



Sub-MeV Direct Detection

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Sub-MeV masses \implies collective excitations

Inverse momentum transfer becoming comparable to interatomic spacing:

$$\Delta p \sim 10^{-3} m_{DM} \lesssim \text{keV}$$

Need to consider *collective excitations* instead of individual nuclear recoils

Challenge: requires detectors with energy thresholds $\lesssim 100$ meV

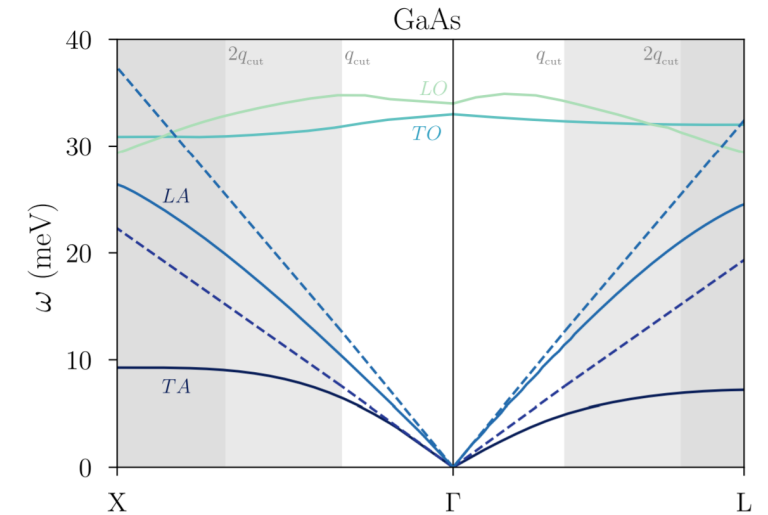
Some examples

- phonons in crystals, superfluid He
- avalanche gains in molecular magnets
- electron systems with ultralow bandgaps
- magnons
- ...

Phonons

Acoustic: Goldstone bosons, linear dispersion relation, coherent motion of unit cell

Optical: gapped, relative motion within unit cell

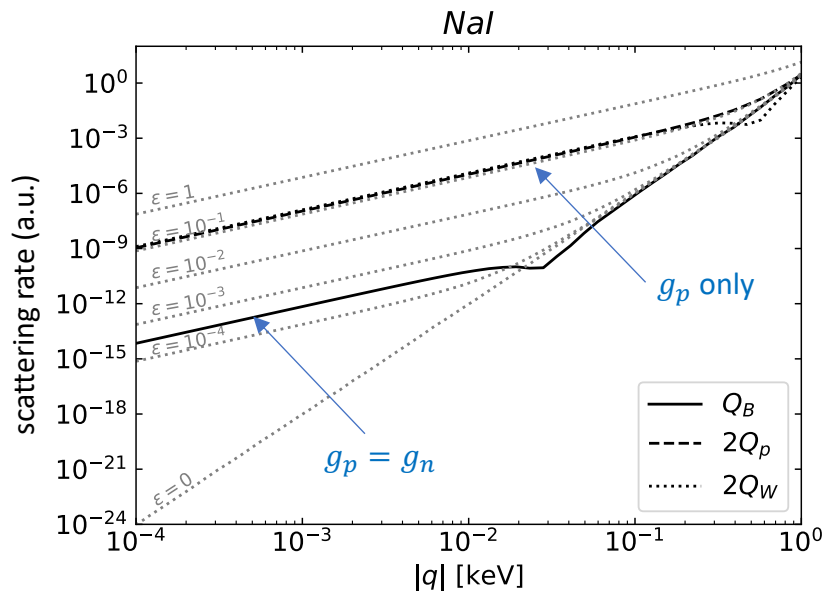


1) DM-optical phonon scattering

[PC, Melia, Rajendran 1905.05574]

Scattering rate suppressed for DM that couples equally to protons and neutrons.

“coupling-to-mass” effect

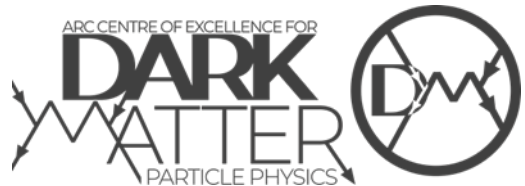
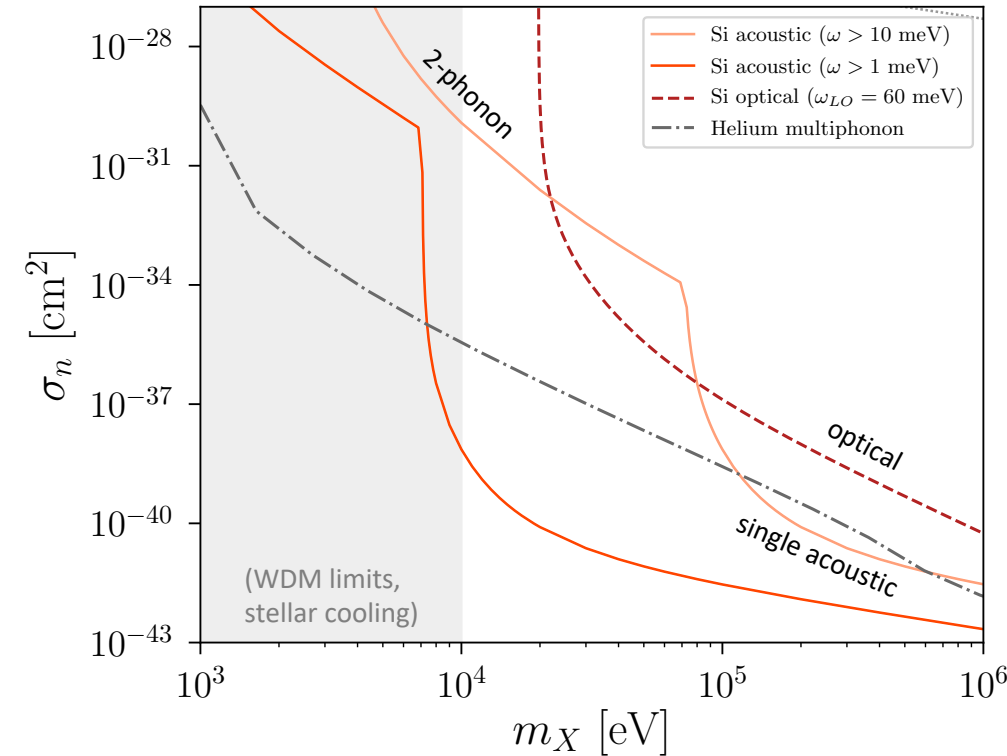
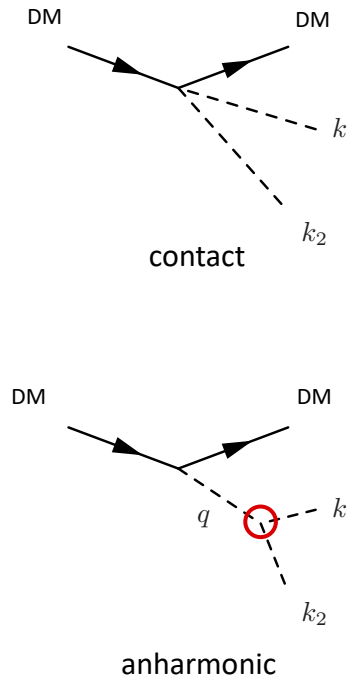


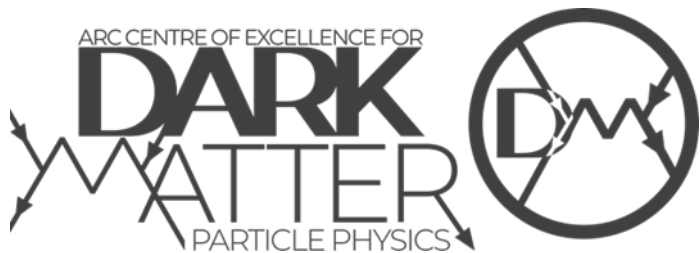
2) Multi-phonon scattering

[Campbell-Deem, PC, Lin, Melia, Knapen 1911.03482]

Single acoustic mode requires very low energy threshold.

2-phonon processes can be relevant for low masses.





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