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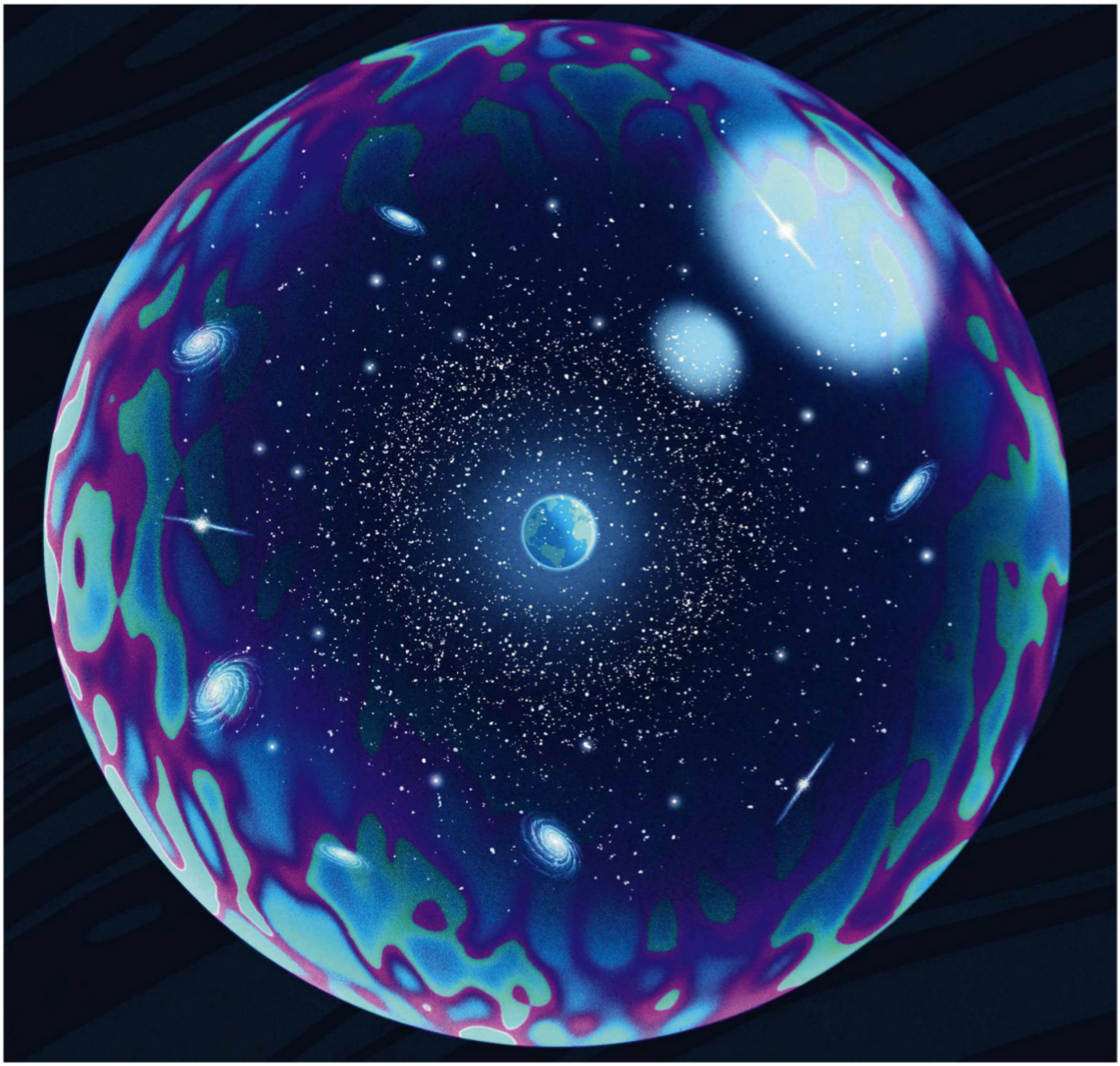

COMMENT

AT THE EDGE OF EVERYTHING

Puzzling over the answers to a centuries-old cosmic paradox can teach us profound things about the Universe

Whether it's more troubling to imagine that the Universe goes on forever in every direction, or that it has an edge, beyond which there is nothing, is hard to say. Astrophysics doesn't provide any guidance as to which flavour of existential crisis we should be having – while we can't say with any level of confidence whether the Universe goes on forever or not, we can say that our observable universe has an edge, in the sense that

there's a distance beyond which, whatever may or may not exist, we absolutely cannot see it.

The existence of this cosmic horizon is part of the answer to an ancient conundrum about the darkness of the night sky, reportedly first posed by Johannes Kepler in 1610 but later attributed to fellow astronomer Heinrich Olbers in the 1800s.

Olbers' Paradox asks: if the Universe is infinite, and if there are stars (or galaxies) throughout it, why is the sky dark? Surely, if we look in any direction in the sky, that sightline will, eventually, land on a star. Common sense therefore tells us that everywhere we look, the sky should be as bright as the Sun, constantly aglow.

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SOLVING THE PARADOX

The standard resolution to this paradox invokes the finite age of the cosmos and the speed of light. Even if the cosmos is endless and full of stars, one might reason, we can only see the ones that are close enough for there to have been enough time (since the beginning of the Universe) for the light to reach us from there. Anything so distant from Earth that the light travel time is more than the age of the Universe is invisible to us.

This doesn't entirely resolve the paradox, for reasons that involve some much stranger physics. But this light travel distance limit is responsible for our horizon – the edge of the observable universe. The most distant things we can see in the cosmos are the things whose light has been travelling to us for the age of the Universe: 13.8 billion years.

The stranger physics comes in when you ask what are those things whose light has travelled for that long? The Big Bang theory says that the Universe 13.8 billion years ago was a hot, dense inferno, in which all of space was filled with glowing-hot plasma, rippling and churning like the surface of the Sun. Because all of space was glowing, when we look into the farthest reaches of the cosmos in any direction, that glow is in fact what we see.

So if all of space was glowing, why is the sky dark? Have we just unsolved the paradox?

The reason the Universe can be glowing all around us but still look dark comes down to the physics of light in an expanding universe. When space expands, and the distance between objects grows, the light passing between those things gets stretched out, shifting the light to lower frequencies on the electromagnetic spectrum. For visible light, lower frequencies correspond to redder colours, so this effect is called "redshift". You can think of it like a Doppler shift – the same kind of effect that's responsible for a siren dropping to a lower tone when an ambulance speeds away from you, since distant objects appear to speed away from us as the Universe expands.

But this effect is not limited to visible light: it spans the whole spectrum. Visible light gets stretched to infrared, infrared to microwave, microwave to radio. And the farther away that light, the more the cosmos has expanded, and hence the more intense the redshift. Light from the glowing early Universe has been so stretched out by cosmic expansion that we now receive it as a faint glow of microwave radiation, all around us.

While we may never know if the Universe as a whole is infinite or bounded, we know that the cosmic microwave background – the distant shell of fading fire that surrounds us – is the most distant light we can ever see, at the edge of our observable universe. But just like the darkness of the night sky, this edge is a matter of perspective. Someone living in a galaxy billions of light years away from us sits at the centre of their own observable universe, which may only partly overlap our own.

There will always be mysteries that the fundamental laws of the Universe will not allow us to unlock. But whether we blithely accept our limitations or not, the best approach to understanding will always be in learning to look around us in new ways, and question why it is that we see what we see. Or why we might look up on a particularly dark night and not see anything at all.

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