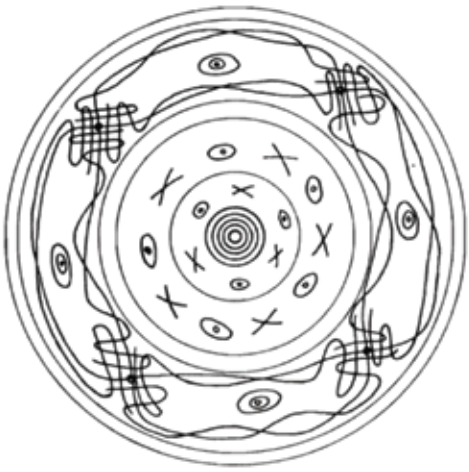
BRIN MATHEMATICS RESEARCH CENTER

HAMILTONIAN DYNAMICS AT MARYLAND

FEBRUARY 24 - 28, 2025

ABOUT THE WORKSHOP

At the crossroads of dynamics and mathematical physics, the study of Hamiltonian systems demands a deep exchange of ideas between many different areas of mathematics. Indeed, many of the recents advances in the field merge techniques coming from dynamics and nonlinear analysis, perturbation theory, symplectic geometry or probability. The benefit is reciprocal since, the intrinsic complexity of the dynamics exhibited by Hamiltonian systems, has led to the development of many powerful techniques which are now standard tools in dynamics, analysis and geometry. Our program aims to gather several experts in the field, providing them a unique opportunity to interact tackle longstanding questions and explore new emerging directions.



SPEAKERS

Dario Bambusi, Università Degli Studi di Milano
Massimiliano Berti, SISSA
Abed Bounemoura, UPPA
Jacopo De Simoi, University of Toronto
Benoit Grebert, Université de Nantes
Marcel Guardia, Universitat de Barcelona
Raphael Krikorian, École Polytechnique
Sergei Kuksin, Universite Paris-Diderot
Martin Leguil, École Polytechnique
Jessica Massetti, Università Roma Tor Vergata
Aleksei Okunev, Penn State University
Michela Procesi, Università di Roma Tre
Tere Seara, Universitat Politécnica de Catalunya
Alfonso Sorrentino, Università Roma Tor Vergata
Dmitry Turaev, Imperial College London
Amir Vig, University of Michigan
Ke Zhang, University of Toronto
Jing Zhou, Great Bay University

ORGANIZERS

Bassam Fayad, University of Maryland
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Jaime Paradela, University of Maryland

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DEPARTMENT OF MATHEMATICS

Contents

Schedule at a Glance

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11:00	Massetti	Lunch	Turaev	Bambusi	de Simoi
12:00	Grebert		Osterman	Berti	Zhang
13:00	Lunch	Seara	Lunch (on your own)	Lunch	
14:00					
15:00	Procesi	Krikorian		Guardia	
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17:00	Zhou	Leguil		Tsodikovich	
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Workshop Overview

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- Averaging theory and statistical properties of Hamiltonian Systems.
- Coexistence of hyperbolic and elliptic behavior in Hamiltonian Systems.
- KAM theory.
- Stability and Instability in Innite Dimensional Hamiltonian Systems (Growth of Sobolev norms, KAM theory for innite dimensional systems, Anderson Localization...)
- Perturbative techniques in Celestial Mechanics.
- Hamiltonian systems with noise.

Organizing committee

Bassam Fayad University of Maryland

Dima Dolgopyat University of Maryland

Vadim Kaloshin, IST, Austria

Jaime Paradela, University of Maryland

Workshop Schedule

Monday, February 24, 2025

8:30 - 8:50 Breakfast

8:50 - 9:00 Doron Levy (University of Maryland/Director, Brin MRC)
Opening

9:00 - 10:00 Sergei Kuksin (Universite Paris-Diderot)
Mixing in Nonlinear ODEs and PDEs with Random Forces: Non-Markov Case

10:00 - 10:30 Coffee Break

10:30 - 11:30 Jessica Massetti (Università Roma Tor Vergata)
On Linearization of Infinite Dimensional Vector Fields

12:00 - 1:00 Benoit Grebert (Université de Nantes)
Infinite Dimensional Invariant Tori for Nonlinear Schrodinger Equations

1:00 - 2:30 Lunch

2:30 - 3:30 Michela Procesi (Università di Roma Tre)
Asymptotically Full Measure Sets of Almost-Periodic Solutions for the NLS Equation

3:30 - 4:00 Coffee Break

4:00 - 5:00 Jing Zhou (Great Bay University)
Arnold Tongues in Standard Map with Drift

Tuesday, February 25, 2025

9:30 - 10:00	Breakfast
10:00 - 11:00	Aleksei Okunev (Penn State University) *Averaging and Passage Through Resonances in Two-Frequency Systems Near Separatrices*
11:00 - 1:15	Lunch
1:15 - 2:15	Tere Seara (Universitat Politécnica de Catalunya) *Analytic convex billiards are generically chaotic*
2:30 - 3:30	Raphael Krikorian (École polytechnique) *Exotic Rotation Domains and Herman Rings for Quadratic Hénon Maps*
3:30 - 4:00	Coffee Break
4:00 - 5:00	Martin Leguil (École polytechnique) *Rigidity of Transitive Anosov Flows in Dimension 3*
7:00 - 9:00	Conference Dinner

Wednesday, February 26, 2025

8:30 - 9:00 Breakfast

9:00 - 10:00 Jaime Paradela (University of Maryland)
KAM stability for large n-body problems

10:00 - 10:30 Coffee Break

10:30 - 11:30 Dmitry Turaev (Imperial College London)
Universal Dynamics Near Whiskered Tori

12:00 - 1:00 Vaughn Osterman (University of Maryland)
Stable Motions in the Planar Circular Restricted 3-Body Problem

1:00 - 2:30 Lunch (on your own)

1:00 - 1:10 Group Photo

Thursday, February 27, 2025

8:30 - 9:00	Breakfast
9:00 - 10:00	Abed Bounemoura (UPPA) *Rigidity near an Invariant Diophantine Torus*
10:00 - 10:30	Coffee Break
10:30 - 11:30	DARIO BAMBUSI (Università degli studi di Milano) *Non Relativistic Limit of Quasiperiodic Solutions of the Klein Gordon Equation*
12:00 - 1:00	Massimiliano Berti (Scuola Internazionale Superiore di Studi Avanzati) *Unstable Stokes Waves*
1:00 - 2:30	Lunch
2:30 - 3:30	Marcel Guardia (Universitat de Barcelona) *Diffusive Behavior Along Mean Motion Resonances in the 3 Body Problem*
3:30 - 4:00	Coffee Break
4:00 - 5:00	Daniel Tsodikovich (IST Austria) *Local Rigidity of Integrable Symplectic Billiards*

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8:30 - 9:00 Breakfast

9:00 - 10:00 Amir Vig (University of Michigan)
Cancellations in the Wave Trace

10:00 - 10:30 Coffee Break

10:30 - 11:30 Jacopo de Simoi (University of Toronto)
Local Marked Spectral Determination for $\mathbb{Z}_2$-Symmetric Planar Billiards Close to the Disk (for now)

12:00 - 1:00 Ke Zhang (University of Toronto)
Generic Global Diffusion for Analytic Uncoupled a Priori Unstable Systems

1:00 - 1:05 Workshop Closing

Abstracts of talks

Mixing in Nonlinear ODEs and PDEs with Random Forces: Non-Markov Case

Sergei Kuksin

Universite Paris-Diderot

Monday, February 24, 2025 @ 9:00 AM

I will discuss long-time behaviour of dynamical systems in finite- and infinite-dimensional spaces with stationary random forces, and present recent results of A.Shirikyan and myself on the mixing for such systems. The novelty of our work is that we do not assume that the values of the random forces in different instants of time are independent. Accordingly, the random dynamics, defined by these systems, is not Markovian. Apart from applications to ODEs and PDEs with random inputs, out results apply to the general theory of stationary stochastic processes and allow to get for them results, related to the Dobrushin theorems on reconstructing stationary processes by their conditional distributions.

On Linearization of Infinite Dimensional Vector Fields

Jessica Massetti

Università Roma Tor Vergata

Monday, February 24, 2025 @ 10:30 AM

Given an infinite dimensional vector field $X = \lambda_j x_j(\partial/\partial x^j)$ with $j \in \mathbf{Z}$, $\lambda_j \in \mathbf{C}$, where the frequencies λ_j may satisfy infinitely many resonant relations, we discuss the linearization of holomorphic perturbations $Y = X + P$ and show that Y can be put in some appropriate normal form such that, when restricted to the resonant manifold, the flow is linear with the same characteristic exponents λ_j. This is a joint work with M. Procesi and L. Stolovitch.

Infinite Dimensional Invariant Tori for Nonlinear Schrodinger Equations

Benoit Grebert

Université de Nantes

Monday, February 24, 2025 @ 12:00 PM

We prove that nonlinear Schro?dinger equations on the circle, without external parameters, admits plenty of almost periodic solutions. Indeed we prove that arbitrarily close to most of the finite dimensional KAM tori constructed by Kuksin–Poschel in 1996 there exist infinite dimensional non resonant Kronecker tori, i.e. rotational invariant tori. This result answers a natural question well identified by the Hamiltonian PDE community since the first KAM-type result for PDEs by Kuksin in a 1987. In collaboration with Joackim Bernier and Tristan Robert.

Asymptotically Full Measure Sets of Almost-Periodic Solutions for the NLS Equation

Michela Procesi

Università di Roma Tre

Monday, February 24, 2025 @ 2:30 PM

In the study of close to integrable Hamiltonian PDEs, a fundamental question is to understand the behaviour of "typical" solutions. With this in mind it is natural to study the persistence of almost-periodic solutions and infinite dimensional invariant tori, which are in fact typical in the integrable case. In this talk I shall consider a family of NLS equations parametrized by a smooth convolution potential and prove that for "most" choices of the parameter there is a positive measure set of Gevrey initial data that give rise to almost-periodic solutions whose hulls are invariant tori. As a consequence the elliptic fixed point at the origin turns out to be statistically stable in the sense of Lyapunov. This is a joint work with L.Biasco, L. Corsi and G.Gentile.

Arnold Tongues in Standard Map with Drift

Jing Zhou

Great Bay University

Monday, February 24, 2025 @ 4:00 PM

In the early 60's J. B. Keller and D. Levy discovered a fundamental property: the instability tongues in Mathieu-type equations lose sharpness with the addition of higher-frequency harmonics in the Mathieu potentials. Twenty years later, V. Arnold discovered a similar phenomenon on the sharpness of Arnold tongues in circle maps (and rediscovered the result of Keller and Levy). In this paper we find a third class of object where a similar type of behavior takes place: area-preserving maps of the cylinder. Loosely speaking, we show that periodic orbits of standard maps are extra fragile with respect to added drift (i.e. non-exactness) if the potential of the map is a trigonometric polynomial. That is, higher-frequencyharmonicsmake periodic orbits more robust with respect to "drift". This observation was motivated by the study of traveling waves in the discretized sine-Gordon equation which in turn models a wide variety of physical systems. We will also discuss the implications of these results to Aubry-Mather theory and quantum chaos, and propose open problems therein. This is joint work (in progress) with Mark Levi.

Averaging and Passage Through Resonances in Two-Frequency Systems Near Separatrices

Aleksei Okunev

Penn State University

Tuesday, February 25, 2025 @ 10:00 AM

The averaging method is a powerful tool used in perturbation theory. There are two major obstacles to applying the averaging method, resonances and separatrices. We study the averaging method for the simplest situation where both these obstacles are present at the same time, time-periodic perturbations of one-frequency Hamiltonian systems with separatrices. The Hamiltonian depends on a parameter that slowly changes for the perturbed system (so slow-fast Hamiltonian systems with two and a half degrees of freedom are included in our class). We obtain realistic estimates on the accuracy of the averaging method for most initial data. The main novelty of our setting is that so called strong resonances (i.e., resonances such that capture into resonance is possible) accumulate on the separatrices, so there are infinitely many strong resonances. This is joint work with Anatoly Neishtadt.

Analytic convex billiards are generically chaotic

Tere Seara

Universitat Politécnica de Catalunya

Tuesday, February 25, 2025 @ 1:15 PM

In this talk we study chaotic dynamics generated by analytic convex billiards.
We consider the set S of analytic billiards with negative curvature satisfying the following property: for any rational rotation number, there exists a hyperbolic periodic orbit whose stable and unstable manifolds intersect tansversally along a homolinic orbit.
And we prove that the set S is residual among analytic billiards with negative curvature with the ususal analytic topology. This result is a consequence of the Baire property and the main result of this work, which reads: Fixing a rational rotation number p/q, we can prove that the set of analytic billiards with negative curvature having a hyperbolic periodic orbit of rotation umber p/q whose stable and unstable manifolds intersect tansversally along a homolinic orbit, is open and dense.
As a consequence of our results, we have that chaotic billiards are dense among analytic biliards.
Our proof combines Aubrey-Mather theory to study periodic orbits of any rotation number as well as their heteroclinic trajectoris, with the work by Zehnder on planar twist maps with ellipric points in the 1970's, which provides a methodology for constructing analytic perturbations of maps in order to obtain transversality between the invariant manifolds of hyperbolic periodic orbits.

Exotic Rotation Domains and Herman Rings for Quadratic Hénon Maps

Raphael Krikorian

École polytechnique

Tuesday, February 25, 2025 @ 2:30 PM

Quadratic Hénon maps are polynomial automorphism of $\mathbb{C}^2$ of the form $h : (x, y) \mapsto (\lambda^{1/2}(x^2 + c) - \lambda y, x)$. They have constant Jacobian equal to λ and they admit two fixed points. If λ is on the unit circle (one says the map h is conservative) these fixed points can be elliptic or hyperbolic. In the elliptic case, a simple application of Siegel Theorem shows (under a Diophantine assumption) that h admits an open set of quasi-periodic orbits with two frequencies in the neighborhood of its fixed points. Fundamental results by Bedford-Smillie and Barrett-Bedford-Dadok suggest that there could exist more general « Rotation domains », i.e. open sets filled with quasi-periodic motions, but without fixed points (the rotation domains are then said to be « exotic »). In some hyperbolic cases, Shigehiro Ushiki observed numerically some years ago, what seems to be such « Exotic rotation domains » (quasi-periodic orbits though no Siegel disks exist). I will give a proof of the existence of such ERDs and provide a mathematical explanation for S. Ushiki's discovery. In the dissipative case (λ of module less than 1), the same theoretical framework, predicts, and provides a proof of, the existence of (attracting) Herman rings. These Herman rings, which were not observed before, can be systematically produced in numerical experiments.

Rigidity of Transitive Anosov Flows in Dimension 3

Martin Leguil

École polytechnique

Tuesday, February 25, 2025 @ 4:00 PM

In a joint work with Andrey Gogolev and Federico Rodriguez Hertz, we study when two transitive Anosov flows X,Y in dimension 3 which are topologically conjugated are actually smoothly conjugated. By the work of de la Llave, Marco, Moriyón and Pollicott from the late 80s, a necessary and sufficient condition for that to happen is that stable and unstable eigenvalues at corresponding periodic points match. In our work we show that for generic transitive Anosov flows X,Y in dimension 3, the latter condition is already implied by the existence of a topological conjugacy; in particular, the conjugacy is smooth, unless the conjugacy swaps positive and negative SRB measures of the two flows. This complements a recent work of Gogolev and Rodriguez Hertz in the volume preserving case. I will try to explain how this rigidity problem is connected with other notions, in particular, the so-called templates introduced by Tsujii and Zhang to study the regularity of stable and unstable distributions, and a positive proportion Livschits Theorem recently shown by Dilsavor and Marshall Reber.

KAM stability for large n-body problems

Jaime Paradela

University of Maryland

Wednesday, February 26, 2025 @ 9:00 AM

In a joint work with Dima Dolgopyat and Bassam Fayad, we develop an abstract infinite-dimensional KAM theorem which can accommodate long-range all to all interactions. The main application of the abstract theorem is the construction of real analytic infinite (full) dimensional KAM tori in mechanical systems of infinitely many particles under mild genericity assumptions on the interaction potential. Our proof introduces a new functional setting that extends previous ideas of Peschel and on the construction of a suitable set of infinite dimensional Diophantine frequencies, both adapted to the all to all interactions framework. Unlike previous works, the vector field affecting each particle does not decay with the particle's index. The set of initial conditions that give rise to full dimensional KAM tori is *as large as possible* under the requirement of avoiding the resonances in this long range all to all interaction problem.

Universal Dynamics Near Whiskered Tori

Dmitry Turaev

Imperial College London

Wednesday, February 26, 2025 @ 10:30 AM

We show that Cr-generic (r=1, ..., omega) dynamics of a 4-dimensional symplectic map with a homoclinic to a whiskered torus are 2-universal: the iterations of a Cr-generic map Cr-approximate, in the projection to the center subspace, all possible sequences of symplectic maps of a 2-dimensional disc.

Stable Motions in the Planar Circular Restricted 3-Body Problem

Vaughn Osterman

University of Maryland

Wednesday, February 26, 2025 @ 12:00 PM

We consider the planar circular restricted three-body problem, modeling the motion of a massless asteroid in the plane undergoing gravitational attraction toward two bodies, each of which moves in a circular path around their common center of mass. For small mass ratios, the motion of the asteroid is approximated by the Kepler problem when the asteroid is far from a collision. In this case, a large set of Kepler motions in which the paths of the asteroid and the smaller body do not intersect persist as quasi-periodic motions in the perturbed system. However, these quasi-periodic motions with incommensurable frequencies are not possible for Kepler motions in which the paths intersect due to the potential for close interactions between the asteroid and the smaller body. The existence of hyperbolic sets in which the asteroid repeatedly comes close to a collision was proven independently by Bolotin and MacKay and by Font, Nunes, and Simu. My result, currently in preparation, is that there also exists stable motions of the asteroid near resonant Kepler orbits in which the asteroid repeatedly undergoes close interactions with the smaller body.

Rigidity near an Invariant Diophantine Torus

Abed Bounemoura

UPPA

Thursday, February 27, 2025 @ 9:00 AM

We will discuss some questions on the rigidity near an invariant Diophantine torus for a Hamiltonian system.

Non Relativistic Limit of Quasiperiodic Solutions of the Klein Gordon Equation

DARIO BAMBUSI

Università degli studi di Milano

Thursday, February 27, 2025 @ 10:30 AM

It is well known that solutions of the Nonlinear Klein Gordon equation

$$\frac{1}{c^2}u_{tt} - u_{xx} + c^2 u \pm u^3 = 0 \ , \quad u(0,t) = u(\pi,t) = 0$$

are well approximated in the non relatistic limit ($c \to \infty$) by solutions of the cubic Nonlinear Schrödinger equation. In the present talk I will present a result based on KAM theory, according to which the quasiperiodic solutions of NLKG constructed thorugh KAM theory converge *uniformly for* $t \in \mathbb{R}$ to solutions of NLS. I will start the presentation by recalling some classical results on the justification of the NLS as the classical limit of NLKG, then I will give a precise statement of the result and the main ideas of the proof. Joint work with Andrea Belloni and Filippo Giuliani.

Unstable Stokes Waves

Massimiliano Berti

Scuola Internazionale Superiore di Studi Avanzati

Thursday, February 27, 2025 @ 12:00 PM

In this talk I will review results achieved in the last years concerning the problem of determining the stability/instability of Stokes waves, i.e. periodic traveling solutions of the pure gravity water waves equations in an ocean of depth, subject to longitudinal perturbations.

Diffusive Behavior Along Mean Motion Resonances in the 3 Body Problem

Marcel Guardia

Universitat de Barcelona

Thursday, February 27, 2025 @ 2:30 PM

Consider the Restricted Planar Elliptic Three Body Problem. This problem models the Sun-Jupiter-Asteroid dynamics. For eccentricity of Jupiter e_0 small enough, we show that there exists a family of probability measures supported at the $3:1$ mean motion resonance such that the push forward under the associated Hamiltonian flow has the following property. At the timescale te_0^{-2}, the distribution of the Jacobi constant of the Asteroid weakly converges to an Ito diffusion process on the line as $e_0 \to 0$. This resonance corresponds to the biggest of the Kirkwood gap on the Asteroid belt in the Solar System. This is a joint work with V. Kaloshin, P. Martin and P. Roldan.

Local Rigidity of Integrable Symplectic Billiards

Daniel Tsodikovich

IST Austria

Thursday, February 27, 2025 @ 4:00 PM

Symplectic billiards were introduced by Albers and Tabachnikov as an alternative billiard model where the generating function is the area form. The resulting system behaves somewhat differently from the usual billiards, but as it turns out, several rigidity results for billiards have been recently adapted to this setting. In this talk, we explain that the integrability of ellipses is locally rigid: an integrable domain near an ellipse is an ellipse. This is an adaptation of the result of Avila, De Simoi, and Kaloshin, for Birkhoff billiards.

Cancellations in the Wave Trace

Amir Vig

University of Michigan

Friday, February 28, 2025 @ 9:00 AM

In 1966, Mark Kac posed the famous question "Can you hear the shape of a drum?" Mathematically, this amounts to recovering the geometry of a Riemannian manifold from knowledge of its Laplace spectrum. In the case of strictly convex and smooth bounded planar domains, the problem is very much open. One technique for studying the inverse spectral problem is via the wave trace, a distribution with singular support contained in the length spectrum. The length spectrum is the collection of lengths of closed geodesics, which for planar domains are just periodic billiard orbits. A dual object to study is the resolvent (of the Laplacian), whose trace asymptotics are related via the Paley-Wiener theorem to singularities of the wave trace. In this talk, I will describe joint work with Vadim Kaloshin and Illya Koval in which we introduce the Balian-Bloch-Zelditch method of constructing a parametrix for the resolvent trace via layer potentials. The result is an oscillatory integral to which one can apply the method of stationary phase. A novel feature is the organization of stationary phase coefficients in terms of graph theory and Feynman diagrams. The resulting formulae can be used to match Maslov indices of orbits, producing cancellations in the wave trace, which comes close to showing that the length spectrum and the Laplace spectrum are inherently distinct objects, at least insofar as the wave trace is concerned. I will also discuss applications of these formulae to the remainder term in Weyl's law.

Local Marked Spectral Determination for $\mathbb{Z}_2$-Symmetric Planar Billiards Close to the Disk (for now)

Jacopo de Simoi

University of Toronto

Friday, February 28, 2025 @ 10:30 AM

Given a planar domain with sufficiently regular boundary, one can study periodic orbits of the associated billiard problem. Periodic orbits possess a rich and intricate structure: it is then natural to ask how much information about the domain is encoded in the set of lengths of such orbits. The quantum analog of this question is the celebrated Laplace inverse problem, or "Can one hear the shape of a drum?" We prove Marked Dynamical Spectral Determination among $\mathbb{Z}_2$-symmetric smooth convex domains close to the disk: if any two such domains have the same Marked Length Spectrum, they must necessarily be isometric domains. This substantially improves the deformational result obtained in a prior work with Kaloshin and Wei.

Generic Global Diffusion for Analytic Uncoupled a Priori Unstable Systems

Ke Zhang

University of Toronto

Friday, February 28, 2025 @ 12:00 PM

We show that a generic Mane perturbation to an an uncoupled, priori unstable, real analytic Hamiltonian system admits diffusion orbits over a prescribed range of action variable. The unperturbed Hamiltonian is an uncoupled product of a pendulum like system and rotator, similar to Arnold's original example. While the general question of analytic Arnold diffusion remains difficult, we show that in the uncoupled case, the geometric approach to Arnold diffusion applies. This is a joint work with Amadeu Delshams.

The Brin Mathematics Research Center

The Brin Mathematics Research Center is a research center that sponsors activity in all areas of pure and applied mathematics and statistics. The Brin MRC was funded in 2022 through a generous gift from the Brin Family. The Brin MRC is part of the Department of Mathematics at the University of Maryland, College Park.

Activities sponsored by the Brin MRC include long programs, conferences and workshops, special lecture series, and summer schools. The Brin MRC provides ample opportunities for short-term and long-term visitors that are interested in interacting with the faculty at the University of Maryland and in experiencing the metropolitan Washington DC area.

The mission of the Brin MRC is to promote excellence in mathematical sciences. The Brin MRC is home to educational and research activities in all areas of mathematics. The Brin MRC provides opportunities to the global mathematical community to interact with researchers at the University of Maryland. The center allows the University of Maryland to expand and showcase its mathematics and statistics research excellence nationally and internationally.

List of Participants

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