



**Program for Research in  
Mathematics, Engineering and Science**



**Second Annual  
Yulia's Dream  
Virtual Conference  
June 13, 2024**

**8:15 am (Boston) [15:15 (Kyiv)]: Welcoming Remarks**

- Prof. Pavel Etingof, Yulia's Dream Chief Research Advisor
- Dr. Slava Gerovitch, Yulia's Dream Program Director

**8:30 am (Boston) [15:30 (Kyiv)]: Guest lecture**

- Prof. [Pavlo Pylyavskyy](#) (University of Minnesota Twin Cities), “Incidences and tilings” (joint work with Prof. [Sergey Fomin](#) (University of Michigan))

**9:40-10:40 am (Boston) [16:40-17:40 (Kyiv)]: Session 1**

- Maryna Lubimova, Denis Liabakh, Maksym Skulysh, “Counting spanning trees with linear algebra” (mentor Dr. Maksym Chaudkhari, Fields Institute / University of South Florida)
- Yehor Shudrenko, Maksym Shvydenko, Theodor Gabel, “Combinatorial Nullstellensatz” (mentor Kyrylo Muliarchyk, University of Texas at Austin)
- Mykhailo Barkulov, Heorhii Zhylynskyi, Mathew Kutach, “Finite reflection groups and Coxeter groups” (mentor Dr. Kostiantyn Tolmachov, University of Edinburgh)

**10:50-11:50 am (Boston) [17:50-18:50 (Kyiv)]: Session 2**

- Volodymyr Chub, Stanislav Surmylo, “Cumulants for Asymmetric Additive Convolution” (mentor Prof. Cesar Cuenca, Ohio State University)
- Ivan Bortnovskyi, Borys Holikov, Vadym Pashkovskyi, “First examples of non-abelian quotients of the Grothendieck-Teichmüller group” (mentor Prof. Vasily Dolgushev, Temple University) (continuation of last year Yulia’s Dream project)
- Kostiantyn Molokanov, Severyn Khomych, Nazar Korniiichuk, “Affine root systems via Lyndon words” (mentor Prof. Oleksandr Tsymbaliuk, Purdue University)

**12:00-1:00 pm (Boston) [19:00-20:00 (Kyiv)]: Session 3**

- Daria Ukshe, Yevheniia Frankevych, Viktoriia Honcharenko, “Spectral correspondence theorem for Higgs fields” (mentor Dr. Mykola Matviichuk, Imperial College London)
- Yaroslav Molybog, Constantine Bulavenko, Ivan Balashov, “Tesler matrices and Lusztig data” (mentor Prof. Anne Dranowski, University of Southern California)
- Andrii Smutchak, Sofiia Breslavets, “Double groupoids” (mentor Prof. Harshit Yadav, University of Alberta)

**1:10-2:10 pm (Boston) [20:10-21:10 (Kyiv)]: Session 4**

- Maksym Chaplanov, Tymofii Kolisnyk, Lev Kekalo, “Color plane groups” (mentor Andrei Zabolotskii, Open University)
- Danylo Saienko, Kyrylo Osipov, Title TBA (mentor Andrei Mandelshtam, Stanford University)
- Oleksandr Borodin, Maryna Spektrova, Ivan Bortnovskyi, “Combinatorial Hikita conjecture in types B,C,D” (mentor Prof. Andrei Ionov, Boston College)

## **Guest lecture**

**Prof. Pavlo Pylyavskyy (University of Minnesota Twin Cities)**  
**“Incidences and tilings”**  
**(joint work with Prof. Sergey Fomin, University of Michigan)**

We show that various classical theorems of real/complex linear incidence geometry, such as the theorems of Pappus, Desargues, M'obius, and so on, can be interpreted as special cases of a single “master theorem” that involves an arbitrary tiling of a closed oriented surface by quadrilateral tiles. This yields a general mechanism for producing new incidence theorems and generalizing the known ones. This is joint work with Sergey Fomin, see arxiv:2305.07728.

## **Session 1**

**Maryna Lubimova, Denis Liabakh, Maksym Skulysh**  
**“Counting spanning trees with linear algebra”**  
**(mentor Dr. Maksym Chaudkhari, Fields Institute / University of South Florida)**

We are going to discuss the matrix-tree theorem and its applications. Moreover, we will also provide a brief overview of related topics in linear algebra.

**Yehor Shudrenko, Maksym Shvydenko, Theodor Gabel**  
**“Combinatorial Nullstellensatz”**  
**(mentor Kyrylo Muliarchyk, University of Texas at Austin)**

The Combinatorial Nullstellensatz is a fundamental algebraic tool with significant applications in combinatorics and number theory. It generalizes the well-known fact that a single variable polynomial of degree  $n$  cannot have more than  $n$  roots to a multidimensional case. This presentation will introduce the theorem originally formulated by Noga Alon and its primary applications, such as the classical Cauchy-Davenport and Chevalley theorems. In addition, we provide a simple solution to the hardest problem from the 2007 International Mathematical Olympiad competition.

**Mykhailo Barkulov, Heorhii Zhylinskyi, Mathew Kutach**  
**“Finite reflection groups and Coxeter groups”**  
**(mentor Dr. Kostiantyn Tolmachov, University of Edinburgh)**

In this reading group, we focused on learning the basic concepts of linear algebra and group theory. Our final goal was to understand the classification of finite reflection groups, as well as important concepts around it, such as root systems, Coxeter presentation and Dynkin diagrams.

## Session 2

**Volodymyr Chub, Stanislav Surmylo**  
**“Cumulants for Asymmetric Additive Convolution”**  
**(mentor Prof. Cesar Cuenca, Ohio State University)**

The goal of the project is to define and study cumulants for polynomials that linearize the operation of asymmetric additive convolution from the theory of Finite Free Probability. Besides the linearization property, the second main result are new moment-cumulant formulas.

**Ivan Bortnovskiy, Borys Holikov, Vadym Pashkovskiy**  
**“First examples of non-abelian quotients of the Grothendieck-Teichmuller group”**  
**(mentor Prof. Vasily Dolgushev, Temple University)**  
**(continuation of last year Yulia’s Dream project)**

Our work is motivated by a very hard question about the surjectivity of the famous Ihara homomorphism from the absolute Galois group of rational numbers to the Grothendieck-Teichmuller group. We will start with a few words about the above objects, formulate our main result and list the tools that we used in our paper. Then we will give more details about the main ingredient, the groupoid of GT-shadows, and outline the future directions of our research. Our talk is based on the arXiv preprint <https://arxiv.org/abs/2405.11725>

**Kostiantyn Molokanov, Severyn Khomych, Nazar Korniiichuk**  
**“Affine root systems via Lyndon words”**  
**(mentor Prof. Oleksandr Tsymbaliuk, Purdue University)**

The combinatorial approach to Lie algebras and consequently associated quantum groups has a long history, starting with the independent works of Lyndon and Shirshov who constructed bases of free Lie algebras through the combinatorics of Lyndon words. A few decades later, Lalonde and Ram generalized this construction to finitely generated Lie algebras by constructing their Grobner-type bases parametrized by so-called standard Lyndon words. In the special case of the positive subalgebra of simple Lie algebras, their work implies a bijection between the set of positive roots and the set of standard Lyndon words. This theory provides an elegant approach to quantum groups of finite type, as noticed independently by Green, Rosso, and Schauenburg in the mid-90s, and further elaborated in the works of Leclerc and Kharchenko.

The generalization of such combinatorial approach to Kac-Moody algebras of affine type and the associated quantum groups was undertaken more recently in the work of Negut and Tsymbaliuk. The present project addresses a "weighted" version of the latter results. While the overall pattern remains similar, many proofs require interesting upgrades. We note that the corresponding order on the set of positive roots conjecturally matches the classical construction of Beck and Damiani for any strictly dominant integral weight.

## Session 3

**Daria Ukshe, Yevheniia Frankevych, Viktoriia Honcharenko**  
**“Spectral correspondence theorem for Higgs fields”**  
**(mentor Dr. Mykola Matviichuk, Imperial College London)**

By a Higgs field we mean a square matrix whose entries are power series in one variable. We discuss the problem of classification of Higgs fields up to conjugation. We will state the Spectral correspondence theorem, which encodes a Higgs field in terms of a spectral ring  $R$  and a spectral module over  $R$ . We will discuss the problem of classifying the relevant modules over a fixed ring.

**Yaroslav Molybog, Constantine Bulavenko, Ivan Balashov**  
**“Tesler matrices and Lusztig data”**  
**(mentor Prof. Anne Dranowski, University of Southern California)**

We study asymptotics of Tesler matrices using Kostant pictures, as well as partial orders on these. We show that the Lusztig data partial order on Kostant pictures refines the ‘merge’ partial order on Kostant pictures, and that the merge partial order on Kostant pictures is equivalent to a poset structure on Tesler matrices. This equivalence requires integral flow graphs. Finally, using Kostant pictures we conjecture sharp bounds on previously studied families of Tesler matrices.

**Andrii Smutchak, Sofiia Breslavets**  
**“Double groupoids”**  
**(mentor Prof. Harshit Yadav, University of Alberta)**

Double groupoids are a categorical structure that generalize categories. We review known techniques of obtaining semisimple weak Hopf algebras from a double groupoid. Additionally we review how to obtain a double groupoids using certain data of groupoids. All these constructions are illustrated using the example of a matched pair of groups.

## **Session 4**

**Maksym Chaplanov, Tymofii Kolisnyk, Lev Kekalo**  
**“Color plane groups”**  
**(mentor Andrei Zabolotskii, Open University)**

We have considered the symmetry groups of repeated (crystallographic) patterns on the plane and have enumerated the types of symmetries of these patterns when colored in 2,  $p$ , or  $2p$  colors (where  $p$  is a prime greater than 3). Although some results on this topic have already been published, our work revises and generalizes them.

**Danylo Saienko, Kyrylo Osipov**  
**Title TBA**  
**(mentor Andrei Mandelshtam, Stanford University)**

**Oleksandr Borodin, Maryna Spektrova, Ivan Bortnovskiy**  
**“Combinatorial Hikita conjecture in types B,C,D”**  
**(mentor Prof. Andrei Ionov, Boston College)**