Do chiral bands really exist in $^{105,106,107}$Ag?
— The risk of misinterpretation

Hai-Liang Ma (马海亮)

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Do chiral bands really exist in $^{105,106,107}$Ag?
Building chiral bands:

- triaxial
- a few high-\( j \) valence particles
- a few high-\( j \) valence holes

Experimental criteria:

- nearly degenerate \( \Delta I = 1 \) bands
- constancy of \( S(I) = \frac{[E(I) - E(I - 1)]}{2I} \)
- identical spin alignment, MOI, electromagnetic properties
- odd-even staggering of intraband \( B(M1)/B(E2) \) and interband \( B(M1) \) values
- vanishing of the interband \( B(E2) \) transitions at high spin

Candidate chiral doublet bands:

- \( A \sim 80 \pi g_{9/2} \otimes \nu g_{9/2}^{-1} \)
- \( A \sim 100 \pi g_{9/2}^{-1} \otimes \nu h_{11/2} \)
  \( \pi g_{9/2} \otimes \nu h_{11/2}^2 \)
- \( A \sim 130^* \)
  \( \pi h_{11/2} \otimes \nu h_{11/2}^{-1} \)
- \( A \sim 190 \pi g_{9/2}^{-1} \otimes \nu i_{13/2} \)
Chiral symmetry in nuclei

Building chiral bands:
✓ triaxial
✓ a few high-$j$ valence particles
✓ a few high-$j$ valence holes

Experimental criteria:
✓ nearly degenerate $\Delta I = 1$ bands
✓ constancy of $S(I) = [E(I) - E(I - 1)]/2I$
✓ identical spin alignment, MOI, electromagnetic properties
✓ odd-even staggering of intraband $B(M1)/B(E2)$ and interband $B(M1)$ values
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Chiral bands in the silver isotopes


TABLE I. (Continued.)

<table>
<thead>
<tr>
<th>Eγ (keV)</th>
<th>Iγ (rel.)</th>
<th>RDCO</th>
<th>Multipolarity</th>
<th>Ei (keV)</th>
<th>Jπi</th>
<th>Bandi</th>
</tr>
</thead>
<tbody>
<tr>
<td>1093.7</td>
<td>0.30</td>
<td>0.57(17)</td>
<td>D 2775 17/2+</td>
<td>1102.5</td>
<td>1.40</td>
<td>3125 21/2+</td>
</tr>
<tr>
<td>1105.2</td>
<td>1.99</td>
<td>0.99(12)</td>
<td>E 3092 21/2+</td>
<td>1114.3</td>
<td>0.66</td>
<td>7806 41/2+</td>
</tr>
<tr>
<td>1137.6</td>
<td>1.33</td>
<td>0.38(19)</td>
<td>A 3033 23/2+</td>
<td>1147.1</td>
<td>1.50</td>
<td>6609 35/2−</td>
</tr>
<tr>
<td>1158.3</td>
<td>3.50</td>
<td>0.52(14)</td>
<td>A 3092 19/2+</td>
<td>1163.5</td>
<td>0.99</td>
<td>6221 35/2−</td>
</tr>
<tr>
<td>1182.0</td>
<td>1.11</td>
<td>0.14(14)</td>
<td>C 3114 35/2−</td>
<td>1272.1</td>
<td>1.20</td>
<td>6717 37/2−</td>
</tr>
<tr>
<td>1288.8</td>
<td>1.20</td>
<td>0.20(15)</td>
<td>C 3125 37/2−</td>
<td>1373.5</td>
<td>2.66</td>
<td>3351 21/2+</td>
</tr>
<tr>
<td>1493.8</td>
<td>1.44</td>
<td>0.58(15)</td>
<td>F 2470 15/2−</td>
<td>1552.9</td>
<td>1.70</td>
<td>3424 17/2−</td>
</tr>
</tbody>
</table>

The energies are given in keV; the width of the transitions are proportional to their relative intensities.

Do chiral bands really exist in 105, 106, 107 Ag?
Chiral bands in the silver isotopes

\[ ^{106}\text{Ag} \]

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure.png}
\caption{Plot of excitation energy, kinematic moments of inertia, quasiparticle alignments, and the $S$/$I$ parameter as a function of spin for bands 1 and 2 in \(^{106}\text{Ag}\).}
\end{figure}


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FIG. 3. Plot of excitation energy, kinematic moments of inertia, quasiparticle alignments, and the $S(I)$ parameter as a function of spin for bands 1 and 2 in $^{106}$Ag.
Shun-He Yao, Hai-Liang Ma, Xiao-Guan Wu et al., to be published

Do chiral bands really exist in $^{105,106,107}\text{Ag}$?
Motivation

Interpretations excluding chiral picture:
- $\gamma$ band;
- Shape coexistence;
- Many particle correlations (Chen Y.S. & Gao Z.C.);
- Pseudospin partner bands.

We need:
configuration dependent calculation in the full deformation mesh!!!
Mean field calculation - modified oscillator (Nilsson) potential, LSD liquid drop model, $E_{tot}(I) = E_{shell}(I) + E_{rld}(I)$

Construction of diabatic orbitals:
- possible to interpolate spins;
- accurate configuration tracing;
- distinguish between high-$j$ shells and low-$j$ orbitals.


Do chiral bands really exist in $^{105,106,107}$Ag?
**Particle-number-projected CNSB (cranked-Nilsson-Strutinsky-Bogoliubov) model**

\[ H_{\text{CNSB}} = h_{\text{MO}}(\varepsilon_2, \gamma, \varepsilon_4) - \omega_x j_x - \Delta(P^\dagger + P) - \lambda \hat{N} \]

\[ E_p(\omega, \Delta_p, \lambda_p, \varepsilon_2, \gamma, \varepsilon_4) = \frac{\langle \Psi | HPZ | \Psi \rangle}{\langle \Psi | PZ | \Psi \rangle}, \]

\[ E_{\text{tot}}(I) = \min_{\varepsilon_i} [E_{\text{RLD}}(I, \varepsilon_i)] + E_{\text{shell}}(I, \varepsilon_i) + E_{\text{pair}}(I, \varepsilon_i) \]

\[ G_p = [17.54 + 0.173 (N - Z)]/A, \]

\[ G_n = [16.68 - 0.069 (N - Z)]/A. \]

- virtual crossing removed, possible to interpolate spins;
- particle number projection;
- varying pairing gaps and Fermi levels in the \((\Delta, \lambda)\) mesh to obtain the self-consistent \((\Delta, \lambda)\) and avoid fluctuations in the iteration methods;
- full \((\varepsilon_2, \gamma, \varepsilon_4)\) mesh calculation;
- direct comparison with unpaired calculations;
- difficult to fix configurations in a large mesh.

**Typical potential energy surfaces on the \((\Delta, \lambda)\) plane.**
Nilsson diagram

Configuration labeling

\[[p, n] \equiv \pi(1g_{9/2})^p \otimes \nu[(2d_{5/2}1g_{7/2})^{10-n}(1h_{11/2})^n]\]

The pairing correlation is dependent on:
- the level density around the Fermi level;
- the blocked orbitals;

Nilsson能级随着四极形变参数\(\varepsilon_2\)变化图。实线和虚线分别代表字称为正和负的轨道。
Routhian

\[ \varepsilon_2 = 0.18, \gamma = 0.0, \varepsilon_4 = 0.0 \]

\[ [p, n](\pi_p, \alpha_p)(\pi_n, \alpha_n) \]

\[ ^{105}\text{Ag} \text{ yrast band } [7,2](+, \pm 1/2)(+, 0) \]

转动摇Nilsson单粒子能级(routhian)图。实线、点线、折线和点折线分别代表 \((\pi, \alpha) = (+, 1/2), (+, -1/2), (-, 1/2)\) 和 \((-,-1/2)\) 轨道。
Routhian

\[ \varepsilon_2 = 0.18, \gamma = 0.0, \varepsilon_4 = 0.0 \]

\[ [p, n] (\pi_p, \alpha_p) (\pi_n, \alpha_n) \]

\[ ^{105}\text{Ag} (\pi = -) \]

\[ [7,1] (+, \pm 1/2)(-, 1) \]

转不Nilsson单粒子能级(routhian)图。实线、点线、折线和点折线 分别代
表\((\pi, \alpha) = (+, 1/2), (+, -1/2), (-, 1/2)\)和\((-,-1/2)\)轨道。
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Do chiral bands really exist in \(^{105,106,107}\text{Ag} \)?
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Routhian

\[ \varepsilon_2 = 0.18, \gamma = 0.0, \varepsilon_4 = 0.0 \]

\( \hbar \omega \) [MeV]

Single-neutron energies \( \varepsilon_i \) [MeV]

\[ \begin{align*}
\varepsilon_2 &= 0.18, \gamma = 0.0, \varepsilon_4 = 0.0 \\
[550] &\quad \text{1/2} \\
[411] &\quad \text{3/2} \\
[541] &\quad \text{3/2} \\
[413] &\quad \text{5/2} \\
[422] &\quad \text{7/2} \\
[431] &\quad \text{1/2} \\
[404] &\quad \text{9/2} \\
[420] &\quad \text{1/2} \\
[413] &\quad \text{7/2} \\
[431] &\quad \text{3/2} \\
\end{align*} \]

\( 1h_{11/2} \)

\( 2d_{5/2} 1g_{7/2} \)

\( 1g_{9/2} \)

\( 2d_{5/2} 1g_{7/2} \)

\( 1g_{9/2} \)

\( 2p_{1/2} 1f_{5/2} \)

\( 56 \)

\( 58 \)

\( 48 \)

\( 46 \)

转Routhian单粒子能级（routhian）图。实线、点线、折线和点折线分别代表
表(\( \pi, \alpha \) = (+, 1/2), (+, -1/2), (-, 1/2)和(-, -1/2)轨道。
转Nilsson单粒子能级（routhian）图。实线、点线、折线和点折线分别代表

\[ p, n \,(\pi_p, \alpha_p)(\pi_n, \alpha_n) \]

\[ ^{106}\text{Ag} \]

\[ [7,1](+, \pm 1/2)(+, -1/2) \]

\[ [7,1'](+, \pm 1/2)(+, 1/2) \]

\[ [7,3](+, \pm 1/2)(+, -1/2) \]
Routhian

\( \varepsilon_2 = 0.18, \gamma = 0.0, \varepsilon_4 = 0.0 \)

\[ [p, n](\pi_p, \alpha_p)(\pi_n, \alpha_n) \]

\(^{107}\text{Ag}\) yrast band

\([7,2](+, \pm 1/2)(+, 0)\)

转动Nilsson单粒子能级（routhian）图。实线、点线、折线和点折线分别代表

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\[ [p, n](\pi_p, \alpha_p)(\pi_n, \alpha_n) \]

\(^{107}\)Ag (\(\pi = -\))
\([7,1](+ , \pm 1/2)(-, 1)\)
\([7,1](+ , \pm 1/2)(-, 0)\)
Routhian

\[ \varepsilon_2 = 0.18, \gamma = 0.0, \varepsilon_4 = 0.0 \]

\[ \begin{align*}
\epsilon_{\frac{1}{2}} & = 0.18, \gamma = 0.0, \epsilon_{\frac{3}{2}} = 0.0 \\
\end{align*} \]

\[ \begin{align*}
1g_{\frac{7}{2}}, 2d_{\frac{5}{2}}, 1g_{\frac{7}{2}}, 1g_{\frac{9}{2}} \\
1h_{\frac{11}{2}}, 2d_{\frac{5}{2}} \\
[541] \frac{3}{2}, [413] \frac{5}{2}, [411] \frac{3}{2}, [550] \frac{1}{2}, [422] \frac{3}{2} \\
\end{align*} \]

\[ p, n (\pi_p, \alpha_p) (\pi_n, \alpha_n) \]

\[ ^{107} \text{Ag} (\pi = -) \]

\[ [7,1] (+, \pm \frac{1}{2}) (-, 1) \]

\[ [7,1'] (+, \pm \frac{1}{2}) (-, 0) \]

\[ [7,1'] (+, \pm \frac{1}{2}) (-, 1) \]

转态Nilsson单粒子能级（routhian）图。实线、点线、折线和点折线分别代表
表（\( \pi, \alpha \) = (+, 1/2), (+, - 1/2), (-, 1/2) 和(-, -1/2) 轨道。
Introduction Models Discussions Summary

Routhian

\[ \varepsilon_2 = 0.18, \gamma = 0.0, \varepsilon_4 = 0.0 \]

Single-neutron energies \( \varepsilon_i [\text{MeV}] \)

\[
\begin{align*}
\text{56} & \quad 2d_{5/2}^{1/2} \\
\text{58} & \quad 2d_{5/2}^{1/2}, 1g_{7/2}^{3/2} \\
\text{48} & \quad 1g_{9/2}^{3/2}, 2g_{7/2}^{5/2} \\
\text{46} & \quad 1g_{9/2}^{3/2}, 2p_{1/2}^{1/2}, 1f_{5/2}^{3/2}
\end{align*}
\]

Rotational frequency \( h\omega [\text{MeV}] \)

\[ [p, n] (\pi_p, \alpha_p) (\pi_n, \alpha_n) \]

\[ ^{107}\text{Ag} (\pi = -) \]

\[
\begin{align*}
[7,1] & \quad (+, \pm 1/2)(-, 1) \\
[7,1'] & \quad (+, \pm 1/2)(-, 0) \\
[7,3] & \quad (+, \pm 1/2)(-, 1)
\end{align*}
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Hai-Liang Ma (马海亮)  Do chiral bands really exist in \(^{105,106,107}\text{Ag}\)?
Rotational energies in $^{105}$Ag. The energies of rotational liquid drop have been subtracted.

Potential energy surfaces of the $[7,1]$ and $[7,1']$ configurations in $^{105}$Ag.

Deformation trajectories of the $[7,1]$ and $[7,1']$ configurations.

Do chiral bands really exist in $^{105,106,107}$Ag?
Rotational energies in $^{106}$Ag

Potential energy surfaces of the $[7,1]$ and $[7,3]$ configurations in $^{106}$Ag.

Deformation trajectories of the $[7,1]$ and $[7,3]$ configurations.

Do chiral bands really exist in $^{105,106,107}$Ag?
Rotational energies in $^{107}$Ag

Potential energy surfaces of the [7,1] and [7,3] configurations in $^{107}$Ag.

Deformation trajectories of the [7,1], [7,1'], and [7,3] configurations.

Hai-Liang Ma (马海亮)
The triaxial deformation is small for the negative parity bands in $^{105,106,107}$Ag.

The pairing correlation plays minor role in the negative parity bands of $^{105,107}$Ag due to the proton shell gaps and the neutron blocking effect. The spectroscopies of the yrast bands in $^{106}$Ag are improved if the pairing correlations are self-consistently taken into account.

The doublet bands in $^{105}$Ag can be well explained as the combination of orbitals with different parity and signature within the same configuration. The chirality of the doublet bands is strongly questioned.

In $^{105,106,107}$Ag, there are two bands with high moments of inertia which will cross the yrast bands at intermediate spin. They are mostly likely to be build upon $\pi(1g_{9/2})^7 \otimes \nu[(1h_{11/2})^3]$ configuration. Together with the small triaxial deformation predicted by the CNS model, this raises the doubt on the chirality of negative parity bands in $^{106}$Ag.
Summary

- The triaxial deformation is small for the negative parity bands in $^{105,106,107}\text{Ag}$.

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Thank you!

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