Earth Science 11 - Week 5: May 11 – 15

Anticipated time required: 3 hours

New learning objective: **Formation of the universe through the big bang and the electromagnetic spectrum**

Goals to be completed:

1. Construct a timeline of the big bang

2. Differentiate between different frequencies on the electromagnetic spectrum

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Please read through the lesson package and watch all of the videos included within it. The formal portions to submit are indicated throughout the package. These can be sent to Charlie.feht@yesnet.yk.ca either as a scanned and uploaded PDF attachment to email, or as a jpeg image file.

Upcoming next week:

The uniqueness of earth

The earth – sun – moon interaction system

Section 1: The big bang and the formation of the universe

Background

Before we begin this package, please note that there is an extremely high volume of extra detail required to fully understand exactly what is going on with the formation and expansion of the universe. Astrophysicits have been working for decades attempting to describe the big bang and theorize how our universe began. The bottom line is that we don't know everything about what happened before the big bang, what the future holds for the universe, or if our theories are 100% accurate. Quantum theory, general relativity and string theory require a high understanding of physics and subatomic particles/forces to properly describe how the universe behaves and interacts. If you are curious, I highly suggest doing your own research into the topic to learn as much as you can about the universe you live in. For this package, we will be doing a general and simplified overview of the timeline of the big bang, and the expanding universe. If you see a term that peaks your interest – I encourage you to look it up!

So what is the big bang?

The big bang is the accepted theory that describes how our universe was formed. It states that all energy and matter exploded out of a singularity (1 infinitely small and dense point) to form everything in our universe. Watch the following video to summarize the big bang:

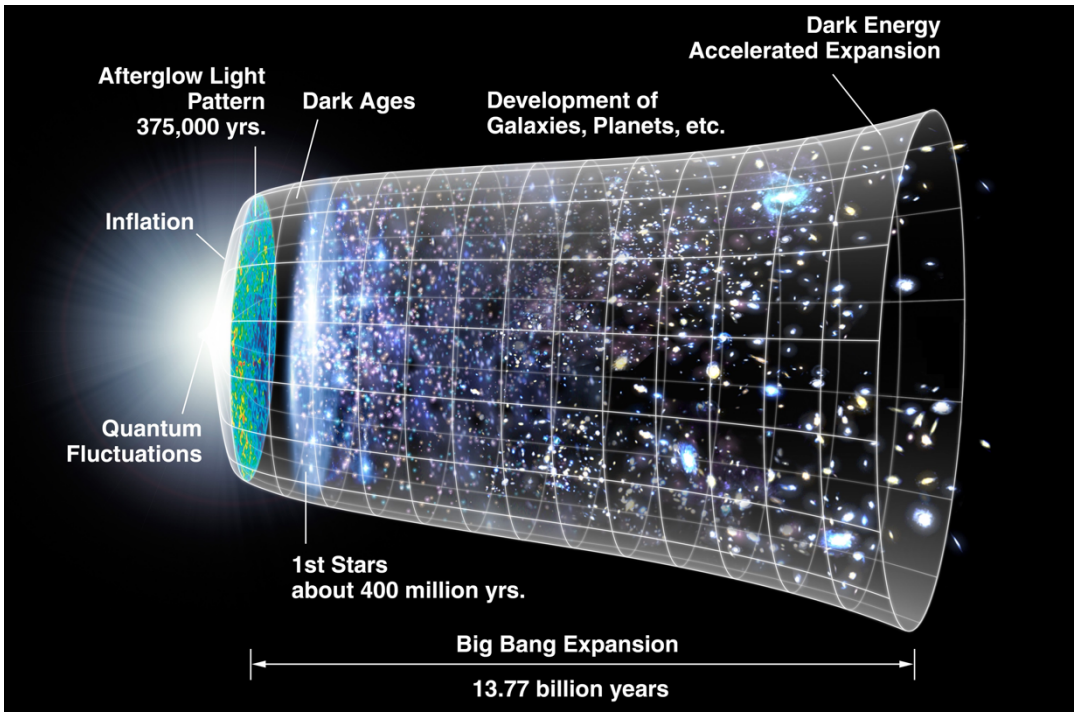
https://www.youtube.com/watch?v=wNDGgL73ihY

Curious about what came before the big bang? Well, we don't really know. But check out this video that suggests a few possible ideas such as the big bounce:

https://www.youtube.com/watch?v=qQX4mKvqSoo

Curious about string theory? Check out this detailed explanation below:

https://www.youtube.com/watch?v=Da-2h2B4faU



Lets start with the timeline of the big bang that all scientists accept as true.

Approximately 14 billion years ago, all matter and energy of the known universe was contained in a volume one trillionth the size of a grain of sand. This point rapidly expanded with immense heat in a big bang.

1. The Plank era
    a. From t = 0 (time does not exist yet) to t = 10^{-43} (one ten million trillion trillion trillionth of a second)
    b. The universe expands from a singularity to a distance of 10^{-35} metres wide
    c. Temperature is over 10^{32} degrees Celsius

2. The grand unification era
    a. From t = 10^{-43} to t = 10^{-36}
    b. The force of gravity is separated from all the other fundamental forces that remain unified

3. The inflation era
    a. The strong nuclear force (the force that binds protons and neutrons together) separates causing a rapid expansion of the universe known as cosmic inflation
    b. The universe is now the size of a grapefruit
    c. The remaining two fundamental forces separate, giving us the four known fundamental forces of the universe: 1) Gravity 2) Strong nuclear force 3) Weak nuclear force (responsible for radioactive decay of subatomic particles) and 4) Electromagnetism (interaction between charged particles)

4. The quark era
    a. t = 10^{-32}
    b. Subatomic particles form including bosons, quarks, leptons and neutrinos
    c. Antimatter forms alongside regular matter

5. The hadron era
    a. t = 10^{-6}
    b. As the universe continues to expand, the temperature drops to 1 trillion degrees Celsius
    c. It is now cool enough for hadrons to form, which give rise to protons and neutrons

6. The nucleosynthesis era
    a. t = 1 second
    b. The universe grows to a few light years across and cools to 1 billion degrees Celsius
    c. Most of the antimatter has been destroyed and nuclear fusion allows hydrogen and helium to form

7. The photon era
    a. t = 2 minutes
    b. Visible light begins to form, but cannot be seen through the density of the universe

8. Recombination and Decoupling
    a. t = 240,000 – 300,000 years
    b. Universe temperature falls to 3000 degrees Celsius
    c. Universe becomes visible and transparent to light as density decreases

9. The dark age
    a. t = 300,000 to 150,000,000 years
    b. The period before the formation of any stars

10. Star and galaxy formation
    a. 300 to 500 million years and onwards
    b. Gravity causes cosmic gas to collapse in nuclear fusion to form stars and galaxies

11. Solar system formation
    a. 9 billion years ago
        i. Our sun forms
        ii. Planets begin to form and take shape around the sun
    b. 4.6 billion years ago
        i. The earth forms

12. Today
    a. Approximately 14 billion years have passed since the big bang
    b. The universe continues to expand at an exponential rate
    c. Temperature is approximately 3 Kelvin (-270 degrees Celsius)

Check out the videos below to help you understand some of the material mentioned above.

The four fundamental forces of the universe:

https://www.youtube.com/watch?v=a-6skWBuHaE

Elementary and subatomic particles influencing the fundamental forces:

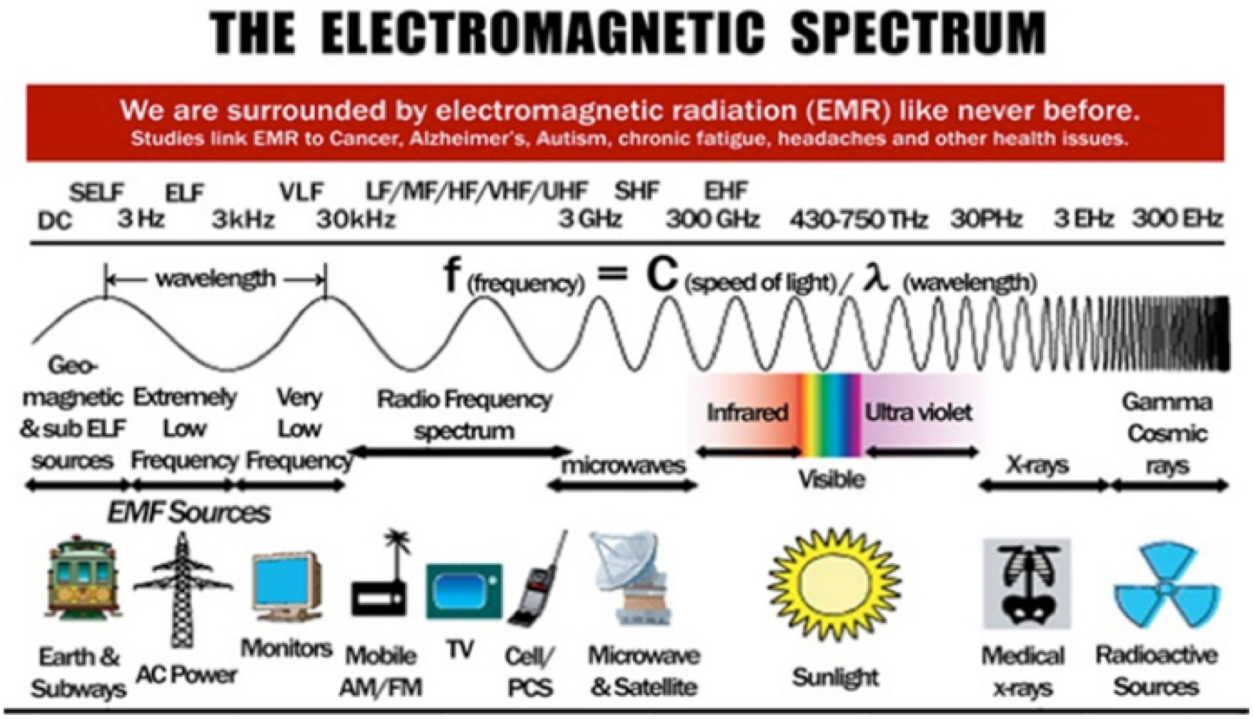
https://www.youtube.com/watch?v=ehHoOYqAT_U

Sections 2: The expansion of the universe and electromagnetic radiation

Scientists know that the universe is expanding because of an observed redshift displayed by objects in the galaxy. To understand what a redshift is, we need to first understand the electromagnetic spectrum.

All of the colours of the rainbow (Red, Orange, Yellow, Green, Blue, Indigo, Violet) comprise what we know as visible light. This visible light is named as such because we humans can observe it with the naked eye.

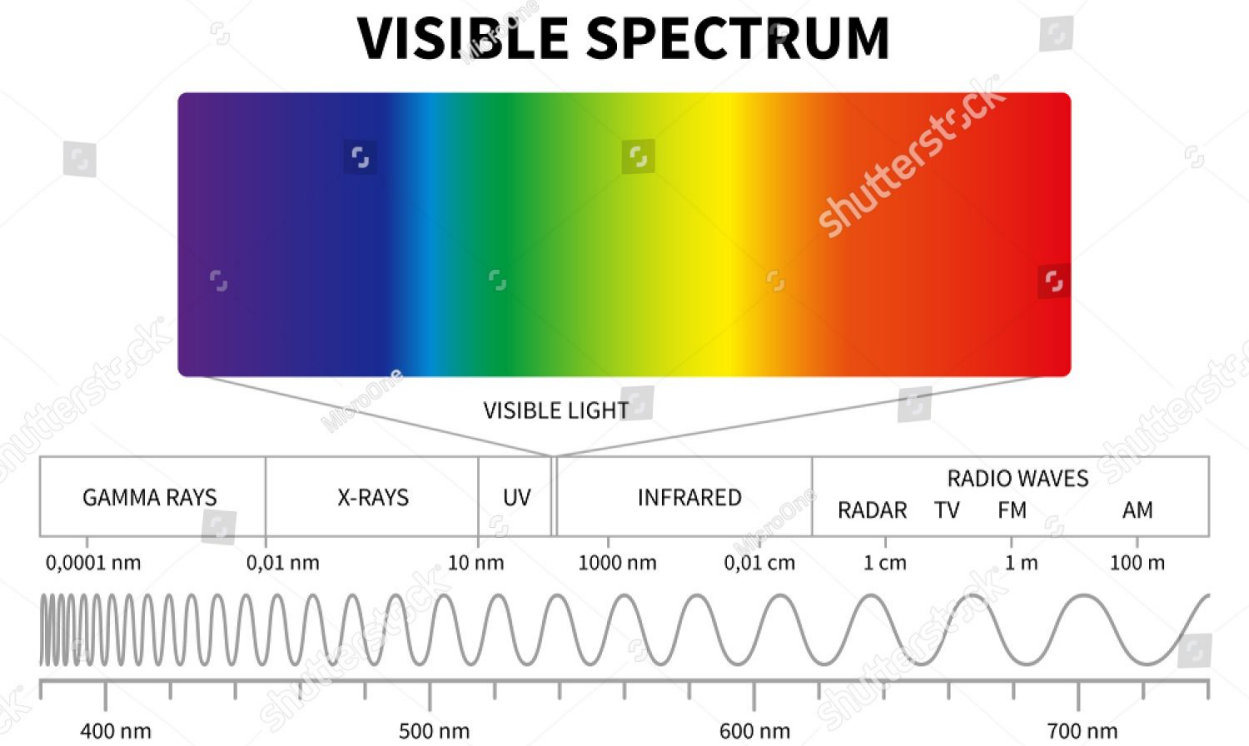
Visible light, however, is just one extremely small portion of an entire spectrum of electromagnetic waves that contain different amount of energy and frequency. Take infrared light for example, we humans cannot see infrared light because it has a longer wavelength and less frequency than our eyes have evolved to pick up. But did you know that animals such as goldfish and some types of snakes can see infrared?



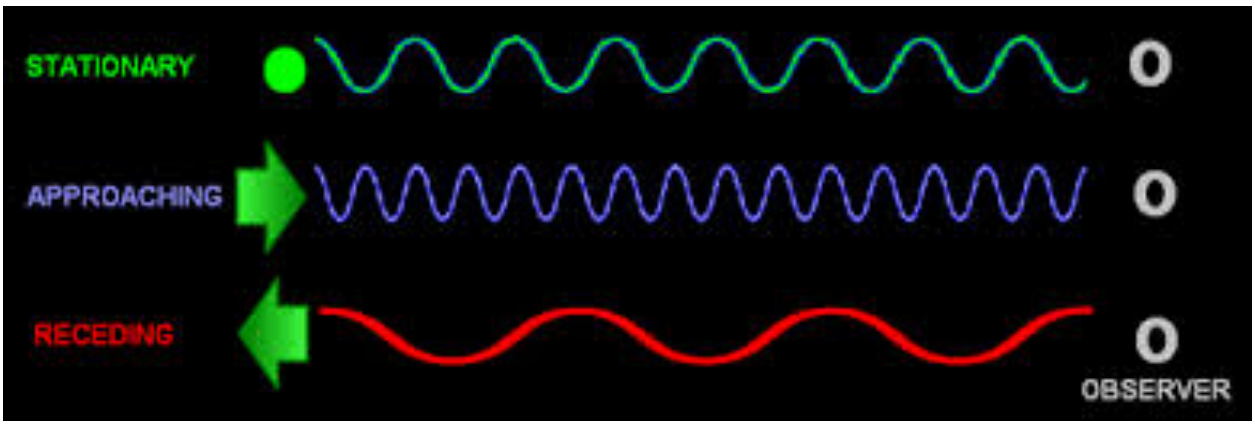
The universe is full of electromagnetic radiation, despite the fact that we can only directly see a very small fraction of it (visible light). Scientists have developed special telescopes to detect more than just visible light. We can now observe the universe through telescope lenses that display images of UW rays, X rays, radio waves and infrared waves. This has allowed scientists to see further into the universe. This is also how the first ever image of a black hole was produced. Black holes do not emit visible light, but we can observe them using different frequencies on the electromagnetic spectrum.

Lets simplify this to see how scientists know that the universe is expanding…

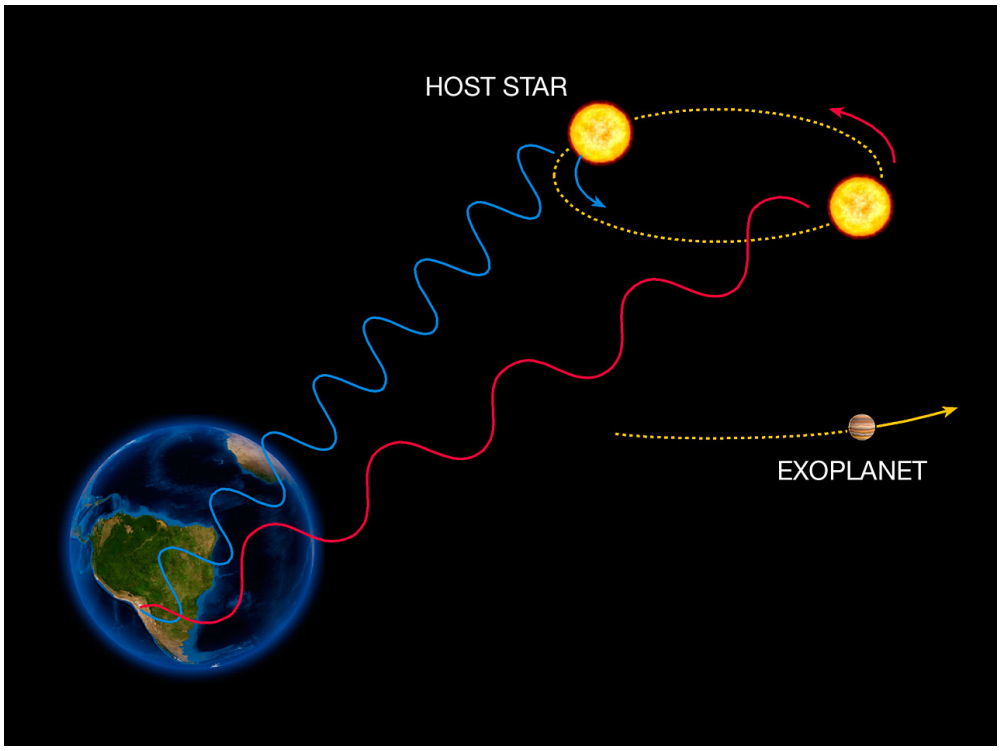
When we look at the visible light section of the spectrum below, we can see that different colours of light have different waves lengths. The red colour is closer to the longer wavelength and lower frequency side, whereas the blue colour is closer to the short wavelength and high frequency side.



Under normal conditions, observed light displays yellow/green characteristics because it is in the middle of the spectrum. However, if an object were to move closer towards you or further away from you, the frequency of the wavelength would change, and the colour emitted would also change.



When scientists observe galaxies, they observe them with a large red shift. Red light has a long stretched out wavelength whereas blue has a short, compressed wavelength. Think of it like an accordion being stretched apart the more you pull on it.



The observed red shift tells us that the universe is expanding.

So what is causing the universe to expand, despite the fact that our knowledge tells us that gravity should be holding the universe together? Dark matter. We do not know what it is or how to quantify it, but dark matter composes 96% of the known universe.

Check out the video that describes possible outcomes for our universe as it continues to expand:

Three ways the universe could end: https://www.youtube.com/watch?v=itpLU7OzNV8

What is redshift?: https://www.youtube.com/watch?v=ikgRZt1BSyk

Dark matter and energy:

Kurzgesagt → https ://www.youtube.com/watch?v=Qaa2O_8wBUQ

Crash course astronomy → https://www.youtube.com/watch?v=9W3RsaWuCuE

The electromagnetic spectrum: https://www.youtube.com/watch?v=7v2gs8rdQzU

Week 5 Assignment – To Be Submitted

Part 1: Questions

1. How do scientists know that the universe is expanding?

2. What is the force responsible for the expansion of the universe, and which of the four fundamental forces is it outweighing?

3. Describe the mechanisms behind each of the three ways the universe could end. (From the video: **Three ways the universe could end**)

4. Describe the difference between redshift and blueshift.

Part 2: Big Bang Timeline

Make a 12-frame comic strip showing the main stages of the formation of the universe starting with the plank era and ending with today. Each cartoon should include the time the event occurred and a brief sentence describing what occurred during that time period. The comic strip should be coloured and contain creative pictures that depict the events of the timeframe.