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PI/PD Name: Dan Romik

Gender: Male Female

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(Select one or more)

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 Asian
 Black or African American
 Native Hawaiian or Other Pacific Islander
 White

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 Visual Impairment
 Mobility/Orthopedic Impairment
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Pecase Eligibility: N

REQUIRED: Check here if you are currently serving (or have previously served) as a PI, co-PI or PD on any federally funded project

Ethnicity Definition:

Hispanic or Latino. A person of Mexican, Puerto Rican, Cuban, South or Central American, or other Spanish culture or origin, regardless of race.

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American Indian or Alaska Native. A person having origins in any of the original peoples of North and South America (including Central America), and who maintains tribal affiliation or community attachment.

Asian. A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.

Black or African American. A person having origins in any of the black racial groups of Africa.

Native Hawaiian or Other Pacific Islander. A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.

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WHY THIS INFORMATION IS BEING REQUESTED:

The Federal Government has a continuing commitment to monitor the operation of its review and award processes to identify and address any inequities based on gender, race, ethnicity, or disability of its proposed PIs/PDs. To gather information needed for this important task, the proposer should submit a single copy of this form for each identified PI/PD with each proposal. Submission of the requested information is voluntary and will not affect the organization's eligibility for an award. However, information not submitted will seriously undermine the statistical validity, and therefore the usefulness, of information received from others. Any individual not wishing to submit some or all the information should check the box provided for this purpose. (The exceptions are the PI/PD name and the information about prior Federal support, the last question above.)

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COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 09-29					FOR NSF USE ONLY	
NSF 08-557			07/23/09		NSF PROPOSAL NUMBER	
FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)					0955584	
DMS - PROBABILITY, DMS - ALGEBRA, NUMBER THEORY, AND COM						
DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION	
07/23/2009	2	03040000 DMS	1263	047120084	07/01/2010 2:54pm S	
EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)		SHOW PREVIOUS AWARD NO. IF THIS IS <input type="checkbox"/> A RENEWAL <input type="checkbox"/> AN ACCOMPLISHMENT-BASED RENEWAL		IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES <input type="checkbox"/> NO <input checked="" type="checkbox"/> IF YES, LIST ACRONYM(S)		
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University of California-Davis			OR/Sponsored Programs 1850 Research Park Dr., Ste 300 Davis, CA 95618-0000			
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TITLE OF PROPOSED PROJECT CAREER: Combinatorial probability, limit shapes and enumeration						
REQUESTED AMOUNT \$ 520,324		PROPOSED DURATION (1-60 MONTHS) 60 months		REQUESTED STARTING DATE 07/01/10		SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW						
<input type="checkbox"/> BEGINNING INVESTIGATOR (GPG I.G.2) <input type="checkbox"/> HUMAN SUBJECTS (GPG II.D.7) Human Subjects Assurance Number _____ Exemption Subsection _____ or IRB App. Date _____ <input type="checkbox"/> DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e) <input type="checkbox"/> PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d) <input type="checkbox"/> INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j) <input type="checkbox"/> HISTORIC PLACES (GPG II.C.2.j) <input type="checkbox"/> EAGER* (GPG II.D.2) <input type="checkbox"/> RAPID** (GPG II.D.1) <input type="checkbox"/> VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date _____ PHS Animal Welfare Assurance Number _____ <input type="checkbox"/> HIGH RESOLUTION GRAPHICS/OTHER GRAPHICS WHERE EXACT COLOR REPRESENTATION IS REQUIRED FOR PROPER INTERPRETATION (GPG I.G.1)						
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CO-PI/PD						
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CERTIFICATION PAGE

Certification for Authorized Organizational Representative or Individual Applicant:

By signing and submitting this proposal, the Authorized Organizational Representative or Individual Applicant is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding debarment and suspension, drug-free workplace, and lobbying activities (see below), nondiscrimination, and flood hazard insurance (when applicable) as set forth in the NSF Proposal & Award Policies & Procedures Guide, Part I: the Grant Proposal Guide (GPG) (NSF 09-29). Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U. S. Code, Title 18, Section 1001).

Conflict of Interest Certification

In addition, if the applicant institution employs more than fifty persons, by electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative of the applicant institution is certifying that the institution has implemented a written and enforced conflict of interest policy that is consistent with the provisions of the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.A; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the institution's conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

Drug Free Work Place Certification

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Grant Proposal Guide.

Debarment and Suspension Certification

(If answer "yes", please provide explanation.)

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency?

Yes

No

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Debarment and Suspension Certification contained in Exhibit II-4 of the Grant Proposal Guide.

Certification Regarding Lobbying

The following certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding \$100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding \$150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:

- (1) No federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.
- (2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, "Disclosure of Lobbying Activities," in accordance with its instructions.
- (3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than \$10,000 and not more than \$100,000 for each such failure.

Certification Regarding Nondiscrimination

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative is providing the Certification Regarding Nondiscrimination contained in Exhibit II-6 of the Grant Proposal Guide.

Certification Regarding Flood Hazard Insurance

Two sections of the National Flood Insurance Act of 1968 (42 USC §4012a and §4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the:

- (1) community in which that area is located participates in the national flood insurance program; and
- (2) building (and any related equipment) is covered by adequate flood insurance.

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant located in FEMA-designated special flood hazard areas is certifying that adequate flood insurance has been or will be obtained in the following situations:

- (1) for NSF grants for the construction of a building or facility, regardless of the dollar amount of the grant; and
- (2) for other NSF Grants when more than \$25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE		SIGNATURE	DATE
NAME Suzanne E Oliver		Electronic Signature	Jul 23 2009 1:19PM
TELEPHONE NUMBER 530-754-8036	ELECTRONIC MAIL ADDRESS suzoliver@ucdavis.edu	FAX NUMBER 530-854-8229	

* EAGER - EARly-concept Grants for Exploratory Research

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CAREER ELIGIBILITY CERTIFICATIONS

A. CAREER ELIGIBILITY CERTIFICATION

To be eligible for a CAREER award, you must meet the CAREER eligibility requirements as defined in the CAREER Program Solicitation (also refer to the CAREER FAQ for further explanations). To certify your eligibility, complete each section of the CAREER checklist below. The CAREER Eligibility Certification checklist will be included as part of the proposal and will be sent to reviewers.

I certify that by the relevant July deadline for submission of CAREER proposals, I will have met all of the following criteria.

- I will hold a doctoral degree in a field of science or engineering supported by NSF
- I will be untenured
- I will not have received an NSF PECASE or CAREER award
- I will not have competed more than two times in previous NSF CAREER Program Competitions

I certify that by October 1st following the relevant July deadline for submission of CAREER proposals I will

- be employed in a tenure-track position
- OR**
- be employed in a tenure-track equivalent position

- hold the title of assistant professor
- OR**
- hold a title that is equivalent to assistant professor

- be employed at an institution in the U.S., its territories, or possessions, or the Commonwealth of Puerto Rico that awards degrees in a field of science or engineering supported by NSF
- OR**
- be employed at an institution in the U.S., its territories, or possessions, or the Commonwealth of Puerto Rico that is a non-profit, non-degree granting institution such as a museum, observatory, or research lab

CAREER: Combinatorial probability, limit shapes and enumeration

Project Summary

The PI proposes a 5-year integrated research and education project, focusing on the study of discrete combinatorial objects in a probabilistic setting, and primarily two-dimensional lattice models appearing in algebraic combinatorics and in statistical physics. Examples of such models include: Young tableaux, plane partitions, alternating sign matrices, domino tilings, and the square ice model. These models have been under intense study in recent years due to their beautiful structure and their multidisciplinary nature exhibiting fascinating and often unexpected connections to different fields such as combinatorics, random matrix theory, statistical physics and representation theory. The PI has himself made significant contributions to these fields in previous work and believes there is an extraordinary opportunity for making additional important discoveries in these areas. Furthermore, the multidisciplinary nature and inherent elegance of the proposed topics makes them suitable for inclusion in an educational effort to bring beautiful mathematical ideas to a wider audience of students and active research mathematicians in other fields.

One part of the project which the PI believes has considerable intellectual merit will involve the study of “limit shapes” of random combinatorial objects. Many of the objects considered can be viewed as discrete random surfaces which can be embedded in a space of continuous surfaces. The question of the limit shape involves determining the asymptotic behavior of the typical (randomly chosen) element in the combinatorial class of objects as a natural size parameter tends to infinity. Limit shapes are a central subject of study for these kinds of models. Related results have been obtained by Vershik-Kerov, Logan-Shepp, Cerf-Kenyon, Kenyon-Okounkov-Sheffield, Jockusch-Propp-Shor and other authors including the PI and his collaborators. Some of the methods may also be applicable to obtaining finer results on the fluctuations of the random object from its limit shape.

Another aspect of the intellectual merit of the project lies in its additional focus on questions related to the enumeration of various classes of combinatorial objects. Such questions arise naturally in the study of random combinatorial models but often are of considerable independent interest. In many cases, striking exact enumeration formulas appear, and this is often a telltale sign of a deep algebraic or combinatorial structure that makes these models worthy of special study. The PI believes that enumeration questions have a natural place alongside the study of probabilistic behavior of random combinatorial objects, since the same techniques are applicable to both kinds, and since the deep structures uncovered in the study of enumeration questions are often also reflected in especially interesting limiting behavior of the corresponding random model.

The activities described in the proposal are likely to have broader impacts on the mathematical community of researchers and students and beyond it. In addition to fostering future researchers through mentorship of graduate students and post-doctoral fellows, the PI plans to actively involve undergraduate students in research activities and in the creation of new knowledge. This will be achieved in part using computer software that the PI has developed, and plans to continue to develop, for the visualization of complex mathematical ideas in the fields of the proposal. On a broader level, the PI plans to bring knowledge of the field of probabilistic combinatorics to a wider audience of students and research mathematicians active in other fields by writing a textbook that will solidify the knowledge in the field, much of which is currently only accessible to experts through technical research articles.

TABLE OF CONTENTS

For font size and page formatting specifications, see GPG section II.B.2.

	Total No. of Pages	Page No.* (Optional)*
Cover Sheet for Proposal to the National Science Foundation		
Project Summary (not to exceed 1 page)	1	_____
Table of Contents	1	_____
Project Description (Including Results from Prior NSF Support) (not to exceed 15 pages) (Exceed only if allowed by a specific program announcement/solicitation or if approved in advance by the appropriate NSF Assistant Director or designee)	15	_____
References Cited	3	_____
Biographical Sketches (Not to exceed 2 pages each)	2	_____
Budget (Plus up to 3 pages of budget justification)	7	_____
Current and Pending Support	2	_____
Facilities, Equipment and Other Resources	1	_____
Special Information/Other Supplementary Docs/Mentoring Plan	2	_____
Appendix (List below.) (Include only if allowed by a specific program announcement/ solicitation or if approved in advance by the appropriate NSF Assistant Director or designee)	_____	_____
Appendix Items:		

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

Project Description

1 The proposed research

1.1 Background

This proposal deals with two-dimensional lattice models, which are combinatorial classes of objects defined over a two-dimensional lattice (finite or infinite) and equipped with a probability measure arising naturally from the combinatorics of the model, for example the uniform measure on a finite set or some limit of such measures. Some well-known examples of such models are domino tilings (the dimer model on a square lattice), Young tableaux, plane partitions, and alternating sign matrices. Over the last few decades, much attention has been given to these models, and in fact, there has been a convergence of interest in them from several fields such as probability, statistical physics, algebraic and enumerative combinatorics, and representation theory, resulting in many fascinating and often surprising connections being discovered between these fields. A particularly exciting development has been the discovery, through the works of Baik-Deift-Johansson [12] and others, that some of these models exhibit behavior that was previously thought to belong more properly to classical objects of “continuous” or non-combinatorial probability, namely random matrices. Such deep connections are continuing to be studied extensively and have produced a veritable gold-mine of beautiful research developments which are of interest to a large community of mathematicians and mathematical physicists.

Much of my own research in the last few years has been along the same lines, resulting in what I believe are some significant contributions by myself and co-authors. A main focus of my efforts has been the study of random Young tableaux. This resulted in a sequence of publications [2, 3, 8, 7, 9, 10, 11] exploring their behavior in depth, and finding beautiful connections between random Young tableaux and random permutations, sorting networks, plane partitions, random matrices and, recently, domino tilings and alternating sign matrices.

I will now describe two particular aspects of the above-mentioned combinatorial models, which I feel are especially worthy of study and which my past work has dealt with successfully through the development of new techniques which may also be applicable in future settings. These are *limit shapes* and *enumeration*. I should emphasize that these two aspects are by no means the only interesting ones worth considering, and in my proposed research I will very likely consider other aspects as well; however, I find it convenient to loosely categorize these two aspects as the main proposed avenues of research.

Limit shapes

Many classes of combinatorial objects can be viewed as discrete versions of continuous geometric objects, and in such cases one can embed the discrete objects in a space of such

continuous objects. In the case of two-dimensional objects, the continuous objects are typically surfaces, and therefore the random combinatorial objects under discussion can be viewed as *discrete random surfaces*. It is then natural to ask about the asymptotic behavior of these discrete random surfaces as the size parameter tends to infinity. The question of the limit shape concerns these asymptotics on the large-scale or *macroscopic* level. In other words, one is interested in the shape of the surface when “viewed from afar”. In many cases, the shape of the surface of the typical random element approaches a continuous limit. In such a case we say the model has a “limit shape”.

Examples. Many limit shape results are known. Here are some examples, including a few from my own research.

- **Uniformly random partitions (Szalay-Turán [32], Vershik [33]).** If $\lambda_n = (\lambda_n(1), \lambda_n(2), \lambda_n(3), \dots)$ is a uniformly random partition of an integer n , then the graph of the partition converges to the limit shape described by the curve

$$e^{-cx} + e^{-cy} = 1, \quad (c = \pi/\sqrt{6}).$$

- **Plancherel-random partitions (Logan-Shepp [25], Vershik-Kerov [34, 35]).** If λ_n is a random partition of n chosen according to Plancherel measure (the push-forward under the Robinson-Schensted correspondence of the uniform measure on permutations of order n), then its limit shape is given in the “Russian” (u, v) -coordinate system (in which the principal axes are rotated by 45 degrees) by the curve

$$v = \Omega(u) = \frac{\sqrt{2}}{\pi} \left(\sqrt{2 - u^2} + u \arcsin \left(\frac{u}{\sqrt{2}} \right) \right), \quad (|u| \leq \sqrt{2}).$$

See Figure 4.

- **The corner growth model (Rost [27]).** If λ_n is a random partition of n “grown” randomly by starting from an empty Young diagram and successively adding square boxes, each time choosing uniformly where to add the box from all available places, then λ_n has the limit shape described by the curve

$$\sqrt{x} + \sqrt{y} = 6^{1/4}.$$

- **Random square Young tableaux (Pittel-Romik [7]).** If $T_n = (t_{i,j})_{i,j=1}^n$ is a uniformly random square Young tableau of order n , then T_n has a limit shape, shown in Figure 2. Its level set $\{L = \alpha\}$ is given¹ in Russian (u, v) -coordinates by the curve

$$v = \frac{2}{\pi} u \tan^{-1} \left(\frac{(1 - 2\alpha)u}{\sqrt{2\alpha(1 - \alpha) - u^2}} \right) + \frac{\sqrt{2}}{\pi} \tan^{-1} \left(\frac{\sqrt{2(2\alpha(1 - \alpha) - u^2)}}{1 - 2\alpha} \right),$$

$$|u| \leq \sqrt{2\alpha(1 - \alpha)}.$$

¹for $\alpha < 1/2$, which by symmetry is enough.

- **Random Extremal Erdős-Szekeres permutations (Romik [10]).** If π_n is a random permutation of order n^2 chosen uniformly at random from the set of Extremal Erdős-Szekeres permutations (permutations whose shortest monotone subsequence is of length n , the minimum guaranteed to exist by the Erdős-Szekeres theorem), then the graph of π_n has the limit shape described by the quartic algebraic curve

$$(x^2 - y^2)^2 + 2(x^2 + y^2) = 3,$$

as shown in Figure 3. This is proved using the limit shape result for random square Young tableaux mentioned above.

- **Uniformly random plane partitions (Cerf-Kenyon [14]).** The shape of a uniformly random plane partition of n converges as $n \rightarrow \infty$ to the limiting surface

$$\left\{ c \cdot \left(f(A, B, C) - \log A, f(A, B, C) - \log B, f(A, B, C) - \log C \right) : A, B, C > 0 \right\},$$

where $c = (\zeta(3)/4)^{-1/3}$ and the function f is given by

$$f(A, B, C) = \frac{1}{4\pi^2} \int_0^{2\pi} \int_0^{2\pi} \log(A + Be^{iu} + Ce^{iv}) \, du \, dv, \quad (A, B, C > 0).$$

- **Random domino tilings of the Aztec diamond (Cohn-Elkies-Propp [15]).** The limiting height function of a uniformly random domino tiling of the Aztec diamond (Fig. 1) is given by the function

$$\mathcal{H}(x, y) = 2 \left(y\mathcal{P}(x, y) - y\mathcal{P}(-x, -y) + (1-x)\mathcal{P}(-y, x) + (1+x)\mathcal{P}(y, -x) \right),$$

where

$$\mathcal{P}(x, y) = \begin{cases} 0 & x^2 + y^2 \geq \frac{1}{2} \text{ and } y < \frac{1}{2}, \\ \frac{1}{2} + \frac{1}{\pi} \tan^{-1} \left(\frac{2y-1}{\sqrt{1-2x^2-2y^2}} \right) & x^2 + y^2 < \frac{1}{2}, \\ 1 & x^2 + y^2 \geq \frac{1}{2} \text{ and } y > \frac{1}{2}. \end{cases}$$

A new proof of this fact [11] relates this result in a surprising way to the limit shape result for random square Young tableaux mentioned above, by showing that the two results are equivalent. See pages 9–10 for more discussion of this connection.

- **Oriented swapping model (Angel-Holroyd-Romik [1]).** If n particles labelled 1 through n arranged on a line perform adjacent swaps independently and with an exponential rate 1 for each adjacent pair, conditioned to increase the number of inversions, then the trajectory of each particle is given in the limit by a family of possible limit shapes (of which a uniformly random curve is chosen), as shown in Figure 5.

- **Random sorting networks (Angel-Holroyd-Romik-Virág [2]).** In the same probability space as the oriented swapping model, if one imposes a different probability law by choosing the sequence of swaps leading from the identity permutation to the reverse permutation uniformly at random from all sorting networks, it is conjectured that the family of possible limit shapes for the particle trajectories are all sine curves. See Figure 5.
- **Random alternating sign matrices (Colomo-Pronko [16]).** In [16] it is conjectured based on a non-rigorous analysis that the non-zero entries in a uniformly random alternating sign matrix of high order cluster with high probability inside the limit shape described by the equation

$$x^2 + y^2 + |xy| = |x| + |y|.$$

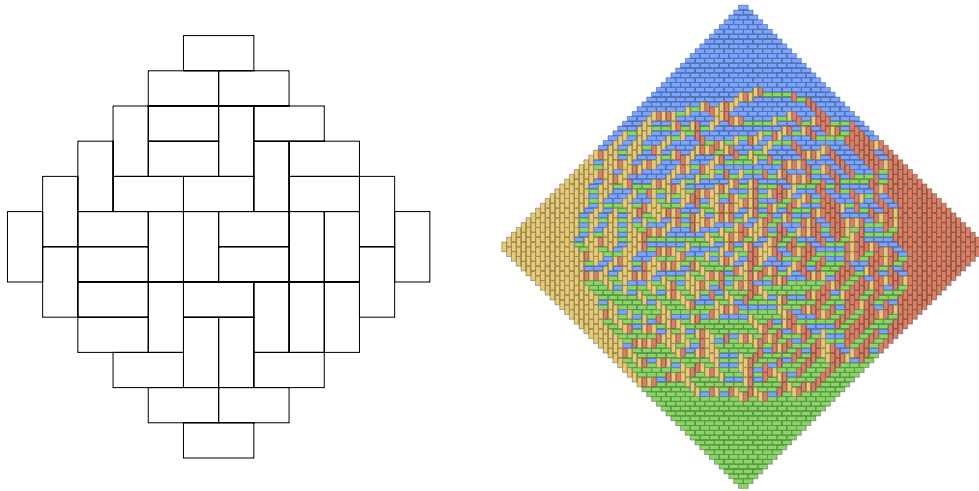


Figure 1: A domino tiling of the Aztec diamond of order 6, and a random tiling of the Aztec diamond of order 50. The density of dominoes of each of the 4 possible types determines the gradient of the height function, and is frozen outside the “arctic circle” inscribed in the diamond.

I hope that these examples are enough to convince the reader that studying the shapes of random combinatorial objects is well worth the effort. Aside from the intriguing pictures, mathematically there is a remarkable wealth of beautiful techniques and ideas that have been developed to approach these sorts of questions. There are also many fascinating and highly non-trivial connections between the different models. For example, the results for the oriented swapping model are derived using Rost’s results for the corner growth model and some later refinements of them. Similarly, the Jockusch-Propp-Shor [22] Arctic Circle Theorem for random domino tilings of the Aztec diamond (which is

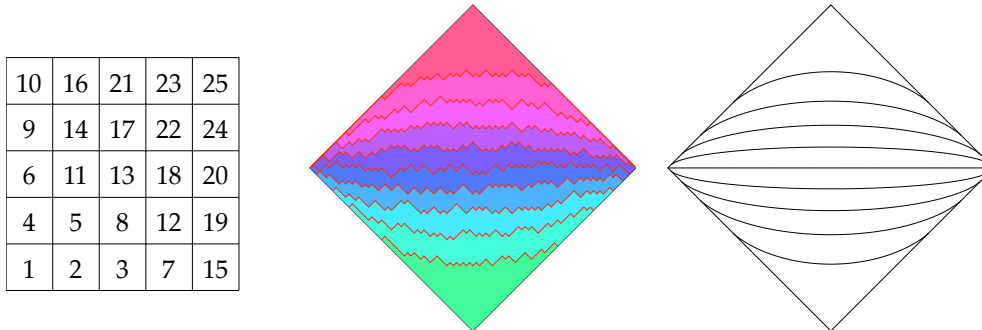


Figure 2: A square Young tableau of order 5, the family of level curves in a uniformly random square Young tableau of order 50, and the limiting curves.

essentially a less detailed version of the limit shape result mentioned above for the height function) was proved by studying a discrete-time variant of the corner growth model. More recently, I discovered that the same result for domino tilings is equivalent to the limit shape result for random square Young tableaux, although this is not at all apparent from looking at the combinatorics of the two models.

Enumeration

The second focus of the proposed research will be on questions of enumeration. Here the goal is to study explicit formulas for enumeration of various classes of combinatorial objects. This usually involves some mixture of algebraic and combinatorial techniques. Here are some examples of such formulas, some of them related to the random models mentioned in the previous section. For the sake of brevity, some technical definitions are omitted.

- **Domino tilings of the Aztec diamond (Elkies-Kuperberg-Larsen-Propp [17]).** The number of domino tilings of the Aztec diamond of order n is equal to

$$2^{\binom{n}{2}}.$$

- **Boxed plane partitions (MacMahon [26]).** The number of plane partitions bounded in a box of dimensions $r \times s \times t$ is equal to

$$\prod_{i=1}^r \prod_{j=1}^s \prod_{k=1}^t \frac{i+j+k-1}{i+j+k-2}.$$

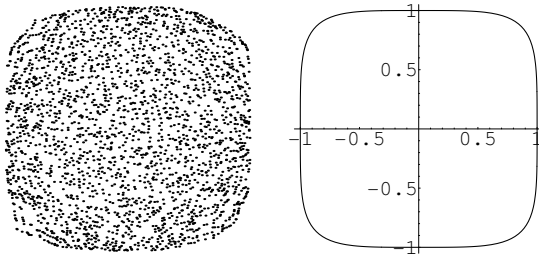


Figure 3: The graph of a random Extremal Erdős-Szekeres permutation of order 10000 and its limit shape, a quartic algebraic curve.

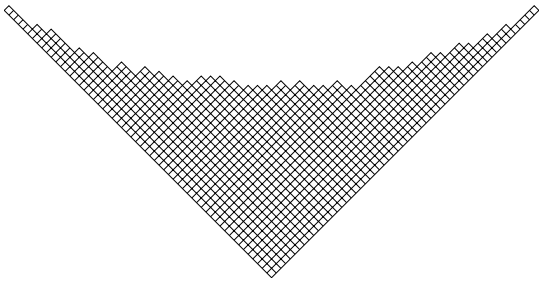


Figure 4: A random Young diagram of order 1000 chosen according to Plancherel measure, shown in “Russian” coordinates.

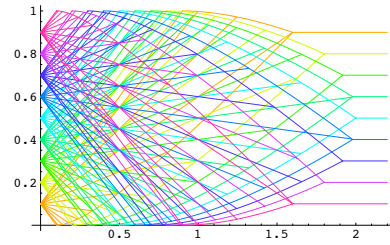
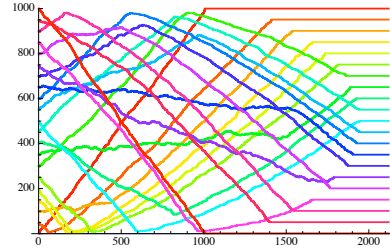


Figure 5: Particle trajectories in the oriented swap process and their limit shapes, and similar particle trajectories in a uniformly random sorting network (conjectured to be shifted sine curves).

- **The total and refined enumeration of alternating sign matrices (Zeilberger [36, 37]).** The number A_n of alternating sign matrices of order n is equal to

$$A_n = \frac{1! 4! 7! 10! \cdots (3n-2)!}{n!(n+1)! \cdots (2n-1)!}.$$

The number $A_{n,k}$ of alternating sign matrices of order n with a 1 in position k of the first row is equal to

$$A_{n,k} = \binom{n+k-2}{k-1} \frac{(2n-k-1)!(2n-2)!(2n-1)!}{(n-k)!(3n-2)!} \cdot A_n.$$

- **The doubly-refined enumeration of alternating sign matrices (Karklinsky-Romik [6]).** The “doubly-refined” enumeration numbers $A_{n,i,j}$ for alternating sign matrices are given by

$$A_{n,i,j} = \sum_{p=0}^{n-j} \sum_{q=0}^p (-1)^q \binom{p}{q} X_n(i+q, j+p),$$

where

$$X_n(s, t) = \frac{1}{A_{n-1}} \left(A_{n-1,t}(A_{n,s+1} - A_{n,s}) - A_{n-1,s}(A_{n,t+1} - A_{n,t}) \right).$$

- **The hook-length formula (Frame-Robinson-Thrall [21]).** If λ is a Young diagram of size n , The number of Young tableaux of shape λ is equal to

$$\frac{n!}{\prod_{(i,j) \in \lambda} h_{i,j}},$$

where $h_{i,j}(\lambda)$ is the hook length of the cell (i, j) in λ . (In particular, the number s_n of $n \times n$ square Young tableaux is equal to

$$s_n = \frac{(n^2)!}{\prod_{i,j=1}^n (i+j-1)},$$

and as a result the number of Extremal Erdős-Szekeres permutations of order n^2 is equal to s_n^2 .)

- **Skew Young tableaux and generalized zig-zag permutations (Baryshnikov-Romik [3]).** The number of generalized zig-zag permutations defined by the skew Young diagram $(n+3, n+2, \dots, 5, 4) \setminus (n-1, n-2, \dots, 1)$ is equal to

$$(4n)! \left(\frac{E_{2n}^2}{((2n)!)^2} - \frac{E_{2n-2} E_{2n+2}}{(2n-2)!(2n+2)!} \right)$$

where $(E_{2k})_{k=0}^{\infty}$ are the Euler numbers defined by the generating function

$$\sec x = \sum_{k=0}^{\infty} \frac{(-1)^k E_{2k} x^{2k}}{(2k)!}.$$

- **Reduced word decompositions (Stanley [28]).** The number of reduced word decompositions of the reverse permutation of order n (a.k.a. sorting networks or maximal chains in the weak Bruhat order) is equal to

$$\frac{\binom{n}{2}!}{1^{n-1} 3^{n-2} 5^{n-3} \dots (2n-3)^1}.$$

As in the discussion on limit shapes above, while it is impossible to go into the technical details in this short space, it is clear from looking at the formulas mentioned above that under the surface lies a rich algebraic and combinatorial theory, and that the study of enumeration questions can yield satisfying rewards even when no asymptotic or probabilistic issues are involved. Indeed, enumeration is a large and well-established field covered in great depth in textbooks such as Stanley’s *Enumerative Combinatorics* [29, 30]. While historically questions of enumeration have been studied somewhat separately from probabilistic questions, my personal philosophy (which I believe my own track record of research contributions demonstrates to some extent) is that both of these types of questions have a lot in common and that there is much to be gained from treating them in a unified manner. Not only do enumeration questions arise naturally when one tries to answer purely probabilistic questions; but also, those models which exhibit a high level of structure, as often indicated by the existence of striking or “nice” exact enumeration formulas, can be a rich source of examples for studying in a probabilistic setting.

1.2 Research objectives and methodology

Having described the scientific background for the proposed research, I will now list several specific research objectives that I hope to tackle over the duration of the project and some of the tools and techniques that may be used to attack them. These objectives differ in their level of difficulty and ambition (but all of them are somewhat difficult and ambitious). I believe that such a moderate amount of diversification in focus and hardness will give the highest chance of significant research contributions emerging as a result.

Enumeration of alternating sign matrices. I plan to continue my previous focus on enumeration of alternating sign matrices satisfying certain constraints. The “doubly-refined” enumeration which refines Zeilberger’s Refined Alternating Sign Matrix Theorem was treated in [5] and [6], but the conjectures stated in [5] suggest that there is

still a lot of room to extend and generalize these results to the “multiply-refined” case in which one enumerates alternating sign matrices of order n where the first k rows are given. A good understanding of such enumerations would give a possible approach for attacking the problem of the limit shape of random alternating sign matrices; see below.

The techniques that may prove useful for attacking such enumeration problems come from two sources: There are the “monotone triangle” techniques, developed by Fischer in her papers [18, 19] and used again in the multiply-refined context by Fischer and myself [5] and later by Fischer [20]. In parallel, there are the equally elegant “square ice” techniques building on the works of Izergin-Korepin [13], Kuperberg [24], Stroganov [31] and others, which Karklinsky and I used in [6]. These two techniques were developed completely separately and seem to complement each other. Another interesting project would be to try to attain a deeper understanding of their connection. As is evident from the recent preprints cited above, I have cultivated a good working knowledge of both techniques, which I hope will enable me to achieve such an understanding as well as to “ride the winner” to obtain the most general results.

Limit shapes of x -enumerated alternating sign matrices. If x is a positive real parameter, the x -enumeration is a probability measure on alternating sign matrices of a given order, where one assigns to a matrix M a weight proportional to $x^{N(M)}$, where $N(M)$ is the number of -1 entries in M . For $x = 2$ this gives the “domino measure” induced by uniformly random domino tilings of the Aztec diamond, and in this case the limit shape is the “arctic circle”. A similar arctic circle phenomenon occurs in the random square Young tableau model studied in [7] (see Figure 6). Recently I discovered a unified approach (based on a large-deviations analysis) to treating both of these models, which shows that they are equivalent and represents the height functions in both models as simple transformations one of the other. I believe the same technique may be applicable to treat the more general case of the x -enumeration. This will most likely require a very nontrivial asymptotic analysis and possibly some new combinatorial or algebraic insights to transform formulas which have a lot of cancellation into other formulas with no significant cancellation. Strangely, this seems to have a better chance of working for $x \geq 2$ (for technical reasons that I will not explain here), and possibly the case $x = 3$ will be the easiest to analyze. In both the cases $x = 1$ (which corresponds to the uniform measure) and $x = 3$, Colomo and Pronko [16] have derived conjectural formulas for the limit shapes.

Another possible technique for attacking the limit shape problem (mainly for the uniform measure case $x = 1$, which is also the most interesting), would be to use the explicit enumeration formulas described above. This looks quite challenging, since even if the work from the papers [5, 6, 20] could be extended to a detailed enough level of enumeration, there would still probably be a significant problem of cancellation from terms with opposing signs, which could make it difficult to derive the kind of accurate asymptotics needed. However, in my opinion this problem is certainly important enough to justify such a long-term approach that requires surmounting multiple obstacles. This is

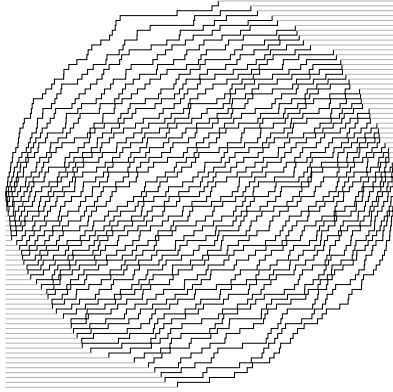


Figure 6: A family of nonintersecting paths encoded by a random square Young tableau of order 40. The arctic circle visible here is the “same” as the arctic circle, shown in Fig. 1, that appears in the study of random domino tilings of the Aztec diamond (in the sense that the height function describing the density of lines can be directly mapped to the height function in that model [11]).

especially so since, as the current preliminary results already obtained show, the insights gained in the attempt are themselves of great independent interest even if the end result is not yet achieved.

Limit shape of random Young tableaux. One goal that I have had for a few years is to understand the limit shape of uniformly random Young tableaux. The works of Vershik-Kerov/Logan-Shepp treat the case of “free” random Young tableaux, but what if one were to restrict the probability space to the set of Young tableaux whose Young diagram is of a given shape? This question is of interest from both the statistical physics and representation theory contexts. In the special case when the diagram is a square (or more generally a rectangle), the question is answered in my paper [7] with Pittel, and solving it already presents a formidable technical challenge. The general case remains unsolved. However, in joint work with Yuliy Baryshnikov in 2007–2008 there has been a breakthrough in our understanding of the problem. Taking a large-deviations approach, we managed to analyze the transfer operator corresponding to a level-curve of arbitrary rational slope in the tableau (some of these results are contained in the paper [3]). By interpolating to general real-valued slopes and piecing together many small pieces, we think it may be possible to prove the following conjecture (again, I omit some technical details and precise definitions of the relevant terms):

Conjecture (The limit shape of random Young tableaux with given diagram).
If D is a continual Young diagram and λ_n is a sequence of Young diagrams approximating D in the limit, then as $n \rightarrow \infty$ the limit shape of the typical Young tableau with dia-

gram λ_n is given by the unique function $G = G(t, u)$ that out of all “feasible” functions maximizes the following integral functional:

$$I(G) = \int_0^1 \int_{-\infty}^{\infty} \left[\log \left(\frac{2}{\pi} \cos \left(\frac{\pi}{2} \frac{\partial G(t, u)}{\partial u} \right) \right) - \log \frac{\partial G(t, u)}{\partial t} \right] \frac{\partial G(t, u)}{\partial t} du dt.$$

Here G is given in the Russian coordinate system.

The conjecture appears within reach, since we already have a fairly detailed understanding of the problem. However, there are still quite a few technical obstacles to overcome.

Random matrices and the oriented swap process. In the paper [1] on the oriented swap process with Angel and Holroyd, we proved that the Tracy-Widom distribution from random matrix theory appears as the limiting distribution of the finishing times of individual particles. An even more natural quantity to look at in that model is the hitting time of the entire process. From looking at the connection between this quantity and the finishing times, it seems clear that this random variable should also have a limiting distribution that is expressible in terms of the usual processes appearing in random matrix theory such as the Airy process. However, proving this and computing explicitly the distribution are both technically challenging questions which I hope to address, possibly in collaboration with experts on random matrix theory who are present at UC Davis such as Craig Tracy and Alexander Soshnikov.

Another possibility is to extend the treatment of the oriented swap process to other natural variants of the same model such as the one in which swaps can occur so as both to increase or *decrease* the number of inversions, except at different rates (the “partially asymmetric” dynamics), or the “triangular” swapping dynamics studied by Fomin and Stanley in which swaps occur at a rate proportional to the index of the particle on the left side of each adjacent pair.

Random sorting networks. Another sorting process which leaves many interesting questions for further study is the Uniform Sorting Network model studied in [2]. The main conjecture of that paper seems like it may be too difficult to approach currently, but it would be very interesting to try and gain new insights into this model. The new understanding of random Young tableaux mentioned above in connection with my joint work [3] with Yuliy Baryshnikov may prove helpful in this regard.

Other directions. The nature of mathematical research is such that although one has a good idea of the direction in which one is going, one is not always able to predict the final destination. A good scientist should always be on the lookout for promising problems to apply her techniques to, and often an unexpected insight gained in the pursuit of the answer to one problem leads to the solution of another. I therefore think it likely that over the duration of the project, new directions of research will be added,

dealing with problems and subjects that are related to the topics described above, but not coinciding with them exactly. The focus will stay on combinatorial probability, but I am also very interested in connections between different fields. One particular direction that I would like to better understand is the connection of many of the classes of objects I have studied to date to algebra and representation theory. The theory of alternating sign matrices for example seems to have an algebraic aspect that is still not very well understood, and this is something that I would like to study more in depth, should the available time allow it.

2 Educational activities and their integration in the project

The research project described above will be integrated with an educational effort whose goals are to promote mathematical learning and awareness at the undergraduate and graduate levels and in the scientific community at large, both on the general level and at a level focusing on specific knowledge in the fields discussed above. My philosophy is that research and education have synergistic influences on each other: education can contribute to ongoing research efforts, for example by involving undergraduates and graduate students in active research activities, or by providing a convenient venue for a researcher to sharpen her insight into research problems by presenting them to graduate students; conversely, popularizing new research by integrating it into teaching materials, whether through classroom teaching, textbooks or popular lectures, can provide a source of much inspiration and a sense of involvement to students and laymen alike. I have personally been active in such endeavors and witnessed firsthand the positive impact that this can have. To give just one small example, recently I finished teaching a freshman class in linear algebra at the Hebrew University by giving a “recreational” lecture about connections between linear algebra and the combinatorics of alternating sign matrices and domino tilings. I was heartened to receive email from students later telling me how much they enjoyed it, and felt that it was well worth the time invested in the activity, which could equally well have been used to teach some “serious” proofs.

My proposal comprises several activities. Some of them are extensions of existing initiatives that I am already engaged in.

- **Educational computer software.** In my research I use computers extensively for experimentation, symbolic computation and visualization. While in my research I use mostly the Mathematica software, in the last couple of years I have written several stand-alone applications that are more educational in nature and are designed for very easy interactive visualization of complex mathematical ideas related to my research. Two years ago I published software for simulating random Young tableaux and Young diagrams; random sorting processes; and optimal allocation schemes. Recently I released another application for experimenting with random alternating sign matrices and domino tilings. All the software is freely available for download from my website.

My experience has shown that software of this type can be a powerful aid to understanding complicated mathematical objects. It has helped me personally develop my intuition on certain problems, but I have also used it in the classroom and can appreciate its effect as a first-rate educational tool. My plan is therefore to continue with development of such software in the future. The very act of developing such software can be a valuable educational experience suitable for an undergraduate project. I also plan to use the software in an effort to involve undergraduate students (and of course graduate students too) in active research, as I describe below.

- **Involving undergraduates in research.** Modern research in mathematics is often very technical and requires a large amount of prerequisite knowledge. As such, it is not very accessible to undergraduate students. In some fields this is not the case however, and in my opinion when it is possible to involve undergraduates in research activities, it can be highly beneficial to do so, from both the education and research standpoints. Undergraduates are often highly motivated and excited about learning new material and can contribute their creativity and hard work. Involving them in research can leave them with a memorable experience and an appreciation for scientific endeavors that they will carry with them afterwards, even as they turn to miscellaneous professional directions and activities that may not be related to research.

In the context of the research activities described above, I believe that they are very suitable for such involvement of undergraduates. The problems are relatively easy to describe and do not require a very technical background. The methods of analysis do require a serious technical background, but I believe that with the help of the educational software I developed and described above and additional software that will be developed, it becomes feasible to explain much of the background to a highly motivated student without a detailed technical knowledge of the field, and to set her loose on discovering new and interesting phenomena that may later materialize into serious research contributions.

- **A textbook on longest increasing subsequences.** Another activity that I believe integrates in a very nice way the ideas of research and education manifested in this proposal, is a textbook that I have made plans to write. This is a rather ambitious project that is likely to take several years of hard work, but could have an enormous positive influence on the field and on the scientific community: On the one hand it could encourage additional research in the field by making the existing knowledge more accessible to researchers with a less detailed technical background and thus drawing in new creative forces; on the other hand it can be helpful in popularizing the subject by spreading knowledge of the beautiful research developments in the field from the last few decades to a much wider audience of students and mathematicians from different areas. My thinking on this matter is inspired for example by textbooks such as Stanley's *Enumerative Combinatorics*

and Knuth's *The Art of Computer Programming*, although these are of course canonical examples whose impact it would be nearly impossible to match.

The working title for the project will be "Longest Increasing Subsequences". The basic idea is to start by presenting in an expository fashion the classical developments of Ulam's problem on the longest increasing subsequence of a random permutation, Schensted's work on increasing subsequences, the Robinson-Schensted-Knuth algorithm, and the remarkable solution of Ulam's problem by Vershik-Kerov and Logan-Shepp. However, I would like to follow this up with more modern developments from the last 15 years or so on random Young tableaux, connections to random matrix theory, directed percolation models and several other related topics like domino tilings, square ice and alternating sign matrices. Almost all of the material has not appeared in book form before and is accessible only through articles published in research publications, most of which are quite difficult for a non-expert to understand.

- **Developing graduate-level teaching materials on combinatorial probability.** This is an activity that goes hand in hand with the textbook project I described above. My plan is to use the classroom as a "test-bed" for the material that will go into the book, by developing a graduate course (or two, or maybe even three) on some of the subjects of the book. The students will benefit from this by being taught about these exciting developments in modern research from an expert in the field. The book will benefit by having an audience of critics to provide useful feedback that would improve its presentation and accuracy. Like with any advanced graduate class, it is also likely that the discussion in the class could encourage research developments through the interaction of my expertise in the field with fresh thinking minds with new and creative ways of looking at things. So once again, I believe that this activity provides a good example of the integration of education and research activities.

3 Results of prior funded projects

3.1 NSF support

- I have not been a primary investigator in an NSF funded research.
- In the academic year 2005/2006 my post-doctoral research at the UC Berkeley Statistics Department was funded under the NSF grants DMS-0104079 and DMS-0244479. This resulted in two publications:
 1. S. Chatterjee, R. Peled, Y. Peres, D. Romik. Gravitational allocation to Poisson points. *Ann. Math.*, to appear. In this paper we study fair allocation schemes assigning cells of equal volume to random points dispersed uniformly in d -dimensional space. In dimensions 3 and higher we manage to construct

such an allocation that is extremely efficient, using an idea based on Newtonian gravitation.

2. O. Angel, A.E. Holroyd, D. Romik, B. Virág. Random sorting networks. *Adv. Math.* 215 (2007), 839–868. In this paper we study random sorting networks, which are natural combinatorial objects that have strong connections to Young tableaux. We prove several results about them and present several fascinating conjectures about their asymptotic behavior.

3.2 Other support

As PI, in 2008 I was awarded grant number 1051/08 by the Israeli Science Foundation (ISF). This includes support of about \$30,000 annually for 4 years, but was relinquished after one year due to my move from the Hebrew University to UC Davis. I am pleased to report however that in that year I have made considerable progress on some of the research objectives stated in my original proposal.

- **Enumeration of alternating sign matrices.** I started studying the enumeration of alternating sign matrices as a possible tool for deriving asymptotic results that would enable deriving the limit shape of uniformly random alternating sign matrices (research goal 3 in the proposal). This has been very fruitful, and resulted in two preprints with important new results in the field:
 1. M. Karklinsky, D. Romik. A formula for the doubly refined enumeration of alternating sign matrices. Preprint (2009), [arXiv:0906.3405](https://arxiv.org/abs/0906.3405).
 2. I. Fischer, D. Romik. More refined enumerations of alternating sign matrices. *Adv. Math.*, to appear.
- **Domino tilings of the Aztec diamond and square Young tableaux.** Through my studies of alternating sign matrices I managed to get an important new insight into the limit shape of alternating sign matrices chosen not uniformly but according to the “domino measure” projected by choosing a uniformly random domino tiling of the Aztec diamond. I discovered that the limiting height function in this model, derived originally by Cohn-Elkies-Propp [15], is in fact equivalent under a simple transformation to the limit shape for random square Young tableaux from my earlier paper [7] with Boris Pittel. A paper describing these developments is now in preparation. This does not answer the specific research objectives mentioned in the proposal but definitely constitutes a very interesting development along the same lines of Sections 2.1 and 2.2 in the proposal.
 1. D. Romik. Arctic circles, domino tilings and random square Young tableaux. In preparation.

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Biographical Sketch: Dan Romik

Professional Preparation

- **B.Sc.** (*Summa Cum Laude*) in Mathematics, Tel-Aviv University, 1996.
- **M.Sc.** (*Summa Cum Laude*) in Mathematics, Tel-Aviv University, 1997.
- **Ph.D.** in Mathematics, Tel-Aviv University, 2002.
- **Post-doctoral research** in probability and combinatorics at *Université Pierre et Marie Curie* (Paris VI University), the Weizmann Institute of Science, the Mathematical Sciences Research Institute (MSRI), and the University of California, Berkeley; 2001-2006.

Appointments

- 2009–present. Assistant Professor at the Department of Mathematics, University of California, Davis.
- 2007–2009. Senior Lecturer (Israeli equivalent of Assistant Prof.) at the Einstein Institute of Mathematics, The Hebrew University of Jerusalem.
- 2006–2007. Member of the Fundamental and Industrial Mathematics Group at the Mathematical and Algorithmic Sciences Center, Bell Laboratories, New Jersey.

Publications

1. I. Fischer, D. Romik. More refined enumerations for alternating sign matrices. *Adv. Math.*, to appear.
2. S. Chatterjee, R. Peled, Y. Peres, D. Romik. Gravitational allocation to Poisson points. *Ann. Math.*, to appear.
3. O. Angel, A.E. Holroyd, D. Romik. The oriented swap process. *Ann. Probab.*, to appear.
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5. O. Angel, A.E. Holroyd, B. Virág, D. Romik. Random sorting networks. *Adv. Math.* 215 (2007), 839–868.
6. B.G. Pittel, D. Romik. Limit shapes for random square Young tableaux. *Adv. Appl. Math.* 38 (2007), 164–209.
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9. T. Liggett, A.E. Holroyd, D. Romik. Integrals, partitions and cellular automata. *Trans. Amer. Math. Soc.* 356 (2004), 3349–3368.

10. D. Romik. Explicit formulas for hook walks on continual Young diagrams. *Adv. Appl. Math.* 32 (2004), 625–654.

Synergistic Activities

- **Development of teaching materials.** The PI has developed and taught the following graduate courses and seminars covering advanced topics: Topics in Probability and Number Theory; Alternating Sign Matrices; Partition Theory Seminar.
- **Development of computer-based educational tools.** The PI has developed, and made freely available on his website, several software packages and applications for the numerical processing and visualization of complex mathematical objects originating in his research work, such as Young tableaux, random sorting networks, fair allocation schemes and alternating sign matrices. This software has been used successfully as an aid in both the PI's research and educational activities.
- **Organization of scientific activities.** The PI has co-organized the Random Sorting Processes workshop at the Banff International Research Station (BIRS), Banff, Alberta, April 22–May 6, 2006.
- **Services to the scientific community.** The PI is active in facilitating the transfer of new research knowledge through refereeing work for scientific journals and research grant proposals. He has refereed articles for journals such as the *Annals of Probability*, the *Electronic Journal of Probability*, *Electronic Communications in Probability*, *Journal of Combinatorial Theory (Ser. A)*, *Discrete Mathematics* and many others, and grant proposals for the Israeli Science Foundation.

Collaborators and Other Affiliations

- **Recent collaborators (past 48 months).** Omer Angel (University of British Columbia); Yuliy Baryshnikov (Bell Laboratories); Sourav Chatterjee (UC Berkeley); Ilse Fischer (University of Vienna and University of Klagenfurt); Alexander Holroyd (University of British Columbia and Microsoft Research); Ron Peled (New York University); Yuval Peres (Microsoft Research).
- **Graduate advisors and post-doctoral sponsors.** David Gilat (*Emeritus*, Tel Aviv University); Yuval Peres (Microsoft Research); Amitai Regev (Weizmann Institute of Science); Marc Yor (Paris VI University).
- **Thesis Advisor.** 1 graduate student advised: Matan Karklinsky (M.Sc. student, the Hebrew University).

SUMMARY PROPOSAL BUDGET

YEAR 1

ORGANIZATION University of California-Davis				FOR NSF USE ONLY			
				PROPOSAL NO.	DURATION (months)		
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Dan Romik				AWARD NO.	Proposed	Granted	
				A. SENIOR PERSONNEL: PI/PP, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)			
				CAL	ACAD	SUMR	
1. Dan Romik - Assistant Professor				0.00	0.00	2.00	\$ 17,890
2.							
3.							
4.							
5.							
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)				0.00	0.00	0.00	0
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)				0.00	0.00	2.00	17,890
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)							
1. (0) POST DOCTORAL SCHOLARS				0.00	0.00	0.00	0
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)				0.00	0.00	0.00	0
3. (3) GRADUATE STUDENTS							28,402
4. (0) UNDERGRADUATE STUDENTS							0
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)							0
6. (0) OTHER							0
TOTAL SALARIES AND WAGES (A + B)							46,292
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)							3,904
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)							50,196
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING \$5,000.)							
TOTAL EQUIPMENT							0
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)							2,000
2. FOREIGN							2,000
F. PARTICIPANT SUPPORT COSTS							
1. STIPENDS \$ _____ 0							
2. TRAVEL _____ 0							
3. SUBSISTENCE _____ 0							
4. OTHER _____ 0							
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS							0
G. OTHER DIRECT COSTS							
1. MATERIALS AND SUPPLIES							3,500
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION							0
3. CONSULTANT SERVICES							0
4. COMPUTER SERVICES							0
5. SUBAWARDS							0
6. OTHER							8,640
TOTAL OTHER DIRECT COSTS							12,140
H. TOTAL DIRECT COSTS (A THROUGH G)							66,336
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) a,b,c,e,g1 (Rate: 53.0000, Base: 57696)							
TOTAL INDIRECT COSTS (F&A)							30,579
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)							96,915
K. RESIDUAL FUNDS							0
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)							\$ 96,915
M. COST SHARING PROPOSED LEVEL \$ 0				AGREED LEVEL IF DIFFERENT \$			
PI/PPD NAME Dan Romik				FOR NSF USE ONLY			
ORG. REP. NAME* Suzanne Oliver				INDIRECT COST RATE VERIFICATION			
				Date Checked	Date Of Rate Sheet	Initials - ORG	

SUMMARY PROPOSAL BUDGET

YEAR **2**

ORGANIZATION University of California-Davis				FOR NSF USE ONLY			
				PROPOSAL NO.	DURATION (months)		
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Dan Romik				AWARD NO.	Proposed	Granted	
				A. SENIOR PERSONNEL: PI/PP, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)			
				CAL	ACAD	SUMR	
1. Dan Romik - Assistant Professor				0.00	0.00	2.00	\$ 18,785
2.							
3.							
4.							
5.							
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)				0.00	0.00	0.00	0
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)				0.00	0.00	2.00	18,785
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)							
1. (0) POST DOCTORAL SCHOLARS				0.00	0.00	0.00	0
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)				0.00	0.00	0.00	0
3. (3) GRADUATE STUDENTS							29,254
4. (0) UNDERGRADUATE STUDENTS							0
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)							0
6. (0) OTHER							0
TOTAL SALARIES AND WAGES (A + B)							48,039
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)							4,088
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)							52,127
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING \$5,000.)							
TOTAL EQUIPMENT							0
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)							2,000
2. FOREIGN							2,000
F. PARTICIPANT SUPPORT COSTS							
1. STIPENDS \$ _____ 0							
2. TRAVEL _____ 0							
3. SUBSISTENCE _____ 0							
4. OTHER _____ 0							
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS							0
G. OTHER DIRECT COSTS							
1. MATERIALS AND SUPPLIES							1,000
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION							0
3. CONSULTANT SERVICES							0
4. COMPUTER SERVICES							0
5. SUBAWARDS							0
6. OTHER							9,505
TOTAL OTHER DIRECT COSTS							10,505
H. TOTAL DIRECT COSTS (A THROUGH G)							66,632
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) a, b, c, e, g1 (Rate: 53.5000, Base: 57127)							
TOTAL INDIRECT COSTS (F&A)							30,563
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)							97,195
K. RESIDUAL FUNDS							0
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)							\$ 97,195 \$
M. COST SHARING PROPOSED LEVEL \$ 0				AGREED LEVEL IF DIFFERENT \$			
PI/PP NAME Dan Romik				FOR NSF USE ONLY			
ORG. REP. NAME* Suzanne Oliver				INDIRECT COST RATE VERIFICATION			
		Date Checked	Date Of Rate Sheet	Initials - ORG			

SUMMARY PROPOSAL BUDGET

YEAR 3

ORGANIZATION University of California-Davis				FOR NSF USE ONLY			
				PROPOSAL NO.	DURATION (months)		
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Dan Romik				AWARD NO.	Proposed	Granted	
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)				NSF Funded Person-months		Funds Requested By proposer	Funds granted by NSF (if different)
		CAL	ACAD	SUMR			
1.	Dan Romik - Assistant Professor	0.00	0.00	2.00	\$ 19,724	\$	
2.							
3.							
4.							
5.							
6.	(0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0		
7.	(1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	2.00	19,724		
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)							
1.	(0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0		
2.	(0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0		
3.	(3) GRADUATE STUDENTS				30,132		
4.	(0) UNDERGRADUATE STUDENTS				0		
5.	(0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0		
6.	(0) OTHER				0		
TOTAL SALARIES AND WAGES (A + B)					49,856		
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)					4,281		
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)					54,137		
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING \$5,000.)							
TOTAL EQUIPMENT					0		
E. TRAVEL					2,000		
1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)							
2. FOREIGN					4,000		
F. PARTICIPANT SUPPORT COSTS							
1.	STIPENDS \$ _____				0		
2.	TRAVEL _____				0		
3.	SUBSISTENCE _____				0		
4.	OTHER _____				0		
TOTAL NUMBER OF PARTICIPANTS (0)				TOTAL PARTICIPANT COSTS	0		
G. OTHER DIRECT COSTS							
1. MATERIALS AND SUPPLIES					1,000		
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION					0		
3. CONSULTANT SERVICES					0		
4. COMPUTER SERVICES					0		
5. SUBAWARDS					0		
6. OTHER					10,455		
TOTAL OTHER DIRECT COSTS					11,455		
H. TOTAL DIRECT COSTS (A THROUGH G)					71,592		
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) a,b,c,e,g1 (Rate: 54.0000, Base: 61137)							
TOTAL INDIRECT COSTS (F&A)					33,014		
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)					104,606		
K. RESIDUAL FUNDS					0		
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)					\$ 104,606	\$	
M. COST SHARING PROPOSED LEVEL \$ 0				AGREED LEVEL IF DIFFERENT \$			
PI/PD NAME Dan Romik				FOR NSF USE ONLY			
ORG. REP. NAME* Suzanne Oliver				INDIRECT COST RATE VERIFICATION			
		Date Checked	Date Of Rate Sheet	Initials - ORG			

SUMMARY PROPOSAL BUDGET

YEAR 4

ORGANIZATION University of California-Davis				FOR NSF USE ONLY			
				PROPOSAL NO.	DURATION (months)		
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Dan Romik				AWARD NO.	Proposed	Granted	
				A. SENIOR PERSONNEL: PI/PP, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)			
	CAL	ACAD	SUMR				
1. Dan Romik - Assistant Professor	0.00	0.00	2.00	\$	20,710	\$	
2.							
3.							
4.							
5.							
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00		0		
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	2.00		20,710		
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)							
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00		0		
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00		0		
3. (3) GRADUATE STUDENTS					31,036		
4. (0) UNDERGRADUATE STUDENTS					0		
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)					0		
6. (0) OTHER					0		
TOTAL SALARIES AND WAGES (A + B)					51,746		
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)					4,484		
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)					56,230		
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING \$5,000.)							
TOTAL EQUIPMENT					0		
E. TRAVEL					2,000		
1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)							
2. FOREIGN					4,000		
F. PARTICIPANT SUPPORT COSTS							
1. STIPENDS	\$		0				
2. TRAVEL			0				
3. SUBSISTENCE			0				
4. OTHER			0				
TOTAL NUMBER OF PARTICIPANTS (0)				TOTAL PARTICIPANT COSTS	0		
G. OTHER DIRECT COSTS							
1. MATERIALS AND SUPPLIES					1,000		
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION					0		
3. CONSULTANT SERVICES					0		
4. COMPUTER SERVICES					0		
5. SUBAWARDS					0		
6. OTHER					11,500		
TOTAL OTHER DIRECT COSTS					12,500		
H. TOTAL DIRECT COSTS (A THROUGH G)					74,730		
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) a, b, c, e, g1 (Rate: 53.5000, Base: 63229)							
TOTAL INDIRECT COSTS (F&A)					33,828		
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)					108,558		
K. RESIDUAL FUNDS					0		
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				\$	108,558	\$	
M. COST SHARING PROPOSED LEVEL \$ 0				AGREED LEVEL IF DIFFERENT \$			
PI/PP NAME Dan Romik				FOR NSF USE ONLY			
ORG. REP. NAME* Suzanne Oliver				INDIRECT COST RATE VERIFICATION			
		Date Checked	Date Of Rate Sheet	Initials - ORG			

SUMMARY PROPOSAL BUDGET

YEAR 5

ORGANIZATION University of California-Davis				FOR NSF USE ONLY			
				PROPOSAL NO.	DURATION (months)		
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Dan Romik				AWARD NO.	Proposed	Granted	
				A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)			
	CAL	ACAD	SUMR				
1. Dan Romik - Assistant Professor	0.00	0.00	2.00	\$	21,745	\$	
2.							
3.							
4.							
5.							
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00		0		
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	2.00		21,745		
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)							
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00		0		
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00		0		
3. (3) GRADUATE STUDENTS					31,967		
4. (0) UNDERGRADUATE STUDENTS					0		
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)					0		
6. (0) OTHER					0		
TOTAL SALARIES AND WAGES (A + B)					53,712		
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)					4,695		
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)					58,407		
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING \$5,000.)							
TOTAL EQUIPMENT					0		
E. TRAVEL					2,000		
1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)					2,000		
2. FOREIGN					4,000		
F. PARTICIPANT SUPPORT COSTS							
1. STIPENDS	\$		0				
2. TRAVEL			0				
3. SUBSISTENCE			0				
4. OTHER			0				
TOTAL NUMBER OF PARTICIPANTS (0)				TOTAL PARTICIPANT COSTS		0	
G. OTHER DIRECT COSTS							
1. MATERIALS AND SUPPLIES					1,000		
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION					0		
3. CONSULTANT SERVICES					0		
4. COMPUTER SERVICES					0		
5. SUBAWARDS					0		
6. OTHER					12,651		
TOTAL OTHER DIRECT COSTS					13,651		
H. TOTAL DIRECT COSTS (A THROUGH G)					78,058		
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) a, b, c, e, g1 (Rate: 53.5000, Base: 65408)							
TOTAL INDIRECT COSTS (F&A)					34,993		
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)					113,051		
K. RESIDUAL FUNDS					0		
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				\$	113,051	\$	
M. COST SHARING PROPOSED LEVEL \$ 0				AGREED LEVEL IF DIFFERENT \$			
PI/PD NAME Dan Romik				FOR NSF USE ONLY			
ORG. REP. NAME* Suzanne Oliver				INDIRECT COST RATE VERIFICATION			
		Date Checked	Date Of Rate Sheet	Initials - ORG			

Budget Justification

A. Senior Personnel

The PI will devote 2 months of the summer each year to the project. Salary is estimated to increase by 5% each year.

B. Other Personnel

Each year there will be support for 1 graduate student for 3 academic quarters.

Two GSR students for three summer months at 50% time.

The GSR (Graduate Student Researcher) salary is based on the Department of Math Graduate Student Researcher Compensation Plan. Salary is estimated to increase by 3% each year.

C. Fringe Benefits

Fringe benefits are calculated at PI 18.7%, GSR 1.3% for the academic year and 3% for the summer. This includes the increase in retirement contributions.

E. Travel

The PI expects to travel to take part in national and international meetings and conferences to disseminate the results of the research. The PI also expects to undertake visits to other academic institutes for purposes of collaboration with colleagues. This will probably include travel to some of the following countries where the PI has active collaborators: the United States, Canada, Israel, Britain and Austria. There is also allowance for some travel of students to professional meetings for the purpose of presenting ongoing research work and interacting with colleagues.

In years 3-5 of the project the PI expects to invite collaborators on short visits to UC Davis of 2-3 weeks. Such concentrated collaboration efforts are likely to further the goals of the research. There is also an expected educational benefit in allowing students at the UC Davis Department of Mathematics to interact with experts in mathematical fields that are not well-represented at Davis.

G. Other Direct Costs

G1. Materials and Supplies. The PI requests a small amount of funds each year to purchase books and software (such as Mathematica) that may be necessary for the project. In the first year funds are also requested to purchase a laptop computer to facilitate continued research while traveling and presentation of research efforts in conferences.

G6. Other. Funds are requested to pay for the GSR fees at 75%. These costs are based on current costs and are estimated to go up 10% each year.

I. Facilities and Administration

Overhead costs are calculated at 53.0% (7/1/10-6/30/11), 53.5% (7/1/11-6/30/12), 54% (7/1/12-6/30/13), 53.5% (7/1/13-6/30/15).

Current and pending support

- I am the recipient of grant number 1051/08 of the Israeli Science Foundation (ISF). The starting date was 10/01/08. This includes support of about \$30,000 annually for 4 years, but was relinquished after one year due to my move from the Hebrew University to UC Davis. The official termination date is 09/30/09, so the grant will not be in effect at the beginning of the current proposed project.
- There is no pending support.

Current and Pending Support

(See GPG Section II.C.2.h for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.	
Investigator: Dan Romik	Other agencies (including NSF) to which this proposal has been/will be submitted.
<p>Support: <input type="checkbox"/> Current <input checked="" type="checkbox"/> Pending <input type="checkbox"/> Submission Planned in Near Future <input type="checkbox"/> *Transfer of Support</p> <p>Project/Proposal Title: CAREER: Combinatorial probability, Limit Shapes and Enumeration</p> <p>Source of Support: National Science Foundation</p> <p>Total Award Amount: \$ 520,325 Total Award Period Covered: 07/01/10 - 06/30/15</p> <p>Location of Project: UC Davis</p> <p>Person-Months Per Year Committed to the Project. Cal:0.00 Acad:0.00 Sumr: 2.00</p>	
<p>Support: <input type="checkbox"/> Current <input type="checkbox"/> Pending <input type="checkbox"/> Submission Planned in Near Future <input type="checkbox"/> *Transfer of Support</p> <p>Project/Proposal Title:</p> <p>Source of Support:</p> <p>Total Award Amount: \$ Total Award Period Covered:</p> <p>Location of Project:</p> <p>Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:</p>	
<p>Support: <input type="checkbox"/> Current <input type="checkbox"/> Pending <input type="checkbox"/> Submission Planned in Near Future <input type="checkbox"/> *Transfer of Support</p> <p>Project/Proposal Title:</p> <p>Source of Support:</p> <p>Total Award Amount: \$ Total Award Period Covered:</p> <p>Location of Project:</p> <p>Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:</p>	
<p>Support: <input type="checkbox"/> Current <input type="checkbox"/> Pending <input type="checkbox"/> Submission Planned in Near Future <input type="checkbox"/> *Transfer of Support</p> <p>Project/Proposal Title:</p> <p>Source of Support:</p> <p>Total Award Amount: \$ Total Award Period Covered:</p> <p>Location of Project:</p> <p>Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:</p>	
<p>Support: <input type="checkbox"/> Current <input type="checkbox"/> Pending <input type="checkbox"/> Submission Planned in Near Future <input type="checkbox"/> *Transfer of Support</p> <p>Project/Proposal Title:</p> <p>Source of Support:</p> <p>Total Award Amount: \$ Total Award Period Covered:</p> <p>Location of Project:</p> <p>Person-Months Per Year Committed to the Project. Cal: Acad: Summ:</p>	

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

FACILITIES, EQUIPMENT & OTHER RESOURCES

FACILITIES: Identify the facilities to be used at each performance site listed and, as appropriate, indicate their capacities, pertinent capabilities, relative proximity, and extent of availability to the project. Use "Other" to describe the facilities at any other performance sites listed and at sites for field studies. USE additional pages as necessary.

Laboratory: N/A

Clinical: N/A

Animal: N/A

Computer: The project will use standard computer equipment such as desktop and laptop computers. The main tools used are the Mathematica software (and possibly other symbolic math software) and standard software for typesetting documents, preparing presentations for conferences, etc.

Office: The project will use office facilities of the UC Davis math department..

Other: N/A

MAJOR EQUIPMENT: List the most important items available for this project and, as appropriate identifying the location and pertinent capabilities of each.

N/A

OTHER RESOURCES: Provide any information describing the other resources available for the project. Identify support services such as consultant, secretarial, machine shop, and electronics shop, and the extent to which they will be available for the project. Include an explanation of any consortium/contractual arrangements with other organizations.

N/A



DEPARTMENT OF MATHEMATICS

1 Shields Avenue
Davis, California 95616-8633
<http://www.math.ucdavis.edu/>

July 22, 2009

National Science Foundation
DMS, CAREER Program
In support of the proposal by Dan Romik

Dear Program Directors,

On behalf of the Department of Mathematics, University of California, Davis, I would like to express my strongest support for Dan Romik's application for an NSF CAREER Award.

Dan Romik (PhD 2001, Tel-Aviv University) is a newly appointed assistant professor (tenure track, July 1, 2009) in my department and he satisfies the eligibility requirements for the CAREER program as spelled out in the Program Solicitation (NSF 08-557).

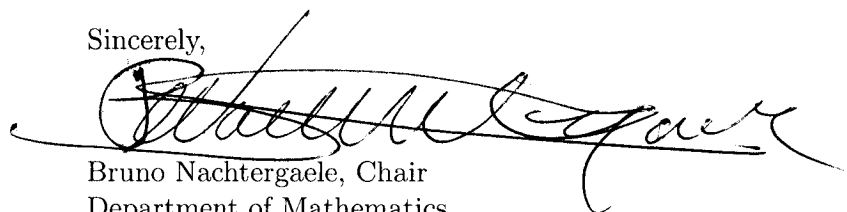
Dan Romik is a probabilist with strong interests and accomplishments in combinatorial probability. His application and subsequent hiring generated very broad support and excitement in my department, not only because of his strong record and glowing letters of recommendation from several luminaries in his field, but also because he so perfectly fits one of the goals the department faculty had formulated for new faculty recruitments: to strengthen and broaden two relatively young flourishing research communities in the department: combinatorics and probability. In both areas, Davis has made some very strong hires in the past decade and with the addition of Dan Romik we hope to create a new level of synergy between the two areas. To quote from one of his reference letters, Dan indeed "has a remarkable gift for finding and developing connections of probability theory with other areas of mathematics".

Dan has also demonstrated a broad ranging interest in teaching mathematics at all levels. He describes in his proposal concrete plans to involve graduate and undergraduate students in his research, to raise enthusiasm for mathematics using recreational lectures and software, and to develop courses materials for the students. I expect Dan to be an energetic and very effective contributor to our VIGRE project when he starts here later this summer. The department is committed to help recruit and provide additional support for graduate students to work with Dan Romik.

As Department Chair, I am available to advise Dan in all matters of professional development. In addition to informal conversations throughout the year, I have regularly scheduled annual meetings with assistant professors to hear about their progress and concerns. I routinely ask senior colleagues to help mentor them in specific aspects of their professional development when I see the need, or refer them to campus resources for specific concerns (participation in the Davis VIGRE project, work-life balance issues, effective teaching, obtaining funding for travel and research, sometimes even for help with spoken English etc).

I find Dan's to be a rich proposal replete with interesting and challenging problems. I am 100% confident that he has great ability to involve other department members and especially students in his research and teaching projects. He has my strongest possible support.

Sincerely,

A handwritten signature in black ink, appearing to read 'Bruno Nachtergaele', written in a cursive style. The signature is positioned above the typed name and contact information.

Bruno Nachtergaele, Chair
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