Odd-even splitting in scissors bands

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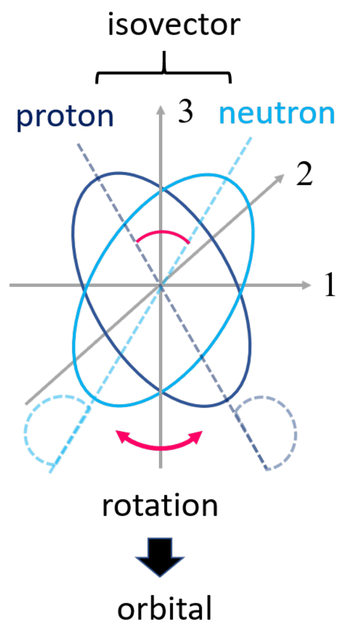
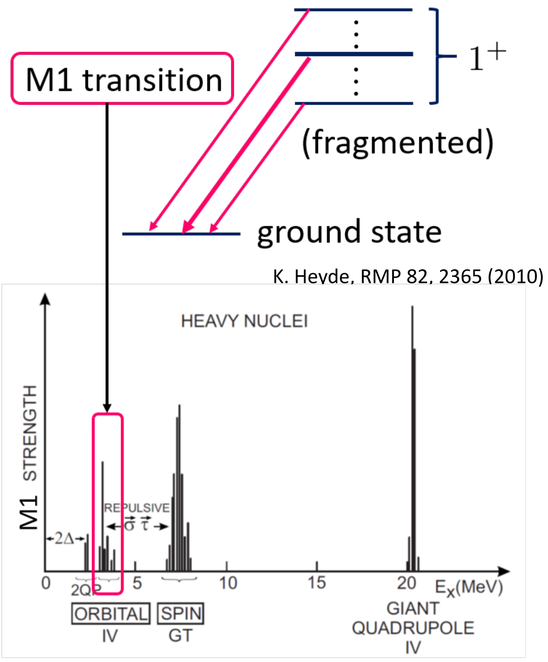
Introduction of scissors mode

➢ **The idea of scissors mode**

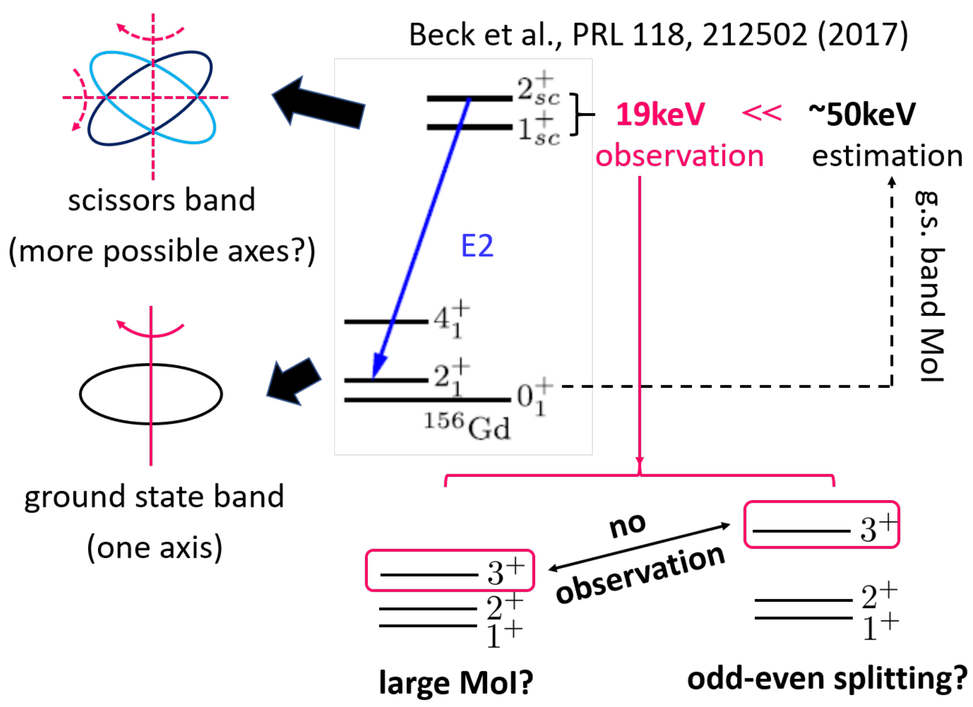


➢ **Observation of scissors mode**



➢ **Rotation of scissors mode**

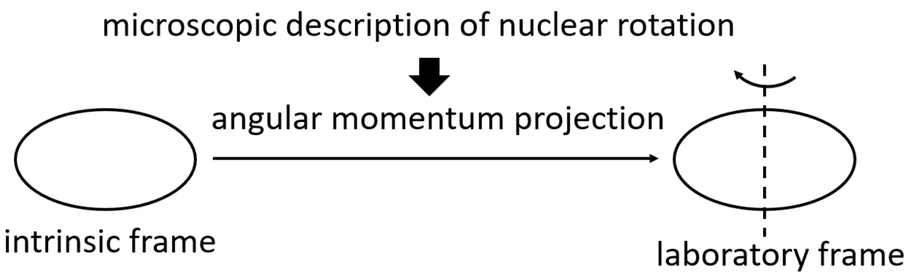
First observation of scissors band:
Beck et al., PRL 118, 212502 (2017)



Projected shell model for scissors band

➢ **Projected shell model**

microscopic description of nuclear rotation



laboratory wave function $|\Psi\rangle = \sum_{\kappa_\nu\kappa_\pi} f(\kappa_\nu,\kappa_\pi)\hat{P}^I_{MK}|\kappa_\nu\kappa_\pi\rangle$ intrinsic configuration

configuration mixing

angular momentum projector

$$\hat{P}^I_{MK} = \frac{2I+1}{8\pi^2}\int d\Omega D^{I*}_{MK}(\Omega)\hat{R}(\Omega)$$

isoscalar rotation ⬅ common Euler angle for proton & neutron

➢ **Inclusion of scissors degree of freedom**

Independent projection for proton & neutron

$$|\Psi\rangle = \sum_{I_\nu I_\pi}\sum_{\kappa_\nu\kappa_\pi} f(I_\nu\kappa_\nu I_\pi\kappa_\pi)\,[\,\hat{P}^{I_\nu}_{M_\nu K_\nu}|\kappa_\nu\rangle \otimes \hat{P}^{I_\pi}_{M_\pi K_\pi}|\kappa_\pi\rangle]^I_M$$

$\hat{P}^I_{MK}|\kappa_\nu\kappa_\pi\rangle \to \Omega_\nu,\ \Omega_\pi$

isovector rotation ⬅ independent Euler angles for proton & neutron

➢ **Picture of the scissors vibration & rotation**

$$\{\Omega_\nu,\Omega_\pi\} \xrightarrow{\text{coordinate transformation}} \{\Omega_t,\Omega_{\pi\nu}\}$$

Ω_t → for the nucleus **as a whole** → **collective rotation**

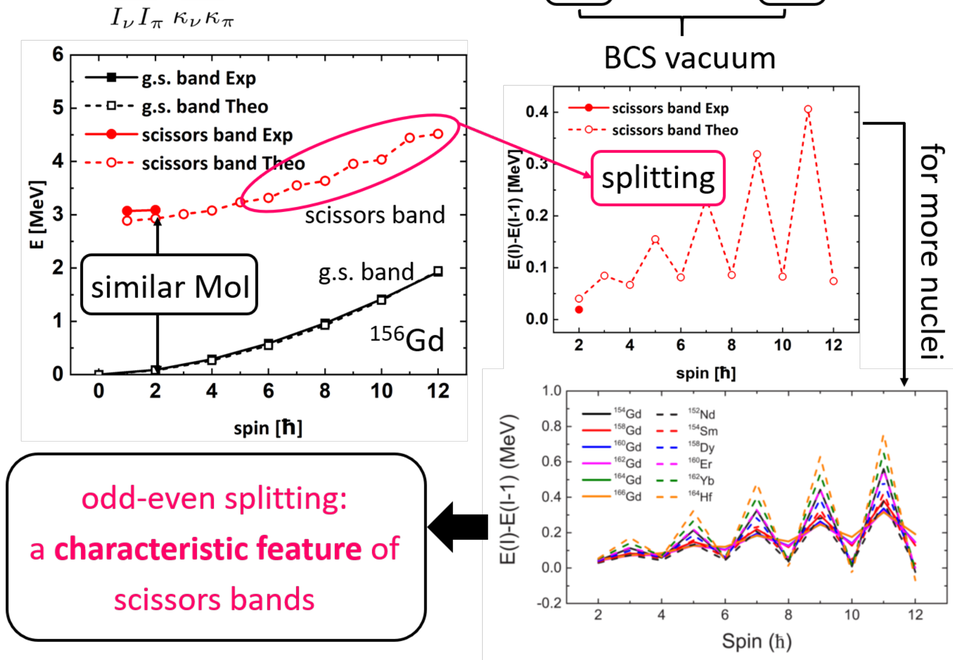
$\Omega_{\pi\nu}$ → **between** proton & neutron → **scissors vibration**

picture of motion

The odd-even splitting of scissors band

$$|\Psi\rangle = \sum_{I_\nu I_\pi}\sum_{\kappa_\nu\kappa_\pi} f(I_\nu\kappa_\nu I_\pi\kappa_\pi)[\hat{P}^{I_\nu}_{M_\nu K_\nu}|\kappa_\nu\rangle \otimes \hat{P}^{I_\pi}_{M_\pi K_\pi}|\kappa_\pi\rangle]^I_M$$

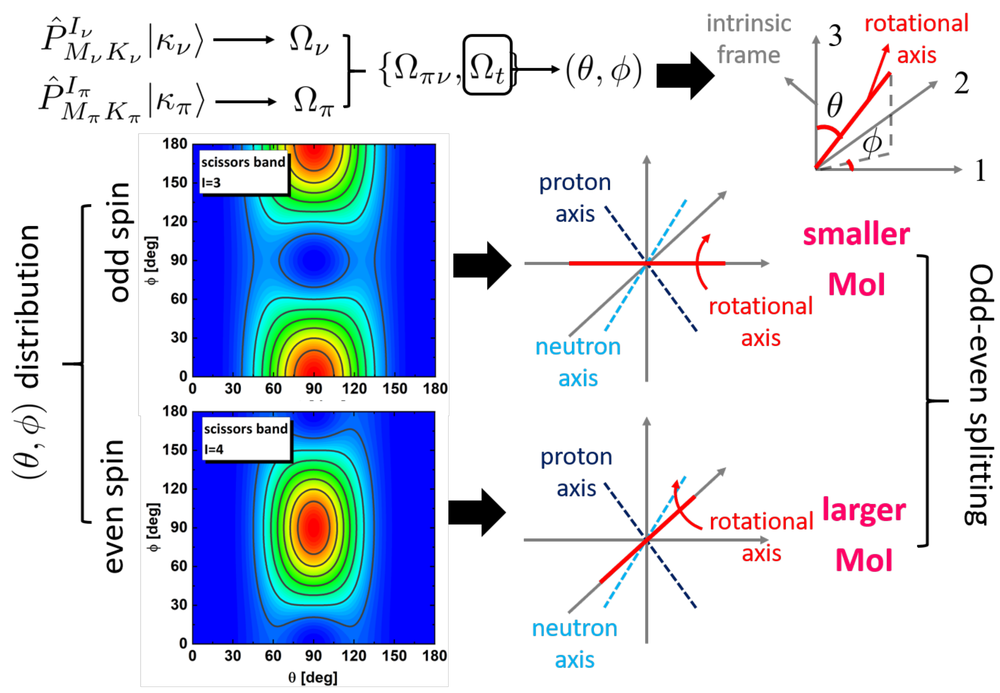
BCS vacuum



odd-even splitting: a **characteristic feature** of scissors bands

Origin of odd-even splitting

——flipping of rotational axis between odd and even spins

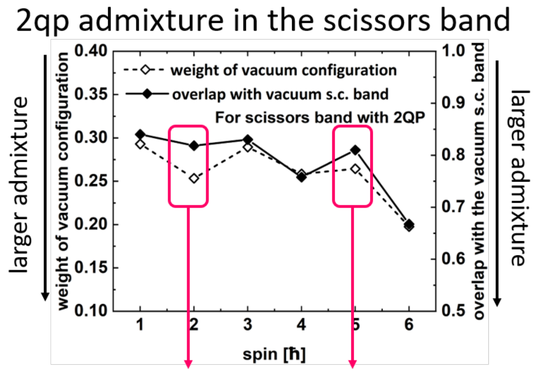


Enhancement of odd-even splitting by quasiparticle excitations

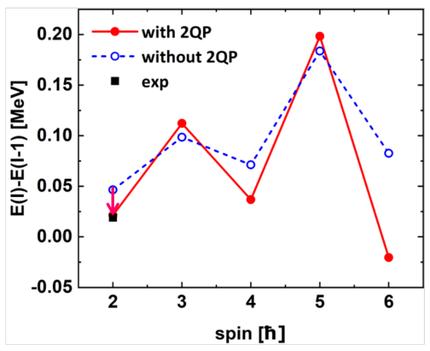
$$|\Psi\rangle = \sum_{I_\nu I_\pi}\sum_{\kappa_\nu\kappa_\pi} f(I_\nu\kappa_\nu I_\pi\kappa_\pi)[\hat{P}^{I_\nu}_{M_\nu K_\nu}|\kappa_\nu\rangle \otimes \hat{P}^{I_\pi}_{M_\pi K_\pi}|\kappa_\pi\rangle]^I_M$$

BCS vacuum + 2-quasiparticle configurations

2qp admixture in the scissors band



odd-even splitting amplitude



even spin > odd spin

suppression of even spin states → enhancement of odd-even splitting

Summary & Perspective

- Odd-even splitting is a characteristic feature of scissors bands.
- The odd-even splitting arises due to flipping of rotational axis between odd and even spins.
- The splitting can be enhanced by the mixing with two-quasiparticle excitations.
- With the consideration of scissors and quasiparticle excitations, the M1 strength function (and its low-energy enhancement) can be investigated.

In collaboration with Cui-Juan Lv, Yang Sun, and Mike Guidry
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