Semiclassical study
of shape resonances in the Stark effect

Kentaro Kameoka

Abstract. Semiclassical behavior of Stark resonances is studied. The complex distortion outside a cone is introduced to study resonances in any energy region for the Stark Hamiltonians with non-globally analytic potentials. The non-trapping resolvent estimate is proved by the escape function method. The Weyl law and the resonance expansion of the propagator are proved in the shape resonance model. To prove the resonance expansion theorem, the functional pseudodifferential calculus in the Stark effect is established, which is also useful in the study of the spectral shift function.

1. Introduction

In this paper, we study the semiclassical behavior of the resonances for the Stark Hamiltonian:

$$P(\hbar) = -\hbar^2 \Delta + \beta x_1 + V(x),$$

where $V(x) \in C^\infty(\mathrm{R}^n; \mathrm{R})$ is a non-globally analytic potential and $\beta > 0$. Throughout this paper, the constant $\beta > 0$ is fixed.

We set the cone

$$C(K, \rho) = \{x \in \mathrm{R}^n \mid |x'| \leq K(x_1 + \rho)\},$$

where $x' = (x_2, \ldots, x_n)$, and denote its complement by $C(K, \rho)^c$. We denote the set of all bounded smooth functions with bounded derivatives by C_b^∞. Our assumption on the potential V is as follows:

Assumption 1. The potential $V(x) \in C_b^\infty(\mathrm{R}^n; \mathrm{R})$ has an analytic continuation to the region $\{x \in \mathrm{C}^n \mid \mathrm{Re}\, x \in C(K_0, \rho_0)^c, |\mathrm{Im}\, x| < \delta_0\}$ for some $\rho_0 \in \mathrm{R}$, $K_0 > 0$ and $\delta_0 > 0$, and $\partial V(x)$ goes to zero when $\mathrm{Re}\, x \to \infty$ in this region.

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Semiclassical Theory Of Shape Resonances:

Semiclassical Theory of Shape Resonances in Quantum Mechanics Peter D. Hislop,Israel Michael Sigal,1989 In this paper we prove the existence of shape resonances in the semi classical approximation for Hamiltonians of the form italic H lowercase Greek Lambda triple bar symbol capital Greek Delta lowercase Greek Lambda2 italic V italic U on italic L2 bold R superscript italic n where lowercase Greek Lambda triple bar symbol 1 h with stroke h with stroke triple bar symbol 2 lowercase Greek Pi 1h   **Semiclassical Theory of Shape Resonances in Quantum Mechanics** ,1989   *Introduction to Spectral Theory* P.D. Hislop,I.M. Sigal,2012-12-06 The intention of this book is to introduce students to active areas of research in mathematical physics in a rather direct way minimizing the use of abstract mathematics The main features are geometric methods in spectral analysis exponential decay of eigenfunctions semi classical analysis of bound state problems and semi classical analysis of resonance A new geometric point of view along with new techniques are brought out in this book which have both been discovered within the past decade This book is designed to be used as a textbook unlike the competitors which are either too fundamental in their approach or are too abstract in nature to be considered as texts The authors text fills a gap in the marketplace   **Mathematical Theory of Scattering Resonances** Semyon Dyatlov,Maciej Zworski,2019-09-10 Scattering resonances generalize bound states eigenvalues for systems in which energy can scatter to infinity A typical resonance has a rate of oscillation just as a bound state does and a rate of decay Although the notion is intrinsically dynamical an elegant mathematical formulation comes from considering meromorphic continuations of Green s functions The poles of these meromorphic continuations capture physical information by identifying the rate of oscillation with the real part of a pole and the rate of decay with its imaginary part An example from mathematics is given by the zeros of the Riemann zeta function they are essentially the resonances of the Laplacian on the modular surface The Riemann hypothesis then states that the decay rates for the modular surface are all either or An example from physics is given by quasi normal modes of black holes which appear in long time asymptotics of gravitational waves This book concentrates mostly on the simplest case of scattering by compactly supported potentials but provides pointers to modern literature where more general cases are studied It also presents a recent approach to the study of resonances on asymptotically hyperbolic manifolds The last two chapters are devoted to semiclassical methods in the study of resonances   **Spectral Analysis on Graph-like Spaces** Olaf Post,2012-01-05 Small radius tubular structures have attracted considerable attention in the last few years and are frequently used in different areas such as Mathematical Physics Spectral Geometry and Global Analysis In this monograph we analyse Laplace like operators on thin tubular structures graph like spaces and their natural limits on metric graphs In particular we explore norm resolvent convergence convergence of the spectra and resonances Since the underlying spaces in the thin radius limit change and become singular in the limit we develop new tools such as norm convergence of operators acting in different Hilbert spaces an extension of the concept of boundary triples to partial

differential operators and an abstract definition of resonances via boundary triples These tools are formulated in an abstract framework independent of the original problem of graph like spaces so that they can be applied in many other situations where the spaces are perturbed **Recent Developments in Quantum Mechanics** Anne Boutet de Monvel,P. Dita,G. Nenciu,Radu Purice,2012-12-06 Proceedings of the Brasov Conference Poiana Brasov 1989 Romania Spectral Theory and Mathematical Physics: A Festschrift in Honor of Barry Simon's 60th Birthday Fritz Gesztesy,2007 This Festschrift had its origins in a conference called SimonFest held at Caltech March 27 31 2006 to honor Barry Simon s 60th birthday It is not a proceedings volume in the usual sense since the emphasis of the majority of the contributions is on reviews of the state of the art of certain fields with particular focus on recent developments and open problems The bulk of the articles in this Festschrift are of this survey form and a few review Simon s contributions to aparticular area Part 1 contains surveys in the areas of Quantum Field Theory Statistical Mechanics Nonrelativistic Two Body and N Body Quantum Systems Resonances Quantum Mechanics with Electric and Magnetic Fields and the Semiclassical Limit Part 2 contains surveys in the areas of Random andErgodic Schrodinger Operators Singular Continuous Spectrum Orthogonal Polynomials and Inverse Spectral Theory In several cases this collection of surveys portrays both the history of a subject and its current state of the art A substantial part of the contributions to this Festschrift are survey articles on the state of the art of certain areas with special emphasis on open problems This will benefit graduate students as well as researchers who want to get a quick yet comprehensiveintroduction into an area covered in this volume Long Time Behaviour of Classical and Quantum Systems Sandro Graffi,André Martinez,2001 Return to equilibrium in classical and quantum systems Carlangelo Liverani Quantum resonances and trapped trajectories Johannes Sjostrand Return to thermal equilibrium in quantum statistical mechanics Volker Bach Small oscillations in some nonlinear PDE s Dario Bambusi and Simone Paleari The semi classical Van Vleck Formula Application to the Aharonov Bohm effect Jean Marie Bily and Didier Robert Fractal dimensions and quantum evolution associated with sparse potential Jacobi matrices Jean Michel Combes and Giorgio Mantica Infinite step billiards Mirko Degli Esposti Semiclassical expansion for the thermodynamic limit of the ground state energy of Kac s operator Bernard Helffer and Thierry Ramond Asymptotics of scattering poles for two strictly convex obstacles Mitsuru Ikawa Parabolic dynamical systems and inducing Stefano Isola QFT for scalar particles in external fields on Riemannian manifolds Hiroshi Isozaki Existence and born Oppenheimer Asymptotics of the total scattering cross section in ion atom collisions Thierry Jecko Markus Klein and Xue Ping Wang On asymptotic perturbation theory for quantum mechanics Gheorghe Nenciu Destruction of the beating effect in a periodically driven double well Andrea Sacchetti Berezin Toeplitz quantization and Berezin transform Martin Schlichenmaier **Long Time Behaviour Of Classical And Quantum Systems - Proceedings Of The Bologna Aptex International Conference** Sandro Graffi,Andre Martinez,2001-04-02 This book is centered on the two minicourses conducted by C Liverani Rome and J Sjoestrand Paris on the return to equilibrium in classical statistical

mechanics and the location of quantum resonances via semiclassical analysis respectively The other contributions cover related topics of classical and quantum mechanics such as scattering theory classical and quantum statistical mechanics dynamical localization quantum chaos ergodic theory and KAM techniques   *Functional Analysis And Related Topics - Proceedings Of The International Symposium* Shozo Koshi,1991-10-31 The objective of this symposium is to discuss the recent developments in the various areas of functional analysis This volume consists mainly of articles in the fields of topological algebra Banach spaces function spaces harmonic analysis operator theory and application of functional analysis   *European Congress of Mathematics* Carles Casacuberta,Rosa Maria Miro-Roig,Joan Verdera,Sebastia Xambo-Descamps,2012-12-06 This is the first volume of the proceedings of the third European Congress of Mathematics Volume I presents the speeches delivered at the Congress the list of lectures and short summaries of the achievements of the prize winners as well as papers by plenary and parallel speakers The second volume collects articles by prize winners and speakers of the mini symposia This two volume set thus gives an overview of the state of the art in many fields of mathematics and is therefore of interest to every professional mathematician Contributors R Ahlswede V Bach V Baladi J Bruna N Burq X Cabr P J Cameron Z Chatzidakis C Ciliberto G Dal Maso J Denef R Dijkgraaf B Fantechi H F llmer A B Goncharov A Grigor yan M Harris R Iturriaga K Johansson K Khanin P Koskela H W Lenstra Jr F Loeser Y I Manin N S Manton Y Meyer I Moerdijk E M Opdam T Peternell B M A G Piette A Reznikov H Schlichtkrull B Schmidt K Schmidt C Sim B T th E van den Ban M F Vign ras O Viro   *Dynamics of Molecular Collisions* W. Miller,2013-11-11 Activity in any theoretical area is usually stimulated by new experimental techniques and the resulting opportunity of measuring phenomena that were previously inaccessible Such has been the case in the area under consideration he re beginning about fifteen years aga when the possibility of studying chemical reactions in crossed molecular beams captured the imagination of physical chemists for one could imagine investigating chemical kinetics at the same level of molecular detail that had previously been possible only in spectroscopic investigations of molecular stucture This created an interest among chemists in scattering theory the molecular level description of a bimolecular collision process Many other new and also powerful experimental techniques have evolved to supplement the molecular be am method and the resulting wealth of new information about chemical dynamics has generated the present intense activity in molecular collision theory During the early years when chemists were first becoming acquainted with scattering theory it was mainly a matter of reading the physics literature because scattering experiments have long been the staple of that field It was natural to apply the approximations and models that had been developed for nuclear and elementary particle physics and although some of them were useful in describing molecular collision phenomena many were not   *Spectral Theory and Mathematical Physics* Pablo Miranda,Nicolas Popoff,Georgi Raikov,2020-11-12 This proceedings volume contains peer reviewed selected papers and surveys presented at the conference Spectral Theory and Mathematical Physics STMP 2018 which was held in Santiago Chile at the Pontifical Catholic University

of Chile in December 2018 The original works gathered in this volume reveal the state of the art in the area and reflect the intense cooperation between young researchers in spectral theoryand mathematical physics and established specialists in this field The list of topics covered includes eigenvalues and resonances for quantum Hamiltonians spectral shift function and quantum scattering spectral properties of random operators magnetic quantum Hamiltonians microlocal analysis and its applications in mathematical physics This volume can be of interest both to senior researchers and graduate students pursuing new research topics in Mathematical Physics   *A Study of the Isoscalar Giant Monopole Resonance* Darshana Chandrakant Patel,2015-12-24 This thesis reports on investigations of a specific collective mode of nuclear vibration the isoscalar giant monopole resonance ISGMR the nuclear breathing mode the energy of which is directly related to a fundamental property of nuclei the nuclear incompressibility The alpha inelastic scattering experiments reported in this thesis have been critical to answering some fundamental questions about nuclear incompressibility and the symmetry energy quantities that are crucial to our understanding of a number of phenomena in nuclear physics and astrophysics including collective excitations in nuclei radii of neutron stars and the nature of stellar collapse and supernova explosions The work described included three sets of experiments and subsequent sophisticated data analysis both leading to results that have been welcomed by the community and recognised as important contributions to the field   *Operator Calculus and Spectral Theory* M. Demuth,B.W. Schulze,B. Gramsch,2012-12-06   **Sum of Even Powers of Real Linear Forms** Bruce Arie Reznick,1992 This work initiates a systematic analysis of the representation of real forms of even degree as sums of powers of linear forms and the resulting implications in real algebraic geometry number theory combinatorics functional analysis and numerical analysis The proofs utilize elementary techniques from linear algebra convexity number theory and real algebraic geometry and many explicit examples and relevant historical remarks are presented   *Selberg Trace Formulae and Equidistribution Theorems for Closed Geodesics and Laplace* Steven Zelditch,1992 This memoir extends the author s earlier work and gives a generalization of the Selberg trace formula and applications to generalizations of the eigenvalue counting problem and the prime geodesic theorem As a consequence of these results he obtains both a proof of the equidistribution theorem for closed geodesics and sharp error estimates His previous work derived the relevant trace formulae in the compact quotient case and this paper is concerned largely with the additional complications that occur in the noncompact case both in terms of deriving the relevant formulae and in estimating various terms   Algebraic and Analytic Microlocal Analysis Michael Hitrik,Dmitry Tamarkin,Boris Tsygan,Steve Zelditch,2018-12-19 This book presents contributions from two workshops in algebraic and analytic microlocal analysis that took place in 2012 and 2013 at Northwestern University Featured papers expand on mini courses and talks ranging from foundational material to advanced research level papers and new applications in symplectic geometry mathematical physics partial differential equations and complex analysis are discussed in detail Topics include Procesi bundles and symplectic reflection algebras microlocal condition for non

displaceability polarized complex manifolds nodal sets of Laplace eigenfunctions geodesics in the space of K hler metrics and partial Bergman kernels This volume is a valuable resource for graduate students and researchers in mathematics interested in understanding microlocal analysis and learning about recent research in the area **Spectral and Scattering Theory** M. Ikawa,2020-12-17 This useful volume based on the Taniguchi International Workshop held recently in Sanda Hyogo Japan discusses current problems and offers the mostup to date methods for research in spectral and scattering theory

Advances in Chemical Physics, Volume 138 Stuart A. Rice,2008-04-30 This series provides the chemical physics field with a forum for critical authoritative evaluations of advances in every area of the discipline This stand alone special topics volume reports recent advances in electron transfer research with significant up to date chapters by internationally recognized researchers

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