

IAMP Bulletin

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International Association of Mathematical Physics

Bulletin Editor

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Elliott H. Lieb, Svetlana Jitomirskaya

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The New *Bulletin*

Welcome, readers, to the new *Bulletin of the IAMP*, which is henceforth the title of what has until now been called the *News Bulletin of the IAMP*! In recognition that this publication has for quite some time contained far more than news of our society, the Executive Committee approved the change earlier this year. We should recall that the previous Editor-in-Chief, Valentin Zagrebnov, had the vision of expanding the mission of the publication to include reviews of scientific research and articles of interest to our community. We are grateful to Valya for setting us on this path, and give thanks also to many of you for contributing so much excellent material to our publication.

There is, nonetheless, news to report in these pages. As noted in the January issue, mathematical physics was expected to play a prominent role at the International Congress of Mathematicians and its satellite conferences. Since then the ICM went to a mainly virtual format, as did the World Meeting for Women in Mathematics, while other satellite conferences adapted in a hybrid format, including the Helsinki conference on Probability and Mathematical Physics and the two conferences in St. Petersburg in memory of O. A. Ladyzhenskaya and of M. Sh. Birman. We recalled Ladyzhenskaya in the April issue, and we recall Birman in this issue.

On a happy note, IAMP members have shone as recipients of awards given out this month: Hugo Duminil-Copin won a Fields Medal, Svetlana Jitomirskaya was the first recipient of the new Ladyzhenskaya Prize, and Elliott Lieb was awarded the Gauss Prize. The citations for these honors read as follows



[Hugo Duminil-Copin](#) has won a 2022 Fields Medal

for solving longstanding problems in the probabilistic theory of phase transitions in statistical physics, especially in dimensions three and four.

The inaugural Ladyzhenskaya Prize in Mathematical Physics (OAL Prize) was awarded to [Svetlana Jitomirskaya](#)

for her seminal and deep contributions to the spectral theory of almost periodic Schrödinger operators.



The Gauss Prize was awarded to [Elliott H. Lieb](#)

for deep mathematical contributions of exceptional breadth which have shaped the fields of quantum mechanics, statistical mechanics, computational chemistry, and quantum information theory.

Our most hearty congratulations to Hugo, Lana, and Elliott!

Evans Harrell
Chief Editor of IAMP Bulletin

Picture credits: Matteo Fieni (Hugo Duminil-Copin); Svetlana Jitomirskaya (Svetlana Jitomirskaya); Lance Murphey (Elliott Lieb)

Mikhail Shlemovich Birman (1928 - 2009)

by TATIANA SUSLINA and DMITRI YAFAEV

It is hard to overestimate M. S. Birman's contributions to the spectral theory of operators and to mathematical physics more generally. Especially well known is the Birman-Schwinger principle in the theory of discrete spectra, which serves as a starting point for many problems in quantum mechanics. To a large extent, Birman's works on scattering theory set the course for the development of this field. In particular, he discovered the invariance principle for wave operators. Another famous result is the Birman-Krein formula, linking a scattering matrix to the spectral shift function. M. S. Birman and M. Z. Solomyak created the theory of double operator integrals and developed the method of piecewise-polynomial approximations of functions from Sobolev classes. Using it they got precise estimates and asymptotics for the spectra of differential and integral operators. Jointly with his students and colleagues, he extended the spectral theory of the Maxwell operator to non-smooth cases. He also studied discrete spectra that appear in gaps of self-adjoint Hermitian operators under perturbations of various classes. Together with T. A. Suslina, he contributed a lot to the spectral theory of periodic differential operators by solving the problem about the absolute continuity of a spectrum and by developing an operator-theoretical approach to homogenization theory.

Mikhail Shlemovich (Solomonovich) Birman was born on January 17, 1928, in Leningrad. His father was a scientist, a specialist on theoretical mechanics. He was a professor at the Leningrad Institute of Refrigeration. Mikhail Solomonovich's mother was a schoolteacher.

During WWII, Birman's family was evacuated to Sverdlovsk (now Ekaterinburg), where Mikhail graduated from high school. When the war ended and the family moved back to Leningrad, he was accepted to the Leningrad Electrotechnical University (LEU). The math teacher there noticed Mikhail's extraordinary mathematical abilities and advised him to transfer to the Faculty of Mathematics and Mechanics of the Leningrad State University (LSU). Mikhail followed his advice.

During his studies at the math department, he specialized in numerical analysis. Mikhail Solomonovich considered his teachers to be Mark Konstantinovich Gavurin, who supervised his thesis, and Leonid Vital'evich Kantorovich. When he was still a student, Mikhail Solomonovich worked at the Steklov Institute in Kantorovich's laboratory. Leonid Vital'evich recognized his young coworker's strong intellect and independent thinking, and started giving him tasks that greatly surpassed the level of standard technical work. In 1950, Mikhail Solomonovich graduated from the University. Although he was one of the best students of his graduating class, he wasn't accepted to graduate school because of the tacit antisemitic policies during that time.

In 1947, Mikhail Solomonovich married his classmate, Tatyana Petrovna Il'ina. In 1948 they had a son, Zhenya. He and Tatyana Petrovna lived happily together throughout their whole lives; she died just two years before he did. Thanks to her love, loyalty, patience and care, he could fully dedicate himself to mathematics.

After graduating from the university, Mikhail Solomonovich worked as a teaching assistant at the Leningrad Mining University, in the department of mathematics. Despite his heavy teaching load, he was very active in scientific research. In 1954 he got his Candidate's degree. In 1956, when state policy eased up, Mikhail Solomonovich got a position in the department

of mathematical physics of LSU, at the initiative and with the serious support of V. I. Smirnov and O. A. Ladyzhenskaya. In fact, Smirnov declared an ultimatum to the President of the University: “Either you take Birman, or I leave LSU.” Smirnov’s demand was granted, and in time, Birman became one of the best lecturers at the Physics Faculty. In 1962, he got the Doctor of Sciences degree for his thesis “Spectra of Singular Boundary Value Problems”. Mikhail Solomonovich worked at the department of mathematical physics for the rest of his life – over 50 years.



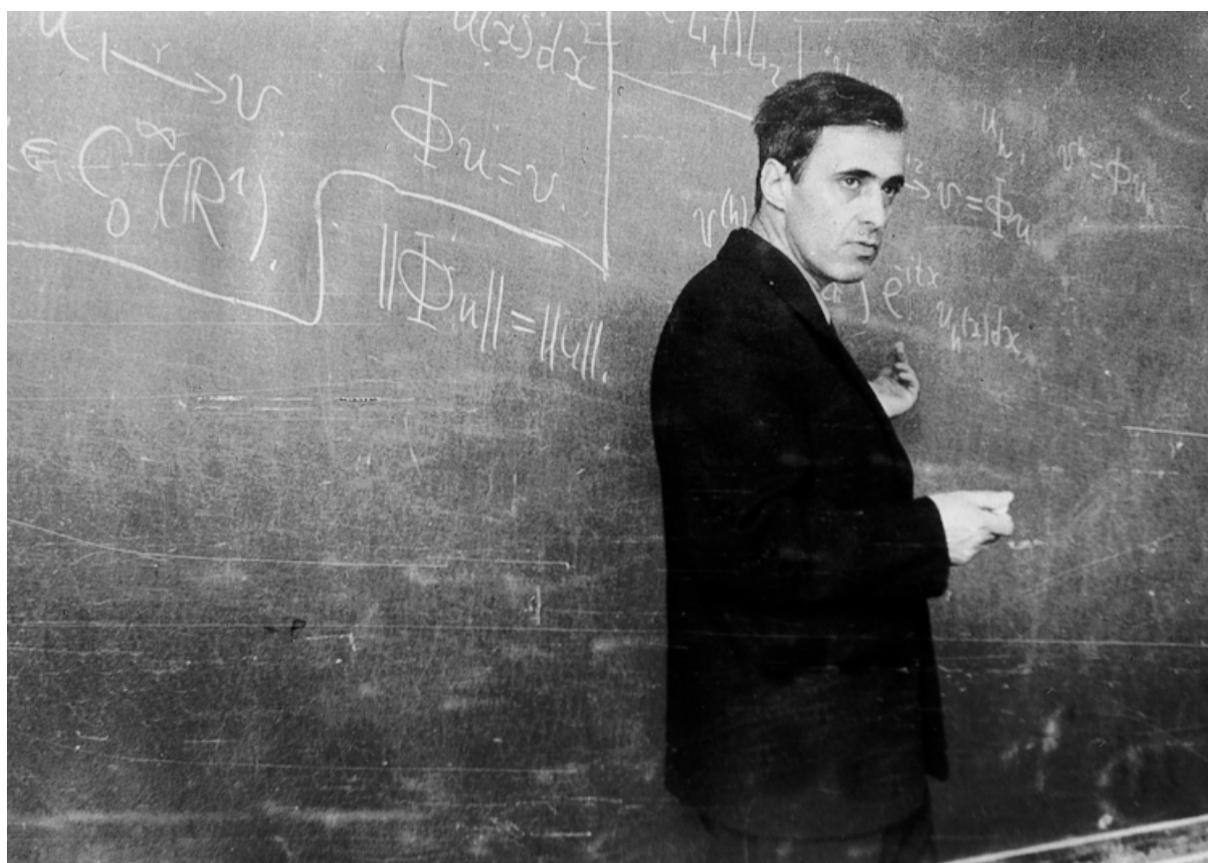
An important role for Mikhail Solomonovich was his active participation in the Leningrad Seminar of Mathematical Physics, which was founded by Vladimir Ivanovich Smirnov in the early '50s. Now the seminar carries Smirnov’s name. So, for many years, Mikhail Solomonovich was head of the V. I. Smirnov Seminar, along with Olga Alexandrovna Ladyzhenskaya. In the photo (from the left): M. Z. Solomyak, N. N. Uraltseva, N. F. Morozov, M. S. Birman, M. M. Smirnov.

With the help of his colleague, Mikhail Zakharovich Solomyak, Birman created a strong scientific school in spectral operator theory, which is known all over the world. Many of his students became famous scientists and are now working at the best universities in Russia and the West.

Mikhail Solomonovich Birman is the author of over 160 scientific papers and 2 books. He was a member of the editorial boards for the journals *St. Petersburg Mathematical Journal* and *Functional Analysis and its Applications*. Some of Birman’s awards include the title of Honored Scientist of the Russian Federation, Honored Professor at St. Petersburg State University, and

the Chebyshev Award granted to him by the St. Petersburg government. Birman's works have obtained international recognition and are often quoted in the literature. On multiple occasions, he was a plenary speaker at international conferences. He was personally invited to some of the best universities and scientific centers of the world.

Let us describe Mikhail Solomonovich's scientific style a bit. He rarely thought in terms of separate problems, no matter how interesting they seemed to be by themselves. His typical approach was as follows. First, he looked for a general pattern that includes the problem, and then that pattern was analyzed from every angle. Any theories emerging from this process can be applied to a wide range of similar problems. Finally, he figured out how parts of the theory worked in the case of the original problem. Usually, this approach led to an exhaustive analysis not only of the original problem, but also of a whole class of similar problems.



Mikhail Solomonovich was a brilliant lecturer. His lectures were not only informative and well-thought-out, but inspiring as well. He was one of the department's leaders and had an exceptionally high reputation. He always had very high professional standards, which, above all, he applied to himself. Mikhail Solomonovich was very attentive to the people around him. Many of his colleagues regarded him as an excellent professor and a wise person in general.

His approach of developing theories to solve many related problems didn't mean, however, that Mikhail Solomonovich was worse at solving specific problems. His works are filled with technical findings that are still widely used.

He was always pushing forward, although he never left a topic unfinished. Mikhail Solomonovich liked to repeat the phrase: "All my life, I am writing the same paper," even though he contributed a significant amount of work to different fields of mathematical physics. When he moved from one topic to another, however, there was always a string connecting them.

His mindset was not purely mathematical. When choosing a new topic of research, he was often guided by direct applications to natural physics problems. He had many talents, so mathematics should consider itself lucky that he preferred it to other fields.





Photo with his students, St. Petersburg, 1999. First row (from the left): V. A. Slousch, A. B. Pushnitsky, R. G. Shterenberg. Next row: N. D. Filonov, E. L. Korotyaev, O. L. Safronov, M. S. Birman, T. A. Suslina, A. A. Laptev.

Mikhail Solomonovich's relationship with his numerous students was very close, and their interactions were far from limited to purely mathematical subjects. In particular, the authors of this article learned a lot from him on the subject of human nature. Mikhail Solomonovich had a sharp mind and a well-rounded education. It was interesting and edifying to listen to him. He was constantly thinking about various events that were going on in the world, and, to use Mikhail Solomonovich's own way of putting it, always tried to form the right perspective on the world. Sometimes this perspective was overly romantic. He wrote poems. He especially loved nature. He was known to go on walks or bike rides outside the city and enjoyed hiking. He knew St. Petersburg and its outskirts very well.

Despite bad health, he actively worked on mathematics until his last days. Mikhail Solomonovich Birman died on July 2, 2009, after a severe and long illness.

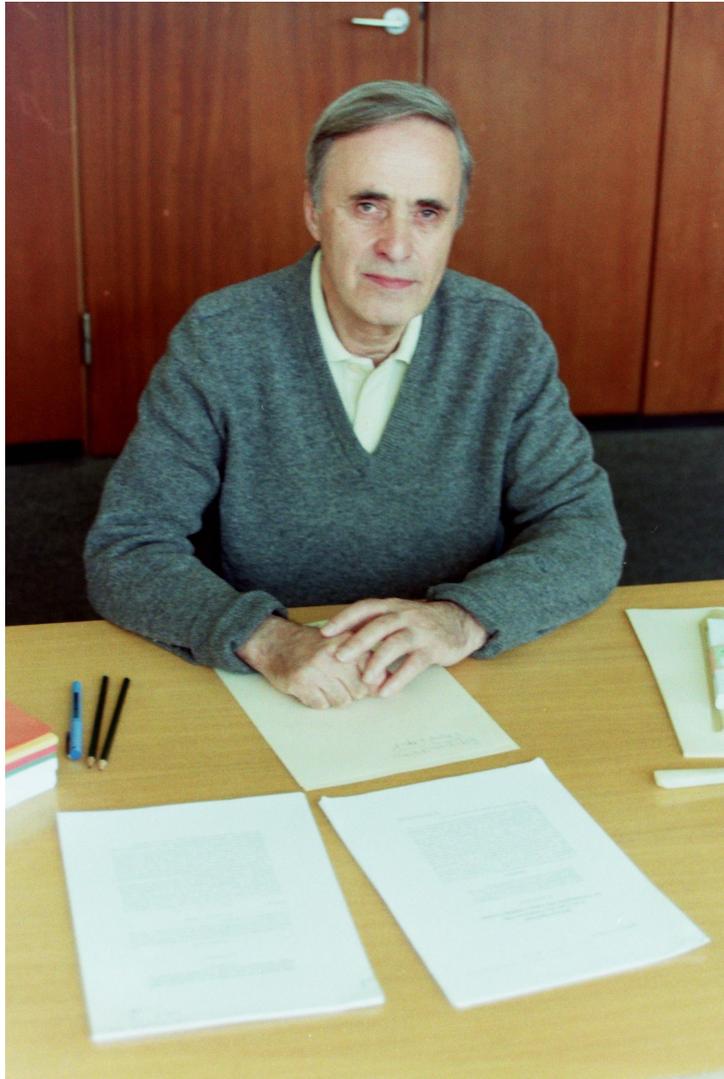


M. S. Birman and O. A. Ladyzhenskaya hiking in Azau, Caucasus, 1972.

This article was originally prepared for the book “Mathematicians from Saint Petersburg and their theorems,” edited by Nikita Kalinin in connection with the ICM 2022. (The satellite conference “Spectral Theory and Mathematical Physics” in honor of Birman took place in a hybrid format in June, 2022.) Printed here with permission.

M. Sh. Birman: Spectral and Scattering Theories

by TATIANA SUSLINA and DMITRI YAFAEV



Perturbation theory plays an important role in spectral theory of self-adjoint operators. It draws conclusions about a self-adjoint operator B given information regarding a simpler operator A close in some sense to B . In particular, perturbation theory for the absolutely continuous (a.c.) spectrum is known as scattering theory.

Originally, M. Sh. was not an expert in scattering theory. In the fifties he wrote a series of seminal papers on essential and discrete spectra of self-adjoint differential operators. In particular, he proved stability of the essential spectra of elliptic operators under a wide class of perturbations of their coefficients and of the associated boundary conditions. As far as discrete spectrum is concerned, we only mention the famous estimate on the total number N of negative

eigenvalues of the Schrödinger operator $-\Delta + V(x)$ in $L^2(\mathbb{R}^3)$:

$$N \leq \frac{1}{16\pi^2} \int_{\mathbb{R}^3} \int_{\mathbb{R}^3} \frac{V_-(x)V_-(y)}{|x-y|^2} dx dy. \quad (1)$$

This was the first quantitative estimate for the negative spectrum in the multi-dimensional case. It was independently found by J. Schwinger and is usually called Birman-Schwinger estimate. Its proof relied on a general result of operator theory which is now known as the Birman-Schwinger principle.

M. Sh. turned his attention to the a.c. spectrum after the famous theorem by T. Kato and M. Rosenblum appeared in 1957. This theorem concerns a pair of self-adjoint operators A and B acting in a separable complex Hilbert space. It states that if the difference $B - A$ belongs to the trace class, then the wave operators defined as strong limits

$$\lim_{t \rightarrow \pm\infty} e^{iBt} e^{-iAt} P_{ac}(A) =: W_{\pm}(B, A) \quad (2)$$

exist; here $P_{ac}(A)$ is the orthogonal projection on the a.c. subspace of A . In particular, this result implies that the a.c. parts of the operators A and B are unitarily equivalent.

Wave operators appear naturally in quantum mechanics. Indeed, consider two systems described by vectors f_0 and f at time $t = 0$ and governed by the “free” A and “perturbed” B Hamiltonians. Their time-dependent evolutions are described by unitary groups $e^{-iAt} f_0$ and $e^{-iBt} f$. It turns out that these evolutions are asymptotically close as $t \rightarrow \pm\infty$, that is, $e^{-iAt} f_0 \sim e^{-iBt} f$ if $f = W_{\pm}(B, A) f_0$.

If the wave operators exist, then the scattering operator $\mathbf{S} := W_+^*(B, A)W_-(B, A)$ commutes with A and thus acts as multiplication by an operator-valued function $S(\lambda)$ in the diagonal representation for A . The scattering operator \mathbf{S} and the scattering matrix $S(\lambda)$ are usually of great interest in mathematical physics problems, because they connect the initial (for $t \rightarrow -\infty$) and the final (for $t \rightarrow +\infty$) characteristics of the process directly, bypassing its consideration for finite times. This also explains the term “scattering theory” borrowed from physics.

Although beautiful and very sharp in the general framework of operator theory, the Kato-Rosenblum theorem cannot be directly applied to differential operators where $B - A$ is a multiplication operator. Naturally, the problem of applications of this general result attracted attention of T. Kato himself, S.T. Kuroda and many other mathematicians. The contribution of M. Sh. to this highly competitive domain was crucial.

The study of the a.c. spectrum was for M.Sh. a natural continuation of his analysis of the essential spectrum. The connecting point is his paper of 1962 where the invariance of the a.c. spectrum was verified for perturbations of the boundary and of the boundary condition for elliptic operators in unbounded domains. The initial, and as it turned out later very fruitful, idea of M.Sh. was to consider suitable functions φ (for example, inverse powers) of the operators A, B and to apply the Kato-Rosenblum theorem to the pair $\varphi(A), \varphi(B)$.

The invariance of the absolutely continuous spectrum allowed M.Sh. to conjecture that for a trace-class difference $\varphi(B) - \varphi(A)$ not only the a.c. spectrum is preserved but also the wave operators $W_{\pm}(\varphi(B), \varphi(A))$ exist and

$$W_{\pm}(\varphi(B), \varphi(A)) = W_{\pm}(B, A). \quad (3)$$

This result, proven by M.Sh. in 1963 for a wide class of functions φ , was later called *the invariance principle*. This is an important generalization of the Kato-Rosenblum theorem which can be directly applied to differential operators of the Schrödinger type.

At the same period, jointly with M. G. Krein, M. Sh. found a link of scattering theory with the theory of the spectral shift function. The concept of the spectral shift function $\xi(\lambda)$ appeared at the beginning of fifties in the physics literature in the papers of I.M. Lifshitz in connection with the trace formula

$$\text{Tr} (\varphi(B) - \varphi(A)) = \int_{-\infty}^{\infty} \varphi'(\lambda)\xi(\lambda)d\lambda. \quad (4)$$

Its mathematical theory was created by M. G. Krein who proved the trace formula for a pair of self-adjoint operators with a trace-class difference for a wide class of functions φ . To a large extent, the trace formula can be considered as a far reaching generalization of the equality of the matrix and spectral traces in the finite-dimensional case.

M. Sh. and M. G. Krein showed that the scattering matrix $S(\lambda)$ differs from the identity by a trace-class operator (so that the determinant of $S(\lambda)$ is well defined) and found a remarkable formula

$$\det S(\lambda) = \exp (-2\pi i\xi(\lambda)) \quad (5)$$

valid for almost all λ in the a.c. spectrum. This elegant relation (known as the Birman-Krein formula) is often used as the definition of the spectral shift function on the a.c. spectrum.

Motivated by applications, M. Sh. developed scattering theory in various directions. Thus, he carried over (jointly with M.G. Krein) the Kato-Rosenblum theorem to unitary operators, introduced local wave operators related to some interval of the spectral axis and constructed scattering theory for self-adjoint operators A, B acting in different Hilbert spaces.

M. Sh. was a brilliant lecturer. He had an exceptional ability to present difficult things in a particularly transparent way and to find non-trivial connections between apparently different facts. It is noteworthy that M.Sh. had always a firm hand over the audience, which was very beneficial for everybody.

Relations of M. Sh. with his numerous students were very tight and went far beyond purely mathematical subjects. In particular, the authors of this text benefited a lot from his human personality.

M. Sh. was a very wise person. He permanently thought about different events happening in the world and, as he put it himself, always tried to create the correct world picture. Sometimes this picture was overly romantic.

This very sketchy presentation can be supplemented by a more detailed paper by M. Z. Solomyak, T. A. Suslina and D. R. Yafaev "On the mathematical works of M. Sh. Birman", A/A, Saint-Petersburg Math. J., v. 23, n.1, 5-60, 2011. This version was originally prepared for the book "Mathematicians from Saint Petersburg and their theorems," edited by Nikita Kalinin in connection with the ICM 2022. (The satellite conference "Spectral Theory and Mathematical Physics" in honor of Birman took place in a hybrid format in June, 2022.) Printed here with permission.

Hugo Duminil-Copin wins Fields Medal



International
Mathematical
Union

The Fields Medal 2022

Long citation for Hugo Duminil-Copin

Hugo Duminil-Copin has transformed the mathematical theory of phase transitions in statistical physics and solved several longstanding open problems, in particular in the dimensions three and four as well as in the non-integrable cases in dimension 2. His work has opened up several new research directions. Here we describe only a few of his many results in this field.

The most striking results of Duminil-Copin are for Ising-type models in dimensions three and four. Together with collaborators, he has established the continuity and sharpness of the phase transition in dimension three, problems open since the eighties. In dimension four, together with Aizenman, he has proved mean field critical behavior of the Ising model and remarkably, the triviality of the four-dimensional Euclidean scalar quantum field theory, an open conjecture in physics since the 70s.

Likewise, in two dimensional dependent Fortuin–Kasteleyn (FK) percolation, Duminil-Copin and collaborators have proven continuity or discontinuity of the transition for all parameter values, and universality in the critical FK model on isoradial graphs. Furthermore, by proving rotational invariance at large scale for the critical FK models, he has taken an important step towards establishing their large-scale conformal invariance, which in turn would provide the missing ingredient for connecting them rigorously to the world of 2D conformal field theories.

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where further materials about Hugo Duminil-Copin's Fields Medal, including a video interview and the laudatio by Martin Hairer, are available.

Elliott H. Lieb receives the 2022 Carl Friedrich Gauss Prize



International
Mathematical
Union

The Carl Friedrich Gauss Prize 2022

Long citation for Elliott H. Lieb

Elliott H. Lieb is a mathematical physicist who has made outstanding contributions to physics, chemistry, and pure mathematics.

Reminiscent of Gauss and other 18th and 19th century giants, Elliott H. Lieb, driven by problems in and applications to physics, has unraveled elegant and fundamental mathematical structures, vastly transcending the original motivations.

In doing so, Lieb has introduced concepts which have shaped whole fields of research in mathematics even beyond his original area, while having a transformative impact on physics and chemistry.

His work from the 60s discovering the exact solvability of some fundamental models (square ice, Lieb–Liniger, Lieb–Mattis, Temperley–Lieb) contributed to the definition of much of modern statistical mechanics, and to the foundations of the modern field of integrable probability. His exact solutions of percolation and coloring problems, introducing what is now called the Temperley–Lieb algebra along the way, also had long-lasting algebraic and combinatorics implications, for knot invariants, quantum groups, braid groups and braid statistics, and also conformal field theory.

Lieb developed a whole program of the analysis of “stability of matter” and “existence of the thermodynamic limit” putting on firm mathematical grounds the study of quantum particles interacting through physically realistic potentials. An essential ingredient in this analysis is the celebrated Lieb–Thirring inequality estimating the sum of negative eigenvalues of Schrödinger operators. It has had an enormous impact over the years on spectral estimates, in particular on semi-classical analysis.

One of the most important computational tools of modern chemistry is density functional theory (DFT). Lieb provided a mathematically sound formulation of it, the now famous Lieb or Levy–Lieb functional most widely used in theoretical chemistry. A very important concept in DFT is to understand what is known as the indirect Coulomb energy. Lieb, partly in collaboration with Oxford, gave rigorous bounds on it, providing an ultimate benchmark for all suggested forms of the indirect energy. These very important bounds have been abundantly used and cited by chemists.

Lieb has proved several celebrated results in the area of matrix analysis including what became known as Lieb's concavity theorem. As a consequence of the latter, he and Ruskai were able to prove the strong subadditivity of the von Neumann entropy, a result which decades later has become the foundational result in the very active modern area of quantum information theory.

Lieb has made fundamental contributions to the areas of functional analysis and functional inequalities. He has both proved a long list of new functional inequalities, some of which now bear his name, as for instance the Brascamp–Lieb inequality, and brought existing ones into their sharp form, as for instance the Young and the Hardy–Littlewood–Sobolev inequalities. He has developed and masterly applied symmetrization and compactness methods. These works of Lieb are widely used by analysts, probabilistic and mathematical physicists and continue to have a tremendous impact in mathematics.

Elliott H. Lieb's work has a truly outstanding combination: as mathematical work, his contributions have a hard-to-rival impact on other sciences, and as applied work, his contributions have a hard-to-rival mathematical depth. It continues the tradition of a dialogue at the highest level between mathematics and physics, and beautifully demonstrates the power of mathematics as a theoretical and practical tool to understand nature.

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<https://www.mathunion.org/imu-awards/carl-friedrich-gauss-prize/carl-friedrich-gauss-prize-2022>

Further materials about Elliott Lieb's Gauss Medal, including a video interview and the laudatio by Rupert Frank are available at [the IMU website](#).

2022 Gauss Prize: Elliott H. Lieb

by ALLYN JACKSON

For more than six decades Elliott Lieb has been among the most influential figures in mathematical physics. From his first work in the late 1950s through research that continues to the present day, he has displayed an uncanny ability to perceive the mathematical structures that lie at the heart of physical systems. In elucidating these structures, he has enriched both mathematics and physics.

Different Fields, Different Goals

The two fields have always had a symbiotic relationship: Mathematics supplies a rigorous basis for expressing physical intuitions, and physics supplies rich inspiration for new mathematics. Nevertheless the two fields are very different in their goals, outlook, and culture. Lieb is nearly unique in having repeatedly made profound and ground-breaking contributions to both fields. Both have awarded him top honors; in this year alone, he receives not only the Gauss Prize, but also the 2022 APS Medal for Exceptional Achievement in Research, the highest honor of the American Physical Society.

Lieb is very much a mathematician in the way he applies the utmost rigor to problems from physics. He has produced mathematical results about classical questions that, at the time he addressed them, were not fashionable in physics but that later turned out to have an impact in that field. One example is Lieb's 1973 work with Mary Beth Ruskai, which proved a key result about relations among certain characteristics of quantum mechanical systems. That result, known as "strong subadditivity of the entropy," is today one of the cornerstones of the burgeoning field of quantum information theory.

At the same time, Lieb works like a physicist in that his main aim is to understand physical reality. His physical intuition has identified many ideas in physics that subsequently had a significant impact in mathematics. For example, in 1976 Lieb and Herm Jan Brascamp were led by their work in statistical mechanics to develop a new tool now called the Brascamp-Lieb inequalities. Thirty years later, these inequalities had a major impact in the branch of mathematics known as harmonic analysis, and they and their relatives appear in some of the work that earned Terence Tao a Fields Medal in 2006. Even more recently, the Brascamp-Lieb inequalities have had an impact in theoretical computer science.

Comprising over 400 publications across a variety of subjects, Lieb's opus is impossible to summarize in a short space. Instead we provide here a closer look at three examples of his work that convey a sense of his taste in problems and his approach to solving them.

Square Ice

In the late 1950s, mathematical physics was concerned largely with classical mechanics and dynamics. Lieb and others forged a completely new line of research by using tools from mathematical analysis to attack problems in quantum and statistical mechanics. A signal example of this is Lieb's 1967 solution to the "square ice" problem from physical chemistry.

In landmark experiments in the 1930s, researchers were able to bring ice to extremely low temperatures and measure its “residual entropy.” This quantity captures the amount of entropy, or disorder, that remains despite the low temperature and that cannot be accounted for by vibrations within the crystalline lattice of the water molecules.

Abstractly, one can picture frozen H_2O as a three-dimensional lattice, in which the oxygen atoms lie on the nodes of the lattice and the hydrogen atoms lie on lines connecting the nodes. A 1935 paper by Linus Pauling proposed what came to be known as the “ice rule.” In the abstract lattice, the bonds between H and O atoms can be represented by arrows pointing inward towards the O atoms. The ice rule says that each node in the lattice has exactly two inward-pointing arrows.

The number of possible lattice configurations abiding by the ice rule grows enormously as the size of the lattice grows. It is this proliferation of configurations that produces the disorder, and thus the residual entropy, in ice. The two quantities— the number of configurations and the residual entropy—ought to be related by a simple mathematical expression. So if one knew the number of configurations and plugged it into that expression, would it match the residual entropy measured in the experiments?

This was the question Pauling asked. An exact calculation of the number of configurations was out of reach. Instead, Pauling made a careful estimate and found that it accorded very well with the experimental value. This has been hailed as one of the most successful confirmations of the validity of statistical mechanics.

But because the result relied on an estimate, its potential was unfulfilled. In the mid-1960s Lieb took up the two-dimensional version of the ice problem, which is called “square ice.” In the square-ice model, one has a two-dimensional lattice where the nodes in the lattice are connected by arrows that obey the ice rule: Each node has exactly two incoming arrows.

In 1967, Lieb used insights from mathematical combinatorics, together with concepts imported from a different part of physics, to calculate the exact number of configurations of square ice. This “magic number,” as Freeman Dyson once called it, also aligned closely to the experimental value and confirmed the validity of the ice rule.

Immediately recognized as a turning point, this result ushered in the flourishing field of what is now known as exactly soluble models, which lies at the border of mathematics and physics. Lieb continued to make decisive contributions to this field, some of which subsequently had wide impact within mathematics. One example is a construct known as the Temperley-Lieb algebra, which Lieb invented with Neville Temperley and which played a key role in the revolutionary work in knot theory that earned Vaughan Jones a Fields Medal in 1990.

Stability of Matter

Lieb’s square-ice result exemplifies a theme that has pervaded his work ever since: the quest to understand matter in the lowest energy states. It is in such states that one can hope to perceive the most fundamental structures of matter and investigate them mathematically. This was the motivation behind another facet of Lieb’s work that we will now consider, his work on the stability of matter.

By the mid-1960s, the 40-year-old theory of quantum mechanics had been widely con-

firmed. But at its heart lay a basic unanswered question: Why is matter stable? Quantum mechanics says that the basic components of matter are electrons and positively charged nuclei. These oppositely charged particles ought to simply implode and collapse. But they don't. Instead, all matter around us – rocks, people, trees – remains stable. Can quantum mechanics account for this?

The first proof that the answer is yes came in 1967-68, in long papers by Freeman Dyson and Andrew Lenard. The goal is to show that the minimal energy of N particles scales not like N^2 – that is, the number of interactions among the particles – but rather like N . Dyson and Lenard reached this goal, showing that the minimal energy is less than a constant times N . However, due to an accumulation of inefficient estimates, that constant was so huge, on the order of 10^{15} , that it was physically meaningless.

Together with Walter Thirring, Lieb came up with a completely new and greatly improved proof of the stability of matter. Just four pages long, their 1976 paper was not only far simpler mathematically but also shed new light on the physics. In particular, they greatly sharpened the constant that Dyson and Lenard had groped for. This epitomizes a major theme in Lieb's work, which is to optimize constants to elucidate their physical meaning.

Together with Thirring and others, Lieb went on to investigate in a mathematically precise way how stability of matter is governed by two basic tenets of quantum mechanics, the Pauli exclusion principle and the Heisenberg uncertainty principle. They showed how both principles can most usefully be captured in what became known as the Lieb-Thirring inequality, which is a vast generalization of the classic mathematical result called the Sobolev inequality. The Lieb-Thirring inequality has also found applications beyond the problem of stability of matter. This work fed back into mathematics, as Lieb and his collaborators worked on generalizing and sharpening related inequalities, such as the Hardy-Littlewood-Sobolev inequality. In the process, they uncovered symmetries that brought new meaning and usefulness to these tools. This work has had a major impact within mathematics, especially in the fields of analysis and geometry.

Bose-Einstein Condensate

Our third example from Lieb's work concerns a state of matter called the Bose-Einstein condensate, a state that can be reached only at extremely low temperatures close to absolute zero. In this extraordinary state, quantum mechanical effects, which normally operate only at the microscopic level, emerge at the macroscopic level. Many of the properties of this state come from quantum mechanical dynamics having no classical analog.

The phenomenon was predicted in the mid-1920s by Albert Einstein, following ideas of Satyendra Nath Bose. However, the technical capability of bringing matter to such low temperatures took another 70 years to develop. The physicists who produced the first Bose-Einstein condensate in 1995 received the Nobel Prize for their achievement. That landmark work set off a burst of new research.

It was in the early 1960s that Lieb first took up this problem. Earlier work had resulted in a formula for the ground-state energy in a Bose-Einstein condensate. While correct physically, the formula lacked a rigorous mathematical basis. Lieb hoped to supply that basis by proving

the validity of the formula. In 1963 he managed to re-derive the formula in a new way, providing additional confirmation of its basic correctness. However, he was not able to prove its validity.

In a tour de force that exemplifies Lieb's persistence and long-term view, he finally produced the proof 40 years later, in a 1998 paper with Jakob Yngvason. Coming on the heels of the 1995 experiments, the Lieb-Yngvason paper added to the surge of interest in Bose-Einstein. The topic has since become one of the most active areas of research in mathematical physics.

In related work, Lieb, together with Ian Affleck, Tom Kennedy, and Hal Tasaki, invented and solved what is now known as the AKLT quantum spin system. Carried out in 1987, this work provides an early example of a system exhibiting what is today referred to as a topological state of matter, a subject of great current interest.

Shaping Decades of Research

Over his long career, Lieb has had more than 100 co-authors. Many of these collaborations have had an intense, exhilarating quality, due to Lieb's prodigious intellectual energy, immense powers of concentration, and exacting work ethic. These traits have also marked his interactions with young researchers, including his ten doctoral students, all of whom have gone on to flourishing careers of their own. Some of them appear on the stellar list of speakers for a conference honoring Lieb's 90th birthday, held 30 July to 1 August this year.

Lieb has also made notable contributions to support the professions of mathematics and of physics. He twice served as president of the International Association of Mathematical Physics (1982-1984 and 1997-1999). During 1992-1995, he served as a Member-at-Large of the Council of the American Mathematical Society. His exceptional probity and integrity led in 1994 to his appointment to a committee that formulated the Society's first-ever ethical guidelines.

In shaping decades of research in mathematics and in physics, Elliott Lieb has reached to the very roots of these twin trees of human knowledge. He stands out as one of the great thinkers of our time.

Curriculum vitae of Elliott Lieb:

<https://web.math.princeton.edu/lieb/vita-short.html>

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<https://www.mathunion.org/imu-awards/carl-friedrich-gauss-prize/carl-friedrich-gauss-prize-2022>

Further materials about Elliott Lieb's Gauss Medal, including a video interview and the laudatio by Rupert Frank are available at [the IMU website](#).

Inaugural Olga-Ladyzhenskaja-Prize given to Svetlana Jitomirskaja



OAL Prizewinner

Here is the [link to \(WM\)² YouTube channel](#) where the record of the OAL Celebration appears.

The inaugural Ladyzhenskaya Prize in Mathematical Physics (OAL Prize) is awarded to Professor [Svetlana Jitomirskaja](#) “for her seminal and deep contributions to the spectral theory of almost periodic Schrödinger operators.” The prize, named in honor of the influential mathematician [Olga Alexandrovna Ladyzhenskaya](#) (1922-2004), is established in 2022 to mark 100 years from Ladyzhenskaya’s birth. There is no restriction of age or gender associated with the prize; in particular, it can be awarded to men as well as to women. The prize is awarded in 2022 at the OAL Celebration – a joint session of the World Meeting for Women in Mathematics (WM)² and the Probability and Mathematical Physics Conference, both satellite conferences of the virtual International Congress of Mathematicians.

Svetlana Jitomirskaja was born in 1966 in Kharkiv, Ukraine, where both of her parents were professors of mathematics. She studied at the Moscow State University, obtaining a PhD in 1991. From 1991 on, she has held positions at University of California Irvine, rising there to the rank of a Distinguished Professor. In July 2022 she has started as the inaugural Elaine M. Hubbard Chair at the Georgia Institute of Technology. Jitomirskaja was an invited speaker at the 2002 International Congress of Mathematicians in Beijing, and she gives a plenary invited lecture at the 2022 International Congress of Mathematicians. Jitomirskaja has received numerous prizes for her work, including the AMS Ruth Lyttle Satter Prize in 2005 and the APS & AIP Dannie Heineman Prize for Mathematical Physics in 2020. She was elected a member of the American Academy of Arts and Sciences in 2018 and of the US National Academy of Sciences in 2022.

Jitomirskaja’s research concerns the spectral theory of Schrödinger operators. Schrödinger operators arise in quantum mechanics. Their spectra describe the possible values of energy measurements of quantum mechanical systems, and they determine the dynamics of the quantum systems.

Svetlana Jitomirskaja has in particular solved a number of famous open mathematical problems concerning what is known as the almost Mathieu operator – a prototypical example of

an almost periodic Schrödinger operator on a lattice, whose spectrum has intricate features depending on parameters. The prize committee's citation emphasizes the large impact that Jitomirskaya's work has had on the research community. Jitomirskaya pioneered the use of non-perturbative methods, starting a new way to approach a field where only KAM-type methods had been used previously. In a 1999 article, she proved that the almost Mathieu operator has a metal-insulator transition at the critical point. Notable problems Jitomirskaya solved with her collaborators include the first general result on the continuity of the Lyapunov exponents with Jean Bourgain in 2002, the celebrated Ten Martini Problem with Artur Avila in 2009, and the universal hierarchical structure of eigenfunctions with Wencai Liu in 2018.



Citation by the prize committee of the OAL Prize 2022

Svetlana Jitomirskaya has made profound, transformative contributions to the spectral theory of almost periodic Schrödinger operators and Jacobi matrices. The prototypical example is the almost Mathieu operator, a three-parameter family of discretized Schrödinger operator on a one-dimensional lattice with an incommensurate periodic potential, of great interest both for mathematicians and physicists. Physically it describes an electron on a two-dimensional lattice in a perpendicular magnetic field. For this model and related almost periodic Schrödinger operators and Jacobi matrices, Jitomirskaya developed new techniques to obtain landmark results on the spectrum, the Lyapunov exponents, and the delicate arithmetic effects at non-Diophantine frequency parameter. She and her work have a big impact on the community, both by drawing senior mathematicians to the field and by raising a new generation of young researchers.

In particular, she established the existence of the metal-insulator transition for the almost Mathieu operator: she proved that as one varies the coupling parameter the spectrum goes from absolutely continuous to pure point, with singular continuous spectrum at the transition point. This was the first non-perturbative result on a problem with small denominators, for which previous results, based on Kolmogorov-Arnold-Moser perturbation theory, applied only for very small or (by duality) very large coupling parameter. With Jean Bourgain, Jitomirskaya proved the first general result on the continuity of the Lyapunov exponents. With Artur Avila, she established a key component in the solution of the celebrated Ten Martini Problem, by showing that the pure point spectrum is a Cantor set. With Igor Krasovsky, she settled the Thouless $1/2$ -conjecture, by proving that the Hausdorff dimension of the spectrum at critical coupling is at most $1/2$ for all irrational values of the frequency parameter.

Composition of the prize committee

The members of the prize committee of the OAL Prize 2022, chaired by Giovanni Felder, ETH Zurich, were Michael Aizenman, Princeton University, Peter Forrester, University of Melbourne, Dan Freed, University of Texas at Austin, Gregory Seregin, University of Oxford, Corinna Ulcigrai, University of Zurich and Michèle Vergne, IMJ-PRG Paris.

Information about the prize

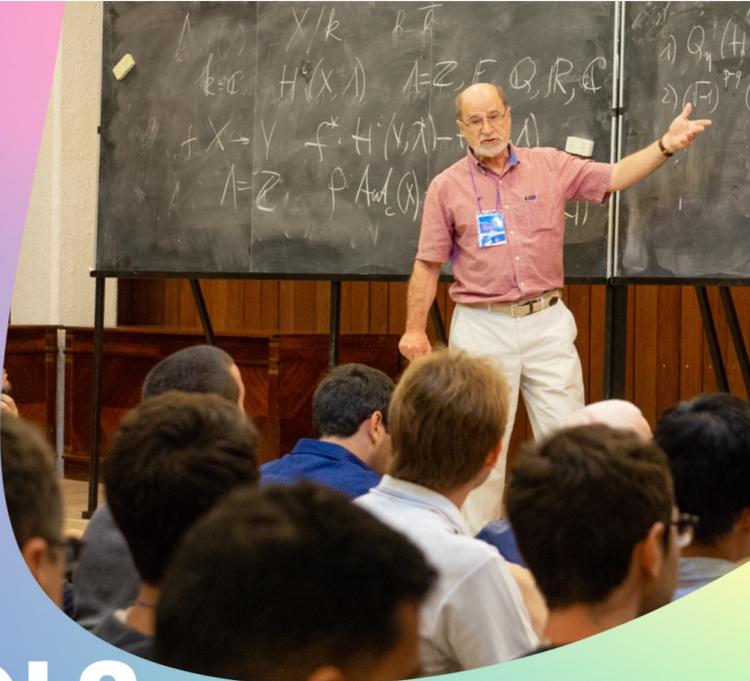
The OAL Prize Winner receives a cash award of 10.000 euros. The funding is provided by the Simons Foundation.

This press release is reprinted with permission from [The World Meeting for Women in Mathematics](https://2022.worldwomeninmaths.org/OAL-prize-winner). The original article is available at <https://2022.worldwomeninmaths.org/OAL-prize-winner>.

Contact with (WM)² organizers: contact@worldwomeninmaths.org.

A video interview of Svetlana Jitomirskaya may be found at [the Simons Foundation website](https://www.simonsfoundation.org/).

Calls for Proposals



THE CALL FOR PROPOSALS IS OPEN!

2024 CIMPA SCHOOLS

Contribute to the promotion of research in mathematics with developing countries!

Deadline: **October 9, 2022**

The call for projects for 2024 CIMPA schools is open. **The project proposals must be submitted online by October 9, 2022.** For details and links see <https://www.cimpa.info/en/node/41>.

Call for proposals 2024



The SwissMAP Research Station (SRS)

organizes international topical conferences and targeted workshops in the fields of mathematics and theoretical physics.



- ☞ around 14 conferences and workshops throughout the year
- ☞ fully equipped conference and meeting rooms
- ☞ based in Les Diablerets (VD), Switzerland

Interested in organizing a conference in 2024 at the SRS?
The application template including possible conference dates is available on the SRS Website

<https://swissmaprs.ch>



Application deadline: September 30, 2022 at contact@swissmaprs.ch





Scientific Program 2023

JANUARY/FEBRUARY

Winter School in Mathematical Physics

January 8-13

A. Alekseev (Geneva), A. Cattaneo (Zurich),
G. Felder (ETH Zurich), M. Podkopaeva (IHES),
T. Strobl (Lyon 1), A. Szenes (Geneva).

New connections: chaos, field theory and quantum gravity

January 15-20

S. Shatashvili (Dublin & Stony Brook), J. Sonner (Geneva),
E. Verlinde (Amsterdam).

Workshop on Quantization and Resurgence

January 29 - February 3

M. Mariño (Geneva), R. Schiappa (Lisbon).

Integrability in Condensed Matter Physics and Quantum Field Theory

February 3-12

V. Bazhanov (ANU), R. Kashaev (Geneva), G. Kotousov (DESY)
H. Saleur (IPhT & USC), V. Schomerus (DESY).

Non-Archimedean methods in arithmetic and geometry

February 12-17

R. Cluckers (Lille & Leuven), A. Forey (EPF Lausanne),
A. Szenes (Geneva), D. Wyss (EPF Lausanne).

Workshop in Statistical Mechanics 2023

February 19-24

S. Smirnov (Geneva).

MAY/JUNE

Geometric and analytic aspects of the Quantum Hall effect

May 7-12

A. Alekseev (Geneva), S. Klevtsov (Strasbourg),
P. Wiegmann (Chicago).

Interactions of Low-dimensional Topology and Quantum Field Theory

May 21-26

D. Kosanović (ETH Zurich),
R. Schneiderman (Lehman College CUNY),
C. Schommer-Pries (University of Notre Dame),
S. Stolz (University of Notre Dame).

Analytic techniques in Dynamics and Geometry

May 28 - June 2

A. Avila (Zurich), M. Cekic (Zurich), T. Lefeuvre (Sorbonne).

Helvetic Algebraic Geometry Seminar (HAGS) 2023

June 4-9

R. Pandharipande (ETH Zurich), A. Szenes (Geneva).

Effective theories in classical and quantum particle systems

June 18-23

M. Porta (SISSA, Trieste), C. Saffirio (Basel).

Junior Euler Society Summer school

June 28 - July 3

T. Samrowski (Zurich).

Euler Camp Summer school

July 3-7

J. Scherrer (EPF Lausanne).

AUGUST/SEPTEMBER

S-matrix Bootstrap Workshop V

August 20-25

A. Guerrieri (Tel Aviv), J. Penedones (EPF Lausanne),
B. van Rees (Ecole Polytechnique),
P. Vieira (Perimeter Institute & ICTP-SAIFR),
A. Zhiboedov (CERN).

Categorical Symmetries in Quantum Field Theory (School & Workshop)

August 27 - September 1 & September 3-8

M. Bullimore (Durham), A. Cattaneo (Zurich),
I. G. Etxebarria (Durham), D. Jordan (Edinburgh),
K. Ohmori (Tokyo), C. Scheimbauer (Munich).

Mapping class groups: pronilpotent and cohomological approaches

September 17-22

N. Kawazumi (Tokyo), G. Massuyeau (Bourgogne),
H. Nakamura (Osaka),
T. Sakasai (Tokyo), C. Vespa (Strasbourg).

Quantisation of moduli spaces from different perspectives

September 24-29

N. Aghaei (SDU), A. Alekseev (Geneva),
N. Orantin (Geneva).

***Communications in Mathematical Physics* (CMP) seeks external Managing Editor (contract role)**

Communications in Mathematical Physics (CMP), a leading international journal in the field of mathematical physics, is establishing the new role of an external “Managing Editor.”

The Managing Editor will:

- Assist CMP’s Editor-in-Chief, in particular with the preliminary assessment and assignment of new submissions
- Monitor and foster the smooth and timely functioning of all aspects of the submission and peer-reviewing processes on the journal’s web-based manuscript handling system in close cooperation with all parties involved (EiC, Associate Editors, Authors, Reviewers, Editorial Office).

Starting Date: 01.12.2022

Duration: 3-year-contract

Hours per week: 20 (setting own working hours)

Location: remote

Editorial Honorarium: 25,000 EUR per annum, all inclusive.

The successful candidate will

- Be educated in the field of mathematical physics at the PhD level
- Have fluent English skills, both written and spoken
- Have good administrative and organizational skills

Previous experience with scholarly publishing will be an advantage.

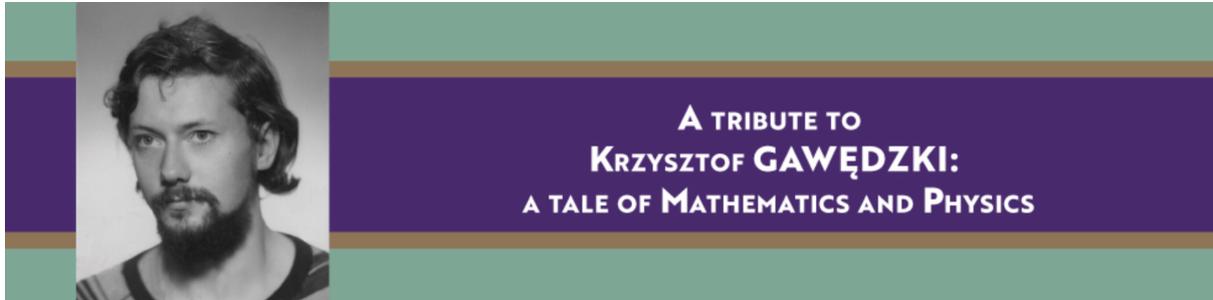
To apply, please send your:

- Curriculum Vitae (Please name the document as: CV-Surname-CMP-Managing Editor)
- Cover Letter (Please name the document as: Cover-Surname-CMP-Managing Editor)
- Letters of recommendation (Please name the document as: Recommendation-Surname-CMP-Managing Editor)

to Alexandra.Lagogianni@springernature.com. The subject line of your email should read: Surname–CMP–Managing Editor

Application deadline: September 15th, 2022

A Tribute to Krzysztof Gawędzki



The aim of this conference is to bring together leading researchers on a wide spectrum of themes which reflects the scientific career of our late colleague and friend Krzysztof Gawędzki, who died in January 2022. Krzysztof has played a major role in our community, at the frontier between mathematics and theoretical physics, for more than twenty years spent at the ENS de Lyon. This conference will be a tribute to his memory and will also be a major event in mathematical physics. The topics of this conference will range from quantum field theory, statistical physics, non-equilibrium systems, to hydrodynamics and open systems, both in their mathematical and physical aspects.

For registration and other links please visit <https://gawedzki2022.sciencesconf.org/>.

Time's Arrow

Scientific anniversaries

1822. On 2 January [Rudolf Clausius](#) was born in Köslin, Prussia.

1822. On 3 July [Charles Babbage](#) published an open letter to [Sir Humphry Davy](#) entitled “On the application of machinery to the purpose of calculating and printing mathematical tables”, outlining the invention of the first calculating machine.

2012. On 4 July the observation of the Higgs boson at the CERN Large Hadron Collider was announced. Follow [this link for related material in *Physics Today*](#).

Awards and Honors

Hugo Duminil-Copin, Svetlana Jitomirskaya, and Elliott Lieb won major prizes in mathematics (see articles in this issue).

Recent personal celebrations

1922. [Vladimir Marchenko](#) was born on 7 July in Kharkiv, Ukraine. We congratulate him on the occasion of his 100th birthday.

Readers are encouraged to send items for “Time's Arrow” to bulletin@iamp.org.

News from the IAMP Executive Committee

New individual members

IAMP welcomes the following new members

1. PROF. DAVID RIDOUT , School of Mathematics and Statistics, The University of Melbourne, Australia
2. MARIE FIALOVÁ, Department of Mathematical Science, University of Copenhagen, Denmark.
3. DR. MICHAEL HOTT, Department of Mathematics, University of Texas, Austin, USA.

Recent conference announcements

4th ZiF Summer School Randomness in physics and mathematics: From integrable probability to disordered systems,

August 1 - 13, 2022, Centre for Interdisciplinary Research (ZiF), Bielefeld University.

Quantum information in many-body physics: a mathematical invitation

August 29 - September 2, 2022, IAMP-EMS Summer School in Mathematical Physics, Munich, Germany

Solid Math 2022, Trieste, Italy. Mathematical and numerical methods for solid-state physics

September 6 - 9, 2022, Trieste, Italy.

Qmath15

September 12 - 16, 2022, University of California, Davis CA, USA.

Asymptotic Analysis and Spectral Theory (Aspect'22)

September 26 - 30, 2022, Oldenburg, Germany.

A Tale of Mathematics and Physics: A Tribute to Krzysztof Gawedzki

November 7 - 10, 2022, École Normal Supérieure, Lyon, France.

The Analysis of Relativistic Quantum Systems

January 9 - 13, 2023, CIRM, Marseille, France.

For an updated list of academic job announcements in mathematical physics and related fields visit

http://www.iamp.org/page.php?page=page_positions

Michael Loss (IAMP Secretary)

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