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The Cosmic Donut Returns: JWST Confirms the "Unified Model" of Active Galaxies by the Circinus Accretion Disk

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Introduction: The Black Hole Energy Crisis and the Unified Model

In January 2026, extragalactic astrophysics achieved a major observational breakthrough with high-resolution James Webb Space Telescope (JWST) observations of the Circinus Galaxy. Utilizing the Aperture Masking Interferometry (AMI) mode of the Near-Infrared Imager and Slitless Spectrograph (NIRISS), an international team led by Dr. Enrique Lopez-Rodriguez resolved the parsec-scale architecture of the galaxy's active nucleus.[1][12] Contrary to prevailing ground-based models suggesting that mid-infrared (MIR) emission in nearby active galaxies is dominated by polar dusty winds, the JWST data demonstrate that approximately 87% of the emission originates within a compact, equatorial accretion disk -- the long-theorized "dusty torus" -- while dusty polar outflows contribute less than 1% of the infrared energy budget.[1][12]

For over half a century, the study of Active Galactic Nuclei (AGN) has centered on how supermassive black holes -- compressing millions to billions of solar masses within their Schwarzschild radius -- acquire fuel and regulate their host galaxies. The standard "Unified Model" of AGN posits a central black hole surrounded by a hot accretion disk, which is encircled by an equatorial, doughnut-shaped torus of molecular gas and dust.[1][3] Viewing orientation relative to this torus explains why some systems appear as unobscured "Type 1" AGN while edge-on systems appear as obscured "Type 2" AGN.[1] Prior to 2026, interferometric studies of archetype galaxies such as NGC 1068 indicated that parsec-scale MIR emission was dominated by feedback-driven polar dust cones rather than the equatorial torus.[4] By resolving the Circinus core free from atmospheric distortion, JWST has overturned the outflow-dominated paradigm for this nearby Seyfert 2 engine.[1]

The Circinus Galaxy Laboratory (ESO 97-G13)

Testing the physics of black hole accretion requires a target that is both bolometrically active and sufficiently nearby for spatial resolution. Located approximately 13 million light-years (4.0 megaparsecs) away in the southern constellation Circinus, the Circinus Galaxy (ESO 97-G13) is one of the closest active spiral galaxies (Type SA(s)b) to the Milky Way.[1][5] Because it lies only 4 degrees below the Galactic plane, heavy foreground extinction delayed its discovery until 1977.[5] Classified as a Compton-thick Seyfert 2 galaxy, Circinus hosts intense circumnuclear star formation organized into an outer ring spanning ~1,400 light-years and a compact inner starburst ring 260 light-years in diameter.[2][5]

Before JWST, multi-wavelength observatories mapped the broader environment surrounding the central engine:

* Hubble Space Telescope (HST): Optical imaging revealed a prominent V-shaped

ionization cone where ultraviolet radiation escaping along the polar axis of the torus photoionizes halo gas.[2][5]

* Chandra X-ray Observatory: X-ray spectroscopy confirmed a Compton-thick obscuring column density alongside shock-heated kiloparsec lobes driven by long-term AGN feedback.[6][7]

* Atacama Large Millimeter/submillimeter Array (ALMA): Submillimeter CO observations traced cold molecular spiral arms channeling fuel inward at 0.3 to 7.5 solar masses per year.[8]

Methodology: Breaking the Diffraction Limit via NIRISS Interferometry

Even with JWST's 6.5-meter primary mirror, standard full-aperture imaging at 3.8-4.8 m is constrained by the Rayleigh diffraction criterion (~ 1.22 /D), which blends the parsec-scale torus with surrounding nuclear starburst emission at a distance of 4 megaparsecs. To surpass this limit, Lopez-Rodriguez and colleagues employed Aperture Masking Interferometry (AMI) aboard NIRISS.[9][12]

The AMI mode inserts a Non-Redundant Mask (NRM) -- an opaque aluminum plate pierced by seven hexagonal sub-apertures -- into the pupil plane.[9][10] Light beams passing through the seven holes interfere on the detector to produce a complex two-dimensional interferogram. Because every pair of sub-apertures forms a unique baseline length and orientation, Fourier analysis of the fringe visibilities and closure phases cancels out wavefront jitter and effectively doubles the angular resolution of JWST.[9][10] Observing across three medium-band filters -- F380M (3.8 m), F430M (4.3 m), and F480M (4.8 m) -- this configuration achieved an effective resolution equivalent to a 13-meter space telescope, resolving physical scales down to 2 parsecs (~6.5 light-years) in the first extragalactic deployment of space-based aperture masking interferometry.[1][9][13]

Results: Anatomy of the Accretion-Dominated Dusty Torus

Reconstructed NIRISS/AMI images spatially resolved a flattened, elongated equatorial disk at the core of the Circinus Galaxy, aligned perpendicular to the optical ionization cone.[10][11][12] For the first time, astronomers directly imaged the central sublimation cavity -- the "donut hole" -- where intense radiation from the inner accretion disk vaporizes dust grains, illuminating the warm inner walls of the torus.[12] Cooler, self-shadowed outer regions of the torus appear as dark absorption patches silhouetted against background emission.[12]

| Morphological Component | | Physical Role & Geometry | | Share of Mid-IR Flux (3.8-4.8 m) |

| Equatorial Dusty Torus (Disk) | | Compact, rotationally supported parsec-scale feeding reservoir | | ~87%[1][12] |

| Extended Nuclear Emission | | Uncollimated host-galaxy and circumnuclear starburst dust | | ~12%[1][12] |

| Polar Dusty Outflows | | Hot dust entrained along the biconical ionization wind | | < 1%[1][12] |

Coupling these radiative measurements with ALMA kinematic maps (Goesaert et al., 2025) completes the mass-flow budget: cold molecular gas inflowing at 0.3-7.5 M yr 1 accumulates stably within the 4.3 m equatorial disk, while less than 1% of the hot dust mass escapes into polar winds.[8][12] Moreover, the smooth, coherent morphology of the resolved disk indicates a high volume-filling factor of dust clouds, supporting dynamical torus models.[3]

Conclusion: Recalibrating AGN Feedback and the Unified Model

The contrast between the accretion-dominated Circinus nucleus (87% equatorial torus emission) and the polar-dust-dominated paradigm derived from NGC 1068 underscores how black hole feeding and feedback depend on the Eddington ratio.[4][13] Operating at a moderate Eddington accretion rate, Circinus lacks sufficient radiation pressure to lift heavy silicate and graphitic dust grains out of the central gravitational potential well, retaining its dust within an equatorial fountain while allowing ionized gas to escape along the poles.[12][13]

By transforming JWST into an interferometric array with 13-meter equivalent resolution, Lopez-Rodriguez and colleagues have vindicated the classic geometric Unified Model of AGN in our nearest Seyfert 2 neighbor.[10][12] Upcoming NIRISS/AMI campaigns targeting a broader statistical sample of nearby active nuclei -- including space-based re-evaluations of NGC 1068 -- will establish how black hole mass and accretion luminosity govern the balance between equatorial feeding and radiative feedback across cosmic time.[12]

Updates... (Nov 22, 2026): Standardized exact publication dates across all 13 cited studies, JWST instrumentation guides, and NASA/STScI/ESA press releases (including Lopez-Rodriguez et al., Nature Communications, January 13, 2026).

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