# Observation of signature partner bands in $^{105}$Pd with one wobbling phonon configuration

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## Introduction

The wobbling motion in a nucleus arises due to the unequal distribution of moment of inertia (MOI) along the three principal axes of a triaxial deformed core. This phenomenon is observed as consecutive rotational bands with increasing excitation energy, corresponding to successive wobbling phonons ($n_\omega$) [1]. Thus, the yrast band corresponds to $n_\omega = 0$. In recent times, the wobbling motion has been reported in a few odd-A nuclei [1, 2, 3]. In all cases, the signature partner band of $n_\omega = 0$ have been observed. In contrast to the case of signature partners, the unidirectional $\Delta I = 1$ transitions from the levels of higher $n_\omega$ to lower $n_\omega$ bands have predominantly E2 characters. In some cases, a $n_\omega = 2$ phonon bands have been identified [4]. The only odd-neutron nucleus, which exhibits the wobbling phenomenon, is $^{105}$Pd [5]. In this nucleus, a $4^{th}$ negative parity band was reported [6], but its origin remains unknown. Hence, we have studied the electromagnetic properties of the excited levels belonging to this band.

## Experiment

The high-spin states of $^{105}$Pd were produced via fusion-evaporation. A 63 MeV $^{13}$C beam from 14-UD Pelletron of TIFR hit a 1 mg/cm$^2$ enriched $^{96}$Zr target with a 9 mg/cm$^2$ $^{206}$Pb backing. De-excitation $\gamma$ rays were detected using the Indian National Gamma Array (INGA) [7], consisting of 18 Compton-suppressed clover detectors arranged in five rings at various angles: three at 40°, two at 65°, four at 90°, three at 115°, three at 140° and three at 157° with respect to the beam direction. A Pixie-16-based data acquisition system [8] recorded two and higher-fold coincidence data. The data were sorted in a $\gamma$-$\gamma$ symmetric matrix and $\gamma$-$\gamma$-$\gamma$ cube using the multiparameter time-stamped-based coincidence search (MARCOS) program [8]. The matrix and cube were used with the RADWARE program LEVIT8R [9] to establish the low-lying negative parity levels of $^{105}$Pd. The partial level scheme of $^{105}$Pd is shown in Fig. 1, where transition widths correspond to relative intensities. The Ratio of Directional Correlations from Oriented states ($R_{DCO}$) and linear polarization (P) of the emitted gamma rays were carried out to determine their multipolarities and electromagnetic characters.

## Analysis and Results

The measured $R_{DCO}$ and polarisation values are consistent with the previously reported measurements [5]. As seen from Fig. 1, Band 4 and Band 3 have interconnected $\Delta I = 1$ transitions, which rules out the possibility of Band 4 being a $n_\omega = 2$ wobbling band. The $17/2^-$, $21/2^-$ and $25/2^-$ levels of Band 3 decay to the $15/2^-$, $19/2^-$ and $23/2^-$ levels of both Band 1 and Band 4. The $\Delta I = 1$ transitions between Bands 3 → 1 show a very large mixing ratio ($\delta$), which means these transitions have large E2 components (≈ 85%). The same holds true for the $\Delta I = 1$ transition of 253.5 keV decaying from Band 4 to Band 2. Thus, Band 2

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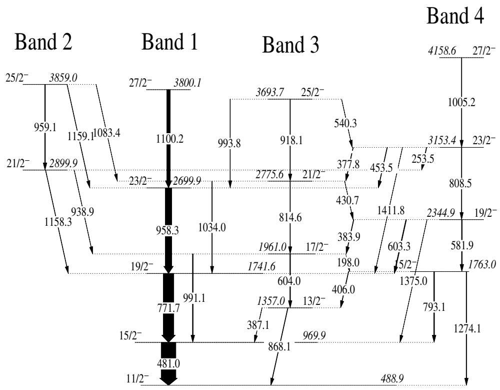


FIG. 1: Partial level scheme of $^{105}$Pd

($n_\omega = 0$) and Band 4 ($n_\omega = 1$) form a pair of wobbling bands. On the other hand, the $\Delta I = 1$ transitions between Bands 3 → 4 are almost purely magnetic in character (E2 component ≤ 2%).

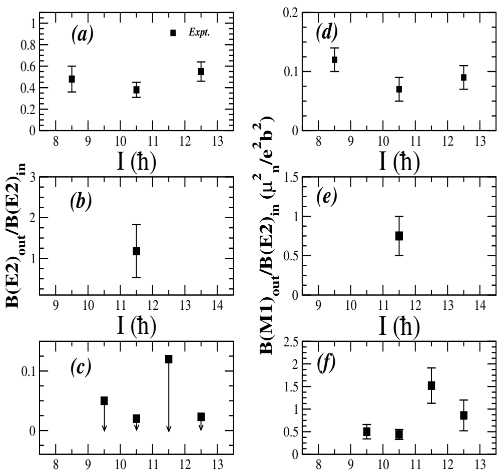


FIG. 2: The ratio of the rates of the out-band $\Delta I = 1$ transitions and the in-band E2 transitions of $^{105}$Pd. The values for transitions between (Band 3 to 1) and (Band 4 to 2) are shown in (a) and (d); and (b) and (e) respectively. The values for the interband transitions between Band 3 and 4 are shown in (c) and (f).

This large difference in the E2 component is reflected in the ratios of the reduced transition rate, which are plotted in Fig. 2. Band 3 → 1 transitions have a large collective contribution, i.e. a higher value for $\frac{B(E2)_{out}}{B(E2)_{in}}$ (Fig. 2(a)), which is an experimental signature of nuclear wobbling. But, the transitions between Band 3 and 4 exhibit significantly larger $\frac{B(M1)_{out}}{B(E2)_{in}}$ values (Fig. 2(f)) compared to the values for transitions from Band 3 to 1 (Fig. 2(d)) or Band 4 to 2 (Fig. 2(e)). The characteristic staggering behaviour of the $\frac{B(M1)_{out}}{B(E2)_{in}}$ values between the two signature partner bands can also be observed in Fig. 2(f). Thus, the present data establish Bands 3 and 4 as signature partners which have $n_\omega = 1$ configuration.

## Conclusion

The signature partner bands for $n_\omega = 0$ have been observed in all the nuclei which exhibit wobbling motion. We have reported the first observation of $n_\omega = 1$ signature partner bands in $^{105}$Pd.

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