UCL

De Morgan Association Newsletter

2019/20

Contents

Letter from the Editor

Professor Ted Johnson

Last year's annual dinner of the De Morgan Association was held on Friday 7th June 2019 at Senate House, University of London.

The Guest of Honour was Rob Eastaway. Rob was awarded the Zeeman medal in 2017 for excellence in the promotion of Mathematics and is active in the popularisation of mathematics.

Sam Hopkins has moved to another role in the department and so we have unfortunately once again lost an excellent Associate Editor of the Newsletter.

Our new Associate Editor is Adrianna Mickiewicz, who joined the department in 2019. Adrianna has rapidly mastered the brief and competently guided this edition, smoothly coping with the disruption from the move to remote working.

We hope you enjoy it, and encourage you to send us articles and photographs for future editions.

Issue 27
July 2020

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Letter from the Head of Department
Professor Helen Wilson

I'm writing this article sitting at home, where I have been ever since UCL stopped face-to-face teaching and became a virtual university in March 2020 in response to the Covid-19 pandemic. When we closed our doors, we were just two weeks away from the end of spring term lectures, so while we did have a bit of a scramble to move those last two weeks of teaching online, the timing was pretty fortunate for us.

UCL examinations are usually run in the ExCeL centre in East London. This year, of course, it became NHS Nightingale and spent the summer busy with something rather more important than university exams. Our staff had to devise assessment methods that didn't require the students to be present, and that allowed suitably for students in different time zones (since so many countries had locked down international travel) and those with relatively limited internet access. We came up with a set of new "open book" assessments, some to be taken in 24 hours and others a week in duration, all to be taken remotely. We had to write questions that would still distinguish different students even though they had access to their notes, and textbooks, while solving them – and yet remain fair so that all students could demonstrate what they have learnt. This was a substantial challenge for us, and I'm really proud of the way my colleagues rose to it. We also brought in a "no detriment" policy – as did many other institutions – ensuring that any final year student who would have been inadvertently disadvantaged by our new, untried assessments would be awarded the degree that their previous form suggested they would get.

Of course, our response to Covid-19 has not just been to ensure that our own activities can continue as far as possible. We have world class mathematical modelling experts in this department, who immediately turned their expertise to the problem at hand.

Professor Christina Pagel (Director of CORU) is on the leadership team of DECOVID, the new national data effort of which UCL is a founding partner. The CORU team (whose expertise in Clinical Operational Research is our greatest asset at this time) have also been working with the Nightingale to design their dashboards and data processes; with UCLH, the Royal Free and St Thomas's helping analyse their real-time data to understand practice; and with NHS Scotland to help design contact tracing for the post-lockdown period. Many other members of the department signed up for the national modelling effort, RAMP, coordinated by the Royal Society.

Absolutely the last thing I did before leaving the department for many months was to hold interviews for lectureships in pure mathematics. These were possibly the last posts to be approved in the whole of UCL before the Covid shutdown, and I'm delighted that Dr Dario Beraldo, Dr Shoham Letzter and Dr Alexey Pokrovskiy will all join us over the summer. We welcome all three of them as our colleagues.

We had a good year for research appointments too. Our Clifford Fellow, applied mathematician Dr Rubén Pérez Carrasco, moved on to a permanent post atImperial College; the next appointee (a pure mathematician this time) is Dr Nikon Kurnosov. Finally, we launched a new senior research fellowship scheme, the IMSS Fellowships – intended to help draw the two departments of Mathematics and Statistical Science closer together as we plan for the joint Institute. Two IMSS Fellows, Dr Elena Luca and Dr Joonkyung Lee are also joining us over the summer.

This year has been far from ordinary. We had to cancel our exams, the De Morgan Dinner, and graduation; as I write, we are looking into the practicalities of delivering our autumn term lectures remotely if need be; and no doubt by the time you read this we will be aware of many members of the UCL Mathematics community who have been badly affected by Covid-19. But we have to look to the future, and I hope we will come out of this not just with new technical skills, but also a different view on ways of working, a deeper appreciation of the teaching profession (for those of us who are parents) and – just perhaps – with the satisfaction of a job well done.

British Society of Rheology Annual Award 2019

The British Society of Rheology (BSR) gave its Annual Award 2019 to our Head of Department, Professor Helen Wilson. This award recognises the contribution of a UK researcher to rheology, either directly through their research or through distinguished service to the BSR itself. In Helen's case it was a combination of the two. Her research over the last 25 years has been on a range of different topics within rheology (defined as the deformation and flow of matter, and now generally viewed as the science of how complex materials behave); from 2015-2017 she was President of the BSR and she has co-organised a large number of meetings on behalf of the BSR.

Professor Wilson then gave her award lecture, entitled "Modelling Complex Suspensions", describing theory she has developed in collaboration with postdoc Dr Jurriaan Gillissen for two different kinds of complex suspensions. In the first category, the particles are attracted to one another and in the absence of flow they would coagulate. Gillissen and Wilson have developed a scaling law that allows experimental researchers to extract information about the size of the attractive force between the particles, from the viscosity of the whole suspension at a range of fast flow rates. In the second category, the particles repel each other and, at high concentrations, the system can jam (this is what's going on in a dense cornflour-and-water mixture when you stir too fast and the "liquid" suddenly shatters like china). Gillissen and Wilson, in collaboration with researchers from Cambridge and Edinburgh, have come up with a new model for these fluids which is the first to be able to capture unsteady effects as well as the behaviour under general flow conditions.

Every recipient of the BSR Annual Award writes a summary of their award lecture for those BSR members who couldn't be there, which is published in the BSR Bulletin. This year the spring edition of the Bulletin, containing Helen's article, was made freely available to all (not just BSR members) – so if you want to read more, it's here: https://www.bsr.org.uk/article/free-bulletin-25/ (page 5).

Professor Helen Wilson

The award was presented at the BSR Midwinter Meeting in Birmingham in December 2019, by the current BSR President, Andrew Howe

Image Credit - Professor Helen Wilson

De Morgan Association Dinner 2019

This year's speaker was Rob Eastaway. Rob has written or co-written eleven books, some of which have appeared in several languages. The majority are about the mathematics of everyday life, but he has also written books on cricket, memory and creative thinking. He is the Director of ''Maths Inspiration'', a national programme of interactive lecture shows in theatres that has reached over 100,000 teenagers in the last ten years. Rob is also closely involved with the UK mathematics community, from primary schools to universities, and gives talks to adults, teenagers and children that range from small interactive workshops to keynote lectures in front of several hundred people. He has also done lots of radio (including numerous appearances on BBC Radio 4's More Or Less) and many podcasts. Rob gave an entertaining after-dinner talk fascinating us with a number of puzzles including his own variation on the famous Monty Hall problem.

Rob Eastaway, speaker

Guests at the De Morgan Dinner

Table set up at the dinner

The Michael Singers Choir performing

Professor Helen Wilson

Emily Maw participating in a demonstration

Image Credit - Soheni Francis

A curious non-linear wave pattern – What biology can do for maths

by Dr Angelika Manhart

I am currently teaching the first year Applied Maths course at UCL. It takes me back to my own first year of studying Mathematics in Vienna. The excitement of sitting in an actual university lecture hall, the joy of being surrounded by fellow students that share my enthusiasm for mathematics, and the deep conviction that there won't be anything university maths can throw at me, that I won't be able to understand. I was proven wrong about that. Of course.

In the UCL Applied Maths course, we recently covered one of the most famous linear partial differential equations (PDEs), the wave equation $\partial_t^2 u = c^2 \partial_x^2 u$, a beautiful model e.g. for vibrating strings. Shortly after we had discussed how to solve it, a student approached me after class and asked, why a function of the form

$$u(x,t) = f(x - ct)$$

would define a travelling wave. I was surprised at first – isn't it obvious? Of course it isn't, and a few multi-coloured sketches later, I had her convinced that *maybe*, just maybe, this expression is in fact reasonable. At least I hope I did. Travelling waves came up of course, because many solutions to the wave equation can be written as sums of travelling waves moving in opposite directions

$$u(x,t) = f(x - ct) + f(x + ct).$$

Here, I want to write about a mathematical curiosity, solutions to non-linear PDEs that are the product of two travelling waves

$$u(x,t) = A(x - ct)B(x + ct).$$

I stumbled across the system and its solution while working on modelling the swarming behaviour of myxobacteria. At this point I should mention that besides Mathematics, Molecular Biology is my second big scientific passion. I wrote my Bachelor's thesis on the movement of cells called keratocytes.

Figure 1: Left: Ripples caused by raindrops in a lake. Right: Ripples in colonies of myxobacteria.

One place where they live is on fish scales, so once a week, a fish delivery guy would pull up in front of the laboratory and deliver freshly killed fish, from which we would harvest the cells to analyse them later. An interesting side effect of this was that one of things I learned during the Bachelor's thesis, was how to disembowel fish. Who would have thought?

However, myxobacteria cells are very different from keratocytes. They dwell in the earth and produce slime to help move around. The nice, earthy smell after a rain is in fact the slime they produce. Each cell is its own organism, however they hunt their prey collectively – just like a pack of wolves. When they encounter prey, they often form an intriguing pattern: Under the microscope the whole colony (think hundreds of thousands of bacteria) looks like the surface of a lake where someone has thrown in some pebbles, Fig. 1: Families of travelling density waves moving in different directions. When the wave families meet, they seem to penetrate each other seemingly without affecting each other. Closer inspection shows that in fact, upon collision many of the individual bacteria in fact reverse their direction, so while *microscopically* the wave that continues after the collision contains completely different bacteria than before the collision, *macroscopically*, the wave looks the same.

My favourite way to approach such problems mathematically is to start by writing an Agent-based model, where each bacterium gets its own equation (typically stochastic, ordinary differential equations (ODEs)) and then derive a continuum PDE description for the densities by *coarse-graining*, i.e. assuming that the number of bacteria is very high and that their interaction length scales are much smaller than the resulting (wave) phenomena.

Fig. 2 shows simulation snapshots for the Agent-based and the PDE-based model.

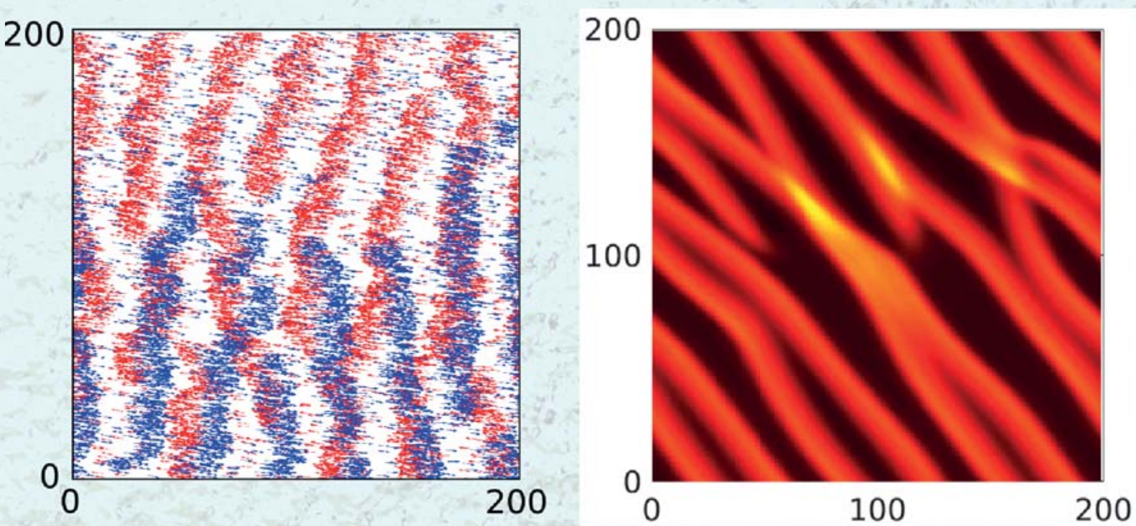

Figure 2: Left: Simulation snapshot from the 2D Agent-based model (colour indicates di-rection). Right: Simulation snapshot from the 2D PDE model showing $u_0 + u_1 + v_0 + v_1$.

Let me show you the 1D version of the PDE system this exercise yielded. It is a system for four densities, two right moving $u_0(x,t)$ and $u_1(x,t)$ and two left moving ones, $v_0(x,t)$ and $v_1(x,t)$. The index 0 and 1 indicates whether bacteria in that group can reverse (index 1) or not (index 0). This comes from a modelling ingredient that says a bacteria has to *wait* a certain time $1/\gamma$ after a reversal, before it can reverse again. Now, if it can reverse, it will do so with a rate $\rho \mapsto \lambda(\rho)$ that depends on the density of oncoming bacteria. You can imagine yourself walking towards Euston station from UCL with speed c and lots of people going the opposite way. The more people you meet, the more likely you are to turn around and go back to UCL to work a bit more.

Here are the equations in 1D:

$$\begin{aligned}
\partial_t u_0 + c\,\partial_x u_0 &= -\gamma u_0 + \lambda(u_0+u_1)v_1,\\
\partial_t u_1 + c\,\partial_x u_1 &= \gamma u_0 - \lambda(v_0+v_1)u_1,\\
\partial_t v_0 - c\,\partial_x v_0 &= -\gamma v_0 + \lambda(v_0+v_1)u_1,\\
\partial_t v_1 - c\,\partial_x v_1 &= \gamma v_0 - \lambda(u_0+u_1)v_1.
\end{aligned} \tag{1}$$

The reaction terms on the right can be understood as cyclic transitions: $u_0 \to u_1 \to v_0 \to v_1 \to u_0$: Imagine a bacteria starting e.g. in the u_0 group and cycling through the four groups by 1. Having waited long enough to join the reversible, right-moving group $u_0 \to u_1$, 2. Reversing and therefore starting to move left, but not being reversible $u_1 \to v_0$, 3. Waiting long enough to be able to reverse $v_0 \to v_1$, 4. And then finally reversing again $v_1 \to u_0$.

From a PDE point of view this doesn't look so bad: All the non-linearity is contained on the reaction side, in the function $\lambda(\rho)$, which could e.g. have a sigmoid shape. How do we find the travelling waves? The usual thing to do is to use a *travelling wave ansatz*, i.e. search for solutions of the form $f(x - vt)$, then change into the travelling wave frame $\xi = x - vt$ where everything reduces to an ODE for $f(\xi)$. The problem is that this doesn't work here. After all, the equation is not linear, so we cannot just add up two travelling wave solutions (if they exist) that for a right-moving wave and that for a left moving wave, and expect to get a new solution back. Even more problematic, why would the left-moving densities v_0 and v_1 form a travelling wave to the right at all? It seems more likely that there are two travelling wave frames at work at the same time, one to the right and one to the left.

It turns out the *right* ansatz (as in the successful one), is the following

$$\begin{aligned} u_0(x,t) &= P(x-ct)[1-A(x+ct)], \quad u_1(x,t) = P(x-ct)A(x+ct) \\ v_0(x,t) &= M(x-ct)[1-B(x+ct)], \quad v_1(x,t) = M(x-ct)B(x+ct). \end{aligned} \tag{2}$$

Here we finally have the products of travelling wave I promised earlier. Note how this ansatz implies that

$$u_0(x,t) + u_1(x,t) = P(x-ct), v_0(x,t) + v_1(x,t) = M(x+ct),$$

i.e. the right-moving bacteria form a true travelling wave to the right and the left-moving bacteria form a true travelling wave to the left, just like what we observe under the microscope! (see Fig. 3 middle)

Now what does this ansatz yield? Let's give names to the travelling wave frames $\xi = x - ct$ and $\eta = x + ct$. Substituting (2) into (1) gives

$$\begin{aligned} -2cP(\xi)A'(\eta) &= -\gamma P(\xi)[1-A(\eta)] + \lambda(P(\xi))M(\eta)B(\xi), \\ 2cP(\xi)A'(\eta) &= \gamma P(\xi)[1-A(\eta)] - \lambda(M(\eta))P(\xi)A(\eta), \\ 2cM(\eta)B'(\xi) &= -\gamma M(\eta)[1-B(\xi)] + \lambda(M(\eta))P(\xi)A(\eta), \\ -2cM(\eta)B'(\xi) &= \gamma M(\eta)[1-B(\xi)] - \lambda(P(\xi))M(\eta)B(\xi). \end{aligned} \tag{3}$$

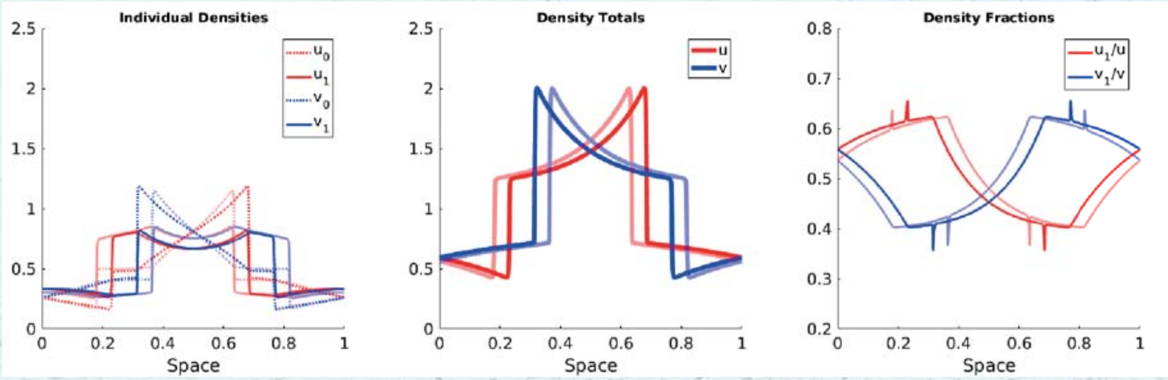

Figure 3: Three views of the same simulation at an earlier (pale colours) and a later (full colours) time step. Left: The individual densities u_0, u_1, v_0, v_1. Middle: The density totals $u = u_0 + u_1$ and $v = v_0 + v_1$. Right: The density fractions $u_1/(u_0 + u_1)$ and $v_1/(u_0 + u_1)$.

At this point we haven't won much, but now a miracle happens: In the second and fourth equation, we can cancel $P(\xi)$ and $M(\eta)$ respectively, giving

$$\begin{aligned} 2cA'(\eta) &= \gamma[1 - A(\eta)] - \lambda(M(\eta))A(\eta), \\ -2cB'(\xi) &= \gamma[1 - B(\xi)] - \lambda(P(\xi))B(\xi), \end{aligned} \tag{4}$$

beautifully decoupled equations for the two wave frames. If we then add up the first and the second, and the third and the fourth equation in (3), we get from both

$$\begin{aligned} 0 &= \lambda(P(\xi))M(\eta)B(\xi) - \lambda(M(\eta))P(\xi)A(\eta) \\ \iff \frac{P(\xi)}{\lambda(P(\xi))B(\xi)} &= \frac{M(\eta)}{\lambda(M(\eta))A(\eta)} \equiv k, \end{aligned}$$

so again the ξ and the η frames are decoupled. So in total we have to solve separately for the ξ and η frame an ODE coupled to an algebraic equation, where the only connection between them is the constant k. Note that there is again some similarity to the separation of variables ansatz one uses to solve the wave equation.

What is really surprising is that we did not decouple the right from the left moving densities! If we inspect e.g. (4) we see that we have coupling between the *sum* of the left-moving bacteria $M(\eta)$ and the *fraction* of the right-moving bacteria that can reverse $A(\eta)$ and vice versa (see Fig. 3). We could now continue analysing the resulting equations, which leads to some beautiful geometric arguments, but I will leave that story for another day.

Biologically the model is useful, because it can recapitulate the behaviour in the bacterial swarms. It says that when the waves collide they don't change each other's shape, but they modify each other's composition in terms of reversible and non-reversible bacteria.

Mathematically, this model led to the discovery of these quite unusual, but very interesting wave patterns. To me this demonstrates really well how, sometimes unexpectedly, modelling biology can lead to new and interesting maths.

References

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UCL MATHEMATICS

4th Floor Opening

30th October 2019

At a party on 30th October 2019 attended by the Provost Professor Michael Arthur, and Dean of the Faculty of Mathematical and Physical Sciences Professor Ivan Parkin, the Department celebrated the official opening of the 4th Floor of 25 Gordon Street. Elizabeth Critchley, an alumna of UCL Mathematics, gave a short talk and cut the ribbon to formally open the new space. The provision of this new and ideally located space suitable for teaching, research and collaboration in mathematics immediately below the Department's long-term occupancy of floors 5-8 realises a long-held dream. Some senior colleagues even claim the idea of expanding to other floors of 25 Gordon Street was mooted as early the 1960s!

The near doubling of staff and researchers since 2010, built on successful recruitment of highly qualified undergraduates and research grant successes, made the previous accommodation unsustainable. Several business cases later and with the strong support of Professor Parkin and, crucially, with the goodwill of the UCL Students' Union, the previous occupiers of the 4th floor, who had their neighbouring spaces improved as part of the same project, the project became reality.

Works involving refurbishment and rebuilding of the 4th floor commenced in spring 2019 and were completed before the start of the 2019-20 academic year.

The new 4th floor provides offices for 16 staff, a tutorial/meeting room with audio-visual facilities, a staff and PhD student social room, and space for 20 PhD students. At the same time, the upper floors were improved with new flooring, signage, re-painting and display of prominent mathematical 'art work' adorning the walls and staircases.

The Head of Department Professor Helen Wilson, Departmental Manager Helen Higgins and Deputy Departmental Manager Soheni Francis along with colleagues in UCL Estates can take great credit in their leadership, design and management of this transformative project. Their efforts have led to a space with a genuine sense of identity, supportive of teaching, research and collaboration and which enhances the experience of students, staff and visitors.

Robb McDonald, March 2020

From Left: Provost Professor Michael Arthur, Professor Helen Wilson, Elizabeth Critchley and Dean of the MAPS Faculty Professor Ivan Parkin

Official cutting of the ribbon on the 4th floor

From Left: Soheni Francis, Provost Professor Michael Arthur, Helen Higgins, Professor Helen Wilson, Dean of the MAPS Faculty Professor Ivan Parkin, Donna Williamson, Dr Nick Ovenden, Nicola Townsend and Adrianna Mickiewicz

Professor Helen Wilson and guests before the ribbon cutting

Image Credit - Alejandro Salinas Lopez from UCL Digital Media

25th International Conference for Difference Equations and Applications

ICDEA 2019

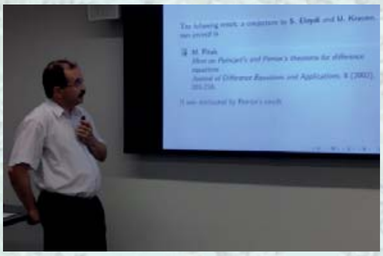
UCL, June 24 – 28, 2019.

Over 120 researchers from over 35 countries participated in the 2019 International Conference for Difference Equations and Applications, hosted by the UCL Mathematics Department.

This was the 25th anniversary of the meeting of the International Society of Difference Equations (ISDE). Since its conception at Trinity University in Texas in 1994, the annual event has been hosted worldwide, including in Germany, Romania, Japan, Poland, China, Oman, Spain, Latvia, Canada, Chile, and many other countries.

There was a very busy program with 8 plenary talks and over 90 contributed talks spread over 4½ days. The plenary speakers were Paul Glendinning (UK), Horst Thieme (USA), Adina Luminiţa Sasu (Romania), Andrey Shilnikov (USA), Ewa Schmeidel (Poland), Patricia Wong (Singapore), Mats Gyllenberg (Finland) and Mihály Pituk (Hungary).

In addition to the plenary and contributed talks, for the first time in the history of the conference we ran a series of tutorial style lectures, including from our own Prof Rod Halburd who spoke on Discrete Integrable Systems, and Prof Steven Bishop who spoke on Agent-based Modelling.



Mihály Pituk presenting his plenary lecture Asymptotic Behavior of the Solutions of Linear Difference Equations.

There was a huge variety of topics covered at the conference. Difference equations pervade Mathematics and we covered chaos, bifurcation theory, renormalization theory, exponential dichotomies, dynamical systems on timescales, monotone systems theory, and many other areas.

Applications ranged from ecology, neuroscience and epidemiology to economics and control theory. Thanks to Rod there were also special sessions of more of a pure flavour organized for Nevanlinna Theory and Discrete Integrable Dynamics.

Several prizes were awarded at the conference. The best student presentation was awarded to Tim Russell (Royal Holloway, UK) for his talk `Difference equations in population genetics', and best student poster was awarded to Mauricio Diaz (Bio-Bio, Chile) for his `Relation between Sensitive systems and MDS using Furstenberg family'. The 2018 prize for the best paper in Journal of Difference Equations and Applications was awarded to R. Bouyekhf & L. T. Gruyitch for their paper `An alternative approach for stability analysis of discrete time nonlinear dynamical systems', JDEA Vol 24(1) (2018).

The society's prestigious prize, the Bernd Aulbach Prize, which is bestowed biennially by the ISDE for significant contributions to the areas of difference equations and/or discrete dynamical systems, was presented to Professor Allan Peterson from Nebraska University.

Professor Allan Peterson (Nebraska) receiving the Bernd Aulbach Prize from Professors Elaydi and Bohner.

As is traditional for the ICDEA, there was a conference excursion. Delegates took a Thames Clipper trip to Greenwich, where through a guided tour they visited well-known attractions such as the National Maritime Museum, the Royal Observatory, and the Cutty Sark.

The weather was kind to us, and we finished the day with a trip across the Thames on the Emirates Air Line and enjoyed dinner of stone-baked pizzas in a converted Double Decker bus in Docklands, before taking the River Cruiser back to the Embankment.

On the penultimate night, the conference dinner was held at the Imperial Hotel in Russell Square. Professor Saber Elaydi, who organised the first ICDEA meeting in Trinity University, and who is now President of ISDE, treated diners to a special powerpoint presentation to celebrate 25 years of the conference.

The ICDEA2019 Dinner at the Imperial Hotel

Any international conference of this size takes a fair amount of organization. So, it is entirely appropriate to wrap up with thanks to all those that contributed to the success of the meeting. That includes Rod and Steven as fellow organisers, and Belgin Seymenoğlu, Jason Vittis and Jordan Hofmann who helped with the day-to-day running of the conference, and finally Soheni Francis who patiently watched over the whole event, booked and orchestrated all the refreshments, and much more, and prompted or rescued us where necessary.

Finally, we would like to acknowledge the generous support of our sponsors, the UCL Mathematics Department and the Taylor & Francis group.

Steve Baigent, Chair of Organising Committee

Symmetries and spaces
Inaugural Lecture of Professor Yiannis Petridis

Hieroglyphics and cuneiform tablets are not a common occurrence in mathematical presentations, but the inaugural lecture of Professor Yiannis Petridis, on the topic of 'Symmetries and spaces', held on the 13th of February 2019, was no normal presentation. Yiannis's lecture, however, did have an underlying theme: that of normal distributions.

Born in Alexandria, Egypt (from which his penchant for hieroglyphics stems), Yiannis studied at the University of Athens and at Stanford University, and joined the UCL Mathematics Department in 2007 following positions at several universities, including research visits to the Max Planck Institute for Mathematics in Bonn, one long visit sponsored by the Humboldt Foundation.

Yiannis's talk began with the question how to multiply numbers — he could not resist the urge to write examples both in arabic numerals and in hieroglyphics. From this, he led to the issue of how multiplication can be done quickly mechanically via logarithms; the younger members of the audience were undoubtedly unfamiliar with the slide rule that was used to demonstrate this. In past times, one used tables of logarithms for numerical calculations. The astronomer Simon Newcomb noticed in 1881 that the earlier pages in these book of tables of logarithms were more worn than the later pages. The mathematical justification for this phenomenon is known as Benford's law; a set of numbers is said to satisfy Benford's law if the leading digit $d \in \{1, ..., 9\}$ of such a number occurs with probability $P(d) = \log_{10}(d+1) - \log_{10}(d)$.

This was all discussed to motivate a result of Yiannis together with his long-time collaborator Morten S. Risager; instead of studying logarithms of positive real numbers, they study the discrete logarithm on free groups. From a pair of generators A, B together with their inverses A^{-1}, B^{-1}, one forms words such as $g = A^{-1}BA^2B^2A^3$. The word length $\mathrm{wl}(g)$ of such a word is the sum of absolute values of the exponents; in this case, $\mathrm{wl}(g) = 1+1+2+2+3 = 9$. The discrete logarithm $\log_A(g)$ with respect to the generator A is the sum of the exponents involving A; in this case, $\log_A(g) = -1+2+3 = 4$. The result of Petridis–Risager is that the discrete logarithm obey a normal distribution:

$$\lim_{x\to\infty} \frac{\#\left\{g : \mathrm{wl}(g) \le x,\ \frac{1}{\sqrt{\mathrm{wl}(g)}} \log_A(g) \in [a,b]\right\}}{\#\{g : \mathrm{wl}(g) \le x\}} = \frac{1}{\sqrt{2\pi}} \int_a^b e^{-\frac{u^2}{2}}\, du.$$

At this point, Yiannis's talk deviated sharply in a wildly different direction: hyperbolic geometry. This is a geometric setting in which Euclid's parallel postulate fails, so that given a line and a point, there exist an infinitude of "parallel" lines passing through that point. A particular model of this geometric setting is the upper half-plane in the complex plane, in which "straight lines" are either vertical lines or great semicircles whose centres lie on the real line. This is the world in which modular symbols live, a research topic that Yiannis has worked on for the past fifteen years.

Modular symbols can be thought of as integrals along certain vertical lines in the upper half-plane of a particular type of function called a modular form; these special functions feature prominently in Andrew Wiles's proof of Fermat's last theorem. The vertical lines involved are those that intersect the real line at rational points a/c. In celebrated joint work with Morten S. Risager, Yiannis studied the behaviour of modular symbols when averaged over the denominators c; they showed that these modular symbols, just like the discrete logarithm, obey a normal distribution.

Professor Yiannis Petridis

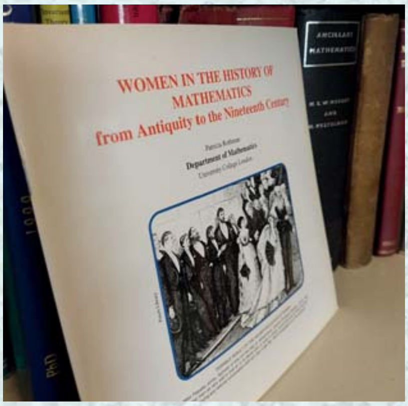
Write-up provided by Peter Humphries
Image Credit - Mary Hinkley from UCL Digital Media

Susan Brown Day – International Women's Day

8th March 2019

On International Women's Day, the Department of Mathematics launched Susan Brown Day, named in honour of the first female Professor appointed here. There were five speakers lined up, from various areas of the department, each presenting on the theme of 'Women Who Inspire Us'.

The first speaker was Kate Fraser, Senior Staffing Officer, who talked about Tina Fey as an example of the experience of being a woman in a particularly in a male-dominated workplace.



Dr Kim Moore, postdoctoral researcher, then delivered a presentation on legendary author Agatha Christie and her extraordinary life. Kim noted that despite Agatha's sensational success as an author, being third behind only Shakespeare and the Bible in terms of publishing numbers, she also experienced what we might recognise as imposter syndrome, a phenomenon that permeates academia with heightened prevalence in women.

Dr Kim Moore

Undergraduate student Vivienne Leech spoke about Anni Albers, a textile artist who reappropriated a traditionally feminine craft as a radical expression of modern art and design. Parallels were drawn between her geometric designs and the mathematical patterns that underpin them.

Vivienne Leech

Postgraduate student David Sheard followed, telling the story of Mary Ellis, a pioneering aviator with the Air Transport Auxiliary – who also happened to be his great aunt. The familial connection allowed him to tell a captivating series of anecdotes on the astonishing role that Mary played in the Second World War, and how she continued to live with the same intrepid passion for flying

David Sheard

From the left: Kate Fraser, Professor Helen Wilson, Dr Kim Moore, Vivienne Leech, David Sheard

Closing off the day, Professor Helen Wilson paid tribute to Professor Susan Brown. She spoke of Susan's reputation as a leading academic, but also of her outstanding commitment to teaching, being an inspirational figure for both students and fellow staff. Helen also recalled meeting Susan at her interview, and the fact that a woman was able to hold such a senior position developed a sense that we hope continues for all women in mathematics – "I belong here."

Professor Helen Wilson

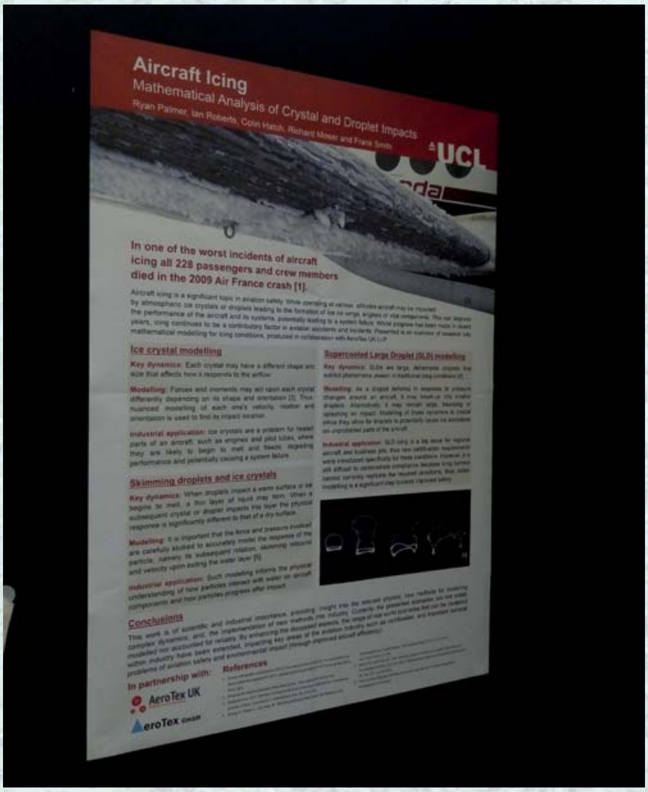
Women in Department of Mathematics

Image credit - Sam Hopkins

STEM for BRITAIN

13th March 2019

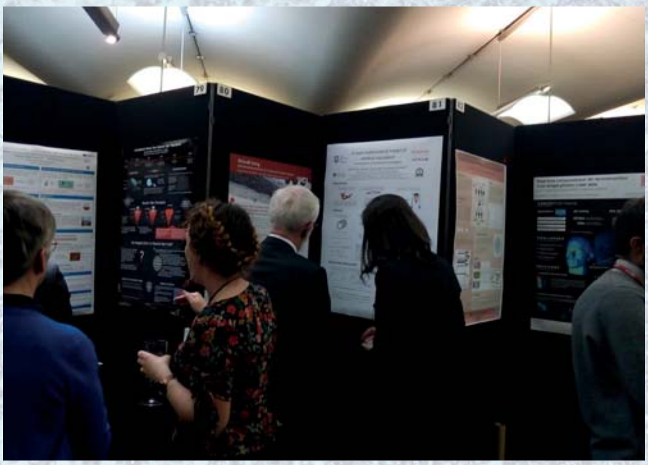
It was a historic day to be in Westminster. The air thick with expectancy, the room stuffed to the rafters with people ready to say their bit. Representatives from all over the country joining in the discussion about the future, the foreseeable problems and the many possible solutions. This being mid-March, throughout the day there was an air of anticipation for the final Brexit votes, a tension as each wondered which way they would ultimately go. STEM for BRITAIN had all the drama expected from a day in parliament.



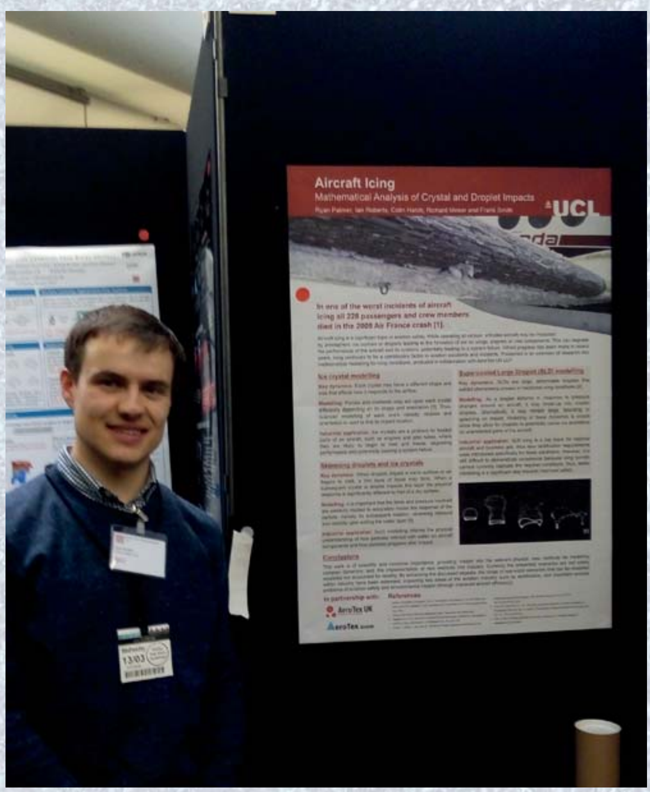
Dr Palmer's work

At a place and time in our country's history with much debate and uncertainty, it was fantastic to be a part of an event that highlighted and showcased the breadth of current world changing STEM research (Scientific, Technological, Engineering, Mathematical). It was an event that added some future hope and perspective to the current climate away from the political sphere. Consisting of participants from all over the world, working in research institutions throughout the UK, there were all sorts of problems on display from all sorts of fields. Spanning mathematics, engineering, biology, physics, chemistry; and ranging from the theoretical to the practical, the industrial to the academic - it was a real celebration of the influential work going on by early career researchers.

But it wasn't just a chance for up and coming researchers to shine amongst one another, it was also a key opportunity to highlight to MPs the strength and importance of UK research. The message was clear: that the UK has an important role in worldwide, collaborative research and that this role should be maintained and protected long into the future. There was a buzz of enthusiasm from all in the room and a collective desire to learn more, solve more problems, and provide future advancement through STEM research. Throughout the day I met people working on some of the most modern problems facing humanity, as well as many working on problems of an age old significance. What really stood out however was the importance of STEM research for our future progress and the undeniable societal benefit of such work, not just for the UK but the whole world. It was encouraging to be a part of the event and learn more about what my peers are up to, and energising to see others' passion for their subjects.



Great interest of Dr Palmer's work



Dr Ryan Palmer with his work

It was said throughout the day that we were all winners to even be there presenting, whether or not we won one of the big prizes - however, (at the risk of sounding cliché) seeing the breadth, depth and societal relevance of the research displayed – our local and global communities will be the winners as big problems are solved and as those talented researchers progress in their careers. The future for STEM research in the UK looks bright if STEM for BRITAIN is anything to go by – and long may that continue.

Dr Ryan Palmer

Image Credit - Dr Ryan Palmer

Colloquium – 23 April 2019

Title: **How to find structure in data?**

Speaker: Jürgen Jost (Director, Max Planck Institute for Mathematics in the Sciences, Leipzig)
Geometry, heuristics, and data analysis

Abstract:
When confronted with large, quickly changing data sets from perhaps unknown sources and of varying reliability and quality, both humans and machine learning algorithms need to make certain structural assumptions in order to make sense of them. These assumptions are usually of a geometric nature, like smoothness, symmetry, hierarchical structure or few sources only. These often translate into powerful heuristics for humans and efficient machine learning algorithms for computers. A deeper understanding is a mathematical challenge at the interface of high dimensional geometry, discrete mathematics, statistics, information theory and other fields. I shall discuss some examples and try to outline some perspectives.

Jürgen's talk was followed by a presentation led by David Tuckett (UCL) from the CRUISSE network (Challenging Radical Uncertainty in Science, Society and the Environment). The decision-making challenges facing Government and Business are complex. We use the term radical uncertainty to refer to contexts in which, at the time you are making decisions, you cannot know if what you are deciding will work out as expected. Many real-world decisions are of this type and David Tuckett (UCL Sociology and Psychology), Lenny Smith (LSE, Maths and Physics), David Good (Cambridge, Psychology and Design) and Timo Ehrig (MPI MiS, Maths) explored the implications as to when and how far it is safe to use the modelling techniques that, to date, have formed the backbone of decision science.

This Colloquium was unusual in that it was longer than normal (90 minutes) and involved four speakers - David Good (Cambridge), David Tuckett (UCL), Jürgen Jost (Leipzig) and Leonard Smith (LSE), pictured here with Dr Kim Moore (UCL Mathematics Research Fellow).

Image credit - Professor Dmitri Vassiliev

UCL Maths Wikithon

8th October 2019

To celebrate Ada Lovelace Day, Professor Helen Wilson and Dr Luciano Rila of UCL Mathematics ran a Wikithon to increase the diversity of mathematicians on Wikipedia.

Ada Lovelace Day aims to increase the profile of women in science, technology, engineering and maths (STEM) and provide role models for young students by celebrating the achievements of women in STEM fields, both from history and the modern day. As part of this, Professor Helen Wilson and Dr Luciano Rila arranged a Wikithon to help promote the work of underrepresented groups in mathematics.

Wikipedia pages being updated on the tablet

Around 30 people attended, as Dr Jess Wade (Imperial) and Dr Alice White (Wellcome Library) provided guidance as to how to create and edit wikipedia pages, and how to avoid common pitfalls.

Everyone working as a team

Following the event, we asked Dr Rila how it had gone:
"The event was a great success. We had representatives from undergraduate students, PhD students, early career academics and professors, all working together. The aim of the Wikithon was to address the gender bias on Wikipedia and we decided to extend that to all under-represented groups. Also, as Ada Lovelace Day is an international celebration of women in STEM, it was the perfect date to improve diverse representation in mathematics. The feedback was very positive, and we plan to continue our efforts to drive equality and diversity in mathematics. We are currently organising a network event for undergraduate students of African-Caribbean descent in February with invited guest speakers followed by a reception".

Image credit - Malcolm Chalmers, UCL MAPS Faculty

Thomas Harriot (1559/60 – 1621) England's leading mathematical scientist before Newton

by Dr Jon V. Pepper

First, a few details about Harriot's life, before I summarise his scientific and other achievements, which were considerable and recognised in his own times, but which were later largely neglected. Harriot was born in or near Oxford, most probably about 1560. His parentage is not known, but he had family connections in the Newbury area (south of Oxford) later on. He matriculated at St Mary Hall (now incorporated into Oriel College, Oxford) in 1577, graduating B.A. in 1580. After that, he possibly worked in London for a short while in the service of Sir Humphrey Gilbert, step-brother to Sir Walter Ralegh. Gilbert was lost at sea later in 1583. Harriot was then in the service of Sir Walter, as his scientific adviser and man of business. Until the late 1590s, when he moved into the service of Henry Percy, earl of Northumberland (a cardplaying friend of Sir Walter), where he remained, with similar duties, until his death in 1621 at the house of an old friend in Threadneedle Street. Very near the former site of St Mary-le-Stocks, where he was buried, and which is covered by the present Bank of England.

After his youth, of which we know nothing, he was never the typical poor scholar, but earned good money, had decent property, and was well-respected in a wide range of society for his scientific achievements, both in England and parts of northwest and central Europe before 1600. Why then is he so little known nowadays? Modern scholars have a nasty habit of ignoring the books which their predecessors haven't written. The simple answer is that, apart from a short colonising tract that came out in 1588 (probably), he published nothing in print of his scientific work. He didn't publish, so he perished! The question remains of why he didn't publish, and there are a number of possible reasons. First, he didn't have to – he was always well-rewarded by his patrons, and publication was often a means of attracting wealthy patrons, which wasn't necessary in his case. Next, his work was often on the boundaries of research of his time, for which a potential audience was always small. Important work could always be circulated in the "invisible colleges" of the times. Linked to this were the technical needs of such printing, for which the presses of (say) the Low Countries were better. England was only beginning to recover from the political and religious turmoil of the previous few reigns, and to spread its wings in the wider world. There was also the "restricted" nature of his work, as we would say nowadays; it would not do to let the king of Spain, for example, into some of his mathematical and scientific work.

There were also health problems, first mentioned in a letter to the Secretary of State, Sir Robert Cecil, later earl of Salisbury, in 1605, which dogged him for the rest of his life. But most of all, certainly for his later reputation, there was the question of his actual patronage. After the mid- 1590s, both Ralegh and Percy were marked men – they were certainly socially elevated (Percy much more so – Elizabeth, unlike her father, didn't promote men who came from nowhere), but they were dangerous to know. After James came to the throne in 1603, with the intention of coming to terms with Spain, both men came under suspicion, and were held in the Tower, and Harriot himself briefly imprisoned in 1605. Percy wasn't released until 1621, and Ralegh had died on the scaffold in 1618 (with his faithful old servant, Harriot, there to make notes, which still survive, of his lengthy speech on that dismal occasion).

So much for social background, but what about the actual academic work? This falls into a number of categories, wide-ranging as one would expect of a prominent late renaissance scholar. There was "A briefe and true report of the new found land of Virginia" (actually modern North Carolina, in particular the area of and behind the Outer Banks) referred to above, which gives a fair if hopeful account of the land and its people, where he had lived for about a year in 1585-86. It is this little book that explains why Harriot is better known in North America than in his own country, and is still in print in one form or another over 400 years later, with illustrations based on the distinguished drawings of John White, who had been there with Harriot. Harriot had learned the local Algonquian language, and devised a phonetic script to write it down, misdescribed later on as his "secret script". There was his early work in mathematical navigation in the 1580s which encompassed all the topics of interest at the time, apart from the longitude problem, which wasn't to be adequately dealt with for nearly two more centuries by John Harrison with his chronometers or Tobias Mayer with his lunar distances. Prior to that, traverses had to be estimated, which led on occasion to some spectacular disasters at sea. But in the later sixteenth century, the English, although trailing the Portuguese and the Spanish, were beginning to catch up. Edward Wright, a fellow mathematician, from Cambridge, later produced his "Certaine errors in navigation … corrected" of 1599 (2nd edn 1610), which, with a further edition, was the standard source in England on these matters for much of the rest of the century, and included the requisite tables and explanations of the methods.

In his work, in addition to the problems of amplitudes and latitudes, Harriot solved the problem of constructing a conformal mapping of the (spherical) globe, which had been proposed by Gerhard Mercator in 1569 (and hinted at by a few earlier writers), by the addition of secants, and later by a method structurally equivalent to the modern logarithmic formula, and constructed the necessary tables of the so-called meridional parts. The latter was no trivial matter. First, he proved (probably for the first time) the conformality of stereographic projection. Then he obtained the fundamental exponential equation involving tangents and a base angle, which came from the geometry of the sphere and the rhumb lines (loxodromes) projected onto the equatorial plane. This led, after the scale factor had been obtained, to the result $d = k \ln \cot(a/2)$, but this, as expressed here, is rather misleading, as modern logarithms hadn't yet been defined, and when they were, they weren't quite the same. (And they were changed by Henry Briggs a few years later.) Incidentally, this result is almost identical to the fundamental formula in hyperbolic non-euclidean geometry, which shouldn't surprise anyone, as that is representable on the surface of constant negative curvature, rather than the sphere of constant positive curvature.

Next he rectified the resultant equiangular spiral, using three separate methods (just to be sure!): algebraical, arithmetical and geometrical, the last using a neat dissection, the first known rectification of any curve; and also of the twisted loxodrome. He also found the quadrature of the spiral, but Archimedes had done that for the parabola (also by three different ways) long ago. (Harriot used the earlier result in its difference form in constructing his resultant tables.) He needed the rectification as a proxy for the integration of the secant function, which of course wasn't available to him. He then had to calculate the so-called fundamental constant, which we would write as the negative exponential of one minute of arc. But he used a different and algebraic procedure, still getting a result correct to the first eleven figures, as it had to be to ensure the figures in his final tables were correct to six or seven figures, as they were. In this work he used a development of the algebraic symbolism of his near contemporary, François Viète (1540 – 1603), which had only just been published. (He might of course have known about it somewhat earlier via correspondence with his friend Nathaniel Torporley (1564 – 1632) who was in touch with Vieta in France at about this time; a sort of early preprint arrangement.) He then plunged into the direct calculation of the meridional parts, but not immediately, as there were some loose ends to tie up. In the calculations he was helped by his assistant Christopher Tooke, using a variety of direct and interpolation methods, which we now associate with the names of Laplace and Newton. This work also included obtaining the exponential series, which he found as the limit of a binomial series. The resultant tables were by far the best available, even after International Hydrographic Bureau publication of the 1920s. (Modern tables also include those taking into account the slight flattening at the poles.) The accuracy of Harriot's tables was far beyond that called for in the navigation of the ships of his time; tables produced by a few a his contemporaries by simply adding secants at small intervals were perfectly adequate, except perhaps at the high latitudes of the Arctic explorers.

When some of his papers were recovered towards the end of the eighteenth century, they were judged to have “only” historic interest; mathematics had moved on. In particular, his algebra, which John Wallis had praised later in the seventeenth century, and which had been published in an incomplete and somewhat mangled form in 1631, ten years after his death, had nevertheless explained how roots of equations were related to binomial factors. This might seem obvious to us now, but someone has to say it for the first time, and the converse isn't actually obvious at all. (It is still disputed whether Gauss' proof is really a proof.) The publication also discusses in some detail numerical methods of solving polynomial equations of various degrees, and obtains some inequalities. It also introduces some notations that remain with us, albeit in a simplified form, e.g. the inequality signs. A modern (2007) translation is now available, from the Latin. (Harriot was also a very good Greek scholar, apparently, praised by George Chapman, his contemporary and long-time friend, and the translator of Homer (*cf. On first looking into Chapman's Homer*, by John Keats). Harriot was, for Chapman, “master of all true and essential knowledge” and one “whose judgement and knowledge I know to be incomparable”. Even allowing for the nature of dedications then, this is no mean praise, and from someone whose own judgement could be relied on in such matters.

Harriot had numerous other things to offer. There was his astronomy, in which he beat Galileo to telescopic observation of the moon, Jupiter's satellites, sunspots (he estimated the rotation of the sun from these) and the comets of 1607 and 1618. Kepler wrote to him from Prague (1606) and there ensued a brief correspondence over the next few years, the period of his (Kepler's) work on Mars coming out. Harriot had close connections with Dutch matters, via the earl of Leicester, who was one of the executors of his estate later on. (One of Leicester's titles was Lisle. The family name was Sidney – Sir Philip was his elder brother. One Adam Harriot, a priest, is recorded at Kingston Lisle, in the Oxford area, several decades earlier. The earl himself had been a Governor of Flushing in the Netherlands. The family connection has never been proved, but of such things history is sometimes made.) This might explain his early knowledge of the telescope, which had been developed in the Netherlands. He made, or had made for him, telescopes with a range of magnifications. Connected with astronomy, he studied optics in the period from about 1597 to 1602, deriving from experiments the sine law of refraction, which he applied to questions of dispersion and the height of the primary rainbow, which he showed occurred when tan i = 2 tan r (the so-called tropical angles; replacing the “2” by other integers gives the height of a whole series of rainbows, the first two or three of which are sometimes to be seen). All of this work is now credited to either Descartes (1596 – 1650) in 1637 or Snell (1581 – 1625) in 1621, the former also getting the honour for most of his predecessor's work in algebra. That attribution seems to have become indelible, with Descartes (1596 – 1650) (1637) getting the sole credit for “the invention of algebraic geometry” (perhaps shared with Fermat (1601 – 65) by the more knowledgeable; *his* work was only published by his son in the 1670s), when Harriot and Vieta are the true modern inventors, as their surviving books or papers clearly show. And so-called “cartesian co-ordinates” are nowhere to be seen in Descartes' writings; it's called cultural appropriation. Harriot's surviving papers show all sorts of other good things, such as the square roots of negative quantities, and binary arithmetic, for which later people like Gauss and Leibniz usually get most of the credit. There is also a solution (probably two) of Alhazen's problem in optics, on which both Barrow and Huygens wrote later on.

In fact, here is a long list of the names of people of whom Harriot was a clear forerunner in various matters: Halley, Barrow, Newton, Bernoulli, Descartes, Snell, James Gregory, Huygens, Laplace. And here are other things that he did, in summary. Impacts and elasticity, ballistics and projectiles, ship design and building (Euler also wrote extensively on these), calendar, combinatorics, spherical triangles (he was probably the first to derive their area – Briggs said so in 1630). He also saw the close connection between his mer-parts and logarithms, and his tables were more accurate than Napier's and he knew it; their fundamental constants were formed in different ways, one was a root, the other an exponential. And between inversion and conformality. It's difficult to see that he had time for anything else, but he did have. He ran Ralegh's estates in Youghal for a while in the 1590s.

He had his own small estates in Cornwall and Norfolk, and worked for its earl up in Northumberland. Perhaps it's not so surprising that he never got around to publication. He had interests in theology as well, which had its dangers in those benighted times; one of the things that he wrote to Kepler (in Latin) was “Here it is not possible for us to philosophise freely. We are stuck in the mud.” (Natural philosophy was the name given to science at that time, and for long after.)

How do we know all that we do know about him? The new Royal Society looked for his surviving papers in the 1660s, but without success. They seem to have been lost, like Aristotle's lecture notes nearly two thousand years earlier (Aristotle's other work really had been lost). But towards the end of the eighteenth century thousands of them turned up among the stable accounts at Petworth, the Sussex seat of his later patron. After some to-ing and fro-ing, they weren't deemed worthy of publication – the mathematical sciences had moved on, or many of them had, but one or two accounts of them were published over the next few decades. Most, but not all of them, went to the British Museum about 1810. F.W. Bessel's very first paper was on Harriot's comet observations of 1607; Franz, Baron von Zach, the German astronomer who had found the papers in Petworth, published accounts of some of them, and Stephen Rigaud, the Oxford astronomer, published a lengthy account in 1833. Some Americans later had an interest in his connection with the Outer Banks of North Carolina and what had been the first English colony in North America; it wasn't the Pilgrim Fathers (1620) or even the Jamestown colony in 1608, but the expedition of 1585-86 which led to “lost colony” of 1588, not a good year for overseas ventures by England. After 1945 scholars began again to show an active interest in Harriot's Nachlass. It was only one of their interests, but it led eventually to a series of over twenty annual lectures being given in Oxford, as well as seminars being held in both Oxford and Durham, with numerous pamphlets (booklets) also published. The manuscripts have been made available online; previously in Xerox copy and microfilm, and some people have spoken of “Harriot revived”. A bronze copy of Harriot's memorial inscription was unveiled in the foyer of the Bank of England on the 350th anniversary of his death, the 2nd July 1971. (Next year will be the 400th anniversary.)

Extensive bibliographies covering the periods of 1974-2000 and 2000-2012 appear in the two volumes of the annual lectures so far published, *Thomas Harriot, an Elizabethan man of science*, Robert Fox (ed.) (Ashgate, 2000) and *Thomas Harriot and his world*, Robert Fox (ed.) (Ashgate, 2012). Earlier works are listed in the bibliography of John Shirley's *Thomas Harriot, a biography* (Oxford, 1983) pp.476-490. It would take up too much space to list the dozens of people who have contributed to Harriot studies in the last fifty years or so. Instead I will illustrate the other plaque, which is now to be seen at Sion House (Isleworth), where Harriot had a house (no longer standing) built for him by Henry Percy in 1608. This gives the visitor an indication of Harriot's achievements.

Chalkdust Memories

To commemorate the 5th birthday of Chalkdust magazine and launch of the 10th issue we decided to share our favourite memories! Here is what it's like behind the scenes:

One of the first things that I got to do as part of Chalkdust was to interview Marcus du Sautoy. He had always been an inspiration to me when I was at school and an undergraduate, and when I joined the team my first job was to find an interview subject. I was quite nervous, but Marcus was extremely friendly and engaging and had lots of great tips for science communication that have helped me ever since, both when writing for the magazine and when doing my own research. It was amazing to have such a great opportunity so early on, and it really helped me feel like a valued part of the team and thus closer to my PhD colleagues.

Chalkdust Team celebrating the 10th issue

The first time that I took part in Chalky Saturday, the bi-annual day where we all come together and make the magazine happen, we started the day with nothing more than a collection of articles in various stages of completion, a few half-formed ideas for jokes and places to hide a scorpion, but after many hours, cups of tea, pizza and some serious LaTeX mastery we had a magazine ready to go. There's always a buzz around this stage of the magazine, and you finish tired but extremely satisfied.

Chalky Saturday

In 2016, I went to the MATRIX conference in Leeds. MATRIX is a conference aimed at people involved in maths outreach and public engagement, and was attended by students, academics, freelancers, and a few famous faces. The famous faces included Rob Eastaway, author of many books including "The Hidden Mathematics of Sport" and "Why Do Buses Come In Threes?"
As I was taking the second sip of my pint, a voice said: "Matthew, isn't it? Can I join you, I've been meaning to catch you all day?" I looked up to see Rob Eastaway! He sat down

and asked me all about Chalkdust, then offered to write an article for us ("Thinking outside outside the box", in issue 07). This was the first time that an established name in popular maths come to ask me about the magazine, rather than me going to introduce them to it, and it was the point at which Chalkdust began to feel like part of the maths outreach community rather than a small project that I worked on with a few friends.

Chalkdust abroad

My favourite memories from Chalkdust are all to do with the launch parties we organise to mark the release of a new issue! Producing a magazine from scratch is a lot of hard work, but it makes the celebration, oh so sweet. The atmosphere is always amazing, people laughing at the maths puns, having heated discussions about the wipeout round or just munching on some pizza and cakes! Seeing everyone happy, and enjoying the magazine is the absolute best feeling!

Opening a box of Chalkdust, after carrying 50 of them up 2 flights of stairs and then holding in your hands a copy of the newest issue with that freshly printed smell in the air, and spotting the first typo you have forgotten – Priceless!

Chalkdust Team

Chalkdust Team with freshly printed 10th issue

Please visit chalkdustmagazine.com to view all the issues.

Image Credit - Chalkdust Team

Scaling, PDEs and Iceberg Melting

by Dr Mahir Hadžić
Associate Professor

1 Stefan problem

Stefan problem is one of the best known free boundary problems. It was introduced by the Slovenian physicist Jožef Stefan at the end of the 19th century with the aim of describing ice melting/freezing. It is one of the best-known *phase transition* models, where the two phases, e.g. water and ice are separated by an interface which is allowed to move. It is also one of the early examples of a *free boundary problem* in the world of partial differential equations.

Figure 1: Jožef Stefan, 1835-1893
(photo from Wikipedia)

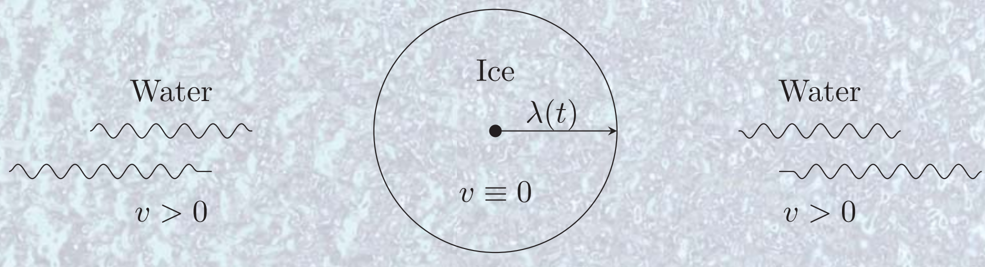
The goal of this article is to give an informal statement of one of the results from [1] about the rate of melting of perfectly round ice blocks and explain its significance. Assume that a round disk of ice of radius $\lambda(t) > 0$ is kept at a constant temperature 0. It is surrounded by an infinite body of water at a warmer temperature, which starts to melt it and consequently the radius $\lambda(t)$ starts to shrink. If we denote the temperature of the water at time t and radial distance $r > 0$ from the origin by $v(t, r)$, the Stefan problem takes the form

$$\partial_t v(t,r) - (\partial_{rr} + \frac{1}{r}\partial_r) v(t,r) = 0, \quad r > \lambda(t) \tag{1.1}$$

$$v(t,r) = 0, \quad r = \lambda(t) \tag{1.2}$$

$$-\partial_r v(t,x) = \dot{\lambda}(t), \quad r = \lambda(t). \tag{1.3}$$

Equation (1.1) is natural and tells us that the temperature of the water evolves by the well-known heat equation, which we are likely to have encountered in a course on basic PDEs. The boundary condition (1.2) simply states that at the interface between the water and ice the temperature has to be exactly 0. Finally, the second boundary condition (1.3) is crucial - it states that the heat flux through the boundary determines the speed of the moving interface!



Assume that initially the water temperature $v_0(r)$ is strictly positive, i.e.

$$v_0(r) > 0 \quad \text{for all } r > \lambda(0). \tag{1.4}$$

A standard maximum principle argument shows that $v(t,r)$ remains strictly positive for all $r > \lambda(t)$ for as long as the solution to (1.1)–(1.3) exists. This has a simple consequence: since $v(t,\lambda(t)) = 0$, we must have $-\partial_r v(t,\lambda(t)) \leq 0$ and consequently $\dot{\lambda}(t) \leq 0$. The ice has started to melt! In fact it will melt after some finite amount of time T and the question we are interested in is the following:

Question 1.1. *What is the generic rate of melting, i.e. can we express $\lambda(t)$ as a function of $T - t$ at the leading order, as t approaches the melting time T? If so, is such a behaviour stable in some precise sense?*

The above question is really about relating the spatial scale determined by the radius $\lambda(t)$ of the melting block of ice to the time scale in the problem. The hope is that on approach to the "singular" time T, there would be some universal law dictating to the leading order a functional relationship

$$\lambda(t) = f(T-t) + \text{ lower order corrections.} \tag{1.5}$$

Such universal laws are usually encoded in the symmetries or invariances of a problem at hand. In that regard, self-similarity is one of the most striking features of many problems one encounters in mathematics and nature alike. It roughly corresponds to the ability of a given system to replicate the same behaviour on "ever smaller scales", where the correct notion of scale can be deduced by studying the scaling invariances of the equation. In the physics literature this corresponds to the so-called *dimensional analysis*.
To make some educated guesses, let us turn to the heat equation for a moment.

1.1 Heat equation and scaling

Consider for a moment one of the most iconic partial differential equations - the heat equation. Here the unknown is the temperature function $u(t,x)$, where $t \in \mathbb{R}$ represents the time variable and $x \in \mathbb{R}^d$ the spatial variable. The heat equation takes the form

$$\partial_t u(t,x) - \Delta u(t,x) = 0. \tag{1.6}$$

Given an initial datum $u(0,x) = u_0(x)$ one can solve the initial value problem for (1.6) and most textbooks will tell us that

$$u(t,x) = (u_0 * G)(x) = \frac{1}{(4\pi t)^{\frac{d}{2}}} \int_{\mathbb{R}^d} u_0(x-y) e^{-\frac{|y|^2}{4t}}\, dy. \tag{1.7}$$

The formula (1.7) is remarkable: it is explicit and teaches us a lot about the solution. With its help one can rigorously prove important properties such as the infinite speed of propagation, instantaneous regularisation and many others. Perhaps the most curious of all is the role played by the function

$$G(t,x) := \frac{1}{(4\pi t)^{\frac{d}{2}}} e^{-\frac{|x|^2}{4t}}, \tag{1.8}$$

also known as the *heat kernel*. It contains a curious dependence on the ratio $\frac{|x|}{\sqrt{t}}$ and this is a fundamental manifestation of the scaling invariances of the problem.

Let us understand this a little bit better. For any $\lambda > 0$ and any $\alpha \in \mathbb{R}$ it is straightforward to check that if u solves (1.6), so does

$$u_{\lambda,\alpha}(t,x) := \lambda^\alpha u\left(\frac{t}{\lambda^2}, \frac{x}{\lambda}\right). \tag{1.9}$$

One says that the problem allows for a 1-parameter family of invariances parametrised by the choice of the exponent α. Is there a "preferred" choice of α? Here "preferred" sounds dangerously lacking of precision, and we address this point by resorting to another powerful concept - that of conserved quantities.

Assuming reasonable decay conditions at spatial infinity, a simple integration-by-parts argument tells us that for any solution of (1.6) the total "mass"

$$I(t) = \int_{\mathbb{R}^d} u(t,x)\, dx \tag{1.10}$$

is in fact independent of time. It is a conserved quantity such that $I(t) = I(0) = \int_{\mathbb{R}^d} u_0(x)\, dx$ for all $t \in \mathbb{R}$. It is therefore reasonable to ask which choices of α in (1.9) will also preserve the total "mass". By a simple change of variables

$$\int_{\mathbb{R}^d} u_{\lambda,\alpha}(t,x)\, dx = \lambda^{\alpha+d} \int_{\mathbb{R}^d} u\left(\frac{t}{\lambda^2}, y\right) dy$$

and we conclude that $\alpha = -d$ is the unique choice that allows the scaling invariance to be compatible with "mass"-conservation. The scaling transformation

$$u_\lambda(t,x) := \lambda^{-d} u\left(\frac{t}{\lambda^2}, \frac{x}{\lambda}\right) \tag{1.11}$$

is therefore aptly termed to be *mass-critical*.
What does all of this have to do with the heat kernel introduced in (1.8)? Let us provide a "complicated" derivation of G, one which is typically not found in most textbooks on partial differential equations. Let $t \mapsto \lambda(t)$ be a time-dependent and for the moment unknown function. Motivated by (1.9) let us introduce new variables

$$u(t,x) = \lambda(t)^{-d} v(s,y), \quad \frac{ds}{dt} = \lambda(t)^{-2}, \quad y = x\lambda(t)^{-1}. \tag{1.12}$$

We have thereby introduced the self-similar time variable s. As a result, a simple change of variables turns (1.6) into

$$\partial_s v - \frac{\partial_s \lambda}{\lambda}(dv + y \cdot \nabla v) - \Delta v = 0. \tag{1.13}$$

Exact self-similar solutions correspond to special solutions of the form

$$v(s,y) = \phi(y) \quad \text{and} \quad -\frac{\partial_s \lambda}{\lambda} = b = \text{const}.$$

Plugging it back into (1.13) we obtain the stationary problem

$$\Delta\phi + b\,(d\phi + y \cdot \nabla\phi) = 0, \tag{1.14}$$

which can be equivalently written in the form

$$\operatorname{div}\left(e^{-\frac{b|y|^2}{2}} \nabla\phi\right) + bde^{-\frac{b|y|^2}{2}}\phi = 0. \tag{1.15}$$

It is now easy to check that a particularly easy solution of (1.15) is given by

$$\phi_b(y) = e^{\frac{b|y|^2}{2}}. \tag{1.16}$$

Normalising $\int_{\mathbb{R}^d} \phi_b(y) = 1$, gives $b = -2\pi$ and from $-\frac{\partial_s \lambda}{\lambda} = b$ and $\frac{ds}{dt} = \lambda(t)^{-2}$, we easily conclude

$$\lambda(t) = (4\pi t)^{\frac{1}{2}}. \tag{1.17}$$

Combining (1.16)–(1.17) and going back to (t,x) coordinates using (1.9) and (1.12) we finally obtain a *mass-critical self-similar solution* to the heat equation

$$G(t,x) = \frac{1}{(4\pi t)^{\frac{d}{2}}} e^{-\frac{|x|^2}{4t}}, \tag{1.18}$$

which of course is the heat kernel from (1.8). Remarkably $G(t,x)$ is manifestly not smooth at $t = 0$ and along any parabola of the form $x(t) = c\sqrt{t}$, we have $\lim_{t\to 0+} G(t,x(t)) = \infty$. This is therefore also a prime example of a self-similar singular solution to an evolutionary PDE! What we have learned is that

- The heat kernel corresponds to a steady state of a suitably rescaled version of the heat equation.
- Dependence on the self-similar variable y translates into a functional dependence on $\frac{x}{\sqrt{t}}$. This in turn reflects the scaling invariance of the problem.
- Nature likes to honour the invariances.

1.2 Stefan problem and scaling

Motivated by the above analysis we may study the scaling invariances of the Stefan problem. After a little bit of algebra, we conclude that there is a unique scaling invariant transformation for the Stefan problem. For any $\mu > 0$ the pair (v_μ, λ_μ) defined by

$$v_\mu(t,r) = v\left(\frac{t}{\mu^2}, \frac{r}{\mu}\right), \quad \lambda_\mu(t) = \mu\lambda(t) \tag{1.19}$$

also solves the Stefan problem. The heat-like scaling (1.19) suggests that a reasonable guess for the functional relation (1.5), if it is to be consistent with self-similarity, should be

$$\lambda(t) \sim_{t\to T} \sqrt{T-t}. \tag{1.20}$$

The central result of [1] is that the prediction (1.20) is wrong!

Theorem 1.2 ([1])**.** *There exists an open set of initial data (v_0, λ_0) in a suitable topology such that $\lambda(t)$ vanishes at a finite time $T > 0$ and moreover*

$$\lambda(t) = \sqrt{T-t}e^{-\frac{\sqrt{2}}{2}\sqrt{\log|T-t|}} + o_{t\to T}(1). \tag{1.21}$$

In addition, this behaviour is stable *with respect to small perturbations.*

The existence of initial data that lead to the asymptotic behaviour (1.21) was first predicted in a beautiful work of Herrero and Velazquez [2]. The proof of both the existence and stability is contained in [1].
From (1.21) we see that on approach to singularity ($\lambda(t) \to 0$) we have

$$\lambda(t) \ll \sqrt{T-t} \quad \text{as } t \to T. \tag{1.22}$$

This remarkable departure from self-similarity can, in a nutshell, be attributed to the nonlinear character of the Stefan problem (1.1)–(1.3). This explanation is vague, but suggestive as related phenomena are encountered in a number of different nonlinear problems coming from maths, physics, even biology [3, 4, 5]. The proof of Theorem 1.2 is intricate as it combines ideas from spectral theory and nonlinear energy methods. We will not attempt to swamp the reader with technical details, but instead give a one paragraph overview of the main idea. After a rescaling analogous to (1.12), if we set $b = -\frac{\partial_s\lambda}{\lambda}$ the dynamics in the rescaled coordinates splits into two "orthogonal" components. One of them is a finite-dimensional dynamical system, which at the leading order is given by

$$\partial_s b + \frac{2b^2}{|\log b|} = 0, \quad b + \frac{\partial_s \lambda}{\lambda} = 0, \quad \frac{ds}{dt} = \frac{1}{\lambda^2}.$$

The solution of this system of ODEs leads precisely to the rate (1.21)! The remainder of the dynamics is infinite-dimensional, but considerably less scary since that part is dynamically dissipated away, much like one would expect from a heat-like equation. For all the details see [1].

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[3] Raphaël, P., Rodnianski, I., Stable blow up dynamics for critical corotational wave maps and the equivariant Yang Mills problems, *Publ. Math. Inst. Hautes Etudes Sci.* **115** (2012), 1–122.

[4] Raphaël, P., Schweyer, R., Stable blow up dynamics for the 1-corotational energy critical harmonic heat flow, *Comm. Pure Appl. Math.* **66** (2013), no. 3, 414–480.

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Institute for Mathematical and Statistical Sciences at UCL

One of the major and more exciting goals for the department in the coming years is the creation of the Institute for Mathematical and Statistical Sciences (IMSS) at UCL. The IMSS aims to be London's leading centre for research, teaching and collaboration in mathematics and statistics, establishing UCL as a global leader in these fields. The project, which includes the co-location and expansion of both the Mathematics and Statistical Science departments, requires also developing a strong joint community. This year we had the first two events looking to foster such a community.

Joint Alumni and Student Mixer

It is not a surprise that the first event organised around the IMSS was directed to our students and alumni as they are at the heart of our educational mission. About 80 participants including alumni, students, and staff of both departments met on Thursday 14th March 2019 for an evening to stay connected with old acquaintances and make new contacts. The main event of the evening: two successful alumni shared their career experiences in industry: Tharindi Hapuarachchi (MSci Mathematics (2010), Master in Mathematical Modelling (2011), and PhD CoMPLEX (2015)) currently Program Manager at DeepMind; and, Jo Kaczmarska (MSc Statistics (2009), and PhD Statistics (2013)) currently Senior Principal Modeller at Risk Management Solutions – RMS. Their stories, about their time at UCL, about the challenges faced after leaving, and about how their time here had helped them to realise their potential and thrive in their paths, inspired the younger attendants and resonated with that of other alumni.

Academic Launch Event

“I am proud to make a bit of history, as this is the first time that you will see the IMSS header in a talk”. This is how Petros Dellaportas summarised the relevance of the first academic meeting in preparation for IMSS, which took place on 30th January 2019 at the Wesley Hotel. The sentence captured the general optimism and enthusiasm of the attendants. The good mood was justified: Professor Ivan Parkin, the Dean of the MAPS Faculty, shared a positive outlook on the creation of the institute. Then, we had the rare opportunity to hear what colleagues from both departments are working on. Professor Karen Page and Professor Jean-Marc Vanden-Broeck from our department and Dr Codina Cotar and Dr Petros Dellaportas from Statistical Science shared the main subjects of their current research with applications in biology, fluid dynamics, physics and machine learning.

Creating a vibrant joint research community is much more than being co-located. These events were a first step to connect and prepare to do world class research under one banner. Expect more of these events in the future.

Dr Camilo Garcia Trillos

The Michael Singers

The Michael Singers, our departmental choir, are still going strong! Our members are mathematicians and sympathisers, of all nationalities, from UCL and across London. Our music reflects this diversity, with songs drawn from around the world and throughout history.

We sang festive songs in the UCL cloisters before the Christmas party last year, and in a joint concert with Contemporary Music for All (CoMA) Singers in the Haldane Room. This year we sang at Imperial's Christmas party and St Pancras station, as well as taking our voices to UCLH to bring cheer to the elderly patients on their wards.

Performing at St Pancras Station

Our 2019 repertoire had a topical environmental theme, encompassing improvised animal cries and English folk songs alike! We worked on this music in a joint workshop and concert with Belsize Community Choir in March, including a Planet Earth ballad arranged to the tune of ‘House of the Rising Sun’ by our fantastic conductor Sheena Phillips. The singing was accompanied by multitalented choir members on their respective instruments. We performed these songs again in Senate House before the De Morgan Dinner, and in the open air on a summer tour of London squares.

The Michael Singers at a practice

We are open to UCL mathematicians past and present, and their friends and family, so do feel free come along and sing with us!

Emily Maw

Image Credit p.38 - Dr Camilo Garcia Trillos
Image Credit p.39 - Emily Maw

Impact Investment Championship

On 7th December 2019, the Social Enterprises Division of UCL Business Society held their very first Impact Investment Championship. The one-day event was attended by a panel of speakers and judges from firms such as Impax Asset Management, Robeco, and Palladium Group. The guests came together to discuss the field of impact investing and its value in today’s world. More than 55 students from UCL, King's College London, Imperial College London, and University of Edinburgh attended the event and participated in a case study competition, sponsored by Robeco, Impax Asset Management, and ILA & Partners.

Here is the UCL winning team:
- Aubry Ma. First Year BA Education Studies
- Jenna Xu. First Year BSc Mathematics and Statistical Science
- Charmi Saujani. First Year BSc Mathematics and Statistical Science
- Claire Willemse. First Year BSc Mathematics with Economics.

Image Credit - Professor Helen Wilson

The GreenUCL

The department achieved a Gold Award for sustainability from GreenUCL. Many thanks to the Green Team, headed by Professor Robb McDonald, for making this happen.

Professor Robb McDonald and Dr Rubén Pérez Carrasco with the Gold Award

International Mathematics Competition for University Students

Axel Kerbec and Krzysztof Kacprzyk - received Third Prize. The team was trained by Petru Constantinescu, a UCL PhD student in the London School of Geometry and Number Theory (LSGNT).

Image Credit - Professor Robb McDonald

Staff Awards

Dr Lauri Oksanen was awarded the Calderón Prize, for his distinguished contributions to the field of inverse problems.

Dr Lars Louder has been the recipient of the Canadian Mathematical Society's (CMS) 2019 G. de B. Robinson Award for his paper "Stackings and the W-cycles Conjecture" (Canadian Mathematical Bulletin Vol. 60(3), 2017 pp.604-612). The G. de B. Robinson Award recognises outstanding contributions to the Canadian Journal of Mathematics (CJM) or the Canadian Mathematical Bulletin (CMB).

Dr Sonya Crowe, Professor Christina Pagel and Professor Martin Utley of CORU were awarded the OR Society's Lyn Thomas Medal for "academic OR research which best demonstrates novelty and real-world impact, backed up by evidence". This was for their programme of work in Congenital Heart Surgery.

Professor Andrei Yafaev has been awarded a Leverhulme Trust grant entitled "Diophantine problems related to Shimura varieties".

Dr Isidoros Strouthos has been awarded the Provost's Education Award for his dedication to teaching. His colleagues appreciate all of his hard work and have even said that Isidoros is "without a doubt one of the best lecturers this department has ever had".

Professor Andrew Granville has been awarded the Paul R. Halmos - Lester R. Ford Award 2019 from the MAA for his paper "Using Dynamical Systems to Construct Infinitely Many Primes".

Graduate Student Awards

Matteo Capoferri has been awarded the MAPS Faculty Education Award 2019 in the Postgraduate Teaching Assistant Category.

The 2019 MAPS Faculty Postgraduate Taught Prize was awarded to Mathematics student Hayley Goold for her impressive work in her MSc Mathematical Modelling during the last academic session. Hayley was widely praised for her dedication, painstaking effort and her superb intellectual ability, which our Head of Department praised as "stunning by any measure".

Mathematics PhD student Alex Doak received a MAPS Faculty Dean's Commendation for his research, one of only two awarded to research students within the Faculty.

Prizes Awarded to Students Summer 2019

First Year Prizes

Kestelman Prize 1st year
Christopher Dunkin

Stevenson Prize
Christoforos Kassianides

Departmental Prizes in Mathematics
Edmond Lo
David Villringer
Paul Zhang
Seth Hardy
Shizhe Xu
Seul Kang
Alexandros Groutides

Second Year Prizes

Bosanquet Prize
Enea Sharxhi

Kestelman Prize
Axel Kerbec

Andrew Rosen Prize
Huw Williams

Departmental Prize in Mathematics
Shiza Naqvi

Third Year MSci Prizes

The Nazir Ahmad Prize
Vivienne Leech

Third Year BSc Prizes

Wynne Roberts Prize
Yohance Osborne

Mathematika Prize
Alexandros Konstantinou

Final Year Prizes (BSc or MSci)

Andrew Rosen Prize
Chuhui He

The Institute of Mathematics and its Applications (IMA) Prizes

One year membership of the IMA
Daniel Bussell; Yohance Osborne

Fourth Year Prizes

Ellen Watson Memorial Scholarship
Anmol Aggarwal

David G Larman Prize
Joshua Daniels-Holgate

Susan N Brown Prize
Robbie Coulson

Fourth Year Project Prize
Joshua Smith

Fourth Year Sessional prize
Daniel Bussell

Joint Honours Prizes

Bartlett Prize (Joint Mathematics & Statistical Science)
Karsana Muhunthan

Castillejo Prize (Joint Mathematics & Physics)
Moustafa Saleh Gamaleldin

MSc Prizes

Frank T Smith Prize
Hayley Goold

Joining Student Prize

Panos Tofarides Prize
Georgios Nathanael

PhD Scholarships 2019-20

John Hawkes Scholarship
Stephanie Chan

Wren Fund Scholarship
Xiaoshu Sun
Baoren Xiao

Monica Hulse Scholarship
Zihua Liu
Carmen Cabrera Arnau

Edwin Power Scholarship
Hang Lou

J J Sylvester Scholarship
Luis Abrego

David Warren Fund Scholarship
William Jackman

Archibald Richardson Scholarship
Albert Wood
Francesco Di Giovanni
Fabian Lehmann

Corte Studentship
Sally Said

Sir George Jessel Studentship
Davide Bela
Mihai Nechita

Mayer de Rothschild Scholarship
Chris Evans
Stefanie Chan

PhD Prizes 2019-20

Andrew Rosen Prize (Applied)
Georgina Al-Badri

Davenport Prize (Pure)
Petru Constantinescu

Students who have recently obtained PhDs from the Department include:

Anna Lambert *(Supervised by Frank Smith)* "Mathematical analysis for two cell culture problems: population balance frameworks and glycoprotein production''

Bernhard Pfirsch *(Supervised by Leonid Parnovski and Alex Sobolev)* ''Szegő-type trace asymptotics for operators with translational symmetry"

Yupeng Jiang *(Supervised by Andrea Macrina and Marc Henrard)* "Joint distribution of passage times of an Ornstein-Uhlenbeck diffusion and real-time computational methods for financial sensitivities"

Alex Doak *(Supervised by Jean-Marc Vanden-Broeck)* "Steady two-dimensional and axisymmetric potential free-surface flows"

Hugo Castillo Sanchez *(Supervised by Helen Wilson)* "Channel flow instabilities of complex fluids"

Matthew Scroggs *(Supervised by Erik Burman)* "Efficient computation and applications of the Calderón projector"

Atheeta Ching *(Supervised by Steve Baigent)* "Balance manifolds in Lotka-Volterra systems"

Mattia Miglioranza *(Supervised by Felix Schulze)* "Volume-preserving mean curvature flow on a Riemannian'"

Davide Bella *(Supervised by Frank Smith)* "Stochastic Solidification Growth in Supercooled Water Droplets''

Matteo Capoferri *(Supervised by Dima Vassiliev)* ''Microlocal analysis of global hyperbolic propagators on manifolds without boundary''

Sam Porritt *(Supervised by Andrew Granville)* ''Polynomials over a finite field: some analytic number theoretic results''

Rudolf Kohulak *(Supervised by Frank Smith)* ''Heat-transfer modelling in freeze-drying and related processes''

Congratulations to all!

New Academic Staff

Dr Marco Javarone - CORU Lecturer

Marco Alberto Javarone is a Lecturer in Applied Mathematics, and his research interests are mainly in the area of statistical physics of complex systems. Notably, Marco studies evolutionary game theory, complex networks, theoretical neuroscience, and foundational problems in deep learning. His research is focused on understanding the emergence of cooperation, the human consciousness, and mathematical applications in interdisciplinary research. More recently, Marco started focusing on topics in mathematical physics.

Dr Angelika Manhart - Lecturer in Applied Mathematics

I am a Mathematical Biologist with an interest in modelling, simulating and analysing cell biological systems using mathematical tools, in particular partial differential equations. At the heart of my research lies the question of how micro scale effects lead to macro scale results, relevant for example for cell movement of collective behaviour. I was born and raised in Vienna, Austria, where I did both my two undergraduate degrees in Mathematics and Molecular Biology, as well as a PhD in Mathematics. After two post-docs at the Courant Institute of the New York University and Imperial College London I now look forward to researching, teaching and working at UCL.

Professor Vladimir Dokchitser - Professor of Pure Mathematics

Vladimir is a number theorist, working on elliptic curves, Jacobians and questions related to the Birch-Swinnerton-Dyer conjecture. His research frequently relies on analysing abstract concepts using explicit mathematical methods and is often aided by numerical experiments.

Dr Duncan Hewitt - Lecturer in Applied Mathematics

I am an applied mathematician and fluid dynamicist, and I am interested in using mathematics to model and understand physical processes in the world around us.

Dr Alex (Alejandro) Diaz De La O - CORU Lecturer

Before UCL, Alex Diaz was a Senior Lecturer at the University of Liverpool and a visiting fellow at the Alan Turing Institute. He is currently an EPSRC Fellow leading DATA-CENTRIC: Developing AccounTAble Computational Engineering Through Robust InferenCe, where he is developing Bayesian techniques for numerical methods that quantify uncertainty due to computation. Within CORU, he is in charge of analysing massive data sets from hospitals to develop methods that enhance clinical decision making. His continuous involvement with industrial partners has led to several projects with companies, government bodies and SMEs.

Dr Jeffrey Galkowski - Lecturer in Pure Mathematics

My main expertise is in the methods of microlocal analysis and I use these tools to understand the high energy behavior of eigenvalues and eigenfunctions for partial differential operators. Microlocal methods decompose functions into pieces which localize in both position and momentum and exploit the fact that PDEs behave differently in various regions of phase space. They can often be used to make the heuristic of 'quantum-classical correspondence' precise.

Dr Lorenzo Foscolo - Lecturer in Pure Mathematics

My work is motivated by geometric questions, it is often inspired by theoretical physics and relies on refined analytic tools to study partial differential equations on geometric spaces.
I am currently interested in the study of Riemannian manifolds with special holonomy, some of the most important geometric structures in differential geometry. Special holonomy manifolds provide examples of Einstein manifolds, in particular Ricci-flat ones. The latter are the Riemannian analogues of the solutions of Einstein's equations of General Relativity with vanishing cosmological constant. In fact, all currently known examples of compact Ricci-flat manifolds have special holonomy!

Dr Luis Garcia Martinez - Lecturer in Pure Mathematics

I am a pure mathematician focusing on number theory and automorphic forms. I am interested in the geometry and cohomology of locally symmetric spaces and applications to values of L-functions.

Dr Mahir Hadzic - Associate Professor in Pure Mathematics

My research is in the field of nonlinear partial differential equations, with emphasis on rigorous understanding of the qualitative dynamic properties of their solutions. I work on mathematical problems coming from fluid mechanics, kinetic theory, and general relativity theory.

Dr Shane Cooper - Lecturer in Applied Mathematics

My research interests lie in the mathematical analysis of multi-scale partial dierential equations (PDEs) that arise in the study of wave phenomena due to scale interactions in highly heterogeneous composite media. The multi-scale PDEs of interest are generally too complicated for practical purposes and even direct numerical simulations would be overly costly and inecient. The goal of my work is to replace these PDEs with simplied and controllably accurate approximate models that are practically useful. Such approximate models are determined by an asymptotic analysis of the original multi-scale PDE in terms of extremal physical and/or geometric parameters. Typically, I work with equations that arise in the study of Acoustic, Elastic, and Electromagnetic waves.

Dr Ian Petrow - Lecturer in Pure Mathematics

My research is in number theory, which is the study of the properties of the integers. More specifically, my domain of expertise is analytic number theory, which tends to ask questions about the integers concerning counting or estimation. For example, one famous unsolved question in analytic number theory is the Goldbach problem: How many ways can one write a positive even integer as a sum of two primes (in particular, is there always at least one way)? My favorite thing in mathematics is when two a priori different areas, such as arithmetic and analysis, come together in an unexpected way. Even more specifically, I am interested in the analytic theory of automorphic forms, which are the fundamental objects in the Langlands program, a wide-ranging web of conjectures that drives a large part of modern research in number theory.

Alumni Careers Advice

The Department is keen to welcome alumni to its careers events and fairs for our current students. This includes alumni who have gone on to complete further study.

If you are interested in this possibility, please contact Professor Helen Wilson at helen.wilson@ucl.ac.uk.

We also encourage you to join the UCL Alumni Online Community (ucl.ac.uk/alumni) to stay up to date with the latest news, views, events, special offers and exclusive opportunities from UCL, and stay connected with your fellow alumni.

Contributing to the De Morgan Association Newsletter

We would welcome news and contributions for the next newsletter, to be sent to:

Professor Ted Johnson, The De Morgan Association, Department of Mathematics, University College London, Gower Street, London WC1E 6BT

Email: editor_newsletter@math.ucl.ac.uk

Professor Yaroslav (Slava) Kurylev

Professor Yaroslav (Slava) Kurylev, died on 19 January 2019 aged 66.

Slava Kurylev was one of the leading researchers who laid the foundations of the theory of multi-dimensional inverse problems in the late 1980's and early 1990's. During this period, he was a researcher at the Leningrad (St. Petersburg) Department of Steklov Mathematical Institute, having obtained his PhD there in 1979.

His seminal result with Belishev says that a compact Riemannian manifold with boundary is determined, up to an isometry, by its Dirichlet eigenvalues together with the normal derivatives of the corresponding eigenfunctions. This result gives a way to see inside the manifold given information on its boundary, and it can be also viewed as a mathematical model for applied problems arising, for example, in geophysical imaging.

Slava continued making major contributions to inverse problems throughout his career. He moved to Loughborough University in 1995 and became professor there in 1998. During his time at Loughborough he wrote the book "Inverse boundary spectral problems", jointly with Katchalov and Lassas, which is now a classical reference in inverse problems.

He also studied counter-examples to inverse problems in the sense of cloaking. This is the mathematical analysis of special materials that can be used to coat an object so that light goes around it, the object thus becoming invisible. For example, his work on electromagnetic wormholes with Greenleaf, Lassas and Uhlmann was featured in Nature journal.

Slava moved to University College London in 2007. He remained creative until his untimely death. Recently, in a series of articles with Bosi and Lassas, he brought to a conclusion a long-term project of his, a stability theory for inverse boundary spectral problems. This is a tour de force that required the authors to establish, for instance, a precise quantification of hyperbolic unique continuation.

Another highly significant recent innovation by him, Lassas and Uhlmann is a technique that leads to a solution of inverse problems for non-linear hyperbolic equations. Strikingly, their result covers a large class of geometric settings for which the corresponding problems for linear equations are open. While their work was published only last year in Inventiones Mathematicae, several researchers have already started applying it to various equations arising in physics.

Slava was widely read and, beyond mathematics, enjoyed conversations on history, arts and culture. He was an outside-the-box thinker and spread his enthusiasm to others. It was always exciting to be around him.

Lauri Oksanen