Contribution ID: **19** Type: **not specified**

Black-hole solutions with primary scalar hair

Wednesday 22 May 2024 12:30 (15 minutes)

We present explicit black holes endowed with primary scalar hair within the shift-symmetric subclass of Beyond Horndeski theories. These solutions depend, in addition to the conventional mass parameter, on a second free parameter encoding primary scalar hair. The properties and characteristics of the solutions at hand are analyzed with varying scalar charge. We observe that when the scalar hair parameter is close to zero or relatively small in comparison to the black hole mass, the solutions closely resemble the Schwarzschild spacetime. As the scalar hair increases, the metric solutions gradually depart from General Relativity. Notably, for a particular relation between mass and scalar hair, the central singularity completely disappears, resulting in the formation of regular black holes or solitons. The scalar field accompanying the solutions is always found to be regular at future or past horizon(s), defining a distinct time direction for each. As a final byproduct of our analysis, we demonstrate the existence of a stealth Schwarschild black hole in Horndeski theory with a non-trivial kinetic term.

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