



Exploratory Workshop Scheme

Scientific Review Group for Physical and
Engineering Sciences

ESF Exploratory Workshop on

**Reconnection events in classical,
quantum and magnetized fluids**

Glasgow (UK), 16th-18th June 2015

Convened by:
Andrew Baggaley

SCIENTIFIC REPORT

1. Executive summary

The setting for the workshop is the following: Reconnections are dramatic events, leading to irreversible changes in the topology of a system. In particular they are crucial in understanding magnetic fields in rarefied plasmas, such as the solar corona, and the dynamics of quantised vortices in superfluid helium. Yet these two research communities remained distinct, and there was little opportunity to discuss recent breakthroughs and common problems. The goal of the workshop was to bring together leading researchers in these fields to discuss open and important problems. The hope was this could pave the way for future progress in both fields, as well as establishing communication and collaboration between scientists from different areas.

The workshop was held at a specialist conference centre at the University of Glasgow. Lunches took place in the Universities canteen and the conference dinner was held in a private room at Oran Mor, in Glasgow. We aimed to carefully balance the program to ensure there was sufficient time for discussion (both formal and informal) and this meant up to 3.5 hours each day (excluding lunch) of both structured and unstructured sessions. These proved to be incredibly successful and there was as clearly visible coming together of researchers from the two communities as the workshop progressed. Participants stayed in two hotels within close proximity to each other and around a twenty minute walk from the conference venue. In order to help the cohesion of the group we arranged an informal meeting at a local pub the night before the workshop began, and around 75% of the participants were present, with the others arriving into Glasgow too late to attend.

Unfortunately due to extenuating circumstances two of the participants (Bérengère Dubrulle & Brenda Quinn) were not able to attend the workshop. In order to ensure a critical mass, and a balance between the two communities, we additionally invited Gunnar Hornig from the University of Dundee, who is a world renowned expert in Magnetic reconnection. This left the total number of participants at 20, representing 7 European countries.

When organising the conference and asking participants to submit abstracts a conscious effort was made to ensure participants carefully planned their talks to account for the two different communities. The workshop opened with two introductory talks, which are detailed in section 2, again with the aim of bridging knowledge between the two communities.

The atmosphere of the workshop was very friendly and informal, but with a genuine passion for science, and an interest in understanding issues in the two different fields and sharing ideas, mathematical and computational techniques, and accessible papers. Questions were actively encouraged during talks and this ensured the two fields got to know each other a little better.

I believe the main conclusion of the workshop was that there should be a greater interaction between the two communities. In particular many of the formal and informal discussions focused on numerical techniques used by the different communities and the visualisation software used to extract results from the large complex datasets generated by these numerical simulations. At the next level participants were given detailed introductions to a new field, I know myself this will make accessing the respective literatures far more manageable.

None of this would be possible with the funding provided by the ESF, which brought the various participants together for the Exploratory Workshop. We therefore thank the ESF and its staff for funding the workshop and providing subsequent support.

2. Scientific content of the event

As stated the workshop opened with two introductory talks from Prof. Parnel (focusing on MHD reconnection) and Dr. Hänninen (quantised vortex reconnection). The first day was primarily devoted to MHD reconnection. Time was spent identifying differences between the theories of magnetic reconnection in two-dimensional and three-dimensional space. In addition the concept of magnetic null points, specific to the MHD community was carefully dissected for the benefit of the other communities. Three-dimensional magnetic null points are singular points in space where the magnetic field vector vanishes. These are therefore one type of locations in three-dimensional Magnetic fields where differently directed magnetic field vectors can relative easily get into contact and reconnect. Different theoretical modes exist which can drive reconnection. Some of the talks presented the results of various numerical 'experiments', to compare and contrast the applicability of these theories. Many of these numerical techniques are very complicated (as the underlying mathematics is inherently 3D and nonlinear) and so plenty of time during the workshop was spent in lively discussions of the various merits, and issues with the numerical methods used in the literature. Towards the end of the first day and during the early part of the second day attention turned to topological aspects of reconnections. Magnetic fields in the solar corona are observed to be braided, presumably due to turbulent foot-point motion at the solar surface. Some of the talks discussed the occurrence of magnetic reconnection in braided magnetic fields. For example Dr. Wilmot-Smith described the results of numerical simulations of the evolution of a complex braided magnetic field, whilst Prof. Berger Magnetic field showed how braiding may contribute to the heating of the solar atmosphere.

From a more mathematical viewpoint reconnections have deep connection to low dimensional topology. For example one can argue that a reconnection is analogous to a band move. Prof. Ricca led a very interesting talk and discussion of his recent work, which has been published in the Proceedings of the National Academy of Science (USA). He presented new results on the conservation of writhe helicity under anti-parallel reconnection of two flux tubes. In particular he proved that under anti-parallel reconnection of a pair of interacting flux-tubes of equal flux the writhe of the tube axes remains conserved. As a consequence, any change in helicity is solely ascribed to a change in total twist, inserted or deleted locally at the reconnection site. Moreover, since the normalized total torsion is also additive upon reconnection, any change in helicity is given to a change in intrinsic twist. His results have profound implications for helicity and energy considerations in turbulent and astrophysical flows, and for the mathematical modeling of various aspects of structural complexity of fluid flows. The workshop was a fitting place for early dissemination of these results.

Finally attention turned to quantized vortex reconnection. Some of the highlights were the talk of Dr. Allen who presented results of reconnection studies in weakly interacting, dilute atomic Bose-Einstein condensates (BECs). Recently, atomic BECs have been used to investigate quantum turbulence both experimentally and theoretically, stimulated largely by the high degree of control which is available in quantum gases. The study of vortex reconnections is an essential ingredient of understanding quantum turbulence. Dr. Allen showed that, despite the established temperature dependence of vortex motion in such systems, vortex reconnections are actually temperature independent on the typical length and time scales of atomic condensates. She also compared vortex reconnections in

homogeneous condensates and showed that vortex reconnections are also insensitive to the inhomogeneity of the background density.

Dr Rorai also presented results of a similar configuration for reconnection, studying the dynamics of two vortices in superfluid helium by means of the Gross- Pitaevskii equation. The transition between propagating and annihilating vortex dipoles was discussed, and a new family of reconnection fixed points was presented. Single vortex reconnection events were characterized in terms of their velocity of approach and separation and curvature. Interestingly it was pointed out at the workshop that whilst the models of Allen and Rorai were consistent in their mathematical predictions (that vortices approach and move away from reconnections with a separation which scales as a power-law in time) the actual numerical factors from the different models did not agree. Clearly more work in this direction is needed.

Naturally discussion questions tended to be one community asking basic questions of the other community and vice-versa. It is clear that a single event is not enough to give people the knowledge and physical insight of a vast body of research. What is important though is that in my opinion sparks of interest in one another research were seeded. The convenor is currently reflecting on the most efficient means of building on the discussions and results of the workshop. For instance a future planned mini-colloquia and scientific events (see section 3) promise to build upon the progress made at the workshop.

3. Assessment of the results, contribution to the future direction of the field, outcome

The goal of this workshop was to bring together leading scientist from two distinct fields:

- (i) to make them aware of the cutting edge research taking place in each field,
- (ii) to indicate future directions of research in each field,
- (iii) to sow the seeds for future collaboration between scientist in both fields and develop an interface between those interested in reconnection processes in classical, quantum and magnetised fluids.

I am confident that these initial goals were met by the meeting. All presentations were (as expected) of a very high standard and clearly set the scene, where we are and where we (think) research will go in the next five years. In the future plans are in preparation to have a mini-colloquium at the British Applied Mathematics Conference (BAMC) 2016 will take place in Oxford (April, 2016). Before submitting a proposal to host a 3 month scientific program at the Newnton Institute, Cambridge. The core attendees will include participants of the ESF workshop and the wider community. In particular, whilst the ESF workshop focused on bring the leading 'established' figures together, at the BAMC we shall try to focus on early career researchers.

4. Final programme

Sunday 15th June 2014

Afternoon *Arrival*

19:00 *Informal social event, Curlers Rest, 256-260 Byres Rd, Glasgow G12 8SH*

Monday 16th June 2014

09.45-10.00 **Welcome by Convenor**
Andrew Baggaley (University of Glasgow, UK)

10.00-12.30 Morning Session: Introduction to reconnection events
Chair: Andrew Baggaley

10.00-11.10 **Presentation 1 "MHD reconnection"**
Clare Parnell (University of St. Andrews, UK)

11.00-11.30 *Coffee / tea break*

11.30-12.30 **Presentation 2 "Quantised vortex reconnection"**
Risto Hänninen (Aalto University, Finland)

12.30-14.00 *Lunch*

14.00-18.30 Afternoon Session: MHD Reconnection
Chair: Mitch Berger

14.00-14.30 **Presentation 1**
Antonia Wilmot-Smith (University of Dundee, UK)

14.30-15.00 **Presentation 2**
Simon Candelers (Nordita, Sweden)

15.00-15.30 **Presentation 3**
Klaus Galsgaard (University of Copenhagen, Denmark)

15.30-16.00 **Presentation 3**
Jörg Buchner, (Max Planck Institute for Solar System Research, Germany)

16.00-17.00 *Coffee / tea break*

17.00-18.30 **Discussion**

19.00 *Dinner - **Ashoka**, 19 Ashton Ln, Glasgow, Lanarkshire G12 8SJ*

Tuesday 17th June 2014

09.00-10:30 Morning Session I: Topological aspects of reconnection
Chair: Jörg Buchner

09.00-09.30 **Presentation 1**
Renzo Ricca (University of Milano-Bicocca, Italy)

09.30-10.00 **Presentation 2**
Mitch Berger (University of Exeter, UK)

10.00-10.30 **Presentation 3**
Francesca Maggioni (Università di Bergamo, Italy)

10.30-11.00 *Coffee / Tea Break*

- 11.00-13:00** **Morning Session II: Quantum vortex reconnection**
Chair: Ladik Skrbek
- 11.00-11.30 **Presentation 1**
Andrew Baggaley (University of Glasgow, UK)
- 11.30-12.00 **Presentation 2**
Miron Kursa (University of Warsaw, Poland)
- 12.20-12.30 **Presentation 3**
Cecilia Rorai (Nordita, Sweden)
- 12.30-14.00 *Lunch*
- 14.00-15:30** **Afternoon Session: Mixed session**
Chair: Renzo Ricca
- 14.00-14.30 **Presentation 1**
Joy Allen (Newcastle University, UK)
- 14.30-15.00 **Presentation 2**
Rachel Mulungye (University College Dublin, Ireland)
- 15.00-15.30 **Presentation 3**
Clare Parnell (University of St. Andrews, UK)
- 15.30-16.00 **Presentation 4**
Gunnar Hornig (University of Dundee, UK)
- 16.00-17.00 *Coffee / Tea Break + Discussion*
- 18:00-18:45 *Wine reception, common room, Mathematics building*
- 19.00 *Conference Dinner – Òran Mór, Byres Rd, Glasgow G12 8QX*

Wednesday 18th June 2014

- 09.00-10:30** **Morning Session I: Experimental systems**
Chair: Risto Hänninen
- 09.00-09.30 **Presentation 1**
Ladik Skrbek (Charles University, Czech Republic)
- 09.30-10.00 **Presentation 2**
Julian Salort (École normale supérieure de Lyon, France)
- 10.00-10.30 **Presentation 3**
Phillippe Roche (Institut Neel, France)
- 10.30-11.00 *Coffee / Tea Break*
- 11.00-12:30** **Morning Session II: Physical systems – where reconnections 'live'**
Chair: Antonia Wilmot-Smith
- 11.00-11.30 **Presentation 1**
Marc Brachet (Ecole Normale Supérieure, France)
- 11.30-12.00 **Presentation 2**
Giorgio Krstulovic (Observatoire de la Côte d'Azur, France)
- 12.00-12.30 **Presentation 3**
Risto Hänninen (Aalto University, Finland)
- 12.30-14.00 *Lunch*
- 14.00 *Departure, room booked so participants leaving later could continue with discussions.*

5. Final list of participants

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6. Statistical information on participants

Age:

<40 – 11
 >40 – 9

Sex:

Male – 14
 Female - 6

Country of origin:

UK – 6
 Germany – 1
 Denmark – 1
 Poland – 1
 Czech Republic – 1

Finland – 1
 France – 4
 Sweden – 2
 Italy – 2
 Ireland – 1