BraintankAI ASIA

EXPLAINER · EARLY BLACK HOLES · 6 MIN

TOKYO · Institute for Cosmic Ray Research

How a broadened hydrogen line exposed ten low-mass black holes in early galaxies

Sifting 185 Webb spectra, astronomers found ten modest feeding black holes in distant galaxies, weighed them from a single line of light, and found them heavy for their hosts.

20 November 2026 · based on a paper in The Astrophysical Journal

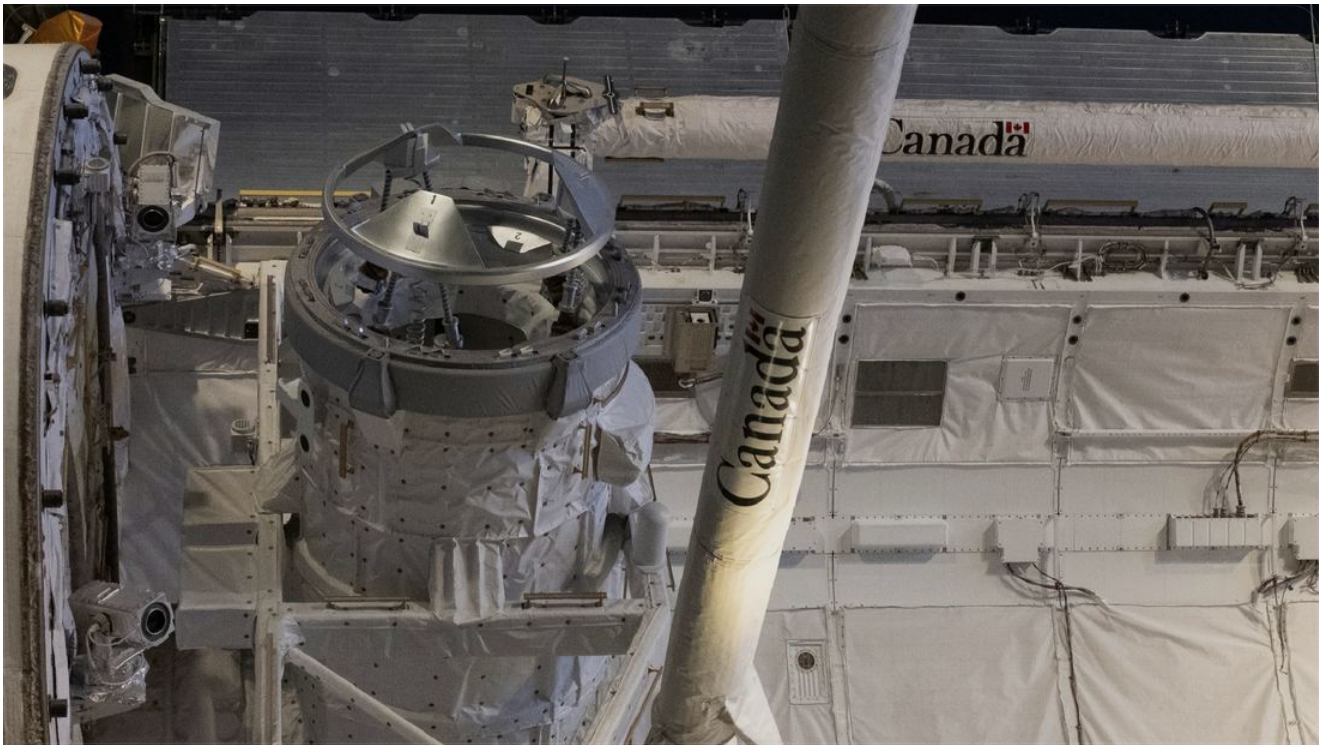


Photo: Frederick Wallace

Before the James Webb Space Telescope (JWST), nearly everything astronomers knew about black holes in the distant universe came from quasars: active galactic nuclei, or AGNs, which are black holes feeding on gas and shining brightly enough for ground-based telescopes to pick out. Even the low-luminosity quasars found beyond a redshift of 4 held black holes of a hundred million to a billion times the Sun's mass. That is heavy compared with the feeding black holes found nearby. (Redshift, written z, measures how much cosmic expansion has stretched an object's light. The higher it is, the further back in time we are seeing.)

Smaller black holes are another matter. One feeding more quietly inside an ordinary galaxy has its glow mixed in with starlight. Early JWST studies had reported individual examples, but nobody had a sample large enough to say how common they were or how they grew alongside their galaxies. In a 2023 paper accepted by The Astrophysical Journal, Yuichi Harikane and colleagues at

the University of Tokyo, the National Astronomical Observatory of Japan and other institutions set out to find, confirm and weigh such objects as a population. They describe the result as the first statistical census of faint broad-line AGNs at z = 4–7.

The idea

The method rests on how gas glows. A galaxy's spectrum, its light spread out by wavelength, is marked by emission lines: bright spikes at specific wavelengths produced by particular atoms. Hydrogen produces a strong red line called H-alpha (Hα) and a weaker blue one called H-beta (Hβ). Moving gas smears a line out through the Doppler effect, and faster motion makes a wider line. Astronomers express that width as the FWHM (full width at half maximum), quoted in kilometres per second.

Gas orbiting close to a feeding black hole moves fast enough to produce very broad lines. An AGN seen from an angle where this inner gas is visible is called a type-1, or broad-line, AGN. The distinction between permitted and forbidden lines is what the test relies on. Permitted lines such as Hα can form in the dense gas right next to the black hole. Forbidden lines, such as those from doubly ionised oxygen (written [OIII]), form only in thinner gas further out. A broad permitted line alongside a narrow forbidden line therefore points to gas orbiting the black hole rather than a wind sweeping through the galaxy.

The same broad line also serves to weigh the black hole. Its width gives the speed of the gas, and its brightness stands in for how far that gas sits from the black hole. Combining the two through a relation calibrated on nearby AGNs gives a so-called single-epoch mass estimate from just one spectrum.

How this paper puts it to work

The team reanalysed spectra from NIRSpec, JWST's near-infrared spectrograph, taken by three public programmes: the telescope's Early Release Observations of the galaxy cluster SMACS 0723, the GLASS survey towards the cluster Abell 2744, and the CEERS survey. Together these covered 185 galaxies with confirmed redshifts between 3.8 and 8.9. The data were uneven. Exposure per instrument setting ranged from under an hour in CEERS to about five hours in the other two fields, and spectral resolution differed between them.

For each galaxy the authors fitted the Hβ, [OIII], Hα and nitrogen [NII] lines with narrow components, adding outflow or broad components where needed. An object counted as a type-1 AGN only if it passed two tests. First, its Hα line (or Hβ for the most distant objects) needed a broad component wider than 1,000 km/s, detected with a signal more than five times the noise. Second, its forbidden lines, including any outflow component, had to stay narrower than 700 km/s. The team also compared fits with and without the broad component using the Akaike Information Criterion, a score that rewards a better fit but penalises added complexity.

For objects that passed, black hole masses came from the broad Hα line's luminosity and width, using a calibration derived from nearby AGNs. Total energy output was estimated from Hα, with a range from alternative recipes. To weigh the host galaxies, the team split JWST and Hubble images into a point-like source for the AGN and a smooth galaxy profile, then modelled the host's light to

estimate its mass in stars. Finally they combined the share of galaxies hosting AGNs with known counts of galaxies at each brightness. That gave an estimate of how common such AGNs are and how much they contributed to reionisation, the era when ultraviolet light stripped electrons from hydrogen between galaxies.

What it shows, and what it does not

Ten of the 185 galaxies passed, at redshifts from 4.015 to 6.936. Their broad Hα components span roughly 1,000 to 6,000 km/s, while [OIII], detected even more strongly than Hα, shows only narrow emission of about 500 km/s or less. The broad component was strongly favoured statistically in every case. Two objects match ones reported independently by another team, with consistent widths. The black holes come out at roughly a million to a hundred million solar masses, well below the ground-based quasars, and none had turned up in an earlier X-ray search. Seven of the ten look like extended galaxies rather than points of light. Two of the compact ones are heavily reddened by dust.

The host galaxies have systematically lower stellar masses than nearby AGN hosts with black holes of similar mass. The authors read this as a sign that the black holes grew faster than their galaxies. They estimate that about 5% of galaxies at z = 4–7 host such an AGN, against 1–2% locally at similar luminosity. They also find these AGNs could supply up to about half of the hydrogen-ionising radiation inferred at z ~ 6, a real but not dominant share. At similar black hole mass, the AGNs also appear on average more luminous than nearby ones, which would mean they are feeding faster.

The study has clear limits. The selection behind which galaxies were targeted for spectroscopy is not known and could be very complex, so the authors call their abundance figures rough estimates and urge caution over the 5% fraction. Other JWST surveys with different sensitivity find fractions from under 1% to around 10%. The surveyed sky area is small and the sample is ten objects. Masses rely on a calibration from the nearby universe. Uncertainty over whether the narrow part of Hα comes from the AGN shifts them by up to a factor of about 2.5. Four host masses are only upper limits. The higher luminosities may be a selection effect, since AGNs with faint broad Hα could fall below the detection threshold. The reionisation share depends on assuming half the ionising light escapes, where published values span 0.3 to 0.8. The case that these are AGNs rests mainly on line widths. High-ionisation lines are largely absent, and a standard diagnostic plot of line ratios cannot separate the hosts from ordinary star-forming galaxies, probably because their gas is poorer in heavy elements than the Sun. Mergers and outflows are argued against by comparing the line widths with earlier studies of such systems. What the study does establish is that faint broad-line AGNs were present and not rare at these epochs. Its population figures are best treated as rough estimates.

PAPER *A JWST/NIRSpec First Census of Broad-line AGNs at z = 4–7: Detection of 10 Faint AGNs with M_BH ~ 10^{6} –10^{8} $M_{\odot}$ and Their Host Galaxy Properties*

AUTHORS Yuichi Harikane, Yechi Zhang, Kimihiko Nakajima, Masami Ouchi, Yuki Isobe, Yoshiaki Ono, Shun Hatano, Yi Xu, Hiroya Umeda et al.

VENUE The Astrophysical Journal · 1 December 2023

LINK doi:10.3847/1538-4357/ad029e

INDEX stacks.braintank.ai