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Who knows what dark matter lurks in the heart of M87: The shadow knows, and so does the ringdown.

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We calculate the effect of dark matter on the ringdown waveform and shadow of supermassive black holes at the core of galaxies. Our main focus is on the supermassive black hole at the core of M87, which is large enough to allow for viable observational data. We compare the effects of a dark matter spike to those expected from a galactic halo of the same mass. Our calculation for the halo starts from the Hernquist density function and assumes anisotropic pressure that is zero in the radial direction. The resulting Tolman-Oppenheimer-Volkoff equations allow the corresponding metric to be obtained analytically in closed form. The geometry of the anisotropic dark matter spike is the same as that obtained in [ApJ 940 33 (2022)] under the assumption of isotropy. The effect of the spike is orders of magnitude more significant than the halo as long as the distribution scale of the latter is within a few orders of magnitude of the value expected from observations. Our results indicate that the impact of the spike surrounding M87* on the ringdown waveform may in principle be detectable. Finally, we point out the somewhat surprising fact that existing Event Horizon Telescope observations of black hole shadows are within an order of magnitude from being able to detect, or rule out, the presence of a spike.

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