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Analytic structure of scattering amplitudes

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We calculate the onshell $2 \longrightarrow 2$ scattering amplitude in a scalar model to exemplify the use of contour deformations when solving Lorentz-invariant integral equations. The integrals produce branch cuts in the complex plane of the integrand which prohibit a naive Euclidean integration path. By employing contour deformations, we can also access the kinematical regions associated with the scattering amplitude in Minkowski space. We show that in principle a homogeneous Bethe-Salpeter equation together with analytic continuation methods is sufficient to determine the resonance pole locations on the second Riemann sheet as long as they are well above the threshold. However, this scalar model does not produce resonance poles but instead virtual states on the real axis of the second sheet, which poses difficulties for analytic continuation methods. To address this, we calculate the scattering amplitude on the second sheet directly and use the two-body unitarity relation which follows from the scattering equation.

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