Integrable perturbation theory for dark solitons

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A method for studying perturbations of bright soliton solutions of integrable systems by performing an expansion in a complete set of "squared eigenfunctions" has been well understood for decades. Over the years, several attempts have been made to apply a similar method to dark solitons on a nonzero background. In this talk, we revisit the problem of dark soliton perturbation theory for the defocusing NLS equation, addressing several aspects that had not been accounted for in previous works. We derive a completeness relation for the squared eigenfunctions and use it to obtain slow-time evolution equations for all soliton parameters. Additionally, we compute the first order term in the perturbation expansion and show that it can be used to describe the propagating shelf that develops around the perturbed soliton. We apply the method to several physically relevant examples and compare our results to numerical simulations.