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# The Inner Shadow of the Black Hole in M87*: A Direct View of the Event Horizon

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Simulated images of a black hole surrounded by optically thin emission typically display two main features: a central brightness depression and a narrow, bright "photon ring" consisting of strongly lensed images superposed on top of the direct emission. The photon ring closely tracks a theoretical curve on the image plane corresponding to light rays that asymptote to unstably bound photon orbits around the black hole. This critical curve has a size and shape that are purely governed by the Kerr geometry; in contrast, the size, shape, and depth of the observed brightness depression all depend on the details of the emission region. For instance, images of spherical accretion models display a distinctive dark region – the "black hole shadow" – that completely fills the photon ring. By contrast, in models of equatorial disks extending to the black hole's event horizon, the darkest region in the image is restricted to a much smaller area – an inner shadow – whose edge lies near the direct lensed image of the equatorial horizon. Using both semi-analytic models and general relativistic magnetohydrodynamic (GRMHD) simulations, we demonstrate that the photon ring and inner shadow may be simultaneously visible in submillimeter images of M87*, where magnetically arrested disk (MAD) simulations predict that the emission arises in a thin region near the equatorial plane. We show that the relative size, shape, and centroid of the photon ring and inner shadow can be used to estimate the black hole mass and spin, breaking degeneracies in measurements of these quantities that rely on the photon ring alone. Both features may be accessible to direct observation via high-dynamic-range images with a next-generation Event Horizon Telescope.

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