Geometric Models of Nuclear Matter

July 20-22, 2022

University of Kent, Canterbury

University of Kent

LONDON MATHEMATICAL SOCIETY
EST. 1865

Contents

About

The conference

This conference will be an in person event based at the University of Kent in Canterbury. The theme of the conference is intentionally broad, focussing on topological solitons and their applications in physics. We welcome any talks within this loose brief.

While we will be making the talks available online through the solitons at work network, all speakers will be in person. This is due to the numerous years without in person interaction due to the pandemic. We look forward to welcoming you to the university and seeing some faces we haven't seen in some time.

Sponsors and support

We would like to thank the London Mathematical Society (LMS) and the Institute of Physics (IOP) for funding this meeting. We would also like to thank the University of Kent for hosting the event. Finally, we would like to thank the solitons at work network for advertising the event, as well as keeping the topological solitons field active during the pandemic.

Organizing committee

Steffen Krusch
James Bradshaw
Christopher Halcrow
Jack McKenna
Thomas Winyard
Morgan Rees

Timetable

Wednesday, 20th July

9:30–10:00	**Registration**	
10:00–10:30	**Martin Speight** University of Leeds, Leeds	Geometry of vortices in the sphere in the dissolving limit
10:40–11:10	**Josh Cork** Leibniz University, Hannover	ADHM skyrmions
11:20–11:50	**Coffee**	
11:50–12:20	**Jack McKenna** University of Kent, Canterbury	A (1+1)d model of soliton-fermion coupling with analytic solutions
12:30–13:00	**Carlos Naya** Stockholm University, Stockholm	Hunting 3D solitons in frustrated magnets
13:10–14:30	**Lunch**	
14:30–15:00	**Calum Ross** University College London, London	Calorons and constituent monopoles
15:10–15:40	**Nicholas Manton** University of Cambridge, Cambridge	Skyrmions, Isospin and Beta decay
15:50–16:20	**Coffee**	
16:30-17:00	**Arpad Lukacs** Durham University, Durham	Stability analysis of electroweak-dark strings
19:00–?	**Pub**	

Thursday, 21st July

10:00–10:30	**Paul Sutcliffe** Durham University, Durham	A broken Skyrme model
10:40–11:10	**Maciej Dunajski** University of Cambridge, Cambridge	Elizabethan vortices
11:20–11:50	**Coffee**	
11:50–12:20	**Matthew Wheeler** University of East Anglia, Norwich	Vortex connections across topological interfaces in spin-2 BECs
12:30–13:00	**Patrick Dorey** Durham University, Durham	Resonant collisions of weakly-bound kinks
13:10–14:30	**Lunch**	
14:30–15:00	**Shota Yanai** University of Tokyo, Tokyo	Variety of Q-compactons and compact boson star
15:10–15:40	**Jarah Evslin** Institute of Modern Physics, Lanzhou	A Very Linear Perturbation Theory for Quantum Solitons
15:50–16:20	**Coffee**	
16:30-17:00	**Thomas Galvin** University of Leeds, Leeds	Monopoles of Large Magnetic Charge
19:00–?	**Conference dinner**	

Friday, 22nd July

10:00–10:30	**Derek Harland** University of Leeds, Leeds	Instantons and the nucleon-nucleon potential
10:40–11:10	**Nuno Romao** IPhT, Universite Paris-Saclay, Paris	A tale of two metrics
11:20–11:50	**Coffee**	
11:50–12:20	**Paul Leask** University of Leeds, Leeds	Skyrmion Crystals
12:30–13:00	**Alberto Alonso Izquierdo** University of Salamanca, Salamanca	Wobbling kinks in the ϕ^4 and MSTB models: interaction between shape modes
13:10–14:30	**Lunch**	
14:30–15:00	**Marco Barsanti** Universita Di Pisa, Pisa	Near-BPS Skyrmions
15:10–15:40	**Magnus Borgh** University of East Anglia, Norwich	Towards Non-Abelian Defects: Vortices With Discrete Point-Group Symmetries
15:50–16:20	**Coffee**	
16:30-17:00	**Nicholas Manton** University of Cambridge, Cambridge	Summary

19:00–?	**Pub**

List of Abstracts – Talks

Wednesday 20th

Geometry of vortices in the sphere in the dissolving limit

Martin Speight
University of Leeds, Leeds

There is an upper bound on how many abelian Higgs vortices a compact Riemann surface can accommodate, proportional to its area. In the limit that the area shrinks to the minimum allowed (for a given vortex number), the vortices spread out and delocalize completely. Hence this is sometimes called the "dissolving limit". For vortices on a two-sphere, the moduli space M_n of n-vortices is diffeomorphic to CP^n. This space carries a natural metric which controls the classical and quantum dynamics of vortices. In 2003, Baptista and Manton conjectured that, in the dissolving limit, this metric converges to the Fubini-Study metric on CP^n. I will describe how this conjecture can be made precise and proved. (Joint work with Rene Garcia Lara.)

ADHM skyrmions

Josh Cork
Leibniz University, Hannover

In order to allow for a full quantum treatment of skyrmions, one requires an approximation method which uses a configuration space with enough flexibility to generate a variety of different configurations. Among the patchwork of available methods, the moduli space of instanton ADHM data is the only known example which fits the bill. Historically, studying skyrmions with instantons has been neglected, likely due to its perceived complexity (both analytically and numerically) when compared with other methods. A new numerical scheme due to Harland has removed one of these obstacles, so that generating Skyrme fields from instantons is now significantly less computationally expensive. The aim of this talk is to demonstrate a framework for generating the instantons in the first place; we will give a step-by-step guide for how to parameterise different Skyrme configurations using ADHM data, with a focus on some simple well-motivated examples. This talk is based on joint work with Chris Halcrow.

A (1+1)d model of soliton-fermion coupling with analytic solutions

Jack McKenna
University of Kent, Canterbury

We present a simple model in (1+1) dimensions of fermions coupled to a periodic scalar field. The coupling term is analogous to many "chiral bag" interaction terms in various low-dimensional studies of fermion behaviour on background soliton fields. We compute the Hamiltonian eigenstates and spectra in the absence of back-reaction. We show back-reaction can be introduced by giving the system an axial symmetry which is responsible for localising the fermion on the scalar field. By taking an ansatz that the scalar field is static and passing to a set of bosonic coordinates constructed from fermionic bispinors, we show that the scalar field may be eliminated from the bosonic equations of motion. The bosonic dynamical system is solved by elliptic functions. The geometric structure of these bosonic solutions suggests a method to hunt quite generally for analytic fermionic solutions of the underlying Dirac equations. We comment on the applicability of the method to other theories of solitons with chiral bag coupling.

Hunting 3D solitons in frustrated magnets

Carlos Naya
Stockholm University, Stockholm

In the last years, the study of solitons and related structures in condensed matter systems has attracted much attention. Different configurations such as planar Skyrmions or Hopfions have been studied in detail, but 3D Skyrmions, resembling those from the Skyrme model itself, have remained elusive. In this talk, I will show how frustrated magnets may host these configurations. In particular, I will present a toy model which can interpolate between Hopfions and 3D Skyrmions, paying attention to the configurations arising for different values of the topological charge and their similarities to the solitons from the Skyrme model of nuclei.

Calorons and constituent monopoles

Calum Ross
University College London, London

Calorons are instantons on $\mathbb{R}^3 \times S^1$. Studying the limit as the circle collapses, calorons can be decomposed in terms of constituent pieces. These constituent pieces are essentially charge 1 monopoles. This feature of calorons has been observed in some explicit examples constructed via the Nahm transform. Here I will present recent work, joint with Lorenzo Foscolo, which gives a gluing construction of generic calorons in terms of the constituents. Using the constituent monopole picture we can understand some features of the moduli space, including computing its dimension.

Skyrmions, Isospin and Beta decay

Nicholas Manton
University of Cambridge, Cambridge

Abstract to follow.

Stability analysis of electroweak-dark strings

Arpad Lukacs
Durham University, Durham

The stability of “visible” electroweak-type cosmic strings is investigated in an extension of the Standard Model by a minimal dark sector, consisting of a U(1) gauge field, broken spontaneously by a scalar. The visible and dark sectors are coupled through a Higgs-portal and a gauge-kinetic mixing term. It is found that strings whose core is “filled” with a dark scalar condensate exhibit better stability properties than their analogues in the Standard Model, when the electroweak mixing angle is close to $\theta_W = \pi/2$. They become unstable as one lets θ_W approach its physical value. The instability mechanism appears to be a W-boson condensation mechanism found in previous studies on the stability of electroweak strings.

Thursday 21st

A broken Skyrme model

Paul Sutcliffe
Durham University, Durham

The Skyrme model is extended by the addition of derivative terms that break chiral symmetry to isospin symmetry, in a way that brings the Skyrmion energy closer to the topological lower bound.

Elizabethan vortices

Maciej Dunajski
University of Cambridge, Cambridge

Abstract to follow.

Vortex connections across topological interfaces in spin-2 BECs

Matthew Wheeler
University of East Anglia, Norwich

Spinor BECs offer a rich variety of phase diagrams and topological defects. In this work we construct topological interfaces between different ground state phases in spin-2 BECs by means of spatially dependent Zeeman shifts and interaction parameters. We investigate how singly quantised vortices (SQVs) connected across the interface evolve as the system relaxes. We observe splitting of SQVs into fractional vortices in the biaxial-nematic and cyclic phases. We further find complex, composite core structures develop in the ferromagnetic and uniaxial-nematic phases.

Resonant collisions of weakly-bound kinks

Patrick Dorey
Durham University, Durham

Abstract to follow.

Variety of Q-compactons and compact boson star

Shota Yanai
University of Tokyo, Tokyo

Abstract to follow.

A Very Linear Perturbation Theory for Quantum Solitons

Jarah Evslin
Institute of Modern Physics, Lanzhou

We provide a formalism for perturbatively treating quantum solitons which is much faster, simpler and less generally applicable than the standard collective coordinate approach. One begins by freely choosing a base point in moduli space. Everything is linearized by decomposing with respect to the normal modes of the soliton at that point. At each fixed moment in time, one expands in both the coupling and the distance from the base point. The drawback is that one cannot treat a soliton coherently smeared over a large region of moduli space, although one can in fact calculate form factors and energies for such solitons. There is no such limitation in the one-soliton sector, for problems such as soliton-meson scattering.

Monopoles of Large Magnetic Charge

Thomas Galvin
University of Leeds, Leeds

Abstract to follow.

Friday 22nd

Instantons and the nucleon-nucleon potential

Derek Harland
University of Leeds, Leeds

Abstract to follow.

A tale of two metrics

Nuno Romao
IPhT, Universite Paris-Saclay, Paris

Abstract to follow.

Skyrmion Crystals

Paul Leask
University of Leeds, Leeds

Abstract to follow.

Wobbling kinks in the ϕ^4 and MSTB models: interaction between shape modes

Alberto Alonso Izquierdo
University of Salamanca, Salamanca

In this talk the interaction between the shape modes of the wobbling kinks arising in the family of two-component MSTB scalar field theory models is studied. The spectrum of the second order small kink fluctuation in this model has two localized vibrational modes associated to longitudinal and orthogonal fluctuations with respect to the kink orbit. It has been found that the excitation of the orthogonal shape mode immediately triggers the longitudinal one. In the first component channel the kink emits radiation with twice the orthogonal wobbling frequency (not the longitudinal one as happens in the ϕ^4 model). The frequencies of the radiation emitted in the second component are threefold the orthogonal wobbling frequency and the sum of the longitudinal and orthogonal frequencies. This behavior has been analytically explained by employing perturbation expansion theories.

Near-BPS Skyrmions

Marco Barsanti
Universita Di Pisa, Pisa

In this talk, I will consider the Skyrme model in the near-BPS limit. This kind of model seems to provide Skyrmions with low binding-energy and thus it represents a reliable candidate to solve the binding energy problem of the original Skyrme theory. In our work, we considered the BPS sector made of the sextic term plus a potential and the BPS-deformation made of the standard massive Skyrme model, controlled by a small parameter. The model was explored by implementing a perturbative scheme, already successfully applied for the 2D baby-Skyrme theory. In the talk, I will show firstly the result of the computation in the B = 1 sector and then I will use the perturbative scheme to calculate the bound state of two B = 1 Skyrmions, which corresponds, prior to quantization, to the deuteron in our model.

Towards Non-Abelian Defects: Vortices With Discrete Point-Group Symmetries

Magnus Borgh
University of East Anglia, Norwich

Spatially discrete symmetries appear ubiquitously in nature, but point-group symmetries are also found with profound consequences in the internal states of systems. We demonstrate realisation of vortices in phases of spin-2 Bose-Einstein condensates, which, despite being spatially continuous and isotropic exhibit internal polytope symmetries. As a consequence vortices have non-Abelian topological charges. This provides a platform that may be used to demonstrate non-Abelian vortex properties in atomic superfluids, with possible applications in quantum information and interferometry. Here we present the underlying theoretical foundations as well as recent experimental results.

Y. Xiao, M. O. Borgh, A. A. Blinova, T. Ollikainen, J. Ruostekoski, D. S. Hall, arXiv:2203.08186

List of Posters

Thursday Session

TBA
James Bradshaw, *University of Kent*, *Canterbury*

Asymmetric nuclear matter in the Skyrme model
Alberto García Martín-Caro, *University of Salamanca*, *Salamanca*

Ring Baby Skyrmions
Morgan Rees, *University of Kent*, *Canterbury*

List of Participants

Marco Barsanti	Universita Di Pisa, Pisa
Bruno Barton-Singer	Heriot-Watt University, Edinburgh
Magnus Borgh	University of East Anglia, Norwich
James Bradshaw	University of Kent, Canterbury
Gautam Chaudhuri	University of Leeds, Leeds
Josh Cork	Leibniz University, Hannover
Patrick Dorey	Durham University, Durham
Maciej Dunajski	University of Cambridge, Cambridge
Jarah Evslin	Institute of Modern Physics, Lanzhou
Thomas Galvin	University of Leeds, Leeds
Peter Gerlagh	Heriot-Watt University, Edinburgh
Tathagata Ghosh	University of Leeds, Leeds
Derek Harland	University of Leeds, Leeds
Alberto Alonso Izquierdo	University of Salamanca, Salamanca
Steffen Krusch	University of Kent. Canterbury
Paul Leask	University of Leeds, Leeds
Arpad Lukacs	Durham University, Durham
Nicholas Manton	University of Cambridge, Cambridge
Alberto García Martín-Caro	USC, Santiago de Compostela
Jack McKenna	University of Kent, Canterbury
Carlos Naya	Stockholm University, Stockholm
Jose Queiruga	University of the Basque Country
Morgan Rees	University of Kent, Canterbury
Nuno Romao	IPhT, Universite Paris-Saclay, Paris
Calum Ross	University College London, London
Martin Speight	University of Leeds, Leeds
Paul Sutcliffe	Durham University, Durham
Matthew Wheeler	University of East Anglia, Norwich
Thomas Winyard	University of Kent, Canterbury
Shota Yanai	University of Tokyo, Tokyo

Useful Information

General details

Talks will be held in the Cornwallis East building, in room SR1 (marked on map). The room is on the ground floor, after entering through the main entrance turn left and go to the end of the corridor.

Coffee and lunches will be provided also in the Cornwallis East building (same as the talks).

The informal **poster session** will be held on Thursday in the coffee room during both coffee sessions.

The **conference dinner** will be held on Thursday evening at 19:00, at the Ambrette 14-15 beer cart lane Canterbury CT12NY. If you wish to attend drop Steffen Krusch an email at S.Krusch@kent.ac.uk and the cost will be £20 for three courses, excluding drinks.

How to get to the University of Kent

The University of Kent is North West of Canterbury and overlooks it from a hill. The post code CT2 7UF will get you to the accommodation and CT2 7NF will get you to Cornwallis East where the talks will take place.

- **Train:** You will most likely arrive at Canterbury West, which is connected to London via HS1, though Canterbury East is just a slightly longer walk (the stations are not connected).
  - **To walk From Canterbury West:** takes about 30mins, but is uphill. Turn left out of the main exit and walk past the small roundabout, then take the footpath on your left under the tracks. You will reach a park where you immediately turn left, following the foot path straight on until it finishes on Beaconsfield road. Turn right and take the next left onto St Michaels rd, keep going straight (through a pedestrianised break), the road becomes Salisbury rd then take the next right onto Lyndhurst Cl and soon you will see a footpath going up hill. Follow the footpath to the University. The end of the footpath is marked on the map below.
  - **To get the bus from Canterbury West:** turn right out of the station exit and walk to the end of the road. Turn left at the roundabout and about 60 metres down the road you will see a bus stop on the far side of the street from the station. From here you can get one of the buses mentioned below (going uphill).
  - **To walk From Canterbury East:** takes about 50mins, you must find your way to Canterbury West station first and then follow the directions from there, I would recommend the bus or taxi.

- **To get the bus from Canterbury East:** exit through the main exit onto station road and turn right (east), you will walk past the station car park. As you approach the main road you will see the bus stop. From here you can get one of the buses mentioned below.

- **Bus:** The university is served by two main bus routes, the Uni 1 bus comes around every 30 mins and starts at the bus station. If you get off at Darwin college (the last stop), this is across the road from Cornwallis east where the talks take place and not far from the accommodation. If you take the Uni 2 you will have to get off at Keynes college on the other side of campus.

- **Car:** There is a lot of parking on campus, though this fills up fast in the middle of the day and you may have to park a little further from your destination. There is parking off Darwin road near the accommodation, if this is full try the Giles lane car park which is bigger.

Accommodation

Rooms booked through the University are en-suite and located in Tyler Court Block B (marked on the map).

Breakfast is included and served from 07:45 - 09:30 in the Rutherford dinning hall (marked on the map).