Webb identifies the earliest strands of the cosmic web

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This deep galaxy field from Webb's NIRCam (Near-Infrared Camera) shows an arrangement of 10 distant galaxies marked by eight white circles in a diagonal, thread-like line. (Two of the circles contain more than one galaxy.) This 3 million light-year-long filament is anchored by a very distant and luminous quasar—a galaxy with an active, supermassive black hole at its core. The quasar, called J0305-3150, appears in the middle of the cluster of three circles on the right side of the image. Its brightness outshines its host galaxy. The 10 marked galaxies existed just 830 million years after the big bang. The team believes the filament will eventually evolve into a massive cluster of galaxies. Credit: NASA, ESA, CSA, Feige Wang (University of Arizona); image processing: Joseph DePasquale (STScI)

Galaxies are not scattered randomly across the universe. They gather together not only into clusters, but into vast interconnected filamentary structures with gigantic barren voids in between. This "cosmic web" started out tenuous and became more distinct over time as gravity drew matter together.

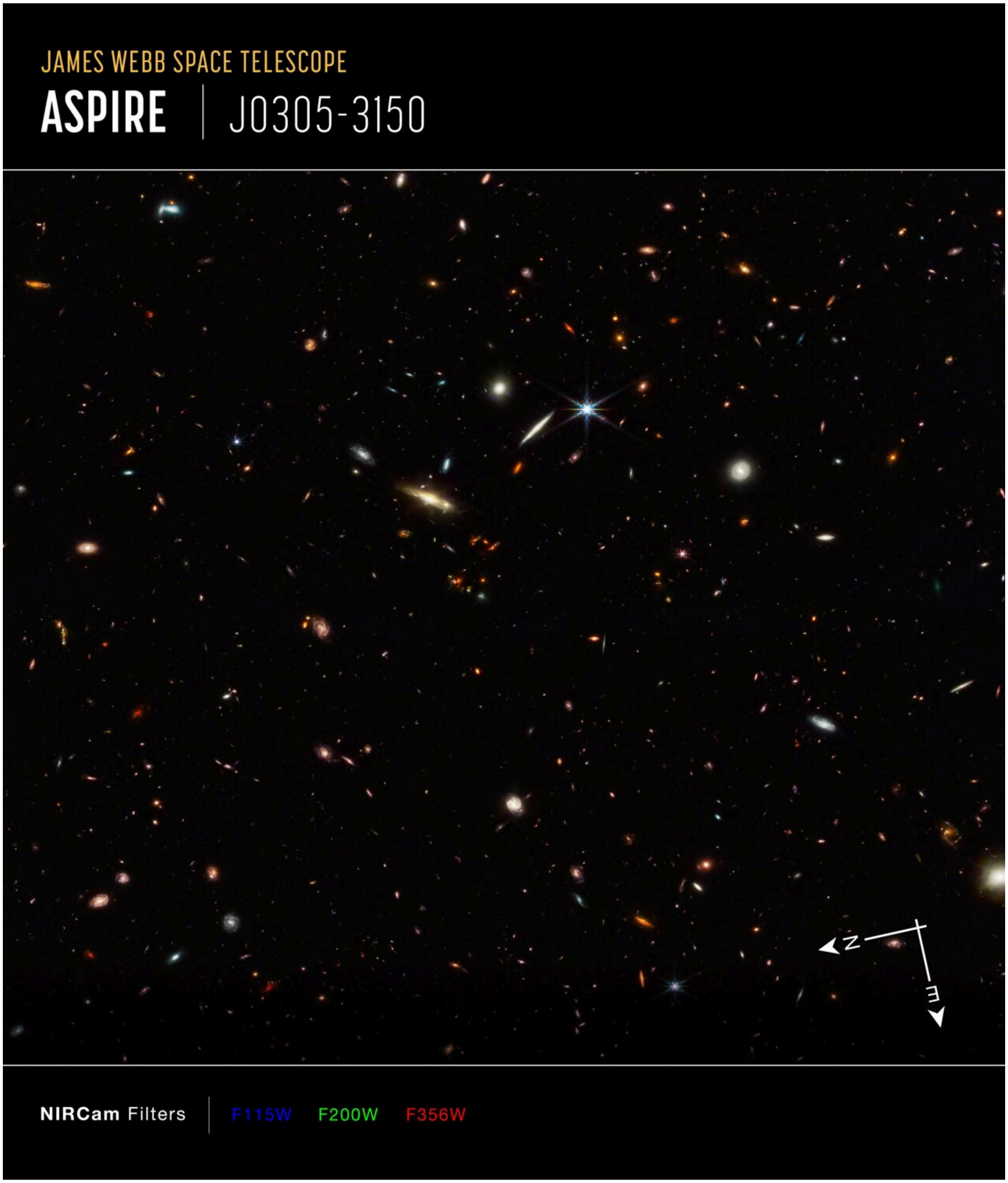
Astronomers using the James Webb Space Telescope have discovered a thread-like arrangement of 10 galaxies that existed just 830 million years after the Big Bang. The 3 million light-year-long structure is anchored by a luminous quasar—a galaxy with an active, supermassive black hole at its core. The team believes the filament will eventually evolve into a massive cluster of galaxies, much like the well-known Coma Cluster in the nearby universe.

"I was surprised by how long and how narrow this filament is," said team member Xiaohui Fan of the University of Arizona in Tucson. "I expected to find something, but I didn't expect such a long, distinctly thin structure."

"This is one of the earliest filamentary structures that people have ever found associated with a distant quasar," added Feige Wang of the University of Arizona in Tucson, the principal investigator of this program.

This discovery is from the ASPIRE project (A SPectroscopic survey of biased halos In the Reionization Era), whose main goal is to study the cosmic environments of the earliest black holes. In total, the program will observe 25 quasars that existed within the first billion years after the Big Bang, a time known as the Epoch of Reionization.

"The last two decades of cosmology research have given us a robust understanding of how the cosmic web forms and evolves. ASPIRE aims to understand how to incorporate the emergence of the earliest massive black holes into our current story of the formation of cosmic structure," explained team member Joseph Hennawi of the University of California, Santa Barbara.



This compass image shows a deep galaxy field imaged by Webb's NIRCam (Near-Infrared Camera) for the ASPIRE program. The field includes a quasar, called J0305-3150, whose brightness outshines its host galaxy. At the bottom right are compass arrows indicating the orientation of the image on the sky.

Below the image is a color key showing which NIRCam filters were used to create the image and which visible-light color is assigned to each filter. Credit: NASA, ESA, CSA, Feige Wang (University of Arizona), and Joseph DePasquale (STScI)

Growing monsters

Another part of the study investigates the properties of eight quasars in the young universe. The team confirmed that their central black holes, which existed less than a billion years after the Big Bang, range in mass from 600 million to 2 billion times the mass of our sun. Astronomers continue seeking evidence to explain how these black holes could grow so large so fast.

"To form these supermassive black holes in such a short time, two criteria must be satisfied. First, you need to start growing from a massive 'seed' black hole. Second, even if this seed starts with a mass equivalent to a thousand Suns, it still needs to accrete a million times more matter at the maximum possible rate for its entire lifetime," explained Wang.

"These unprecedented observations are providing important clues about how black holes are assembled. We have learned that these black holes are situated in massive young galaxies that provide the reservoir of fuel for their growth," said Jinyi Yang of the University of Arizona, who is leading the study of black holes with ASPIRE.

Webb also provided the best evidence yet of how early supermassive black holes potentially regulate the formation of stars in their galaxies. While supermassive black holes accrete matter, they also can power tremendous outflows of material. These winds can extend far beyond the black hole itself, on a galactic scale, and can have a significant impact on the formation of stars.

"Strong winds from black holes can suppress the formation of stars in the host galaxy. Such winds have been observed in the nearby universe but have never been directly observed in the Epoch of Reionization," said Yang. "The scale of the wind is related to the structure of the quasar. In the Webb observations, we are seeing that such winds existed in the early universe."

These results were published in two papers in *The Astrophysical Journal Letters* on June 29.

More information: Feige Wang et al, A SPectroscopic Survey of Biased Halos in the Reionization Era (ASPIRE): JWST Reveals a Filamentary Structure around a z = 6.61 Quasar, *The Astrophysical Journal Letters* (2023). DOI: 10.3847/2041-8213/accd6f

Jinyi Yang et al, A SPectroscopic Survey of Biased Halos in the Reionization Era (ASPIRE): A First Look at the Rest-frame Optical Spectra of z > 6.5 Quasars Using JWST, *The Astrophysical Journal Letters* (2023). DOI: 10.3847/2041-8213/acc9c8

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