Dark Night Sky Paradox - Olber's Paradox

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https://ca.wikipedia.org/wiki/Paradoxa_d%27Olbers

Looking out into the never-ending dark of the night sky, one might think of our universe as being anything but flat. It seems very much full, unending, and richly dotted with the spherical bodies of stars and planets, asteroids and moons. Before I knew much about physics and the science behind that night sky, my first inclination was to think of the universe as round. I'm sure I'm not the only one. But as it turns out, not only do we live in a relatively flat galaxy, the entire observable universe is flat as well.

Thinking of space as having any kind of shape can be hard to imagine. The complexities of the universe are sometimes quite literally impossible for us to visualize as we exist only in three dimensions and can only mentally process 3-dimensional models and a limited number of colors and sounds within certain ranges. But through mathematics and scientific theories, we can catch a glimpse of the true nature of reality.General relativity has taught us that space can be manipulated, contracted, bent and expanded. In this case, general relativity tells us that it's not only the objects within space, but space itself which can be curved.

While Einstein's famous theory also tells us space has three spatial dimensions and one time dimension, here we'll be condensing it down to two dimensions to make it easier to imagine. In these two dimensions, there are three mathematical possibilities regarding the curvature of space. The possibilities have to do with the amount of mass available within that space and consequently, how much overall gravitational strength is available.

From top to bottom: positive (closed), negative (open), and flat universes. Diagram from NASA.

Positive curvature of space would give us a spherical universe, one in which traveling for long enough in any one direction will bring you back to your original starting point. Here on the spherical surface of Earth, for example, parallel lines don't stay parallel and instead meet at one of the globe's poles. In the sky, our observations would note that distant light rays converge instead of staying on their original path the way they do now.

Positive curvature also means that there's enough mass present to stop the expansion of the universe, making it finite. There will at some point be a contraction in which all the galaxies that were once receding away from each other will collapse.

On the other hand, a universe with negative curvature does not have enough mass to counteract expansion and will continue to expand forever. Parallel paths in this saddle-shaped universe will diverge, as would the rays of distant light in the sky.

Something that both these universe shapes have in common, however, is that triangles would not add up to 180 degrees but instead to more than that in a closed universe and to less than 180 in an open one. By using a map of the CMB — cosmic background radiation left over from the Big Bang — scientists were able to measure different spatial relationships between points on the map and found that the triangles shown had angles adding up to exactly 180 degrees, a phenomenon you'd expect to see in a flat universe.

The CMB portrays leftover radiation 400,000 years after the Big Bang.

In a flat universe — that is, a universe with zero curvature — there is just enough mass present to counteract the expansion but only after an infinite amount of time, meaning that it too will continue to expand forever. Over time, the rate of expansion will approach zero. The mass needed to create a flat universe is called the critical density. Observations from the CMB and supernovas tell us that the universe is expanding even faster than we thought it would be and, to further support the claim that the universe has no curvature, observations from the Baryon Oscillation Spectroscopic Survey telescope — or the BOSS telescope for short — detail 1.2 million galaxies with a location accuracy of one percent. Light from the galaxies mapped by the BOSS telescope remained parallel even across larger distances.

The amount of mass required for critical density is a precise and delicate number. Five hydrogen atoms per cubic meter of space. A single atom more, a single atom less and our universe would have taken a completely different shape. Why the universe has the density that it does is still unknown, but it's quite a remarkable outcome.

The implications of this flat universe bring into question something which seems to have an obvious answer, but which is in fact more complicated to explain than it first seems.

Why is the sky dark at night?

Because the planet has rotated on its axis and is no longer facing the sun in our part of the world. That's the answer anyone would give. But the problem with this in a supposedly infinite universe is that stars should be so densely scattered across the sky that you should be able to see one no matter where you look, each freckle of a star overlapping thousands behind it. Even if the stars were obscured by clouds of space dust, these clouds would eventually absorb so much light that they would continue to radiate it out again, giving us a bright, intense sky both day and night.

This is known as Olbers' Paradox, and it does have some solutions. Because the universe has only been expanding for a certain amount of time and because light can only move so fast, light from those faraway stars simply hasn't had enough time to reach us here on Earth. Also, the further away a star is, the faster it travels as the universe expands and the more the wavelength of light gets stretched into the red end of the electromagnetic spectrum. We can't see infrared light with the naked eye, making the sky appear dark even if it isn't.

Because of the finite speed of light, the farther out we look into the universe the farther we're traveling back in time. "Full Moon" by Fabian Oelkers.

But the biggest explanation by far for this flat, enormous space we call the universe has to be a period of intensely fast growth known as inflation.

Inflation was so rapid that it was able to enlarge the universe by 10^{2}? at faster than the speed of light. Once inflation stopped, the regular expansion we see now took its place. The universe has been expanding in the 13.7 billion years since. But because our universe has managed to maintain a flat shape for so long, this means that the observable universe must have already been fairly smooth at the instance of the Big Bang. You see, the universe was compacted down into a tiny speck, and even if that speck was rough and bumpy in texture, the small section of it that came to be our observable universe could still have been smooth and flat at such a small scale. This implies, too, that what we call the entire universe is actually just a fragment of a much, much bigger picture.

Inflation, while not entirely accepted as fact, provides a solution to the horizon problem — the question of how space can be so homogenous despite regions of it being causally disconnected — and the flatness of our universe. General relativity does allow the mechanism needed for this to take place. And while inflation explains so many of our observations beautifully, scientists still need more evidence before inflation becomes a fact.

There’s also a simpler explanation for the flat shape of our home: we just don’t have the tools needed to detect any curvature. Our view of the universe is limited, and trying to infer its true shape is like trying to infer the shape of the entire Earth from one small field out in the midwest; to our eyes the rolling plains look relatively flat and unending. It’s only when we go far, far up that we can begin to see the true shape of the planet — a clouded, gauzy sphere. A pale blue dot.