**Speaker:** Uli Wagner

**Title:** Eliminating Higher-Multiplicity Intersections and the Topological Tverberg Conjecture

**Speaker:** Winnie Li

**Title:** Langlands L-functions and counting geodesic cycles in complexes

**Abstract:** The Zeta function of an algebraic variety counts points.

The Selberg zeta function counts closed geodesic cycles on a compact Riemann surface. For combinatorial objects like graphs and complexes, their zeta functions count closed geodesic cycles. In this talk we shall explain how the Langlands L-function arises naturally in the combinatorial zeta function for the 2-dimensional complex which is a finite quotient of either an apartment or the building attached to PGL(3) and PGSp(4).

**Speaker:** Dudi Mass (joint with Tali Kaufman)

**Title:** Combinatorial Random Walks in High dimensions

**Abstract:** We consider a d-dimensional complex and study a natural combinatorial high order random walk on this complex. Namely, a walk that moves at random from an i-face (e.g an edge) to and i-face if the two are connected by an i+1-face (e.g. a triangle). We show that if the links of the complex are sufficiently expanding then this walk converges quickly to the uniform distribution. Recent works have studied some topological high order walks that are related to oriented Laplacians. However, the studied topological walks are different than our natural combinatorial walk and the convergence of the combinatorial walk does NOT seem to follow from previous works.

**Speaker:** Amir Yehudayoff

**Title:** An exposition to topological overlap in the plane

**Abstract:** The talk will mostly be an attempt to visualize Gromov's proof for topological overlap in the plane. We will also consider a weighted version of Gromov's theorem, when there is some probability distribution on the vertices, and deduce a dual statement using von Neumann's minimax theorem.

**Speaker:** Uriya First

**Title:** The Ramanujan property in higher dimensions

**Abstract:** Let $X$ be a simplicial complex $X$ and let $G$ be a group of automorphisms of $X$, e.g. consider a $k$-regular tree and its automorphism group. We consider quotients of $X$ by subgroups of $G$. We introduce a notion of high-dimensional spectrum for these quotients. This spectrum takes into consideration operators such as the high dimensional Laplacians and adjacency operators between high-dimensional cells. We prove a theorem in the flavor of the Alon-Boppana Theorem for our spectrum. This leads to a notion of quotients of $X$ which are Ramanujan in dimension $d$. Ramanujan graphs and the Ramanujan complexes of Lubotzky, Samuels and Vishne (2005) turn out to be Ramanujan in dimension $0$ in our setting. Using deep results about automorphic representations, we show that the Ramanujan complexes of Lubotzky, Samuels and Vishne (2005) are in fact Ramanujan in all dimensions, and furthermore, that affine Bruhat-Tits buildings of inner forms of $GL_n$ have infinitely many Ramanujan quotients.

**Speaker:** Tomoyuki SHIRAI (IMI, Kyushu Univ.)

**Title:** Persistent homology and minimum spanning acycle for certain random complexes

**Abstract:** Persistent homology measures topological features of objects or point cloud data. Much attention has been paid to it in the context of Topological Data Analysis. Persistent homology describes “birth and death” of homology classes as persistence diagram for an increasing sequence of simplicial complexes. We would like to apply this theory to random objects to obtain information on appearance and dissappearance of random topological feature in it. In the talk, we would like to discuss the relationship between persistent homology and minimum spanning acycle (a higher dimensional version of minimum spanning trees) in simplicial complexes, and also apply it to study certain random complex

processes, especially the Linial-Meshulam complex process, which is one of the natural higher dimensional generalizations of the Erd˙os-R´enyi random graph process.
This talk is based on a joint work with Yasuaki Hiraoka (AIMR, Tohoku Univ.)

**Speaker:** Lior Eldar

**Title:** High dimensional expanders and robust forms of quantum entanglement

**Abstract:** In the past few years researchers in the quantum community have been trying to probe the big question of quantum entanglement using concrete, and hopefully easier-to-answer questions ported from complexity theory.

One such question - now a major open conjecture, is called the quantum PCP conjecture (due to Aharonov et al.) which asks whether or not approximating the ground-energy of a set of locally-defined Hamiltonians is as hard as computing it to arbitrary precision.

A natural way to attack such questions is via the use of quantum error-correcting codes, and construction of quantum codes that are robust in certain ways, specifically locally testable - i.e. construct quantum locally testable codes.

Since almost all known quantum codes can be formulated in the language of complex chains (i.e. CSS codes) it gives rise to a natural connection to high-dimensional expanders. Concretely: if we could find a chain complex of bounded degree which has co-boundary / boundary expansion - this would already imply an important milestone on the way resolving the qPCP conjecture.

**Speaker:** Kristóf Huszár

**Title:** Overlap of Equivariant Maps

**Speaker:** Alain VALETTE (Neuchâtel)

**Title:** Expanders and box spaces

**Abstract:** Expanders, especially those coming from box spaces of residually finite groups, have been used to test various forms of the coarse Baum-Connes conjecture. The first construction of a pair of expanders, one not coarsely embedding in the other, was provided by Mendel and Naor in 2012. This was extended by Hume in 2014 who constructed a continuum of expanders with unbounded girth, pairwise not coarsely equivalent. In joint work with A. Khukhro, we construct a continuum of expanders with geometric property (T) of Willett-Yu, as box spaces of $SL(3,\Z)$. We also show that, for $m>n\geq 2$, box spaces of $SL(m,\Z)$ are not coarsely equivalent to box spaces of $SL(n,\Z)$. An application to the Ramanujan complexes of Lubotzky-Samuels-Vishne will be provided.

**Speaker:** Zur Luria

**Title:** High-dimensional permutations satisfying an expander mixing lemma

**Abstract:** An order-n d-dimensional permutation is a 0-1 (d+1)-dimensional array A of side length n, such that each line contains a single 1 element. Here a line is the set of elements of A obtained by fixing all but one index and letting that index vary from 1 to n. A 1-dimensional permutation is a permutation matrix, and 2-dimensional permutations are equivalent to Latin squares.

We define the discrepancy of A to be the maximum over all tuples of subsets X = (X_1, ... ,X_d+1) of V of ||A(X)|-|X_1||X_2|...|X_d+1|/n|. Here A(X) counts the number of 1-elements in A in the combinatorial box X. Motivated by the expander mixing lemma, we conjecture that a typical A satisfies disc(A) < O((|X_1||X_2|...|X_d+1|)^(1/2)).

A consequence of this conjecture is that the maximal volume of an empty box (for any d) is O(n^2). Using Peter Keevash's recent construction of designs, we showed that this is true in dimension 2.

Joint work with Nati Linial.

**Speaker:** Ori Parzanchevski

**Title:** High Dimensional Golden Gates

**Abstract:** Quite recently, the work of Lubotzky, Philips and Sarnak on Ramanujan graphs found surprising applications to quantum computing with a single qubit. I will explain this development, and show how computing with more cubits lead naturally to the study of high dimensional Ramanujan complexes. Based on joint work with Peter Sarnak.

**Speaker:** Irit Dinur

**Title:** A local to global question on complexes with applications to computational complexity and PCPs

**Abstract:** A basic goal in the theory of PCPs and local testing is to deduce a global "picture" by looking at very small (local) pieces.

We formulate a concrete question of the same type on simplicial complexes. The global picture will be a function on the vertices, the "local pieces" will be the restrictions to k-faces of the complex. We investigate how the local consistency of the pieces lifts to a globally consistent function.

I will

1) show how known (PCP) theorems can be viewed as solutions to this problem in specific complexes, and how the expansion of the complex plays a key role

2) describe some conjectures and open questions regarding expansion of complexes and PCP constructions

**Speaker**: Roy Meshulam

**Title**: Betti numbers of complexes with highly connected links

**Abstract**:

Let X be a pure k-dimensional complex. Garland's local to global theorem asserts, roughly speaking, that if for each j-dimensional simplex s of X, the (k-j-2)-Laplacian of the link lk(X,s) has sufficiently large spectral gap, then the real (k-1)-dimensional homology of X vanishes. We address the following natural question: What can be said about the (k-1)-th Betti number of X assuming only that lk(X,s) has vanishing (k-j-2)-homology for each j-simplex s ?

We obtain a upper bound which is shown to be nearly sharp using certain arithmetically constructed complexes.

Joint work with Amir Abu-Fraiha.

**Speaker:** Ming-Hsuan Kang

**Title:** Ramanujan complexes and Riemann Hypothesis

**Abstract:** For a finite graph, it is a Ramanujan graph if and only if its graph zeta function satisfies the Riemann Hypothesis.

However, both concepts (Ramanujan-ness and zeta functions) are not well-defined for high dimensional complexes.

In this talk, we would define Ramanujan properties and geometric zeta functions on complexes of type An. Besides, we will discuss the relation between Ramanujan properties and Riemann Hypothesis of geometric zeta functions.

**Speaker:** Shai Evra

**Title:** Topological expanders

**Abstract:** A classical result of Boros-Furedi (for d=2) and Barany (for d>=2) from the 80's, asserts that given any n points in R^d, there exists a point in R^d which is covered by a constant fraction (independent of n) of all the geometric (=affine) d-simplices defined by the n points. In 2010, Gromov strengthen this result, by allowing to take topological d-simplices as well, i.e. drawing continuous lines between the n points, rather then straight lines and similarly continuous simplices rather than affine.

Gromov changed the perspective of these questions, by considering the above results as a result about geometric/topological expansion properties of the complete d-dimensional simplicial complex on n

vertices. He asked whether there exits bounded degree simplicial complexes with the above topological properties, i.e. "bounded degree topological expanders".
This question was answer affirmatively for dimension d=2, by Kaufman, Kazhdan and Lubotzky. By extending the method of proof of Kaufman, Kazhdan and Lubotzky, we gave a solution to the general problem, showing that the (d-1)-skeletons of the d-dimensional Ramanujan complexes give bounded degree topological expanders.
This is a joint work with Tali Kaufman.

**Speaker:** Anna Gundert

**Title:** High-dimensional Theta Numbers

**Abstract:** The celebrated Lovász theta number of a graph is a semidefinite programming upper bound for the independence number of a graph.
This talk presents a generalization of the theta number to higher-dimensional simplicial complexes and, based on this notion, a hierarchy of semidefinite relaxations for the independence number of a graph.
We will then consider the behavior of these higher-dimensional theta numbers for random complexes and graphs.
(Joint work with Christine Bachoc)

**Speaker:** Sayan Mukherjee

**Title:** Learning Group Actions and the Geometry of Synchronization Problems

**Abstract:** Authors: Jacek Brodzki, Tingran Gao, and Sayan Mukherjee
Synchronization problems arise in applications in computer vision, molecular chemistry, and global shape matching. Essentially, the synchronization problem is a generalization to the non-commutative setting of the little Grothendieck problem; the latter has found many applications, including graph MAX-CUT and cut-norm approximation. In this work, we reformulate the synchronization problem in a general group representation framework, drawing analogy from holonomy and non-commutative geometry to build a “twisted” Hodge theory on simplicial complexes. We present a unified treatment, as well as cohomological interpretations, of the various Cheeger-type inequalities established in the analysis of the connection Laplacian. Furthermore, we formulate a new class of statistical inference problems closely related to synchronization, that allow for the inference of group actions from observations; we also propose a message-passing algorithm to tackle such problems and demonstrate its applicability in practice.

**Speaker:** Amitay Kamber

**Title:** Hecke Algebras and High Dimensional Expanders

**Abstract:** We show how the graph expander property is related to the behavior of $L_{p}$ functions on the covering tree. This allows us to define high dimensional expander complexes, constructed as quotients of buildings.

**Speaker:** Izhar Oppenheim

**Title:** Cohomologies with coefficients in Banach representations for groups acting on buildings

**Abstract:** The classical group theoretical constructions of expanders relied on notions such as property (T) or property tau regarding properties of unitary representations of a group on Hilbert spaces. In the last decade there has been much work on generalizing these notions to the more general setting of group representations in Banach spaces.
A major result in this direction was achieved by V. Lafforgue, who showed that a special linear group (with dimension strictly larger than 2) on a non archimedian local field has a very strong notion of

Banach property (T) with respect to a large class of Banach spaces. An application of this fact was the construction of Banach expanders.

In my lecture I will discuss how to recover some of Lafforgue's results for a BN-pair group acting on a building using new considerations relying on the building geometry and how to use these same considerations to deduce new results concerning the vanishing of higher cohomologies with coefficients in Banach representations (which can be thought of high dimensional analogues of Banach property (T).

**Speaker:** Ron Rosenthal

**Title:** On groups and simplicial complexes

**Abstract:** We will discuss a new framework for constructing high-dimensional simplicial complexes as quotient of a certain group, thus generalizing the notion of Schreier graphs.

The quotients obtained in this way are not always simplicial complexes in the strict sense, but rather multicomplexes. However, the approach enables one in principle to build systematically all finite $k$-regular complexes (and multicomplexes). Based on a joint work with Alex Lubotzky and Zur Luria.

**Speaker:** Konstantin Golubev

**Title:** On the Chromatic Number of a Hypergraph

**Abstract:** The chromatic number of a hypergraph is the minimal number of colors needed to color the vertices in such a way that no edge is monochromatic. We will present a spectral bound on the chromatic number of a hypergraph, and show some applications to it. In particular, we will show that the Ramanujan complexes (which generalize LPS graphs) have large chromatic number.

Joint work with S. Evra and A. Lubotzky.

**Speaker:** Michael Farber

**Title:** Multi-parameter random simplicial complexes

**Abstract:** In the talk I shall discuss a model of random simplicial complexes generalising several well-known models.

I will describe the Betti numbers and the fundamental group of these complexes.

I shall also examine the validity of a probabilistic version of the Whitehead conjecture about aspherical 2-complexes.

This is a joint work with Armindo Costa.