Warwick Symposium on Geometric Mechanics and Symmetry GR/R09619/01

FINAL REPORT

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Contents

1 Overview

The 2001-2002 Warwick Symposium was on *Geometric Mechanics amd Symmetry*. The principal organiser was Mark Roberts (Warwick/Surrey), assisted by a Scientific Advisory Board: Tom Bridges (Surrey), Richard Cushman (Utrecht), Jeroen Lamb (Imperial), Ben Leimkuhler (Leicester), Robert Littlejohn (Berkeley), Jerry Marsden (Caltech), Ken Meyer (Cincinnati), James Montaldi (UMIST), Tudor Ratiu (Lausanne) and Gregor Tanner (Nottingham). Altogether there were over 200 participants (see list in Section 4), or whom approximately 80 were from the UK.

The Symposium focused on the symplectic and differential geometry of symmetric Hamiltonian systems and applications of geometry and symmetry techniques to the classical, semiclassical and quantum mechanics of N-body problems (gravitational, atomic, molecular) and to fluid mechanics. The Symposium began with a European Summer School held in France, followed by a further Spring School and four workshops at Warwick. In addition three satellite workshops were held at Surrey, Leicester and UMIST. These were 'peaks' within a sea of research activity, seminars etc that took place throught the year and which continued into the year 2002-2003. During the second year the Symposium grant also provided partial support for a workshop on the Calculus of Variations at Warwick. Details of all the Schools and Workshops are given below.

Distinctive features of the Symposium included:

- A strong emphasis on 'interdisciplinarity': the participants included physicists, chemists, engineers and astronomers, as well as mathematicians specializing in areas as diverse as symplectic geometry, classical mechanics, equivariant bifurcation theory, continuum mechanics and numerical methods. Feedback from the participants (see section 5) shows that they particularly appreciated these aspects.
- Its organization within the context of an active research programme pursued by the EC Research Training Network *Mechanics and Symmetry in Europe*, coordinated by Mark Roberts. The Network brought additional funds to the Symposium, which in return provided opportunities for the Network participants to interact with other scientists from Europe and elsewhere.
- A large number of 'long stay' participants: apart from the permanent Warwick staff with interests in the area, one postgraduate student (Schebesch) and three postdocs (Sbano, Schmah, Wulff) came for the whole year. Researchers who spent a month or more at Warwick included Cushman, Derks, Hanßman, Holm, Meyer, Mitchell, Montaldi, Patrick, Sniatycki, Sousa Dias and Zhilinskii.

The major sources of funding for the Symposium were:

EPSRC	Travel and subsistence for visitors. Administrative and computing support
European Commission FP5	1) Support for the European Summer School, via grant to James Montaldi 2) Travel and subsistence for participants in the RTN MASIE
London Mathematical Society	Support for UK participants via the Warwick British Visitors Fund
National Science Foundation	Support for young researchers based in the USA via a grant to Ken Meyer.

In addition many participants received full or partial support from their own institutions and/or national research funding agencies.

As usual the Symposium was very efficiently organized by the staff of the Warwick Mathematics Research Centre in their customary relaxed and friendly manner, and benefitted considerably from the unique atmosphere of the Warwick Mathematics Institute. See the comments from participants in section 5.

2 The Programme

2.1 Schools

Two Schools were organized in conjuction with the Symposium to provide a series of introductory lectures covering many of the central themes. The first focused on geometric and numerical aspects of Hamiltonian systems with symmetry and applications to fluid dynamics, while the second was dedicated to aspects related to atomic and molecular systems.

2.1.1 Mechanics and Symmetry European Summer School: 2-15 September 2001

The Symposium began with a two-week Summer School organized by James Montaldi (UMIST) in the 'conference village' of Peyresq in the Alpes Maritime in the south of France. The School was the second of two at Peyresq supported by a European Commission grant awarded to Montaldi, and by the European Research Training Network MASIE. No EPSRC funding was used. There were 46 participants, of whom over 30 were PhD students or young postdocs. The lecturers and courses were:

Tudor Ratiu (Lausanne) and Matthew Perlmutter (Lisbon)
Phase Space Reduction and Reconstruction

This course began with an overview of the method of Hamiltonian phase space reduction by Lie groups and its application to Hamiltonian dynamical systems and the reverse process of phase space reconstruction. It then gave detailed account of new results by the lecturers and colleagues on 'reduction by stages' for central extensions of symmetry groups.

Steve Shkoller (UC Davis) and Marcel Oliver (Bremen)
Geometry and Analysis in Hydrodynamics

This course surveyed recent analytic and geometric developments in fluid dynamics. It presented a Lagrangian approach to well-posedness theory for the Lagrangian averaged Navier-Stokes (LANS-alpha) and Lagrangian averaged Euler (LAE-alpha) equations, based on the development of new subgroups of the volume-preserving diffeomorphism group. It also included a complete derivation of these models of fluid turbulence.

Sebastian Reich (Imperial College)
Numerical Methods for Hamiltonian PDEs

This series of lectures gave a review of standard methods for truncating Hamiltonian PDEs to a finite-dimensional Hamiltonian ODE and then discussed recent developments in the area of multi-symplectic integration of dispersive wave equations. The final part was devoted to numerical methods for the rotating shallow-water equations.

Tom Bridges (Surrey) and Gianne Derks (Surrey)
Multi-Symplectic Geometry and Mechanics

These lectures introduced the concept of multi-symplecticity and showed how it is a useful framework for analyzing nonlinear Hamiltonian PDEs. The framework is related to Lagrangian field theory and the Cartan form, and to higher-order symplectic structures in field theory. The lectures showed that symmetries in multi-symplectic systems occur often and lead naturally to a generalisation of relative equilibria with interesting consequences and interpretations. Examples included the stability of solitary waves, the stability of periodic patterns and quasiperiodic patterns, and dimension breaking of nonlinear elliptic PDEs.

Mark Roberts (Warwick/Surrey) and Claudia Wulff (Berlin/Warwick)
Stability and Bifurcations of Relative Equilibria

This course provided an introduction to old and new results on the stability and bifurcations of relative equilibria (invariant group orbits) of symmetric Hamiltonian systems. Topics included Energy-Casimir methods for equilibria of Poisson systems, Energy-Momentum methods for relative equilibria, the local structure of Hamiltonian vector fields near relative equilibria, and generic bifurcation of families of relative equilibria parametrised by conserved quantities. Particular emphasis was placed on recent results for noncompact symmetry groups and applications to systems with Euclidean symmetry.

Henk Broer (Groningen) and Franceso Fasso (Padova)
KAM theory and Nekhoroshev stability

The first part of this course focused on KAM theory for multiperiodicity in dissipative and conservative systems. It gave a survey of KAM proofs and of applications of KAM theory. The second part of the course was devoted to Nekhoroshev theory for perturbations of superintegrable Hamiltonian systems, ie systems which have more integrals of motion than degrees of freedom such as the Kepler problem and the free rigid body. The geometry of these systems plays a central role in the long-time behaviour of their perturbations.

2.1.2 Semi-Classical and Quantum Multibody Systems: **18-22 March 2002**

This 'Spring School' was held at the University of Warwick and was supported by the EPSRC Symposium grant. It provided introductions to themes that were picked up in the subsequent Workshop, described below. The Spring School and Workshop together attracted about 60 participants, or whom approximately 20 were PhD students or young postdocs. The lecturers and courses were:

Matthias Brack (Regensburg)
The Role of Symmetries in Periodic Orbit Theory

This course gave an introduction to periodic orbit theory and an overview of semiclassical trace formulae for systems with various symmetries. Applications to various physical systems (nuclei, atoms, metal clusters, semiconductor-nanostructures) were also described, together with the effects of breaking symmetries and bifurcations.

Frederic Faure (Grenoble)
Topological Quantum Numbers in Molecular Spectra

Topological phenomena occurring in molecular spectra were presented. This included a concrete application of the Atiyah-Singer index formula, giving the exact number of levels in energy band structures in terms of vector bundles topology, all described within the adiabatic Born-Oppenheimer approximation. The evolution of the topology and the redistribution of levels in the exact spectrum as an external or internal physical parameter is varied was described. This topological phenomenon was described in the context of concrete examples relevant to vibrational structure of molecules possessing several groups of nearly degenerate frequencies and in the Jahn-Teller model for vibronic coupling.

Gero Friesecke (Warwick)
Introduction to the Mathematics of N-Electron Systems

These lectures focused on the relationship between the full 'ab initio' many-electron Schroedinger equation and its linear and nonlinear approximations (Hartree-Fock-equations, multiconfiguration equations, Kohn-Sham equations). The emphasis was on concepts and rigorous results rather than computational aspects. Topics covered included an introduction to approximations to the many-electron Schroedinger equation for atoms and molecules, the one- and two-body density matrices of an N-electron system, and a description of 'bond-breaking' as a bifurcation problem.

Robert Littlejohn (Berkeley)
Gauge Theory of Rotations in the N-Body Problem

These lectures presented a geometrical framework for the reduction of the classical and quantum n-body problems with respect to translations and rotations, and explained how it is related to the more traditional coordinate-based approaches. Topics included Jacobi coordinates, rovibrational and Watson Hamiltonians, fiber bundles and gauge theories, covariant derivatives, Coriolis and

Yang-Mills gauge fields, the Iwai monopole, Kaluza-Klein identities and the description of small vibrations of a rotating system in Eckart coordinates.

William Miller (Berkeley)
Semiclassical Methods in Chemical Dynamics

This course gave an introduction to semiclassical theory (WKB and stationary phase approximations) and generalizations to multidimensional systems (semiclassical transformation theory, application to inelastic and reactive scattering). It included a discussion of the initial value representation, the reason why this provides a practical way for including quantum effects in classical molecular dynamics simulations, various applications and generalization to include electronically non-adiabatic processes.

Jan Michael Rost (Dresden)
1) Semiclassical Time-Dependent Phenomena in Strong Laser Pulses: From Atoms to Clusters

These lectures described methods for analysing the effects of strong laser pulses on atoms and clusters. The pulses generate an electric field which act non-perturbatively on bound electrons and so in principle a solution of the time-dependent Schroedinger equation is required. The lectures discussed a semiclassical treatment for the process of higher harmonic generation where the interference is an essential part of the dynamical effects encountered. For clusters individual phases average out and a quasiclassical approach can be formulated in which tunelling is incorporated.

2) Derivation of the Time-Dependent Schroedinger Equation from the Time-Independent One

This lecture described a derivation of the time-dependent Schroedinger equation from its time-Independent version, obtained by formulating time as a concept which can be derived logically from space. Semiclassics played an important role in the derivation.

Dmitrii Sadovskii (Dunkerque)
Quantum-Classical Analysis of Molecular Rotation-Vibration Systems

This course discussed rotational and vibrational relative equilibria and their use in analyzing the structure of quantum multiplets. It also explained the so-called semi-quantum model, also known as the rotational or vibrationsl energy surface method. Examples included the Henon-Heiles oscillator, a similar three-mode vibrational system, a 1:2 resonance, the rotational spectrum of asymmetric and spherical top molecules and the Coriolis interaction.

2.2 Workshops at Warwick

2.2.1 Geometry and Symmetry in Continuum Mechanics: **9-15 December 2001**

The first Workshop of the programme focused specifically on Hamiltonian PDEs and their applications, particularly to fluid dynamics. The emphasis was on geometrical and symmetry aspects: symplectic and multisymplectic structures, conservation laws, reduction, variational asymptotics, structure preserving integration, stability and bifurcations. There were over 40 participants. The talks given were:

Nicoleta Bila	Cambridge	Symmetry reductions, variational symmetries and conservation laws for the shallow water and semi-geostrophic PDE systems
Tom Bridges	Surrey	Secondary bifurcation of multi-symplectic relative equilibria
Peter Clarkson	Kent	Symmetry reductions and exact solutions of the Navier-Stokes equations
Mike Cullen	ECMRWF	Applications of geometric mechanics to weather systems
Gianne Derks	Surrey	Solitary wave solutions of fifth-order KdV equations and their stability
Antonio Fernandez & Pedro Garcia	Salamanca	Lagrangian reduction in dissipative relativistic hydrodynamics
Yasuhide Fukumoto	Kyushu	Stationary configuration of a vortex filament and related integrable systems
Mark Groves	Loughborough	A dimension-breaking phenomenon in the theory of steady gravity-capillary water waves
Gert van der Heijden	UCL	Rods subject to (in)equality constraints: a variational approach
Peter Hydon	Surrey	Conservation laws for multisymplectic PDEs
Tsutomu Kambe	Tokyo	Geometrical aspects of dynamical systems and integrable systems
Igor Kanatchikov	Hamburg	Poisson-Gerstenhaber brackets and polysymplectic structure in precanonical Hamiltonian field theory
Debra Lewis	Santa Cruz	Isotropy in Lie group integration schemes on homogeneous manifolds
Eric Lombardi	INLN	Gravity travelling waves for two superposed fluid layers, one being of infinite depth: a new type of bifurcation
Ian Melbourne	Surrey	Ginzburg-Landau theory of transitions in spatially extended systems
Marcel Oliver	Tubingen	Variational asymptotics for the shallow water equations in the low Rossby number limit
Renzo Ricca	UCL	In search of symmetries in magnetic knots
Vassilis Rothos	Loughborough	Chaotic rotations of an asymmetric body with time-dependent moments of inertia and viscous drag
Ian Roulstone	Met Office	Quaternionic and Kähler structures in hydrodynamical models of geostrophic flows
Florian Theil	Warwick	On the evolution of oscillations in Hamiltonian PDEs
Matthew West	Caltech	Asynchronous variational integrators for solid mechanics
Djoko Wirosoetisno & Jacques Vanneste	Edinburgh	Two-dimensional fluid flows in deformed domains

2.2.2 Semi-Classical and Quantum Multibody Systems: **24-27 March 2002**

This Workshop was held immediately after the Spring School described above and focused on the same set of themes: semiclassical and quantum properties of Hamiltonian systems modelling atomic and molecular systems, and the roles played by symmetry, monodromy etc. The Spring School and Workshop together attracted over 60 participants from a wide variety of mathematical, physical and chemical backgrounds. A number of key participants also attended the next workshop on classical N-body systems, stimulating some cross-fertilization between the 'micro' and 'macro' N-body communities. The talks given in this workshop were:

Matthias Brack	Regensburg	SU(2) Symmetry Breaking in Some Hamiltonian Systems
Stephen Creagh	Nottingham	Dynamics in Wavefunction Statistics and Tunnelling
Paul Dando	UCL	Closed Orbit Theory for Molecules in Fields
John Delos	William & Mary	Semiclassical Physics from Aristotle to Schroedinger
John Delos	William & Mary	Classical Orbits and Quantum Spectra of Atoms in Fields
Bertrand Georgeot	Toulouse	Quantum Computing: Many-Body Effects and Simulation of Chaos
Toshihiro Iwai	Kyoto	Boundary Conditions at Singular Configurations of Many Bodies
Charles Jaffe	West Virginia	Transition States: Molecular, Atomic and Celestial
Patricio Leboeuf	Orsay	Thermodynamics of Small Fermi Systems: Quantum Fluctuations
Igor Kozin	Aberdeen	Relative Equilibria and Periodic Orbits in Molecules
Robert Littlejohn	Berkeley	Gauge Theory of Vibrations of Polyatomic Molecules
Robert Mackay	Warwick	Persistence of Spectral for Large Projections Networks of Quantum Units, and Quantum Discrete Breathers
Jorg Main	Stuttgart	Use of Harmonic Inversion Techniques in Semiclassical Quantization
Kevin Mitchell	William & Mary	Chaotic Ionization of Hydrogen in Parallel Fields
San Vu Ngoc	Grenoble	Redistribution of Eigenvalues in Polyads via Quantum Monodromy
Igor Pavlichenkov	Moscow	Quantum Phase Transitions in Rotational Bands
Jonathan Robbins	Bristol	Spin-Statistics and Quantum Mechanics
Jan-Michael Rost	Dresden	Dimensional Effects in Few-Electron Quantum Dots
Howard Taylor	USCLA	A Simple Scheme for Extracting Internal Motions from Spectroscopic Hamiltonians
Turgay Uzer	Georgia Tech	Phase Space Transition States
Holger Waalkens	Bremen	Quantum Monodromy in the Two Centers Problem
Boris Zhilinskii	Dunkerque	Hamiltonian Monodromy as a Lattice Defect

2.2.3 Classical N-Body Systems and Applications: **14-20 April 2002**

This Workshop was designed as a 'classical' parallel to the previous one on semiclassical and quantum multibody systems, and also as a prelude to the following workshop on Astrodynamics at the University of Surrey (described below). These links were made by a number of the talks. Other topics included variational methods for periodic orbits of N-body problems (eg choreographies), the N-vortex problem, and analogies between N-body problems and coupled cell systems. There were over 40 participants at this workshop. The talks given were:

Alain Albouy	Paris	Self-Similar Motions. The N-Body Problem and the N-Vortex Problem
Mitchell Berger	UCL	Hamiltonian Dynamics Generated by Vassiliev Invariants
Leo Butler	Northwestern	The Fundamental Group of a Manifold with an Integrable Geodesic Flow
Kuo-Chang Chen	Northwestern	Constructing Periodic Solutions for the Planar 4N-Body Problem by Variational Methods
Alain Chenciner	Paris	From Lagrange to the Eight: Marchal's P12 Family
Jacques Fejoz	Paris	Diffusion in the Five-Body Problem
Angel Jorba	Barcelona	Dynamics near the Lagrangian Points of the Earth-Moon System
Wang Sang Koon	Caltech	Invariant Manifolds, the Spatial Three-Body Problem and Space Mission Design
Vadim Kuznetsov	Leeds	Solution of Inverse Problem for Integrable Lattices
Eduardo Leandro	Paris	Finiteness of Some Symmetrical Classes of Central Configurations
Ken Meyer	Cincinatti	Are Hamiltonian Flows Geodesic Flows?
Shane Ross	Caltech	Invariant Manifolds and Transport in the Three-Body Problem
Luca Sbano	Warwick	Exchange Orbits with Negative Energy in the Three-Body Problem with Short-Range Newtonian Potential
Zhang Shiqing	Chongqing	Non-Planar and Non-Collision Periodic Solutions for Newtonian $n > 3$ Body Problems in 3-Dimensional Space
Ian Stewart	Warwick	Coupled Cell Systems and Multibody Problems
Susanna Terracini	Milan	Topological Aspects in the Variational Approach to the Search for Periodic Solutions
Tadashi Tokieda	Montreal	Point Vortices on Surfaces
Alexei Tsygvintsev	Loughborough	Complex Monodromy, Differential Galois Theory and the Three-Body Problem
Andre Vanderbauwhede	Gent	Continuation and Bifurcation of Periodic Orbits in the 3-Body Problem
Andrea Venturelli	Milan	A Family of $Z_4 \times Z_{2q}$-Symmetric Periodic Solutions in the Spatial Four Body Problem with Equal Masses
Laurent Wiesenfeld	Grenoble	Transport in $N > 2$ Degree of Freedom Hamiltonian Systems: Fractal Domains and Transition States

2.2.4 Geometry, Symmetry and Mechanics II: **21-27 July 2002**

This was the final workshop of the main Symposium year, and also the second annual meeting of the European Research Training Network MASIE (hence the title). The talks crossed many of themes of earlier workshops, with a number of speakers giving preliminary reports on work stimulated by the Symposium. There was a particular emphasis on core 'geometry and symmetry' aspects. There were almost 70 participants. The talks given were:

Michele Bartuccelli	Surrey	On a Class of Integrable Time-Dependent Dynamical Systems
Larry Bates	Calgary	The Odd Symplectic Group in Geometry
Anthony Bloch	Michigan	Dissipative Dynamics and Instabilities in Coupled Hamiltonian Systems
Stefanella Boatto	Paris	Vortices on the Plane and Sphere: the Non-Linear Stability of a Polygonal Ring
Tom Bridges	Surrey	Instability and Breakup of Standing Waves (Spatially Periodic Breathers) of Nonlinear Wave Equations: Geometric Properties of $O(2)$-Equivariant Hamiltonian PDEs on the Real Line
Alexander Burov	Moscow	The Routh Theory of Steady Motions for the Systems Subjected to Unilateral Constraints
Richard Cushman	Utrecht	The Rotation Number and the Herpolhode Angle in the Euler Top
Gianne Derks	Surrey	Travelling Waves in a Singularly Perturbed Sine-Gordon Equation
Francesco Fasso	Padova	Rigid Body: the Stability of Gyroscopic Motions
Yuri Fedorov	Moscow	Integrable Nonholonomic Systems on Lie Groups
Katrin Gelfert	Dresden	All Volume Expanding Dynamical Systems Have Positive Topological Entropy
Mark Groves	Loughborough	Nonlinear Water Waves and Spatial Dynamics
Darryl Holm	Los Alamos	Nonlinear Balance and Exchange of Stability in Dynamics of Solitons, Peakons, Ramps/Cliffs and Leftons in a $1+1$ Nonlinear Evolutionary PDE
Andy Hone	Kent	Peakon Systems and Poisson Brackets
Peter Hydon	Surrey	The Discrete Variational Complex
Delia Ionescu	München	Analysis of the Electrogravitational Kepler Problem
Toshihiro Iwai	Kyoto	Singularity of Many-Body Hamiltonians at Singular Configurations
Bozidar Jovanovic	SANU, Belgrade	Reduction and Integrability
Melvin Leok	Caltech	A Discrete Theory of Connections on Principal Bundles
Anna Litvak Hinenzon	Warwick	On Energy Surfaces and Instabilities
Karsten Matthies	Berlin/Warwick	Exponential Averaging for Hamiltonian Systems
Jerry Marsden	Caltech	Controlled Lagrangian and Hamiltonian Systems with Symmetry
Chris McCord	Cincinatti	Integral Manifolds of the N-Body Problem
James Montaldi	UMIST	Bifurcation and Stability of Systems of Point Vortices
Marcel Oliver	Tübingen	Variational Asymptotics for Rotating Fluids near Geostrophy
Maxim Pavlov	Moscow	Hydrodynamic Integrable Chains
Milena Radnovic	SANU, Belgrade	Caustics of Elliptical Billiard Trajectories
Renzo Ricca	UCL	On Kelvin's Vortex Knots
Luca Sbano	Warwick	The Odd-Symplectic Group in First Order Partial Differential Equations
Jedrzej Sniatycki	Calgary	Poisson Reduction
Britta Sommer	Aachen	Not So Proper Degeneracy of Systems Living According to Three Different Time Scales - A KAM Theorem for the Spatial Lunar Problem
Alex Tsygvintsev	Loughborough	Integral Invariants of H.Poincare
Tadashi Tokieda	Montreal	Standing Vortices, Fidgeting Vortices, Dancing Vortices
Jacques Vanneste	Edinburgh	Adiabatic Invariance and Geometric Angle for Fluids in Deforming Domains
Cornelia Vizman	Timisoara	Central Extensions of Lie Algebras of Symplectic Vector Fields
Matt West	Caltech	Geometric Collision Integrators
Claudia Wulff	Berlin/Warwick	Approximate Momentum Conservation for Spatial Semidiscretizations of Nonlinear Wave Equations

2.2.5 Calculus of Variations: **15-18 May 2003**

This workshop was organized by Ali Taheri and brought together mathematicians working on a range of topics related to the calculus of variations, including topological and analytical foundations and applications. Symposium funds were used to support a number of participants working on problems related to 'geometry, mechanics and symmetry'. The complete list of speakers was:

Frank Duzaar	Erlangen	p-Harmonic Approximation
Mariano Giaquinta	Pisa	About limits of sequences of maps into Riemannian manifolds with equibounded energies.
Qing Han	Leipzig	Harmonic functions and several complex variables
Vagn Lundsgaard Hansen	TU Denmark	The component problem in mapping spaces
Tadeusz Iwaniec	Syracuse	Weakly differentiable mappings between manifolds
Bernd Kirchheim	Oxford	Multi-well problems and shape memory materials
Jan Kristensen	Heriot-Watt	Uniform and mean oscillation estimates for minimizers of multi-well energies
Sergei Kuksin	Heriot-Watt	Perturbed harmonic map equations and elliptic PDEs on manifolds
Ernst Kuwert	Freiburg	Removability of point singularities of Willmore surfaces
Yanyan Li	Rutgers	On some conformally invariant fully nonlinear equations: Liouville, Yamabe and Harnack
Jan Maly	Prague	Fine properties of Sobolev functions related to the co-area formula
Paul Rabinowitz	Wisconsin	On some results of Moser and of Bangert
Tristan Riviere	Zurich	The singular set of almost complex cycles
Jeyabal Sivaloganathan	Bath	Singular weak solutions and modelling fracture in nonlinear elasticity
Michael Struwe	Zurich	Convergence of the Yamabe flow for 'large' energies
Charles Stuart	Lausanne	Global bifurcation using the degree for Fredholm maps
Hans Triebel	Jena	The fractal Laplacian; multifractal quantities

2.3 Outreach: Workshops elsewhere in the UK

As part of the 'Outreach' programme of the Symposium three workshops were organized outside Warwick, at the University of Surrey, the University of Leicester and UMIST. The themes for these could also be regarded as providing a scientific 'outreach' to the spacecraft engineering, numerical algorithms and symplectic geometry communities, respectively. As well as attracting 'local' participants, these workshops also included participants from disciplines who were not well represented at the Warwick workshops.

2.3.1 Astrodynamics: **22-23 April 2002, University of Surrey**

This workshop was co-organized with Phil Palmer at the Surrey Space Centre at the University of Surrey and held on the Space Centre's premises. Surrey Space Centre is the world leader in low cost satellite missions, covering all aspects from mission design, through manufacture to launch. As well as the talks listed below the workshop included a tour of the Space Centre. The EPSRC Symposium grant was the main source of funding for the workshop. There were over 30 participants, including both mathematicians specialising in Hamiltonian mechanics and engineers working on spacecraft mission design. The main theme was the development of the mathematical methods needed to explore and analyse new mission design and control concepts. The talks were:

Kyle T. Alfriend	Texas A & M	Dynamics and Control of Formation Flying Satellites
Apostolos Christou	Armagh Observatory	NEO Rendezvous Opportunities: Targets, Dynamics and Statistics
Michael Dellnitz	Paderborn	Set Oriented Numerical Methods in Space Mission Design
Yoshi Hashida	Surrey	Autonomous Onboard Orbit Determination and UoSat-12 InOrbit Results
Wang Sang Koon	Caltech	Low Energy Transfer to the Moon
Vaios Lappas	Surrey	A Control Moment Gyroscope Cluster for Agile Small Satellites
Ben Leimkuhler	Leicester	Reversible Multiple Time-Scale Integrators
Seppo Mikkola	Turku Observatory	Satellites in Proximity Theory Software and Numerical Experiments
Phil Palmer	Surrey	Optimal Control of Satellite Formations
Mark Psiaki	Cornell	Exploiting Euler Dynamics in order to use the Earth's Magnetic Field for 3-Axis Attitude Determination or Control
Shane Ross	Caltech	The Lunar L1 Gateway: Portal to the Planets
Bong Wie	Arizona	Dynamic Modeling and Attitude/Orbit Control of Solar Sail Spacecraft

2.3.2 Simulation Algorithms for N-Body Problems: **25-26 April 2002, University of Leicester**

This workshop, with the full title "Invariant and Symmetry Preserving Simulation Algorithms for N-Body Problems" was organized by Ben Leimkuhler at the University of Leicester. The EPSRC Symposium grant chiefly supported the participation of mathematicians who were also attending other workshops in the Symposium series. Altogether there were about 35 participants. The main themes included: geometric (symplectic, reversible) integrators; multiple time-scale integrators (multiple timestepping mollified methods, reversible averaging); methods for treating close approaches in Coulombic systems, symplectic correction methods, adaptive geometric integrators, individual timestep methods; backward error analysis of geometric integrators; switching methods.

2.3.3 Geometry of Momentum Maps and Hamiltonian Dynamics: **3-5 July 2002, UMIST**

This workshop was organized by James Montaldi at UMIST. The EPSRC Symposium grant was the main source of funding for the workshop and there were about 30 participants. The central theme of the workshop was the geometry of

symplectic and Poisson spaces, momentum maps and phase space reduction. The talks given were:

Richard Cushman	Utrecht	Integrable systems and singularity theory
John Delos	William & Mary	Fractal structure of the escape time in chaotic dynamics
Leonor Godinho	Lisbon	Blowing up on symplectic orbifolds
Heinz Hanssmann	Aachen	Normal-internal resonances in quasi-periodically forced oscillators: a conservative approach
Kirill MacKenzie	Sheffield	A unified approach to Poisson reduction
Juan-Pablo Ortega	Nice	Singular dual pairs and optimal momentum maps
Mark Roberts	Surrey	Stratifying momentum maps
Jonathan Robbins	Bristol	Singularities and sources of the Maslov index in integrable systems
Jedrzej Sniatycki	Calgary	Symplectic reduction without a momentum map

3 Publications

3.1 Papers on talks given during the Symposium

1. H. Aref, P. Newton, M. Stremler, T. Tokieda and D.L. Vainchtein, Vortex crystals, *Adv. Appl. Mech.* **39** (2003) 1-79.
2. M. Brack, Bifurcation cascades and self-similarity of periodic orbits with analytical scaling constants in Henon-Heiles type potentials, *Foundations of Physics* **31** (2001), 209.
3. M. Brack, Semiclassical description of shell effects in finite fermion systems, *Adv. in Solid State Phys.* **41** (2001), 459.
4. M. Brack, S. C. Creagh and J. Law, Level density fluctuations at the bottom of a potential, *Phys. Rev. A* **57** (1988), 788.
5. M. Brack, M. Mehta and K. Tanaka, Occurrence of periodic Lame functions at bifurcations in chaotic Hamiltonian systems, *J. Phys. A* **34** (2001), 8199.
6. M. Brack, P. Meier and K. Tanaka, Uniform trace formulae for SU(2) and SO(3) symmetry breaking, *J. Phys. A* **32** (1999).
7. T.J. Bridges, G. Derks and G. Gottwald, Stability and instability of solitary waves of the fifth-order KDV equation: a numerical framework, *Physica D* **172** (2002), 190-216.
8. J.S. Briggs and Jan M Rost, On the derivation of the time dependent equation of Schroedinger, *Foundations of Physics* **31** (2001), 693.
9. J.S. Briggs and Jan M Rost, Time dependence in quantum mechanics, *Eur. Phys. J.* **D 10** (2000), 311.
10. A. Burov, The existence and stability of the equilibria of mechanical systems with constraints produced by large potential forces, *J. Appl. Maths. Mechs. (PMM)* **67**, 193-200.
11. E. Castella and A. Jorba, Trojan motion in the Earth-Moon system, Preprint.
12. D. Chang, A. M. Bloch, N. Leonard, J. E. Marsden and C. Woolsey, The equivalence of controlled Lagrangian and controlled Hamiltonian systems, *Control and the Calculus of Variations* **8** (2002), 393-422.
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15. J.J. Collins, M. Golubitsky, I. Stewart, and L. Buono, A modular network for legged locomotion, *Physica D* **115** (1998), 56-72.
16. S.C. Creagh, S.-Y. Lee and N.D. Whelan, Scarring and the statistics of tunnelling, *Ann. Phys.* **295** (2002), 194-215.
17. R. Cushman and L. Bates, The rotation number and the herpolhode angle in Euler's top, to appear in *ZAMP*.
18. R. Cushman and J. Sniatycki, Differential structure of orbit spaces, *Canad. J.Math.* **53** (2001), 235-248.
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D. Sadovskii	Littoral	I. San Pedro	Royal Holloway	N. Sansonetto	Padua
T. Sauvaget	Nottingham	L. Sbano	Warwick	A. Schebesch	Berlin
T. Schmah	Warwick	S. Shkoller	UC Davis	G. Smith	Nottingham

J. Sniatycki	Calgary	B. Sommer	Aachen	N. Sondergaard	Nottingham
A. Souliere	Montreal	M.E.R. Sousa Dias	Lisbon	J. Stadel	Victoria
I.N. Stewart	Warwick	E. Straume	Trondheim	M. Struwe	Zurich
A. Stuart	Warwick	G. Tanner	Nottingham	H. Taylor	USC, Los Angeles
S. Terracini	Milan	S. Teufel	München	F. Theil	Warwick
T. Tokieda	Montreal	A. Tsygvintsev	Loughborough	I. Tuval	Zaragoza
T. Uzer	Georgia Tech	A. Vanderbauwhede	Gent	J. Vanneste	Edinburgh
A. Venturelli	Milan	C. Vizman	Timisoara	T. Vozmischeva	Moscow
M. Vranicar	Maribor	M. Vuk	Ljubljana	H. Waalkens	Bremen
M. West	Caltech	B. Wie	Arizona	L. Wiesenfeld	Grenoble
D. Wirosoetisno	Edinburgh	D. Wood	Warwick	C. Wulff	Berlin/Warwick
H. Yoshida	Tokyo	S. Zhang	Chongqing	B.I. Zhilinskii	Littoral

5 Selected Comments from Participants

Scientific Highlights:

M. Brack: Many stimulating discussions with colleagues, in particular with J. Robbins and S. Creagh concerning Maslov indices. Nice lectures by several colleagues! It was an extremely well conceived and well organized Workshop! Many thanks for the invitation!

S. Creagh: Development of geometrical techniques for molecular dynamics, as explained by Jaffe, Uzer.

R. Cushman: There were a great number of very good talks by prominent researchers. I learned quite a bit. The whole atmosphere I found very stimulating. I was simultaneously working with Bates, Sniatycki, Holm, Westbury on topics ranging from computing rotation angles, fractional monodromy and the resonant swing spring. All this activity resulted in ... four papers and forms the basis of my current research. All in all I profited very much from attending this conference.

Y. Fedorov: The idea on how to relate nonholonomic systems with right-invariant constraints to geodesic flows on homogeneous spaces. I had an excellent opportunity to learn about new approaches in discretization of dynamical systems and to discuss some problems of nonholonomic mechanics with the participants

G. Friesecke: The workshop on N-body quantum problems. Great mix of maths, physics, chemistry. Flavour much more "applied" (linking with 21st century phys/chem) rather than just getting stuck with the foundations of QM, ie linking to early 20th century phys/chem, as in too many maths-organized meetings on the topic. Learned a lot from Faure's and Miller's lectures, and also from participants' questions on my own lectures.

M. Groves: Conference on *Geometry and Symmetry in Continuum Mechanics* in December was very fruitful.

T. Iwai: "Singular reduction" was stimulating to me. I tried to consider what is or should be a singular reduction in quantum mechanics.

W. S. Koon I really enjoyed my stay at U. of Surrey where I learned a lot about its small satellite project. My meeting with Angel Jorba have led to my collaboration with his student Frederic Gabern who is now visiting Caltech as a postdoc.

P. O'Mahony: I attended the workshop on *Semi-classical and quantum multibody problems* which I found very informative. It was also a great opportunity to discuss research with leading international experts in the field. The quality of the list of speakers was impressive.

K. Mitchell: For me, the highlight was the weeklong "spring school" on semi-classical methods. It contained an excellent selection of tutorial talks on current research interests. Of course, the opportunity to meet and converse with a large assortment of notable individuals was a constant highlight of the entire program. I enjoyed the whole program! Thanks for the invitation, and I look forward to returning to Warwick at some point in the (hopefully) not too distant future.

M. Psiaki: I especially enjoyed getting to visit the Surrey Space Center and meeting the dynamics and control researchers who are connected with that center.

N. Søndergaard: For me it opened up to index theorems. Also the stuff on geometric integration has made me interested in Cartan's method of equivalence even though my background is physics. So the symposia in general had a great educational impact. From time to time it is good to learn problems and methods in other fields.

B. Wie: Opportunity to learn more about dynamical systems theory applied to astrodynamics. Hope to have another one in the near future.

B. Zhilinskii: The concept of fractional monodromy has been appeared during the discussions and collaboration at the Symposium.

Other Comments

M. Dellnitz: ... the Workshop at Surrey has been very nice as well, and I think that this has been a milestone wrt the generation of the EU proposal that you have put together. Moreover the Surrey Workshop has certainly fostered the cooperation of the Surrey Space Center with my group at Paderborn.

G. Derks: Very interesting to see both applications and theoretical work. Excellent environment and atmosphere to do research and a good group of people to work with.

J. Fejoz: Very pleasant and useful workshop. Great common room, great organization.

A. Hone: I attended the workshop *Geometry, Symmetry & Mechanics II* and found it very interesting with an ideal atmosphere for discussion and collaboration.

I. Kanatchikov: It would be good to have this series of Symposia continued and the subject possibly extended to accomodate a broader scope of applications in physics.

R. Littlejohn: One of the best meetings I have been to in many years - many new, profound ideas.

C. McCord: All the arrangements for the conference, both scientific and logistical, have been excellent. I have been very impressed with the thoughtful attention to detail displayed by the conference staff.

K. Meyer: It was a great symposium and I am glad I could help.

A. Ramos: In my opinion, the symposium was of very high quality and with a number of the best scientists on the field at an international level. The talks covered a wide rank of topics so that a good overview of current research trends was obtained. Finally, some specific talks on subjects nearer to personal research interests led me to establish contacts with the corresponding researchers.....the place were the symposium took place had an excellent infrastructure and material for presentations, including modern means and technology. Other available infrastructure (library, computers, rooms) was also excellent, as well as the working atmosphere. The treatment was exquisite, by very efficient but extremely kind personnel.

R. Ricca: Workshop went successfully and organisation was perfect. Many, many thanks for the warm hospitality and efficient assitance I received from the staff. Thanks Peta and Yvonne!

J. Robbins: I enjoyed the workshops I attended very much and established new scientific contacts from which I have benefited.

S. Ross: I very much appreciated the satellite event at Surrey (22-23 April 2002: *Astrodynamics*). The mix of theoretical and practical application of astrodynamics was very interesting. This has encouraged me to pursue further collaborations with individuals at Surrey & Warwick after I finish my doctoral work. I liked the format of the mathematical workshop at Warwick (14-20 April 2002: *Classical N-Body Systems and Applications*). I believe there were only three or four talks per day, with plenty of time for chatting over work and stimulating possible collaborations. Furthermore, the arrangement of a mathematical workshop followed by a more engineering oriented workshop (22-23 April 2002: *Astrodynamics*, Surrey) was very good idea as well.

L. Sbano: I would like to stress that the Symposium has been an very useful opportunity to work together with scientists who, focusing on the common interest in mechanics, have different expertise. This increased the possibility to develop interdisciplinary point of view on different problems. The enviroment and the organisation of the activities allowed most of us to collaborate fruitfully.

J. Stadel: Great conference, nice people, hope to attend one with a similar"constellation" in the future.

H. Taylor: A very useful meeting. I personally worked with several other people there. It was nice to be ableto have a question answered on such a short time scale. In other words, all experts were there.

T. Tokieda: For me and my collaborators, this Symposium was an unqualified success: thanks to its thoughtful organization, convivial setting and generous funding, we could work apace and finish several projects, and even more importantly start new lines of research. I very much hope that there will be many future programmes like this, which enhance the position of the UK as a primary 'clearing house' of mathematical research on the European and the world scene.

T. Uzer: ....many outstanding people in the field had been brought together in a congenial setting. It gave the participants an opportunity to keep up with the field and make new contacts.