

# EXCILL 3: Schedule

## Monday, August 8th, 2016

8am-9am:	Tea/Coffee
9am-9:35am	Alon: Generalized Turan-type problems for graphs
9:40am-10:15am	Nikiforov: The $p$ -spectral radius and the spectral $p$ -norm of hypergraphs and hypermatrices
10:15am-10:45am	Break
10:45am-11:20am	Kohayakawa: Parameter estimation for monotone graph properties
11:25am-12pm	Suk: On the Erdős-Szekeres convex polygon problem
12pm-2pm	Lunch break
2pm-2:35pm	Stiebitz: Brooks' Theorem and Beyond
2:40pm-3:15pm	Zhu: Defective online list colouring of planar graphs
3:15pm-3:45pm	Break
3:45pm-4:20pm	Haxell: Stability in hypergraph matching and transversal problems
4:25pm-5pm	Pikhurko: König's Line Coloring and Vizing's Theorems for Graphings
5:30pm-7pm	Poster Session

## Tuesday, August 9th, 2016

8am-9am	Tea/Coffee
9am-9:35am	Scott: Induced subgraphs of graphs with large chromatic number
9:40am-10:15am	Chudnovsky: Approximately coloring graphs without long induced paths
10:15am-10:45am	Break
10:45am-11:20am	Yu: On the Kelmans-Seymour conjecture
11:25am-12pm	Norin: Extremal properties of minor-closed classes of graphs
12pm-2pm	Lunch break
2pm-2:35pm	Conlon: Universality-type results in random graphs
2:40pm-3:15pm	Fox: A tight bound for Green's arithmetic triangle removal lemma
3:15pm-3:45pm	Break
3:45pm-4:20pm	Keevash: Counting designs
4:25pm-5pm	Furedi: On Erdős' conjecture on pentagonal edges and on other graphs
5pm-6pm	Break/Discussion/Conference Photo
6pm-8pm	Conference Dinner (Hermann Hall)

## Wednesday, August 10th, 2016

8am-9am	Tea/Coffee
9am-9:35am	Frieze: On the insertion time of random walk cuckoo hashing
9:40am-10:15am	Steger: Symmetric and asymmetric Ramsey properties in random hypergraphs
10:15am-10:45am	Break
10:45am-11:20am	Kuhn: A blow-up lemma for approximate decompositions
11:25am-12pm	Osthus: On the decomposition threshold of a graph
12pm-2pm	Lunch break
2pm-2:35pm	Verstraete: On a generalized Turán problem
2:40pm-3:15pm	Molla: Perfect triangle-tilings
3:15pm-3:45pm	Break
3:45pm-4:20pm	Lidicky: Decomposing random $r$ -regular graphs into stars
4:25pm-5pm	Kierstead: Recent results on disjoint cycles and equitable coloring

# EXCILL 3: Talk and Poster Abstracts

## Invited Talks (MTCC Auditorium)

Monday, August 8th

**Time:** 9am-9:35am

**Speaker:** Noga Alon, Tel Aviv University

**Title:** Title: Generalized Turan-type problems for graphs

**Abstract:** What is the maximum possible number of copies of a graph  $T$  in an  $H$ -free graph on  $n$  vertices? When  $T$  is a single edge, this is the main subject of extremal graph theory starting with the theorems of Mantel and Turan. I will describe several results and questions arising in the study of the general question, and consider several variants including its sparse random version.

Based on joint work with Shikhelman and with Kostochka and Shikhelman.

**Time:** 9:40am-10:15am

**Speaker:** Vladimir Nikiforov, University of Memphis

**Title:** The  $p$ -spectral radius and the spectral  $p$ -norm of hypergraphs and hypermatrices

**Abstract:** This talk outlines some extremal results about the  $p$ -spectral radius and the spectral  $p$ -norm of hypergraphs and hypermatrices. It will be shown that these parameters can be used to extend many results of classical extremal graph theory and to provide analytic tools for extremal hypergraph theory.

On the other hand, some new combinatorial concepts can be applied to extend classical extremal results about the spectral  $p$ -norm of hypermatrices. Two such applications will be shown: strengthening an inequality of Hardy, Littlewood, and Polya, and extending a result of Banach.

**Time:** 10:45am-11:20am

**Speaker:** Yoshiharu Kohayakawa, University of Sao Paulo

**Title:** Parameter estimation for monotone graph properties

**Abstract:** Let  $z$  be a graph parameter, that is, a real function defined on the set of finite graphs that is invariant under graph isomorphisms. Certain graph parameters are said to be estimable, as they may be estimated by sampling a randomly chosen induced subgraph whose order is independent of the order of the graph. The sample complexity of an estimable parameter  $z$  is the order of the random subgraph required to ensure that the value of  $z(G)$  may be estimated within a given error with high probability.

We discuss the sample complexity of two graph parameters associated with monotone graph properties and obtain improved bounds by making use of Jacob Fox's bounds on the graph removal lemma. We observe that any graph that satisfies a monotone property  $\mathcal{P}$  may be partitioned equitably into a 'small', constant number of classes in such a way that the cluster

graph induced by the partition is not far from satisfying a natural weighted graph generalization of  $\mathcal{P}$ . We call properties for which this holds recoverable, and we suggest that the study of recoverable properties might be of independent interest.

This is joint work with C. Hoppen (Porto Alegre), R. Lang (Santiago), H. Lefmann (Chemnitz) and H. Stagni (Sao Paulo).

**Time:** 11:25am-12pm

**Speaker:** Andrew Suk, University of Illinois at Chicago

**Title:** On the Erdos-Szekeres convex polygon problem

**Abstract:** Let  $ES(n)$  be the smallest integer such that any set of  $ES(n)$  points in the plane in general position contains  $n$  points in convex position. In their seminal 1935 paper, Erdos and Szekeres showed that  $ES(n) \leq \binom{2n-4}{n-2} + 1 = 4^{n-o(n)}$ . In 1960, they showed that  $ES(n) \geq 2^{n-2} + 1$  and conjectured this to be optimal. Despite the efforts of many researchers, no improvement in the order of magnitude has been made on the upper bound over the last 81 years. In this talk, we will sketch a proof showing that  $ES(n) = 2^{n+o(n)}$ . We will also discuss several related open problems including a higher dimensional variant, and on mutually avoiding sets.

**Time:** 2:00pm-2:35pm

**Speaker:** Michael Stiebitz, Technische Universität Ilmenau, Germany

**Title:** Brooks' Theorem and Beyond

**Abstract:** Using a sequential coloring argument is it easy to show that every graph  $G$  satisfies

$$\chi(G) \leq \text{col}(G) \leq \Delta(G) + 1.$$

Here  $\chi(G)$  is the chromatic number of  $G$ ,  $\text{col}(G) = 1 + \max_{H \subseteq G} \delta(H)$  is the coloring number of  $G$ ,  $\delta(G)$  is the minimum degree of  $G$ , and  $\Delta(G)$  is the maximum degree of  $G$ , respectively. Brooks' theorem characterizes the graphs  $G$  satisfying  $\chi(G) = \Delta(G) + 1$  and is among the most fundamental theorems in graph coloring.

In the talk we consider connectivity parameters of graphs. For a graph  $G$  let  $\lambda(G)$  and  $\kappa(G)$  denote that maximum local edge connectivity and the maximum local connectivity of  $G$ , respectively. Clearly, every graph  $G$  satisfies  $\lambda(G) \leq \kappa(G)$ . By a result of Mader it follows that every graph  $G$  satisfies

$$\chi(G) \leq \text{col}(G) \leq \lambda(G) + 1 \leq \kappa(G) + 1 \leq \Delta(G) + 1.$$

In the talk we shall discuss a characterization for the class of graphs  $G$  satisfying  $\chi(G) = \lambda(G) + 1$ . This characterization leads to a polynomial algorithm that finds for every graph  $G$  a coloring with  $\lambda(G)$  colors or shows that no such coloring exists. This provides a positive answer to a conjecture due to Albouker, Brettell, Havet, Marx, and Trotignon

**Time:** 2:40pm-3:15pm

**Speaker:** Xuding Zhu, Zhejiang Normal University

**Title:** Defective online list colouring of planar graphs

**Abstract:** Given an integer  $k$ , the  $d$ -defective  $k$ -painting game on  $G$  is played by two players: Lister and Painter. Initially, each vertex has  $k$  tokens and is uncoloured. In each round, Lister chooses a set  $M$  of uncoloured vertices and removes one token from each chosen vertex. Painter colours a subset  $X$  of  $M$  which induces a subgraph  $G[X]$  of maximum degree at most  $d$ . Lister wins the game if at the end of some round, a vertex  $v$  has no more tokens left, and is uncoloured. Otherwise, at some round, all vertices are coloured and Painter wins. We say  $G$  is  $d$ -defective  $k$ -paintable if Painter has a winning strategy in this game. We have the following results on this problem:

- Every planar graph is 3-defective 3-paintable, and this result is sharp, as there are planar graphs that are not 2-defective 3-paintable. (In contrary to the online case, it is known that every planar graph is 2-defective 3-choosable.)
- Every outerplanar graph is 2-defective 2-paintable, and this result is sharp.
- Every planar graph is 2-defective 4-paintable. We do not know if this is sharp. It is known that every planar graph is 1-defective 4-choosable.
- Every planar graph is 1-defective  $(9, 2)$ -paintable.

The talk contains joint work with Grzegorz Gutowski, Ming Han and Tomasz Krawczyk.

**Time:** 3:45pm-4:20pm

**Speaker:** Penny Haxell, University of Waterloo

**Title:** Stability in hypergraph matching and transversal problems

**Abstract:** We consider stability versions of certain hypergraph matching and transversal results that are known to be best possible in general, and discuss some of their consequences. For example, every  $r$ -regular tripartite hypergraph with  $n$  vertices in each class has a matching of size at least  $n/2$ , and this is tight. We show that those hypergraphs with matching size close to  $n/2$  are close in structure to the extremal configuration.

**Time:** 4:25pm-5pm

**Speaker:** Oleg Pikhurko, University of Warwick

**Title:** König's Line Coloring and Vizing's Theorems for Graphings

**Abstract:** The classical theorem of Vizing states that every graph of maximum degree  $d$  admits an edge-coloring with at most  $d+1$  colors. Furthermore, as it was earlier shown by König,  $d$  colors suffice if the graph is bipartite.

We discuss the existence of measurable edge-colorings for graphings. A graphing is an analytic generalization of a bounded-degree graph that appears in various areas, such as sparse graph limits, orbit equivalence theory and measurable group theory. We show that every graphing of maximum degree  $d$  admits a measurable edge-coloring with  $d+o(d)$  colors; furthermore, if the graphing has no odd cycles, then  $d+1$  colors suffice. In fact, if a certain conjecture about finite graphs that strengthens Vizing's theorem is true, then our method will show that  $d+1$  colors are always enough.

Joint work with Endre Csoka and Gabor Lippner

## Tuesday, August 9th

**Time:** 9am-9:35am

**Speaker:** Alex Scott, University of Oxford

**Title:** Induced subgraphs of graphs with large chromatic number

**Abstract:** Let  $G$  be a graph with large chromatic number. What induced subgraphs must it contain? It may contain a large complete subgraph, but what can we say if this is not the case? We shall discuss some old questions and new results on this topic. (Joint work with Maria Chudnovksy and Paul Seymour.)

**Time:** 9:40am-10:15am

**Speaker:** Maria Chudnovsky, Princeton University

**Title:** Approximately coloring graphs without long induced paths

**Abstract:** It is an open problem whether the 3-coloring problem can be solved in polynomial time in the class of graphs that do not contain an induced path on  $t$  vertices, for fixed  $t \geq 8$ . In this talk we present a polynomial time algorithm that, given a 3-colorable graph with no induced  $t$ -vertex path constructs a coloring with at most  $\max(5, t-2)$  colors. This result can also be stated as a polynomial time algorithm that given a graph  $G$  with no induced path of length  $t$  either determines that  $G$  is not 3-colorable, or outputs a coloring with at most  $\max(5, t-2)$  colors. This is joint work with Oliver Schaudt, Sophie Spirkl, Maya Stein, and Mingxian Zhong.

**Time:** 10:45am-11:20am

**Speaker:** Xingxing Yu, Georgia Tech

**Title:** On the Kelmans-Seymour conjecture

**Abstract:** Seymour and, independently, Kelmans conjectured that every 5-connected non-planar graph contains a subdivision of  $K_5$ . We have recently proved this conjecture. I will give a sketch of our proof, and mention several related problems. Joint work with D. He and Y. Wang

**Time:** 11:25am-12pm

**Speaker:** Sergey Norin, McGill University

**Title:** Extremal properties of minor-closed classes of graphs

**Abstract:** We will survey recent extremal results in graph minor theory, including bounds on the number of edges necessary to guarantee a given 2-regular graph as a minor, bounds for the bootstrap percolation on graphs in minor-closed classes, and rationality of densities of minor-closed families of graphs. Based on joint work with E. Csoka, I. Lo, H. Wu and L. Yepremyan, with Z. Dvorak and with R. Kapadia, respectively.

**Time:** 2:00pm-2:35pm

**Speaker:** David Conlon, University of Oxford

**Title:** Universality-type results in random graphs

**Abstract:** A graph is said to be  $(n, \Delta)$ -universal if it contains every graph on  $n$  vertices with maximum degree at most  $\Delta$ . In this talk, we will discuss the question of determining the range of  $p$  for which the binomial random graph  $G(N, p)$  with  $N = O(n)$  is a.a.s.  $(n, \Delta)$ -universal. We will also discuss the related problem of determining when the binomial random graph is  $(n, \Delta)$ -Ramsey-universal, that is, such that every two-colouring of the edges of the graph contains a monochromatic copy of every graph on  $n$  vertices with maximum degree at most  $\Delta$ , and discuss its implications for the size-Ramsey number of bounded-degree graphs. This talk touches upon joint work with Rajko Nenadov and with Asaf Ferber, Rajko Nenadov and Nemanja Skoric.

**Time:** 2:40pm-3:15pm

**Speaker:** Jacob Fox, Stanford University

**Title:** A tight bound for Green's arithmetic triangle removal lemma

**Abstract:** Let  $p$  be a fixed prime. A triangle in  $\mathbb{F}_p^n$  is an ordered triple  $(x, y, z)$  of points satisfying  $x + y + z = 0$ . Let  $N = p^n = |\mathbb{F}_p^n|$ . Green proved an arithmetic triangle removal lemma which says that for every  $\epsilon > 0$  and prime  $p$ , there is a  $\delta > 0$  such that if  $X, Y, Z \subset \mathbb{F}_p^n$  and the number of triangles in  $X \times Y \times Z$  is at most  $\delta N^2$ , then we can delete  $\epsilon N$  elements from  $X, Y$ , and  $Z$  and remove all triangles. Green posed the problem of improving the quantitative bounds on the arithmetic triangle removal lemma, and, in particular, asked whether a polynomial bound holds. Despite considerable attention, prior to this work, the best known bound, showed that  $1/\delta$  can be taken to be an exponential tower of twos of height logarithmic in  $1/\epsilon$ .

We solve Green's problem, proving an essentially tight bound for arithmetic triangle removal lemma in  $\mathbb{F}_p^n$ . We show that a polynomial bound holds, and further determine the best possible exponent. Namely, there is a computable number  $C_p$  such that we may take  $\delta = (\epsilon/3)^{C_p}$ , and we must have  $\delta \leq \epsilon^{C_p - o(1)}$ . In particular,  $C_2 = 1 + 1/(5/3 - \log_2 3) \approx 13.239$ , and  $C_3 = 1 + 1/c_3$  with  $c_3 = 1 - \frac{\log b}{\log 3}$ ,  $b = a^{-2/3} + a^{1/3} + a^{4/3}$ , and  $a = \frac{\sqrt{33}-1}{8}$ , which gives  $C_3 \approx 13.901$ . The proof uses Kleinberg, Sawin, and Speyer's essentially sharp bound on multicolored sum-free sets, which builds on the recent breakthrough on the cap set problem by Croot-Lev-Pach, and the subsequent work by Ellenberg-Gijswijt, Blasiak-Church-Cohn-Grochow-Umans, Alon, and Naslund. This is joint work with Lszl Mikls Lovsz.

**Time:** 3:45pm-4:20pm

**Speaker:** Peter Keevash, University of Oxford

**Title:** Counting designs

**Abstract:** A Steiner Triple System on a set  $X$  is a collection  $T$  of 3-element subsets of  $X$  such that every pair of elements of  $X$  is contained in exactly one of the triples in  $T$ . An example considered by Plücker in 1835 is the affine plane of order three, which consists of 12 triples on a set of 9 points. Plücker observed that a necessary condition for the existence of a Steiner Triple System on a set with  $n$  elements is that  $n$  be congruent to 1 or 3 mod 6. In 1846, Kirkman showed that this necessary condition is also sufficient. In 1974, Wilson conjectured

an approximate formula for the number of such systems. We will outline a proof of this conjecture, and a more general estimate for the number of Steiner systems. Our main tool is the technique of Randomised Algebraic Construction, which we introduced to resolve a question of Steiner from 1853 on the existence of designs.

**Time:** 4:25pm-5pm

**Speaker:** Zoltán Füredi, Rényi Institute of Mathematics, Budapest, Hungary

**Title:** On Erdős' conjecture on pentagonal edges and on other graphs

**Abstract:** Erdős, Faudree, and Rousseau (1992) showed that a graph on  $n$  vertices and at least  $\lfloor n^2/4 \rfloor + 1$  edges has at least  $2\lfloor n/2 \rfloor + 1$  edges in triangles. To see that this result is sharp, consider the graph obtained by adding one edge to the larger side of the complete bipartite graph  $K_{\lfloor n/2 \rfloor, \lfloor n/2 \rfloor}$ .

In this talk, we give an asymptotic formula for  $h(n, e, K_3)$ , the minimum number of edges contained in triangles in a graph having  $n$  vertices and  $e$  edges, where  $e > n^2/4$  arbitrary.

The main tool of the proof is a generalization of Zykov's symmetrization method that can be applied for several graphs simultaneously. We apply our weighted symmetrization method to tackle Erdős' conjecture concerning the minimum number of edges on 5-cycles.

We further extend our results to give an asymptotic formula for  $h(n, e, F) :=$  the minimum number of  $F$ -edges in an  $(n, e)$ -graph when  $n \rightarrow \infty$  and  $F$  is a given 3-chromatic graph. Many problems remain open.

This is a joint work with Zeinab Maleki (Isfahan University of Technology, Isfahan, Iran).

## Wednesday, August 10th

**Time:** 9am-9:35am

**Speaker:** Alan Frieze, Carnegie-Mellon University

**Title:** On the insertion time of random walk cuckoo hashing

**Abstract:** Cuckoo Hashing is a hashing scheme invented by Pagh and Rodler. It uses  $d=2$  distinct hash functions to insert items into the has table. It has been an open question as to the expected time for Random Walk Insertion to add items. We show that if the number of hash functions  $d=O(1)$  is sufficiently large, then the expected insertion time is  $O(1)$  per item.

Joint with Tony Johansson

**Time:** 9:40am-10:15am

**Speaker:** Angelika Steger, ETH Zrich

**Title:** Symmetric and asymmetric Ramsey properties in random hypergraphs

**Abstract:** A celebrated result of Rödl and Ruciński states that for every graph  $F$ , which is not a forest of stars and paths of length 3, and fixed number of colors  $r$  there exist positive constants  $c, C$  such that for  $p \leq cn^{-1/m_2(F)}$  the probability that every coloring of the edges of the random graph  $G(n, p)$  contains a monochromatic copy of  $F$  is  $o(1)$  (the "0-statement"), while for  $p \geq Cn^{-1/m_2(F)}$  it is  $1 - o(1)$  (the "1-statement"). Here  $m_2(F)$  denotes the so called 2-density of  $F$ . On the other hand, the case where  $F$  is a forest of stars and paths of length

3 has a coarse threshold which is determined by the appearance of certain small subgraphs in  $G(n, p)$ .

Recently, the natural extension of the 1-statement of this theorem to  $k$ -uniform hypergraphs was proved by Conlon and Gowers and, independently, by Friedgut, Rödl and Schacht. In particular, they showed an upper bound of order  $n^{-1/m_k(F)}$  for the 1-statement, where  $m_k(F)$  denotes the  $k$ -density of  $F$ . Similarly as in the graph case, it is known that the threshold for star-like hypergraphs is given by the appearance of small subhypergraphs. Surprisingly, we show that another type of thresholds exists if  $k \geq 4$ : there are  $k$ -uniform hypergraphs for which the threshold is determined by the so-called asymmetric Ramsey problem in which a different hypergraph has to be avoided in each colour-class.

Along the way we obtain a general bound on the 1-statement for asymmetric Ramsey properties in random hypergraphs. This extends the work of Kohayakawa and Kreuter and Kohayakawa, Schacht, and Spöhel who showed the similar result in the graph case.

**Time:** 10:45am-11:20am

**Speaker:** Daniela Kuhn, Birmingham University

**Title:** A blow-up lemma for approximate decompositions

**Abstract:** Questions on packings and decompositions have a long history, going back to the 19th century. For instance, the existence of Steiner triple systems (proved by Kirkman in 1847) corresponds to a decomposition of the edge set of the complete graph  $K_n$  on  $n$  vertices into triangles (if  $n$  satisfies the necessary divisibility conditions). There are several beautiful conjectures which have driven a large amount of research in this area. A prime example is the tree packing conjecture of Gyárfás and Lehel, which would guarantee a decomposition of a complete graph into a suitable given collection of trees. We develop a new tool for constructing approximate decompositions of dense quasirandom graphs into bounded degree graphs. Our result can be viewed as an extension of the classical blow-up lemma of Komlós, Sárközy and Szemerédi to the setting of approximate decompositions. I will discuss this tool and some of its applications. (Joint work Jaehoon Kim, Deryk Osthus and Mykhaylo Tyomkyn)

**Time:** 11:25am-12pm

**Speaker:** Deryk Osthus, Birmingham University

**Title:** On the decomposition threshold of a graph

**Abstract:** A fundamental theorem of Wilson states that, for every graph  $F$ , every sufficiently large  $F$ -divisible clique has an  $F$ -decomposition. Here a graph  $G$  has an  $F$ -decomposition if the edges of  $G$  can be covered by edge-disjoint copies of  $F$  and  $F$ -divisibility is a trivial necessary condition for this. We extend Wilson's theorem to graphs which are allowed to be far from complete. In particular, we determine the 'decomposition threshold' for arbitrary bipartite graphs  $F$ . For general graphs  $F$  we reduce the decomposition threshold to at most 3 possible values.

Our main contribution is a general "iterative absorption" method which turns an approximate or fractional decomposition into an exact one. Our results are also connected to the question of when a partially completed Latin square can be extended to a full one. (This covers joint work with Ben Barber, Stefan Glock, Allan Lo, Richard Montgomery, Deryk Osthus and Amelia Taylor.)



**Time:** 2:00pm-2:35pm

**Speaker:** Jacques Verstraete, University of California San Diego

**Title:** On a generalized Turán problem

**Abstract:** The study of Turán numbers  $\text{ex}(n, F)$  given a family  $F$  of bipartite graphs is one of the central topics in combinatorics. In this talk we discuss the associated quantity  $\text{ex}(G, F)$ , which is the maximum number of edges in an  $F$ -free subgraph of a graph  $G$ . We refer to this as a generalized Turán problem. In particular, we prove for wide classes of graphs  $F$  that if  $\text{ex}(d, F) = \Theta(d^\alpha)$  then every  $d$ -regular graph has a spanning  $F$ -free subgraph of minimum degree  $\Omega(d^\alpha)$ , which is tight up to a constant factor. This answers a conjecture of Krivelevich, Foucaud, and Perarnau for such graphs  $F$ .

Joint work with Mike Molloy and Benny Sudakov

**Time:** 2:40pm-3:15pm

**Speaker:** Theo Molla, University of Illinois Urbana-Champaign

**Title:** Perfect triangle-tilings

**Abstract:** A perfect triangle-tiling is a collection of vertex disjoint copies of the complete graph on three vertices that covers every vertex. The Corrdi-Hajnal theorem, a fundamental result in the area, implies that a graph on  $3k$  vertices with minimum degree  $2k$  contains a perfect triangle-tiling. In this talk, we will discuss analogues of the Corrdi-Hajnal theorem in various settings.

**Time:** 3:45pm-4:20pm

**Speaker:** Bernard Lidicky, Iowa State University

**Title:** Decomposing random  $r$ -regular graphs into stars

**Abstract:** In 2006 Barat and Thomassen conjectured that every planar 4-regular 4-edge-connected graph has an edge decomposition into claws; shortly after, Lai constructed a counterexample. Recently, Delcourt and Postle showed that a random 4-regular graph has an edge decomposition into claws a.a.s.. We generalize the result to decomposition of  $r$ -regular graphs into stars. We use the small subgraph conditioning method of Robinson and Wormald. This is joint work with Delcourt and Postle.

**Time:** 4:25pm-5pm

**Speaker:** Hal Kierstead, Arizona State University

**Title:** Recent results on disjoint cycles and equitable coloring

**Abstract:** I will discuss recent results with Kostochka, McConvey, Molla, and Yeager extending the Corrdi-Hajnal Theorem and the Hajnal-Szemerdi theorem. The goal is not only to strengthen and prove analogs of these theorems in various settings, but also to develop a theory strong enough to attack the Chen-Lih-Wu conjecture that if a  $t$ -colorable graph  $G$  with maximum degree at most  $t$  has no equitable  $t$ -coloring, then  $G$  contains  $K_{t,t}$  and  $t$  is odd. Along the way we answer a question of Dirac and strengthen results of Dirac and Erdős from the sixties.

## Posters (Monday, 5:30-7:00pm, August 8th, MTCC Ballroom)

**Speaker:** Andrii Arman, University of Manitoba

**Title:** Maximal size of a  $k$ -uniform intersecting hypergraph with cover number  $k$

**Abstract:** A  $k$ -uniform hypergraph  $\mathcal{F}$  is called *intersecting hypergraph* iff any two edges of  $\mathcal{F}$  have a non-empty intersection. A subset  $C$  of vertices of  $\mathcal{F}$  is called a *cover* (or a *transversal*) if every edge of  $\mathcal{F}$  has a non-empty intersection with  $C$ . The *cover number* of  $\mathcal{F}$  is the number of vertices in the smallest cover of  $\mathcal{F}$ . Define  $r(k)$  to be the maximal size of intersecting hypergraph  $\mathcal{F}$  with a cover number  $k$ .

In 1975, Erdős and Lovász proved that  $r(k)$  is at most  $k^k$ . In 1994, Tuza improved the upper bound by a constant factor. I will outline the proof of a new upper bound which is of the order  $k^{k-1}$ . This is a joint work with Troy Retter.

**Speaker:** Alexander Cameron, UIC

**Title:** Extremal Problems on Directed Hypergraphs: Forbidden Subgraphs with Two Edges

**Abstract:** A  $(k \rightarrow 1)$ -uniform directed hypergraph,  $H = (V, E)$ , is a  $(k + 1)$ -uniform hypergraph where the vertices of each edge is partitioned into a tail set of size  $k$  and a head set of size 1. In other words, each edge is a pointed set of  $k + 1$  vertices. For a given directed hypergraph,  $F$ , define the extremal number,  $\text{ex}(n, F)$ , as the maximum number of edges that a directed hypergraph on  $n$  vertices can have without containing a copy of  $F$  as a (not necessarily induced) subgraph. When  $k = 2$ , I have determined all extremal numbers of the form  $\text{ex}(n, I)$  where  $I$  represents a directed hypergraph with exactly two edges. In many cases, the set of extremal constructions up to isomorphism can be determined completely. Additionally, I have found upper and lower bounds on the extremal numbers for graphs with exactly two edges for general  $k$ .

**Speaker:** Michelle Delcourt, UIUC

**Title:** Intersecting Families of Permutations

**Abstract:** Enumerating families of combinatorial objects with given properties and describing the typical structure of these objects are fundamental problems in extremal combinatorics. We focus in particular on the structure of  $t$ -intersecting families of permutations on  $[n]$  and explore the structure of intersecting families in a variety of other settings. Main tools include generalizations of the Bollobas set-pairs inequality and Ellis's stability theorem for intersecting families of permutations. This is joint work with Jzsef Balogh, Shagnik Das, Hong Liu, and Maryam Sharifzadeh.

**Speaker:** Colin Desmarais, University of Manitoba

**Title:** Constructions for lower bounds of extremal numbers for small hypergraphs

**Abstract:** This poster outlines constructions of 3-uniform hypergraphs attaining the best known lower bounds for the number of hyperedges in  $K^3(2, 2, 3)$  and  $K^3(2, 2, 2)$ -free hypergraphs. These constructions rely on finite geometries.

**Speaker:** Miaomiao Han, West Virginia University

**Title:** Neighbor sum distinguishing total coloring of graphs with bounded treewidth

**Abstract:** A proper total  $k$ -coloring  $\phi$  of a graph  $G$  is a mapping from  $V(G) \cup E(G)$  to  $\{1, 2, \dots, k\}$  such that no adjacent or incident elements in  $V(G) \cup E(G)$  receive the same color. Let  $m_\phi(v)$  denote the sum of colors on the edges incident with vertex  $v$  and the color on vertex  $v$ . A proper total  $k$ -coloring of  $G$  is called neighbor sum distinguishing if  $m_\phi(u) \neq m_\phi(v)$  for each edge  $uv \in E(G)$ . Let  $\chi_\Sigma^t(G)$  be the neighbor sum distinguishing total chromatic number of a graph  $G$ . Pilśniak and Woźniak conjectured that for any graph  $G$ ,  $\chi_\Sigma^t(G) \leq \Delta(G) + 3$ . In this paper, we show that if  $G$  is a graph with treewidth  $l \geq 3$  and  $\Delta(G) \geq 2l + 3$ , then  $\chi_\Sigma^t(G) \leq \Delta(G) + l - 1$ . This upper bound confirms the conjecture for graphs with treewidth 3 and 4. Furthermore, when  $l = 3$ , we show that  $\Delta(G) + 1 \leq \chi_\Sigma^t(G) \leq \Delta(G) + 2$  and characterize graphs with equalities.

**Speaker:** David Hannasch, UIUC (CS)

**Title:** Posets with the maximum number of linear extensions

**Abstract:** We define the number of edges of a poset by representing it as a directed acyclic graph. Fishburn and Trotter went looking for the posets with the maximum number of linear extensions for a given number of edges, but only have results up to  $2n-3$  edges. Fishburn and Trotter did prove that all optimal posets fall into a class of posets called semiorders. We identify three small classes of posets, all defined as modifications of complete bipartite graphs: a complete bipartite overlaid with a star, and two categories of “peeled bipartite,” removing edges from a single vertex at a time, chosen from the larger or the smaller partite set. We claim that every optimal poset falls into one of these three classes.

**Speaker:** Laars Helenius, University of Western Michigan

**Title:** Weak and Strong Versions of the 1-2-3 Conjecture For Uniform Hypergraphs

**Abstract:** Given an  $r$ -uniform hypergraph  $H = (V, E)$  and a weight function  $\omega : E \rightarrow 1, \dots, w$ , a coloring of vertices of  $H$ , induced by  $\omega$ , is defined by  $c(v) = \sum_{e \ni v} \omega(e)$  for all  $v \in V$ . If there exists such a coloring that is strong (that means in each edge no color appears more than once), then we say that  $H$  is strongly  $\omega$ -weighted. Similarly, if the coloring is weak (that means there is no monochromatic edge), then we say that  $H$  is weakly  $w$ -weighted. In this paper, we show that almost all 3 or 4-uniform hypergraphs are strongly 2-weighted (but not 1-weighted) and almost all 5-uniform hypergraphs are either 1 or 2 strongly weighted (with a nontrivial distribution). Furthermore, for  $r \geq 6$  we show that almost all  $r$ -uniform hypergraphs are strongly 1-weighted. We complement these results by showing that almost all 3-uniform hypergraphs are weakly 2-weighted but not 1-weighted and for  $r \geq 4$  almost all  $r$ -uniform hypergraphs are weakly 1-weighted. These results extend a previous work of Addario-Berry, Dalal and Reed for graphs. We also prove general lower bounds and show that there are  $r$ -uniform hypergraphs which are not strongly  $(r^2r)$ -weighted and not weakly 2-weighted. Finally, we show that determining whether a particular uniform hypergraph is strongly 2-weighted is NP-complete.

**Speaker:** Rachel Kirsch, University of Nebraska-Lincoln

**Title:** The Maximum Number of Triangles in a Graph with a Fixed Number of Edges and Maximum Degree

**Abstract:** Extremal problems concerning the number of independent sets or complete subgraphs have been well studied in recent years. Cutler and Radcliffe proved that among graphs with  $n$  vertices and maximum degree at most  $r$ , where  $n = a(r + 1) + b$  with  $0 \leq b \leq r$ ,  $aK_{r+1} \cup K_b$  has the maximum number of complete subgraphs, answering a question of Galvin. Gan, Loh, and Sudakov conjectured that  $aK_{r+1} \cup K_b$  also maximizes the number of complete subgraphs  $K_t$  for each fixed size  $t \geq 3$ , and proved this for  $a = 1$ . Cutler and Radcliffe proved this conjecture for  $r \leq 6$ . We investigate a variant of this problem where we fix the number of edges instead of the number of vertices. We conjecture that  $aK_{r+1} \cup C(b)$ , where  $C(b)$  is the colex graph on  $b$  edges, maximizes the number of triangles among graphs with  $m$  edges and maximum degree  $r$ , where  $m = a\binom{r+1}{2} + b$ ,  $0 \leq b < \binom{r+1}{2}$ . We prove this conjecture for  $r \leq 6$ .

**Speaker:** Gal Kronenberg, Tel Aviv University

**Title:** On MAXCUT in supercritical random graphs, and coloring of random graphs and random tournaments

**Abstract:** We determine the asymptotic behavior of maximum cut in supercritical random graphs  $G(n, (1 + \epsilon)/n)$  as a function of  $\epsilon$ . The argument is based on a theorem of Ding, Lubetzky and Peres, describing the typical structure of the giant component of random graphs in this regime. We then apply this result to prove the following conjecture of Frieze and Pegden. For every  $\epsilon > 0$  there exists  $k_\epsilon$  such that with high probability a random graph  $G(n, (1 + \epsilon)/n)$  is not homomorphic to the cycle on  $2k + 1$  vertices. Finally, we analyze typical coloring properties of biased random tournaments. A  $p$ -random tournament is obtained from the transitive tournament on  $n$  vertices by reversing each edge independently with probability  $p$ . We show that for  $p \sim 1/n$  the chromatic number of a  $p$ -random tournament behaves similarly to that of a random graph with the same edge probability. We use the aforementioned result for MAXCUT in sparse random graphs to treat the supercritical case  $p = (1 + \epsilon)/n$ .

A joint work with Lior Gishboliner and Michael Krivelevich, Tel Aviv University.

**Speaker:** Jiaao Li, West Virginia University

**Title:** Edge-disjoint Spanning Trees and Nowhere-Zero 3-Flow on Highly Essentially Edge-connected Graphs

**Abstract:** Tutte's 3-Flow Conjecture states that every 4-edge-connected graph admits a nowhere-zero 3-flow. Thomasson et al. recently made a breakthrough and they obtained that every 6-edge-connected graph admits a nowhere-zero 3-flow. A graph is  $M_3$ -extendable at a vertex  $v$  if any pre-orientation at  $v$  can be extended to a modulo 3-orientation of  $G$ . An edge cut  $X$  in a connected graph  $G$  is essential if at least two components of  $G - X$  are nontrivial. Kochol showed the 3-Flow Conjecture is equivalent to the statement that every 5-edge-connected essentially 6-edge-connected graph is  $M_3$ -extendable at any vertex of degree 5. By applying the results of Thomasson et al., we prove that a graph admits a nowhere-zero 3-flow provided it contains 4 edge-disjoint spanning trees. Using some density argument, we find a relation between essentially edge-connectivity and number of edge-disjoint spanning trees. Thus, every 5-edge-connected essentially 23-edge-connected graph is  $M_3$ -extendable at any vertex of degree 5.

**Speaker:** Sarah Loeb, UIUC

**Title:** Fractional Separation Dimension

**Abstract:** Given a linear order  $\sigma$  of  $V(G)$ , say that a pair of non-incident edges is *separated* by  $\sigma$  if both vertices of one edge precede both vertices of the other. The *separation dimension* is the minimum size of a set of vertex orders needed to separated every pair of non-incident edges. The *t-separation dimension*  $\pi_t(G)$  of a graph  $G$  is the minimum size of a multiset of vertex orders needed to separate every pair of non-incident edges of  $G$   $t$  times. The *fractional separation dimension*  $\pi_f(G)$  of a graph  $G$  is  $\liminf_t \pi_t(G)/t$ .

We show that every graph has fractional separation dimension at most 3, and equality holds if and only if  $K_4$  is a subgraph. On the other hand, we show there are triangle-free graphs with fractional separation dimension arbitrarily close to 3 by showing  $\pi_f(K_{m,m}) = \frac{3m}{m+1}$ . Finally, we show that the fractional separation dimension of every forest is less than  $\sqrt{2}$ . This is joint work with Douglas B. West.

**Speaker:** Tamás Mészáros, Freie Universität Berlin

**Title:** A conjecture on shattering-extremal set systems

**Abstract:** We say that a set system  $\mathcal{F} \subseteq 2^{[n]}$  shatters a given set  $S \subseteq [n]$  if

$$\mathcal{F}|_S = \{F \cap S : F \in \mathcal{F}\} = 2^S.$$

One related notion is the VC-dimension of a set system: the size of the largest set shattered by  $\mathcal{F}$ . The Sauer inequality states that in general, a set system  $\mathcal{F}$  shatters at least  $|\mathcal{F}|$  sets. A set system is called shattering-extremal if it shatters exactly  $|\mathcal{F}|$  sets. Such families have many interesting features. Here we present several approaches to study shattering-extremal set systems together with a conjecture about the eliminability of elements from extremal families.

**Speaker:** Jeffrey Mudrock, IIT

**Title:** Using Strong Choosability and Unique Choosability to Bound the List Chromatic Number of the Cartesian Product of Graphs

**Abstract:** The concept of list coloring was introduced independently by Vizing and by Erdős, Rubin, Taylor in the 1970s as a natural generalization of graph coloring. A graph is  $L$ -colorable if there exists a proper coloring  $f$  of  $G$  such that  $f(v) \in L(v)$  for each  $v \in V(G)$  where  $L(v)$  is a list of allowed colors for vertex  $v$ . The list chromatic number of a graph  $G$ , denoted  $\chi_l(G)$ , is the minimum  $k$  such that  $G$  is  $L$ -colorable whenever the list assignment  $L$  satisfies  $|L(v)| \geq k$  for each  $v \in V(G)$ .

A graph  $G$  is called *chromatic choosable* if  $\chi_l(G) = \chi(G)$ . An important question is to find classes of chromatic choosable graphs. We study this question, and more generally the question of bounding list chromatic number, for the Cartesian product of graphs. The list coloring of the Cartesian product of graphs is not well understood. The best result is by Borowiecki, Jendrol, Kral, and Miskuf (2006) who proved that the list chromatic number of the Cartesian product of two graphs can be bounded in terms of the list chromatic number and the coloring number of the factors, implying a bound exponential in the list chromatic

number of the factors. We show how to improve this bound for certain large classes of graphs. A list assignment,  $L$  is called a *bad  $k$ -assignment* for  $G$  if  $G$  is not  $L$ -colorable and  $|L(v)| = k$  for each  $v \in V(G)$ . A list assignment,  $L$ , is called *constant* if  $L(v)$  is the same list for each  $v \in V(G)$ . We call a graph  $G$  *strong  $k$ -chromatic choosable* if its chromatic number is  $k$  and every bad  $(k - 1)$ -assignment for  $G$  is constant. This generalizes the notion of strong critical graphs, introduced by Stiebitz, Tuza, and Voigt in 2008, and, we show, it gives a strictly larger family of graphs that includes odd cycles, cliques, join of a clique with any other such graph, and many more families of graphs.

Our main result gives a sharp bound on choosability of the Cartesian product of a strong  $k$ -chromatic choosable graph and a traceable graph. This result can be applied to find chromatic choosable families of graphs improving the existing bounds on their choosability. The proof uses the notion of unique-choosability as a sufficient condition for list colorability, discovered by Akbari, Mirrokni, and Sadjad in 2006, to set up a loaded inductive statement that guarantees non-unique list colorings. This is joint work with Hemanshu Kaul.

**Speaker:** Luke Nelsen, University of Colorado Denver

**Title:** Monochromatic cycle partitions of graphs with large minimum degree

**Abstract:** Lehel conjectured that in every 2-coloring of the edges of  $K_n$ , there is a vertex disjoint red cycle and blue cycle which span  $V(K_n)$ . Łuczak, Rödl, and Szemerédi proved Lehel’s conjecture for large  $n$ , Allen gave a different proof for large  $n$ , and finally Bessy and Thomassé gave a proof for all  $n$ . Balogh, Barát, Gerbner, Gyárfás, and Sárközy proposed a significant strengthening of Lehel’s conjecture where  $K_n$  is replaced by any graph  $G$  with  $\delta(G) > 3n/4$ ; if true, this minimum degree condition is essentially best possible. They proved that  $\delta(G) > (3/4 + o(1))n$  is sufficient to find cycles which span all but at most  $o(n)$  vertices. DeBiasio and Nelsen proved that their conjecture holds when  $\delta(G) > (3/4 + o(1))n$ . Their proof makes use of the regularity–blow-up method along with notions such as robust expansion and absorbing.

**Speaker:** Martin Rolek, University of Central Florida

**Title:** Graph Minors and Colorings

**Abstract:** A graph  $G$  is double-critical if  $G$  is  $t$ -chromatic, but  $G - u - v$  is  $(t - 2)$ -colorable for any two adjacent vertices  $u, v$  of  $G$ . It is known that any double-critical  $t$ -chromatic graph contains a  $K_t$ -minor for  $t < 9$ , but the proof for  $t = 7, 8$  is computer assisted. Here, a computer-free proof is given for the cases  $t = 7, 8$ , and the result is extended to show that every  $t$ -chromatic double-critical graph contains a  $K_9$ -minor for  $t \geq 9$ . In a separate work, it is shown that any graph not contractible to  $K_8$  minus an edge is 9-colorable. It is hoped that a lemma from this proof will be of use in further showing that any  $K_8$ -minor-free graph is 10-colorable.

**Speaker:** Sergei Tsaturian, University of Manitoba

**Title:** Triangle-free graphs with the maximum number of cycles

**Abstract:** One of the central questions in extremal graph theory is determining maximal possible number of edges in a graph with given number of vertices that doesn’t contain a specific subgraph. Examples of such statements are famous Mantel’s and Turán’s theorems. More

general questions can be considered determining how many copies of some fixed subgraphs (or collections of subgraphs) can be there in a graph that satisfies some conditions. I will talk about some results of that kind. In particular, I will show the result of our recent work with A.Arman and D.Gunderson about maximal number of cycles in a graph that doesnt contain triangles, and discuss possible generalizations and open questions.

**Speaker:** Adam Wagner UIUC

**Title:** Tutorial on the Container Method

**Abstract:** Many important theorems and conjectures in combinatorics can be rephrased as problems about counting independent sets in some specific graphs and hypergraphs. The Container Method, whose basic idea can be traced back to Kleitman-Winston, and has recently been further developed by Balogh-Morris-Samotij and Saxton-Thomason, essentially states that hypergraphs satisfying some natural conditions have very few independent sets. Here I show some recent applications of the method, and try to give an easy recipe containing all the key ideas one needs to know to prove similar results.


















**Speaker:** Rupei Xu, University of Texas at Dallas

**Title:** Parameterization: Bridging Combinatorial Optimization and Extremal Graph Theory

**Abstract:** Although both combinatorial optimization and extremal graph theory are areas dealing with extrema of a function defined in most cases on a finite set, these two areas develop in two different directions due to historical and cultural factors. While combinatorial optimization is developing efficient(exact or approximate)algorithms and heuristics for solving specified types of problems, the extremal graph theory is finding bounds for various graph invariants under some constraints and with constructing extremal graphs. While combinatorial optimization is more popular in operations research, theoretical computer science and all kinds of engineering applications, extremal graph theory is mostly in the domain of mathematics. Could the two different areas benefit to each other? If so, how? In this paper I discuss the interconnections between the two areas with the example of studying the Minimum Rectilinear Steiner Tree Problem. In 1955, Few asked the question what is the minimum steiner tree of  $n$  points in a unit square. 25 years later, Chung and Graham gave a tighter bounded and conjectured that the minimum rectilinear steiner tree of  $n(n \geq 2)$  points in a unit square is bound by  $\sqrt{n} + 1$ , which is still open. However, in combinatorial optimization area, this problem is well studied: the decision version of this problem is NP-complete, it has subexponential time exact algorithm and there exists a polynomial time approximation scheme (PTAS) due to the work of Arora, yet Few's question could not be answered. I will show how the parameterization bridge the two different approaches for this problem and give further analysis.

# EXCILL 3: Location Map

## EXCILL @ IIT

- Conference Proceedings**
-  MTCC
  -  IIT Applied Math Dept.
  -  Hermann Hall
- 
- Nearby Food**
-  Jimmy John's
  -  Starbucks
  -  Ferro's
  -  Dragon Bowl
  -  Rocky's Sports Restaurant
  -  Turtle's Bar & Grill
  -  Cork & Kerry at The Park
- 
- Nearby Parking & Public Transportation**
-  #29 Bus State & 32nd St. Stop (Southbound)
  -  CTA Red Line Sox-35th Station (33rd St. entrance)
  -  CTA Red Line Sox-35th Station (35th St. entrance)
  -  CTA Green Line 35th-Bronzeville-IIT Station
  -  Lot A4 (Metered Parking)
  -  Lot B5 (Metered Parking)
  -  Lot D5 (Metered Parking)

