UC SANTA BARBARA

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The earliest quasars yet observed are shedding light on the infancy of our cosmos

Quasars are among the brightest, most energetic objects in the universe, powered by supermassive black holes devouring matter at the centers of galaxies. Their extreme luminosity makes them visible across tremendous cosmic distances.

An international team of scientists has discovered 31 of the most ancient quasars ever found. Two of these are the earliest yet observed in cosmic history. They radiated the light of a trillion suns back when the universe was a mere 670 million years old. The findings, published in the journal Astronomy & Astrophysics, mark a significant step forward in our understanding of the early universe.

“These objects provide the best clues for understanding how supermassive black holes form,” said co-author Joseph Hennawi, a physics professor with joint appointments at UC Santa Barbara and Leiden University. “These monsters — weighing billions of times the mass of our sun — somehow already existed when the universe was in its infancy. We don't yet have a good understanding of how they grew so massive, so fast.”

Bright, yet elusive

Astronomers have been hunting for the universe’s very first quasars for decades. These objects reveal what was happening during the cosmos’ earliest days, including how the first supermassive black holes and galaxies took shape.

Yet, quasars from earlier than about 770 million years after the Big Bang are exceedingly rare and difficult to detect. Few galaxies had yet grown large enough to create a quasar. Even then, the light from these primordial quasars is both faint and easily mistaken for signals from stars lying closer to us.

What’s more, their light is stretched from ultraviolet into near-infrared wavelengths by cosmic expansion, falling into a range where Earth’s atmosphere glows brightly, drowning out faint signals. Scientists actually use this “redshift” as a measure of an object’s age and distance, since light from farther away (and thus earlier in the life of the universe) has been shifted more toward longer wavelengths by the subsequent expansion of spacetime. “A redshift of 7 takes us to when the universe was just 750 million years old, less than 6% of its current age,” Hennawi said.

“These two things make finding quasars at these distances incredibly difficult,” said lead author Daming Yang, a doctoral student in Hennawi’s group at Leiden University. “For every one of them there are thousands of stars in our Milky Way and nearby galaxies that look almost identical in the imaging surveys. And since their light is stretched to the infrared at such distances, we need a survey that is both wide enough to capture these rare objects and deep enough to detect their faint light.” The task is nearly impossible to carry out on the ground. You need to get a view from space.

Image

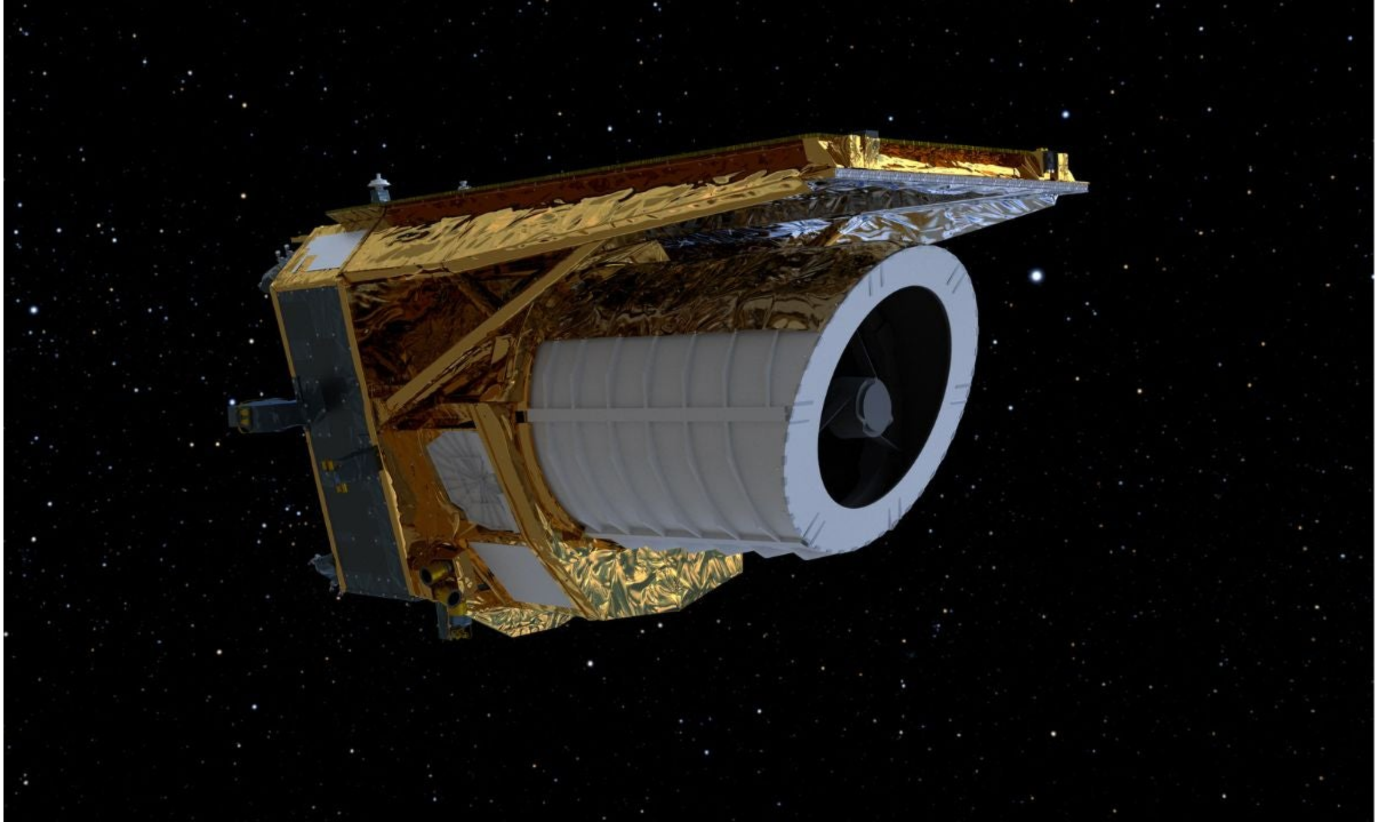

Photo Credit
European Space Agency
The Euclid Space Telescope was developed to measure the accelerating expansion of the universe so scientists could better understand dark matter, dark energy, and the early cosmos.

Eye in the sky

In 2023, the European Space Agency (ESA) launched the Euclid space telescope to help demystify this era of ancient cosmic history. It views the universe from above our planet’s infrared haze, surveying an area of the sky far larger than ground-based observatories could cover at comparable depth. The telescope has now discovered an unprecedented number of 31 new quasars in the early universe, pushing back to a time when the cosmos was just 5% of its current age. These appeared in data from the Euclid Wide Survey, which will cover more than one-third of the total sky once complete.

The earliest quasars we knew of until now were the rare, bright outliers that had been easiest to spot. We hadn’t yet found enough quasars from the universe’s early days to study them properly as a group. “Euclid is a true game-changer,” Daming said. “Before, we could only find a handful of the very brightest ancient quasars, but Euclid lets us search far more efficiently across huge areas of sky to capture much fainter light. It’s a unique tool for quasar hunting.”

Beacons from the early universe

The second most ancient quasar found by Hennawi, Daming and their colleagues was recently studied in more detail. The analyses revealed that the quasar was embedded in a dusty, gas-filled galaxy that was furiously forming new stars, hinting at what the host galaxy of an early supermassive black hole may have been like.

These quasars hark back to a fascinating period in cosmic history — known as the epoch of reionisation — when the first stars and galaxies ionized the dark, neutral hydrogen fog filling the early universe. This was a crucial era that set the stage for everything we see today.

Of the 31 new quasars, 14 are at or above a redshift of 7. The two most ancient of the batch have redshifts of 7.69 and 7.77, setting a new record for the earliest quasars ever found. Both lie just over 13 billion light-years away, and emerged during the universe’s first 670 million years. They also break the previous record for earliest quasar that Hennawi’s group set back in 2021.

But each new record isn't just a record for its own sake. “Every step further back in time makes the puzzle more perplexing: How did the Universe produce supermassive black holes so quickly?” Hennawi said. “We're finding black holes with hundreds of millions of times the mass of our sun at a time when the universe was barely getting started.” Answering this quandary will require looking even farther into our cosmic past.

Pushing ever earlier

A combination of better telescopes and smarter searches have enabled astronomers to continue peering deeper into the universe’s history. Discovering the first 10 or so quasars at a redshift of 7 or above took astronomers more than a decade — but

Euclid has already discovered more than that in a single year. This finding more than doubles the number of quasars we know of that are so ancient.

In addition to revolutionary observatories like Euclid, new machine-learning methods enable scientists to sift through tens of millions of sources and reliably pick out the handful of real quasars from the far more common imposters, Hennawi explained.

Hennawi’s group has spent years developing the algorithms that proved critical in these recent discoveries. He’s also the lead developer of PypeIt, the software that astronomers at the University of California use to process the data that they collect at the Keck telescopes. Two-thirds of these new quasars, including the three most distant ones, were discovered with Keck through the UC’s privileged access.

The team’s new goal is to push the distance frontier even further, and find the first quasar beyond redshift 8. That would place it within the first 630 million years of the universe’s lifetime.

But discovery is just half the story. The team already has approved programs with the James Webb Space Telescope to study many of these quasars in detail, including measuring the masses of their black holes, probing the chemistry of the gas around them, and using the imprint of the intergalactic medium on their light to trace how reionization progressed. Meanwhile, telescopes like the Atacama Large Millimeter Array will target the cosmic dust glowing in the host galaxies themselves, revealing aspects about their dust, gas and star formation.

“The bigger vision is to stitch all of this together into a coherent timeline,” Hennawi said: “a quasar chronicle of the first billion years.”

Daming Yang, Antoine Basset and Jean-Charles Cuillandre of the Euclid Consortium contributed to this story.

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About UC Santa Barbara

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