Black Hole Shadows

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100 years after Albert Einstein formulated General Relativity (GR), we finally face a realistic prospect of testing one of its most dramatic consequences: black holes (BHs). The evidence for astrophysical BHs, gathered for over half a century, has built a strong case, but it could not yet confirm the existence of event horizons, the defining property of BHs.

We live, however, exciting times. A new channel of observation – gravitational waves – has just been opened and electromagnetic measurements of unprecedented precision are taking place, hopefully clarifying this central issue.

A particularly promising prospect is the use of Very Large Baseline Interferometry (VLBI) techniques to resolve the angular scale of the event horizon for some supermassive BH candidates and determine the corresponding BH "shadow". This is the silhouette of the BH against background light sources. Its observation would probe the spacetime geometry in the vicinity of the horizon and consequently test the existence and properties of the latter. It is therefore timely to study BH models that yield phenomenological deviations from the paradigmatic GR BH, described by the Kerr metric.

Exact solutions with physically reasonable and astrophysically plausible matter sources, however, are scarce; but Kerr BHs with scalar hair (KBHsSH), discovered in 2014, by Aveiro U. researchers [1] are arguably one such model. These are exact solutions of Einstein's gravity minimally coupled to a massive complex scalar field, and interpolate between Kerr BHs and gravitating solitons – boson stars – suggested as dark matter candidates and BH mimickers.

In this letter we have shown that the shadows of KBHsSH are distinguishable, or even drastically different, from those of Kerr BHs, and can thus yield new templates for the ongoing and future VLBI searches of BH shadows.

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FIGURE 1
The shadow of a KBHSH, produced by our lensing code, against nebula NGC 346 (NASA/ESA image).

FIGURE 2
Image with the lensing of a boson star.