The Loneliest Places in the Universe – Cosmic Supervoids

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To the public imagination, the study of the universe is tied to its most luminous and massive observables, such as the searing plasma of stars, the spiral arms of galaxies and the violent accretion disks of black holes. However, to understand the universe's true structure, we must look at the extreme opposite: the vast, cold expanses where matter is extraordinarily sparse. These are cosmic voids-the loneliest places in the universe.

On the largest scales, the universe resembles a three-dimensional spiderweb. Gravity draws matter into dense filaments and leaves behind bubble-like regions of emptiness. Our standard model of cosmology predicts statistically how these voids should grow. We expect them to follow a pattern where most are of average size and very few are extremely small or extremely large. However, observational data has revealed the existence of supervoids so vast that they are rare in the standard cosmological model [1].

These are one of the universe's true extremes: while a typical void might span 50 to 100 million light-years, supervoids can stretch for over a billion light-years or more [2,3]. One such candidate is the Eridanus Supervoid. This region is not only an abyss of emptiness but is also linked to the Cold Spot in the Cosmic Microwave Background - a mysterious chill in the afterglow of the Big Bang that is colder than typical regions in standard cosmological predictions.

Why do these extremes matter? Because they let us stress-test our models where they are most delicate. If the universe began with tiny, random quantum fluctuations, structures as extreme as supervoids are rare [1]. This creates a tension worth examining. It forces us to ask uncomfortable questions. Is our understanding of gravity on the largest scales correct? Is dark energy behaving differently in these extreme environments?

These rare giants act as a useful lens on dark energy. As photons pass through a supervoid, they traverse a region where matter is sparse and cosmic expansion dominates. This can leave a subtle imprint on the light known as the Integrated Sachs-Wolfe (ISW) effect, which can be used to test how cosmic acceleration influences the growth of structures [4].

By hunting for the largest, emptiest and most unusual patches of the sky, we are stress-testing the laws of physics. By staring into the extremely lonely places, we might just find one of the clearest windows into how our Universe works.

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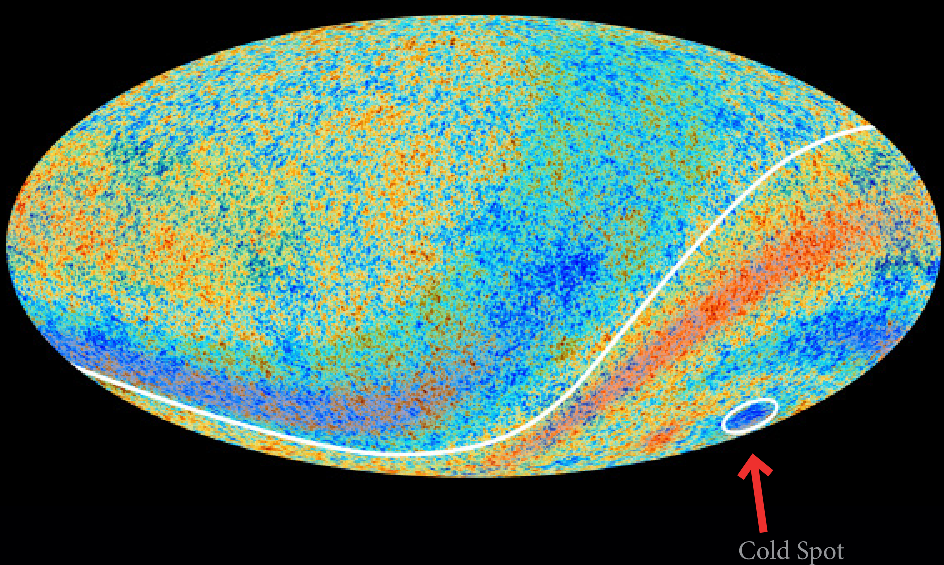

Figure: Planck's map of the cosmic microwave background, the faint afterglow of the Big Bang. The highlighted region marks the Cold Spot, an unusually large cooler patch in the sky [5].

References:

[1] Kovács, A., et al. (2022). The DES view of the Eridanus supervoid and the CMB Cold Spot. Monthly Notices of the Royal Astronomical Society.

[2] Sánchez, C., et al. (2017). Cosmic voids and void lensing in the Dark Energy Survey science verification data. Monthly Notices of the Royal Astronomical Society.

[3] Szapudi, I., et al. (2015). Detection of a supervoid aligned with the cold spot of the cosmic microwave background. Monthly Notices of the Royal Astronomical Society.

[4] Pisani, A., et al. (2019). Cosmic voids: a novel probe to shed light on our Universe. Bulletin of the American Astronomical Society.

[5] ESA and the Planck Collaboration. Hemispheric asymmetry and cold spot in the Cosmic Microwave Background. ESA Science & Technology, 20 March 2013.