Coupling Lorentz Integral Transform and Coupled Cluster Methods: a way towards continuum spectra of not-so-light systems.

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The Lorentz Integral Transform (LIT) method allows to calculate spectra in the continuum, without dealing with the many-body scattering problem. The method consists in reducing the continuum problem to a bound state one, when calculating the spectra, (discrete and/or continuum) of a many-body system. In fact the response $S(\omega)$ of a system to a perturbative reaction induced by the operator Θ can be accessed by first calculating, and then inverting, the integral transform of $S(\omega)$ with a Lorentzian kernel $K(\omega,\omega_0,\Gamma) = \Gamma[\pi((\omega-\omega_0)^2+\Gamma^2)]^{-1}$. The main point is that the LIT of $S(\omega)$ can be calculated much more easily than $S(\omega)$ itself. In fact it turns out that the LIT of $S(\omega)$ is the norm of the solution $|\widetilde{\psi}\rangle$ of the following bound state-like equation

$$(H-z)|\widetilde{\psi}\rangle = \Theta|0\rangle\,, \tag{1}$$

where $z=\omega_0+i\Gamma$.

The method has been applied successfully on few-body systems for A=3 and 4, using both realistic and chiral effective field theory potentials (including also three-body forces), and to A=6 and 7 with semirealistic central potentials. For all these systems the solution of the bound-state-like equation (1), representing the core of the method, has been solved using typical bound-state approaches, like hyperspherical harmonics or no-core-shell-model expansions, as well as the Faddeev-Yakubowski formulation (see Ref.[1] for a review).

In view of extending the range of applicability of the LIT method to larger systems we have formulated Eq. (1) using the Coupled Cluster (CC) technique (see Ref. [2] for a review). Here one has to solve a right Schrödinger-like equation

$$(\bar{H}-z)|\widetilde{\psi}_R\rangle = \bar{\Theta}|0_R\rangle\,, \tag{2}$$

where $\bar{H}(\bar{\Theta}) = \exp(-T)H(\Theta)\exp(T)$ are the similarity transformed Hamiltonian(excitation operator). The state $|0_R\rangle$ is the ground-state of the non-hermitian similarity-transformed Hamiltonian and $|\widetilde{\psi}_R\rangle = R|\phi_0\rangle$ where $|\phi_0\rangle$ is a Slater determinant and the operator R is a linear expansion in particle-hole excitations. One has also to solve an equivalent left

Schrödinger-like equation for $\langle\widetilde{\psi}_L| = \langle\phi_0|L$ where L can be written via an expansion equivalent to that for R. In the CCSD approximation we truncate T as well as R and L at the $2p$-$2h$ excitation level. The LIT of $S(\omega)$ is given by $\langle\widetilde{\psi}_L|\widetilde{\psi}_R\rangle$. It can be computed efficiently by employing a generalization of the Lanczos algorithm for non-symmetric matrices in the solution of the linear problem in Eq. (2).

Figure 1 represents the calculated LIT ($\Gamma = 10$ MeV) of $S(\omega)$ for ^{16}O and Θ equal to the dipole operator. The Hamiltonian contains the chiral effective field theory two-nucleon potential from Ref. [3]. The theoretical result is compared to experimental data by folding the $S(\omega)$ obtained from photonuclear cross section measurements [4] with a Lorentzian of 10 MeV width. One notices the presence of a peak, which is the *remnant* of the giant dipole resonance (GDR). In spite of the lack of three-nucleon forces the position of the GDR is rather well reproduced. It will be interested to check if this result is accidental, when three-nucleon forces are included. More informations will be obtained by inverting the transform.

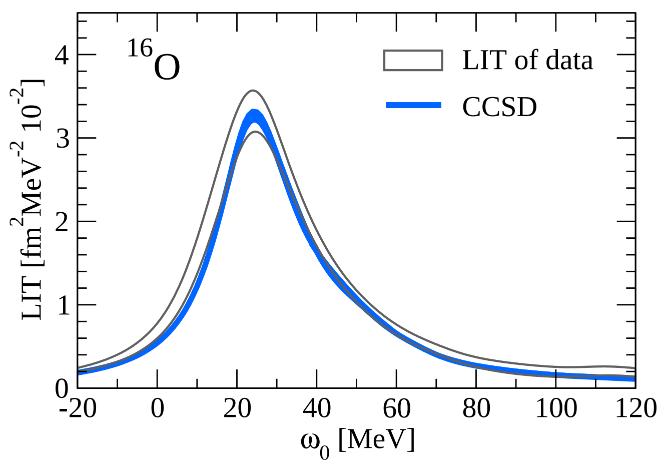

Figure 1: Comparison of the LIT of the dipole response of ^{16}O calculated within CCSD at $\Gamma = 10$ MeV and the LIT of the photonuclear data from Ref. [4].

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