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## 150 Years of vortex dynamics

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**Abstract** An IUTAM symposium with the title of this paper was held on October 12–16, 2008, in Lyngby and Copenhagen, Denmark, to mark the sesquicentennial of publication of Helmholtz’s seminal paper on vortex dynamics. This volume contains the proceedings of the Symposium. The present paper provides an introduction to the volume.

**Keywords** Vortex dynamics · Helmholtz sesquicentennial · IUTAM symposium

### 1 Overview of the symposium

In 1858, interleaved with work on physiology for which he may today be better known, Hermann Ludwig Ferdinand Helmholtz—the titulation “von” was added later—published “Über Integrale der hydrodynamischen Gleichungen, welche den Wirbelbewegungen entsprechen” [4]. This paper may rightfully be seen as the initiation of the subfield of fluid mechanics that we today refer to as *vortex dynamics*. Thus, in 2008, it seemed fitting to commemorate and celebrate the sesquicentennial of Helmholtz’s seminal work, and the birth of vortex dynamics, by holding an IUTAM symposium on the subject. Logically, *150 Years of Vortex Dynamics* became the title of the symposium. The symposium was held in the facilities of the Technical University of Denmark (DTU), at Kongens Lyngby, a suburb of Copenhagen, from October 12 to 16, 2008. The main auditorium used is known as Oticon salen (see Fig. 1).

The International Scientific Committee of the Symposium consisted of M. Brøns (Denmark), G. J. F. van Heijst (The Netherlands), S. Kida (Japan), V. V. Meleshko (Ukraine), H. K. Moffatt (UK, IUTAM representative), P. K. Newton (USA), and H. Aref (Denmark and USA) as the chair. The Local Organizing Committee at DTU consisted of A. Andersen, T. Bohr, M. Brøns (Treasurer), H. Bruus, D. Glass, and again H. Aref as chair. We had great help from three of our PhD students, J. Rønby Pedersen, T. Schnipper, and L. Tophøj.

IUTAM has recognized the field of vortex dynamics through a number of symposia in the past. The apt characterization by Küchemann [2] of vortices as the “sinews and muscles of fluid motions” stems from his summary of the symposium on *Concentrated Vortex Motions in Fluids* (Ann Arbor, 1964). Later, IUTAM symposia on vortices and vortex dynamics include *Fundamental Aspects of Vortex Motion* (Tokyo 1988) [1], *Dynamics of Slender Vortices* (Aachen, 1997), *Tubes, Sheets and Singularities in Fluid Dynamics* (Zakopane, 2001), *Elementary Vortices and Coherent Structures: Significance in Turbulence Dynamics* (Kyoto, 2004) and *Hamiltonian Dynamics, Vortex Structures and Turbulence* (Moscow, 2006). This 2008 symposium was

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**Fig. 1** Attendees assembled in the lecture hall, Oticon salen at DTU, for the IUTAM symposium *150 Years of Vortex Dynamics*



**Fig. 2** Group photo of attendees at the IUTAM symposium *150 Years of Vortex Dynamics*

intended as a broad state-of-the-art survey of the field. It concerned vortices and vortex dynamics in all manner of flows, from laminar to turbulent, terrestrial to cosmic, geophysical to biological, addressed through analysis, experiment, and computation. Classical themes and theories are still of interest, e.g., relative equilibria of point vortices, albeit now applied to Bose–Einstein condensates, or kinetic theory now applied to systems of vortices as a prototype of turbulence. The variety of topics will be evident from the program listed below and the papers presented in this volume. The role of vortices in the drag and propulsion of swimming and flying animals was explored by a number of attendees and would, undoubtedly, have pleased Helmholtz whose contributions to physiology are well known.

The symposium was attended by 108 registered participants and 10 accompanying persons. A group photo of attendees appears as Fig. 2. Some students and researchers at the DTU also attended off and on. The official scientific participants came from 19 nations: Algeria (1), Belgium (1), Brazil (2), Canada (1), Czech Republic (2), Denmark (14), France (11), Germany (1), Greece (1), Israel (1), Italy (4), Japan (14), Lithuania (3), Mexico (2), The Netherlands (2), Poland (4), Russia (8), Ukraine (4), UK (6), and USA (26). A participant from Bangladesh was unable to secure a visa on time and so did not attend. The oral part of his seminar/poster presentation was given by the chair assisted by Prof. A. Leonard (Caltech) based on slides he had sent, and his poster was displayed in the appropriate session.

The social events included a get-together party at Hotel Strand in Copenhagen on the evening of Sunday, October 12, a Reception at the Carlsberg Academy, the former Honorary Residence primarily known for its illustrious resident Niels Bohr, on Monday, October 13, where two special lectures were presented, and a banquet at Charlottenlund Travbane (the sulky race track) north of Copenhagen on Wednesday, October 15. The two lectures given at the reception were by H. K. Moffatt, “The persistence of spin” (see Fig. 3), and



**Fig. 3** *Top left* Lunch time, Glassalen at DTU; *top right* Keith Moffatt lecturing at the reception at the Carlsberg Academy; *bottom left* Ed Spiegel speaking at the banquet at Charlottenlund Travbane; *bottom right* making sure the AV is set up correctly

R. J. Donnelly, “What goes around comes around: Why study vortex dynamics?” Both were designed for a somewhat general audience although the assembled specialists in vortex motion listened most attentively! The written versions of these lectures are not included in the present *Special Issue* but are included in the accompanying IUTAM Symposium book. Tomas Bohr made some remarks about the history and layout of the remarkable building we were in, and added some recollections from his childhood when his grandfather was the honorary resident. Several speeches were made at the banquet. Vladimir Zakharov recited one of his poems in Russian and then provided an impromptu translation into English. The main banquet speaker was Ed Spiegel (see Fig. 3).

The technical program of the Symposium consisted of 5 keynote lectures, 39 contributed lectures, and 50 seminar/poster presentations. An additional 26 papers had been submitted for consideration. Some of these had been declined by the International Scientific Committee, which reviewed all submissions and decided on the list of keynote speakers, others had been accepted but the author was ultimately unable to attend. As will be seen from the detailed program listing, the papers were distributed over 4 days with a keynote lecture to start off the morning. This was followed by contributed lectures. The seminar/poster sessions were grouped around the lunch breaks with 10 papers in each and an hour for short oral presentations and discussion. The posters were on display around the periphery of the lecture hall for the full 4 days of the Symposium so that continued discussion of them could and did take place. Paul Newton generously offered a copy of his book on the  $N$ -vortex problem [3] as a prize for the seminar/poster presentation that garnered the most votes from attendees. The winner was Philip du Toit for his seminar/poster presentation “Visualizing mixing in geophysical vortices.”

Financial support for the Symposium was provided by: The Center for Fluid Dynamics at the Technical University of Denmark, *Fluid•DTU*, Florida State University, Virginia Tech Foundation, and IUTAM. All funds received from IUTAM were used for the support of younger participants in the Symposium.

## 2 The program

The detailed program of papers presented and other events at the Symposium is given below. Only the presenting author is indicated. An asterisk before an entry indicates that a written version of the paper is included in the

proceedings. The author list and title may deviate from the corresponding paper presented at the Symposium. The papers follow in this *Special Issue* in the sequence they were presented at the Symposium.

All lecture presenters were encouraged to submit papers for the current *Special Issue*, papers that would then be re-published in the proceedings volume. Seminar/poster presenters were encouraged to submit very brief papers on their work for possible inclusion. However, depending on the number and lengths of papers received, these papers might not all be published in the *Special Issue*. Since all papers submitted were subject to standard reviewing practices of *Theoretical and Computational Fluid Dynamics*, any paper could be published subsequently with an annotation that the work was first presented at the Symposium. In the end, a total of 48 manuscripts were received, reviewed, and accepted for the *Special Issue*. Of these, only 7 are based on seminar/poster presentations. The current volume should, therefore, give a particularly good impression of the work presented as lectures at the Symposium. These, by themselves, provide a good overview of the directions of the field that are currently active.

The detailed program follows:

### **Sunday, October 12, 2008**

Meet and greet attendees at Copenhagen's Kastrup airport;  
*Get-together party* at Hotel Strand.

### **Monday, October 13, 2008**

#### *Registration*

*Opening:* 09:00–09:30:

Welcome by Hassan Aref, Chair of the Symposium;

Welcome on behalf of IUTAM by Keith Moffatt, Vice President of IUTAM;

Welcome to DTU by Kristian Stubkjær, Dean of Research, DTU.

*Keynote lecture 1:* 09:30–10:20 (Hassan Aref, chair)

\*Darren Crowdy, "A new calculus for two-dimensional vortex dynamics"

*Lecture session 1:* 10:20–11:20 (Slava Meleshko, chair)

\*Mark Stremler, "On the statics and dynamics of point vortices in periodic domains"

\*Kevin O'Neil, "Collapse and concentration of vortex sheets in two-dimensional flow"

\*Scott Kelly, "Self-propulsion of a free hydrofoil with localized discrete vortex shedding: analytical modeling and simulation"

*Break:* 11:20–11:45

*Seminar session and poster viewing I:* 11:45–12:45 (Keith Moffatt, chair)

Vaclav Kolar, "On the relationship between a vortex and vorticity"

Elena Meshcheryakova, "New exact solutions in vortex dynamics"

\*Milton Lopes Filho, "Vortex dynamics in a two-dimensional domain with holes"

Hassan Aref, "Relative equilibria of point vortices"

Peter Clarkson, "Polynomials and soliton equations"

Laust Tophøj, "Chaotic scattering of two identical point vortex pairs"

Yuko Matsumoto, "A moment model for the motion of a dipole in two-dimensional incompressible fluid"

Irene Gned, "The self-induced dynamics of vortex patches"

Eugene Wayne, "A generalization of the Helmholtz–Kirchhoff model"

Alexey Borisov, "Chaotic vibration of the liquid ellipsoid filled with vortical fluid"

*Lunch,* Glassalen, DTU Cantine: 12:45–13:45 (see Fig. 3)

*Seminar session and poster viewing II:* 13:45–14:45 (GertJan van Heijst, chair)

Eduardo Ramos, "Vortices generated by fixed and free-moving magnets in shallow electrolyte layers"

Pavlos Vlachos, "Kelvin–Helmholtz and Rayleigh–Taylor instabilities during accumulation and dispersion of ferrofluid aggregates"

Clara Velte, "Local helical symmetry of vortices by vortex generators in a low Reynolds number wall bounded flow"

Georgi Sutyrin, "Dynamics of coherent vortices in rotation-dominated flows"

Philip duToit, "Visualizing mixing in geophysical vortices"

\*Konstantin Koshel, "Background current concept and chaotic advection in an oceanic vortex flow"

\*Gregory Reznik, “Quasi-geostrophic singular vortices embedded in a regular flow”  
 Oleg Derzho, “Rotating dipole and tripole vortices in polar regions”  
 Tatyana Krasnopolskaya, “Modelling of Gulf Stream by the von Kármán vortex street”  
 Dmytro Cherniy, “The vortex model of circulation flow in sea channel”  
*Lecture session 2: 14:45–15:45* (Mikhail Sokolovskiy, chair)

\*Ed Spiegel, “Cosmic vortices”  
 \*Xavier Perrot, “Baroclinic vortex interaction in a time-varying flow”  
 \*Ziv Kizner, “Localized shallow-water dipoles”

*Break: 15:45–16:15* Photograph of all attendees, see Fig. 2.

*Lecture session 3: 16:15–17:15* (Gregory Reznik, chair)  
 \*Ruben Trieling, “Elliptical barotropic  $f$ -plane dipoles in a rotating fluid”  
 \*Mikhail Sokolovskiy, “On the instability of elliptic hetons”  
 \*Xavier Carton, “Explosive instability of geostrophic vortices”

*Lectures and Reception at the Carlsberg Academy, 18:00–20:30* (see Fig. 3).

## **Tuesday, October 14, 2008**

*Keynote lecture 2: 09:30–10:20* (Alexey Borisov, chair)  
 \*Paul Newton, “The  $N$ -vortex problem on a sphere”

*Lecture session 4: 10:20–11:20* (Ziv Kizner, chair)  
 \*Takashi Sakajo, “Motion of a ring structure of coherent vortices on a sphere with pole vortices”  
 \*Rhodri Nelson, “Finite area vortex motion on a sphere with impenetrable boundaries”  
 \*Keiko Nomura, “Asymmetric vortex merger: mechanism and criterion”

*Break: 11:20–11:45*

*Seminar session and poster viewing III: 11:45–12:45* (Paul Newton, chair)  
 Stefanella Boatto, “Vortices on closed surfaces”  
 Vitalii Ostrovskiy, “Platonic and Archimedean solid based point vortex equilibria on the sphere”  
 George Chamoun, “Von Kármán streets on the sphere”  
 Ivan Mamaev, “New integrable problem of motion of point vortices on a sphere”  
 Adas Jakubauskas (for A. J. V. Milyus), “On a question of definition of potential by the vortex motion of a liquid”  
 Xinyu He, “An example of finite-time singularities in the 3D Euler equations”  
 Valery Klyatskin, “Sound radiation by vortex motions”  
 E. Milyute, “A dynamics of a substance in an isolated spherical vortex and its relationship with radiation”  
 Sergio Pirozzoli, “Vortical structures in turbulence growth”  
 Osamu Sano, “Collision of a vortex ring on granular layer”

*Lunch, Glassalen, DTU Cantine: 12:45–13:45.*

*Seminar session and poster viewing IV: 13:45–14:45* (Mark Stremmer, chair)  
 Anders Andersen, “The vortices in the wake of a falling paper card”  
 \*Kai Schneider, “Numerical simulation of falling leaves using a pseudo-spectral method with volume penalization”  
 Makoto Iima, “Robustness of insects free-flight in terms of flapping motion and vortex patterns”  
 Vasileios Vlachakis, “Vortex dynamics of wakes: analysis of the Domm system”  
 Takeshi Watanabe, “Study of vortex flows behind the circular cylinder”  
 Hamid Oualli, “Vortex flow eddy street behind a circular cylinder superimposed to simultaneous rotation and cross-section variation in uniform flow”  
 Grgoire Winckelmans, “Redistribution on hierarchically refined grids for Lagrangian vortex element methods”  
 \*Tarun Kumar Sheel, “High performance computing technique for vortex method calculations”

Monika Nitsche, “High order quadratures for the boundary integrals governing axisymmetric interface motion”  
 Robert Krasny, “Lagrangian panel method for vortex sheet motion in 3D Flow”

*Lecture session 5: 14:45–15:45 (Charles Williamson, chair)*

Ian Eames, “Ghost vortices and disappearing bodies: the concept of momentum and impulse”

\*Paolo Luzzatto-Fegiz, “Determining the stability of steady inviscid flows through preferred bifurcation diagrams”

\*Oscar Velasco Fuentes, “Chaotic streamlines in the flow of knotted and unknotted vortices”

*Break: 15:45–16:15*

*Lecture session 6: 16:15–17:15 (Anders Andersen, chair)*

\*Sebastian Michelin, “Falling, flying, swimming, flapping: understanding fluid-solid interactions using a vortex shedding model”

\*Eva Kanso, “Low-order models of swimming in an inviscid fluid”

\*Dmitry Kolomenskiy, “Vorticity generation during the clap-fling-sweep of hovering insects”

*Banquet, Charlottenlund Travbane 18:00 (see Fig. 3)*

### **Wednesday, October 15, 2008**

*Keynote lecture 3: 09:30–10:20 (Ed Spiegel, chair)*

\*Pierre-Henri Chavanis, “Kinetic theory of two dimensional point vortices from a BBGKY-like hierarchy”

*Lecture session 7: 10:20–11:20 (Anthony Leonard, chair)*

\*Nicholas Kevlahan, “Vortices for computing: the engines of turbulence simulation”

\*Paolo Orlandi, “Vorticity dynamics in turbulence growth”

\*Jens Juul Rasmussen, “Sharp vorticity gradients in two-dimensional turbulence and the energy spectrum”

*Break: 11:20–11:45*

*Lecture session 8: 11:45–12:45 (Jens Nørkær Sørensen, chair)*

Roman Lagrange, “Dynamics of a fluid inside a precessing cylinder”

\*Shigeo Kida, “Super-rotation flow in a precessing sphere”

\*Fazle Hussain, “Mechanisms of core perturbation growth in vortex-turbulence interaction”

*Lunch, DTU Cantine: 12:45–13:45*

*Seminar session and poster viewing V: 13:45–14:45 (Morten Brøns, chair)*

Charles Williamson, “Stability of classical flows and new vortical solutions from preferred bifurcation diagrams”

Leonid Shirkov, “Statistical mechanics of shear layers”

\*Keita Iga, “Statistical theory applied to a vortex street generated from meander of a jet”

Jens Nørkær Sørensen, “Onset of three-dimensional flow structures in rotating flows”

Bo Hoffmann Jørgensen, “Control of vortex breakdown in a closed cylinder with a rotating lid”

Ziemowit Malecha, “Bursting phenomena of boundary layer induced by 2D vortex patch”

\*Paul Krueger, “Vortex ring velocity and minimum separation in an infinite train of vortex rings generated by a fully-pulsed jet”

Pawel Regucki, “Investigation of vortex ring with finite-amplitude Kelvin waves using 3D VIC method”

Chris Weiland, “The role of vortex ring formation on the development of impulsively induced supercavitation”

V. Milyuvene, “A new look at a vortical dynamics of a substance in the Universe”

*Lecture session 9:* 14:45–15:45 (Fazle Hussain, chair)

\*Morten Brøns, “Topology of vortex creation in the wake of a circular cylinder”

\*David Fabre, “Bifurcations in the wake of axisymmetric objects”

Luca Zannetti, “About finite area wakes past bluff bodies and growing vortex patches”

*Break:* 15:45–16:15

*Lecture session 10:* 16:15–17:15 (Oscar Velasco Fuentes, chair)

\*GertJan van Heijst, “Behavior of a vortex in a time-periodic shear flow”

\*Hiroshi Niino, “Structure of a bathtub vortex: importance of the bottom boundary layer”

\*Tomas Bohr, “Separation vortices and surface shapes”

### Thursday, October 16, 2008

*Keynote lecture 4:* 09:30–10:20 (Shigeo Kida, chair)

\*Yasuhide Fukumoto, “Global time evolution of viscous vortex rings”

*Lecture session 11:* 10:20–11:20 (Russell Donnelly, chair)

\*Stéphane Le Dizés, “Viscous ring modes in vortices with jet”

\*Yuji Hattori, “Short-wave stability of a helical vortex tube: The effect of torsion on the curvature instability”

\*Anthony Leonard, “On the motion of thin vortex tubes”

*Break:* 11:20–11:45

*Lecture session 12:* 11:45–12:45 (Yasuhide Fukumoto, chair)

\*Vladimir Zakharov, “Dynamics of vortex line in presence of stationary vortex”

\*Makoto Umeki, “A locally induced homoclinic motion of the vortex filament”

\*Yoshifumi Kimura, “Self-similar collapse of 2D and 3D vortex filament models”

*Lunch,* Glassalen, DTU Cantine: 12:45–13:45

*Lecture session 13:* 13:45–14:45 (Yoshifumi Kimura, chair)

\*Valery Okulov, “Applications of 2D helical vortex dynamics”

\*Slava Meleshko, “Coaxial axisymmetric vortex rings – 150 years after Helmholtz”

\*Russell Donnelly, “Dynamics of vortex rings in viscous fluids”

*Keynote lecture 5:* 14:45–15:35 (Tomas Bohr, chair)

Thomas Leweke, “Vortex pairs”

*Closing:* 15:35–15:45

In view of the variety of topics covered, the fields of science included, the multitude of analytical, numerical, and experimental techniques used, the areas of application, and the generally very high level of scientific discourse at the Symposium, one has to conclude that on its 150th birthday the field of vortex dynamics, Helmholtz’s brainchild of 1858, is alive, vibrant, and thriving.

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