Information and Announcements

Mathematics Prizes Awarded at ICM 2014

The International Congress of Mathematicians (ICM) is held once in four years under the auspices of the International Mathematical Union (IMU). The ICM is the largest, and the most prestigious, meeting of the mathematics community. During the ICM, the Fields Medal, the Nevanlinna Prize, the Gauss Prize, the Chern Medal and the Leelavati Prize are awarded. The Fields Medals are awarded to mathematicians under the age of 40 to recognize existing outstanding mathematical work and for the promise of future achievement. A maximum of four Fields Medals are awarded during an ICM. The Nevanlinna Prize is awarded for outstanding contributions to mathematical aspects of information sciences; this awardee is also under the age of 40. The Gauss Prize is given for mathematical research which has made a big impact outside mathematics – in industry or technology, etc. The Chern Medal is awarded to a person whose mathematical accomplishments deserve the highest level of recognition from the mathematical community. The Leelavati Prize is sponsored by Infosys and is a recognition of an individual's extraordinary achievements in popularizing among the public at large, mathematics, as an intellectual pursuit which plays a crucial role in everyday life. The 27th ICM was held in Seoul, South Korea during August 13–21, 2014.

Fields Medals

The following four mathematicians were awarded the Fields Medal in 2014.

1. Artur Avila, "*for his profound contributions to dynamical systems theory, which have changed the face of the field, using the powerful idea of renormalization as a unifying principle*".

Work of Artur Avila (born 29th June 1979): Artur Avila's outstanding work on dynamical systems, and analysis has made him a leader in the field. He has solved long-standing open problems and has shaped the subject of dynamical systems.

Avila is from Brazil and spends part of his time in France. His collaborations with at least 30 mathematicians from around the world combines the strong mathematical cultures of Brazil as well as France.

Avila's work possesses tremendous technical power, tenacity, ingenuity and problem-solving ability. He has made significant progress in a wide spectrum of areas ranging from real and complex one-dimensional dynamics to spectral theory of the one-frequency Schrödinger operator, to partially hyperbolic dynamics. Thanks to Avila's work, we have now a full understanding of the probabilistic point of view, and of a complete renormalization theory in real one-dimensional dynamics. His contributions to complex dynamics has led to a thorough knowledge of the fractal geometry of Feigenbaum Julia sets.

In the spectral theory of one-frequency difference Schrödinger operators, Avila established stratified analyticity of the Lyapunov exponent. He also obtained several deep results and proved long-standing conjectures on the ergodic behavior of interval-exchange maps.

Avila's collaborative approach is a real inspiration for the new generation of mathematicians.

2. Manjul Bhargava, "*for developing powerful new methods in the geometry of numbers, which he applied to count rings of small rank and to bound the average rank of elliptic curves*".

Work of Manjul Bhargava (born 8th August 1974): Bhargava's work has had a profound influence in number theory. His extraordinary creativity along with a passion for simple problems of timeless beauty, have resulted in the development of beautiful and powerful new methods that offer deep insights into classical problems.

In his thesis, he reformulated Gauss's composition rule of binary quadratic forms. By establishing a dictionary between the orbits of the product of three copies of the modular group SL(2,Z) on the tensor product of three copies of the standard integral representation and quadratic rings together with three ideal classes with trivial product, he recovered Gauss's composition law in a totally new, astonishing way which also had the advantage of being computationally effective.

Bhargava went on to study orbits in more general integral representations, and showed that they correspond to cubic, quartic, and quintic rings. This enabled him to count the number of such rings with bounded discriminant. After this stupendous accomplishment, Bhargava looked at representations with a polynomial ring of invariants. One such is given by the action of the modular group on binary quartic forms. As the two independent invariants are related to the moduli of elliptic curves, he had found a way to address the deep problem of estimating the average ranks of elliptic curves. Bhargava and Arul Shankar (his doctoral student) used subtle estimates on the number of integral orbits of bounded height to bound the average rank of elliptic curves. He has recently generalized these ideas to higher genus, and showed that most hyperelliptic curves of genus higher than one have no rational points. In fact, if the degree of the polynomial is 10, the chances of having no rational points are more than 99 per cent.

Another area where Bhargava proved a stunning theorem is the theory of universal quadratic forms, a topic to which Ramanujan has also contributed; Ramanujan produced 54 forms in 4 variables which are universal – that is, take all integer values. Bhargava and Hanke found a set of 29 integers – the largest of which is 290 – satisfying the property that, if a quadratic form in any number of variables represents these 29 integers, then it represents all integers. The proof of this ‘290-theorem’ is amazing in its ingenuity.

A lot of Bhargava’s work involves a deep understanding of the representations of arithmetic groups; it carries a unique blend of algebraic and analytic skills – which some people have hailed as a ‘Midas touch’.

Bhargava is an accomplished musician; he plays several instruments which include the tabla which he plays at a professional level. He has won several accolades and prizes for his teaching and his lucid communication skills.

3. Martin Hairer, “*for his outstanding contributions to the theory of stochastic partial di erential equations, and in particular for the creation of a theory of regularity structures for such equations*”.

Work of Martin Hairer (born 14th November 1975): Martin Hairer has done seminal work in the theory of stochastic partial differential equations. He created a new theory which provides the means to attack problems that had seemed impenetrable until now.

In contrast with deterministic differential equations that describe phenomena like planetary motion, there are differential equations which are stochastic. These equations describe systems containing randomness inherently. An equation describing the change of a stock price over time is a typical example. These equations need to incorporate terms corresponding to fluctuations in the stock market price. Several natural phenomena are governed by nonlinear PDE’s (partial differential equations) and are very difficult to study. Hairer has developed a general theory which applies to a large class of nonlinear stochastic PDE’s like the KPZ equation which has significance in physics but lacks a precise meaning mathematically.

In a spectacular achievement, Hairer described a new approach to the KPZ equation that allows us to give a precise mathematical meaning to the equation and its solutions. Building on these ideas, he developed the so-called ‘theory of regularity structures’, that can be applied in higher dimensions too. This has led to a lot of excitement among the mathematics community. Hairer’s outstanding contribution in another context is in his joint work with Jonathan Mattingly to understand a stochastic version of the Navier–Stokes equation.

Hairer has superlative skills also as a computer programmer. When he was in school, he invented an audio editing software which he later developed and marketed.

In summary, Hairer’s deep intuition about physical systems and his technical power provided astonishingly for the first time, rigorous intrinsic meaning to many stochastic nonlinear PDE's arising in physics.

4. Maryam Mirzakhani, "for her outstanding contributions to the dynamics and geometry of Riemann surfaces and their moduli spaces."

Work of Maryam Mirzakhani (born May 1977): Maryam Mirzakhani has made stunning advances in the theory of Riemann surfaces and their moduli spaces. Her deep geometric intuition has integrated several mathematical disciplines such as algebraic geometry, complex analysis, topology, and probability theory. Mirzakhani obtained asymptotic formulae and counting results for the number of simple closed geodesics on a single Riemann surface. These led to a totally unexpected proof of a formula for characteristic classes for the moduli spaces of Riemann surfaces with marked points which had been conjectured by Witten.

Mirzakhani also discovered a remarkable bridge between the holomorphic and the symplectic aspects of the moduli space. She used it to show that Thurston's earthquake flow is ergodic and mixing.

The closure of a real geodesic in moduli space can be a fractal cobweb but recently, Mirzakhani and her collaborators proved that the closure of a complex geodesic is always an algebraic subvariety; this had been conjectured a long time ago. The significance of this result is that, though complex geodesics are transcendental in nature, being defined in terms of analysis and differential geometry, their closures are algebraic in nature. Hence, these closures have certain rigidity properties. Therefore, this aspect of Mirzakhani's work has revealed that the rigidity theory of homogeneous spaces of Lie groups has a close analogue in the inhomogeneous world of moduli spaces. Mirzakhani's deep insights have made her a world leader in her subject.

The 2014 Nevanlinna Prize

Subhash Khot, "for his prescient definition of the "Unique Games" problem, and leading the effort to understand its complexity and its pivotal role in the study of efficient approximation of optimization problems; his work has led to breakthroughs in algorithmic design and approximation hardness, and to new exciting interactions between computational complexity, analysis and geometry."

Work of Subhash Khot (born 10th June 1978): The famous conjecture known as 'P is not equal to NP' has been open for at least four decades. In simple terms, the conjecture means that some problems are so difficult that computers cannot reliably find the answer in any reasonable amount of time.

Subhash Khot defined the 'Unique Games' in 2002 – a simple problem which plays a pivotal role in encapsulating what makes many problems hard to solve, even approximately, in a reasonable amount of time.

Khot and his collaborators demonstrated that the hardness of the Unique Games problem implies a precise characterization of the best possible approximation for a vast number of NP-hard optimization problems. Thus, the Unique Games problem has come to be viewed as a major open problem in the theory of computation.

Khot's study of its complexity led to new central limit theorems, invariance principles, isoperimetric inequalities, and inverse theorems. Efforts to prove the Unique Games Conjecture, or even to disprove it, have led to enormous benefits. The Unique Games Conjecture will be driving research in theoretical computer science for many years to come.

The 2014 Gauss Prize

Stanley Osher, "for his influential contributions to several fields in applied mathematics, and for his far-ranging inventions that have changed our conception of physical, perceptual, and mathematical concepts, giving us new tools to comprehend the world."

Work of Stanley Osher (born 24th April 1942): Stanley Osher is known as a one-man bridge between advanced mathematics and real-world problems. He has been interacting deeply with engineers and industry and has developed mathematical techniques to solve their problems time and again. Osher's mathematical techniques have had unprecedented impact in a wide variety of practical problems. His work has helped catch criminals, create animation movies, improve MRI scans, design computer chips, and in many more things.

Stanley Osher's level set contributions have been extremely influential in computer vision, image processing, and computer graphics. These methods have also motivated some of the most basic studies in the theory of partial differential equations recently, thereby demonstrating a picture of applied mathematics inspiring pure mathematics. Osher created (along with Rudin) Cognitech, a company, to commercialize a mathematical technique to sharpen blurred images.

The most famous success of the company came during a trial after the 1992 Los Angeles riots. Rioters attacked a truck that happened to be driving through the area, throwing rocks at it, dragging the driver out of the cab, beating him to unconsciousness, and breaking his skull in 91 places. The entire attack was filmed by a TV helicopter. One of the attackers danced over the victim's unconscious body and flashed gang symbols to the helicopter. The footage was blurred; so, the prosecutors turned to Cognitech for help in identifying the attackers. Investigators focused on a speck on the arm of one of the men – which was less than (1/6,000)-th of the size of the total photograph – and the algorithms revealed it to be a rose-shaped tattoo.The man was later identified as Damian Monroe Williams, and he was convicted of the attack. Cognitech continues to be used by police departments across the United States. Osher continues to amaze the mathematics community with the invention of simple and clever schemes and gives us new tools to comprehend the world.

The 2014 Chern Medal

Phillip Griffiths, "for his groundbreaking and transformative development of transcendental methods in complex geometry, particularly his seminal work in Hodge theory and periods of algebraic varieties."

Work of Phillip Griffiths (born 18th October 1938): For more than five decades, Griffiths has been a world leader in mathematics research. He has also been an exceptional teacher and mentor for young mathematicians. His work in algebraic and differential geometry and in differential equations continues to influence and inspire a major amount of research even today. Griffiths's work has the striking aspect that while it often has a specific problem in view, it applies to several other situations and opens up entire areas of research.

Apart from his mathematical contributions, he has rendered invaluable service through his responsibilities of chairmanship of numerous international committees and boards. For twelve years, he served as the Director of the Institute for Advanced Study, Princeton. Griffiths currently chairs the Science Initiative Group, which assists the development of mathematical training centers in the developing world. His legacy of research and service to the science and mathematics community continues to be an inspiration to mathematicians all over the world.

The 2014 Leelavati Prize

Adrián Paenza, "for his decisive contribution in changing the mind of a whole country about the way that mathematics is perceived in daily life. He has accomplished this through his books, his TV programs, and his unique gift of enthusiasm and passion in communicating the beauty and joy of mathematics."

Work of Adrian Paenza (born 9th May 1949): Adrián Paenza hosts a weekly TV program '*Cientificos Industria Argentina*' (Scientists Made in Argentina) which is in its twelfth consecutive season. Each episode consists of interviews with mathematicians and scientists from very diverse disciplines; it usually ends with a mathematical problem, the solution of which is given in the next program.

Paenza has also been the host of a TV program '*Alterados por Pi*' (Altered by Pi), which is a weekly half-hour show dedicated to the popularization of mathematics. Each episode is recorded in front of a live audience in several public schools across Argentina. Since 2005, Paenza has written a weekly column about mathematics, on the back page of *Pagina 12*, one of Argentinas's three national newspapers. Usually, his articles contain historical notes, and brain teasers but occasionally, they contain even proofs of theorems.

A series of five books[1] dedicated to the popularization of mathematics which Paenza published, have sold over a million copies. The first of the series, published in September of 2005, headed the lists of bestsellers for 73 consecutive weeks. The extraordinary impact of these books has extended throughout Latin America and Spain. The books have been published also in Portugal, Italy, the Czech Republic, and Germany, and recently translated also into Chinese.

Some tidbits from ICM 2014:-

1. ICM 2014 was the first one when a woman won the Fields Medal.
2. This ICM also saw the first time that a mathematician of Indian origin being awarded the Fields Medal.
3. The Nevanlinna Prize has gone for the second time to an Indian; Madhu Sudan had won the Prize in 2002.
4. Ron Fedkiw, a student of Stanley Osher, won an Oscar award; he used mathematics to create special effects in dozens of movies, including *Pirates of the Caribbean*.

Acknowledgements

Thanks are due to the laudators of various ICM awardees for the descriptions of the works of awardees; this was useful in preparing the above announcement.

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[1] The five books are called *Matemática…¿estás ahí*? ("Math… are you there?), published by Siglo XXI Editores, 2010.

B Sury
Editor, *Resonance*