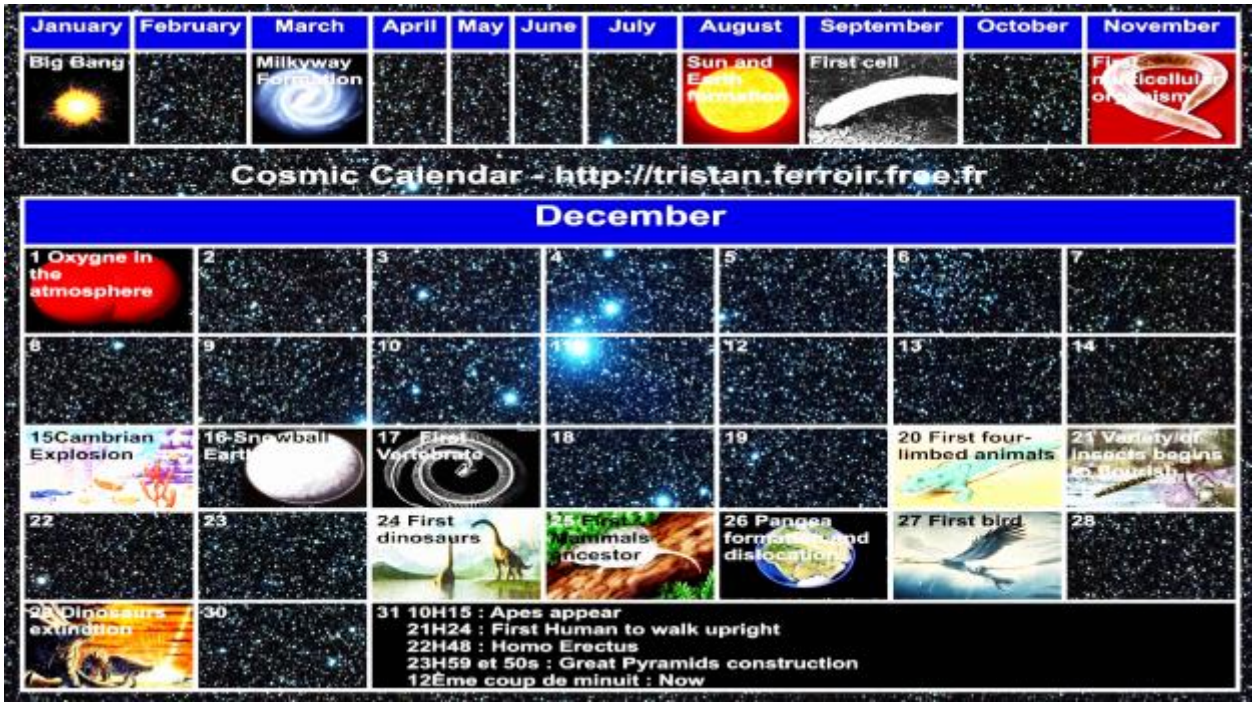
If we model the timeline of the origin of the universe until our existence into a calendar, the illustration on the next page shows how the calendar would look.[3]

Here is the written version of the calendar:

Jan - Big Bang
Mar - Milky Way Formation
Aug - Sun and Earth formation
Sep - First cell
Nov - First multicellular organism

Dec 1 - Oxygen in the atmosphere
Dec 15 - Cambrian explosion
Dec 16 - Snowball Earth
Dec 20 - First four limbed animal
Dec 21 - Variety of insects begins to flourish
Dec 24 - First dinosaurs
Dec 25 - First mammals' ancestor
Dec 26 - Pangea formation and dislocation
Dec 27 - First bird
Dec 29 - Dinosaurs' extinction
Dec 31 - An explosion of life

Using this calendar, humans came into existence during the last minutes on December 31st!



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Part 2 - Celestial Objects: Planets and constellations

Now that we know how the universe was formed, we will explore celestial objects and the scale of the universe. Here is our solar system:[4]

11. Why do you think all the planets are round?

There are eight planets in our solar system, starting with Mercury (closest to the sun), Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. There are also some other smaller bodies, such as dwarf planets, asteroids and comets. There is only one star in our solar system, which is the Sun.

12. Saturn is the most unusual looking planet with its rings. Describe what a sunrise and sunset would look like on Saturn.

You might wonder how we differentiate a star from a planet, and even a planet from a dwarf planet. Here are some astronomical definitions:

- **Star:** a star is a luminous ball of gas made mostly of hydrogen and helium. It is held together by its own gravity. It produces its own energy due to nuclear reactions that happen deep in its core. Example: Our Sun.
- **Planet:** a planet must be a celestial object that orbits a star and has enough mass to be round. It cannot rotate around another planet. Example: Earth.
- **Dwarf Planet:** a dwarf planet is neither a planet nor a satellite. It does orbit a star just like a planet does, but it does not have enough gravitational force to pull celestial objects into its orbit. Example: Pluto.
- **Asteroid:** an asteroid is a small rocky body, sometime referred to as a minor planet, that orbits the sun.
- **Comet**: a comet is a small icy celestial object. When it passes close to the sun, it heats up and forms a tail.

The picture on the left[5] is an asteroid, and on the right is a comet.[6]

Orbiting the Earth is a satellite called the Moon. Like Earth, Mars also has moons orbiting it, two of them. In between the planet Mars and Jupiter, we have an asteroid belt, a part of the sky filled with many asteroids. Jupiter, Saturn, Uranus and Neptune have numerous moons in their orbits. Beyond Neptune, we have a *Kuiper Belt*, which is similar to the asteroid belt, but where we find even more asteroids in addition to dwarf planets! Beyond the Kuiper Belt is an *Oort cloud*, a cloud made of icy celestial objects and gas. And this is our Solar System!

13. Pick the asteroid belt, Kuiper Belt, or Oort cloud and think of an explanation for it. You can think of a scientific explanation or make up a story to explain its existence.

14. Why would an asteroid belt be found between only two of the planets?

Our Solar system is part of the *Milky Way Galaxy*, which is a collection of stars, gas and dust. Our galaxy has approximately 200-400 billion stars, some of which have their own planets surrounding them. Our Milky Way is a member of a small collection of galaxies, called the *Local Group*. The Local Group is a member of a large collection of thousands of galaxies called the *Virgo Supercluster*! And this is our "cosmic address".

15. Write out our entire cosmic address as if you were addressing a letter.

What is contained in our cosmic address is just what we can see. The universe extends far beyond this! In fact, it is often said that the universe is like a vast ocean of stars. There are around 100 billion galaxies in our observable universe. This means that there are approximately 1 billion trillion stars in our universe! Yet among 1 billion trillion stars, ONLY one star that we know of has a planet that supports life. Life may exist only on our planet Earth, and we could have easily not existed! If the strength of the gravitational force was slightly smaller, matter would never have combined to form a star. We are here because the universe provided the precise conditions for the existence of life. Once, a teacher when asked why the universe is so beautiful, replied, "*The same patterns that appear in the stars, in the oceans, in the earth, in our bodies, in nature, in machines, everywhere are like music: the same basic elements combine in millions of different ways to give us millions of different things, but they're all music.*"

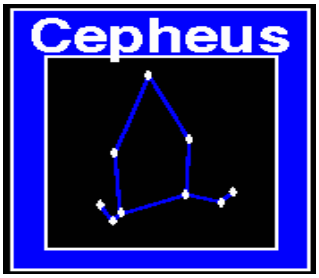
16. What would you compare the universe to?

17. Write a poem about a star, a galaxy, the sun, the moon or one of the planets.

18. Of all the things we have discussed so far, what did you find most surprising?

Unfortunately, most of the universe is invisible to the naked eye. We need telescopes to see other planets and far away stars because they are billions of light years away from Earth. Sometimes the planets Venus, Mars, and Jupiter can be seen in the night sky, but they don't look like planets. Instead, they appear as very small lights in the sky—like stars.

When you look up at the night sky, there are many stars. Sometimes those stars form recognizable patterns or shapes, which we call constellations. Most constellations' names are based on Greek mythology. Currently, there are 88 recognized constellations. They include Ursa Major and Ursa Minor (that look like bears), Cygnus (swan), Leo (lion), Pisces (fish), and Cepheus (which looks like a little house).[7]



19. Think of a modern day object that would match the pattern of stars in one of these ancient Greek constellations. What would you call your constellation?

20. Pick 2 constellations, bring them to life and pretend they are meeting in the sky. Tell a story about what happens when they meet.

21. Draw the pattern of the new constellation that forms when these 2 constellations meet.

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Part 3: Light and Astronomical Measurement

Given that the planets and Stars are very far away from Earth, how do astronomers know about them? How can astronomers measure their distance from us? One of the most important tools in astronomy is the telescope. Telescopes allow us to capture light from far away, and to magnify far away objects. There are many types of telescopes, but the optical telescope is the most well-known and widely used.

Light tells the secrets of the universe. In their book *Astronomy*, astronomers Kay, Palen, Smith, and Blumenthal call light the "most informative messenger." An entire course could be spent on the properties and laws of light, but here are just a few of light's characteristics:

- Nothing, including matter and energy, can travel faster than light through space.
- Light travels at 300,000,000 meters per second.
- Light carries information and energy.

Our knowledge of the universe comes from light. For each object, light carries information about that object's temperature, composition, and speed.

22. Name 5 uses of light in our daily lives.

We know how far away a star is based on how long it takes the light from that star to travel from the star to us. Astronomers use the term *light-year* to refer to the distance that light travels within one year, about 9.5 trillion kilometers. We use light-years instead of kilometers, because those stars are so very far away from us. But within our solar system, we use *Astronomical Units* (AU) to measure distances between the planets. One astronomical unit is the distance from the Sun to Earth, which is about 150 million kilometers. So, the Earth is one astronomical unit from the Sun. Mercury is 0.39 astronomical units from the Sun, and Venus is 0.723 astronomical units from the Sun.

23. Would you rather travel to other galaxies or explore our own solar system? Explain.

24. Write a letter to a friend or family member from a space explorer.

25. What part of astronomy would you choose to study in more depth? Is this the same answer you gave for #2?

It is almost impossible to imagine the scale of the universe! Actually, we don't even know the scale of our universe. We are within the universe, but we don't know if the universe has an edge. What would it mean for the universe to be infinite or finite? If we can't see it, how do we know? Even with all these unknowns, we are still amazed by the beauty of the universe! The universe is like a puzzle, and we are here trying to arrange all the pieces of that puzzle!

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Remember: First names only & please let us know if your address changes

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