Contribution ID: **110** Type: **not specified**

The enigma of the largest cosmic structures: mapping the CMB Cold Spot region with the Dark Energy Survey

Tuesday 29 March 2022 15:00 (1h 20m)

The Cold Spot is a puzzling large-scale feature in the Cosmic Microwave Background temperature maps and its origin has been subject to active debate. As an important foreground structure at low redshift, the Eridanus supervoid was recently detected, but it was subsequently determined that, assuming the standard LCDM model, only about 10-20% of the observed temperature depression can be accounted for via its Integrated Sachs-Wolfe imprint. However, R > 100 Mpc/h supervoids elsewhere in the sky have shown ISW imprints about 5 times stronger than expected from LCDM, which warrants further inspection. Using the Year-3 redMaGiC catalogue of luminous red galaxies from the Dark Energy Survey, our new analysis confirmed the detection of the Eridanus supervoid as a significant under-density in the Cold Spot's direction at z < 0.2. The DES Year-3 data also revealed, with S/N > 5 significance, that the Eridanus supervoid appears as the most prominent large-scale under-density in the dark matter mass maps reconstructed from gravitational lensing data. While we report no significant anomalies, an interesting aspect is that the amplitude of the lensing signal from the Eridanus supervoid at the Cold Spot centre is about 30% lower than expected from similar peaks found in N-body simulations based on the standard LCDM model. Overall, the new DES Y3 results confirm the causal relation between these individually rare structures in the cosmic web and in the CMB. Yet, the observed dimensions of the Eridanus supervoid cannot fully account for the Cold Spot's deep temperature depression if the standard model of dark energy is assumed in the calculations; the full explanation would require an even stronger dark energy component to cause faster expansion and a less clumpy Universe at late times. In this talk, I will also describe how the ISW analysis of supervoids in the more distant Universe, probed by eBOSS quasars, may also help to understand the core of this long-standing problem in cosmology.

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