A diagrammatic approach to composite, rotating impurities

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The study of composite, rotating impurities interacting with a quantum many-body environment is extremely important for the description of several experimental settings: cold molecules in a Bose-Einstein condensate or embedded in helium nanodroplets, electronic excitations in a BEC or in a solid. In all these cases the vibrational and rotational degrees of freedom create an involved energy level structure, with a continuous exchange of angular momentum with the surrounding environment.

The recently-introduced angulon quasiparticle [1, 2] formalises the concept of a rotating, interacting impurity. We introduce an alternative approach to the angulon problem making use of the path integral formalism, extending Feynman's treatment for the polaron [3]. A first, clear advantage is that the bath degrees of freedom and the interaction can be integrated out exactly, resulting in an effective, single-particle description for the angulon in which the many-body character of the original problem is encoded in a time-non-local interaction term. Subsequently, the interaction is treated perturbatively obtaining a diagrammatic expansion from which, in turn, a set of Feynman rules for the angulon is derived. These rules extend the machinery of the graphical theory of angular momentum – well known from theoretical atomic spectroscopy – to the context of many-body theory. In fact, each diagram can interpreted as a 'skeleton,' enforcing angular momentum conservation, dressed by an additional many-body contribution.

The results obtained allow for the possibility of including higher-order processes in the description of an impurity exchanging angular momentum with a many-body environment, and are compared with other theoretical descriptions and with experimental data.

[1] M. Lemeshko, Phys. Rev. Lett. **118**, 095301 (2017).

[2] R. Schmidt and M. Lemeshko, Phys. Rev. Lett. **114**, 203001 (2015) and Phys. Rev. X **6**, 011012 (2016).

[3] G. Bighin and M. Lemeshko, in preparation.