# **Topic: The Big Bang and The Expanding Universe**

# 1. Factsheet

**The Doppler effect**

* The Doppler effect is usually noticed when a vehicle with a siren approaches and moves away from an observer.
* If a fire engine passes us we notice the pitch of the siren to be higher coming towards us and lower going away from us.
* The apparent shift in frequency is due to the wavelength changing as shown in the diagram and the speed of the sound staying constant.

# **Redshift**

* The same shifts in frequency and wavelength are also observed for light coming from stars in distant galaxies.
* By comparing the light from distant stars with the spectrum of light from our Sun it was noticed that the spectra from distant stars had a slightly decreased frequency. This indicated the stars were moving away from Earth.
* As the light was shifted towards the red end of the spectrum this phenomenon was termed 'redshift'.

# **Hubble's Law**

* American astronomer Edwin Hubble (the space telescope was named after him) measured the speed of galaxies and their distance from Earth.
* He found that the further a galaxy is from Earth, the faster it is moving.
* Hubble's constant is approximately if the distance is in metres and the speed in metres per second. The real significance of Hubble's Law is that the Universe is expanding in all directions not just from Earth.
* This means all matter in the Universe started at one point in space at the time of 'the Big Bang'.

# **Expansion of the Universe**

* The expansion of the Universe is not constant. Recent measurements have shown that the rate of the Universe's expansion is increasing.
* This is currently explained by 'dark matter' and 'dark energy'.
* The evidence for this area of physics comes from observations of the rotation of galaxies and planets.
* Our Milky Way is a spiral galaxy rotating around a central point.
* The Sun's orbital speed is determined almost entirely by the gravitational pull of matter inside its orbit.
* The orbital speed of the Sun and other stars gives a way of determining the mass of our galaxy.
* Physicists noticed that the effects of gravitation suggested a greater mass that the mass calculated from “luminous matter” that could be seen – stars, gas and dust. They suggested that this extra mass was made up of ‘dark matter’ - a form of matter with a strong 'negative pressure'
* Observations of the rotation of galaxies indicated that most of the mass of the universe was originally dark matter.
* Matter can convert to energy over time. Dark energy is on the increase allowing increased expansion.
* Unlike gravity where the force of attraction between masses would slow the expansion down, dark energy works to speed the expansion up.

# **Big Bang theory**

* Redshift and the expansion of the Universe support the idea of a 'Big Bang' but they are not conclusive.
* They only show the current movement of the galaxies and not the evidence of the aftermath of any 'Big Bang' itself.
* The final piece of evidence depends on the relationship between temperature and emitted radiation.
* From everyday life we know that hot metal glows 'red hot' and if it gets hotter still the colour changes to 'white hot' then blue.
* The light emitted from stars can be analysed to determine the temperature of the star. Such temperatures are usually measured on the Kelvin scale, where 0 Kelvin is the coldest temperature possible – absolute zero.

# **Cosmic microwave background radiation**

* In addition to the electromagnetic radiation that reaches us from stars we can also detect some very long wavelength microwave radiation which is all around us in space.
* This Cosmic Microwave Background Radiation (CMBR) is the conclusive evidence for the Big Bang theory.
* The 'temperature' of deep space has been measured as around 3K, not absolute zero, due to the afterglow of the Big Bang.
* This radiation is now used to 'map' the early Universe.

*(*Source: <https://www.bbc.co.uk/education/guides/zphppv4/revision/1>*)*

# 2. The Doppler Effect - Image



The Doppler Effect

# 3. What is the big bang theory?

The Big Bang Theory is the leading explanation about how the universe began. At its simplest, it says the universe as we know it started with a small singularity, then inflated over the next 13.8 billion years to the cosmos that we know today.

Because current instruments don't allow astronomers to peer back at the universe's birth, much of what we understand about the Big Bang Theory comes from mathematical formulas and models. Astronomers can, however, see the "echo" of the expansion through a phenomenon known as the cosmic microwave background.

While the majority of the astronomical community accepts the theory, there are some theorists who have alternative explanations besides the Big Bang — such as eternal inflation or an oscillating universe.

The phrase "Big Bang Theory" has been popular among astrophysicists for decades, but it hit the mainstream in 2007 when a comedy show, with the same name, premiered on CBS. The show follows the home and academic life of several researchers (including an astrophysicist).

In the first second after the universe began, the surrounding temperature was about 10 billion degrees Fahrenheit (5.5 billion Celsius), according to NASA. The cosmos contained a vast array of fundamental particles such as neutrons, electrons and protons. These decayed or combined as the universe got cooler.

This early soup would have been impossible to look at, because light could not carry inside of it. "The free electrons would have caused light (photons) to scatter the way sunlight scatters from the water droplets in clouds," NASA stated. Over time, however, the free electrons met up with nuclei and created neutral atoms. This allowed light to shine through about 380,000 years after the Big Bang.

This early light — sometimes called the "afterglow" of the Big Bang — is more properly known as the cosmic microwave background (CMB). It was first predicted by Ralph Alpher and other scientists in 1948, but was found only by accident almost 20 years later.

Arno Penzias and Robert Wilson, both of Bell Telephone Laboratories in Murray Hill, New Jersey, were building a radio receiver in 1965 and picking up higher-than-expected temperatures, according to NASA. At first, they thought the anomaly was due to pigeons and their dung, but even after cleaning up the mess and killing pigeons that tried to roost inside the antenna, the anomaly persisted.

Simultaneously, a Princeton University team (led by Robert Dicke) was trying to find evidence of the CMB, and realized that Penzias and Wilson had stumbled upon it. The teams each published papers in the Astrophysical Journal in 1965.

(Source: Elizabeth Howell, Space.com Contributor - <https://www.space.com/25126-big-bang-theory.html>)

# 4. Dark Energy & Dark Matter – NASA Article

In the early 1990s, one thing was fairly certain about the expansion of the universe. It might have enough energy density to stop its expansion and re-collapse, it might have so little energy density that it would never stop expanding, but gravity was certain to slow the expansion as time went on. Granted, the slowing had not been observed, but, theoretically, the universe had to slow. The universe is full of matter and the attractive force of gravity pulls all matter together. Then came 1998 and the Hubble Space Telescope (HST) observations of very distant supernovae that showed that, a long time ago, the universe was actually expanding more slowly than it is today. So, the expansion of the universe has not been slowing due to gravity, as everyone thought, it has been accelerating. No one expected this, no one knew how to explain it. But something was causing it.

Eventually theorists came up with three sorts of explanations. Maybe it was a result of a long-discarded version of Einstein's theory of gravity, one that contained what was called a "cosmological constant." Maybe there was some strange kind of energy-fluid that filled space. Maybe there is something wrong with Einstein's theory of gravity and a new theory could include some kind of field that creates this cosmic acceleration. Theorists still don't know what the correct explanation is, but they have given the solution a name. It is called dark energy.

**What Is Dark Energy?**

More is unknown than is known. We know how much dark energy there is because we know how it affects the universe's expansion. Other than that, it is a complete mystery. But it is an important mystery. It turns out that roughly 68% of the universe is dark energy. Dark matter makes up about 27%. The rest - everything on Earth, everything ever observed with all of our instruments, all normal matter - adds up to less than 5% of the universe. Come to think of it, maybe it shouldn't be called "normal" matter at all, since it is such a small fraction of the universe.

One explanation for dark energy is that it is a property of space. Albert Einstein was the first person to realize that empty space is not nothing. Space has amazing properties, many of which are just beginning to be understood. The first property that Einstein discovered is that it is possible for more space to come into existence. Then one version of Einstein's gravity theory, the version that contains a cosmological constant, makes a second prediction: "empty space" can possess its own energy. Because this energy is a property of space itself, it would not be diluted as space expands. As more space comes into existence, more of this energy-of-space would appear. As a result, this form of energy would cause the universe to expand faster and faster. Unfortunately, no one understands why the cosmological constant should even be there, much less why it would have exactly the right value to cause the observed acceleration of the universe.

(Source: <https://science.nasa.gov/astrophysics/focus-areas/what-is-dark-energy>)

# 5. Questions

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| 1. What is the Doppler Effect? |
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| 2. What is the term given for the comparable shifts in frequency and wavelength, in relation to light? |
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| 3. Do red shift and the expanding universe confirm the Big Bang Theory? Please explain. |
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| 4. What does CMBR stand for? How is this relevant to the Big Bang Theory? |
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| 5. What is the relevance of pigeons when it comes to CMB? |
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| 6. In relation to the expansion of the universe, how does the effect of gravity differ from the effect of dark energy? |
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| 7. What percentage of the universe is said to be made up of dark energy? |
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| 9. Given that the rate of the universe’s expansion is increasing, what conclusions can we draw in relation to our view of other galaxies? |
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| 8. What was the first important property of space discovered by Albert Einstein? How is this discovery limited? |
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