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Linear response theory for light dark matter-electron scattering in materials

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I combine the non-relativistic effective theory of dark matter (DM) - electron interactions with linear response theory to obtain a formalism that fully accounts for screening and collective excitations in DM-induced electronic transition rate calculations for general DM-electron interactions. In the same way that the response of a dielectric material to an external electric field in electrodynamics is described by the dielectric function, so in our formalism the response of a detector material to a DM perturbation is described by a set of generalised susceptibilities which can be directly related to densities and currents arising from the non-relativistic expansion of the Dirac Hamiltonian. I apply our formalism to assess the sensitivity of non-spin-polarised detectors, and find that in-medium effects significantly affect the experimental sensitivity if DM couples to the detector's electron density, while being decoupled from other densities and currents. Our formalism can be straightforwardly extended to the case of spin-polarised materials.

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