

Using Lagrangian descriptors to calculate the Maslov index of periodic orbits

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The Maslov index of a periodic orbit is an important piece in the semiclassical quantization of non-integrable systems, while almost all existing techniques that lead to a rigorous calculation of this index are elaborate and mathematically demanding. In this paper, we describe a straightforward technique, for systems with two degrees of freedom, based on the Lagrangian descriptors. Our method is illustrated by applying it to the two-dimensional coupled quartic oscillator.

I. INTRODUCTION

At present the most important theoretical result concerning the semiclassical quantization of chaotic systems remains perhaps the celebrated Gutzwiller trace formula [1]. In this formula, the quantized density of states, which peaks sharply at each quantized energy, is expressed as a sum over the periodic orbits (POs) of the system, where the classical action in Planck constant units $S/\hbar$ appears as a phase factor. Moreover, the reflections of the PO with the potential energy boundaries bring a phase loss that, in the case of an unstable PO, is given by $\mu\frac{\pi}{2}$, where μ is the so-called Maslov index of the PO. Consequently, the calculation of these indices is a principal step in the procedure of quantization of Gutzwiller. For a more general scope of the Maslov index see, e.g., Ref. [2].

Notice that, although the development of standard quantum mechanics has led to more efficient methods, semiclassical quantization still remains a topic of interest, mainly due to the fact that it allows us to establish a correspondence between classical and quantum mechanics. In the last few years, many papers have been published where the semiclassical quantization, and more specifically the quantization of POs, is used. Thus, the quantization of POs of Gutzwiller has been used to obtain an optimal basis set for the representation of eigenstates [3], to calculate the level density of the Hénon-Heiles potential in the context of the symmetry breaking problem [4], has been extended for steady states of nonadiabatic systems [5], to calculate different properties in nuclear collective dynamics [6], to obtain the exceptional points in the elliptical three-disk scatterer [7], to achieve an alternative (continuous time) representation of quantum maps on the torus [8], to propose an alternative approach to the periodic orbit theory of spectral correlations [9], to unveil the creation mechanism of Devil's Staircase surface in the anisotropic Kepler problem [10], to study quantum chaos in many-body systems [11], to develop a chaotic lattice

field theory in one dimension [12], and also to obtain the frontier of scars determining the order-chaos transition when the Planck constant is continuously changed [13].

It is noteworthy that in Gutzwiller original derivation [1], the parameter μ was not identified as a Maslov index, but rather as the number of conjugate points (i.e., the points where caustics occur) over one period of the PO. Later, Creagh *et al.* [14] showed that μ is an intrinsic property of the PO, since it is independent of the coordinate system used. Specifically, these authors demonstrated that the parameter μ is determined by a winding number, namely, it is equal to twice the number of times the stable and unstable manifolds rotate around the PO over one period. Then, the parameter μ is a topological invariant of the PO and can be properly called *Maslov index* in the usual sense. Also, Creagh *et al.* [14] showed that, in general, the Maslov index of a PO cannot be identified with the number of caustics, since this number is not a topological invariant of the PO which can depend on the set of coordinates used and the starting point of the orbit.

Moreover, the rigorous calculation of the Maslov index of a PO is not a simple task. There are some easy but non rigorous methods, such as the count of the turning points in each degree of freedom over one period, which give the correct result in many cases but fail in others. There are also rigorous but elaborate and mathematically demanding methods. Some time ago, Eckhardt and Wintgen [15] developed the theoretical result of Creagh *et al.* [14] obtaining computationally useful formulas, which are based on the linearized classical mechanics, to calculate the number of half-turns that the invariant manifolds rotate around the PO. Recently, Vergel *et al.* [16] showed how the conjugate points of a PO can be computed by using the geometrodynamical approach to classical dynamics, the number of them being equal to the value of the Maslov index. Both methods are rigorous, albeit laborious and not easy to implement. Now, in this paper, we propose a rigorous and straightforward method to obtain, for systems with two degrees of freedom, the number of half-turns that the invariant manifolds rotate around the PO, hence the Maslov index, which is based on the calculation of the Lagrangian descriptors (LDs) along the PO.

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Maslov Clabes Metaplectic Representation And Lagrangian Quantization

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Maslov Classes Metaplectic Representation And Lagrangian Quantization:

Maslov Classes, Metaplectic Representation and Lagrangian Quantization Maurice de Gosson, 1998-01-12 The Maslov Classes have been playing an essential role in various parts of applied and pure mathematics and physics since the early 70 s Their correct definition is due to V I Arnold and J Leray in the transversal case and to P Dazord and the author in the general case The aim of this book is to give a thorough treatment of the theory of the Maslov classes and of their relationship with the metaplectic group It is among other things shown that these classes can be reconstructed modulo 4 using only the analytic properties of the metaplectic group In the last chapter the author sketches a scheme for geometric quantization by introducing two new concepts that of metaplectic half form and that of Lagrangian catalogue the latter generalizes and simplifies the notion of Lagrangian function introduced by J Leray A Lagrangian catalogue is a collection of metaplectic half forms which are themselves cohomological wave functions whose definition is made possible by using the combinatorial properties of the Maslov classes The transformation of Lagrangian catalogues under the metaplectic group and of Hamiltonian flows is studied and it is shown that one thus recovers very easily the so called quasi classical approximation to the solutions of Schr dinger equation if one introduces a natural concept that of projection of a Lagrangian catalogue An application to geometric phase shifts including Berry s phase is given

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