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# SPECTRAL THEORY OF THE RIEMANN ZETA- FUNCTION

by HARVEY D. DUMFRIES



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# Spectral Theory Of The Riemann Zeta Function

**Peter B. Borwein**



## **Spectral Theory Of The Riemann Zeta Function:**

**Spectral Theory of the Riemann Zeta-Function** Yoichi Motohashi, 1997-09-11 The Riemann zeta function is one of the most studied objects in mathematics and is of fundamental importance In this book based on his own research Professor Motohashi shows that the function is closely bound with automorphic forms and that many results from there can be woven with techniques and ideas from analytic number theory to yield new insights into and views of the zeta function itself The story starts with an elementary but unabridged treatment of the spectral resolution of the non Euclidean Laplacian and the trace formulas This is achieved by the use of standard tools from analysis rather than any heavy machinery forging a substantial aid for beginners in spectral theory as well These ideas are then utilized to unveil an image of the zeta function first perceived by the author revealing it to be the main gem of a necklace composed of all automorphic L functions In this book readers will find a detailed account of one of the most fascinating stories in the development of number theory namely the fusion of two main fields in mathematics that were previously studied separately [Riemann Hypothesis and Spectral Theory](#) Jason Cole, 2020-01-10 This book provides a brief overview of the Riemann Zeta function Riemann Hypothesis and the Hilbert Polya spectral operator approach to proving RH Also included in this book is a new discovery that describes a correlation between the Riemann Xi function and gravity rotational curves Surprisingly there is a mathematical correlation between the complex system of the Riemann Xi function and the large scale distribution of galaxies and rotational curves Also included in this book are new discoveries on the Prime Number theorem Riemann Zeta function and other new science and math discoveries *Dynamical, Spectral, and Arithmetic Zeta Functions* Michel Laurent Lapidus, Machiel Van Frankenhuysen, 2001 The original zeta function was studied by Riemann as part of his investigation of the distribution of prime numbers Other sorts of zeta functions were defined for number theoretic purposes such as the study of primes in arithmetic progressions This led to the development of L functions which now have several guises It eventually became clear that the basic construction used for number theoretic zeta functions can also be used in other settings such as dynamics geometry and spectral theory with remarkable results This volume grew out of the special session on dynamical spectral and arithmetic zeta functions held at the annual meeting of the American Mathematical Society in San Antonio but also includes four articles that were invited to be part of the collection The purpose of the meeting was to bring together leading researchers to find links and analogies between their fields and to explore new methods The papers discuss dynamical systems spectral geometry on hyperbolic manifolds trace formulas in geometry and in arithmetic as well as computational work on the Riemann zeta function Each article employs techniques of zeta functions The book unifies the application of these techniques in spectral geometry fractal geometry and number theory It is a comprehensive volume offering up to date research It should be useful to both graduate students and confirmed researchers *Quantized Number Theory, Fractal Strings And The Riemann Hypothesis: From Spectral Operators To Phase Transitions And Universality* Hafeedh Herichi, Michel

L Lapidus, 2021-07-27 Studying the relationship between the geometry arithmetic and spectra of fractals has been a subject of significant interest in contemporary mathematics This book contributes to the literature on the subject in several different and new ways In particular the authors provide a rigorous and detailed study of the spectral operator a map that sends the geometry of fractal strings onto their spectrum To that effect they use and develop methods from fractal geometry functional analysis complex analysis operator theory partial differential equations analytic number theory and mathematical physics Originally M L Lapidus and M van Frankenhuysen heuristically introduced the spectral operator in their development of the theory of fractal strings and their complex dimensions specifically in their reinterpretation of the earlier work of M L Lapidus and H Maier on inverse spectral problems for fractal strings and the Riemann hypothesis One of the main themes of the book is to provide a rigorous framework within which the corresponding question Can one hear the shape of a fractal string or equivalently Can one obtain information about the geometry of a fractal string given its spectrum can be further reformulated in terms of the invertibility or the quasi invertibility of the spectral operator The infinitesimal shift of the real line is first precisely defined as a differentiation operator on a family of suitably weighted Hilbert spaces of functions on the real line and indexed by a dimensional parameter  $c$  Then the spectral operator is defined via the functional calculus as a function of the infinitesimal shift In this manner it is viewed as a natural quantum analog of the Riemann zeta function More precisely within this framework the spectral operator is defined as the composite map of the Riemann zeta function with the infinitesimal shift viewed as an unbounded normal operator acting on the above Hilbert space It is shown that the quasi invertibility of the spectral operator is intimately connected to the existence of critical zeros of the Riemann zeta function leading to a new spectral and operator theoretic reformulation of the Riemann hypothesis Accordingly the spectral operator is quasi invertible for all values of the dimensional parameter  $c$  in the critical interval  $(0, 1)$  other than in the midfractal case when  $c = 1/2$  if and only if the Riemann hypothesis RH is true A related but seemingly quite different reformulation of RH due to the second author and referred to as an asymmetric criterion for RH is also discussed in some detail namely the spectral operator is invertible for all values of  $c$  in the left critical interval  $(0, 1/2)$  if and only if RH is true These spectral reformulations of RH also led to the discovery of several mathematical phase transitions in this context for the shape of the spectrum the invertibility the boundedness or the unboundedness of the spectral operator and occurring either in the midfractal case or in the most fractal case when the underlying fractal dimension is equal to or  $1$  respectively In particular the midfractal dimension  $c = 1/2$  is playing the role of a critical parameter in quantum statistical physics and the theory of phase transitions and critical phenomena Furthermore the authors provide a quantum analog of Voronin's classical theorem about the universality of the Riemann zeta function Moreover they obtain and study quantized counterparts of the Dirichlet series and of the Euler product for the Riemann zeta function which are shown to converge in a suitable sense even inside the critical strip For pedagogical reasons most of the book is devoted to the study of the quantized Riemann zeta function However the

results obtained in this monograph are expected to lead to a quantization of most classic arithmetic zeta functions hence further naturally quantizing various aspects of analytic number theory and arithmetic geometry The book should be accessible to experts and non experts alike including mathematics and physics graduate students and postdoctoral researchers interested in fractal geometry number theory operator theory and functional analysis differential equations complex analysis spectral theory as well as mathematical and theoretical physics Whenever necessary suitable background about the different subjects involved is provided and the new work is placed in its proper historical context Several appendices supplementing the main text are also included

***Zeta and  $q$ -Zeta Functions and Associated Series and Integrals*** Hari M Srivastava, Junesang Choi, 2011-10-11 *Zeta and  $q$  Zeta Functions and Associated Series and Integrals* is a thoroughly revised enlarged and updated version of *Series Associated with the Zeta and Related Functions* Many of the chapters and sections of the book have been significantly modified or rewritten and a new chapter on the theory and applications of the basic or  $q$  extensions of various special functions is included This book will be invaluable because it covers not only detailed and systematic presentations of the theory and applications of the various methods and techniques used in dealing with many different classes of series and integrals associated with the Zeta and related functions but stimulating historical accounts of a large number of problems and well classified tables of series and integrals Detailed and systematic presentations of the theory and applications of the various methods and techniques used in dealing with many different classes of series and integrals associated with the Zeta and related functions

**Symmetry and the Riemann Hypothesis - dialogue with the machine** Vitaly Fartushnov, 2025-07-23 The Riemann hypothesis is an unsolved mathematical problem proposed by Bernhard Riemann in 1859 It states that all nontrivial zeros of the Riemann zeta function that is the complex numbers at which the function is zero lie on a line with real part  $\frac{1}{2}$  The conjecture has deep connections to the distribution of prime numbers and is considered one of the most important unsolved problems in mathematics

**The Conference on L-Functions** Lin Weng, Masanobu Kaneko, 2007 This invaluable volume collects papers written by many of the world's top experts on L functions It not only covers a wide range of topics from algebraic and analytic number theories automorphic forms to geometry and mathematical physics but also treats the theory as a whole The contributions reflect the latest most advanced and most important aspects of L functions In particular it contains Hida's lecture notes at the conference and at the Eigenvariety semester in Harvard University and Weng's detailed account of his works on high rank zeta functions and non abelian L functions

**The Geometry of Total Curvature on Complete Open Surfaces** Katsuhiko Shiohama, Takashi Shioya, Minoru Tanaka, 2003-11-13 This is a self contained account of how some modern ideas in differential geometry can be used to tackle and extend classical results in integral geometry The authors investigate the influence of total curvature on the metric structure of complete non compact Riemannian 2 manifolds though their work much of which has never appeared in book form before can be extended to more general spaces Many classical results are introduced and then extended by the

authors The compactification of complete open surfaces is discussed as are Busemann functions for rays Open problems are provided in each chapter and the text is richly illustrated with figures designed to help the reader understand the subject matter and get intuitive ideas about the subject The treatment is self contained assuming only a basic knowledge of manifold theory so is suitable for graduate students and non specialists who seek an introduction to this modern area of differential geometry

**An Approach to the Selberg Trace Formula via the Selberg Zeta-Function** Jürgen Fischer, 2006-11-15 The Notes give a direct approach to the Selberg zeta function for cofinite discrete subgroups of  $SL(2, \mathbb{R})$  acting on the upper half plane The basic idea is to compute the trace of the iterated resolvent kernel of the hyperbolic Laplacian in order to arrive at the logarithmic derivative of the Selberg zeta function Previous knowledge of the Selberg trace formula is not assumed The theory is developed for arbitrary real weights and for arbitrary multiplier systems permitting an approach to known results on classical automorphic forms without the Riemann-Roch theorem The author's discussion of the Selberg trace formula stresses the analogy with the Riemann zeta function For example the canonical factorization theorem involves an analogue of the Euler constant Finally the general Selberg trace formula is deduced easily from the properties of the Selberg zeta function this is similar to the procedure in analytic number theory where the explicit formulae are deduced from the properties of the Riemann zeta function Apart from the basic spectral theory of the Laplacian for cofinite groups the book is self contained and will be useful as a quick approach to the Selberg zeta function and the Selberg trace formula

**Metric Diophantine Approximation on Manifolds** V. I. Bernik, M. M. Dodson, 1999-10-14 This book is concerned with Diophantine approximation on smooth manifolds embedded in Euclidean space and its aim is to develop a coherent body of theory comparable with that which already exists for classical Diophantine approximation In particular this book deals with Khintchine type theorems and with the Hausdorff dimension of the associated null sets All researchers with an interest in Diophantine approximation will welcome this book

**The Riemann Hypothesis** Peter B. Borwein, 2008 The Riemann Hypothesis has become the Holy Grail of mathematics in the century and a half since 1859 when Bernhard Riemann one of the extraordinary mathematical talents of the 19th century originally posed the problem While the problem is notoriously difficult and complicated even to state carefully it can be loosely formulated as the number of integers with an even number of prime factors is the same as the number of integers with an odd number of prime factors The Hypothesis makes a very precise connection between two seemingly unrelated mathematical objects namely prime numbers and the zeros of analytic functions If solved it would give us profound insight into number theory and in particular the nature of prime numbers This book is an introduction to the theory surrounding the Riemann Hypothesis Part I serves as a compendium of known results and as a primer for the material presented in the 20 original papers contained in Part II The original papers place the material into historical context and illustrate the motivations for research on and around the Riemann Hypothesis Several of these papers focus on computation of the zeta function while others give proofs of the Prime Number Theorem since the

Prime Number Theorem is so closely connected to the Riemann Hypothesis The text is suitable for a graduate course or seminar or simply as a reference for anyone interested in this extraordinary conjecture

**Multiple Dirichlet Series, L-functions and Automorphic Forms** Daniel Bump, Solomon Friedberg, Dorian Goldfeld, 2012-07-09 Multiple Dirichlet Series L functions and Automorphic Forms gives the latest advances in the rapidly developing subject of Multiple Dirichlet Series an area with origins in the theory of automorphic forms that exhibits surprising and deep connections to crystal graphs and mathematical physics As such it represents a new way in which areas including number theory combinatorics statistical mechanics and quantum groups are seen to fit together The volume also includes papers on automorphic forms and L functions and related number theoretic topics This volume will be a valuable resource for graduate students and researchers in number theory combinatorics representation theory mathematical physics and special functions Contributors J Beineke B Brubaker D Bump G Chinta G Cornelissen C A Diaconu S Frechette S Friedberg P Garrett D Goldfeld P E Gunnells B Heim J Hundley D Ivanov Y Komori A V Kontorovich O Lorscheid K Matsumoto P J McNamara S J Patterson M Suzuki H Tsumura

*Harmonic Maps Between Riemannian Polyhedra* James Eells, B. Fuglede, 2001-07-30 Harmonic maps between smooth Riemannian manifolds play a ubiquitous role in differential geometry Examples include geodesics viewed as maps minimal surfaces holomorphic maps and Abelian integrals viewed as maps to a circle The theory of such maps has been extensively developed over the last 40 years and has significant applications throughout mathematics This 2001 book extends that theory in full detail to harmonic maps between broad classes of singular Riemannian polyhedra with many examples being given The analytical foundation is based on existence and regularity results which use the potential theory of Riemannian polyhedral domains viewed as Brelot harmonic spaces and geodesic space targets in the sense of Alexandrov and Busemann The work sets out much material on harmonic maps between singular spaces and will hence serve as a concise source for all researchers working in related fields

**An Introduction to the Langlands Program** Joseph Bernstein, Stephen Gelbart, 2013-12-11 For the past several decades the theory of automorphic forms has become a major focal point of development in number theory and algebraic geometry with applications in many diverse areas including combinatorics and mathematical physics The twelve chapters of this monograph present a broad user friendly introduction to the Langlands program that is the theory of automorphic forms and its connection with the theory of L functions and other fields of mathematics Covered are a variety of areas in number theory from the classical zeta function up to the Langlands program The exposition is systematic with each chapter focusing on a particular topic devoted to special cases of the program and accessible to graduate students and researchers in the field

Collected Papers V Serge Lang, 2000-10-23 Serge Lang 1927 2005 was one of the top mathematicians of our time He was born in Paris in 1927 and moved with his family to California where he graduated from Beverly Hills High School in 1943 He subsequently graduated from California Institute of Technology in 1946 and received a doctorate from Princeton University in 1951 before holding faculty positions at the

University of Chicago and Columbia University 1955-1971 At the time of his death he was professor emeritus of Mathematics at Yale University An excellent writer Lang has made innumerable and invaluable contributions in diverse fields of mathematics He was perhaps best known for his work in number theory and for his mathematics textbooks including the influential Algebra He was also a member of the Bourbaki group He was honored with the Cole Prize by the American Mathematical Society as well as with the Prix Carrière by the French Academy of Sciences These five volumes collect the majority of his research papers which range over a variety of topics

Explicit Formulas Dorian Goldfeld, Jay Jorgenson, Serge Lang, 2006-11-14 The theory of explicit formulas for regularized products and series forms a natural continuation of the analytic theory developed in LNM 1564 These explicit formulas can be used to describe the quantitative behavior of various objects in analytic number theory and spectral theory The present book deals with other applications arising from Gaussian test functions leading to theta inversion formulas and corresponding new types of zeta functions which are Gaussian transforms of theta series rather than Mellin transforms and satisfy additive functional equations Their wide range of applications includes the spectral theory of a broad class of manifolds and also the theory of zeta functions in number theory and representation theory Here the hyperbolic 3 manifolds are given as a significant example

Automorphic Forms and L-Functions for the Group  $GL(n, \mathbb{R})$  Dorian Goldfeld, 2006-08-03 L functions associated to automorphic forms encode all classical number theoretic information They are akin to elementary particles in physics This book provides an entirely self contained introduction to the theory of L functions in a style accessible to graduate students with a basic knowledge of classical analysis complex variable theory and algebra Also within the volume are many new results not yet found in the literature The exposition provides complete detailed proofs of results in an easy to read format using many examples and without the need to know and remember many complex definitions The main themes of the book are first worked out for  $GL(2, \mathbb{R})$  and  $GL(3, \mathbb{R})$  and then for the general case of  $GL(n, \mathbb{R})$  In an appendix to the book a set of Mathematica functions is presented designed to allow the reader to explore the theory from a computational point of view

Fractal Geometry, Complex Dimensions and Zeta Functions Michel L. Lapidus, Machiel van Frankenhuysen, 2007-08-08 Number theory spectral geometry and fractal geometry are interlinked in this study of the vibrations of fractal strings that is one dimensional drums with fractal boundary The Riemann hypothesis is given a natural geometric reformulation in context of vibrating fractal strings and the book offers explicit formulas extended to apply to the geometric spectral and dynamic zeta functions associated with a fractal

Value-Distribution of L-Functions Jörn Steuding, 2007-06-06 These notes present recent results in the value distribution theory of L functions with emphasis on the phenomenon of universality Universality has a strong impact on the zero distribution Riemann's hypothesis is true only if the Riemann zeta function can approximate itself uniformly The text proves universality for polynomial Euler products The authors approach follows mainly Bagchi's probabilistic method Discussion touches on related topics almost periodicity density estimates Nevanlinna theory and



functional independence      *Zeta Functions of Graphs* Audrey Terras, 2010-11-18 Graph theory meets number theory in this stimulating book Ihara zeta functions of finite graphs are reciprocals of polynomials sometimes in several variables Analogies abound with number theoretic functions such as Riemann Dedekind zeta functions For example there is a Riemann hypothesis which may be false and prime number theorem for graphs Explicit constructions of graph coverings use Galois theory to generalize Cayley and Schreier graphs Then non isomorphic simple graphs with the same zeta are produced showing you cannot hear the shape of a graph The spectra of matrices such as the adjacency and edge adjacency matrices of a graph are essential to the plot of this book which makes connections with quantum chaos and random matrix theory plus expander Ramanujan graphs of interest in computer science Created for beginning graduate students the book will also appeal to researchers Many well chosen illustrations and exercises both theoretical and computer based are included throughout

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