

9th Slovenian International Conference on Graph Theory BLED'19

Abstracts of the  
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Conference on Graph Theory**

Bled, Slovenia, June 23 – 29, 2019



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# WELCOME

We thank all of you for coming to the 9th Slovenian International Conference on Graph Theory, Bled'19, and wish you a pleasant and successful meeting in Bled.

This conference has come a long way from its first meeting in Dubrovnik (now in Croatia) in 1985. The second meeting of the series *Slovenian (International) Conference on Graph Theory* was held at Lake Bled in 1991, following by the subsequent meetings at the same location in 1995, 1999, 2003, 2007, and 2011. In 2015 the meeting took place in Kranjska Gora. For this edition we are back to Bled.

The conference has seen a substantial growth, from 30 participants at the 1991 meeting to well over 300 participants at the present *9th Slovenian Conference on Graph Theory*. We are very happy to see participants that have attended previous editions, always a clear indicator of successful previous meetings, and we welcome the newcomers.

The growth of the conference has been parallel to the growth of graph theory in Slovenia, two achievements to be proud of. Our international colleagues, and friends, are largely responsible for this success. We thank you for this.

In this edition we have 11 plenary speakers and 16 invited special sessions. We believe that the quality of the plenary speakers and the invited special sessions play a key role in the success of the conference. This booklet contains the abstracts of the 287 talks to be delivered at our conference.

Similar to the last edition, the conference is linked to the *Meeting of the International Academy of Mathematical Chemistry*, and the *9th PhD Summer School in Discrete Mathematics* will take place on Rogla the week after the conference. Looking to the future, an event deserves special attention: the *8th European Congress of Mathematics* to take place in Portorož, Slovenia, from July 5 to July 11, 2020. This will be a challenge and a great opportunity to promote Discrete Mathematics at large and in particular Slovenian Discrete Mathematics. We hereby warmly invite you to participate in the event.

The organization of this meeting would not have been possible without financial and technical support from the Institute of Mathematics, Physics and Mechanics, Ljubljana (IMFM); University of Ljubljana, Faculty of Mathematics and Physics (UL FMF); University of Maribor, Faculty of Natural Sciences and Mathematics (UM FNM); University of Primorska, Faculty of Mathematics, Natural Sciences and Information Technologies (UP FAMNIT), and Andrej Marušič Institute (UP IAM); the Society of Mathematicians, Physicists and Astronomers of Slovenia (DMFA); the Slovenian Discrete and Applied Mathematics Society (SDAMS); and Abelium d.o.o.

We hope that you enjoy this instance of our conference and wish you a fruitful, pleasant week devoted to graph theory.

Bled, June 2019

Sandi Klavžar  
Dragan Marušič  
Bojan Mohar  
Tomaž Pisanski



# CONTENTS

<b>Bled 2019</b>	<b>5</b>
Welcome . . . . .	5
Contents . . . . .	7
General Information . . . . .	17
Past Conferences . . . . .	19
<b>Abstracts</b>	<b>21</b>
<b>Plenary Invited Talks</b> . . . . .	21
Noga Alon: <i>Random and quasi-random Cayley sum graphs with applications</i> . . . . .	22
Marco Buratti: <i>Cyclic designs: some selected topics</i> . . . . .	22
Gareth A. Jones: <i>Paley, Carlitz and the Paley Graphs</i> . . . . .	22
Gábor Korchmáros: <i>Permutation groups in the study of geometric structures</i> . . . . .	23
Daniel Král': <i>Profiles of graphs and tournaments</i> . . . . .	23
Daniela Kühn: <i>Resolution of the Oberwolfach problem</i> . . . . .	24
Sergei Lando: <i>Integrability property of polynomial graph invariants</i> . . . . .	24
János Pach: <i>Many Pairwise Crossing Edges</i> . . . . .	24
Cheryl E. Praeger: <i>Limited geodesic transitivity for finite regular graphs</i> . . . . .	24
Zsolt Tuza: <i>Parity colorings in graphs and hypergraphs</i> . . . . .	25
Xuding Zhu: <i>List colouring and Alon-Tarsi number of planar graphs</i> . . . . .	25
<b>Association Schemes</b> . . . . .	27
Harvey Blau: <i>Nilpotent commutative standard integral table algebras of order <math>p^3</math></i> . . . . .	28
Christopher French: <i>Hypergroup rings</i> . . . . .	28
Allen Herman: <i>Rationality for irreducible representations of association schemes of rank 6 and 7</i> . . . . .	28
Stephen Humphries: <i>Schur rings over infinite groups</i> . . . . .	29
Akihiro Munemasa: <i>Krein parameters of fiber-commutative coherent configurations</i> . . . . .	29
Misha Muzychuk: <i>Non-commutative schemes of rank six and related objects</i> . . . . .	29
Ilia Ponomarenko: <i>A characterization of some equivalenced association schemes</i> . . . . .	30
Grigory Ryabov: <i>Infinite family of non-schurian separable association schemes</i> . . . . .	30
Gábor Somlai: <i>New family of CI-groups</i> . . . . .	30
Sho Suda: <i>Linked systems of group divisible designs</i> . . . . .	31
Andrey Vasil'ev: <i>Closures of permutation groups and the isomorphism problem for schurian coherent configurations</i> . . . . .	31
Janoš Vidali: <i>On tight 4-designs in Hamming association schemes</i> . . . . .	32
Paul-Hermann Zieschang: <i>Residually Thin Hypergroups</i> . . . . .	32
<b>Biomathematics and Bioinformatics</b> . . . . .	33
Daniel Doerr: <i>On the Computational Hardness of Ancestral Genome Reconstructions</i> . . . . .	34
André Fujita: <i>Network Statistics on biological data analyses</i> . . . . .	34
Marc Hellmuth: <i>Best Match Graphs</i> . . . . .	35
Lina Herbst: <i>Trees on scales – measures of balance for rooted binary trees</i> . . . . .	35
Remie Janssen: <i>Navigating the space of phylogenetic networks</i> . . . . .	36

Manuel Lafond: <i>Will we ever find a forbidden subgraph characterization of leaf powers?</i> . . . . .	36
Nikolai Nøjgaard: <i>Partial Homology Relations - Satisfiability in terms of Di-Cographs</i> . . . . .	37
Guillaume Scholz: <i>Un-folding and folding-up phylogenetic networks</i> . . . . .	37
Carsten R. Seemann: <i>The Matroid Structure of Representative Triple Sets and Triple-Closure Computation</i> . . . . .	37
Kristina Wicke: <i>Phylogenetics meets classic graph theory – Connections between Hamiltonicity, GSP graphs and treebased networks</i> . . . . .	38
<b>Chemical graph theory</b> . . . . .	<b>39</b>
Simon Brezovnik: <i>Resonance graphs of catacondensed even ring systems (CERS)</i>	40
Zhongyuan Che: <i>Resonance graphs of plane elementary bipartite graphs</i> . . . . .	40
Haiyan Chen: <i>The average Laplacian polynomial of a graph</i> . . . . .	40
Peter Dankelmann: <i>On the Wiener Index of Eulerian Graphs</i> . . . . .	41
Tomislav Došlić: <i>Packing stars in fullerenes</i> . . . . .	41
Boris Furtula: <i>Novel method for measuring sensitivity of topological descriptors on structural changes</i> . . . . .	41
Xian'an Jin: <i>On the existence of some strong traces of graphs</i> . . . . .	42
Martin Knor: <i>Bounding the Graovac-Pisanski index</i> . . . . .	42
Xueliang Li: <i>The asymptotic value of graph energy for random graphs with degree-based weights</i> . . . . .	43
Jelena Sedlar: <i>On combining Zagreb and Forgotten index to obtain better predictive power</i> . . . . .	43
Niko Tratnik: <i>Computing Distance-Based Topological Indices from Quotient Graphs</i>	43
Jianfeng Wang: <i>Median eigenvalues and HOMO-LUMO index of graphs</i> . . . . .	44
Heping Zhang: <i>Anti-Kekulé number of graphs</i> . . . . .	44
Petra Žigert Pleteršek : <i>Two topological indices applied on hydrocarbons</i> . . . . .	45
<b>Configurations</b> . . . . .	<b>47</b>
Leah Wrenn Berman: <i>Eventually, 5-configurations exist for all <math>n</math></i> . . . . .	48
Jürgen Bokowski: <i>On the Finding of Symmetric Polyhedral Realizations without Self-Intersections of Hurwitz's Regular Map <math>(3,7)_{18}</math> of Genus 7</i> . . . . .	48
Gábor Gévay: <i>Exotic configurations</i> . . . . .	48
Harald Gropp: <i>On the early history of configurations</i> . . . . .	49
Milagros Izquierdo: <i>Configurations and Dessins d'Enfants</i> . . . . .	49
Jurij Kovič: <i>Platonic configurations</i> . . . . .	49
Vito Napolitano: <i>Configurations and some classes of finite linear spaces</i> . . . . .	49
Tomaž Pisanski: <i>The remarkable rhombic dodecahedron graph</i> . . . . .	49
Michael Raney: <i>Trilateral matroids</i> . . . . .	50
Metod Saniga: <i>Doily – A Gem of the Quantum Universe</i> . . . . .	50
Klara Stokes: <i>Dualities, trialities, configurations and graphs</i> . . . . .	50
Arjana Žitnik: <i>Chiral astral realizations of cyclic 3-configurations</i> . . . . .	51
<b>Designs</b> . . . . .	<b>53</b>
Sara Ban: <i>New extremal Type II <math>\mathbb{Z}_4</math>-codes of length 32 obtained from Hadamard designs</i> . . . . .	54
Simone Costa: <i>Relative Heffter arrays and biembeddings</i> . . . . .	54

Dean Crnković: <i>Self-orthogonal codes from block designs and association schemes</i>	55
Ronan Egan: <i>Complementary sequences and combinatorial structures</i>	55
Vladislav Kabanov: <i>Deza graphs with parameters <math>(v,k,k-2,a)</math></i>	55
Francesca Merola: <i>Cycle systems of the complete multipartite graph</i>	56
Oktay Olmez: <i>Partial Geometric Designs and Their Links</i>	56
Anita Pasotti: <i>Odd sun systems of the complete graph</i>	57
Mario Osvin Pavčević: <i>Constructions of some new <math>t</math>-designs acted upon non-abelian automorphism groups</i>	57
Alexander Pott: <i>Homogeneous cubic bent functions</i>	58
John R. Schmitt: <i>Distinct partial sums in cyclic groups</i>	58
Andrea Švob: <i>Self-orthogonal codes from orbit matrices of Seidel and Laplacian matrices of strongly regular graphs</i>	58
Tommaso Traetta: <i>Pyramidal Steiner and Kirkman triple systems</i>	59
Tanja Vučićić: <i>Groups <math>S_n \times S_m</math> in construction of flag-transitive block designs</i>	59
Alfred Wassermann: <i>On <math>q</math>-analogues of group divisible designs</i>	59
<b>Discrete and computational geometry</b>	<b>61</b>
Drago Bokal: <i>Bounded degree conjecture holds precisely for <math>c</math>-crossing-critical graphs with <math>c \leq 12</math></i>	62
Sergio Cabello: <i>Maximum Matchings in Geometric Intersection Graphs</i>	62
Éric Colin de Verdière: <i>Multicuts in planar and surface-embedded graphs</i>	62
Cyril Gavoille: <i>Shorter Implicit Representation for Planar Graphs</i>	63
Petr Hliněný: <i>On Colourability of Polygon Visibility Graphs</i>	63
Yulia Kempner: <i>Spanoids, Greedoids and Violator Spaces</i>	63
Giuseppe Liotta: <i>Bend-minimum Orthogonal Drawings</i>	64
Dömötör Pálvölgyi: <i>Polychromatic coloring of geometric hypergraphs</i>	64
Maria Saumell: <i>Hamiltonicity for convex shape Delaunay and Gabriel graphs</i>	65
Hans Raj Tiwary: <i>Lower bounds for semantic read-once BDDs using Extension Complexity</i>	65
Alen Vegi Kalamar: <i>Counting Hamiltonian cycles in 2-tiled graphs</i>	65
<b>Distance-regular graphs</b>	<b>67</b>
Robert F. Bailey: <i>On distance-regular graphs on 486 vertices</i>	68
Sarah Bockting-Conrad: <i>Tridiagonal pairs of Racah type and the universal enveloping algebra <math>U(\mathfrak{sl}_2)</math></i>	68
Blas Fernández: <i>On the Terwilliger Algebra of Locally Pseudo-Distance-Regular Graphs</i>	68
Štefko Miklavič: <i>Irreducible <math>T</math>-modules with endpoint 1 of almost 1-homogeneous distance-regular graph</i>	68
Arnold Neumaier: <i><math>t</math>-point counts in distance-regular graphs</i>	69
Safet Penjić: <i>A combinatorial approach to the Terwilliger algebra modules of a bipartite distance-regular graph</i>	69
Hiroshi Suzuki: <i>The universal <math>C</math>-cover of a completely regular clique graph</i>	70
Paul Terwilliger: <i>Leonard pairs, spin models, and distance-regular graphs</i>	70
<b>Domination in graphs</b>	<b>71</b>
Boštjan Brešar: <i>Graphs with a unique maximum open packing</i>	72
Paul Dorbec: <i>Reconfiguring and enumerating dominating sets.</i>	72



Tanja Gologranc: <i>On graphs with equal total domination and Grundy total domination number</i> . . . . .	72
Michael A. Henning: <i>The independent domatic number and the total domatic number</i> . . . . .	73
Lisa Hernandez Lucas: <i>Dominating sets in finite generalized quadrangles</i> . . .	73
Marko Jakovac: <i>Relating the annihilation number and two domination invariants</i>	73
Sandi Klavžar: <i>The Maker-Breaker domination game</i> . . . . .	74
Tim Kos: <i>On the Grundy dominating sequences</i> . . . . .	74
Tadeja Kraner Šumenjak: <i>On <math>k</math>-rainbow independent domination in graphs</i> . .	74
Aparna Lakshmanan S.: <i>Double Roman Domination Number</i> . . . . .	74
Berenice Martínez-Barona: <i>Identifying codes in line digraphs</i> . . . . .	75
Iztok Peterin: <i><math>[1, k]</math>-domination number of lexicographic product of graphs</i> . . .	75
Aleksandra Tepeh: <i>On <math>k</math>-rainbow total domination in graphs</i> . . . . .	76
<b>Finite Geometries</b> . . . . .	77
Sam Adriaensen: <i>An Investigation into Small Weight Code Words of Projective Geometric Codes</i> . . . . .	78
Simeon Ball: <i>Maximum Distance Separable Codes: Recent advances and applications</i> . . . . .	78
Zoltán L. Blázsik: <i>Balanced upper chromatic number of <math>PG(2, q)</math></i> . . . . .	79
Bence Csajbók: <i>Generalising KM-arcs</i> . . . . .	80
Maarten De Boeck: <i>Cameron-Liebler classes for finite geometries</i> . . . . .	80
Lins Denaux: <i>Small weight code words arising from the incidence of points and hyperplanes in <math>PG(n, q)</math></i> . . . . .	81
Jozefien D'haeseleer: <i>Projective solids pairwise intersecting in at least a line</i> . .	81
Stephen Glasby: <i>Classical groups and transitive actions on subspaces</i> . . . . .	82
Ferdinand Ihringer: <i>New SDP Bounds on Subspace Codes</i> . . . . .	82
György Kiss: <i>On resolving sets for the point-line incidence graph of <math>PG(n, q)</math></i> . . .	83
Michel Lavrauw: <i>MDS codes, arcs and tensors</i> . . . . .	83
Giuseppe Marino: <i>Subspace code constructions</i> . . . . .	84
Sam Mattheus: <i>Bipartite Ramsey numbers: <math>C_4</math> versus the star</i> . . . . .	85
Valentina Pepe: <i>A construction for clique-free pseudorandom graphs</i> . . . . .	85
Tamás Szőnyi: <i>On the stability of Baer subplanes</i> . . . . .	85
<b>Games on graphs</b> . . . . .	87
Csilla Bujtás: <i>Domination and transversal games: Conjectures and perfectness</i> .	88
Simone Dantas: <i>The Graceful Game</i> . . . . .	88
Jarosław Grytczuk: <i>Choosability Games</i> . . . . .	89
Vesna Iršič: <i>Some results on the connected domination game</i> . . . . .	89
Tijo James: <i>Domination game on split graphs</i> . . . . .	89
Daniel Pinto: <i>Replicator equations on graphs</i> . . . . .	91
András Pongrácz: <i>Non-deterministic decision making on finite graphs</i> . . . . .	91
Gregory J. Puleo: <i>Online Sum-Paintability: Slow-Coloring of Trees</i> . . . . .	91
Éric Sopena: <i>A connected version of the graph coloring game</i> . . . . .	92
Daša Štesl: <i>Indicated coloring game on Cartesian products of graphs</i> . . . . .	92
Douglas B. West: <i>The Slow-Coloring Game on a Graph</i> . . . . .	92
<b>General Graph Theory</b> . . . . .	95

Marién Abreu: <i>Orthogonal Array Configurations</i> . . . . .	96
Kiyoshi Ando: <i>Some new local conditions for <math>k</math>-contractible edges</i> . . . . .	96
Suzana Antunović: <i>Exponential generalised network descriptors</i> . . . . .	97
Gábor Bacsó: <i>The Equal-Sum-Free Subset problem</i> . . . . .	97
Fernando I. Becerra López: <i>Integer invariants of a graph manifold using Hirzenbruch-Jung continued fractions on the linking matrix.</i> . . . . .	97
Simona Bonvicini: <i>A variant of orthogonality for symmetric Latin squares</i> . . . . .	98
Sylwia Cichacz: <i>Group distance magic hypercubes</i> . . . . .	98
Jacob Cooper: <i>Finitely forcible graph limits are universal</i> . . . . .	99
Michał Dębski: <i>Edge colorings avoiding patterns</i> . . . . .	99
Mark Ellingham: <i>The structure of 4-connected <math>K_{2,t}</math>-minor-free graphs</i> . . . . .	99
Igor Fabrici: <i>Circumference of essentially 4-connected planar graphs</i> . . . . .	100
Gašper Fijavž: <i>Forbidding prism immersions</i> . . . . .	100
Hanna Furmańczyk: <i>Equitable list vertex colourability and arboricity of grids</i> . . . . .	101
Jerzy Garus: <i>Underwater vehicle trajectory planning using the graph theory in dynamic environments with obstacles</i> . . . . .	101
Jan Goedgebeur: <i>Graphs with few Hamiltonian Cycles</i> . . . . .	101
Mariusz Grech: <i>Wreath product of permutation groups as the automorphism group of a graph.</i> . . . . .	102
Dan Hawtin: <i><math>s</math>-Elusive Codes in Hamming Graphs</i> . . . . .	103
Michael Hecht: <i>Tight Localisations of Minimal Feedback Sets in Cubic Time</i> . . . . .	103
Florian Hoersch: <i>Highly vertex-connected orientations of regular eulerian graphs</i> . . . . .	103
Szabolcs Horvát: <i>Exact random sampling of connected graphs with a given degree sequence</i> . . . . .	104
Gyula Y. Katona: <i>Complexity questions for minimally <math>t</math>-tough graphs</i> . . . . .	104
Grzegorz Kubicki: <i>An optimal algorithm for stopping on the element closest to the center of an interval</i> . . . . .	104
Mariusz Kwiatkowski: <i>Tree structured <math>z</math>-knotted triangulations of a sphere.</i> . . . . .	105
Domenico Labbate: <i>Non bipartite regular 2-factor isomorphic graphs: an update</i> . . . . .	105
Florian Lehner: <i>On the cop-number of toroidal graphs</i> . . . . .	105
Christian Lindorfer: <i>Ends of graphs and the language of self-avoiding walks</i> . . . . .	106
Mária Maceková: <i>Acyclic coloring of graphs with prescribed maximum average degree</i> . . . . .	106
Snježana Majstorović: <i>Graphs preserving total distance upon vertex removal</i> . . . . .	107
Davide Mattiolo: <i>Some results regarding upper and lower bounds on the circular flow number of snarks</i> . . . . .	107
Giuseppe Mazzuoccolo: <i>Reduction of the Berge-Fulkerson Conjecture to cyclically 5-edge-connected snarks</i> . . . . .	107
Maria Chiara Molinari: <i>Colored even cycle decompositions</i> . . . . .	108
Atsuhiko Nakamoto: <i>Vertex-face structures in quadrangulations on surfaces</i> . . . . .	108
Gábor Nyul: <i>Various generalizations of Bell numbers</i> . . . . .	109
Deryk Osthus: <i>Decompositions into isomorphic rainbow spanning trees</i> . . . . .	109
Silvia Pagani: <i>Discrete tomography: a graph-theoretical formulation of local uniqueness for two directions</i> . . . . .	109
Vincenzo Pallozzi Lavorante: <i>AG codes from the second generalization of the GK maximal curve</i> . . . . .	110
Mark Pankov: <i>Face <math>z</math>-monodromies in triangulations of surfaces</i> . . . . .	110
Balázs Patkós: <i>On the general position problem on Kneser graphs</i> . . . . .	110

Sofia J. Pinheiro: <i>Erdős-Gallai type results on weighted degree sequences of graphs</i>	111
Miguel Pizaña: <i>Cliques, Logic and Games</i>	111
Gabriella Rácz: <i>Generalized Lah numbers and their graph theoretical interpretation</i>	112
Murat Sahin: <i>Core partitions with <math>d</math>-distinct parts</i>	112
Binod Kumar Sahoo: <i>Vertex connectivity of the power graph of a finite cyclic group</i>	112
Yusuke Suzuki: <i>Partially Broken Orientations of Eulerian Plane Graphs</i>	113
Adam Tyc: <i>Z-knotted triangulations of surfaces</i>	113
Stefan Veldsman: <i>Congruences and subdirect representations of graphs</i>	113
Aleksander Vesel: <i>Packing colorings of Sierpiński-type and <math>H</math> graphs</i>	114
Mate Vizer: <i>On the Turán number of edge ordered graphs</i>	114
Chuanqi Xiao: <i>The Turán number of the square of a path</i>	114
Dong Ye: <i>Circuit Covers of Signed Graphs</i>	114
Bogdan Žak: <i>Determination of the optimal ship trajectory in a collision situation with the use of directed graphs</i>	115
Jean Paul Zerafa: <i>Hamiltonian cycles containing a prescribed perfect matching</i>	115
<b>Graph coloring</b>	117
Marcin Anholcer: <i>Majority coloring of infinite digraphs</i>	118
János Barát: <i>Decomposition of cubic graphs related to Wegner’s conjecture</i>	118
Ewa Drgas-Burchardt: <i>Consecutive colouring of oriented graphs</i>	118
Jasmina Ferme: <i>Graphs that are critical for the packing chromatic number</i>	119
Ewa Kubicka: <i>Total coloring of graphs with minimum sum of colors; existence of <math>T</math>-strong graphs and trees.</i>	119
Xueliang Li: <i>Monochromatic disconnection of graphs</i>	119
Borut Lužar: <i>Homogeneous Coloring of Graphs</i>	120
Jakub Przybyło: <i>The 1–2–3 Conjecture almost holds for regular graphs</i>	120
Douglas Rall: <i>Packing chromatic vertex-critical graphs</i>	120
Ingo Schiermeyer: <i>Polynomial <math>\chi</math>-binding functions and forbidden induced subgraphs - a survey</i>	121
Riste Škrekovski: <i>Some results and problems on unique-maximum colorings of plane graphs</i>	121
Małgorzata Śleszyńska-Nowak: <i>Strong cliques in graphs</i>	121
<b>Metric Graph Theory</b>	123
Bhaskar DasGupta: <i>Computational complexities of three problems related to computing the metric anti-dimension of a graph.</i>	124
Ville Junnila: <i>On the Solid-Metric Dimension of a Graph</i>	124
Cong X. Kang: <i>The connected metric dimension at a vertex of a graph</i>	125
Aleksander Kelenc: <i>Hausdorff Distance Between Trees in Polynomial Time</i>	125
Dorota Kuziak: <i>Metric and strong metric dimensions of direct product graphs</i>	125
Tero Laihonen: <i>On Resolving Several Vertices in a Graph</i>	126
Mercè Mora: <i><math>k</math>-Fault-tolerant resolving sets in graphs</i>	126
María Luz Puertas: <i>Bounding the determining number of a graph by removing twins</i>	127
Yunior Ramírez-Cruz: <i>Constrained incremental resolvability in dynamic graphs: a case study in active re-identification attacks on social networks</i>	127
Rinovia Simanjuntak: <i>Centroidal dimensions of product graphs</i>	129

Andrej Taranenko: <i>On graphs achieving the trivial upper bound for edge metric dimension</i> . . . . .	129
Ismael G. Yero: <i>Uniquely identifying the vertices of a graph by means of distance multisets</i> . . . . .	129
Eunjeong Yi: <i>The fractional <math>k</math>-metric dimension of graphs</i> . . . . .	130
<b>Polytopes</b> . . . . .	131
Javier Bracho: <i>A family of finite quiral polyhedra in <math>S^3</math></i> . . . . .	132
Marston Conder: <i>Chiral polytopes of arbitrarily large rank</i> . . . . .	132
Maria Elisa Fernandes: <i>Locally spherical hypertopes</i> . . . . .	132
Isabel Hubard: <i>Geometric chiral polyhedra in 3-dimensional spaces</i> . . . . .	132
Dimitri Leemans: <i>Rank reduction of string <math>C</math>-group representations</i> . . . . .	133
Tilen Marc: <i>Oriented matroids as graphs</i> . . . . .	133
Elias Mochan: <i>2- orbit polytopes</i> . . . . .	133
Luis Montejano: <i>On the Geometric Banach Conjecture</i> . . . . .	134
Antonio Montero: <i>Highly symmetric toroidal polytopes</i> . . . . .	134
Daniel Pellicer: <i>Tight chiral abstract polytopes</i> . . . . .	134
Claudio Alexandre Piedade: <i>Possible degrees of Toroidal Regular Maps</i> . . . . .	134
Moshe Rosenfeld: <i>Branko Grünbaum, the mathematician who beat the odds</i> . . . . .	135
Asia Ivić Weiss: <i>Realizations of regular abstract polytopes in euclidean spaces</i> . . . . .	135
Gordon Williams: <i>Geometric realizability of simplicial 3-spheres</i> . . . . .	135
Steve Wilson: <i>Rotary 4-Manifolds having one facet</i> . . . . .	136
<b>Spectral Graph Theory</b> . . . . .	137
Aida Abiad: <i>A characterization and an application of weight-regular partitions of graphs</i> . . . . .	138
Ambat Vijayakumar: <i>The Distance Spectra of Some Graph Classes — A Survey</i> . . . . .	138
Milica Andelic: <i>Tridiagonal matrices and spectral properties of some graph classes</i> . . . . .	140
Francesco Belardo: <i>On some recent results of Slobodan K. Simić (1948-2019)</i> . . . . .	140
Maurizio Brunetti: <i>On Some Spectral Properties of Signed Circular Caterpillars</i> . . . . .	140
Cristina Dalfo: <i>A new general method to obtain the spectrum and local spectra of a graph from its regular partitions</i> . . . . .	141
Alexander Farrugia: <i>Generating Pairs of Generalized Cosppectral Graphs from Controllable Graphs</i> . . . . .	141
Alexander Gavriluk: <i>On the multiplicities of digraph eigenvalues</i> . . . . .	141
Wilfried Imrich: <i>The Structure of Quartic Graphs with Minimal Spectral Gap</i> . . . . .	142
Bojana Mihailović: <i>Some examples of transformations that preserve <math>\text{sgn}(\lambda_2 - r)</math></i> . . . . .	142
Bojan Mohar: <i>About the smallest eigenvalue of non-bipartite graphs</i> . . . . .	142
Kamal Lochan Patra: <i>Laplacian eigenvalues of the zero divisor graph of the ring <math>\mathbb{Z}_n</math></i> . . . . .	142
Soňa Pavlíková: <i>Inverting non-invertible labeled trees</i> . . . . .	143
Paula Rama: <i>Spectral and combinatorial properties of lexicographic polynomials of graphs</i> . . . . .	143
Irene Sciriha: <i>On graphs with the same main eigenspace</i> . . . . .	144
Zoran Stanić: <i>Notes on spectra of signed graphs</i> . . . . .	144
Tetsuji Taniguchi: <i>A generalization of Hoffman Graph</i> . . . . .	144
Jianfeng Wang: <i>On graphs whose spectral radius does not exceed the Hoffman limit value</i> . . . . .	145

Pepijn Wissing: <i>The negative tetrahedron and the first infinite family of connected digraphs that are strongly determined by the Hermitian spectrum</i> . . . . .	145
<b>Structural and algorithmic graph theory</b> . . . . .	147
Pierre Aboulker: <i>Subgraphs of directed graphs with large dichromatic number</i> .	148
Jesse Beisegel: <i>Maximum Weighted Clique in Hole-Cyclically Orientable Graphs</i>	148
Michael Hecht: <i>Topological Invariants of Elementary Cycles and a Generalization of Biggs Theorem</i> . . . . .	148
Tony Huynh: <i>Unavoidable minors for graphs with large <math>\ell_p</math>-dimension</i> . . . . .	148
Eunjung Kim: <i>Erdős-Pósa Property of Chordless Cycles and its Applications</i> . . .	149
Miklós Krész: <i>Uniquely restricted <math>(g, f)</math>-factors</i> . . . . .	149
Matjaž Krnc: <i>On the End-Vertex Problem of Graph Searches</i> . . . . .	150
William Lochet: <i>Immersion of transitive tournaments</i> . . . . .	150
Martin Milanič: <i>Avoidable Vertices, Avoidable Edges, and Implications for Highly Symmetric Graphs</i> . . . . .	151
Alantha Newman: <i>Explicit 3-colorings for exponential graphs</i> . . . . .	151
Shmuel Onn: <i>Deciding and Optimizing over Degree Sequences</i> . . . . .	152
Nevena Pivač: <i>Minimal separators in graph classes dened by small forbidden induced subgraphs</i> . . . . .	152
Miguel Pizaña: <i>Algorithmic Aspects of the Finite Extension Problem</i> . . . . .	152
Ni Luh Dewi Sintuari: <i>Layered wheels</i> . . . . .	153
 <b>Symmetries of graphs and maps</b> . . . . .	 155
Martin Bachraty: <i>Skew morphisms of simple groups</i> . . . . .	156
Antonio Breda d’Azevedo: <i>Regular bi-oriented maps of negative prime characteristic</i> . . . . .	156
Domenico Catalano: <i>Strong map-symmetry of <math>SL(3, K)</math> and <math>PSL(3, K)</math> for any finite field <math>K</math></i> . . . . .	156
Marston Conder: <i>Observations and answers to questions about edge-transitive maps</i> . . . . .	156
Ted Dobson: <i>Every 2-closed group of degree <math>qp^2</math> has a semiregular element</i> . . .	157
Ben Fairbairn: <i>Some non-Beauville groups: Why you should always pay attention to what is said at wine receptions</i> . . . . .	157
Michael Giudici: <i>Arc-transitive bicirculants</i> . . . . .	157
Robert Jajcay: <i>Generalized Cayley maps</i> . . . . .	157
Gareth A. Jones: <i>Realisation of groups as automorphism groups of maps and hypermaps</i> . . . . .	158
Rafał Kalinowski: <i>Symmetry breaking in claw-free graphs of small maximum degree</i> . . . . .	158
Carlisle King: <i>Edge-primitive 3-arc-transitive graphs</i> . . . . .	159
István Kovács: <i>Groups all of whose Haar graphs are Cayley graphs</i> . . . . .	159
Young Soo Kwon: <i>Square roots of automorphisms of cyclic groups</i> . . . . .	159
Hoi Ping Luk: <i>Tilings of the Sphere by Almost Equilateral Pentagons</i> . . . . .	160
Martin Mačaj: <i>On external symmetries of Wilson maps</i> . . . . .	160
Aleksander Malnič: <i>Covers of digraphs</i> . . . . .	160
Adnan Melekoğlu: <i>Patterns of edge-transitive maps</i> . . . . .	161
Rögnvaldur G. Möller: <i>Infinite vertex-transitive graphs and their arc-types</i> . .	161

Luke Morgan: <i>The distinguishing number of 2-arc-transitive graphs and permutation groups</i> . . . . .	162
Roman Nedela: <i>Reductions of maps preserving the isomorphism relation I</i> . . .	162
Monika Pilšniak: <i>Distinguishing colorings of maps</i> . . . . .	163
Daniel Pinto: <i>Duality and Chiral-Duality</i> . . . . .	163
Primož Potočnik: <i>Generalised voltage graphs</i> . . . . .	163
Nemanja Poznanovic: <i>Normal quotients of four-valent G-oriented graphs</i> . . .	164
Marina Šimac: <i>LDPC codes constructed from cubic symmetric graphs</i> . . . . .	164
Primož Šparl: <i>On loosely attached tetravalent half-arc-transitive graphs</i> . . . .	164
Micael Toledo: <i>Cubic graphs with long orbits</i> . . . . .	165
Thomas Tucker: <i>Surface Symmetry: Kulkarni Revisited</i> . . . . .	165
Peter Zeman: <i>Reductions of maps preserving the isomorphism relation II</i> . . . .	165
<b>Speaker index</b>	<b>167</b>



# GENERAL INFORMATION

## **Bled'19 – 9th Slovenian International Conference on Graph Theory**

Bled, Slovenia, June 23 – 29, 2019

### **ORGANIZED BY:**

IMFM (*Institute of Mathematics, Physics and Mechanics*)

### **IN COLLABORATION WITH:**

DMFA (*Society of Mathematicians, Physicists and Astronomers of Slovenia*) SDAMS (*Slovenian Discrete and Applied Mathematics Society*) UL FMF (*University of Ljubljana, Faculty of Mathematics and Physics*),

UM FNM (*University of Maribor, Faculty of Natural Sciences and Mathematics*),

UP FAMNIT (*University of Primorska, Faculty of Mathematics, Natural Sciences and Information Technologies*),

UP IAM (*University of Primorska, Andrej Marušič Institute*),

Abelium d.o.o.

### **SCIENTIFIC COMMITTEE:**

Sandi Klavžar, Dragan Marušič, Bojan Mohar (chair), Tomaž Pisanski

### **ORGANIZING COMMITTEE:**

Boštjan Brešar, Sergio Cabello, Ademir Hujdurović, Rok Požar

### **CONFERENCE VENUES:**

Hotel Kompas Bled, Cankarjeva Cesta 2, SI-4260, Bled, Slovenia

Best Western Premier Hotel Lovec, Ljubljanska cesta 6, SI-4260, Bled, Slovenia

Rikli Balance Hotel, Cankarjeva Cesta 4, SI-4260, Bled, Slovenia

### **CONFERENCE WEBSITE:**

<https://conferences.matheo.si/e/bled19>



**PLENARY SPEAKERS:**

Noga Alon, *Princeton University, USA, and Tel Aviv University, Israel*

Marco Buratti, *Università di Perugia, Italy*

Gareth A. Jones, *University of Southampton, UK*

Gábor Korchmáros, *Università della Basilicata, Italy*

Daniel Král', *Masaryk University, Czech Republic, and University of Warwick, UK*

Daniela Kühn, *University of Birmingham, UK*

Sergei Lando, *University Higher School of Economics, Skolkovo Institute of Science and Technology, Moscow, Russia*

János Pach, *EPFL, Switzerland, and Rényi Institute, Hungary*

Cheryl E. Praeger, *University of Western Australia*

Zsolt Tuza, *Rényi Institute and University of Pannonia, Hungary*

Xuding Zhu, *Zhejiang Normal University, China*

**INVITED SPECIAL SESSIONS AND THEIR ORGANIZERS**

Association Schemes (*Mikhail Muzychuk*)

Biomathematics and Bioinformatics (*Marc Hellmuth*)

Chemical graph theory (*Xueliang Li*) – This session is associated with the meeting of the International Academy of Mathematical Chemistry, IAMC 2019

Configurations (*Gábor Gévay*)

Designs (*Dean Crnković*)

Discrete and computational geometry (*Sergio Cabello*)

Distance-regular graphs (*Štefko Miklavič*)

Domination in graphs (*Michael A. Henning*) – This session celebrates the 70th birthday of Douglas F. Rall.

Finite Geometries (*Tamás Szőnyi*)

Games on graphs (*Csilla Bujtás*)

Graph coloring (*Ingo Schiermeyer*)

Metric Graph Theory (*Ismael G. Yero*)

Polytopes (*Asia Ivić Weiss*) – This session celebrates the life and work of Branko Grünbaum

Spectral Graph Theory (*Francesco Belardo*)

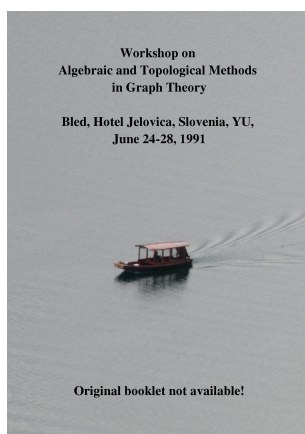
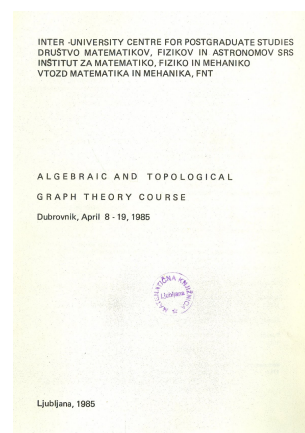
Structural and algorithmic graph theory (*Pierre Aboulker*)

Symmetries of graphs and maps (*Marston Conder*)

# PAST CONFERENCES

## 1ST SLOVENIAN INTERNATIONAL CONFERENCE ON GRAPH THEORY

a. k. a. Algebraic and Topological Graph Theory Course. Dubrovnik (now Croatia), April 8–19, 1985. 47 participants, 10 invited speakers, 37 talks. Scientific Committee: W. Imrich, T. D. Parsons, T. Pisanski.

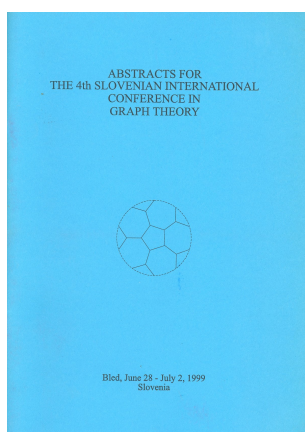
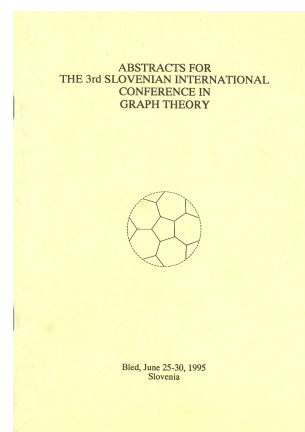


## 2ND SLOVENIAN INTERNATIONAL CONFERENCE ON GRAPH THEORY

a. k. a. Workshop on Algebraic and Topological Methods in Graph Theory. Bled, Slovenia, YU, June 24–28, 1991. Around 30 participants, 7 invited speakers. The meeting started in FLR Yugoslavia and ended in independent Slovenia. Scientific Committee: V. Batagelj, D. Marušič, B. Mohar and T. Pisanski. Conference proceedings printed in a special issue of Discrete Math, Vol 134 (1994).

## 3RD SLOVENIAN INTERNATIONAL CONFERENCE ON GRAPH THEORY

Bled, June 25–30, 1995. 8 invited speakers, 79 talks, general session and 6 special sessions. Scientific Committee: D. Marušič and B. Mohar. Conference proceedings printed in a special issue of Discrete Math, Vol 182 (1998).

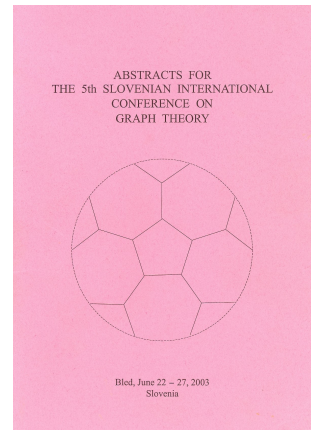


## 4TH SLOVENIAN INTERNATIONAL CONFERENCE ON GRAPH THEORY

Bled, June 28–July 2, 1999. 18 invited speakers, 92 talks. Scientific Committee: S. Klavžar, D. Marušič and B. Mohar. Proceedings in a special issue of Discrete Math, Vol. 244 (2002).

### 5TH SLOVENIAN INTERNATIONAL CONFERENCE ON GRAPH THEORY

Bled, June 22–27, 2003. 87 participants, 13 invited speakers, 72 talks. Scientific Committee: B. Brešar, M. Juvan, S. Klavžar, D. Marušič, A. Malnič, B. Mohar, T. Pisanski. Conference proceedings printed in a special issue of Discrete Math, Vol. 307 (2007).



### 6TH SLOVENIAN INTERNATIONAL CONFERENCE ON GRAPH THEORY

Bled, June 24–30, 2007. 15 invited speakers, 189 registered contributions, general session, 14 minisymposia and 2 satellite conferences. Scientific Committee: S. Klavžar, D. Marušič, B. Mohar, T. Pisanski. Conference proceedings printed in special issues of Discrete Math, Vol. 310 (2010) and Ars Mathematica Contemporanea, Vol. 1 (2008).

### 7TH SLOVENIAN INTERNATIONAL CONFERENCE ON GRAPH THEORY

Bled, June 19–25, 2011. 10 keynote speakers, 222 registered contributions, general session, 17 minisymposia and 4 satellite events. Scientific Committee: S. Klavžar, D. Marušič, B. Mohar, T. Pisanski. Conference proceedings printed in special issue of Ars Mathematica Contemporanea, Vol. 6 (2013).



### 8TH SLOVENIAN CONFERENCE ON GRAPH THEORY

Kranjska Gora, June 21–27, 2015. 9 plenary speakers, 247 registered contributions, general session, 13 minisymposia and 3 satellite events. Scientific Committee: S. Klavžar, D. Marušič, B. Mohar, T. Pisanski.

## Unavoidable minors for graphs with large $\ell_p$ -dimension

Tony Huynh

*Université libre de Bruxelles (ULB)*

A *metric graph* is a pair  $(G, d)$ , where  $G$  is a graph and  $d : E(G) \rightarrow \mathbb{R}_{\geq 0}$  is a distance function. Let  $p \in [1, \infty]$  be fixed. An *isometric embedding* of the metric graph  $(G, d)$  in  $\ell_p^k = (\mathbb{R}^k, d_p)$  is a map  $\phi : V(G) \rightarrow \mathbb{R}^k$  such that  $d_p(\phi(v), \phi(w)) = d(vw)$  for all edges  $vw \in E(G)$ . The  $\ell_p$ -*dimension* of  $G$  is the least integer  $k$  such that there exists an isometric embedding of  $(G, d)$  in  $\ell_p^k$  for all distance functions  $d$  such that  $(G, d)$  has an isometric embedding in  $\ell_p^K$  for some  $K$ .

It is easy to show that  $\ell_p$ -dimension is a minor-monotone property. We characterize the minor-closed graph classes  $\mathcal{C}$  with bounded  $\ell_p$ -dimension, for  $p \in \{2, \infty\}$ . For  $p = 2$ , we give a simple proof that  $\mathcal{C}$  has bounded  $\ell_2$ -dimension if and only if  $\mathcal{C}$  has bounded treewidth. In this sense, the  $\ell_2$ -dimension of a graph is ‘tied’ to its treewidth.

For  $p = \infty$ , the situation is completely different. Our main result states that a minor-closed class  $\mathcal{C}$  has bounded  $\ell_\infty$ -dimension if and only if  $\mathcal{C}$  excludes a graph obtained by joining copies of  $K_4$  using the 2-sum operation, or excludes a Möbius ladder with one ‘horizontal edge’ removed.

This is joint work with Samuel Fiorini, Gwenaël Joret, and Carole Muller. Preprint available at <https://arxiv.org/abs/1904.02951>.

## Erdős-Pósa Property of Chordless Cycles and its Applications

Eunjung Kim

*CNRS, LAMSADE, Paris-Dauphine University*

A chordless cycle, or equivalently a hole, in a graph  $G$  is an induced subgraph of  $G$  which is a cycle of length at least four. We prove that the Erdős-Pósa property holds for chordless cycles, which resolves the major open question concerning the Erdős-Pósa property. Our proof for chordless cycles is constructive: in polynomial time, one can find either  $k + 1$  vertex-disjoint chordless cycles, or  $ck^2 \log k$  vertices hitting every chordless cycle for some constant  $c$ . It immediately implies an approximation algorithm of factor  $\mathcal{O}(\text{opt} \log \text{opt})$  for CHORDAL VERTEX DELETION. We complement our main result by showing that chordless cycles of length at least  $\ell$  for any fixed  $\ell \geq 5$  do not have the Erdős-Pósa property.

We also consider an edge version of Erdős-Pósa property for chordless cycles (this time, triangle is also considered to be a chordless cycle) of length at least  $\ell$ . Partial results are obtained for different values of  $\ell$ .

This talk is based on joint work with O-joung Kwon, Pierre Aboulker and Valia Mitsou. (Preprint is available at <https://arxiv.org/abs/1711.00667>.)

## Uniquely restricted $(g, f)$ -factors

Miklós Krész

*InnoRenew CoE & UP IAM, Slovenia*

*University of Szeged, Hungary*

The concept of  $(g, f)$ -factors is a classical generalization of matchings in graphs. Given an undirected graph  $G$ , let  $g$  and  $f$  be nonnegative integer-valued functions defined on the vertex set  $V$  of  $G$  with  $g(v) \leq f(v) \leq \deg_G(v)$  for all  $v \in V$ , where  $\deg_G(v)$  represents the degree of vertex

$v$  in  $G$ . Then a  $(g, f)$ -factor is defined as a subgraph  $H$  of  $G$  with  $g(v) \leq \deg_H(v) \leq f(v)$  for every  $v \in V$ .

One of the relevant characteristics of a  $(g, f)$ -factor is the so-called *degree pattern*: a vector  $p_H$  of the degrees of the vertices with a preliminary fixed order of the vertices. A  $(g, f)$ -factor  $H$  is *uniquely restricted* if the degree pattern of any other  $(g, f)$ -factor in  $G$  is different from  $p_H$ .

The above concept was originally introduced for matchings by M. C. Golumbic, T. Hirst and M. Lewenstein in 2001. They have proved that finding a maximum uniquely restricted matching is NP-hard; consequently research in the recent year mainly focused on special cases of this problem. Another approach was considered by V. E. Levit and E. Mandrescu in a paper from 2003, when posed the question whether it is polynomially solvable for a graph  $G$ , if all maximum matchings are uniquely restricted. For the above question Penso et al provided recently (Journal of Graph Theory, 2018, 89[.]) a positive answer.

In this talk we will show that the above results can be extended to  $(g, f)$ -factors.

**Acknowledgment:** This research was partially supported by the National Research, Development and Innovation Office - NKFIH Fund No. SNN-117879. The author also acknowledges the European Commission for funding the InnoRenew CoE project (Grant Agreement #739574) under the Horizon2020 Widespread-Teaming program and the support of the ARRS grant N1-0093.

## On the End-Vertex Problem of Graph Searches

Matjaž Krnc

*University of Primorska, Koper, and Institute of Mathematics, Physics and Mechanics, Ljubljana, Slovenia*

End vertices of graph searches can exhibit strong structural properties and are crucial for many graph algorithms. The problem of deciding whether a given vertex of a graph is an end-vertex of a particular search was first introduced by Corneil, Köhler, and Lanlignel in 2010. There they showed that this problem is in fact  $\mathcal{NP}$ -complete for LBFS on weakly chordal graphs. A similar result for BFS was obtained by Charbit, Habib and Mamcarz in 2014. Here, we prove that the end-vertex problem is  $\mathcal{NP}$ -complete for MNS on weakly chordal graphs and for MCS on general graphs. Moreover, building on previous results, we show that this problem is linear for various searches on split and unit interval graphs.

Preprint available at <https://arxiv.org/abs/1810.12253>.

## Immersion of transitive tournaments

William Lochet

*University of Bergen*

A classical result by Mader shows the existence of a function  $g$  such that for every  $k$ , every graph with minimum degree at least  $g(k)$  contains a subdivision of the complete graph on  $k$  vertices. An interesting topic is to understand possible generalisations of this result to digraphs. In 1985, Thomassen proved the existence of digraphs with arbitrarily large minimum outdegree and without even directed cycle. This implies in particular that these digraphs do not contain  $\overleftrightarrow{K}_3$  as subdivision. In 1985 however, Mader asked the existence of a function  $f$  such that digraphs with minimum degree at least  $f(k)$  contain a subdivision of the **transitive** tournament on  $k$  vertices. This conjecture remains completely open, as the existence of  $f(5)$  is still unknown. In 2011, DeVos et al. proposed a weakening of this conjecture asking for immersions instead of subdivisions. In this talk, we will present a proof of this conjecture.

# SPEAKER INDEX

- Abiad, Aida, 138  
Aboulker, Pierre, 148  
Abreu, Marién, 96  
Adriaensen, Sam, 78  
Alon, Noga, 22  
Ambat, Vijayakumar, 138  
Andelic, Milica, 140  
Ando, Kiyoshi, 96  
Anholcer, Marcin, 118  
Antunović, Suzana, 97
- Bachraty, Martin, 156  
Bacsó, Gábor, 97  
Bailey, Robert F., 68  
Ball, Simeon, 78  
Ban, Sara, 54  
Barát, János, 118  
Becerra López, Fernando I., 97  
Beisegel, Jesse, 148  
Belardo, Francesco, 140  
Berman, Leah Wrenn, 48  
Blau, Harvey, 28  
Blázsik, Zoltán L., 79  
Bockting-Conrad, Sarah, 68  
Bokal, Drago, 62  
Bokowski, Jürgen, 48  
Bonvicini, Simona, 98  
Bracho, Javier, 132  
Breda d’Azevedo, Antonio, 156  
Brešar, Boštjan, 72  
Brezovnik, Simon, 40  
Brunetti, Maurizio, 140  
Bujtás, Csilla, 88  
Buratti, Marco, 22
- Cabello, Sergio, 62  
Catalano, Domenico, 156  
Che, Zhongyuan, 40  
Chen, Haiyan, 40  
Cichacz, Sylwia, 98  
Colin de Verdière, Éric, 62  
Conder, Marston, 132, 156  
Cooper, Jacob, 99  
Costa, Simone, 54
- Crnković, Dean, 55  
Csajbók, Bence, 80
- Dalfo, Cristina, 141  
Dankelmann, Peter, 41  
Dantas, Simone, 88  
DasGupta, Bhaskar, 124  
De Boeck, Maarten, 80  
Dębski, Michał, 99  
Denaux, Lins, 81  
D’haeseleer, Jozefien, 81  
Dobson, Ted, 157  
Doerr, Daniel, 34  
Dorbec, Paul, 72  
Došlić, Tomislav, 41  
Drgas-Burchardt, Ewa, 118
- Egan, Ronan, 55  
Ellingham, Mark, 99
- Fabrici, Igor, 100  
Fairbairn, Ben, 157  
Farrugia, Alexander, 141  
Ferme, Jasmina, 119  
Fernandes, Maria Elisa, 132  
Fernández, Blas, 68  
Fijavž, Gašper, 100  
French, Christopher, 28  
Fujita, André, 34  
Furmańczyk, Hanna, 101  
Furtula, Boris, 41
- Garus, Jerzy, 101  
Gavoille, Cyril, 63  
Gavrilyuk, Alexander, 141  
Giudici, Michael, 157  
Glasby, Stephen, 82  
Goedbeur, Jan, 101  
Gologranc, Tanja, 72  
Grech, Mariusz, 102  
Gropp, Harald, 49  
Grytczuk, Jarosław, 89  
Gévay, Gábor, 48
- Hawtin, Dan, 103

- Hecht, Michael, 103, 148  
 Hellmuth, Marc, 35  
 Henning, Michael A., 73  
 Herbst, Lina, 35  
 Herman, Allen, 28  
 Hernandez Lucas, Lisa, 73  
 Hliněný, Petr, 63  
 Hoersch, Florian, 103  
 Horvát, Szabolcs, 104  
 Hubard, Isabel, 132  
 Humphries, Stephen, 29  
 Huynh, Tony, 148  
  
 Ihringer, Ferdinand, 82  
 Imrich, Wilfried, 142  
 Iršič, Vesna, 89  
 Izquierdo, Milagros, 49  
  
 Jajcay, Robert, 157  
 Jakovac, Marko, 73  
 James, Tijo, 89  
 Janssen, Remie, 36  
 Jin, Xian'an, 42  
 Jones, Gareth A., 22, 158  
 Junnila, Ville, 124  
  
 Kabanov, Vladislav, 55  
 Kalinowski, Rafał, 158  
 Kang, Cong X., 125  
 Katona, Gyula Y., 104  
 Kelenc, Aleksander, 125  
 Kempner, Yulia, 63  
 Kim, Eunjung, 149  
 King, Carlisle, 159  
 Kiss, György, 83  
 Klavžar, Sandi, 74  
 Knor, Martin, 42  
 Korchmáros, Gábor, 23  
 Kos, Tim, 74  
 Kovič, Jurij, 49  
 Kovács, István, 159  
 Kraner Šumenjak, Tadeja, 74  
 Krnc, Matjaž, 150  
 Král', Daniel, 23  
 Krész, Miklós, 149  
 Kubicka, Ewa, 119  
 Kubicki, Grzegorz, 104  
 Kuziak, Dorota, 125  
 Kwiatkowski, Mariusz, 105  
 Kwon, Young Soo, 159  
 Kühn, Daniela, 24  
  
 Labbate, Domenico, 105  
  
 Lafond, Manuel, 36  
 Laihonen, Tero, 126  
 Lakshmanan S., Aparna, 74  
 Lando, Sergei, 24  
 Lavrauw, Michel, 83  
 Leemans, Dimitri, 133  
 Lehner, Florian, 105  
 Li, Xueliang, 43, 119  
 Lindorfer, Christian, 106  
 Liotta, Giuseppe, 64  
 Lochet, William, 150  
 Luk, Hoi Ping, 160  
 Lužar, Borut, 120  
  
 Maceková, Mária, 106  
 Mačaj, Martin, 160  
 Majstorović, Snježana, 107  
 Malnič, Aleksander, 160  
 Marc, Tilen, 133  
 Marino, Giuseppe, 84  
 Martínez-Barona, Berenice, 75  
 Mattheus, Sam, 85  
 Mattiolo, Davide, 107  
 Mazzuocolo, Giuseppe, 107  
 Melekoğlu, Adnan, 161  
 Merola, Francesca, 56  
 Mihailović, Bojana, 142  
 Miklavič, Štefko, 68  
 Milanič, Martin, 151  
 Mochan, Elias, 133  
 Mohar, Bojan, 142  
 Molinari, Maria Chiara, 108  
 Montejano, Luis, 134  
 Montero, Antonio, 134  
 Mora, Mercè, 126  
 Morgan, Luke, 162  
 Munemasa, Akihiro, 29  
 Muzychuk, Misha, 29  
 Möller, Rögnvaldur G., 161  
  
 Nakamoto, Atsuhiko, 108  
 Napolitano, Vito, 49  
 Nedela, Roman, 162  
 Neumaier, Arnold, 69  
 Newman, Alantha, 151  
 Nøjgaard, Nikolai, 37  
 Nyul, Gábor, 109  
  
 Olmez, Oktay, 56  
 Onn, Shmuel, 152  
 Osthus, Deryk, 109  
  
 Pach, János, 24

- Pagani, Silvia, 109  
 Pallozzi Lavorante, Vincenzo, 110  
 Pankov, Mark, 110  
 Pasotti, Anita, 57  
 Patkós, Balázs, 110  
 Patra, Kamal Lochan, 142  
 Pavčević, Mario Osvin, 57  
 Pavlíková, Soňa, 143  
 Pellicer, Daniel, 134  
 Penjić, Safet, 69  
 Pepe, Valentina, 85  
 Peterin, Iztok, 75  
 Piedade, Claudio Alexandre, 134  
 Pilśniak, Monika, 163  
 Pinheiro, Sofia J., 111  
 Pinto, Daniel, 91, 163  
 Pisanski, Tomaž, 49  
 Pivač, Nevena, 152  
 Pizaña, Miguel, 111, 152  
 Pongrácz, András, 91  
 Ponomarenko, Ilia, 30  
 Potočnik, Primož, 163  
 Pott, Alexander, 58  
 Poznanovic, Nemanja, 164  
 Praeger, Cheryl E., 24  
 Przybyło, Jakub, 120  
 Puertas, María Luz, 127  
 Puleo, Gregory J., 91  
 Pálvölgyi, Dömötör, 64
- Rácz, Gabriella, 112  
 Rall, Douglas, 120  
 Rama, Paula, 143  
 Ramírez-Cruz, Yuniór, 127  
 Raney, Michael, 50  
 Rosenfeld, Moshe, 135  
 Ryabov, Grigory, 30
- Sahin, Murat, 112  
 Sahoo, Binod Kumar, 112  
 Saniga, Metod, 50  
 Saumell, Maria, 65  
 Schiermeyer, Ingo, 121  
 Schmitt, John R., 58  
 Scholz, Guillaume, 37  
 Sciriha, Irene, 144  
 Sedlar, Jelena, 43  
 Seemann, Carsten R., 37  
 Simanjuntak, Rinovia, 129  
 Sintuari, Ni Luh Dewi, 153  
 Somlai, Gábor, 30  
 Sopena, Éric, 92
- Stanić, Zoran, 144  
 Stokes, Klara, 50  
 Suda, Sho, 31  
 Suzuki, Hiroshi, 70, 113  
 Szőnyi, Tamás, 85
- Śleszyńska-Nowak, Małgorzata, 121
- Šimac, Marina, 164  
 Škrekovski, Riste, 121  
 Šparl, Primož, 164  
 Štesl, Daša, 92  
 Švob, Andrea, 58
- Taniguchi, Tetsuji, 144  
 Tararenko, Andrej, 129  
 Tepeh, Aleksandra, 76  
 Terwilliger, Paul, 70  
 Tiwary, Hans Raj, 65  
 Toledo, Micael, 165  
 Traetta, Tommaso, 59  
 Tratnik, Niko, 43  
 Tucker, Thomas, 165  
 Tuza, Zsolt, 25  
 Tyc, Adam, 113
- Vasil'ev, Andrey, 31  
 Vegi Kalamar, Alen, 65  
 Veldsman, Stefan, 113  
 Vesel, Aleksander, 114  
 Vidali, Janoš, 32  
 Vizer, Mate, 114  
 Vučićić, Tanja, 59
- Wang, Jianfeng, 44, 145  
 Wassermann, Alfred, 59  
 Weiss, Asia Ivić, 135  
 West, Douglas B., 92  
 Wicke, Kristina, 38  
 Williams, Gordon, 135  
 Wilson, Steve, 136  
 Wissing, Pepijn, 145
- Xiao, Chuanqi, 114
- Ye, Dong, 114  
 Yero, Ismael G., 129  
 Yi, Eunjeong, 130
- Zeman, Peter, 165  
 Zerafa, Jean Paul, 115  
 Zhang, Heping, 44  
 Zhu, Xuding, 25  
 Zieschang, Paul-Hermann, 32



Žak, Bogdan, 115

Žigert Pleteršek , Petra, 45

Žitnik, Arjana, 51



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