LC06002 – Final Evaluation Report

Pavel Exner

exner@ujf.cas.cz

Doppler Institute

for Mathematical Physics and Applied Mathematics

Prague – Řež – Hradec Králové

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Doppler Institute history in brief

- The group of mathematical physicists existed since the end of the 80's, formally it was established by the FNSPE dean in 1993

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- In 2005 its members applied for support of a Center of Basic Research project under the name Doppler Institute for Mathematical Physics and Applied Mathematics on behalf of three institutions — CTU, NPI, and UHK

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- The group of mathematical physicists existed since the end of the 80's, formally it was established by the FNSPE dean in 1993
- In 2005 its members applied for support of a Center of Basic Research project under the name Doppler Institute for Mathematical Physics and Applied Mathematics on behalf of three institutions — CTU, NPI, and UHK
- The proposal was accepted and the Center was subsequently established with the support of the LC06002 five-year grant amounting to 34.041 mln. CZK; it started functioning on March 1, 2006

Doppler Institute history, continued

- In 2010 the project received a one year extension with the budget of 4.455 mln. CZK

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- N.B. The aftermath: in 2011 an application was made for a continuation as a Czech Science Foundation *Center of Excellence*; it was turned down on a dubious formal pretext
- In August 2011 the three participating institutions signed an agreement in which they pledged to keep Doppler Institute as their common enterprise

Highligts: quantum walks

Quantum walk is an important theoretical concept which can have far-reaching consequences, e.g., in *quantum computing*. The group of Igor Jex in collaboration with University of Erlangen managed to achieve *optical implementation* of such walks in one and two dimensions demonstrating *Anderson localization* and other effects

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[1] Andreas Schreiber, Katiuscia Cassemiro, Václav Potoček, Aurel Gábris, Peter Mosely, Erika Andersson, Igor Jex, Christine Silberhorn: Photons walking the line: a quantum walk with adjustable coin operations, *Phys. Rev. Lett.* **104** (2010), 050502

[2] Andreas Schreiber, Aurel Gábris, Peter P. Rohde, Kaisa Laiho, Martin Štefanák, Václav Potoček, Igor Jex, Craig Hamilton, Christine Silberhorn: A 2D quantum walk simulation of two-particle dynamics, *Science* **335** (2012), to appear

Highlights: quantum graph vertices

Matching wave functions at graph vertices which *conserves probability current* leaves open many possibilities raising question about the coupling *physical meaning*

It can be answered by approximations by graphs with “simple” couplings or by *“fat graphs”* or networks whose transverse diameters converge to zero. The problem was open for many years; we have managed to solve it

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[1] Pavel Exner, Olaf Post: Approximation of quantum graph vertex couplings by scaled Schrödinger operators on thin branched manifolds, *J. Phys. A: Math. Theor.* **42** (2009), 415305

[2] Taksu Cheon, Pavel Exner, Ondřej Turek: Approximation of a general singular vertex coupling in quantum graphs, *Ann. Phys.* **325** (2010), 548-578

Highlights: palindromic complexity

The complexity is an important mean to describe *word structure*. The group of Edita Pelantová demonstrated an inequality relating palindromic complexity of an infinite word with the first difference of factor complexity

Words on which the *inequality is saturated* are richest in palindromes and became object of investigation in many subsequent works having implications in various parts of theoretical computer science

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Words on which the *inequality is saturated* are richest in palindromes and became object of investigation in many subsequent works having implications in various parts of theoretical computer science

[1] Peter Baláži, Zuzana Masáková, Edita Pelantová: Factor versus palindromic complexity of uniformly recurrent infinite words, *Theor. Comput. Sci.* **380** (3) (2007), 266-275

Highlights: magnetic acceleration

Motion of a charged particle in *Aharonov-Bohm field* which depends *periodically on time* is a solvable problem, both in classical and quantum mechanics. Group of Pavel Štovíček demonstrated that classical particle exhibits *delocalization* – after hitting the center it moves away on a cycloid

On the other hand, a non-relativistic quantum particle is *accelerated* if the field frequency is *in resonance* with cyclotron frequency; an explicit formula was derived

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[1] Joachim Asch, Pavel Štovíček: Dynamics of a classical Hall system driven by a time dependent Aharonov-Bohm flux, *J. Math. Phys.* **48** (2007), 052901

[2] Tomáš Kalvoda, Pavel Štovíček: A charged particle in a homogeneous magnetic field accelerated by a time periodic Aharonov-Bohm flux, *Ann. Phys.* **326** (2011), 2702-2716

Highlights: eigenvalue complexification

$\mathcal{PT}$-symmetric Hamiltonians depending on a parameter may exhibit *confluence* a pair of real eigenvalues and their subsequent *complexification*

This effect discovered by Miloslav Znojil can be interpreted as an analogue of *Thom catastrophe theory* in non-Hermitean quantum mechanics; it attracted a lot of attention

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This effect discovered by Miloslav Znojil can be interpreted as an analogue of *Thom catastrophe theory* in non-Hermitean quantum mechanics; it attracted a lot of attention

[1] Miloslav Znojil: Conditional observability, *Phys. Lett.* **B650** (2007), 440-446

Highlights: equilibria in social systems

Data availability makes it possible to investigate *social system* using methods of *statistical physics*. Group of Petr Šeba demonstrated appearance of Markov dynamics equilibria in car parking, pedestrian motion, or land plot distributions

It was also demonstrated that built-up areas in cities exhibit critical behaviour having distributions of a *power-like* type

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It was also demonstrated that built-up areas in cities exhibit critical behaviour having distributions of a *power-like* type

[1] Petr Šeba: Markov chain of distances between parked cars, *J. Math. Phys.* **41** (2008), 122003

[2] Pavel Exner, Petr Šeba, Daniel Vašata: Built-up structure criticality, *Physica* **A390** (2011), 3922-3931

Highlights: ICMP09

In addition to the *research* and *education* work, to be discussed in more detail below, Doppler Institute played important role in the *community life*

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In August 2009 it hosted the world largest conference in mathematical physics, the triennial *16th International Congress on Mathematical Physics*

The congress was attended by 620 participants from all over the world and generally regarded as one of the most successful in IAMP history

[1] Pavel Exner, ed.: *XVIth International Congress on Mathematical Physics*, Proceedings of the ICMP held in Prague, August 3-8, 2009; xvii+690 p.; World Scientific, Singapore 2010.

Now more details: members

Permanent DI staff, paid by the host institutions:

- Pavel Exner, *scientific director*
- Petr Šeba, *deputy director*
- Miloslav Znojil, *deputy director*
- Čestmír Burdík, *in charge of a project*
- Miloslav Havlíček, *senior member*
- Igor Jex, *in charge of a project*
- Edita Pelantová, *in charge of a project*
- Pavel Štovíček, *in charge of a project*
- Jiří Tolar, *senior member*
- Goce Chadzitaskos
- Jaroslav Dittrich
- David Krejčiřík
- Jan Kříž
- Karel Martiník
- Zuzana Masáková
- Severín Pošta
- Vojtěch Svoboda
- Miloš Tater

Temporary members

DI visiting professors:

- Helmut Rauch *(November-December 10)*
- Gernot Alber *(September-October 10)*
- Stephen Barnett *(October-November 09)*
- Saverio Pascazio *(June 09)*
- Takuya Mine *(March 09-February 10)*
- Pedro Freitas *(October-November 08)*
- Alfred M. Grundland *(February-March 2008)*
- Eric Lutz *(May 08)*
- Jiří Patera *(October-December 07)*
- Valery Tolstoy *(October-December 08)*
- Pavel Winternitz *(October-December 07, April-May 08)*

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DI postdocs at the end of 2011:

- Diana Barseghyan *(since April 11)*
- Aurel Gábris *(since July 08)*
- Craig Hamilton *(December 09, and since February 10)*
- Vít Jakubský *(since November 09)*
- Martin Štefaňák *(since June 10)*

Temporary members

Former postdocs, altogether 31 names:

- Petr Ambrož *(October 06-June 07, January-June 10)*
- L'ubomíra Balková *(July-December 08)*
- Gerry Boland *(March-December 10)*
- Denis Borisov *(November 05-April 07)*
- Tomáš Brauner *(October-December 06)*
- Thomas Brougham *(February 08-December 10)*
- Bernhard Burgstaller *(January-December 09)*
- Claudio Cacciapuoti *(June 07-August 08)*
- Rafaelle Carlone *(February 08-August 09)*
- Junhua Chen *(September 07-June 08)*
- Raouf Dridi *(October 08-March 09)*
- Martin Fraas *(July-November 08)*
- Tamás Fülőp *(July 06-August 07)*
- Mark Harmer *(February 07-August 08)*
- Pavel Hejčík *(November 08-September 09)*
- Hector Hernandez-Coronado *(August 09-December 10)*
- Celine Gianesello *(July-September 10)*
- Vít Jakubský *(November 06-March 07)*



Temporary members

Former postdocs, continued:

- Petr Jizba *(May-September 06)*
- Frieder Kleefeld *(June-September 06)*
- Denis Kochan *(October-November 06, September-December 07)*
- Sylwia Kondej *(November 06-February 07)*
- Michael Krbek *(November-December 07)*
- Milan Krbálek *(June-December 06)*
- Jan Kubieniec *(April 07-March 08)*
- Andrea Mantile *(May-November 07)*
- Angela Mestre *(March 08-February 09)*
- Libor Šnobl *(July-December 06)*
- Pavel Soldán *(March 06-August 07)*
- Miroslav Turek *(March-December 06)*
- Matěj Tušek *(January-November 10)*

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Experience:

- The DI visiting professorships were a complete success
- The same for most postdocs but there were a few problematic cases

Students

PhD theses defended in 2006-2011, altogether 21 items:

- Jiří Lipovský: *Quantum graphs and their generalizations* (Exner; def.26.9.11)
- Petr Siegl: *Non-Hermitian quantum models, indecomposable representations, and coherent state quantization* (Gazeau and Znojil; def. 20.9.11)
- Stanislav Vymětal: *Purification protocols in quantum information* (Jex; def. 24.3.11)
- Karel Klouda: *Non-standard numeration systems and combinatorics on words* (Pelantová and Frougny; def. 19.11.10)
- Martin Štefaňák: *Interference phenomena in quantum information* (Jex; def. 14.6.10)
- Petr Vytřas: *Quantum systems with magnetic field and point interactions* (Štovíček; def. 5.5.10)
- Petr Novotný: *Graded contractions of Lie algebra* $sl(3,\mathbb{C})$ (Tolar; def. 6.1.10)

PhD theses, continued

- Ondřej Turek: *Schrödinger operators on metric graphs* (Exner and Duclos; def. 11.12.09)
- Matěj Tušek: *Non-Euclidean geometries in quantum mechanics, quantum planar models* (Štovíček; def. 10.12.09)
- Hynek Bíla: *Pseudo-Hermitian Hamiltonians in quantum physics* (Znojil; def. 11.5.09)
- Pavel Hejčík: *Properties of simple quantum graphs* (Šeba and Cheon; def. 21.8.08)
- Martin Fraas: *Models of quantum systems with strong singular interactions* (Exner; def. 25.06.08)
- Ľubomíra Balková: *Beta-integers and quasicrystals* (Masáková and Gazeau; def. 26.5.08)
- Peter Baláži: *Infinite words coding k-interval exchange transformation* (Pelantová; def. 14.3.08)
- Jiří Hrivnák: *Invariants of Lie algebras* (Tolar; def. 13.12.07)
- Milena Svobodová: *Gradings of Lie algebras* (Pelantová; def. 3.12.07)



Students, continued

PhD theses, the rest:

- Jaroslav Novotný: *Entanglement and its role in quantum information processes* (Jex; def. 11.10.07)
- Hynek Lavička: *Simulation of agents on complex networks* (Jex; def. 11.10.07)
- Ondřej Lev: *Time-periodic quantum systems* (Štovíček; def. 24.5.07)
- Vít Jakubský: *Pseudo-Hermitian quantum mechanics* (Znojil; def. 25.10.06)
- Petr Ambrož: *Arithmetical and combinatorial properties of non-standard numeration systems* (Pelantová and Frougny; def. 25.9.06)

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More about students:

- There are currently 12 doctoral students
- There are also 20 undergraduate students at the master and bachelor level taken together, 33 students finished their Mgr and Bc studies

Visitors

There were *over two hundred visits* in 2006-11 ranging from two days to several months. Some of the visitors kept coming repeatedly; most gave talks at DI seminars

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Apart the DI visiting professors mentioned above, some other important visitors were, for instance,

- Michael Aizenman *(Princeton University)*
- Joseph E. Avron *(Technion)*
- Pierre Duclos *(USTV and CPT Marseille)*
- Jürg Fröhlich *(ETH)*
- Christiane Frougny *(LIAFA Université Paris VII)*
- Giovanni Gallavotti *(Universita di Roma “La Sapienza")*
- Jean-Pierre Gazeau *(APC Université Paris VII)*
- Fritz Gesztesy *(University of Missouri-Columbia)*
- Vladimir A. Geyler *(HU Berlin)*
- Ari Laptev *(Imperial College London)*
- Vyacheslav B. Priezzhev *(JINR Dubna)*
- Yakov G. Sinai *(Princeton University)*
- Jan Philip Solovej *(University of Copenhagen)*
- Lloyd N. Trefethen *(Oxford University)*, etc.

Publications

Publication statistics 2006-08: in total *346* papers of which

- **J. Phys. A: Math. Theor.** *53*
- *submitted 28*
- *refereed conference proceedings 27*
- **Phys. Rev. A** *18*
- **Phys. Lett. A** *8*
- Acta Polytechnica *17*
- Theor. Comp. Sci. *14*
- **J. Math. Phys.** *7*
- SIGMA *9*
- RAIRO *7*
- **Phys. Rev. Lett.** *6*
- Int. J. Theor. Phys. *6*
- **Phys. Rev. D** *6*
- **Phys. Lett. B** *5*
- J. Phys. G: Conf. Ser. *5*

Publications, continued

- **New J. Phys.** *5*
- Rep. Math. Phys. *4*
- PRAMANA *4*
- Discr. Math. Theor. Comp. Sci. *4*
- **Lett. Math. Phys.** *4*
- Acta Phys. Polonica A *3*
- **Ann. Phys.** *3*
- Eur. J. Phys. D *3*
- Phys. Scripta *3*
- **Physics A** *3*
- J. Geom. Phys. *3*
- Integral Equations and Operator Theory *3*
- Integers *3*
- Russ. J. Math. Phys. *3*
- Russ. J. Math. Phys. *3*
- Kybernetika *3*

Publications, continued

- *Two papers in* Asympt. Anal., Lin. Alg. Appl., Europhys. Lett., **J. Stat. Mech.**, Regular and Chaotic Dynamics, **Phys. Rev. E**, J. Nonlin. Math. Phys., **Rev. Math. Phys.**, Int. Rev. Phys. Chem., Mathematical Physics, Analysis and Geometry

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- *A single paper in* **Science**, **Commun. Math. Phys.**, Revista Mexicana de Fisica, Math. Slovaca, Adv. Appl. Math., Nucl. Instr. Meth. Phys. Research, Pacific J. Math., Acta Phys. Slovaca, J. Diff. Eqs, J. Mod. Phys., Funct. Approx. Comment. Math, Discrete and Continuous Dynamical Systems, SIAM J. Appl. Math., Central European J. Phys., J. Mod. Optics, J. Phys. Soc. Japan, Journal de Mathématiques Pures et Appliquées, J. Approx. Theory, J. Funct. Anal., J. Phys. B: Mol. Opt., Phys., Int. J. Quant. Inf., Journal of Graph Algorithms and Applications, Found. Phys., Int. J. Mod. Phys., ESAIM: Control, Optimisation and Calculus of Variations, Proc. Amer. Math. Soc., Mod. Phys. Lett., Journal of Physical Studies, Nonlinear Biomedical Physics, Monatshefte fur Mathematik, J. Stat. Phys., Yad. Fiz., Adv. Studies Theor. Phys., Indiana Univ. Math. J., Math. Res. Lett., Arch. Rat. Mech. Anal., Phys. Rev. C, **Ann. H. Poincaré**, Nucl. Phys. B, Math. Nachr., Annales de l' Institut Fourier

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- *Two papers in* Asympt. Anal., Lin. Alg. Appl., Europhys. Lett., **J. Stat. Mech.**, Regular and Chaotic Dynamics, **Phys. Rev. E**, J. Nonlin. Math. Phys., **Rev. Math. Phys.**, Int. Rev. Phys. Chem., Mathematical Physics, Analysis and Geometry

- *A single paper in* **Science**, **Commun. Math. Phys.**, Revista Mexicana de Fisica, Math. Slovaca, Adv. Appl. Math., Nucl. Instr. Meth. Phys. Research, Pacific J. Math., Acta Phys. Slovaca, J. Diff. Eqs, J. Mod. Phys., Funct. Approx. Comment. Math, Discrete and Continuous Dynamical Systems, SIAM J. Appl. Math., Central European J. Phys., J. Mod. Optics, J. Phys. Soc. Japan, Journal de Mathématiques Pures et Appliquées, J. Approx. Theory, J. Funct. Anal., J. Phys. B: Mol. Opt., Phys., Int. J. Quant. Inf., Journal of Graph Algorithms and Applications, Found. Phys., Int. J. Mod. Phys., ESAIM: Control, Optimisation and Calculus of Variations, Proc. Amer. Math. Soc., Mod. Phys. Lett., Journal of Physical Studies, Nonlinear Biomedical Physics, Monatshefte fur Mathematik, J. Stat. Phys., Yad. Fiz., Adv. Studies Theor. Phys., Indiana Univ. Math. J., Math. Res. Lett., Arch. Rat. Mech. Anal., Phys. Rev. C, **Ann. H. Poincaré**, Nucl. Phys. B, Math. Nachr., Annales de l' Institut Fourier

- most paper, in total *271* are *posted in arXiv*

Publications, continued

A monograph

- J. Blank, P. Exner, M. Havlíček: *Hilbert–Space Operators in Quantum Physics. Second edition (revised and extended)*; $xviii + 666$ p.; Springer, Dordrecht 2008.

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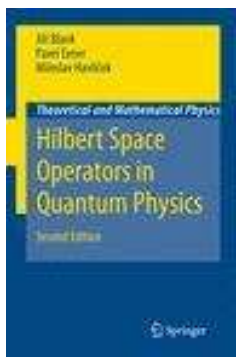
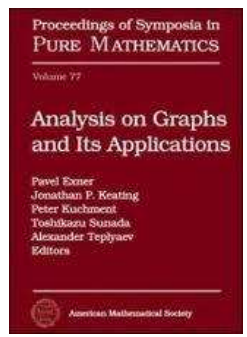
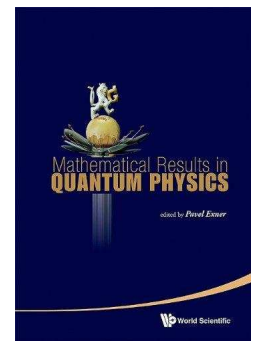
Further publications

- three edited proceedings volumes
- three edited topical journal issues
- a patent and various miscellanea







Meetings

Conferences and workshops 2006-2011:

- Workshop Spectra, Algorithms and Data Analysis
  Hradec Králové, February 28 – March 1, 2006
- **Conference Operator Theory in Quantum Physics**
  Prague, September 9-14, 2006
- Workshop Spectra, Algorithms and Data Analysis II
  Hradec Králové, December 7–8, 2006
- 16th Student Winter School on Mathematical Physics
  Horní Polubný, January 21–27, 2007
- Microconference Analytic and algebraic methods in physics, *Prague, February 20, 2007*
- Microconference Analytic and algebraic methods in physics II, *Prague, April 3, 2007*

Meetings, continued

- Spring School and Workshop on Combinatorics on Words, *Prague, May 19–26, 2007*
- Advanced School Symmetries in Physics: Modern Trends, *Prague, June 8–13, 2007*
- Microconference Analytic and algebraic methods in physics III, *Prague, June 19, 2007*
- **6th International Workshop on Pseudo Hermitian Hamiltonians in Quantum Physics**
  City University London, July 16–18, 2007
- 17th Student Winter School on Mathematical Physics
  Horní Polubný, January 20–26, 2008
- **Workshop on Modern trend in quantum optics and quantum information**, *Prague, May 1–4, 2008*

Meetings, continued

- Conference Journées de Numeration, *Prague, May 26–30, 2008*
- Summer school and workshop Algebraic structures, *Telč, August 10–16, 2008*
- Microconference A canonical realization (AAMP IV), *Prague, October 21, 2008*
- Workshop Physics of social systems *Hradec Králové, November 27-28, 2008*
- 18th Student Winter School on Mathematical Physics *Horní Polubný, January 25–31, 2009*
- Quantization day 2, *Prague, March 24, 2009*
- Microconference Analytic and algebraic methods in physics V, *Prague, May 27–28, 2009*

Meetings, continued

- Spring School and Workshop on Combinatorics on Words, *Děčín, May 31–June 6, 2009*
- **XVI International Congress on Mathematical Physics**, *Prague, August 3–8, 2009*
- 19th Student Winter School on Mathematical Physics *Horní Polubný, January 24–30, 2010*
- Microconference Analytic and algebraic methods in physics VI, *Prague, May 9–11, 2009*
- Spring School and Workshop on Combinatorics on Words, *Hojsova Stráž, May 17–21, 2009*
- Workshop Orbit functions, *Děčín, June 21–24, 2010*

Meetings, continued

- Follow-up meeting concluding the Analysis on Graphs and its Applications programme of the Newton Institute, *Cambridge, July 26–30, 2010*
- Workshop Mathematical aspects of the physics with non-self-adjoint operators
  Prague, August 30–September 3, 2010
- **Conference QMath11 – Mathematical Results in Quantum Physics**
  Hradec Králové, September 6–10, 2010
- 20th Student Winter School on Mathematical Physics
  Horní Polubný, January 23–29, 2010
- Microconference Analytic and algebraic methods VII
  Prague, March 17–18, 2011

Meetings, continued

- Microconference AAMP VIII - Words, numeration and automata
  Prague, March 19–20, 2011
- Spring School and Workshop on Combinatorics on Words, *Mšeno, May 15–21, 2011*
- Conference Special Functions and Orthogonal Polynomials of Lie Groups and their Applications
  Děčín, August 14–20, 2011
- 5th Student Colloquium and School on Mathematical Physics
  Stará Lesná, August 29–September 4, 2011
- **Conference WORDS 2011**
  Prague, September 12–16, 2011

Meetings, continued

- Autumn School and Workshop on Combinatorics on Words, *Telč, October 28-30, 2011*
- Microconference Analytic and algebraic methods IX *Prague, December 12–15, 2011*

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Remarks:

- altogether 37 meetings ranging for small one-day ones to the international congress
- apart from the congress, *five large conferences* (with 80-150 participants)
- many activities oriented at students

Seminars

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- *Doppler Institute Seminar*: Tuesday afternoon, 69 sessions in 2006-2011

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- *DI Microseminar*: Thursday morning, 96 sessions in 2006-2011

The DI Council

- Joseph E. Avron, *Israel Institute of Technology, Haifa*
- Pavel Exner, *DI*
- Jean-Pierre Gazeau, *Université Paris 7*
- Jiří Hošek, *Nuclear Physics Institute ASCR*
- Zdeněk Hradil, *Palacký University, Olomouc*
- Roman Kotecký, *Charles University, Prague*
- Ari Laptev, *Imperial College London*, *chair*
- Edita Pelantová, *DI*
- Wolfgang Peter Schleich, *Universität Ulm*
- Petr Šeba, *DI*
- Pavel Středa, *Institute of Physics ASCR*, *vicechair*
- Jakob Yngvason, *Universität Wien*
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Due to its geographic diversity, most Council discussions are arranged electronically; it works quite well.

Václav Votruba Prize

DI awards the *Václav Votruba Prize* given for the *best PhD thesis in theoretical physics*.

We are just the organizers; the prize money come from generous support of Foundation for Development of Theoretical Physics seated in Slemeno u Rychnova n.K. and founded by Petr Šeba

The recent prize history:

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The recent prize history:

- *2006:* 5 nominations, the prize was awarded to *Ing. Michal Malinský, PhD.* for the thesis *Quark and lepton masses and mixing in supersymmetric grand unified theories*
- *2007:* 4 nominations, the prize was awarded to *Mgr. Miroslav Ježek, PhD.* for the thesis *Quantum measurement and reconstruction with applications in optics*
- *2008:* 9 nominations, the prize was awarded to *Mgr. Lenka Zdeborová, PhD.* for the thesis *Statistical physics of hard optimization problems*
- *2009:* 6 nominations, the prize was awarded to *Mgr. Ludovít Lipták, PhD.* for the thesis *Aspects of thermodynamics nad confinement in the lattice formulation of QCD*
- *2010:* 4 nominations, the prize was awarded to *Mgr. Petr Marek, PhD.* for the thesis *Non-classicality of quantum states: decoherence and purification*
- *2011:* 5 nominations, the prize was awarded to *Dr. Steffen Gielen* for the thesis *Geometric aspects of gauge and spacetime symmetries*

To close this brief survey

Time does not allow me to go into more details; we all will be glad to answer your questions. An exhaustive information can also be found at our web pages,

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On behalf of all Doppler Institute members

Thank you for your attention!