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U.S. NAVAL OBSERVATORY 3450 MASSACHUSETTS AVE., NW WASHINGTON, DC 20392-5420

U.S. Naval Observatory

Press Release

2021 March 1

Information contact:
Dr. Nathan Secrest
Astronomer, CRF Department
U.S. Naval Observatory
nathan.j.secrest.civ@mail.mil

USNO Astronomer Leads Breakthrough Study that Questions Current Cosmological Understanding of the Universe

In a new paper published in the February 2021 issue of *The Astrophysical Journal Letters*,[1] an international team of researchers led by astronomer Dr. Nathan Secrest of the U.S. Naval Observatory (USNO) report the results of the first independent test of the standard cosmological model of the universe using observations taken from space, which show that the distribution of distant supermassive black holes (SMBHs) is in disagreement with theoretical predictions.

Specifically, the standard model of cosmology, called "Lambda Cold Dark Matter," or ΛCDM, predicts that on very large physical scales of hundreds of millions of light-years, the universe is "smooth", meaning that it appears the same everywhere. This "cosmological principle" implies that at the largest scales, any apparent irregularity should be due only to our own motion, which will make distant objects along our direction of motion appear brighter and more numerous (similar to how an approaching ambulance sounds louder).

Observations of the cosmic microwave background, or CMB, a remnant of the Big Bang that permeates the entire universe, show this effect, which translates to our Solar System moving at 370 kilometers per second with respect to the largest physical scales. Using infrared data from the orbiting *Wide-field Infrared Survey Explorer* (WISE) satellite, Secrest's team examined the distribution of distant SMBHs which, when ingesting matter from their nearby surroundings, can be seen across the universe as quasars. To the team's surprise, they found that the distribution of distant quasars is much less smooth than predicted by ΛCDM, suggesting that either the large-scale structure of the universe is more complicated than expected, or that the effect seen in the CMB implies new physics that occurred at the very earliest moments in the universe.

Previously, there were hints that the distribution of SMBHs might not align with that of the CMB, but these earlier studies were hampered by limited sample sizes of only a few hundred thousand quasars selected using radio data. In this work, Secrest's team used a sample of nearly 1.4 million quasars selected from mid-infrared data, which is especially sensitive to quasars.

This is not the first time that USNO has made key scientific contributions using WISE. In a 2015 publication in *The Astrophysical Journal Supplement Series*,[2] also led by Secrest, astronomers produced a quasar catalog that proved to be instrumental in the development of the European Space Agency's *Gaia* celestial reference frame. Now, in 2021, the extraordinary statistical power of WISE is being used to test the foundational assumptions of our understanding of the universe.

"As successful as ΛCDM has been at describing the overall structure and behavior of the universe, there is growing evidence that there may be a problem with it," says Secrest. "One example that has gained a lot of attention in recent years is the so-called 'Hubble tension,' in which the Hubble constant measured using independent methods is consistently larger than that inferred from the cosmic microwave background," he continued. "Now, our team has found that the large-scale distribution of supermassive black holes in the universe is significantly at odds with theoretical predictions, further emphasizing the need to think about cosmology beyond ΛCDM."

[1] *A Test of the Cosmological Principle with Quasars*
Secrest, N.J., von Hausegger, S., Rameez, M., Mohayaee, R., Sarkar, S., & Colin, J. 2021, ApJL, 908, 51

[2] *Identification of 1.4 Million Active Galactic Nuclei in the Mid-Infrared using WISE Data*
Secrest, N.J., Dudik, R.P., Dorland, B.N., Zacharias, N., Makarov, V., Fey, A., & Finch, C. 2015, ApJS, 221, 12