Supermassive black holes shut down star formation during cosmic noon, says astronomer

November 7 2023, by Matt Williams

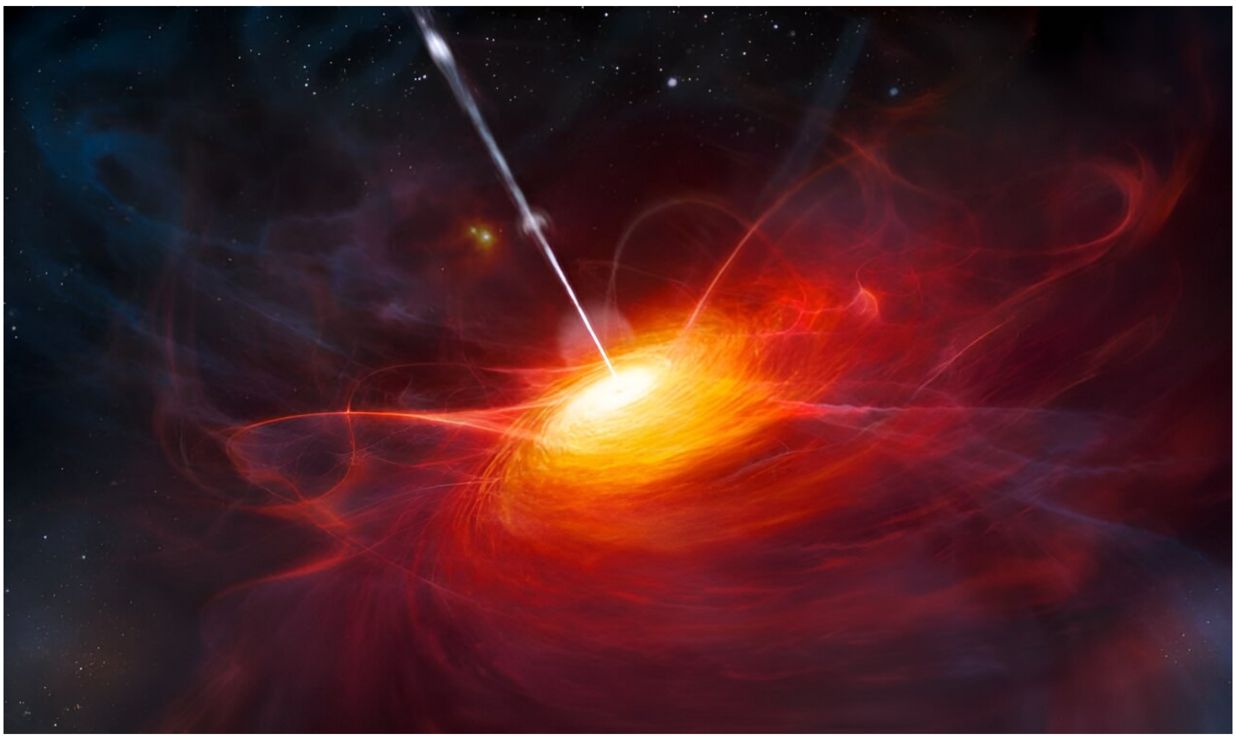

Illustration of an active quasar. New research shows that SMBHs eat rapidly enough to trigger them. Credit: ESO/M. Kornmesser

Since it became operational almost two years ago, the James Webb Space Telescope (JWST) has produced countless breathtaking images of the universe and enabled fresh insights into how it evolved.

In particular, the telescope's instruments are optimized for studying the cosmological epoch known as cosmic dawn, ca. 50 million to one billion years after the Big Bang when the first stars, black holes, and galaxies in the universe formed. However, astronomers are also getting a better look at the epoch that followed, cosmic noon, which lasted from 2 to 3 billion years after the Big Bang.

It was during this time that the first galaxies grew considerably, most stars in the universe formed, and supermassive black holes (SMBHs) became incredibly luminous quasars. Scientists have been eager to get a better look at galaxies dated to this period so they can see how SMBHs affected star formation in young galaxies.

Using near-infrared data obtained by Webb, an international team of astronomers made detailed observations of over 100 galaxies as they appeared 2 to 4 billion years after the Big Bang, coinciding with cosmic noon. The work has been released on the pre-print server *arXiv*.

The research was led by Rebecca L. Davies, a Postdoctoral Research Fellow with the Center for Astrophysics and Supercomputing (CAS) at the Swinburne University of Technology and the ARC Center of Excellence for All Sky Astrophysics in 3 Dimensions (ASTRO 3D).

She was joined by researchers from the Harvard & Smithsonian Center for Astrophysics (CfA), the Leibniz Institute for Astrophysics (AIP), the Institute for Gravitation and the Cosmos (LGC) and Institute for Computational & Data Sciences (ICDS) at Pennsylvania State University, the Kavli Institute for Cosmology and Cavendish Laboratory at the University of Cambridge, the University of Columbia's Astrophysics Laboratory, and many more.

The pre-print of their paper is being reviewed for publication in the *Monthly Notices of the Royal Astronomical Society*. As they indicate in their paper, understanding the mechanism(s) responsible for quenching star formation in massive galaxies is key to understanding how galaxies evolved. When galaxies stop forming stars, they essentially cease growing and changing and become static and "old."

As Dr. Davies told Universe Today via email, quenching is a fundamental process in the life cycle of galaxies, one which astronomers still don't understand in detail.

Over the past decade, several large galaxy surveys have been carried out that have improved our understanding of outflows during cosmic noon—when feedback from SMBHs was expected to be most active. As a result, a general consensus has emerged, which states that it all comes down to Active Galactic Nuclei (AGNs)—a.k.a. a quasar—which are powered by an SMBH at their core.

According to this consensus, an AGN's powerful radiation will expel cold gas while heating the gas reservoir in the galactic halo. This prevents said gas, which fuels star formation, from cooling and being re-accreted to replenish the reservoir.

As Dr. Davies explained, "It is well established that active galactic nuclei—supermassive black holes consuming large amounts of gas—can drive outflows from galaxies. The most powerful AGN drive very massive outflows that could possibly remove all of the gas from their host galaxies in a relatively 'short' amount of time (in astronomical terms!) and cause star formation to cease. However, more 'normal' AGN seem to drive much weaker outflows, and it is debated whether these outflows are powerful enough to quench star-formation."

There are many indirect lines of evidence to suggest that massive galaxies are quenched by supermassive black hole activity, but direct evidence for this has thus far been lacking.

"The picture is complicated because outflows are 'multiphase'—they contain gas spanning a wide range of temperatures and densities, which emits light all the way across the electromagnetic spectrum from X-ray to radio wavelengths," added Davies. "Most of our observations target ionized gas because it is the easiest to see. However, we think this only accounts for about 1% of the outflows, so we are only scraping the tip of the iceberg when it comes to the outflowing mass."

For their study, the team relied on data obtained by Webb's Near-Infrared Slitless Spectrograph (NIRSpec) of 113 galaxies selected from the mass-complete Blue Jay survey. This survey was part of the JWST Cycle 1 General Observations (GO 1810), which investigated the prevalence and typical properties of neutral gas outflows at cosmic coon.

The sensitivity and high resolution of the NIRSpec instrument allowed Daniels and her colleagues to study cold neutral gas outflows in these selected galaxies in ways that were not possible before.

As she explained, "We detected cool neutral gas outflows driven by AGN activity in around 1/4 of the massive galaxies we observed. These neutral outflows are at least as massive as previously measured ionized outflows, and in some cases, the neutral outflows are 10–100x heavier. Importantly, the outflows are seen in galaxies at a wide range of evolutionary stages: some galaxies are actively forming stars and others are almost quenched. In the quenching galaxies, the outflows are removing gas up to 300x faster than it is being converted into stars."

These observations bolster the theory that AGNs are responsible for "shutting down" star formation in galaxies once they reach a certain age. This, in turn, could advance our understanding of galaxy evolution by quantifying the effects of AGNs during a key phase in galactic development.

While ongoing observations of cosmic dawn are providing a glimpse of galaxies when they were emerging from the cradle (the cosmic dark ages), this research offers detailed information on what they looked like as they were moving towards maturity. The combined result, said Davies, is a more complete understanding:

"Our results suggest that AGN-driven outflows are able to rapidly remove cool gas from galaxies, starving them of fuel for star formation. These powerful outflows are not rare but appear to be relatively frequent among massive distant galaxies. Therefore, the removal of cool gas by AGN-driven outflows may be a common cause for the rapid shut-down of star formation in massive, distant galaxies."

More information: Rebecca L. Davies et al, JWST Reveals Widespread AGN-Driven Neutral Gas Outflows in Massive z ~ 2 Galaxies, *arXiv* (2023). DOI: 10.48550/arxiv.2310.17939

Provided by Universe Today