Evidence for a Super-massive Black Hole at the Center of the Milky Way

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While the concept of a black hole formed by the explosive collapse of a dying star is astounding, the possibility that matter from billions of stars can condense into a single super-massive black hole (SMBH) is even more fantastic. Yet astronomers are now confident that they exist at the centers of most galaxies and hold more than 0.01% of the baryonic mass of the Universe.

Early evidence for SMBHs came from “radio galaxies” with two lobes symmetrically placed about the parent galaxy. These lobes are immense and minimum energy estimates require the total conversion of $10^7$ stars to energy! The source of energy was traced to galaxy’s center and observed to vary on time scales < 1 year. Since nuclear reactions convert less than 1% of mass to energy, this would require channeling $> 10^9$ stars through a region smaller than that between the Sun and the nearest star. A very compact radio source was discovered toward the center of the Milky Way and named Sgr A*, leading to speculation that it might be a SMBH. Infrared observations of stars on elliptical orbits give clear evidence of an unseen gravitational source of $4 \times 10^6$ solar masses. One star has been seen moving at 5000 km/s in its 16 year eccentric orbit.

Sgr A* has been located at the position of the gravitational focus of the stellar orbits. However, in contrast to the rapidly moving stars, Sgr A* is motionless (< 1 km/s), requiring the source to be extremely massive. For comparison, gravitational “Brownian motion” of a SMBH at the center of a dense stellar cluster would be comparable to the measured limits. Recent radio interferometric observations show that the radio emission from Sgr A* comes from a region comparable in size to the Schwarzschild radius $(2GM/c^2)$ of 0.1 AU ($1.5 \times 10^7$ km)! Placing any known concentration of $4 \times 10^6$ solar masses within this tiny volume would rapidly condense to a black hole.