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ARC Seminar

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Derivation of Kerr Metric (WITHOUT quotation marks): Newman-Janis Algorithm Demystified

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Abstract

In 1964, Newman and Janis made a curious observation that the Kerr metric can be obtained by performing a "complex coordinate transformation" on the Schwarzschild solution, describing an imaginary displacement into "complex spacetime." This method, nowadays referred to as the Newman-Janis Algorithm (NJA), holds the very historical significance as the idea that facilitated the discovery of the Kerr-Newman black hole solution. However, it is often dismissed as an ad-hoc trick or "fluke" due to the lack of any established physical or geometrical basis. Contrary to this belief, this talk explains how the recent work [arXiv:2412.19611] has eventually refined the NJA into a rigorous and systematic derivation of spinning black hole solutions, after sixty years of mysterious status. Intriguingly, this demystification reveals that spinning black holes can be regarded as "molecules" of magnetic monopoles. This idea will be realized in a precise and quantitative manner in terms of the classical double copy correspondence, which borrows insights from the study of scattering amplitudes in quantum field theory. Important lemmas are the Kerr-Schild metric established in [arXiv:2405.09518] and a theorem concerning nonlinear superpositions of self-dual and anti-self-dual spacetimes. Finally, physical implications of this "molecule" picture will be outlined, with applications to making all-orders-in spin predictions in the post-Minkowskian, self-force, or black hole perturbation theory programs. In particular, a dynamical implementation of the NJA implies that the equations of motion of a Kerr probe describe the Wick rotation of the geodesic deviation equation in a sense, from which all-orders-in-spin conserved quantities are derived.