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The unutterable feebleness of starlight

How darkness at night appears to be telling us there was a beginning to time but is actually telling us something quite different

If the stars are other suns having the same nature as our sun, why do not these suns collectively outdistance our sun in brilliance?

Johannes Kepler

(*Conversations with the Starry Messenger*, 1610)

The only way in which we could comprehend the blackness our telescopes find in innumerable directions would be by supposing the distance of the invisible background so immense that no ray has yet been able to reach us.

Edgar Allan Poe (Eureka, 1848)

Chapter 7 “The unutterable feebleness of starlight” from the book “We need to talk about Kelvin” by Marcus Chown

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It is a crystal clear night far away from the lights of any town or city. The stars are shining like diamonds. There are so many stars that they distract from the most striking feature of the night sky. It is black. Overwhelmingly black. It may seem like a trite observation. However, it is telling us something important about the Universe. The overwhelming majority of astronomers believe is that is telling us that the Universe has not existed for ever; that there was an instant when it came into being; that, in common with you and me and every creature on Earth, the Universe was born. *But, actually, the world’s astronomers are dead wrong. The darkness of the sky at night is telling us something entirely different.*

The person who first realised that such a commonplace observation of the sky might have something to tell us about the cosmos was the German astronomer Johannes Kepler, imperial mathematician to the emperor of the Holy Roman Empire. In 1610, he received a copy of Galileo's best-seller, *The Starry Messenger* in which the Italian scientist documented the astronomical discoveries he had made with the newly invented

telescope. They included mountains on the Moon and the four "Galilean" moons of Jupiter. Kepler was so inspired by the book that he dashed off a letter to Galileo, which was later published as a short book. In *Conversations with the Starry Messenger*, Kepler not only underlined the importance of Galileo's work but pointed out something that nobody else appeared to have noticed - the darkness of the sky at night is deeply surprising.

Most people, if asked why the sky is dark at night, would say because there is no sun and starlight is much weaker than sunlight. It takes a genius to realise that the reason it is black at midnight is far from obvious and may actually have something profound to say about the Universe.

Kepler’s reasoning was straightforward. If the Universe is infinite in extent so that its stars march on forever, then between the bright stars in the night sky we should see more distant, fainter stars, and between them, stars even more distant and even more faint. It was like looking into a dense forest. Between the trunks of a nearby trees you see the trunks of more distant trees and, between them, the trunks of trees even further away. The view that confronts you is therefore of a solid wall of trees.

Similarly, claimed Kepler, when we look out into the Universe, we should see a solid wall of stars.

It is possible to be more precise than this. Imagine the Earth is surrounded by spherical shells of space rather like the concentric skins of an onion. The farther away a shell, the fainter the stars it contains. On the other hand, the further away the shell, the bigger it is, it contains more stars. Well, the increase in the number of stars should exactly compensate for the stars getting fainter. In other words, every onion-shell of stars should contribute exactly the same amount of light to the terrestrial night sky. But this is disastrous. If the Universe goes on forever, there are an infinite number of such shells. Add up the light coming from all of all of them and the answer is an infinite amount. Far from being dark at night, the sky should be infinitely bright.

Infinity - a number bigger than any other - is merely an abstract mathematical concept. Nothing in the real world is infinite in size. The conclusion that the night sky should be infinitely bright must therefore be wrong. Somewhere in the logic used to deduce it there must be a flaw. And there is. Although the stars appear to be dimensionless pinpricks, in reality they are other suns,

shrunken to mere specks by their immense distance. Each is a tiny disc - too small to see with the most powerful telescopes - but a disc nonetheless. Consequently, the discs of nearby stars obscure those of the faraway ones just as nearby trees in a forest hide the faraway ones. This means the night sky should be papered entirely by the discs of stars. Although not infinitely bright, it should be as bright as the surface of a typical star.

Kepler believed the sun was a typical star. Consequently, he concluded that the night sky should be as bright as the surface of the sun. We know today that the sun is not an average star. It is considerably more luminous than most. About 70 per cent of stars in the solar neighbourhood are "red dwarfs", cool suns reminiscent of softly glowing embers. However, this hardly changes Kepler’s conclusion. Rather than being as bright as the surface of the sun, the sky at night should be glowing blood red from horizon to horizon. "In the midst of this inferno of intense light”, said the Anglo-American cosmologist Edward Harrison, “life should cease in seconds, the atmosphere and oceans boil away in minutes, and the Earth turn to vapour in hours.”

Thankfully, the sky is not as bright as the surface of a typical star. It is about a trillion trillion trillion times fainter. This paradox that the night sky is dark when, logically, it should be bright ought to be called Kepler's paradox. However, because it was popularised by a distinguished German astronomer called Heinrich Olbers in the early 19th century, it has instead become known as Olbers' paradox.

When a prediction clashes with a cast-iron observation, clearly it is the prediction that is at fault. More than likely the assumptions that went into making the prediction need re-examining. Kepler's most obvious assumption was that the Universe goes on forever. If this not true, then the paradox can go away. After all, there will be only a limited number of onion shells of stars contributing their starlight to Earth's night sky. It is easy to imagine the sky being filled with so little starlight as to appear black. This was actually Kepler's solution to the dark sky paradox. He abhorred the idea of an infinite Universe. It terrified him. It was monstrous. He therefore concluded, with some relief, that the Universe must be finite in extent.

If Kepler was right, the cosmos was not like an endless forest. It is akin to a localised clump of trees bounded at the rear by a dark wall. Because the clump is so small and sparse, we can see the dark wall behind. This is the blackness between the stars.

As a matter of fact, in the 20th century astronomers did indeed discover that the Universe is finite - or at least the portion of the Universe from which we receive starlight. Recall Edwin Hubble's 1929 discovery that the Universe is expanding, its constituent galaxies flying apart like pieces of cosmic shrapnel. If the expansion is imagined to run backwards, like a movie in reverse, there comes a time when all of Creation is squeezed into the tiniest of tiny volumes. This was the beginning of time, the moment of the Universe's birth, the big bang. According to the best current estimates, space, time, matter and energy exploded into being in the fireball of the big bang about 13.7 billion years ago.

The size of the Universe - or at least its effective size - is inextricably linked to its age. This is because light, though fast, is not infinitely fast, so it takes time for it cross space. An interval of 13.7 billion years may seem an unimaginably huge tract of time.

But it is simply not long enough for light, crawling snail-like across the vastness of space, to have yet made it to Earth from the most distant reaches of the Universe. Consequently, the only celestial objects we can see are those whose light has taken less than 13.7 billion years to reach us. Imagine them occupying a bubble of space - the “observable universe” - centred on the Earth.

The observable universe is bounded by the “cosmic light horizon". This is pretty much like the horizon at sea. We know there is more of the sea over the horizon. And, similarly, we know there is more of the Universe over the cosmic light horizon. Only its light has not got here yet. It is still on its way.

Light travels a light year per year – since that it was a “light year” is, the distance light travels in a year. So an obvious conclusion to draw is that the distance to the cosmic light horizon must be 13.7 billion light years. However, this is incorrect since the Universe, in its first split-second of existence, is believed to have undergone a brief, faster-than-light epoch of expansion. Because of this "inflation", the distance to the light horizon is not 13.7 billion light but about 42 billion light years.

Of course, the Universe may be infinite in extent. In fact, in the inflationary picture it is effectively infinite. However, the combination of the finite age of the Universe and the finite speed of light reduce the volume of space from which we can receive light to a bubble 84 billion light years across. This cuts dramatically the amount of light arriving on Earth.

Remarkably, the first person to realise that the reason the night sky might be black was because there were stars too far away for their light have got to us was Edgar Allan Poe. In his imaginative essay, "Eureka", published in 1848, he wrote: “Were the succession of stars endless, then the background of the sky would present us a uniform luminosity since there could be absolutely no point, in all that blackness, at which would not exist a star. The only way in which we could comprehend the blackness our telescopes find in innumerable directions would be by supposing the distance of the invisible background so immense that no ray has yet been able to reach us.”

It would seem, then, that the evidence that the Universe has a finite age - that it was born in a big bang - stares us in the face every night. In fact, it has been staring people in the face since

the dawn of human history. Only nobody realised. Nobody

guessed the true cosmic significance of dark sky at night.