



# Warwick Centre for Complexity Science

## Newsletter Issue 1, Winter 2014

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### Introduction from the Director

by Robert MacKay

Welcome to the University of Warwick's Centre for Complexity Science newsletter. The Centre is going from strength to strength.

It was a pleasure to attend January's graduation, where 10 Erasmus Mundus Masters students in Complex Systems Science, and 12 MSc and 6 PhD students in Complexity Science graduated. Congratulations to all! Our students have gone on to postdoctoral positions in major universities worldwide and into organisations as diverse as Mercedes Formula 1, Manufacturing Technology Centre Coventry, MRC Biostatistics Unit, and Citibank. Two are even setting up their own company, Spectra Analytics.

In November we received approval from EPSRC for a new Centre for Doctoral Training in Mathematics for Real-World Systems (*MathSys*). This will be a natural progression from our Doctoral Training Centre in Complexity Science. The main changes will be an increased emphasis on mathematics, a requirement for all to address a real-world system challenge, increased engagement with external partners, and explicit inclusion of systems biology into our range of application areas. *MathSys*

is a collaboration between the Centre for Complexity Science (who will host it), Warwick Systems Biology and Warwick Infectious Disease Epidemiology Research (WIDER). It is to be funded by EPSRC, BBSRC, the University of Warwick and external partners, the founding members being BT Innovation & Design, Jaguar Land Rover, National Grid, Pirbright Institute, Polymaths Consulting, Public Health England, Public Health Wales, Thales UK, Sciteb, Simpact, University of Birmingham School of Cancer Sciences, and University Hospitals Birmingham NHS Trust. We are grateful to all for their support, both financial and intellectual. *MathSys* is taking applications for places right now.

Also in November, our first volume of lecture notes "Complexity Science: The Warwick Master's Course" was published by Cambridge University Press in the London Mathematical Society lecture notes series. We look forward to producing more.

In the last week of February, we will run a joint Winter School on Complexity Science with Nanyang Technological University (NTU) Singapore at their campus. Several of our lecturers and students are going.

We have built a vibrant postdoctoral community, with currently 7 members working on topics like management of complex systems, epidemiology, metastability, and energy storage.

Our staff are doing well. We were joined in July by Ben Graham, Assistant Professor in Statistics and Complexity Science, who has expertise in probability theory and machine learning, and won a competition for software to recognise handwritten Chinese characters!

We were pleased to welcome Henry Abarbanel from University of California San Diego as an Erasmus Mundus visiting non-EU scholar for the Autumn term. He gave a module on Topics in Complexity Science, which generated a lot of interest.

Key challenges for the Centre for Complexity Science are adapting to the new *MathSys* CDT, developing the relationships with our external partners, riding the Big Data wave, and seeking to finance the future of our Erasmus Mundus Masters Course, whose last intake on the current European Commission funding will start this September.

# Dragons and Fairy Circles

by Mike Irvine, 3<sup>rd</sup> year PhD student



In Namibia, in the grasslands of Southern Africa something mysterious is going on. The glow of the morning sun casts light over great swathes of grassland. A single wildebeest rests on the barren earth, as flies buzz overhead. What is perhaps strange about this picture is that encircling the wildebeest is a barren patch of earth forming almost a perfect circle. Zooming out of this picture we find the grassland is interspersed with regular barren patches 5-10m in diameter, all of them almost completely perfect circles.

These African Fairy Circles as they're known can be found all across the semi-arid grassland of Southern Africa, yet their origin has long remained an open problem. The indigenous Himba people say that the barren patches are the footprints of the original gods to walk the Earth. Further, some tour guides in the area suggest that the patches are caused by underground-dwelling dragons, whose foul breath seeps through cracks in the crust, killing any plant life it comes into contact with.

So if not mythical dragons or spirits, what could be the cause of these patterns? A team of botanists at the

University of Pretoria investigated and dismissed three main hypotheses: radioactive soil, poisonous plants and termites.

The final hypothesis was born from the idea that termites could maintain the barren patches, allowing them to collect soil moisture that would otherwise be taken up by plant root mass. No evidence was found however, to show that termites were ever present in the circles the Pretoria team studied. So if an external source is not inducing these patterns what is? Perhaps the resulting spatial pattern is instead due to the internal dynamics of the system.

A recent paper modelled the interaction between vegetation and its environment. It assumed plants reproduced at a certain spatial scale due to clonal reproduction and seeding. Plant competition was also modelled via a strong non-local interaction term. This was attributed to individual plants competing for ground and surface water. When these simple interactions were modelled it reproduced beautifully the patterns observed in nature, even down to the higher density vegetation around the

circumference of the Fairy Circle. Further models that explicitly take into account plant and groundwater interaction also reproduce the regular barren circle patterns as a consequence of the aridity of the environment. Even more, as the aridity parameter is changed other patterns begin to emerge: stripes, labyrinths and spots- all of which have been observed in the semi-arid ecosystems of Africa.

As humans, even as scientists, we often look for single exogenous processes as an explanation for some phenomena. These provide convenient stories, short explanations to attribute to something that appears to make sense. The 2008 economic crisis due to the collapse of Lehmann Brothers, the formation of Fairy Circles due to termites for instance. Complexity seeks to answer these questions by taking a step back; by examining the system in its entirety we can study the emergent properties that could not be deduced from a single part alone.

## Some recent publications from our staff and students:

- **C. I. Del Genio, T. House**, *Endemic infections are always possible on regular networks*, Phys. Rev. E 88, 040801(R) (2013)
- **Y. Timofeeva**, S. Coombes and **D. Michieletto** Gap Junctions, Dendrites, and Resonances: A recipe for tuning network dynamics, The Journal of Mathematical Neuroscience (JMN) 3(1), 1-27
- **M. Alanyali**, H. Moat and T. Preis, *Quantifying the relationship between financial news and the stock market*, Scientific Reports 3, 3578 (2013)
- **T. Machon** and **G.P. Alexander**, Knots and nonorientable surfaces in chiral nematics, Proc. Natl. Acad. Sci. USA 110(35): 14174-14179 (2013)
- **R. Ball**, V. Kolokoltsov, **R. MacKay** (Eds.), *Complexity Science: The Warwick Master's course*, London Mathematical Society Lecture Note Series 408 (Cambridge University Press, 2013)

# Warwick Researchers Make Wavelets at ECCS'13

by Ellen Webborn, 2<sup>nd</sup> year PhD student



Conference Venue: The World Trade Centre, Barcelona

Barcelona: city of art, sport, and Catalan cuisine, and this year's venue for the 10<sup>th</sup> European Conference on Complex Systems (ECCS'13). This was the destination of a group of students from the department, when we left autumnal Britain and headed to the sunny Spain, to learn about and discuss the latest research in the complex systems community.

The variety of current research was instantly apparent, as reflected by the six main tracks of the conference: *Foundations of Complex Systems; Information and Communication Technologies; Infrastructures, Planning and Environment; Biological Complexity; Language, Linguistics and Cognition; Social Systems, Economics and Finance*. The three main days comprised six keynote speeches, two poster sessions, and a huge selection talks from these tracks (over 70 options per day). Additionally two days were set aside for 'satellites'; 30 specialised meetings with talks and discussions on topics such as 'Guided self-Organisation', 'Modelling the Complexity of the Immune System' and 'Non-Equilibrium Social Science.'

The plenary talks were generally accessible and varied, on topics ranging from sustainable land use to 'Crackling Noise – the Sound of Complex Systems' (S. Zapperi). As a PhD student researching the potential role of electricity storage, I found several talks related to energy markets, supply and demand networks and urban energy systems. I also attended a satellite on integrated utility systems which was particularly interesting. One of my favourite talks was in the satellite meeting, about the problems of externally controlling fridges to ease demand spikes, and how this can actually cause a whole new set of demand spikes due to synchronization. Generally the satellites were well-received due to the more specific nature of the talks. For example, first-year PhD student Peter Dawson found the "Modelling of Disease Contagion Processes" satellite meeting particularly useful, and made some good contacts with other disease modellers. It has been announced that this satellite will take place again next year, for which he plans to submit a talk.

Most speakers already had a PhD, but this was not a requirement, and second year PhD student Daniel Sprague was one of Warwick's speakers at the event. He says he would highly recommend the opportunities that speaking can present. *"After giving my talk I was approached by some sociologists who gave me some interesting ideas about how to link my work more closely with psychology. I also discovered a research group working on a similar theme. Their talk was fascinating, and chatting with them afterwards I was able to suggest some statistical methods they might find useful. Overall, it was great to have such productive interactions with other members of the complex systems research community."*

Being such a major conference in the complex systems research community, it was a great chance to make new contacts from across the world, and to catch up with a good number of former colleagues from the Erasmus Mundus and PhD programmes, some of whom presented posters or talks. Former complexity student Martine Barons presented her PhD work, receiving a great deal of interest from the audience including a request for her papers. Her networking skills also earned her some expert collaborators for her recently started Postdoc on decision support for food networks. One evening the 'Young Researchers Network on Complex Systems' organised a networking event for early-career researchers at a local tapas bar; a great opportunity to meet fellow young researchers. A highlight remarked upon by Dominic Kerr; *"In addition to the huge variety of talks, I particularly enjoyed the opportunity to meet with and discuss my research with other young researchers, and to hear so many passionate people talk about their interests. I would definitely recommend ECCS'14 to anyone interested"*.

Complexity scientists appreciating a complex biological system



## Winter Graduation 2014



Wednesday the 22<sup>nd</sup> of January saw the winter graduation ceremony for Complexity Science. In addition to the official University proceedings there was also a congratulatory drinks reception in the Centre itself. This proved to be a real hit, especially as several people contributed delicious homemade cakes and brownies!

Along with the graduation of the 2012 MSc cohort and the 2011 Erasmus Mundus cohort, we also saw Martine Barons, Quentin Caudron, Jamie Harris, Gui Pedro Araújo De Mendonça, Christopher Oates and Daniel Peavoy presented with PhDs. Congratulations to all!



## External Partners Day

On 11<sup>th</sup> December we invited our external partners to the centre to introduce themselves to our current students, share their insights on the mathematical problems they face, and celebrate the successful funding of our MathSys CDT.

The large majority of our founding partners (see Director's welcome) were able to attend, hosted for the day by several of our postdocs and members of staff with overlapping interests. After a welcome from the Director, each of our partners gave a short presentation of their work, interests, and, in particular, the mathematical problems they would like to work with the centre on through MSc projects or co-funded PhD studentships.

The range of topics and diversity of interests presented by our partners –analysis of 'big data', modelling of health provision, developing new communications technology, complex design and innovation strategies, and many more– showcased the exciting opportunities and challenges that they will provide for our students.

After lunch there was the opportunity for our current students and external partners to interact and develop ideas through smaller group discussions. The day concluded with a drinks reception and formal celebration of the funding of the MathSys CDT.

We look forward to the next such day and to the development of significant collaboration on the mathematical challenges currently faced by business, industry and government.

## Events coming soon

Some upcoming Warwick events that may be of interest:

- Institute of Digital Healthcare: "Using routine data to analyse patient flow: Insights and challenges" by Prof. Matthew Cooke, 29<sup>th</sup> January 2014
- MIR@W day: Distances between probability distributions, 24<sup>th</sup> February 2014
- TEDx Warwick 2014, including a talk from Kenneth Cukier, co-author of "Big Data: A revolution that will transform how we live, work, and think", 2<sup>nd</sup> March 2014
- Combinatorics and Stat. Mech. Workshop, 7<sup>th</sup>- 11<sup>th</sup> April 2014
- School and conference on Dynamics Games and Optimisation, 29<sup>th</sup> April- 2<sup>nd</sup> May 2014
- Warwick Public Lectures in Maths and Stats: "Data and the Brain – The impact of big data on learning deep neural models for speech, image and language understanding" by Prof. Nando de Freitas, 30<sup>th</sup> April 2014
- Warwick EPSRC Symposium on Statistical Mechanics: Phase transitions in discrete structures and computational problems, 5<sup>th</sup> -9<sup>th</sup> May 2014
- Reading-Warwick Data Assimilation Meeting, 12<sup>th</sup>- 14<sup>th</sup> May 2014

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