Beat structure in the solution of scattering problems with nondecaying sources

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Synopsis We study mathematical properties of scattering solutions of Schrödinger-type equations with nondecaying, outgoing type, driven terms. Beating type structures emerge in the scattering function, and we characterize the resulting ionization amplitudes for each energy component.

We study the scattering solutions emerging from a perturbative type approach, which is general enough to describe single or double ionization by charged particles or photons [1, 2]. For an unperturbed Hamiltonian H_0 and a perturbation $\bar{W}$, we have a set of equations

$$[E_0 - H_0]\,\Psi^{(0)} = 0, \quad (1)$$

$$[E_1 - H_0]\,\Psi^{(1)}_{sc} = \bar{W}\Psi^{(0)}, \quad (2)$$

$$[E_2 - H_0]\,\Psi^{(2)}_{sc} = \bar{W}\Psi^{(1)}_{sc}, \quad (3)$$

$$\vdots$$

$$[E_n - H_0]\,\Psi^{(n)}_{sc} = \bar{W}\Psi^{(n-1)}_{sc}, \quad (4)$$

which are coupled in the sense that for every order, the RHS depends on the immediately previous one. For the following discussions let $E_0 < 0$ and $E_1, E_2 > 0$. The zeroth order solution is spatially bounded, and therefore the first order solution asymptotic behavior is entirely dictated by the LHS. However, if the interaction $\bar{W}$ is long ranged, the second order solution asymptotic behavior is shaped by its RHS as well, introducing beat-type oscillations.

Our first test case is a two-body model problem (see Fig. 1), for which we were able to obtain analytical expressions for the asymptotic regime and transition amplitudes. This analytical investigation is further compared with numerical solutions obtained from two independent approaches: the Exterior Complex Scaling (ECS) [3] and the Generalized Sturmian Functions(GSF) method [4]. The application to the two-photon ionization of Hydrogen illustrates the validity and efficiency of our approach (see Fig. 2).

We then turn to the three-body case, and consider a Temkin-Poet scattering problem. As a fully analytical approach is not possible, we tackled the problem with the GSF method. The same beating phenomenon that is found in the two-body scenario extends to the many channels of the richer three-body case (see Fig. 3). We discuss how the double continuum transition probabilities can be extracted.

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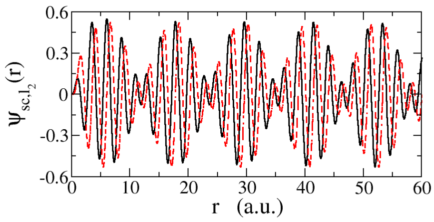

Figure 1. Real and imaginary parts of the second order solution from a two-body benchmark problem [2]

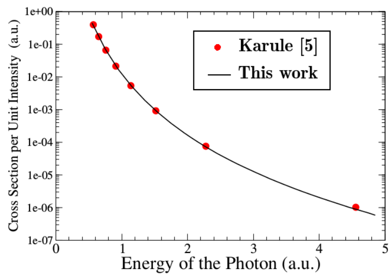

Figure 2. Ionization rate for the two-photon ATI of the $H(1s)$ atom interacting with a linearly polarized laser [1].

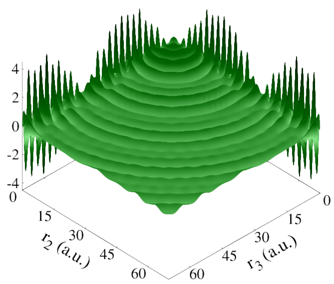

Figure 3. Solution of a model three-body scattering problem with a nondecaying driven term.

References

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