MATHS AND STATS RESEARCH DAY 2021: ABSTRACTS

Vasilis Archontis: Our Star, The Sun: Observations, Theory and Numerical Simulations

Abstract: The closest star to our planet is the Sun. To understand how the Sun interacts with Earth and the solar system, we have to study it's magnetic activity. In this talk, we briefly describe some key observational examples, theoretical aspects and numerical simulations, towards revealing the mechanisms that govern solar dynamics and activity. We also report on recent developments and future challenges on this subject.

Carl Donovan: Greener on the other side - on the optimality of greening calculations in P2P gambling

Abstract: Peer-to-peer (P2P) betting platforms allow players to both offer and accept bets, and offer tools for direct computer-based trading. This makes them very similar to other financial markets and gives great scope for quantitative strategies. Here we examine a common calculation applied when two opposing betting positions (win and lose) are obtained with a favourable differential, ensuring a guaranteed a profit regardless of outcome (termed "greening"). Here we show that minor alterations to this approach can provide similarly guaranteed, but markedly higher, returns, for a small increase in variance under commonplace conditions. We apply the approach to a large dataset of sub-second market data, which shows significant profit increases with little effort. High-frequency traders, betting app developers, or platform operators could exploit this for substantial gain.

Co-authors: Drs C. Bleak & B. A. R. Caneco

David Dritschel: Geostrophic adjustment of a shallow-water flow on the surface of a rotating spherical earth

Abstract: An arbitrary initial shallow-water flow radiates unsteady "inertia-gravity" waves, which disperse across the spherical surface. The simpler problem of a shallow-water flow on the plane radiates these waves to infinity, leaving behind a non-trivial steady flow in "geostrophic balance", in which the Coriolis acceleration balances the horizontal hydrostatic pressure

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gradient. This is called "geostrophic adjustment". On a sphere, the waves cannot escape, and the flow can never become steady due to energy conservation. Nonetheless, a form of adjustment still takes place, in a time-averaged sense, and this flow satisfies an extended form of geostrophic balance dependent only on the conserved mass and angular momentum distributions of fluid particles, just as in the planar case.

Sara Hamis: Mathematical modelling elucidates synergistic treatment responses to dabrafenib-trametinib combination therapies in BRAF-mutant melanoma

Abstract: Clinically used high-dose drug therapies are placing melanoma cells under strong selective pressures that almost inevitably result in drug resistance. In this work we mathematically model the effects of two anti-cancer drugs, dabrafenib and trametinib, that target the BRAF-MEK-ERK mitogen activated protein-kinase (MAPK) cascade in BRAFV600E-mutant melanoma. The regarded drugs inhibit the enzymatic activity of kinaeses at different tiers of the MAPK cascade, ultimately suppressing cellular levels of activated ERK and, by extension, cancer growth. Our modelling results suggest that combination therapies of dabrafenib and trametinib can, without loss of efficacy, be used at lower drug doses than dabrafenib/trametinib mono-therapies in silico.

Natalia Jurga: On the convergence rate of the chaos game

In the 1988 textbook "Fractals Everywhere", M. Barnsley introduced an algorithm for generating fractals through a random procedure which he called the "Chaos Game". In this talk we will discuss the asymptotic behaviour of the expected time taken by this procedure to become dense in the fractal. This is based on joint work with Ian Morris (Queen Mary) and recent work in progress with István Kolossvary (St Andrews) and Balázs Bárány (Budapest).

Deborah Kent: Mathematics at The Old Course: P.G. Tait and the Magnus Effect

Abstract: Nineteenth-century mathematician and physicist Peter Guthrie Tait (1831-1901) is widely known for his collaborations with Maxwell, Hamilton, and Thomson. Less familiar are his extensive aerodynamical studies. In the 1890s, Tait published over a dozen papers on the path of a rotating spherical projectile. Tait's classic work on the trajectory of golf balls was experimentally tested on the course at St. Andrews with the help of his son,

celebrated amateur golfer Freddie Tait. P.G. Tait realized that the combination of a dimpled surface and backspin created lift that allowed the ball to exceed the maximum expected distance.

Yoav Len: Tropical Algebra and the geometry of tangent lines

Abstract: Tropical geometry is concerned with interactions between geometry and combinatorics. Among its recent achievements, the tropical approach has been instrumental in various enumerative problems: counting the number of geometric objects satisfying prescribed conditions. Following a brief introduction to the topic, I will focus on the problem of counting tangent lines to curves. As I will show, tropical geometry provides a hands-on approach, and sheds new light on this beautiful piece of 19th century geometry.

Valentin Popov: Trend shifts in road traffic collisions: An application of Hidden Markov Models and Generalised Additive Models to assess the impact of the 20mph speed limit policy in Edinburgh.

Abstract: Empirical study of road traffic collision rates is challenging at small geographies due to the relative rarity of collisions and the need to account for secular and seasonal trends. In this paper we demonstrate the successful application of Hidden Markov Models (HMMs) and Generalised Additive Models (GAMs) to describe road traffic collision (RTCs) time series using monthly data from the city of Edinburgh (STATS19) as a case study. While both models have comparable level of complexity, they bring different advantages. HMMs provide a better interpretation of the data-generating process, whereas GAMs can be superior in terms of forecasting. In our study both models successfully capture the declining trend and the seasonal pattern with a peak in the autumn and a dip in the spring months. Our best fitting HMM indicates a change in a fast-declining-trend state after the introduction of the 20mph speed limit in July 2016. Our preferred GAM explicitly models this intervention and provides evidence for a significant further decline in the RTCs. In a comparison between the two modelling approaches the GAM outperforms the HMM in out-of-sample forecasting of the RTCs for 2018. The application of HMMs and GAMs to routinely collected data such as the road traffic data may be beneficial to evaluations of interventions and policies, especially natural experiments, that seek to impact traffic collision rates.
