Coriolis contribution to excited states of odd-mass nuclei with deformation-dependent mass formalism

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- 1.1.Bohr Hamiltonian with different mass parameters
- 2.1.Bohr Hamiltonian with deformation-dependent mass (DDM) formalism

2.Solving the Schrödinger equation
- 1.2.Energy levels
- 2.2.Wave functions
- 3.2.Parameters of the theory

3.Results
- 1.3.Treated examples
- 2.3.Effect of DDM and Coriolis interaction on the nuclear excited states
- 3.3. Effect of DDM and Coriolis interaction on the moments of inertia

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1.1.Bohr Hamiltonian with different mass parameters

$\gamma \approx 0$ and $\beta \approx \beta_0 \neq 0$

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$$H = H_V + H_{rot} + H_{int} + H_p(x)$$

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one mass parameter $B \Longrightarrow$ rotational and vibrational modes

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$$H_{vib} = -\frac{\hbar^2}{2}\left(\frac{1}{B_\beta}\frac{\partial^2}{\partial\beta^2} + \frac{2}{B_\gamma}\frac{1}{\beta}\frac{\partial}{\partial\beta} + \frac{2}{B_\beta}\frac{1}{\beta}\frac{\partial}{\partial\beta} + \frac{1}{B_\gamma\beta^2}\frac{1}{\gamma}\frac{\partial}{\partial\gamma}(\gamma\frac{\partial}{\partial\gamma}) - \frac{1}{B_\gamma}\frac{1}{4\beta^2}(\frac{1}{\gamma^2} + \frac{1}{3})(L_3 - j_3)^2\right) + V(\beta,\gamma)$$

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$$H_{rot} = \frac{\hbar^2}{6B_{rot}\beta^2}\left[(L^2 + j^2 - L_3^2 - j_3^2 - 2(L_1 j_1 + L_2 j_2)\right]$$

1.1.Bohr Hamiltonian with different mass parameters

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$$H_{int} = -\beta < T > \left(3j_3^2 - j^2\right)$$

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Bonatsos D, Georgoudis P E, Lenis D, Minkov N and Quesne C 2011 Phys. Rev. C 83 044321

2.1.Bohr Hamiltonian with deformation-dependent mass (DDM) formalism

Bonatsos D, Georgoudis P E, Lenis D, Minkov N and Quesne C 2011 Phys. Rev. C 83 044321

$$H = \frac{\hbar^2}{2\langle i|B_0|i\rangle}\Big(\frac{-\sqrt{f}}{\beta^4}\frac{\partial}{\partial\beta}\beta^4 f\frac{\partial}{\partial\beta}\sqrt{f} - \frac{f^2}{\beta^2 sin3\gamma}\frac{\partial}{\partial\gamma}sin3\gamma\frac{\partial}{\partial\gamma} + \frac{f^2}{4\beta^2}\sum_{k=1,2,3}\frac{(L_k-j_k)^2}{sin^2(\gamma-\frac{2}{3}\pi k)}\Big) - f^2\beta\langle T\rangle(3j_3^2 - j^2) + V_{eff}$$

$$V_{eff} = V(\beta,\gamma) + \frac{\hbar^2}{2\langle i|B_0|i\rangle}\big(\tfrac{1}{2}(1-\delta-\lambda)f\nabla^2 f + (\tfrac{1}{2}-\delta)(\tfrac{1}{2}-\delta)(\nabla f)^2\big)$$

$i \equiv g.s.$, β or γ-vibrational state

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f is the deformation function

2.Solving the Schrödinger equation

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$$V(\beta,\gamma) = U(\beta) + \frac{f^2}{\beta^2} W(\gamma)$$

2.Solving the Schrödinger equation

$$V(\beta,\gamma) = U(\beta) + \frac{f^2}{\beta^2} W(\gamma)$$

Davidson potential $\Longrightarrow U(\beta) = V_0\left(\frac{\beta}{\beta_0} - \frac{\beta_0}{\beta}\right)^2$

2.Solving the Schrödinger equation

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Davidson potential $\Longrightarrow U(\beta) = V_0\left(\frac{\beta}{\beta_0} - \frac{\beta_0}{\beta}\right)^2$

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$$f = 1 + a\beta^2, \qquad a << 1$$

1.2.Energy levels

β part

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Chabab M, Lahbas A and Oulne M 2015 Phys. Rev. C 91 064307

1.2.Energy levels

β part

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$$E_{n_\beta n_\gamma L|m|\tau} =$$
$$\frac{\hbar^2}{2B_\beta}\left(K_0+\frac{a}{2}(2+\frac{B_\beta}{B_\gamma}+2p+2q+pq)+2a(2+p+q)n_\beta+4an_\beta^2\right)+\epsilon_p$$

where $q \equiv q^\tau_{n_\gamma}(L,|m|) = \sqrt{1+4K_{-2}}$,

$$p \equiv p^\tau_{n_\gamma}(L,|m|) = \sqrt{4\frac{B_\beta}{B_\gamma}-3+4\frac{K_2}{a^2}}$$

and

$$K_2 =$$
$$\frac{a^2}{2}\left[\left(1+\frac{B_\beta}{B_\gamma}\right)\left(6\frac{B_\beta}{B_\gamma}+(1-2\delta)(1-2\lambda)+5(1-\delta-\lambda)\right)+\frac{2B_\beta}{\hbar^2}\Lambda\right]+\frac{2g_\beta}{\beta_0^4},$$

$$K_0 = \frac{a}{2}\left[\left(1+\frac{B_\beta}{B_\gamma}\right)\left(8\frac{B_\beta}{B_\gamma}+5(1-\delta-\lambda)\right)+\frac{4B_\beta}{\hbar^2}\Lambda\right]-\frac{4g_\beta}{\beta_0^2},$$

$$K_{-2} = \frac{B_\beta}{B_\gamma}\left(1+\frac{B_\beta}{B_\gamma}\right)+\frac{B_\beta}{\hbar^2}\Lambda+2g_\beta$$

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γ part

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1.2.Energy levels

γ part

$$\frac{B_\beta}{\hbar^2}\Lambda = \frac{2}{g}\frac{B_\beta}{B_\gamma}(1+2n_\gamma+|m|)+\frac{m^2}{3}\frac{B_\beta}{B_\gamma}+\varepsilon_{|m|L\tau}$$

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$$2m = K - \Omega$$

$$X = \frac{1}{3}\frac{B_\beta}{B_{rot}}\Big[L(L+1)+j(j+1)-L_3^2-j_3^2-2(L_1j_1+L_2j_2)\Big] - \frac{1}{3\xi}\Big[3j_3^2-j(j+1)\Big]$$

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The diagonal elements are:

$$\langle LjKm|X|LjKm\rangle = \frac{1}{3}\frac{B_\beta}{B_{rot}}\Big[L(L+1)+j(j+1)-K^2-(K-2m)^2-(-1)^{L-j}\times(L+1/2)(j+1/2)\delta_{K1/2}\delta_{m0}\Big] - \frac{1}{3\xi}\Big[3(K-2m)^2-j(j+1)\Big]$$

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The nondiagonal elements are $\langle LjKm|X|LjK \pm m\rangle =$

$$\frac{1}{3}\frac{B_\beta}{B_{rot}}\Big[(L\mp K)(L\pm K+1)\Big]^{1/2}\times\Big[(j\mp K\pm 2m)(j\pm K\mp 2m+1)\Big]^{1/2}$$

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Bands are specified by n_β, n_γ and m, such as:

1.2.Energy levels

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•$g.s.$ band with $n_\beta = 0$, $n_\gamma = 0$, $m = 0$;

1.2.Energy levels

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Bands are specified by n_β, n_γ and m, such as:

•*g.s.* band with $n_\beta = 0$, $n_\gamma = 0$, $m = 0$;

•β-band with $n_\beta = 1$,$n_\gamma = 0$, $m = 0$;

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Bands are specified by n_β, n_γ and m, such as:

•$g.s.$ band with $n_\beta = 0$, $n_\gamma = 0$, $m = 0$;

•β-band with $n_\beta = 1$,$n_\gamma = 0$, $m = 0$;

•γ-band with $n_\beta = 0$, $n_\gamma = 0$,$m = 1$.

2.2.Wave functions

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2.2.Wave functions

$$\Psi = \beta^{-(1+B_\beta/B_\gamma)} R_{n_\beta,L}(\beta) \sum_{mK} A^{m\tau}_{LK} \chi_{n_\gamma|m|}(\gamma)|LMjKm\rangle$$

where

$$R_{n_\beta,L}(\beta) = \beta^{\frac{1}{2}(1+q)}(1+a\beta^2)^{-n_\beta-\frac{1}{2}(1+\frac{B_\beta}{B_\gamma})-\frac{1}{4}(p+q)}\phi(\beta)$$

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with

$$\phi(\beta) = N_{n_\beta}\ {}_2F_1(-n_\beta - n_\beta - \frac{p}{2}; -2n_\beta - \frac{(q+p)}{2}; 1+a\beta^2),$$

$$\chi_{n_\gamma,|m|}(\gamma) = N_{n_\gamma,|m|}\gamma^{|m|}e^{-\frac{\gamma^2}{2g}}\ {}_1F_1(-n_\gamma, 1+|m|, \frac{\gamma^2}{g})$$

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and

$$|LMjKm\rangle = \sqrt{\frac{2L+1}{16\pi^2}}\Big[D^L_{MK}(\theta_i)\varphi^j_{K-2m}(x) +$$

$$(-1)^{L-j}D^L_{M-K}(\theta_i)\varphi^j_{-K+2m}(x)\Big], i = 1, 2 \text{ or } 3.$$

3.2.Parameters of the theory

3.2.Parameters of the theory

$$g_\beta = \frac{B_\beta V_0 \beta_0^2}{\hbar^2},$$

$$g = \frac{1}{\beta_0^2}\frac{\hbar}{\sqrt{B_\gamma C_\gamma}},$$

$$\xi = \frac{\hbar^2}{6B_\beta \beta_0^3 \langle T\rangle},$$

$$B_\beta / B_{rot},$$

$$B_\beta / B_\gamma,$$

a and β_0

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^{163}Dy

1.3.Treated examples

Coriolis contribution to excited states of odd-mass nuclei with deformation-dependent mass formalism

A AIT BEN HAMMOU

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$^{163}Dy \Longrightarrow 5/2^{-}[523]$ g.s.

1.3.Treated examples

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$^{163}Dy \Longrightarrow 5/2^{-}[523]$ g.s.

^{173}Yb

1.3.Treated examples

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$^{163}Dy \Longrightarrow 5/2^{-}[523]$ g.s.

$^{173}Yb \Longrightarrow 5/2^{-}[512]$ g.s.

1.3.Treated examples

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4.Conclusion

$$^{163}Dy \Longrightarrow 5/2^{-}[523] \text{ g.s.}$$

$$^{173}Yb \Longrightarrow 5/2^{-}[512] \text{ g.s.}$$

$$j = 7/2$$

1.3.Treated examples

$^{163}Dy \Longrightarrow 5/2^{-}[523]$ g.s.

$^{173}Yb \Longrightarrow 5/2^{-}[512]$ g.s.

$j = 7/2$

$m = 0$

1.3.Treated examples

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4.Conclusion

$^{163}Dy \Longrightarrow 5/2^{-}[523]$ g.s.

$^{173}Yb \Longrightarrow 5/2^{-}[512]$ g.s.

$j = 7/2$

$m = 0$

$K = 1/2, ..., 7/2$

2.3.Effect of DDM and Coriolis interaction on the nuclear excited states

Ground state band

Plot of $E(L_{g.s.})/E(7/2^-_{g.s.})$ against L

2.3.Effect of DDM and Coriolis interaction on the nuclear excited states

Ground state band

Plot of $E(L_{g.s.})/E(7/2^{-}_{g.s.})$ against L

For ^{163}Dy

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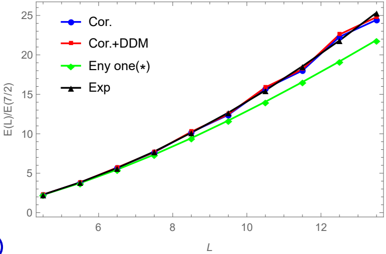
Ground state band

Plot of $E(L_{g.s.})/E(7/2^-_{g.s.})$ against L

For ^{163}Dy



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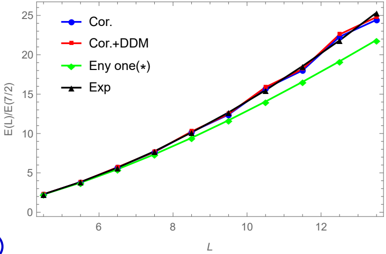
Ground state band

Plot of $E(L_{g.s.})/E(7/2^{-}_{g.s.})$ against L

For ^{163}Dy



For ^{173}Yb

2.3.Effect of DDM and Coriolis interaction on the nuclear excited states

Ground state band

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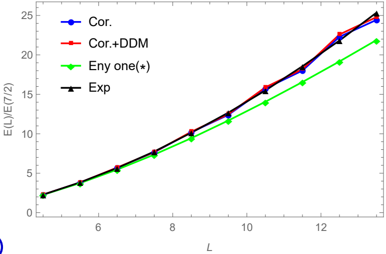
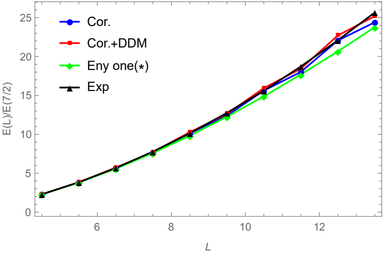
Plot of $E(L_{g.s.})/E(7/2^-_{g.s.})$ against L

For ^{163}Dy



For ^{173}Yb



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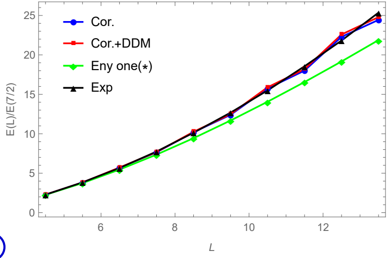
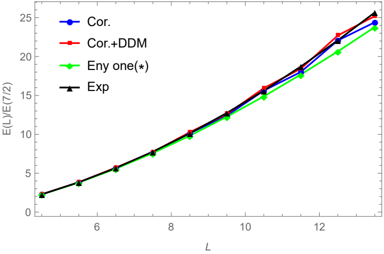
Ground state band

Plot of $E(L_{g.s.})/E(7/2^{-}_{g.s.})$ against L

For ^{163}Dy



For ^{173}Yb



(*)Ermamatov M J, Srivastava P C, Fraser P R, Strnsky P and Morales I O 2012 Phys. Rev. C 85 034307

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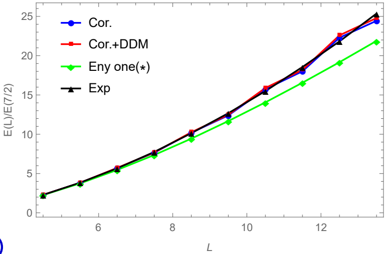
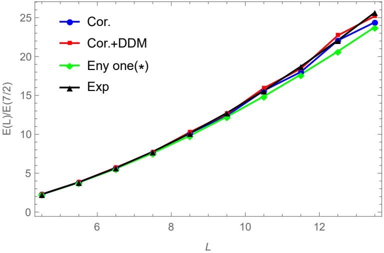


For ^{173}Yb



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Exp:Nuclear Data Sheets (http://nndc.bnl.gov/)

3.3. Effect of DDM and Coriolis interaction on the moments of inertia

1.Elaboration of an extended Bohr Hamiltonian
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Plot of $\Theta(L)/\Theta(7/2)$ against L For ^{173}Yb

3.3. Effect of DDM and Coriolis interaction on the moments of inertia

1.Elaboration of an extended Bohr Hamiltonian
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Without Coriolis interaction

3.3. Effect of DDM and Coriolis interaction on the moments of inertia

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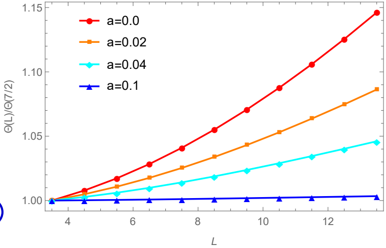
Plot of $\Theta(L)/\Theta(7/2)$ against L For ^{173}Yb

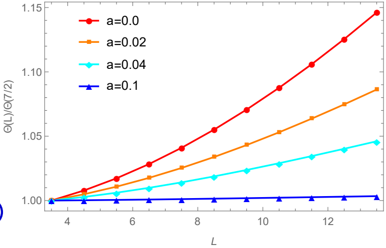
Without Coriolis interaction



3.3. Effect of DDM and Coriolis interaction on the moments of inertia

Plot of $\Theta(L)/\Theta(7/2)$ against L For ^{173}Yb

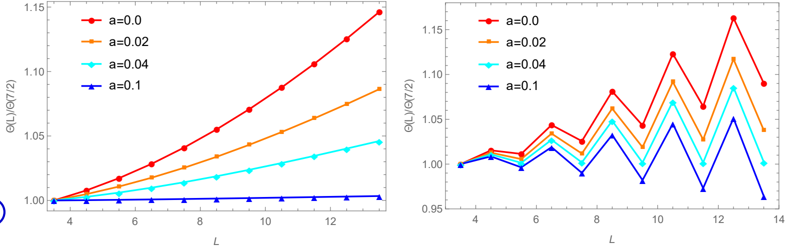
Without Coriolis interaction



Without Coriolis interaction

3.3. Effect of DDM and Coriolis interaction on the moments of inertia

Plot of $\Theta(L)/\Theta(7/2)$ against L For ^{173}Yb



Without Coriolis interaction

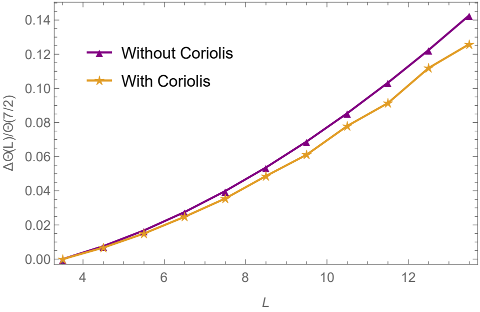
Without Coriolis interaction

3.3. Effect of DDM and Coriolis interaction on the moments of inertia

Plot of $(\Theta(L)|_{a=0} - \Theta(L)|_{a=0.1})/\Theta(7/2)$ against L for ^{173}Yb

3.3. Effect of DDM and Coriolis interaction on the moments of inertia

Plot of $(\Theta(L)|_{a=0}-\Theta(L)|_{a=0.1})/\Theta(7/2)$ against L for ^{173}Yb



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4.Conclusion

•The DDM formalism as well as the Coriolis interaction, affects significantly the structure of nuclear excited states.

Conclusion

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4.Conclusion

•The DDM formalism as well as the Coriolis interaction, affects significantly the structure of nuclear excited states.

•The use of DDM conjointly with Coriolis interaction has two impacts on the moments of inertia, namely: the Coriolis force causes staggering effect and the DDM slows down the moments of inertia rates.

THANK YOU FOR YOUR ATTENTION

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