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DYNAMICAL BEHAVIOR OF A VAN DER POL OSCILLATOR CIRCUIT WITH INTERNAL DELAY

By

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ABSTRACT

The qualitative dynamical behavior of an electronic oscillator based on Van der Pol equation is studied with an inherent delay attributed due to finite propagation time and processing time of signal. The stability governing equations have been obtained analytically. In addition to this, the dynamics of the system has been simulated numerically. Though the inherent delay is generally small, the study has been extended for higher values of delay also. Numerical simulation results are found to be consistent with the analytical predictions. The behavior of the modified system beyond the stable region has also been explored using nonlinear tool like bifurcation diagram and chaotic behavior has been found with proper parameter values.

Keywords: Van Der Pol Oscillator, Delay, Stability, Bifurcation Diagram.

INTRODUCTION

In electrical or electronic circuits comprised of different components, processing delay and propagation delay are very common issues. Sometimes these inherent issues annoy to the users. A processing delay arises due to the finite response time required for internal processing of the input signal. In other words, it is the delay in executing the desired function at each element. Propagation delay, also called transmission delay, is introduced by all the transmission components of an overall connection due to finite propagation speed of any signal between the interacting elements or nodes. In the case of an electric signal, propagation delay is the time taken by a signal to travel through a wire. These two factors, in many cases account for the physical limitations of the system performance. Again it may induce complex behavior in a dynamical system. Effect of delay in the collective dynamics of a coupled system is also drawing the interest of the science community.

Impact of processing delay and propagation delay in coupled as well as isolated dynamical systems can be found in literature (Calzolari et al., 1992; Harb, 2014; Hunt et al., 2010; Premraj et al., 2019; Yao et al., 2020). Yao et al. (2020) addresses the influence of processing delay on the collective dynamical behavior of a network of complex systems. It shows that processing delay may induce rich oscillatory behaviors in an inactive oscillator networks. Premraj et al. (2019) studied the bifurcation delay affected by processing delay in locally coupled FitzHugh-Nagumo (FHN) oscillators. Effect of propagation delay in ring oscillators has been investigated (Calzolari et al., 1992). In Hunt et al. (2010), the impact of competing time delays in coupled stochastic systems has been reported. Harb studied the effect of time delay on the pull-in range of second order phase locked loops (Harb, 2014).

In this paper we report the effect of delay in a Van der Pol (Vdp) oscillator. The Van der Pol oscillator is one of the simplest and typical models in nonlinear analysis. Many nonlinear phenomena can be explored by it in biological and engineering science (Peng et al., 2019; Yao et al. 2020). The dynamical behaviors of such systems can be affected by different means. Time delay is one of the most important factor in this regard both in the design aspects as well as to explore complex behavior. The dynamics of Van

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Chaos, antimonotonicity and coexisting attractors in Van der Pol oscillator based electronic circuit

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Abstract

Studies on the nonlinear dynamics of a modified Van der Pol oscillator based electronic circuit has been reported. It has been found that inclusion of an active RC section (or filter) in the Van der Pol oscillator is able to generate rich nonlinear behavior. Effect of a low pass filter as well as an all pass filter has been reported. The behavior of the proposed system has been explained analytically and numerically with respect to its parameters by exploiting standard nonlinear analysis tools such as bifurcation diagrams, Lyapunov exponent, phase portraits, Poincare sections, and basins of attraction. Occurrence of some fascinating features like antimonotonicity, hysteresis and coexisting attractors have been found in the modified system. The analytical and numerical studies has been verified experimentally with a prototype experiment.

Keywords Van der Pol oscillator · Filtering · Chaos generation · Antimonotonicity · Multistability · Coexistence of multiple attractors

1 Introduction

Among different complex and rich dynamical behavior of nonlinear systems, chaos, is one of the most important discoveries of last century [1, 2]. The initial sensitiveness, aperiodic and wide band nature of chaotic oscillations makes it different from periodic, quasiperiodic or relaxation oscillations. The invention of Chua's circuit, in 1983, showed that chaotic oscillation is not confined to the abstract world of mathematics, but is a physically realizable phenomenon. Nonlinear oscillators have always been relied upon by the researchers due to their importance in modeling various real world phenomena of physical, chemical, biological, engineering and social sciences. This helped the researchers to find or demonstrate chaos in different spheres of these fields [3–8].

Chaotic oscillators are nonlinear in nature but not all nonlinear oscillators are chaotic. Therefore, the focus on modeling chaotic oscillators can be classified into two categories: (a) how simply one can convert an existing oscillating system into a chaotic one by varying the physically accessible design parameters and (b) how a system structure can be modified to generate chaotic oscillations [9–13]. Various electronic realizations of the nonlinear chaotic systems like Logistic map [14], Lorenz system [15], Rossler system [16], Phase lock loop [17], Colpitt oscillator [18], Wien Bridge oscillator [19], Sprott system [20] and many others have already been described by the researchers in last several decades. Efforts are still going on for modeling new chaotic electronic oscillators [21–28].

Researchers are also paying attention to the systematic design methodology of chaotic oscillators [29–32]. In this regard, authors in Ref. [33] considered the Chua circuit as an interconnection between an oscillator, a filter and Chua's diode (or a nonlinear section). Following that protocol one may introduce the filter (or RC section) in between the oscillator and nonlinear section of any conventional nonlinear oscillator to design chaotic oscillator. In this paper we establish this fact and such chaotic systems

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SOME FIXED POINT RESULTS ON RECTANGULAR b–METRIC SPACE

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Abstract. In this paper we have obtained some results on a complete rectangular b–metric space and these results generalized many existing results in this literature.
Keywords: rectangular b–metric space.

1. Introduction and Preliminaries

The Banach fixed point theorem in metric space has generalized by many researchers in various branches such as cone metric space, b–metric space, Generalized metric space, Fuzzy metric space etc. Many researchers such as Tiwary et al.[12], Sarkar et al.([10], [11]), S. Czerwik[3], H. Huang et al.[7], Ding et.al[5], Ozturk[9] and others have worked on Cone Banach Space, b–metric space, rectangular b–metric space. George et al.[6] have proved some results in rectangular b–metric space and have left two open problems for further investigations. Z. D. Mitrović and S. Radenović [8] has given a partial solutions of Reich and Kannan Type contraction in rectangular b–metric space. In this paper we have given partial solution of Ćirić Type, Ćirić almost contraction Type, Hardy Rogers Type contraction condition in rectangular b–metric space with some corollaries.

The following definitions are required to prove the main results.

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UNIQUE COMMON FIXED POINT RESULTS OF INTEGRAL TYPE CONTRACTION CONDITION IN 2-BANACH SPACE

DINANATH BARMAN, KRISHNADHAN SARKAR AND KALISHANKAR TIWARY
(Received : 21 - 11 - 2019 ; Revised : 22 - 03 - 2020)

ABSTRACT. In this paper we have proved some fixed point theorems for integral type contraction condition on 2-Banach space.

1. INTRODUCTION

In a series of papers, Gähler ([4]-[6]) initiated the concept of 2-norm and 2-Banach spaces. Gähler studied the topological property of 2-metric as well as 2-normed spaces. Interested research workers can see the properties in the papers ([4]-[6]). It was Branciari [2] who established fixed point theorem for contractive mapping of integral type on metric spaces. Thereafter, many authors have used this result in 2-metric spaces. Liu et. al. [10], Okeke et. al. [14], Moradi [11], Sarwar [17], Badehian [1], Liu et. al.[9] have worked on integral type contractive condition in metric space. Also many authors have investigated fixed point theorems using various contractive conditions on 2-Banach space. Gangopadhyay et. al.[7], Okeke et. al.[12], Das et. al.[3], Saluja [16], Okeke and Olaleru [13] have proved fixed point theorems on 2-Banach spaces. Gupta et. al. [8], Prajapati et. al. [15] have worked on 2-Banach space for contractive condition of integral type mappings. In this paper we have proved some unique common fixed point theorems for integral type contractive condition on 2-Banach space. We also have used F-contraction to obtain the results and have given some corollaries of these results.

2. DEFINITIONS

We have collected the following definitions from Gähler [4].

Definition 2.1. (*2-norm*) Let X be a linear space and $\|.,.\|$ be a real valued function defined on X, where

i) $\|a, b\| = 0$ if and only if a and b are linearly dependent;

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Nuclear Data Sheets for A=219*

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Abstract: Evaluated experimental structure and decay data are presented for 12 known nuclides of mass 219 (Pb, Bi, Po, At, Rn, Fr, Ra, Ac, Th, Pa, U, Np). Recommended values are given for level parameters, γ and α radiations, and other spectroscopic information. No excited states are known in ^{219}Bi, ^{219}Po, ^{219}Pa, ^{219}U and ^{219}Np. Except for isotopic identification, no information about its half-life or decay characteristics is available for ^{219}Pb. For ^{219}Po, several γ rays have been reported from the decay of ^{219}Bi β^- decay, but no level scheme has been proposed. For ^{219}At, only four excited states are known from α decay of ^{223}Fr. For ^{219}Rn and ^{219}Fr, only the low-spin states are known from α decays of ^{223}Ra and ^{223}Ac, respectively. For ^{219}Ra, ^{219}Ac and ^{219}Th, mainly the data for high-spin states are available from in-beam γ-ray studies. For ^{219}Ra, high-spin data are available from 2017He15, 1992Wi02 and 1987Co36, but evaluators find significant differences in relative photon branchings between the three studies. Detailed comments are given in the Adopted dataset for this nuclide. Half-lives of excited states are known only for seven levels in ^{219}Rn, thus there is a general lack of knowledge about γ-ray transition probabilities. This work supersedes data in the previous evaluations of A=219 published by 2001Br31, 1992Br10 and 1977Ma30.

Cutoff Date: Literature available up to May 19, 2021 has been consulted. Main bibliographic source was the NSR database (2011Pr03) at Brookhaven laboratory webpage: www.nndc.bnl.gov/nsr/.

General Policies and Organization of Material: See the January issue of the *Nuclear Data Sheets* or http://www.nndc.bnl.gov/nds/NDSPolicies.pdf.

General Comments: The statistical analysis of γ-ray data and deduced level schemes is carried out through computer codes available at NNDC, BNL website: www.nndc.bnl.gov. Theoretical total conversion coefficients are calculated using the BrIcc code (2008Ki07) for frozen-orbit option with an implicit uncertainty of 1.4% when not stated. Q values and particle-separation energies have been adopted from 2021Wa16 (AME 2020). In cases where weighted averaging procedures have been used, the assigned uncertainty in the result is not dropped below the lowest uncertainty in the data points used in the procedure.

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Alokkumar De

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Letter

No signature of the saturation of giant dipole resonance width in medium-mass nuclei

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An experimental study on the temperature (T) dependence of giant dipole resonance (GDR) width was performed for the medium mass nucleus ^{74}Kr in the range of $T \approx 2$–2.5 MeV at an average angular momentum of $26\hbar$ using the $^{16}O + ^{58}Ni$ fusion reaction. The emitted high-energy γ rays and evaporated neutrons were measured in coincidence with low-energy discrete γ-ray multiplicities. The GDR parameters, nuclear level density parameter, and nuclear temperature were determined by the statistical model analysis of the high-energy γ-ray spectra as well as evaporated neutron spectra. The measured GDR width is found to increase monotonically with temperature, in contradiction with the recent observation of the width saturation in ^{88}Mo. Comparisons of the measured data with predictions of the adiabatic thermal shape fluctuation model and its refined version, the critical temperature included fluctuation model, are presented and discussed.

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The γ decay of the giant dipole resonance (GDR) has been a promising tool to investigate the structure and dynamics of a hot and fast rotating nuclei. The isovector GDR mode, where protons oscillate against neutrons, can be built on any nuclear state and its overall characteristics depend only on the bulk properties of the system [1]. The evolution of nuclear shape and its fluctuations at extreme conditions of nuclear temperature (T) and angular momentum (J) are directly reflected in the GDR line shape, characterized by three important parameters: the strength (S_{GDR}), the centroid energy (E_{GDR}) and the width (Γ_{GDR}). The strength parameter sets a useful benchmark for collectivity and its disappearance at very high temperature is predicted to be linked with the liquid-to-gas phase transition [2]. The centroid energy, that splits into various components for a deformed nucleus, provides valuable information on the nuclear shape. The most important parameter is the width of the resonance, which is related to the various damping mechanisms of the collective motion within the nuclear matter, and provides vital information on nuclear shear viscosity [3–5].

During the last four decades, one of the prime quests in this field has been how GDR width depends on T and J [6]. Although the intrinsic GDR width has a very weak dependence on temperature [7], the experimentally measured widths (except at low T) increase with T and J. On the theoretical side, several models have been developed to explain the experimental observations. The most popular thermal shape fluctuation model (TSFM) describes the increase in width as a consequence of J-driven nuclear deformation and T-driven shape fluctuations [8]. Alternatively, the microscopic phonon damping model (PDM) describes the broadening of the GDR width ($T > 0$) via coupling of GDR excitation to the noncollective p-p and h-h configurations, that leads to the thermal damping of the GDR [9].

In recent years, extensive experimental studies at low temperature ($T < 1.5$ MeV) over a wide mass region ($A = 30$–208) [10–13] have established that the GDR width remains constant up to a certain critical temperature and increases thereafter. The observed nature has been successfully explained by both TSFM (after taking into account shell effects, pairing field fluctuations, and the GDR induced quadrupole moment) and PDM [11,14,15]. While for $T < 2$ MeV we have a rather good understanding of the problem of the damping of the GDR, at higher temperatures the situation is more complex. In this temperature region ($T > 2$ MeV), one of the long-standing issues is the saturation of the GDR width which was first seen in ^{110}Sn [16] and subsequently around the $A = 135$ mass region [17,18]. However, it was later pointed out by Kelly *et al.* [19] that at higher bombarding energies preequilibrium emission substantially lowers the average excitation energies and hence the estimated temperature. The detailed measurements by the authors (of Ref. [19]), together with a reanalysis of the previous experimental results, showed that the GDR width in Sn and nearby nuclei does not saturate and continues to increase up to temperature ≈ 3.2 MeV [19]. Further investigation carried out by Wieland *et al.* [20] in ^{132}Ce, minimizing the preequilibrium effect through the mass symmetric channel, also provided convincing evi-

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Effect of high angular momentum on η/s of nuclear matter

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The shear viscosity (η) of nuclear matter is investigated in different nuclei (nuclear mass $A \approx 59$–194) using experimental giant dipole resonance (GDR) width (Γ) at high angular momenta ($J = 12$–$54\ \hbar$) and temperatures ($T = 1.2$–2.1 MeV) collected from the existing literature. η, calculated from Γ, is found to increase with T and J. We show that critical temperature included fluctuation model (CTFM) successfully describes J-induced η even beyond critical angular momentum J_c at different values of T. However, the Fermi liquid drop model (FLDM) could not explain the data at higher angular momenta. We propose the addition of a J-dependent term with the FLDM η to improve the prediction at such high-J region. The η/s ratio, highly important for measuring fluidity, is calculated using η and the entropy density s. The latter is estimated using the Fermi gas formula. Interestingly, the experimental value of the ratio is independent of J and A and comes within 2.6–6.0 $\hbar/4\pi k_B$, which is very close to those of a partonic system like quark gluon plasma at high temperature.

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I. INTRODUCTION

The study of the ratio of shear viscosity to entropy density (η/s) of fermionic and bosonic fluids has drawn considerable interest recently in the pursuit of ideal fluid. A recent conjecture of Kovtun *et al.* [1] expresses that for any fluid the ratio obeys a lower limit bound (Kovtun, Son, and Starinets or KSS lower bound), given by $\eta/s = \hbar/4\pi k_B$. A perfect fluid shows lowest possible dissipative energy and saturates the bound [2]. The data on ultrarelativistic collisions from the Relativistic Heavy Ion Collider (RHIC) demonstrate that the quark gluon plasma (QGP) matter at very high temperature (T) could be an ideal fluid with the ratio being very close to that lower limit [3,4]. Remarkably, for RHIC Au + Au collision, η/s at corresponding kinetic freeze-out temperature T (150 MeV) extracted from ALICE and PHENIX data just touches the KSS lower bound [5]. Again, recent experimental data show that the atomic nucleus, in spite of being a quantum Fermi fluid, at low T behaves as an ideal one with the magnitude of η/s nearly equal to that of a partonic system like QGP. Thus, this may be a universal property of strongly coupled systems [4].

The quest for an ideal fluid and liquid-gas phase transition have boosted the ongoing theoretical and experimental research works on the transport properties of atomic nuclei. Experimentally, liquid-gas phase transitions have been studied in the heavy ion collision at the Fermi scale [6]. Theoretically, shear viscosity η in nuclear matter has been estimated using different model-dependent classical and semiclassical calculations. The isospin-dependent quantum molecular dynamics (IQMD) [7], incorporating Pauli blocking and isospin effects, along with parametrization of Danielewicz [8,9] have been utilized to explore T-dependent nuclear viscosity below 400 MeV/nucleon of center-of-mass energy. In the same work, entropy density has been determined using the generalized hot Thomas-Fermi formalism. Finally, the minimum value of the ratio η/s came to nearly five times that of the KSS lower bound [7].

Interestingly, the manifestation of nuclear collectivity over the viscosity of atomic nucleus is another perspective of the transport phenomena within the nuclear matter. The dependence of viscosity on T has been studied in collective motions during nuclear fission [10]. The isovector giant dipole resonance (IVGDR), an out-of-phase oscillation of proton and neutron fluids, has been another probe to understand nuclear viscosity. The width (Γ) of the IVGDR describes the damping phenomena within the finite nuclear matter. It is seen that Γ increases with the decrease in the mass number (A) of the nucleus. This suggests that the damping mechanism is similar to that of a viscous fluid where damping of sound waves under the influence of viscosity increases with the decrease in system volume. Microscopically, the IVGDR is described as the coherent one-particle–one-hole (1p-1h) excitations across the major shells. The width arises from the quantal effects consisting of three components, namely escape width, Landau

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RESEARCH **Open Access**

Predicted antiviral drugs Darunavir, Amprenavir, Rimantadine and Saquinavir can potentially bind to neutralize SARS-CoV-2 conserved proteins

Umesh C. Halder*

Abstract

Background: Novel Coronavirus disease 2019 or COVID-19 has become a threat to human society due to fast spreading and increasing mortality. It uses vertebrate hosts and presently deploys humans. Life cycle and pathogenicity of SARS-CoV-2 have already been deciphered and possible drug target trials are on the way.

Results: The present study was aimed to analyze Non-Structural Proteins that include conserved enzymes of SARS-CoV-2 like papain-like protease, main protease, Replicase, RNA-dependent RNA polymerase, methyltransferase, helicase, exoribonuclease and endoribonucleaseas targets to all known drugs. A bioinformatic based web server Drug ReposeER predicted several drug binding motifs in these analyzed proteins. Results revealed that anti-viral drugs Darunavir,Amprenavir, Rimantadine and Saquinavir were the most potent to have 3D-drug binding motifs that were closely associated with the active sites of the SARS-CoV-2 enzymes.

Conclusions: Repurposing of the antiviral drugs Darunavir, Amprenavir, Rimantadine and Saquinavir to treat COVID-19 patients could be useful that can potentially prevent human mortality.

Keywords: SARS-CoV-2, COVID-19, Antiviral drugs, Darunavir, Amprenavir, Rimantadine, Saquinavir, Non-structural proteins, Enzymes

Background

SARS-CoV-2 has become a menace to the humanity and it imposed unprecedented epidemic condition. Great efforts were carried out by the scientists to develop potent vaccines like Astrazeneca/Oxford [1], Johnson & Johnson [2], Moderna [3], Pfizer/BionTech [4], Sinopharm, Sinovac [5], and COVISHIELD [6], having the potential to curb human mortality. The virus (a positive sense RNA virus with a genome of ~30 kb) has several types of vertebrate hosts including humans and transmission occurs through direct contact or aerosols [7, 8]. Like all animal viruses, their proteins hijack the cellular machineries to complete life cycle. These proteins are of great interest to the scientists to develop specific drug(s) or vaccine schemes against them. Search and trial of potential inhibitory drugs such as Remdesivir, Lopinavir-Ritonaviris were on the way but they were proven ineffective to prevent patient death [9–11]. The present work is based on the fact that most of the viral non-structural proteins (NSPs) which include enzymes remain structurally and chemically conserved as they have to interact with human proteins to carry out same biochemical processes within cell. SARS-CoV-2 genome encodes 16 non-structural proteins (NSPs), involved in genome replication and transcription [12, 13]. Nsp1 is a transcriptional, translational inhibitor and evades host immune

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Puzzle of collective enhancement in the nuclear level density

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ABSTRACT

The collective rotational enhancement in the nuclear level density (NLD) arising due to nuclear deformation is still not well understood due to sparse experimental findings. To address this issue, angular momentum (J) gated neutron, proton and GDR γ-ray spectra have been measured from two deformed nuclei (^{169}Tm and ^{185}Re) and one near spherical nucleus (^{201}Tl) by populating them around 26 MeV excitation energy. An enhanced yield compared to statistical decay is observed in all the three spectra (p, n, γ) for both the deformed nuclei but only statistical decay for near spherical nucleus. Intriguingly, the relative enhancement factors determined independently from all the spectra are very similar (≈ 10) for both the deformed nuclei. Moreover, the results indicate that the fadeout of the collective enhancement does not dependent strongly on the nuclear ground state deformation which is in stark contrast to the expectations of the phenomenological as well as microscopic calculations. The possible reasons for this discrepancy are discussed.

The nucleus is a complex quantum many body system where single particle as well as collective degrees of freedom constitutes elementary modes of excitation. Understanding the coexistence of these two contrasting facets of nuclear dynamics has been a fundamental problem in nuclear science [1,2]. The single particle excited states are described by the concept based on nucleons, comprising of neutrons and protons, occupying single particle orbits which are generated from their independent motion in a mean field potential [3]. The density of these quantum mechanical states increases rapidly with the increase in excitation energy and soon becomes extremely large [4–7]. The knowledge of the nuclear level density (NLD), defined as the number of excited levels per unit of excitation energy for a nucleus, is essential in numerous applications such as basic nuclear physics research, nuclear medicine [8], design of nuclear reactors, astrophysics [9] and fundamentally provides important information about nuclear thermodynamics [10]. On the other hand, the collective mode of excitation arises when the equilibrium shape of the nucleus deviates from spherical symmetry leading to ellipsoidal shapes [1]. The origin of this deformation is explained by the residual interaction between the nucleons occupying the single particle orbits in different configurations [11]. The key role of deformation is that it not only alters the spacing and order of the single particles states but also introduces rotational levels (collective degree of freedom) built on each intrinsic state resulting in an enhancement of the NLD [12,13]. The manifestation of the collective rotational enhancement in the NLD still remains a puzzling topic due to lack of experimental evidence. Up to now, a rather big uncertainty exists in the estimation of the magnitude of collective rotational enhancement and its fadeout with the increase in excitation energy [14–18].

The total collective enhancement in the NLD consists of vibrational and rotational excitations. The rotational enhancement, however, is much stronger and dominates for deformed nuclei [14–16]. The behavior of the rotational enhancement factor has been investigated quantitatively in different theoretical models. It has been predicted, assuming mirror and axial symmetry of the nucleus, that the level density should be $\sigma_\perp^2$ larger ($\sigma_\perp \approx 10$ for $A = 170$) [1,13,16] than the spherical nucleus, while the state densities (taking into account the degeneracy of each level) should only be $\sqrt{2/\pi}\ \sigma_\perp$ times greater [12,18], where $\sigma_\perp$ is the spin cutoff parameter perpendicular to the symmetry axis given as $\sigma_\perp^2 = I_\perp T/\hbar^2$.

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