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ALMA weighs supermassive black hole at center of distant spiral galaxy

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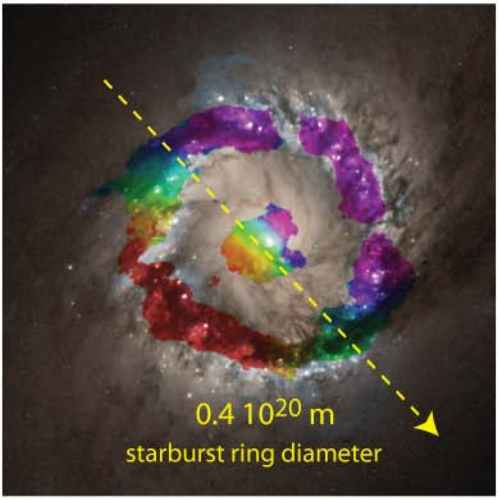

The central region of NGC 1097 observed with ALMA. The velocity of the HCN gas is shown in the color and overlaid on the optical image taken by the Hubble Space Telescope. Red indicates gas is moving away from us while purple is coming closer to us. Credit: ALMA (ESO/NAOJ/NRAO), K. Onishi (SOKENDAI), NASA/ESA Hubble Space Telescope

Supermassive black holes lurk at the center of every large galaxy. These cosmic behemoths can be millions to billions of times more massive than the Sun. Determining just how massive, however, has been daunting, especially for spiral galaxies and their closely related cousins barred spirals.

In a new proof-of-concept observation, astronomers using the Atacama Large Millimeter/submillimeter Array (ALMA) have measured the mass of the supermassive black hole at the center of NGC 1097—a barred spiral galaxy located approximately 45 million light-years away in the direction of the constellation Fornax. The researchers determined that this galaxy harbors a black hole 140 million times more massive than our Sun. In comparison, the black hole at the center of the Milky Way is a lightweight, with a mass of just a few million times that of our Sun.

To achieve this result, the research team, led by Kyoko Onishi at SOKENDAI (The Graduate University for Advanced Studies) in Japan, precisely measured the distribution and motion of two molecules—hydrogen cyanide (HCN) and formylium (HCO+)—near the central region of the galaxy. The researchers then compared the ALMA observations to various mathematical models, each corresponding to a different mass of the supermassive black hole. The "best fit" for these observations corresponded to a black hole weighing in at about 140 million solar masses. The results are published in the *Astrophysical Journal*.

A similar technique was used previously with the CARMA telescope to measure the mass of the black hole at the center of the lenticular galaxy NGC 4526.

The spin vector direction of the plasma epoch turbulent vortex line that fragmented the NGC 1097 protogalaxy is quite clear from these ALMA observations. The size of protogalaxies is 10^20 meters, preserved by all galaxies observed as a fossil of plasma turbulence, Gibson (1996).

Estimate of the size of a plasma protogalaxy

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ABSTRACT

A sample calculation of the fragmentation scale of the plasma is presented based on conditions existing during the plasma epoch between 3000 and 300,000 years after the big bang cosmological event.

SAMPLE CALCULATION

Viscous, gravitational, and turbulence stresses match at scales less than the Hubble scale of causal connection at time 10^{12} seconds according to HGD cosmology, Gibson (1996). The length scale L_{PG} will be slightly larger than the Kolmogorov-Nomura scale of the plasma since the plasma turbulence is weak.

$$L_{PG} \sim [\gamma\nu/\rho G]^{1/2}$$

In the expression, γ is the rate-of-strain, ν is the kinematic viscosity, ρ is the density, and G is Newton's constant of gravity.

Subtituting best estimates in si units gives

$$L_{PG} \sim [\gamma\nu/\rho G]^{1/2} \sim [10^{-12}\ 10^{26}/10^{-17}\ 10^{-10}]^{1/2} = [10^{41}]^{1/2} = 3.2\ 10^{20}\ \text{m}.$$

Thus the expected fragmentation scale of plasma epoch protogalaxies is $\sim 10^{20}$ meters, as observed. The protogalaxy mass is therefore ~ the volume 10^{60} m^3 times the density $\rho \sim 10^{-17}$ kg m^{-3}, or 10^{43} kg. The observed baryonic value for galaxy mass is a factor of 10 smaller.