Thirty-Fifth
Midwestern Conference on Combinatorics and Combinatorial Computing

October 18 - 20, 2024 Duluth, Minnesota

Schedule

Friday, October 18th

4:00	–	5:00	SCC 120	Opening remarks and invited talk by Alison Marr
5:10	–	6:10	SCC 120	Contributed talks
6:10	–		SCC Wedge	Reception

Saturday, October 19th

9:00	–	10:00	SCC 120	Invited talk by Miklos Bona
10:00	–	10:30	SCC 130	Coffee
10:30	–	12:10	SCC 120	Contributed talks
12:10	–	2:00	Duluth!	Lunch
2:00	–	3:00	SCC 120	Invited talk by Jessica McDonald
3:00	–	3:40	SCC 120	Contributed talks
3:40	–	4:10	SCC 130	Coffee
4:10	–	6:10	SCC 120	Contributed talks
6:10	–		SCC Wedge	Reception

Sunday, October 20th

9:00	–	10:00	SCC 120	Invited talk by Edinah Gnang
10:00	–	10:30	SCC 130	Coffee
10:30	–	12:30	SCC 120	Contributed talks

Abstracts

Three puzzles I'm pondering presently

Alison Marr, Southwestern University

4:00pm Friday SCC 120

This talk will briefly discuss three interesting combinatorial problems I'm currently working on with a variety of collaborators. We'll start by discussing a graph labeling question related to directed graphs and a certain magic property. Then, we'll explore a graph coloring question that attempts to create color-balanced neighborhoods. We'll end by playing with dominoes as we attempt to create domino antimagic configurations. There will be opportunities for audience engagement as we all ponder over these fun mathematical puzzles.

Keywords: graph labeling, graph coloring, domino antimagic square

Novel deterministic rotational algorithms for coloring planar graphs

Weiguo Xie, Andrew Bowling, University of Minnesota Duluth*

5:10pm Friday SCC 120

The Four Color Theorem was first posed by Francis Guthrie in 1852, which indicates that any planar graph can be colored with four or fewer such that no two adjacent regions have the same color. Both proving this claim and obtaining a four coloring for an arbitrary graph are nontrivial tasks. We have developed several algorithms based on a systematic rotation method that are entirely deterministic which we have demonstrated to work on a very large number of diverse graphs (over 300 million). These algorithms will be discussed and demonstrated in this paper.

Keywords: four color theorem, Kempe chains, rotational algorithms

Equitable list coloring of sparse graphs

H. A. Kierstead, Arizona State University
Alexandr Kostochka and Zimu Xiang, University of Illinois Urbana–Champaign*

5:30pm Friday SCC 120

If L is a list assignment of k colors to each vertex of an n-vertex graph G, then an *equitable L-coloring* of G is a proper coloring of vertices of G from their lists such that no color is used more than $\lceil n/k \rceil$ times. A graph is *equitably k-choosable* if it has an equitable L-coloring for every k-list assignment L. A multigraph G is *(a,b)-sparse*, if for every nonempty vertex subset A of G, the number of edges induced by A is at most $a|A| + b$. Our main results are that (i) every $(\frac{7}{6}, \frac{1}{3})$-sparse graph with $\delta(G) \geq 2$ is equitably 3-colorable and equitably 3-choosable; (ii) every $(\frac{5}{4}, \frac{1}{2})$-sparse graph with $\delta(G) \geq 2$ is equitably 4-colorable and equitably 4-choosable; (iii) for each $k \geq 5$, every $(\frac{7}{5}, -\frac{3}{5})$-sparse graph G with $\delta(G) \geq 2$ is equitably k-colorable and equitably k-choosable. The first two bounds and the third bound for $k = 5$ are exact for infinitely many graphs. Moreover, we prove our theorem in terms of strongly equitable list coloring which restricts the number of color classes of size $\lceil n/k \rceil$.

Keywords: equitable coloring, list coloring, planar graphs.

Ramsey chains in graphs

Ritabrato Chatterjee, Western Michigan University

5:50pm
Friday
SCC 120

A decomposition $\{G_1, G_2, \ldots, G_k\}$ of a graph G is ascending if G_i is isomorphic to a proper subgraph of G_{i+1} for $i = 1, 2, \ldots, k-1$. The well-known and long-standing Ascending Subgraph Decomposition Conjecture states that every graph has an ascending subgraph decomposition. One of the major topics in graph theory involving edge colorings takes place in Ramsey theory where typically for each red-blue edge coloring of a given graph, one of two prescribed monochromatic subgraphs occurs. We introduce the concept of a Ramsey chain which involves both graph decomposition and Ramsey theory. Our goal is to determine, for each red-blue edge coloring of certain graphs, the existence of the maximum number of monochromatic pairwise edge-disjoint subgraphs satisfying conditions that were initially specified in the Ascending Subgraph Decomposition Conjecture. Results and questions are presented in this area of research. This is joint work with Gary Chartrand and Ping Zhang.

Keywords: red-blue edge coloring, Ramsey chain, Ramsey index.

Permutation patterns

Miklos Bona, University of Florida

9:00am
Saturday
SCC 120

We will survey some of the classic problems of this rapidly evolving field, with special attention given to subfields that have seen significant progress in the last five years. We will show how techniques from analytic and algebraic combinatorics can be useful here and discuss surprising link with partitions of an integer.

Counting pairs of cycles whose product is a permutation with restricted cycle lengths

*Boris Pittel**, *Ohio State University*
Miklos Bona, University of Florida

10:30am
Saturday
SCC 120

This is the joint work with Miklos Bona. We are interested in counting *some* of the permutations of a set $[N]$ whose cycle lengths belong to a given $A \subset \{1, 2, \ldots\}$, calling them type-A permutations. We stress "some", since our focus is on permutations that are *products* of two N-long cycles. Some special cases have direct consequences in the theory of biologically motivated sorting algorithms. We express the probability $q_N(A)$ that the product of two uniformly-random cycles is of type-A through the corresponding probabilities $p_N(A)$ and $p_N(A^c)$ for the uniform permutations of $[N]$, thus generalizing well-known results for $A = \{2, 3, \ldots\}$, i.e. for the case when the product of two cycles has to be a derangement. While explicit, these sum-type formulas do not lend itself easily to an asymptotic analysis, since the terms have alternating signs. However, for the key cases $A = \{\text{even numbers}\}$ and $A = \{\text{odd numbers}\}$, i. e. those with sorting ramifications, we found a way to change the order of computational steps that leads to sums with positive terms only, perfectly amenable to asymptotics. Our key instruments are a Fourier inversion formula for the probability that the product of two random cycles belongs to a generic conjugacy class, based on the characters of irreducible representations of the symmetric group S_N.

Keywords: permutations

On computing solutions to $2^n \equiv 3 \pmod{n}$ and beyond

Max A. Alekseyev, The George Washington University

10:50am
Saturday
SCC 120

Solving a congruence $b^n \equiv c \pmod{n}$ with respect to n for given integers b and c in most cases is a hard problem with no or just a few known solutions. We present a number of computational techniques that can help to find all solutions or to prove their absence below a given bound. In particular, we discuss a folklore problem of solving $2^n \equiv 3 \pmod{n}$, for which we discovered a new solution $n = 3468371109448915$ and now know all solutions below 10^{18}. We further discuss applications of the presented methods to related problems such as finding Carmichael numbers with a prescribed divisor.

Keywords: congruences, computation, Diophantine equations

Revisiting a classical Ramsey number problem

Emma Jent, Western Michigan University

11:10am
Saturday
SCC 120

For two graphs F and H, the Ramsey number $R(F, H)$ of F and H is the minimum positive integer n such that for every red-blue coloring of the edges of the complete graph of order n, there is either a subgraph isomorphic to F every edge of which is colored red or a subgraph isomorphic to H every edge of which is colored blue. Probably the best known classical Ramsey number is $R(K_3, K_3)$. By looking at this number more carefully, new concepts arise and are investigated. We report results and open questions on these concepts. This is joint work with Gary Chartrand and Ping Zhang.

Keywords: red-blue coloring, Ramsey number, extending Ramsey number.

Ramsey-Collatz: a correlation, and some extremal pursuits

Mojtaba Moniri, Normandale Community College

11:30am
Saturday
SCC 120

In their 2011 Combinatorica paper, Downey-Greenberg-Jockusch-Milans defined the weight of a 0-1 edge-labeled ternary tree of arbitrary depth. It is the minimum number of path-labels needed for a binary subtree of the same depth. We focus on depth 5, where there are 2^{363} trees, their weights are between 1-8. Given a number n below that, write it in base 2 and pad left 0s if needed to make the length equal to 363. We define the weigh of n to be the weight of this corresponding tree. We used Mathematica codes to generate examples within three subclasses of numbers: Weight 1, IndAB, and LogSA. Here, IndAB means proceed with labeling level-by-level in an 'inductively almost balanced' way following each of the same current path-labels. The LogSA refers to the log-superadditivity of the weight (here, start with a depth-2 tree of weight 2, and follow each of its leaves by a depth-3 tree of weight 3, this will always result in a depth-5 tree of weight at least 6). We also used a code to generate Rand with no constraint. In parallel to these Ramsey features and algorithms designed to affect the weight, we consider the Collatz stopping time: starting from n, iterate mapping evens $2k$ in the orbit to k and odds $2k+1$ to $3k+2$ until we reach 1–assuming n was not a counterexample to Collatz Conjecture–then divide the number of steps by $\ln(n)$. For numbers below our mentioned bound, this has a mean of about 6.95 and standard deviation of about 0.634. We consider low values below 6.5 and high values above 7.5. In part (1), we report the correlation we have spotted between the four Ramsey classes of numbers and our Collatz classes. This involved 96,000,000 numbers below 2^{363} as follows. For each of the four Ramsey classes, for 240 samples each of size 100,000, we gathered the frequencies of LowCollatz and HighCollatz, and observed that the maximum (23707) of the 240 numbers LCLogSA was less than the least among the minimums of LCW1, LCRand, and LCIndAB (24223). Similarly, the maximum (17749) of HCLogSA was less than the least among the minimums of HCW1, HCRand, and HCIndAB (18434). The mean of LCLogSA was below 23350, while for the other three LC's were over 24600. The standard deviations for the four LC classes were between 128-138. The mean of HCLogSA was below 17450, while for the other three HC's were over 18795. The standard deviations for the four HC classes were between 110-130.

In part (2), our theme is some extremal combinatorics on Ramsey-Collatz. With an extensive search for W8-numbers of Collatz values either below 6.5 or above 7.5, we gathered 25,315 numbers. Subdividing each of these two intervals into 10^j equal-length subintervals for $j = 1, \cdots, 12$, below we show the number of subintervals met (at least once) by our Collatz values for each mesh and either of the two intervals. One of these counts (20) is sharp, the others call for extension. The 25,315 Collatz values (together with a code to count how many subintervals were met for each mesh, but not the actual numbers themselves) are in the file https://zenodo.org/records/12824062.

Int.↓, Mesh →	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}	10^{-11}	10^{-12}
(4.5,6.5)	19	153	507	1209	2691	7239	11820	13576	13994	14055	14064	14066
(7.5,9.5)	20	185	668	1438	3079	7001	10011	10963	11203	11234	11247	11249

Restricting the interval (7.5,9.5) to (7.5,9), the above current hitting rate $\frac{185}{200}$ increases to $\frac{149}{150}$, our witnesses for this are in the file 149LeftOut1.pdf at https://zenodo.org/records/13743454. We mention the similar idea in another file 1110 LoH5.svg at the latter link, with its 1109 predecessors posted elsewhere.

Keywords: ternary tree, binary subtree, Collatz, correlation, extremal

Rainbow Turán problems

John Byrne, University of Delaware
E.G.K.M. Gamlath, Franklin Pierce University
Anastasia Halfpap, Sydney Miyasaki, and Alex Parker, Iowa State University*
Puck Rombach, University of Vermont

11:50am
Saturday
SCC 120

Rainbow Turán problems are a variation on the classic Turán problem introduced by Keevash, Mubayi, Sudakov, and Verstraete in 2007, in which we forbid a given rainbow subgraph and determine the maximum number of edges possible. The introductory paper established the asymptotic behavior of rainbow extremal numbers for non-bipartite graphs, but the behavior of bipartite graphs is harder to determine. Towards this, we determine the rainbow Turán numbers for several families of trees, namely various families of brooms. In doing so, we demonstrate a fruitful connection between edge-colorings and permutations.

Strong Colouring with K_3's and K_4's

Jessica McDonald, Auburn University

2:00pm
Saturday
SCC 120

If H is a graph, and G is obtained from H by gluing on vertex-disjoint copies of K_t, then when can we guarantee that G is t-colourable? The *Strong Colouring Conjecture* posits that $\chi(G) \leq t$ whenever $t \geq 2\Delta(H)$. We'll discuss this seemingly very difficult conjecture, with particular focus on the elusive case of $\Delta(H) = 2$. We'll describe new joint work with Dalal and Shan where the "cycles plus K_4's" problem is reduced to a problem about "strong colouring" with K_3's.

New algorithms for enumerating triangulations of the 3-dimensional cyclic polytopes

Luke Nelson, Independent Researcher
Kevin Treat, U.S. Air Force Academy*

3:00pm
Saturday
SCC 120

In this presentation we will discuss our recently developed recursive formulas for enumerating triangulations of the 3-dimensional cyclic polytope. The triangulations may be viewed as elements of both the higher Stasheff–Tamari orders in dimension three and the Tamari Block lattices we define. We will describe the development of the algorithms to enumerate these triangulations, and compare them to previously known algorithms. Our algorithms increase computational efficiency, allowing us to enumerate previously unenumerated triangulations. The key to the algorithms comes from our work that showed enumerating elements of the Tamari Block lattice is equivalent to counting members of a certain multiset of scope sequences.

Keywords: Tamari lattice, outer Tamari poset, Tamari block lattice, higher Stasheff–Tamari order, persistent graphs, triangulations of cyclic polytopes

Circle configurations from regular skeletal polyhedra

Jieying Jin, Northeastern University*

3:20pm
Saturday
SCC 120

In this talk, I will explore circle configurations derived from regular skeletal polyhedra. We will begin by examining the structure of regular skeletal polyhedra, focusing on their fundamental properties and how they serve as a basis for constructing more complex configurations. Following this, I will present a simple example to demonstrate the edge construction process, illustrating how edges of the polyhedra can be transformed into geometric configurations. Finally, I will delve into the resulting circle configurations. This presentation aims to bridge the understanding of polyhedral structures and their connection to circle configurations, offering insights into the broader implications of these constructions. This is joint work with Egon Schulte.

Keywords: regular polytopes, circle configurations, skeletal polyhedra

Palindrome partitions

David Hemmer and Karlee Westrem, Michigan Technological University*

4:10pm
Saturday
SCC 120

There is a well-known bijection between finite binary sequences and integer partitions. Sequences of length r correspond to partitions of perimeter $r+1$. Motivated by work on rational numbers in the Calkin-Wilf tree, we classify partitions whose corresponding binary sequence is a palindrome. We give a generating function that counts these partitions, and describe how to efficiently generate all of them. Atypically for partition generating functions, we find an unusual significance to prime degrees. Specifically, we prove there are nontrivial *palindrome partitions* of n except when $n = 3$ or $n + 1$ is prime.

Keywords: palindrome partitions, calkin-wilf tree, partition theory

Conflict-free hypergraph matchings and generalized Ramsey numbers

Enrique Gomez-Leos, Emily Heath, Alex Parker, Coy Schwieder, and Shira Zerbib, Iowa State University*

4:30pm
Saturday
SCC 120

Given integers n, p, q, where $p \leq n$, $1 \leq q \leq \binom{p}{2}$, a (p, q)-coloring of the complete graph, K_n, is an edge coloring of K_n in which every clique on p vertices has at least q colors appearing in its edges. Let $f(n, p, q)$ be the minimum number of colors needed for a (p, q)-coloring on K_n. Erdös and Gyárfás originally posed the question in 1997 and determined a general upper bound. In addition to determining the linear and quadratic threshold, they also showed that $5/6(n-1) \geq f(n, 4, 5) \leq n$. Recently, Mubayi and Joos introduced a new method for proving upper bounds on these generalized Ramsey numbers; by finding a "conflict-free" matching in an appropriate auxiliary hypergraph, they determined the value of $f(n, 4, 5)$ to be $5/6n + o(n)$. In this talk, we will introduce recent improvements to $f(n, 5, 8)$. Indeed, we show that $f(n, 5, 8) \geq 6/7(n-1)$ and discuss how to use the conflict-free hypergraph matching method to show that $f(n, 5, 8) \leq n + o(n)$.

Keywords: generalized Ramsey numbers, conflict-free hypergraph matchings, edge-coloring

Cozonal labelings in plane graphs

Andrew Bowling, Wabash College*
Richard Low, San Jose State University
Weiguo Xie, University of Minnesota Duluth

4:50pm
Saturday
SCC 120

Let $G = (V(G), E(G), F(G))$ be a plane graph. A labeling $\ell : V(G) \to \{1, 2\} \subset \mathbb{Z}_3$ is called a zonal labeling if for each region $R \in F(G)$ with boundary $B(R)$, the sum $\sum_{v \in B(R)} \ell(v)$ is $0 \in \mathbb{Z}_3$. Zonal labelings are of special interest due to their strong connection to the Four Color Theorem. Recently, a related labeling called a cozonal labeling has been introduced, which is the dual of a zonal labeling. Here we discuss the existence and nonexistence of cozonal labelings for several families of plane graphs, as well as completely characterize all plane graphs of maximum degree at most 3 which admit a cozonal labeling.

Keywords: labeling, plane graphs, four color theorem

From princes on chessboards to proper total domination in graphs

Sawyer Osborn, Western Michigan University

5:10pm
Saturday
SCC 120

A question involving a chess piece called a prince on the 8×8 chessboard leads to a concept in graph theory involving total domination in the Cartesian products of graphs. The concept of a proper total dominating set is introduced: a type of total dominating set where any pair of adjacent vertices in the given graph are dominated by a different number of vertices. Our goal is to find which graphs in well-known classes of graphs possess a proper total dominating set. Several results and open questions relating to this goal are shown. This is joint work with Ping Zhang.

Keywords: chessboards, proper total domination, Cartesian products of graphs.

On the nonexistence of generalized bent functions

Ka Hin Leung, National University of Singapore
Shuxing Li, University of Delaware*
Songtao Mao, Johns Hopkins University

5:30pm
Saturday
SCC 120

An (m, n)-generalized bent function is a function from $\mathbb{Z}_2^n$ to $\mathbb{Z}_m$ so that its associated Fourier transformations have constant absolute value. It is known that an (m, n)-generalized bent function exists whenever one of the following holds:

(1) both m and n are even.

(2) $4 \mid m$.

On the other hand, all known results suggest that for (m, n) pair that fails to satisfy both of the above conditions, (m, n)-generalized bent function does not exist. In this talk, we will discuss the recent nonexistence result of $(m, 4)$ generalized bent functions with m being odd. This result crucially relies on analyzing vanishing sums of complex roots of unity.

Keywords: generalized bent function, roots of unity, Walsh-Hadamard transformation, vanishing sum

Neighborhood balanced 3-coloring

Mitchell Minyard and Mark R. Sepanski, Baylor University*

5:50pm Saturday SCC 120

A graph is said to be neighborhood 3-balanced if there exists a vertex labeling with three colors so that each vertex has an equal number of neighbors of each color. We give order constraints on 3-balanced graphs, determine which generalized Petersen and Pappus graphs are 3-balanced, discuss when being 3-balanced is preserved under various graph constructions, give two general characterizations of cubic 3-balanced graphs, and classify cubic 3-balanced graphs of small order.

Keywords: graph coloring, generalized petersen, graph products

Every tree on n edges decomposes the complete bipartite graph $K_{n,n}$

Edinah Gnang, Johns Hopkins University

9:00am Sunday SCC 120

We prove a conjecture of Graham and Häggkvist (1989), which states that any tree T on n edges decomposes the complete bipartite graph $K_{n,n}$ into n disjoint copies of T. We do so by translating the decomposition problem into a labeling problem. Our proof employs the polynomial method using functional reformulation of the conjecture. A proof of the graceful tree conjecture (1967) follows as an immediate consequence of our result. The talk is based on joint work with Parikshit Chalise and Antwan Clark.

Decomposition of complete graphs into certain unicyclic bipartite graphs with 7 edges

Aidan Carlson, University of Minnesota Duluth

10:30am Sunday SCC 120

A graph decomposition into G is done by partitioning a complete graph, K_n, into a set S of subgraphs. Each of these subgraphs of K_n is isomorphic to G such that each edge of K_n belongs to exactly one member of S. In this talk, we prove that unicyclic bipartite graphs on 7 edges, with 9 or more vertices, containing a single cycle having a length of 4 decompose the complete graphs K_{14k} and K_{14k+1} for all integers $k \geq 1$. We accomplish this using ordered ρ-labelings and 1-rotational ordered ρ-labelings.

Keywords: graph decompositions, unicyclic graphs, Rosa-type labelings

Decomposition of complete graphs into tripartite graphs with 7 edges and a 3-cycle or 5-cycle

Clayton Higgins, University of Minnesota Duluth

10:50am Sunday SCC 120

A graph decomposition into G is done by partitioning a complete graph, K_n, into a set S of subgraphs. Each of these subgraphs of K_n is isomorphic to G such that each edge of K_n belongs to exactly one member of S. In this talk, we prove certain tripartite graphs on 7 edges and 9 or more vertices with a cycle of length 3 or 5 decompose the complete graphs K_{14k} and K_{14k+1} for all integers $k \geq 1$. We accomplish this using ρ-tripartite labelings and 1-rotational ρ-tripartite labelings.

Keywords: graph decompositions, unicyclic graphs, Rosa-type labelings

Decompositions of complete graphs into unicyclic disconnected non-bipartite graphs on nine edges

11:10am Sunday SCC 120

Alan Bohnert, Texas Tech University
Luke Branson, Dalibor Froncek, and Patrick Otto, University of Minnesota Duluth*

We use Rosa-type labelings to decompose complete graphs into unicyclic, disconnected, non-bipartite graphs on nine edges. For any such graph H, we prove there exists an H-design of K_{18k+1} and K_{18k} for all positive integers k.

Keywords: Rosa-type labelings, graph decompositions, unicyclic graphs

On decompositions of K_{10k}, K_{10k+1} and K_{10k+5} into forests on five edges

11:30am Sunday SCC 120

Dalibor Froncek, University of Minnesota Duluth
Andrew Sailstad, University of Minnesota - Twin Cities*

We show that forests on five edges decompose the complete graphs K_{10k} and K_{10k+1} for $k \geq 1$, using ρ^+-labelings and 1-rotational ρ^+-labelings as defined by Rosa. Additionally, we use ρ-bilabelings and additional methods to decompose K_{10k+5} into the same graphs.

Keywords: graph decompositions

Designs for forests with seven edges

11:50am Sunday SCC 120

Danny Banegas, University of Minnesota Duluth*

Let G be a forest with seven edges and $n > 8$ be an integer. We prove that G decomposes the complete graph K_n if and only if $n \equiv 0, 1, 7, \text{or } 8 \pmod{14}$.

Keywords: designs, forests, decompositions

Application of metric dimension of graph in unraveling the complexity of hyperacusis

12:10pm Sunday SCC 120

Ibrahim Hassan, Federal University of Lafia, Nigeria

The prevalence of hyperacusis, an auditory condition characterized by heightened sensitivity to sounds, continues to rise, posing challenges for effective diagnosis and intervention. This work deepens our understanding of hyperacusis etiology by employing graph theory as a novel analytical framework. Our study constructs a comprehensive graph wherein nodes represent various factors associated with hyperacusis, including aging, head or neck trauma, infection/virus, depression, migraines, ear infection, anxiety, and other potential contributors. Relationships between factors are modeled as edges, allowing us to visualize and quantify the interactions within the etiological landscape of hyperacusis. We employ the concept of the metric dimension of a connected graph to identify key nodes (landmarks) that serve as critical influencers in the interconnected web of hyperacusis causes. This approach offers a unique perspective on the relative importance and centrality of different factors, shedding light on the complex interplay between physiological, psychological, and environmental determinants. Visualization techniques were also employed to enhance the interpretation and facilitate the identification of the central nodes. This research contributes to the growing body of knowledge surrounding hyperacusis by offering a network-centric perspective on its multifaceted causes. The outcomes hold the potential to inform clinical practices, guiding healthcare professionals in prioritizing interventions and personalized treatment plans based on the identified landmarks within the etiological network. Through the integration of graph theory into hyperacusis research, we unravel the complexity of this auditory condition and pave the way for more effective approaches to its management.

Keywords: auditory condition, connected graph, hyperacusis, metric dimension.

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