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The imitation game: Proca stars that can mimic the Schwarzschild shadow

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Can a dynamically robust bosonic star (BS) produce an (effective) shadow that mimics that of a black hole (BH)? The BH shadow is linked to the existence of light rings (LRs). For free bosonic fields, yielding mini-BSs, it is known that these stars can become ultra-compact - i.e., possess LRs - but only for perturbatively unstable solutions. We show this remains the case even when different self-interactions are considered. However, an effective shadow can arise in a different way: if BSs reproduce the existence of an innermost stable circular orbit (ISCO) for timelike geodesics (located at rISCO=6M for a Schwarzschild BH of mass M), the accretion flow morphology around BHs is mimicked and an effective shadow arises in an astrophysical environment. Even though spherical BSs may accommodate stable timelike circular orbits all the way down to their centre, we show the angular velocity along such orbits may have a maximum away from the origin, at RΩ; this scale was recently observed to mimic the BH's ISCO in some scenarios of accretion flow. Then: (i) for free scalar fields or with quartic self-interactions, RΩ≠0 only for perturbatively unstable BSs; (ii) for higher scalar self-interactions, e.g. axionic, RΩ≠0 is possible for perturbatively stable BSs, but no solution with RΩ=6M was found in the parameter space explored; (iii) but for free vector fields, yielding Proca stars (PSs), perturbatively stable solutions with RΩ≠0 exist, and indeed RΩ=6M for a particular solution. Thus, dynamically robust spherical PSs can mimic the shadow of a (near-)equilibrium Schwarzschild BH with the same M, in an astrophysical environment, despite the absence of a LR, at least under some observation conditions, as we confirm by comparing the lensing of such PSs and Schwarzschild BHs.

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