Using the Rossiter-McLauglin effect to map giant exo-ring systems

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Background

Mamajek et al. (2012) analysed lightcurve data from the SuperWASP data for the star 1SWASP J140747.93–394542.6 (J1407 for short). This star is relatively young, only 16MYr, and active, showing photometric modulations due to starspots with an amplitude of 5% on a period of 3.21days. More interestingly, they also noticed a very strong dimming event in 2007, which lasted ~60 days (see Fig. 1). For over 5 days in the middle of this event, the star's flux dropped well below 10% from its undimmed value. Even more interesting is the presence of a large amount of sub-structure in the lightcurve throughout the event. Van Werkhoven et al. (2014) idenitfied at least 24 different structures over the course of the first half of the event and 16 during the latter half. These structures are interpreted as the presence of a large transiting disk with at least 24 individual rings. Such a disk would be expected to orbit an unseen planet, and the presence of the rings would then indicate the presence of exo-moons that interact with the ring particles, just as is seen for the rings and moons of Saturn.

Since the 2007 transit event, no further events have been observed, but if the transiting object is bound, it should transit again in the future, providing us with an opportunity of studying moon systems around young exoplanets.

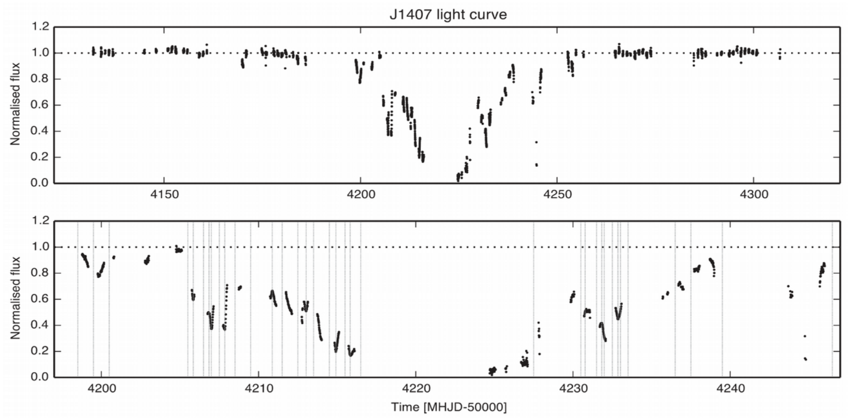

Figure 1: *Lightcurve of J1407b taken from Van Werkhoven et al. (2014). Top panel: All data for 2007, bottom panel: zoom on the eclipse event.*

In De Mooij, Watson and Kenworthy (2017) we propose a novel method to map the structure in relatively small exo-ring system (similar to Saturn's rings) by directly fitting the distortions of the stellar line profile due to transiting objects (the Rossiter-McLaughlin effect). This technique works best for rapidly rotating stars, where the material occults a large range of projected velocities on the stellar surface. The advantage over photometric time series is that this technique does not require continuous monitoring to determine the shape of the transiting object, but can, if the SNR is high enough, rely on short 'snapshot' observations.

This project

The aim of this project is to expand on the method from De Mooij, Watson and Kenworthy (2017) to take into account other effects, such as gravity darkening and differential rotation, as well as modelling giant rings. The project will focus on adapting the original code used in De Mooij, Watson & Kenworthy (2017). This new code will then be used to simulate realisitc high-resolution spectra of stars undergoing events similar to that of J1407b. By fitting these simulations we will be able to investigate our abilities of recovering the shape of the ring parameters, and potential degeneracies, as well as develop optimal strategies for the observations (e.g. sampling frequency vs. integration time) and combining spectroscopic and photometric data.

References

De Mooij, Watson & Kenworthy 2017, MNRAS 472, 2713;
Mamajek et al. 2012, AJ, 143, 72;
Van Werkhoven et al. 2014, MNRAS 441, 2845;

Investigation of graphene oxide membrane technologies for applications in microfluidic systems

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Background

The DCU Microfluidics research group, as part of the Fraunhofer Project Centre, is directed towards the design and testing of novel microfluidic platforms and associated actuation, detection, fabrication and instrumentation technologies for the integration, automation, miniaturization and parallelization of sample preparation and detection of bioanalytical assays (e.g. immunoassays, nucleic acid testing, general chemistry and cell counting) [1,2]. Typical applications are sample-to-answer systems for biomedical point-of-care and global diagnostics, liquid handling automation for the life sciences (e.g. concentration / purification and amplification of DNA / RNA from a range of biosamples), monitoring the environment, infrastructure and agrifood.

Project Description:

Since its discovery in 2004 [3], a wide spectrum of fascinating characteristics of graphene and its compounds, such as graphene oxide (GO), have been extensively investigated by the scientific community. However, while being explored by a broad community, the wide spectrum of the often unique properties of graphene has so far not been widely used for fluidic flow control in microfluidic systems. We have demonstrated, on microfluidic systems, some of these unique properties of the GO membranes: namely their solvent selectivity and air impermeability [4]. Beyond a specific burst pressure, GO membranes allow water to pass through at very low flow resistance; however, it completely blocks the organic solutions IPA and EtOH, oil solutions and air, even at high pressure heads. Other properties of such GO membranes are anticipated to enable a multitude of applications. This project aims to investigate these possible uses including: desalination, solvent separation, particle size separation and reagent storage.

Potential Candidates

The candidate should have a keen interest in hands on experimental work, with an interest in materials technologies. The student will be required to manufacture and test Lab-on-a chip systems in our in-house manufacturing facilities. Some chemistry experience would be desirable but is not required.

References

[1] Gorkin R, Park J, Siegrist J, Amasia M, Lee BS, Park J-M, et al. Centrifugal microfluidics for biomedical applications. Lab Chip. 2010 Jul 21;10(14):1758–73.

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[3] Novoselov KS, Geim a K, Morozov S V, Jiang D, Zhang Y, Dubonos S V, et al. Electric field effect in atomically thin carbon films. Science. 2004 Oct 22;306(5696):666–9.

[4] Gaughran J, Boyle D, et. al. Phase-selective graphene oxide membranes for advanced microfluidic flow control. Microsystems & Nanoengineering. 2016, Vol. 2 Page 16008.

Area and Depth Profiling of Active Pharmaceutical Ingredients (APIs) in Tablets using Laser Induced Breakdown Spectroscopy (LIBS)

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Project Aims/Objectives

Laser Induced Breakdown Spectroscopy (LIBS) is a standard approach for classifying materials be they solid, liquid or gas [1]. LIBS involves using a laser to create an ionized vapour on the surface of a large sample to create a plasma. The spectrum of light emitted from the plasma is characteristic of the elemental composition of the sample, effectively a chemical fingerprint. Hence LIBS can be used to classify (and potentially quantify) the presence of an element on a host. For example we have used LIBS to determine the presence of carbon in steel [2]. The distribution of the API following tabletization in of key interest to the industry and researchers as it affects the takeup of the API by the human system and hence the efficiacy of the drug. Micro Raman Spectroscopy (MRS) can be used to profile the API but it is hugely time consuming and expensive. LIBS is a single laser shot technique and combined with a tight laser focus offers the prospect of being competitive with MRS. If time permits, we will combine employ double pulse LIBS [3] to further optimise the LOD. For the expected complex/rich spectra we will employ statistical techniques, especially Principal Component Analysis [4], for which we have a suite of codes developed by one of the group.

Research Group / Techniques

The Laser Plasma and AMO at the School of Physics in DCU is well established in intense laser matter interactions. We have a suite of well-equipped laboratories, for a list of equipment – cf. http://www.physics.dcu.ie/~jtc/expfacil.html. The group currently comprises 4 faculty members, 1 SFI Fellow, 3 postdoctoral fellows and 10 research students. Our high power lasers produce pulses from the femtosecond to nanosecond range and our spectrometers cover the NIR to soft X-ray range. As a member group of the National Centre for Plasma Science and Technology at DCU we also have access to many materials diagnostics like XRD, AFM, SEM, etc. We also have a number of codes for atomic spectra calculations to aid LIBS.

Potential Candidates

This project would suit a student who has interest in analytical sciences, lasers, optics and spectroscopy. The project involves skills such as optical alignment, vacuum technology and data processing in MATLAB. The candidate should be comfortable working in a high power (Class IV) laser environment (appropriate training will be given and the student will be accompanied by an experienced research student and/or postdoc at all times).

References

[1] R. Noll, Laser-induced Breakdown Spectroscopy, Springer (2012)

[2] X Jiang, P Hayden, J T Costello and E T Kennedy, Dual-Pulse Laser Induced Breakdown Spectroscopy with Ambient Gas in the Vacuum Ultraviolet: Optimization of Parameters for Detection of Carbon and Sulphur in Steel *Spectrochimica Acta Part B: Atomic Spectroscopy* **901** 106-113 (2014)

[3] M.A. Ismail, G. Cristoforetti, S. Legnaioli, L. Pardini, V. Palleschi, A. Salvetti, E. Tognoni, M.A. Harith, Comparison of detection limits, for two metallic matrices, of laser induced breakdown spectroscopy in the single and double-pulse configurations, *Anal. Bioanal. Chem.* **385** 316–325 (2006)

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Synthesis and Characterisation of Metal-Oxides for Hydrogen Fuel Generation via Solar Water Splitting (Dr. Rob O'Connor, School of Physical Sciences, DCU)

Project Aims/Objectives

Metal oxides such as $BiVO_4$ can be used to split water under solar illumination to generate hydrogen which could potentially be used as a fuel for a wide range of applications. However to date a material that displays an economically viable efficiency and lifetime has eluded researchers.
Many groups have been working on theoretical calculations that have suggested metal oxides which may have suitable material properties for such an application. At the DCU Surface and Interface Research Laboratory we have been working on the synthesis, characterization, and testing of these materials. The proposed internship would focus particularly on characterising $Mn_2V_2O_7$ which other groups have suggested might be able to split water with a high efficiency and reliability.

Research Group / Techniques

The Surface and Interface Research Lab have a long history of studying the interfaces between materials used in semiconductor technology and have an ongoing collaboration with Intel Components Research based on confronting technological roadblocks, which need to be overcome for future CMOS generations. The group also has a strong background in semiconductor device reliability. The water splitting project relies on both of these strengths, as the goal is to arrive at reliable device architecture through a fundamental understanding of the materials at the nanometer level.
Techniques and equipment available in the group include x-ray photoelectron spectroscopy, atomic force microscopy, x-ray ray diffraction, secondary ion mass spectroscopy, electron beam deposition, and an electrochemical workstation including solar simulator.

Potential Candidates

This project would suit a student who has interest in solid-state physics, semiconductor physics, or materials science. Previous experience with, or an interest in vacuum science and technology would be of benefit. The project also contains an electrochemical element, as ultimately the splitting of water is a chemical reaction, so some basic electrochemical understanding would be desirable, but not necessary.

References

The following two papers should give students a feel for the field of water splitting research and characterization of metal-oxides:

http://pubs.acs.org/doi/pdf/10.1021/cr1002326
http://onlinelibrary.wiley.com/doi/10.1002/aenm.201401840/full/

Is there an app for that - are microbiomes an "app store" for drug resistance genes?

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Project Aims:

Infectious disease outbreaks are driven by antibiotic resistance in bacteria. Genes causing this are commonly transferred between pathogenic bacteria and other microbiome species in the human gut. Exactly how these genes are donated to non-pathogenic microbiomes remains unclear. Plasmids with these genes are transferred often between bacterial cells and thus act as a driver of antimicrobial resistance (AMR). On top of this, transposable elements move genes promoting AMR both within and between bacterial plasmids and chromosomes. In this project, you will examine these transfer processes in microbiome genomes isolated from humans. AMR genes in pathogenic bacteria are often on plasmids lacking transfer machinery that recombine with other plasmids to enable subsequent AMR gene exchange between cells. You will test for recent AMR gene exchange events between pathogenic *Escherichia coli* genomes and samples from the Human Microbiome Project to associate important plasmids with disease-associated AMR genes. We hypothesise that microbiomes act as AMR gene carriers and thus promote AMR in pathogenic bacteria. Your work will provide new ideas on how AMR genes get transferred between species in the human gut.

Potential Candidates:

This project suits a motivated student interested working at the interface between molecular, computational and infection biology. The project involves skills such as DNA sequence comparison, visualising genomic data and evolutionary analyses: appropriate training in homology searches, sequence alignments and examining large datasets will be provided. You will learn about microbial evolution, molecular diagnostics and how to compare genomes and microbiomes. You will work in the Infection Genomics lab at DCU with one other summer intern and two PhD students and a Bioinformatics Technician. To facilitate this project twinning molecular with computational methods, we have a high-performance computer server. At the end of the project, you will be able to perform sequence alignments between genomes, interpret the effects of genes on antibiotic resistance, and investigate their evolutionary innovations. Learning about these techniques is applicable to a range of problems involving bioinformatics or biomedical research on genomic data.

References

- Downing T. Tackling drug resistant infection outbreaks of global pandemic *Escherichia coli* ST131 using evolutionary and epidemiological genomics. Microorganisms 2015 3:236-267.
- Lloyd-Price J, et al. Strains, functions and dynamics in the expanded Human Microbiome Project. Nature 2017 550:61-66.
- Gibson MK, et al. Developmental dynamics of the preterm infant gut microbiota and antibiotic resistome. Nature Microbiology 2016 1:16024.
- See also our website http://cosmogenomics.wordpress.com

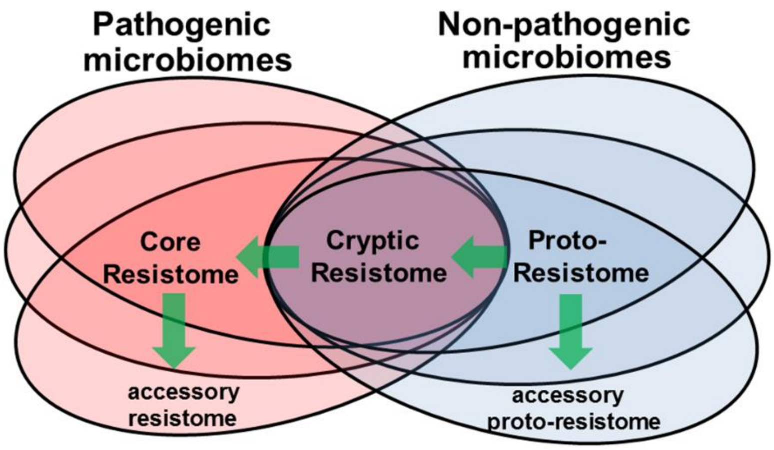

Diagram: The Core Resistome is the antibiotic resistance genes shared by pathogenic bacteria (red), whereas the Proto-Resistome is the antibiotic resistance genes shared by non-pathogenic commensal microbiome species (blue). The intersection of these genes is the Cryptic Resistome (purple). Resistance genes can be transferred reversibly from the Proto-Resistome to the Cryptic Resistome and then to the Core Resistome. When they are no longer needed, genes can be transferred from the core to the accessory resistome.