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Rotating spacetimes with a free scalar field in four and five dimensions

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We construct explicit rotating solutions in Einstein's theory of relativity with a minimally coupled free scalar field rederiving and finding solutions in four or five spacetime dimensions. These spacetimes describe, in particular, the back-reaction of a free scalar field evolving in a Kerr spacetime. Adapting the general integrability result obtained many years ago from Eriş-Gürses to simpler spherical coordinates, we present a method for rederiving the four-dimensional Bogush-Gal'tsov solution. Furthermore, we find the five-dimensional spacetime featuring a free scalar with two distinct angular momenta. In the static limit, these five-dimensional geometries provide higher-dimensional extensions of the Zipoy-Voorhees spacetime. Last but not least, we obtain the four-dimensional version of a Kerr-Newman-NUT spacetime endowed with a free scalar, where the scalar field's radial profile is extended to incorporate dependence on the polar angular coordinate. Our results offer a comprehensive analysis of several recently proposed four-dimensional static solutions with scalar multipolar hair, representing a unified study of spacetimes with a free scalar field in both four and five dimensions under the general integrability result of Eriş-Gürses.

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