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Possible Solutions to Olbers' Paradox

Olbers' Paradox summarises the universe's contradiction of physics and investigates why the sky does not remain light throughout night. Despite the Earth's 24-hour rotation during which we spend approximately 12 hours facing away from direct sunlight, there is statistically enough light energy and matter in the universe to maintain a constant light sky surrounding the Earth. Newton's assumptions that the universe is static, infinite and homogenous (uniform) formed the basis of Olbers' exploration into the dark night sky paradox. Because the universe is infinite, and therefore there are an infinite number of stars, Olbers stated that at the end of every line of sight there must be a star. Olbers further proved that the distance of each star from the Earth remains independent of its intensity because the light emitted from each star accumulates to form significant brightness.

English mathematician and astronomer Thomas Digges conducted foundation research and initial documented interest into the darkness of the universe in the mid-16th century. Because of his research, Digges was the first physicist who proposed the concept of an infinitely large universe with an infinite number of stars. Although considered years prior by Digges and Kepler, German astronomer Heinrich Wilhelm Olbers described the dark night sky as a paradox in 1823. Olbers' calculations showed that the universe should be white at night due to the countless stars and galaxies emitting energy in the form of light. Furthermore, an infinitely old universe provides evidence to suggest that the light emitted from every star will have had sufficient time to reach the Earth. However, recent discoveries have shown that the universe did in fact have a beginning with The Big Bang, providing significant implications for Olbers' Paradox. The constant expansion of the universe and the effects of redshift form the foundation of a possible solution to the paradox. The light emitted from distant stars and galaxies may have been shifted beyond the red region of visible light into a spectrum invisible to the naked eye. Furthermore, the combination of time-space continuum and the finite speed at which light can travel provides evidence to suggest that the stars we see twinkling in the night sky is actually the intensity of that star billions of years prior when the light hadn't actually reached us yet.

Exploration into the limited speed of light forms the basis of the finite universe solution to Olbers' Paradox. Danish astronomer Olaus Roemer successfully measured the speed of light to be a fixed constant of 3.00×10^{8} ms^{-1} in 1676. He determined this value by observing the orbit of Jupiter's moon Io and recording its position in space at various times. It was observed that when the moon was further away from Jupiter, Io seemed to take longer to

complete its orbit. Roemer discovered that when the moon was a greater distance from Jupiter he was actually seeing the moon at its position prior to where it currently was because the light took longer to travel. By knowing how much Io's position varied and how much the distance from Earth to Jupiter seemed to change, Roemer could use his observations to calculate a value for the speed of light. The finite speed of light combined with the great distance between stars and the Earth means that the light emitted from distant stars is unlikely to reach the Earth of near intensity to that emitted from our sun, assuming it reaches the Earth at all. An extension on this theory explores the work of Edwin Hubble and his research into Redshift and The Doppler Effect, two phenomena which provide evidence for the Big Bang Theory. The homogenous universe is constantly expanding at various speeds, occasionally exceeding the speed of light. If a star has been shifted with the vast expansion of the universe at a relative speed exceeding the speed of light, then the light emitted by the star will never reach the Earth.

Red shift states that as a star moves away from an observer on Earth, the wavelength of the light emitted from the star will increase and the wave will be stretched. Consequently, the faster the star or galaxy is moving away, the greater the red shift is. Over centuries, the constantly expanding universe has caused the Electromagnetic waves emitted from distant stars to stretch so much that the wavelength of light exceeds the visible light spectrum. The shortest wavelength of light in the visible spectrum is violet with a wavelength of 390nm (nanometre: $1x10^{-9}$) and the longest wavelength humans can see through the naked eye is 750nm. The vast decrease in frequency causes the light to surpass the visible light region of the electromagnetic spectrum and subsequently enter the infrared region. Once light enters the infrared spectrum and beyond, the Electromagnetic waves will no longer be visible through the naked eye and the universe will appear dark when the Earth is facing away from the sun. This explanation suggests that Olbers was correct and the universe is infinitely bright, however since Hubble did not discover that the universe is expanding until 1929, Olbers could not take into account the red shift of stars. The bright light present in the sky at night is not visible to us when we look up, and so this is why we have a dark sky at night. The Cosmic Microwave Background Radiation (CMBR) present in our atmosphere supports the dark night sky and acts as evidence for the constantly expanding universe. Infrared telescopes and cameras provide evidence of the presence of infrared light in our atmosphere, radiation that represents the light emitted from stars in our universe billions of years ago. The Spitzer Space Telescope (2003) launched into orbit around the sun detected infrared energy coming from cooler objects in space. Since the stars that once emitted the infrared radiation are now many light years away (if they are still alive) the light they are currently emitting will take billions of years to reach the Earth. This infrared radiation detected by the Spitzer Space Telescope supports the wavelength explanation of Olbers' Paradox.

However, if this explanation were true, there would have been a point in time billions of years ago when the universe would have been much smaller and the stars would have been much closer to the Earth. At this time, the light emitted from the not so distant stars would have still been in the visible light region of the Electromagnetic Spectrum. This suggests that in the early years of the universe the sky surrounding the Earth would have been continually light. If this was the case, the light energy from the early stages of the Earth must still be present in our universe. Since the light was emitted from these stars billions of years ago, the wavelength would have increased vastly as the universe expanded and therefore the light would have entered the microwave region of the EM spectrum. Evidence of these microwaves can be seen in the CMBR homogeneously present in our universe. Therefore, the energy from our surrounding stars is still present in the universe, but in a form of radiation which is not visible to us.

Since we now know the universe had a definite beginning at The Big Bang 13.8 billion years ago, the universe is still relatively young. The Big Bang Theory states that initially all the matter in the Universe was concentrated into a single tiny point. This distinct point then endured rapid explosion of intense heat and is still expanding today. The CMBR present in our universe is thought to be the heat left over from the original explosion. Prior to the explosion there were no stars in the universe, and so the existence of stars and time is not infinite. Due to the space-time continuum, when we look up at the sky at night and see small stars twinkling, we are really seeing the position and intensity of the light years prior to their current position. This is because the star is several light years away and light takes time to travel. Essentially, the light is still travelling on its way to Earth. Chase (2004) stated that objects more than 13.7 thousand million years old are too far away for their light ever to reach the Earth, a concept that reinforces research conducted on the time-space continuum and the finite speed of light. This explanation relies on the limited age of the universe and the discovery of The Big Bang.

If we reject Newton's initial assumptions and consider the universe as non-uniform, even if the universe has infinity of stars, there is possibility that thousands of stars lie behind one another in a finite region or row, resulting in the rest of the universe having areas of complete darkness. By this explanation, theoretically it is not definite that a line of sight will meet the surface of a star. Observations into the concentration of stars in our galaxy have led scientists to the conclusion that 'the density of stars within this finite volume is sufficiently low that any line of sight from Earth is unlikely to reach a star' (Poe, 1848). However, by developing the infinity of stars theory further, the intensity of the stars should accumulate to intensity far greater than we observe from the Earth at night. The light from stars in each concentric shell surrounding the Earth reinforce each other and add up to a strong brightness, since light received from first shell adds up to light received from second

shell. For example, if the sun was twice as far away from the Earth, the Earth would receive one quarter as many photons, since intensity is directly proportional to one over the distance squared. However, if behind the sun there was another star whose light radiation reinforced that which is emitted from the sun, and so on, the light received by the Earth would be of significant intensity. Therefore, the dark night sky is a concept that argues against infinity.

Recent discoveries have aided our efforts to resolve Olbers' Paradox; however, a definite solution supported with valid evidence has not yet been published. The wavelength theory exploring the transition of energy from visible light to ultraviolet is credible; however, it also relies on the Earth experiencing constant brightness during the early period subsequent to The Big Bang. Without evidence to support a constantly lit sky billions of years ago, we cannot rely on this solution alone to answer Olbers' Paradox. Furthermore, the CMBR detected throughout the universe does not provide enough evidence to prove this solution since the microwaves could be a direct result of the energy emitted from the explosion at the centre of The Big bang 13.8 billion years ago. Even though contemporary research within physics has disproved Newton's initial assumption of a uniform universe, the infinity of stars and galaxies within our universe is too vast to comprehend. Conclusively, Olbers' 19th century Paradox still troubles many physicists today with one question; why is the sky dark at night?

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Word Count: 1,810