



Spectral theory for fractal pseudodifferential operators

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Abstract

The paper deals with the distribution of eigenvalues of the compact fractal pseudodifferential operator T_{τ}^{μ} ,

$$(T_{\tau}^{\mu} f)(x) = \int_{\mathbb{R}^n} e^{-ix\xi} \tau(x, \xi) (f\mu)^{\vee}(\xi) d\xi, \quad x \in \mathbb{R}^n,$$

in suitable special Besov spaces $B_p^s(\mathbb{R}^n) = B_{p,p}^s(\mathbb{R}^n)$, $s > 0$, $1 < p < \infty$. Here $\tau(x, \xi)$ are the symbols of (smooth) pseudodifferential operators belonging to appropriate Hörmander classes $\Psi_{1,\delta}^{\sigma}(\mathbb{R}^n)$, $\sigma < 0$, $0 \leq \delta \leq 1$ (including the exotic case $\delta = 1$) whereas μ is the Hausdorff measure of a compact d -set Γ in \mathbb{R}^n , $0 < d < n$. This extends previous assertions for the positive-definite selfadjoint fractal differential operator $(\text{id} - \Delta)^{\sigma/2} \mu$ based on Hilbert space arguments in the context of suitable Sobolev spaces $H^s(\mathbb{R}^n) = B_2^s(\mathbb{R}^n)$. We collect the outcome in the **Main Theorem** below. Proofs are based on estimates for the entropy numbers of the compact trace operator

$$\text{tr } \mu : B_p^s(\mathbb{R}^n) \hookrightarrow L_p(\Gamma, \mu), \quad s > 0, \quad 1 < p < \infty.$$

We add at the end of the paper a few personal reminiscences illuminating the role of Pietsch in connection with the creation of approximation numbers and entropy numbers.

Keywords Pseudodifferential operators · Fractals · Besov spaces · Eigenvalues · Entropy numbers

Mathematics Subject Classification 46E35 · 41A46 · 28A80 · 35P15

In memory of Albrecht Pietsch (1934–2024)

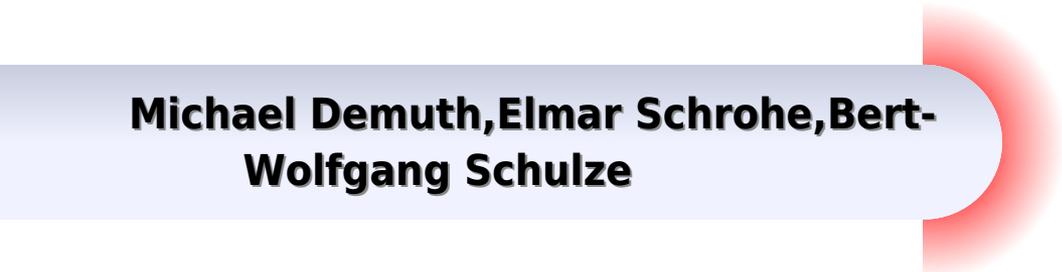
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Advances In Pseudodifferential Operators

**Michael Demuth, Elmar Schrohe, Bert-
Wolfgang Schulze**



Advances In Pseudodifferential Operators:

Advances in Pseudo-Differential Operators Ryuichi Ashino, Paolo Boggiatto, Man-Wah Wong, 2012-12-06 The Fourth Congress of the International Society for Analysis its Applications and Computation ISAAC was held at York University from August 11 2003 to August 16 2003 It was supported by the Academic Initiative Fund of the Faculty of Arts NSERC grants from some members of the Department of Mathematics and Statistics and the Office of the Vice President Academic of York University In spite of two SARS outbreaks in Toronto in 2003 the ISAAC Congress was held as scheduled and was well attended by mathematicians from all over the world There were nine plenary lectures and seventeen special sessions representing most major themes in analysis Among these were two plenary lectures and a special session on pseudo differential operators organized by Ryuichi Ashino of Osaka Kyoiku University Paolo Boggiatto of Universite di Torino and M W Wong of York University In the summer of 2003 M W Wong had the idea of putting together the lectures on pseudo differential operators in a volume to be published in a series that advocates operator theory and its applications In early August of 2003 when Israel Gohberg of Tel Aviv University was consulted about the possibility of publishing a volume entitled Advances in Pseudo Differential Operators in his series Operator Theory Advances and Applications he replied immediately endorsing the proposal enthusiastically

Pseudo-Differential Operators: Analysis, Applications and Computations Luigi Rodino, M. W. Wong, Hongmei Zhu, 2011-03-13 This volume consists of eighteen peer reviewed papers related to lectures on pseudo differential operators presented at the meeting of the ISAAC Group in Pseudo Differential Operators IGPDO held at Imperial College London on July 13 18 2009 Featured in this volume are the analysis applications and computations of pseudo differential operators in mathematics physics and signal analysis This volume is a useful complement to the volumes Advances in Pseudo Differential Operators Pseudo Differential Operators and Related Topics Modern Trends in Pseudo Differential Operators New Developments in Pseudo Differential Operators and Pseudo Differential Operators Complex Analysis and Partial Differential Equations published in the same series in respectively 2004 2006 2007 2009 and 2010

Pseudo-Differential Operators and Generalized Functions Stevan Pilipović, Joachim Toft, 2015-04-27 This book gathers peer reviewed contributions representing modern trends in the theory of generalized functions and pseudo differential operators It is dedicated to Professor Michael Oberguggenberger Innsbruck University Austria in honour of his 60th birthday The topics covered were suggested by the ISAAC Group in Generalized Functions GF and the ISAAC Group in Pseudo Differential Operators IGPDO which met at the 9th ISAAC congress in Krakow Poland in August 2013 Topics include Columbeau algebras ultra distributions partial differential equations micro local analysis harmonic analysis global analysis geometry quantization mathematical physics and time frequency analysis Featuring both essays and research articles the book will be of great interest to graduate students and researchers working in analysis PDE and mathematical physics while also offering a valuable complement to the volumes on this topic previously published in the OT series

An Introduction

to Pseudo-differential Operators Man Wah Wong, 1991 This book gives a straightforward account of a class of pseudo differential operators It is ideal for courses in functional analysis Fourier analysis and partial differential equations Exercises are also included in the text Pseudo-Differential Operators, Generalized Functions and Asymptotics Shahla Molahajloo, Stevan Pilipović, Joachim Toft, M. W. Wong, 2013-02-26 This volume consists of twenty peer reviewed papers from the special session on pseudodifferential operators and the special session on generalized functions and asymptotics at the Eighth Congress of ISAAC held at the Peoples Friendship University of Russia in Moscow on August 22 27 2011 The category of papers on pseudo differential operators contains such topics as elliptic operators assigned to diffeomorphisms of smooth manifolds analysis on singular manifolds with edges heat kernels and Green functions of sub Laplacians on the Heisenberg group and Lie groups with more complexities than but closely related to the Heisenberg group L_p boundedness of pseudo differential operators on the torus and pseudo differential operators related to time frequency analysis The second group of papers contains various classes of distributions and algebras of generalized functions with applications in linear and nonlinear differential equations initial value problems and boundary value problems stochastic and Malliavin type differential equations This second group of papers are related to the third collection of papers via the setting of Colombeau type spaces and algebras in which microlocal analysis is developed by means of techniques in asymptotics The volume contains the synergies of the three areas treated and is a useful complement to volumes 155 164 172 189 205 and 213 published in the same series in respectively 2004 2006 2007 2009 2010 and 2011 *Pseudo-Differential Operators and Related Topics* Paolo Boggiatto, Luigi Rodino, Joachim Toft, M. W. Wong, 2006-01-19 **Pseudo-Differential Operators and Symmetries** Michael V. Ruzhansky, Ville Turunen, 2009-10-19 This monograph is devoted to the development of the theory of pseudo differential operators on spaces with symmetries Such spaces are the Euclidean space \mathbb{R}^n the n torus T^n compact Lie groups and compact homogeneous spaces The book consists of several parts One of our aims has been not only to present new results on pseudo differential operators but also to show parallels between different approaches to pseudo differential operators on different spaces Moreover we tried to present the material in a self contained way to make it accessible for readers approaching the material for the first time However different spaces on which we develop the theory of pseudo differential operators require different backgrounds Thus while operators on the Euclidean space in Chapter 2 rely on the well known Euclidean Fourier analysis pseudo differential operators on the torus and more general Lie groups in Chapters 4 and 10 require certain backgrounds in discrete analysis and in the representation theory of compact Lie groups which we therefore present in Chapter 3 and in Part III respectively Moreover anyone who wishes to work with pseudo differential operators on Lie groups will certainly benefit from a good grasp of certain aspects of representation theory That is why we present the main elements of this theory in Part III thus eliminating the necessity for the reader to consult other sources for most of the time Similarly the backgrounds for the theory of pseudo differential operators on S^1 and $SU(2)$ developed in Chapter 12 can be found in Chapter 11 presented in a self

contained way suitable for immediate use *New Developments in Pseudo-Differential Operators* Luigi Rodino, M. W. Wong, 2009-01-06 This volume consists of peer reviewed papers related to lectures on pseudo differential operators presented at the meeting of the ISAAC Group in Pseudo Differential Operators IGPDO held on August 13 18 2007 and invited papers by experts in the field *Elementary Introduction to the Theory of Pseudodifferential Operators* Xavier Saint Raymond, 2018-02-06 In the 19th century the Fourier transformation was introduced to study various problems of partial differential equations Since 1960 this old tool has been developed into a well organized theory called microlocal analysis that is based on the concept of the pseudo differential operator This book provides the fundamental knowledge non specialists need in order to use microlocal analysis It is strictly mathematical in the sense that it contains precise definitions statements of theorems and complete proofs and follows the usual method of pure mathematics The book explains the origin of the theory i e Fourier transformation presents an elementary construction of distribution theory and features a careful exposition of standard pseudodifferential theory Exercises historical notes and bibliographical references are included to round out this essential book for mathematics students engineers physicists and mathematicians who use partial differential equations and advanced mathematics instructors **Pseudo-Differential Operators and Symmetries** Michael V. Ruzhansky, Ville Turunen, 2010-05-06 This monograph is devoted to the development of the theory of pseudo differential operators on spaces with symmetries Such spaces are the Euclidean space \mathbb{R}^n the n torus T^n compact Lie groups and compact homogeneous spaces The book consists of several parts One of our aims has been not only to present new results on pseudo differential operators but also to show parallels between different approaches to pseudo differential operators on different spaces Moreover we tried to present the material in a self contained way to make it accessible for readers approaching the material for the first time However different spaces on which we develop the theory of pseudo differential operators require different backgrounds Thus while operators on the Euclidean space in Chapter 2 rely on the well known Euclidean Fourier analysis pseudo differential operators on the torus and more general Lie groups in Chapters 4 and 10 require certain backgrounds in discrete analysis and in the representation theory of compact Lie groups which we therefore present in Chapter 3 and in Part III respectively Moreover anyone who wishes to work with pseudo differential operators on Lie groups will certainly benefit from a good grasp of certain aspects of representation theory That is why we present the main elements of this theory in Part III thus eliminating the necessity for the reader to consult other sources for most of the time Similarly the backgrounds for the theory of pseudo differential operators on S^1 and $SU(2)$ developed in Chapter 12 can be found in Chapter 11 presented in a self contained way suitable for immediate use **Modern Trends in Pseudo-Differential Operators** Joachim Toft, M. W. Wong, Hongmei Zhu, 2007-06-25 The ISAAC Group in Pseudo Differential Operators IGPDO met at the Fifth ISAAC Congress held at University of Catania in Italy in July 2005 This volume consists of papers based on lectures given at the special session on pseudodifferential operators and invited papers that bear on the themes of IGPDO Nineteen peer reviewed papers represent

modern trends in pseudo differential operators Diverse topics related to pseudo differential operators are covered

Fourier Analysis Michael Ruzhansky, Ville Turunen, 2014-01-18 This book is devoted to the broad field of Fourier analysis and its applications to several areas of mathematics including problems in the theory of pseudo differential operators partial differential equations and time frequency analysis It is based on lectures given at the international conference Fourier Analysis and Pseudo Differential Operators June 25-30 2012 at Aalto University Finland This collection of 20 refereed articles is based on selected talks and presents the latest advances in the field The conference was a satellite meeting of the 6th European Congress of Mathematics which took place in Krakow in July 2012 it was also the 6th meeting in the series Fourier Analysis and Partial Differential Equations

Recent Trends in Toeplitz and Pseudodifferential Operators Roland V. Duduchava, Israel Gohberg, Sergei M. Grudsky, Vladimir Rabinovich, 2011-02-04 The aim of the book is to present new results in operator theory and its applications In particular the book is devoted to operators with automorphic symbols applications of the methods of modern operator theory and differential geometry to some problems of theory of elasticity quantum mechanics hyperbolic systems of partial differential equations with multiple characteristics Laplace Beltrami operators on manifolds with singular points Moreover the book comprises new results in the theory of Wiener Hopf operators with oscillating symbols large hermitian Toeplitz band matrices commutative algebras of Toeplitz operators and discusses a number of other topics

Pseudo-Differential Calculus and Mathematical Physics Michael Demuth, Elmar Schrohe, Bert-Wolfgang Schulze, 1994-08-23 A major step towards the understanding of differential operators on singular manifolds consists in the construction of algebras of pseudodifferential operators that will allow the solution of natural elliptic equations in terms of parametrix constructions This leads to questions of elliptic regularity Fredholm and index theory The volume contains contributions to the theory of boundary value problems without the transmission property under the aspect of variable branching asymptotics on commutator characterizations in and the submultiplicativity of Boutet de Monvel's algebra the construction of a pseudodifferential calculus for boundary value problems on manifolds with conical singularities and on heat kernel estimates for elliptic singular operators Contributions from the area of Mathematical Physics address the problems of reduction and eigenstates in deformation quantization and spectral theory for Schrödinger operators with electromagnetic potential

Pseudodifferential Operators and Spectral Theory Mikhail A. Shubin, 1987 The theory of pseudo differential operators abbreviated PD is comparatively young in its modern form it was created in the mid sixties The progress achieved with its help however has been so essential that without PD it would indeed be difficult to picture modern analysis and mathematical physics PD are of particular importance in the study of elliptic equations Even the simplest operations on elliptic operators e.g. taking the inverse or the square root lead out of the class of differential operators but will under reasonable assumptions preserve the class of PD A significant role is played by PD in the index theory for elliptic operators where PD are needed to extend the class of possible deformations of an operator PD appear naturally in the

reduction to the boundary for any elliptic boundary problem In this way PD arise not as an end in themselves but as a powerful and natural tool for the study of partial differential operators first and foremost elliptic and hypo elliptic ones In many cases PD allow us not only to establish new theorems but also to have a fresh look at old ones and thereby obtain simpler and more transparent formulations of already known facts This is for instance the case in the theory of Sobolev spaces A natural generalization of PD are the Fourier integral operators abbreviated FIO the first version of which was the Maslov canonical operator

Pseudo-differential Operators Luigi Rodino, Bert-Wolfgang Schulze, Man Wah Wong, 2007-11-21 This volume is based on lectures given at the workshop on pseudo differential operators held at the Fields Institute from December 11 2006 to December 15 2006 The two main themes of the workshop and hence this volume are partial differential equations and time frequency analysis The contents of this volume consist of five mini courses for graduate students and post docs and fifteen papers on related topics Of particular interest in this volume are the mathematical underpinnings applications and ramifications of the relatively new Stockwell transform which is a hybrid of the Gabor transform and the wavelet transform The twenty papers in this volume reflect modern trends in the development of pseudo differential operators

Introduction to the Fourier Transform & Pseudo-differential Operators Bent E. Petersen, 1983

Approaches to Singular Analysis Juan B. Gil, Daniel Grieser, Matthias Lesch, 2012-12-06 The purpose of this publication is to present in one book various approaches to analytic problems that arise in the context of singular spaces It is based on the workshop Approaches to Singular Analysis which was held on April 8 10 1999 at Humboldt University of Berlin The aim of this workshop was to bring together young mathematicians interested in partial differential operators on singular configurations The main idea was to look at different approaches that have been proposed and try to understand to which extent they overlap and how they differ The workshop took place in a rather relaxed atmosphere The participants appreciated that there was a discussion session every day which gave a lot of room for an open exchange of ideas This book contains articles by workshop participants and invited contributions The former are expanded versions of talks at the workshop they give introductions to various pseudodifferential calculi and discussions of relations between them In addition we invited a limited number of papers from mathematicians who have made significant contributions to this field Unfortunately several of these invitations were turned down due to other commitments For this reason only a very small number of contributions from non participants remain The absence of any particular name from the list of invited contributors should not be interpreted as a bias of the editors against that scientist It rather reflects our restricted choice of invitations due to lack of space

Pseudo-Differential Operators on Manifolds with Singularities B.-W. Schulze, 1991-10-17 The analysis of differential equations in domains and on manifolds with singularities belongs to the main streams of recent developments in applied and pure mathematics The applications and concrete models from engineering and physics are often classical but the modern structure calculus was only possible since the achievements of pseudo differential operators This led

to deep connections with index theory topology and mathematical physics The present book is devoted to elliptic partial differential equations in the framework of pseudo differential operators The first chapter contains the Mellin pseudo differential calculus on \mathbb{R} and the functional analysis of weighted Sobolev spaces with discrete and continuous asymptotics Chapter 2 is devoted to the analogous theory on manifolds with conical singularities Chapter 3 to manifolds with edges Employed are pseudo differential operators along edges with cone operator valued symbols

Achievements and Challenges in the Field of Convolution Operators Albrecht Böttcher, Oleksiy Karlovych, Eugene Shargorodsky, Ilya M. Spitkovsky, 2025-03-13 This volume which is dedicated to Yuri Karlovich on the occasion of his 75th birthday includes biographical material personal reminiscences and carefully selected papers The contributions constituting the core of this volume are written by mathematicians who have collaborated with Yuri or have been influenced by his vast mathematical work They are devoted to topics of Yuri Karlovich's work for five decades starting with his work on singular integral operators with shift then broadened to include Toeplitz Wiener Hopf Fourier and Mellin convolution and pseudodifferential operators factorisation of almost periodic matrix functions and local trajectory methods for the study of algebras of convolution and singular integral operators

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