James Webb Telescope: Light on Dark Matter

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Humankind's fascination with the heavens is as old humankind. The sight of countless stars and the faint band of light which stretches from horizon to horizon must have been the cause of amazement and awe for the earliest homo-sapien as she trudged along the plains of East Africa. From the hunter-gatherer to our own times, every culture has developed its own cosmology- the system of beliefs or theories, which explain the origin and structure of the universe.

To study the heavens, a variety of instruments have been used throughout history. From sun dials and astrolabes to telescopes and now gravitational waves detectors, we have tried to observe, chart, study and measure the universe. These observations have in turn led to formulation of our theories of the universe. Thus, it was Kepler's observations of the planets which provided the impetus to Newton to formulate his Law of Gravitation which still forms the basis of celestial mechanics. In the early twentieth century, the observation of receding galaxies by Hubble led to the model of the expanding universe.

The quest to probe the universe received a major impetus with the commissioning of the James Webb Space Telescope. Costing around $10 billion, the telescope has taken more than 3 decades from planning to commissioning and is truly a symbol of humanity's intellectual and creative potential.

Launched in 2021, it reached its final orbit at a distance of around 1.5 million km from the Earth in early 2022 and it took the engineers and scientists another 6 months to ready the instruments before they could be used. The observatory has four major components- the Integrated Science Instrument Module (ISIM) which houses four instruments to analyze the light that is captured by the Optical Telescope Element which has a 21 feet diameter gold-plated beryllium primary mirror made of 18 hexagonal mirrors and secondary mirror to guide the light collected by the primary mirror to the instruments . There is also a huge foldable

sunshield to block the radiation from the Sun, Earth and the Moon since the instruments need to operate at a temperature of -220 C. Finally there is the Spacecraft bus with all the equipment for the operation of the observatory.

And then finally it happened- in July, it released its first images and they were truly breathtaking. The images of galaxies that might date back to almost 13 billion years ago, the cosmic cliffs of Carina nebula, the Cartwheel galaxy, the Stephan's quintet – each of them was spectacular even though the colors were artificial since the images were infrared images and not visible light. It also provided an analysis of the atmosphere of a giant gas planet orbiting a star about a thousand light years away. The analysis indicated the presence of water in the atmosphere.

Developments in telescope technology (in all regions of the electromagnetic spectrum and not just the visible range) over the last century have allowed us to know with reasonable certainty a lot about our universe. We know that at the "beginning" of time, all the energy was concentrated in a primeval fireball of extremely high temperature and density. Then with a massive explosion, termed dramatically the Big Bang about 14 billion years ago, the universe began and has been expanding since. At some point, a couple of hundred million years later, the first stars started forming.

Although the broad contours of the universe are fairly well established, the details are still missing. This is especially true of the earliest times in the history of the universe. It is here that the Webb telescope offers a unique opportunity.

Our window to the universe is electromagnetic radiation. These waves, which span a whole spectrum of wavelengths from the very long radio waves through visible light to the ultra-short gamma rays, travel at the speed of light. And this means that in cosmology, given the enormous distances involved, if one is looking at waves emitted from an object which is very far, one is actually observing the object as it was in the distant past- looking into the distance means looking into the past! The expansion of the universe also stretches the waves and so visible light could be stretched into the longer infrared part of the spectrum. Infrared radiation has the advantage that it passes through dust clouds more easily than visible light.

The Webb has 4 instruments to observe and analyze infrared waves. This makes it singularly suitable to observe the light emitted from the earliest epochs of the universe. This will give us an insight into how the first stars and galaxies formed from the primeval soup of matter and radiation. Because it can peer so far into the past, it will also allow us to compare the earliest galaxies (those that are furthest) to those that we observe today in our own cosmic neighborhood. And since it operates in the infrared, it can see through the dust clouds which obscure regions where star and planet formation is taking place.

The Webb doesn't just produce pretty pictures- it also produces a huge amount of spectroscopic data which reveals, among other things, the chemical composition of the region producing the radiation. Studying the chemical composition of exo-planets, that is planets orbiting other stars, would determine whether life as we know it is possible on these extraterrestrial worlds.

In 1543, the Polish astronomer Nicolaus Copernicus published a book which revolutionized our thinking of the cosmos. We were displaced from being the center of the universe to just another planet revolving around the Sun. Centuries of observations since have made us even more insignificant. In the last few decades, it has been shown that the kind of matter that our world is made of- the stuff of our iPhones, our earth and even us, is a mere 3-4% of the overall matter and energy in the universe. The rest is some combination of a mysterious kind of matter called dark matter and an even more mysterious unknown substance called dark energy. Not only are we not at the center of the universe- we are not even made up of the kind of stuff that the universe is mostly made of! Any vestigial remnant of our species' anthropic arrogance has been finally demolished by cosmology. The universe is vast and most of it is unknown. We hope that the Webb, over its lifetime would provide us with a powerful window to help resolve some of the many mysteries of the cosmos and make it a little bit more comprehensible.

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