The New World Mathematics Awards

Brief Introduction

Mathematics and mathematics education are of great significance in human pursuit of knowledge and truth. They are the foundation of science and technology. In 2007, Dr Henry Cheng, Managing Director of New World Development Company Limited and Professor Yau Shing-Tung, an outstanding mathematician, co-initiated the "New World Mathematics Awards" (NWMA). The goal of this program is to encourage outstanding Chinese mathematics students worldwide in their pursuit of mathematical truth.

2018 NWMA is sponsored by the New World Development Company Limited and China Young Leaders Foundation, organized by Tsinghua University. Chinese undergraduate, master and PhD mathematics students from around the world who have completed or defended their thesis in 2017 or 2018 are qualified to participate in 2018 NWMA. The topics of theses can be Pure or Applied Mathematics, Probability and Statistics, Biomathematics etc.

Application Process

Candidate's submission should have three parts: the thesis, an application form, one letter of recommendation. Student should fill in the application form online and upload the thesis on the webpage of NWMA.

Selection Process

All submissions are subjected to two rounds of review: A scientific committee chaired by Professor Shiu-Yuen Cheng, and then an international committee chaired by Professor Shing-Tung Yau. Members of these committees are all world-renowned mathematicians. The results will be announced around December 2018.

Qualification

This program is open to all undergraduate, master and PhD mathematics Chinese students.

The submitted thesis must be successfully defended and accepted by the students' college/university in 2017 or 2018. Students have to prepare to provide proof of defended of thesis.

Award ceremony is tentatively scheduled in June, 2019, at Beijing. To claim the award, awardees have to be present at the NWMA award ceremony.

Visit http://ymsc.tsinghua.edu.cn/nwma/.

Organization

International Committee

Shing-Tung Yau

Professor Shing-Tung Yau is the William Casper Graustein Professor of Mathematics at Harvard University. He is the inaugural Director of the Yau Mathematical Sciences Center of Tsinghua University. Professor Yau has made fundamental contribution to differential geometry, differential equations and mathematical physics. He is a member of the United States National Academy of Sciences, a member of Russian Academy of Sciences, a foreign member of the Chinese Academy of Sciences, and a member of Academia Sinica.

Prizes and Awards

1981, Oswald Veblen Prize
1982, Fields Medal
1984, MacArthur Fellow
1994, Crafoord Prize
1997, United States National Medal of Science
2003, China International Scientific and Technological Cooperation Award
2010, Wolf Prize in Mathematics
2018, Marcel Grossmann Award

Ben Andrews

Professor Ben Andrews is a senior fellow of Mathematical Sciences Institute, Australian National University, and Professor of the Mathematical Sciences Center of Tsinghua University. Professor Andrews works on differential geometry and related partial differential equation and is well known for his work in geometric evolutions. He is a leading international geometric analyst, who specializes in Riemannian geometry, submanifold geometry, heat flows, image processing, interface model and reaction-diffusion system.

John H. Coates

Professor John H. Coates is the Sadleirian Professor of Pure Mathematics at the University of Cambridge. His research work concerns number theory, arithmetical algebraic geometry and Iwasawa theory. He became Head of the Department of Pure Mathematics and Mathematical Statistics at Cambridge in 1991, served as president of the London Mathematical Society during 1988–90 and as vice-president of the International Mathematical Union from 1991 to 1995, as a member of Council of the Royal Society during 1992–94. Professor Coates was elected a fellow of Emmanuel College in Cambridge twice, a fellow of the Royal Society of London in 1985 and awarded Senior Whitehead Prize by the London Mathematical Society in 1997. Professor Coates is the first receipt of the ICCM International Cooperation Award (2004).

Björn Engquist

Professor Björn Engquist is Director of the Parallel and Scientific Computing Institute. Engquist currently holds the Computational and Applied Mathematics Chair at the Institute for Computational Engineering and Sciences at the University of Texas at Austin. He has been a leading contributor in the areas of multiscale modeling and scientific computing, and a productive educator of applied mathematicians. His research field is computational and applied mathematics and numerical methods for differential equations with applications to multi-scale modeling, electromagnetism, and fluid mechanics. Engquist has authored more than 100 scientific publications and advised 31 PhD students. He is a recipient of numerous distinctions and awards: a member of the Royal Swedish Academy of Sciences and the Royal Swedish Academy of Engineering Sciences, and an invited speaker at the International Congress of Mathematicians (1982 and 1998), European Congress of Mathematics (1992), and European Congress of Fluid Mechanics (1991). He was selected to the Norwegian Academy of Science and Letters in 2011.

Dorian Goldfeld

Dorian Goldfeld is a professor at Columbia University. He is a member of the editorial board of Acta Arithmetica and of The Ramanujan Journal. He is a co-founder and board member of SecureRF, a corporation that has developed the world's first linear-based security solutions. Professor Goldfeld's research interests include various topics in number theory. In his thesis, he proved a version of Artin's conjecture on primitive roots on the average without the use of the Riemann Hypothesis. In 1987 he received the Frank Nelson Cole Prize

in Number Theory, for his solution of Gauss' class number problem for imaginary quadratic fields. He has also held the Sloan Fellowship (1977–1979) and in 1985 he received the Vaughan prize.

Eduard Looijenga

Professor Eduard Looijenga is a Professor of Yau Mathematical Sciences Center of Tsinghua University. His research started in singularity theory, but migrated via Torelli problems to locally symmetric varieties, then to mapping class groups and moduli spaces of curves. His recent work is concerned with automorphic forms with poles that are associated with moduli problems and with the algebraic geometry of Wess-Zumino-Witten systems. One of his major works is a solution of the Zucker conjecture concerning identification of the L2-cohomology of an arithmetic Hermitian locally symmetric space and the intersection cohomology of the Baily-Borel compactification of the space. Professor Looijenga was an invited speaker at the ICM in 1978 and at the ECM in 1992. He is a member of the Royal Netherlands Academy of Arts and Sciences, and an editor of The Michigan Mathematical Journal and Journal of The European Mathematical Society.

Stanley Osher

Stanley Osher is currently Director of Special Projects at the Institute for Pure and Applied Mathematics (IPAM) at the University of California Los Angeles, and Director of Applied Mathematics. Stanley Osher has made fundamental contributions to applied mathematics, computational science, and scientific computing, and has cofounded three companies based on his research. He has applied level set methods for partial differential equations to the field of image processing, to video image enhancement, and movie animation. He has been featured in international media such as Science News, Die Zeit, and Los Angeles Times. Stanley Osher is a recipient of the 2007 USACM Computational and Applied Sciences Award, he was awarded Docteur Honoris Causa in 2006, and elected to the National Academy of Sciences in 2005. Stanley Osher has received the SIAM Kleinman Prize in 2005, the SIAM ICIAM Pioneer Prize in 2003, the NASA Public Service Group Achievement Award, and the Japan Society of Mechanical Engineers Computational Mechanics Award.

Thomas Yizhao Hou

Thomas Yizhao Hou is Charles Lee Powell Professor of Applied and Computational Mathematics in the Department of Computing and Mathematical Sciences at the California Institute of Technology. Hou is known for research on multiscale analysis. He is an author of the monograph Multiscale finite element methods. He has worked extensively on numerical analysis and applied analysis of the Navier-Stokes equations. His recent work focuses on adaptive data analysis. He received an Alfred P. Sloan Research Fellowship in 1990. He was awarded the Feng Kang Prize in Scientific Computing in 1997. He received the James H. Wilkinson Prize in Numerical Analysis and Scientific Computing from the Society for Industrial and Applied Mathematics (SIAM) in 2001, Morningside Gold Medal in Applied Mathematics in 2004, and Computational and Applied Sciences Award in 2005. Hou has also been inducted into several scholarly societies. He was elected Fellow of the Society for Industrial and Applied Mathematics in 2009, Fellow of the American Academy of Arts and Sciences (AAAS) in 2011, and Fellow of the American Mathematical Society (AMS) in 2012.

Jun Li

Dr. Jun Li is a professor at the Department of Mathematics, Stanford University. Since receiving his PhD from Harvard University in 1989, he was on the faculty of UCLA from 1992–96, before joining Stanford University. His research interest is in algebraic geometry; he has made significant contribution to the research on moduli of vector bundles, stable

morphisms and Gromov-Witten invariants. He was the recipient of Sloan fellowship, Terman fellowship; he was awarded the morningside medal in 2001.

Akito Futaki

Akito Futaki is a Professor of Graduate School of Mathematical Sciences at University of Tokyo. His main research interests are differential geometry, complex algebraic geometry. He is interested in the existence problem of extremal Kähler metrics such as Kähler-Einstein metrics, and related problems in geometry. He received the Geometry Prize of Mathematical Society of Japan in 1990, Autumn Prize of Mathematical Society of Japan in 2011. He was elected professor emeritus of Tokyo Institute of Technology in 2012.

Lo Yang

Professor Lo Yang was the Director of Institute of Mathematics (1987–1995) and the President of Academy of Mathematics and System Science (1998–2002), CAS. Now he is the professor and Chairman of Scientific Committee of AMSS. He was elected as the academician of the Chinese Academy of Sciences in 1980. Besides, he was the President (1992–1995) of Chinese Mathematical Society. Professor Yang was mainly engaged in the research on complex analysis. He has made a through study of deficient values and deficient functions. He, cooperated with Guang-hou Zhang, established for the first time a close relation between the numbers of deficient values and Borel directions of entire and meromorphic functions. Among his research on normal families, he built the relationship between normal families and fix-points, as well as that between normal families and differential polynomials. He also made the systematic research on the angular distribution: finding a new kind of singular direction and establi-shing a necessary and sufficient condition for the distribution of singular directions. Distribution Theory was published by the Springer-Verlag.

Horng-Tzer Yau

Horng-Tzer Yau is a professor of Harvard University. Professor Yau is a leader in the fields of mathematical physics, analysis and probability. He is a powerful analyst who has introduced important tools and concepts to study probability, stochastic processes, nonequilibrium statistical physics and quantum dynamics. His insight and skilled teaching are invaluable to students. He has also been a member of the Institute for Advanced Study in Princeton, in 1987–88, 1991–92, and 2003, and a member of the American Academy of Arts and Sciences. He is a member of the editorial boards of Communications in Mathematical Physics, Journal of Statistical Mathematics, Asian Journal of Mathematics and Communications on Pure and Applied Mathematics. He received Henri Poincaré Prize, MacArthur Fellowship and Morningside Gold Medal of Mathematics in 2000 and 2001. He is elected a fellow of the US National Academy of Sciences in 2013.

Scientific Committee

Xu-Jia Wang
Australian National University

Yuefei Wang
AMSS, CAS

Zhiying Wen
Tsinghua University

Nanhua Xi
AMSS, CAS

Zhouping Xin
Chinese University of Hong Kong

Jing Yu
National Taiwan University

Pin Yu
Tsinghua University

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Organization Committee

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Xiaoxia Huang
Tsinghua University

Bangming Deng
Tsinghua University

Huihui Zeng
Tsinghua University

Zuoqiang Shi
Tsinghua University

Recipients of the 2017 New World Mathematics Awards

Doctor Thesis Awards, Gold Prize

Shu-Heng Shao, Harvard University

Thesis title: Supersymmetric Particles in Four Dimensions

Abstract: In this dissertation we study supersymmetric particles in four spacetime dimensions and their relations to other physical observables. For a large class of four-dimensional $\mathrm{N}=2$ systems, the supersymmetric particles are described by the ground states of certain quiver quantum mechanics in the low energy limit. We derive a localization formula for the index of quiver quantum mechanics with four supercharges. Our answer takes the form of a residue integral on the complexified Cartan subalgebra of the gauge group. The wall-crossing phenomenon appears as discontinuities in the value of the residue integral as the integration contour is varied. We then move on to study the ground states in the Kronecker model of quiver quantum mechanics. This is the simplest quiver with two gauge groups and bifundamental matter fields, and appears universally in four-dimensional $\mathrm{N}=2$ systems. The ground state degeneracy may be written as a multi-dimensional contour integral, and the enumeration of poles can be simply phrased as counting bipartite trees. We solve this combinatorics problem, thereby obtaining exact formulas for the degeneracies of an infinite class of models.

For large ranks, the ground state degeneracy is exponential with the slope being a modular function that we are able to compute at integral values of its argument. We also observe that the exponential of the slope is an algebraic number and determine its associated algebraic equation explicitly in several examples. The speed of growth of the degeneracies, together with various physical features of the bound states, suggests a dual string interpretation. In the last part of the dissertation, we conjecture a precise relationship between a limit of the superconformal index of four-dimensional $\mathrm{N}=2$ field theories, which counts local operators, and the spectrum of BPS particles on the Coulomb branch. We verify this conjecture for the case of free field theories, $\mathrm{N}=2$ QED, and $SU(2)$ gauge theories coupled to matter. Assuming the validity of our proposal, we compute the superconformal index of all Argyres-Douglas theories. Our answers match expectations from the connection of Schur operators with two-dimensional chiral algebras.

Advisor: Xi Yin

Rong Zhou, Harvard University

Thesis title: Mod-p isogeny classes on Shimura varieties with parahoric level structure

Abstract: We study the special fiber of the integral models for Shimura varieties of Hodge type with parahoric level structure constructed by Kisin and Pappas in *Integral models of shimura varieties with parahoric level structure, preprint*. We show that when the group is residually split, the points in the mod p isogeny classes have the form predicted by the Langlands Rapoport conjecture in *Shimuravarietäten und Gerben, J. Reine Angew. Math.* We also verify most of the He-Rapoport axioms for these integral models without the residually split assumption. This allows us to prove that all Newton strata are non-empty for these models.

Advisor: Mark Kisin

Doctor Thesis Awards, Silver Prize

Nan Chen, New York University

Thesis title: Filtering and Predicting Complex Nonlinear Turbulent Dynamical Systems with Model Error

Abstract: This dissertation includes five topics in fitering and predicting complex turbulent systems with model error from noisy partial observations. An efficient and accurate model calibration is the prerequisite of filtering and prediction. The first topic involves adopting Bayesian inference that incorporates data augmentation in a Markov chain Monte Carlo algorithm to estimate the parameters in a reduced model that describes nature with hidden instability. A novel pre-estimation of hidden processes greatly enhances the efficiency of the algorithm. The model equipped with the estimated parameters succeeds in predicting the extreme events in nature.

The filtering and prediction of the Madden-Julian oscillation (MJO) and relevant tropical waves have significant implications for extended range forecasting. A physics constrained low-order nonlinear stochastic model involving correlated multiplicative noise defined through energy conserving nonlinear interaction is developed to predict two MJO indices with different features. The special structure of the model allows efficient data assimilation and ensemble initialization algorithms for the hidden variables. Utilizing an information-theoretic framework for model calibration, the model has significant skill for determining the predictability limits of the MJO.

Filtering the stochastic skeleton model for the MJO with noisy partial observations is another central topic. A nonlinear filter, which captures the inherent nonlinearity of the system, is proposed and judicious model error is included. An effectively balanced reduced filter involving a simple fast-wave averaging strategy is developed, which facilitates filtering the moisture and other fast-oscillating modes and enhances the total computational efficiency. Both filters succeed in filtering the MJO and other large-scale features.

The last two topics focus on filtering complex turbulent systems within a conditional

Gaussian framework. Despite the conditional Gaussianity, such systems are nevertheless highly nonlinear and non-Gaussian. The special structure of the filter allows closed analytical formulae for updating the posterior states. Applications of dyad models, triad models and parameter estimations are illustrated, where the effect of model error in filtering is extensively studied. This conditional Gaussian framework is also applied to study filtering multiscale random rotating compressible ow fields with observations from noisy Lagrangian tracers, where model error in different practical reduced filters is assessed via information theory.

Advisor: Andrew J. Majda

Ya Deng, Université de Strasbourg

Thesis title: Generalized Okounkov bodies, on the direct image and hyperbolicity problems

Abstract: In Part 1 of this thesis, we construct "Okounkov bodies" for an arbitrary pseudo-effective (1,1)-class on a Kähler manifold. We prove the differentiability formula of volumes of big classes for Kähler manifolds on which modified nef cones and nef cones coincide. As a consequence we prove Demailly's transcendental Morse inequality for these particular Kähler manifolds; this includes Kähler surfaces. Then we construct the generalized Okounkov body for any big (1,1)-class, and give a complete characterization of generalized Okounkov bodies on surfaces. We show that this relates the standard Euclidean volume of the body to the volume of the corresponding big class as defined by Boucksom; this solves a problem raised by Lazarsfeld and Mustată in the case of surfaces. We also study the behavior of the generalized Okounkov bodies on the boundary of the big cone.

Part 2 deals with Kobayashi hyperbolicity-related problems. Chapter 2's goal is to study the degeneracy of leaves of the one-dimensional foliations on higher dimensional manifolds, along the lines of [McQ98, Bru99, McQ08, PS14]. The first part of Chapter 2 generalizes McQuillan's Diophantine approximations for one-dimensional foliations with absolutely isolated singularities, on higher dimensional manifolds. As an application, we give a new proof of Brunella's hyperbolicity theorem, that is, all the leaves of a generic foliation of degree $d \geq 2$ in $\mathbb{C}P^n$ is hyperbolic. In the second part of Chapter 2 we introduce the so-called weakly reduced singularities for one-dimensional foliations on higher dimensional manifolds. The "weakly reduced singularities" assumption is less demanding than the one required for "reduced singularities", but play the same role in studying the Green-Griffiths-Lang conjecture. Finally we discuss a strategy to prove the Green-Griffiths-Lang conjecture for complex surfaces.

In Chapter 3, assuming that the canonical sheaf $\mathcal{K}_V$ is big in the sense of Demailly, we prove the Kobayashi volume-hyperbolicity for any (possibly singular) directed variety (X, V).

In Chapter 4, our first goal is to deal with effective questions related to the Kobayashi and Debarre conjectures, relying on the work of Damian Brotbek [Bro16] and his joint work with Lionel Darondeau [BD15]. We then combine these techniques

to study the conjecture on the ampleness of the Demailly-Semple bundles raised by Diverio and Trapani [DT10], and also obtain some effective estimates related to this problem. Our result integrates both the Kobayashi and Debarre conjectures, with some (non-optimal) effective estimates.

The purpose of Chapter 5 is twofold: on the one hand we study a Fujita-type conjecture by Popa and Schnell, and give an effective (linear) bound on the generic global generation of the direct image of the twisted pluricanonical bundle. We also point out the relation between the Seshadri constant and the optimal bound. On the other hand, we give an affirmative answer to a question by Demailly-Peternell-Schneider in a more general setting. As applications, we generalize the theorems by Fujino and Gongyo on images of weak Fano manifolds to the Kawamata log terminal cases, and refine a result by Broustet and Pacienza on the rational connectedness of the image.

In Chapter 6, we give a concrete and constructive proof of the equivalence between the category of semistable Higgs bundles with vanishing Chern classes and the category of all representations of the fundamental groups [Cor88, Sim88] on smooth Kähler manifolds. This chapter is written for the complex geometers who are not familiar with the language of differential graded category used by Simpson to prove the above equivalence on smooth projective manifolds, and for those who would like to see an elementary proof of Corlette-Simpson correspondence for semistable Higgs bundles.

Advisor: Jean-Pierre Demailly

Chen Wan, University of Minnesota

Thesis title: A Local Trace Formula and the Multiplicity One Theorem for the Ginzburg-Rallis Model

Abstract: Following the method developed by Waldspurger and Beuzart-Plessis in their proof of the local Gan-Gross-Prasad conjecture, we are able to prove a local trace formula for the Ginzburg-Rallis model. By applying this trace formula, we proved a multiplicity formula for the Ginzburg-Rallis model for tempered representations. Then by applying this multiplicity formula, we proved the multiplicity one theorem for all tempered L-packets. In some cases, we also proved the epsilon dichotomy conjecture which gives a relation between the multiplicity and the exterior cube epsilon factor. Finally, in the archimedean case, we proved some partial results for the general generic representations by applying the open orbit method.

Advisor: Dihua Jiang

Ruixiang Zhang, Princeton University

Thesis title: Perturbed Brascamp-Lieb inequalities and application to Parsell-Vinogradov systems

Abstract: In this thesis, we study the perturbed Brascamp-Lieb inequalities and its applications in translation-dilation systems. We prove the endpoint perturbed Brascamp-Lieb inequalities using polynomial partition techniques. We also look at the Parsell-Vinogradov system and verify the Brascamp-Lieb condition holds in its decoupling approach. As a corollary of this and the work of Guo, the main conjecture about the system is true in dimension 2 and can be proved by the decoupling approach.

Advisor: Peter Sarnak

Yihang Zhu, Harvard University

Thesis title: The stabilization of the Frobenius-Hecke traces on the intersection cohomology of orthogonal Shimura varieties

Abstract: The orthogonal Shimura varieties are associated to special orthogonal groups over $\mathbb{Q}$ of signature $(n,2)$ at infinity. In this work we prove a version of Morel's formula for the Frobenius-Hecke traces on the intersection cohomology of their Baily-Borel compactifications. We then stabilize the formula, in terms of Kottwitz's simplified expression for the geometric side of the Arthur-Selberg trace formula for test functions that are stable cuspidal at infinity.

Advisor: Mark Kisin

Master Thesis Awards, Silver Prize

Pui Tung CHOI, The Chinese University of Hong Kong

Thesis title: Surface Conformal/Quasi-conformal Parameterization with Applications

Abstract: Surface conformal and quasi-conformal parameterizations are important in computer graphics and medical imaging. In this thesis, we develop efficient and practical algorithms for mesh and point cloud parameterizations with various applications. Firstly, we propose a linear algorithm for the spherical conformal parameterizations and an efficient algorithm called *FLASH* forlandmark-aligned spherical optimized conformal mappings of genus-0 closed triangular meshes. The algorithms are applied for the registration of human cortical surfaces, and the shape analysis of the carotid arteries and the hippocampal surfaces in medical imaging. Secondly, we propose two fast disk conformal parameterization algorithms for simply-connected open triangular meshes and apply the parameterizations for texture mapping. Thirdly, we develop a linear algorithm for computing spherical quasi-conformal parameterization and Teichmüller parameterization of genus-0 closed meshes.

Fourthly, we develop an iterative scheme for the spherical conformal parameterizations of genus-0 point clouds with applications in meshing and multilevel representation. Fifthly, we propose a novel algorithm called *TEMPO* for the landmark aligned Teichmüller parameterization of disk-type point clouds with theoretical guarantee. The algorithm is applied for developing a dissimilarity metric of point clouds. Experimental results are presented for demonstrating the effectiveness of our proposed algorithms.

Advisor: Ronald Lok Ming LUI

Undergraduate Thesis Awards, Gold Prize

Bingyi Chen, Tsinghua University

Thesis title: Classification of 3 Dimensional Rational Complete Intersection Singularities

Abstract: In this paper, we classify three dimensional isolated weighted homogeneous rational complete intersection singularities according to the weight type and calculate the Milnor numbers and basis of miniversal deformation of these singularities.

Advisor: Stephen S. T. Yau

Ziyu Li, Ningbo University

Thesis title: Infinite-Dimensional Geometric Structure of Stock Market

Abstract: This paper first reviews and provides a positive analysis on small-world, scale-free and self-similar properties of the stock market. Then, based on the stock market time series and geodesic structure, we construct metric structures on the stock markets in China and NASDAQ. Applying the improved covering and packing algorithms to the above metric structure, we obtain an experimental result that the overall behaviors of the stock markets in China and NASDAQ are characterized by "infinite dimension". Therefore, any forecast of stock market behaviors through finite parameters contains not only white noise but system error.

Advisor: Lifeng Xi