WESTERN SYDNEY
UNIVERSITY

Nanoscale Organisation
and Dynamics Group

NANOSCALE RESEARCH NEWSLETTER

ISSUE 5 – November 2016

7th Biennial Western Sydney University Symposium on NMR, MRI and Diffusion

Register at: www.westernsydney.edu.au/nanoscale

The Western Sydney University Symposium is held biennially and showcases theoretical developments and cutting edge application of Magnetic Resonance Imaging (MRI) and Nuclear magnetic Resonance (NMR) Diffusion measurements. The symposium will include platform and keynote lectures as well as poster presentations.

The symposium allows us to showcase our world class facilities, research and University and brings together leading domestic and international experts on topics ranging from medical to environmental, mining and industrial applications. This will result in knowledge transfer amongst researchers and uptake by industry of cutting-edge methods. The symposium is open to all including people from outside academia (e.g., clinicians and industry) and students. Consequently, one aim of the conference is to inspire the next generation of students and secondly to allow current students to access some of the brightest researchers at the forefront of MRI, NMR and diffusion research.

The symposium fills a void in research symposia in Australia – the university is unique in holding the only symposium in Australia to cover this area of research. There is no dedicated association for researchers in Australia in the diffusion magnetic resonance field.

When: 9:00 am - 5:30 pm

Tuesday 29th November 2016

Where: Western Sydney University, Campbelltown

Venue: Lecture Theatre 5 (CA21.G.03)

Audience: Open to all

Western Sydney University will soon be home to the first fast field cycling nuclear magnetic resonance spectrometer (FFC NMR) in Australia.

Many of the most important chemical processes involve the slow dynamics of molecules that occur in the range between nanoseconds and milliseconds. This includes a diverse range of phenomena from clinical to industrial importance such as MRI contrast and the development of new MRI contrast agents, to the durability of concrete, filtration and even food spoilage. Such slow motions are difficult to measure at the fixed high magnetic field strengths of traditional NMR spectrometers (normally > 7 T) and Magnetic Resonance Imagers (typically 1.5 or 3 T). However, measuring the longitudinal relaxation time ("T_1") of a molecule as a function of the observation frequency (especially at lower frequencies) - known as nuclear magnetic resonance dispersion or NMRD - is a particularly powerful means for probing slow molecular dynamics. The FFC NMR allows the NMRD profile to be measured from about 10^{-6} T up to the maximum field allowed by the magnet (3 T in our case). Examples of problems addressed using FFC NMR include filtration, imbibition, conduction and wettability, protein hydration, dynamics of polymers and liquid crystals, MRI contrast agents, durability of cements and concretes, determination of oil to water ratios in rock cores, filtration and water purification in soils, catalysis.

SPECIAL POINTS OF INTEREST

IF WE KNEW WHAT IT WAS WE WERE DOING, IT WOULD NOT BE CALLED RESEARCH, WOULD IT? — ALBERT EINSTEIN

Western Sydney University presents -

Professor Peter Basser

National Institute of Health, USA

Dr. Peter Basser received his A.B., S.M., and Ph.D. in Engineering Sciences from Harvard University and then received his postdoctoral training in Bioengineering as a Staff Fellow in the Biomedical Engineering and Instrumentation Branch (BEIP), NIH. In 1997, he became Chief of the Section on Tissue Biophysics and Biomimetics (STBB), NICHD and then the Director of the Program on Pediatric Imaging and Tissue Sciences there. In 2015, Dr. Basser was appointed to be an Associate Scientific Director of the Division of Imaging, Behavior and Genomic Integrity, within the NICHD. More recently, his Section has been developing several quantitative MRI methods for performing in vivo MRI histology. Dr. Basser is primarily known for the invention, development, and clinical implementation of MR diffusion tensor imaging (DTI), for explaining the physical basis of magnetic stimulation of nerves, and his early work in convection-enhanced delivery (CED), a means to infuse chemotherapeutic agents to the brain in a targeted way.

Professor Masaya Ishikawa

Applied Biological Science, Tokyo University of Science

Dr Ishikawa is known internationally for his work on exploration of diversity in freezing behaviours (species- and tissue-specific adaptative strategies of freeze survival by controlling cell water behaviours) in plant tissues by developing novel non-invasive visualization methods (MRI and infra-red thermography). He has found extra-organ freezing in flower and leaf buds of woody species and several novel types of freezing behaviours in complex plant organs of cold hardy plant species. He also found that most of the leaf tissues in temperate bamboo species remain supercooled as low as -25 °C as a mechanism of cold hardiness. Moreover, he also conducted pioneering research on how plant tissues regulate freezing to establish such freezing behaviours, including ice nucleation activity and supercooling stabilizing activity. He developed various assays for detecting these activities. He is interested in identifying the substances responsible for these activities and their applications. He finds high resolution MRI to be a powerful tool for studying the diversity and mechanisms of intricate plant freezing behaviours since it can visualize temporal and spatial distribution/dynamics of unfrozen water in complex tissues. He received his PhD (botany) from Hokkaido University and worked as a postdoc at the Institute of Low Temperature Science, Hokkaido University (Sapporo, Japan) and Crop Science Department, University of Saskatchewan (Canada) before getting a PI position at National Institute of Agrobiological Sciences (Tsukuba, Japan), where he commenced a long-standing collaboration with Prof. W.S. Price.

Dr Abhishek Gupta

Western Sydney University.

Abhishek Gupta recently completed his PhD on 'advanced MRI contrast agents' as a joint project between Western Sydney University (WSU) and CSIRO, under the supervision of Prof. William S. Price, Dr Minoo Moghaddam and Dr Timothy Stait-Gardner. He is currently working as a Postdoctoral Research Fellow with Ingham Institute (Liverpool Hospital) and WSU under the supervision of Prof. William S. Price. His main research interests are the development and application of NMR, MRI and relaxation theory, and the development and characterisation of MRI contrast agents.

Dr. David Raffelt

Florey Institute of Neuroscience and Mental Health.

David Raffelt is a Senior research scientist in the Advanced MRI Development lab at the Florey Institute of Neuroscience and Mental Health.

He received his PhD at the University of Queensland in the field of medical image analysis. Current research projects focus on the development of novel methods for quantifying white matter disease using Diffusion-Weighted MRI, in addition to the application of these methods to investigate Alzheimer's Disease, Epilepsy, Motor Neurone Disease, Dravet syndrome, and preterm infants.

Ms Rebecca Hawker

University of New South Wales

Rebecca Hawker is a graduate of the University of New South Wales where she completed her B.Sc.(Hons) in the group of A/Prof. Jason Harper. During her undergraduate and honours projects, her work was focused on developing an understanding of the interactions responsible for solvent effects in ionic liquids and synthesis of novel ionic liquids. She is currently completing a PhD in the Harper group where she is extending this previous work to the rational design of ionic liquids to control reaction outcome and the development of methodology that will enable ionic liquids to be assessed without the need for extensive kinetic analysis.

7th Biennial NMR, MRI and Diffusion Symposium

Professor Gareth Morris FRS

School of Physical Chemistry, Manchester University

I was successively an undergraduate, postgraduate and research fellow at Magdalen College Oxford from 1972 to 1981, first as a Demy and subsequently as a graduate student (supervised by Ray Freeman) and as a Fellow by Examination. In 1978-9 I spent a year's leave of absence with Laurie Hall at the University of British Columbia as an Izaak Walton Killam postdoctoral fellow. In 1982 I moved to Manchester, where I am now Professor of Physical Chemistry. I was awarded the RSC Corday-Morgan prize and medal in 1988, a Leverhulme Fellowship in 1996, and the RSC Industrially-Sponsored Award in Magnetic Resonance Spectroscopy in 2001, and was an invited professor at the Université Pierre et Marie Curie, Paris, in 2010. In 2011 I was awarded the Russell Varian Prize for NMR, in 2014 I was elected a Fellow of the Royal Society, and in 2015 I received the James N. Shoolery Award.

Associate Professor Leigh Johnston

Dept. Electrical and Electronic Engineering, The University of Melbourne

Leigh Johnston is an Associate Professor in the Department of Electrical and Electronic Engineering at the University of Melbourne and holds an honorary appointment at the Florey Institute of Neuroscience and Mental Health, where she is the Head of the Animal MRI Laboratory. Leigh has a PhD in Electrical Engineering, and completed postdoctoral research training at the Centre for Systems Engineering and Applied Mechanics, Université catholique de Louvain in Belgium and at the Centre for Vision Research, York University, Canada, before returning to Melbourne. Her research interests are in MRI acquisition and analysis, in particular the application of signal processing methodology and biophysical modelling to structural and functional MRI.

Associate Professor Gary Liney

Ingham Institute, Liverpool Hospital

A/Prof Liney is the chair of the 5th MR in RT Symposium and the senior MRI physicist at the Ingham Institute for Applied Medical Research and Liverpool Cancer Therapy Centre. He was recruited from the UK in November 2012 to provide the scientific lead into the MR-simulator and MR-Linac programs at Liverpool having previously worked as a Principal radiotherapy imaging physicist in the NHS. His publications includes over 50 peer reviewed journal articles and three textbooks. He is also a member of the faculty for the annual ESTRO imaging for physicist's course.

Dr Petrik Galvosas

School of Chemical and Physical Sciences, Victoria University of Wellington and MacDiarmid Institute for Advanced Materials and Nanotechnology.

Petrik Galvosas is a Senior Research Fellow in the School of Chemical and Physical Sciences (Victoria University of Wellington) and is an Associate Investigator with the MacDiarmid Institute for Advanced Materials and Nanotechnology.

He received a Dipl.-Ing. (FH) degree from the University of applied Sciences of the German Telekom in 1993 which was followed by a Dipl.-Phys. (physics diploma degree) of the University of Leipzig in 1998. The two theses were dealing with audio recording equipment and NMR diffusometry respectively. In 2003 he received his PhD from the University of Leipzig. The thesis revolved around the diffusion in porous materials and high performance NMR diffusometry. From 2003 to 2005 he was a postdoctoral fellow in the MacDiarmid Institute. From 2005 to 2009 he held a position as Junior professor at the University of Leipzig. Since 2009 he is working as a Senior Research Fellow in the School of Chemical and Physical Sciences (Victoria University of Wellington) and is an Associate Investigator with the MacDiarmid Institute for Advanced Materials and Nanotechnology

Dr Dmitry Shishmarev

University of Sydney.

Dmitry Shishmarev completed his undergraduate degree in chemistry at the Lomonosov Moscow State University in 2009. In 2014, he obtained his PhD degree in chemistry from the Australian National University, where he had been working since 2010 on the solution-state NMR studies of proteins in the group of Professor Gottfried Otting. Since 2014, he has been working at the University of Sydney as a Postdoctoral Research Associate in the group of Professor Philip Kuchel. His main current research interests are in the development of NMR methodology as well as biochemistry and cell biology of human erythrocytes.

WSU - National Imaging Facility Node

We have been conducting some preliminary work aimed at measuring flow rates through the xylem and phloem of grapevines using MRI with Dr Suzy Rogiers from the National Wine and Grape Industry Centre (NWGIC). The NWGIC specialises in grape and wine science and is allied with Charles Sturt University and the NSW Department of Primary Industries. Its collaboration with commercial vineyards enables the translation of its research into industry practice.

In our initial scans we inserted a potted grapevine into the bore of the Bruker 600 MHz MRI (Fig. 1, left) and acquired a number of images. Two superimposed images, one red and the other green, are shown on the right of the Fig. 1 giving a yellow image indicating the stability of the stem. Some of the surrounding side stems and leaves move between scans and hence appear as red-green blurs. Flow contrast can be obtained by applying a flow sensitive pulse sequence; however there will be a challenge due to the size of the phloem in relation to the voxel size (a voxel is the 3D analogue of a pixel). Much of the initial work in this project is centred on overcoming this. Micro-CT is also being used to generate highly detailed images of the anatomy near the leaf and inflorescence nodes which will be used for interpreting flow rate data in conjunction with the MRI data.

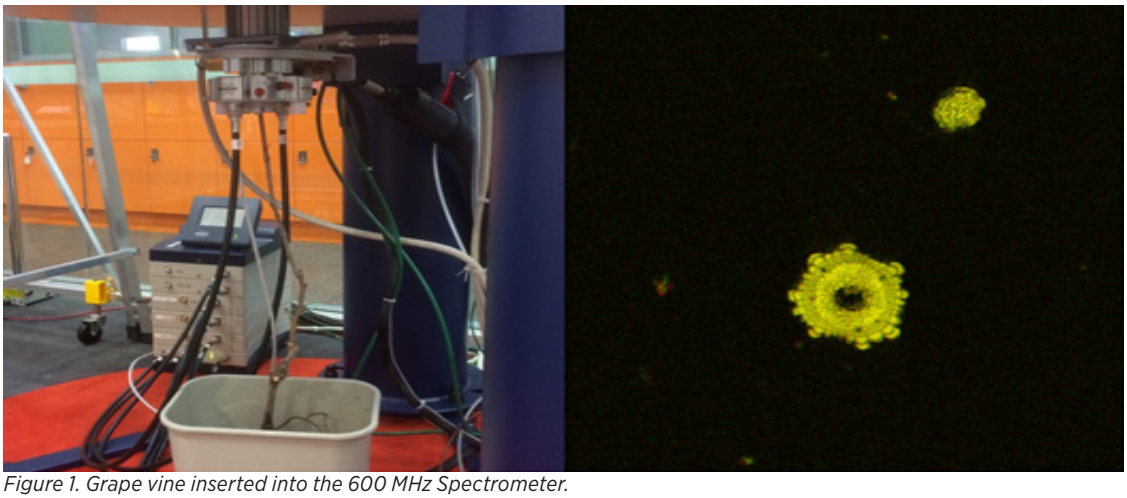


Figure 1. Grape vine inserted into the 600 MHz Spectrometer.

Biomedical Magnetic Resonance Facility

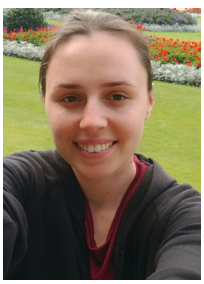
There have been a number of collaborations established in the last months, including with the National Wine and Grape Industry Centre on flow rate measurements in grape vines and with UNSW on mobility in ionic liquids. These and others make use of all the spectrometers in the facility as well as the PerkinElmer micro CT with increasing load being placed on the 600 MHz Avance IIIHD spectrometer both in imaging and spectroscopy modes.

As the number of users increases personal user accounts for frequent users are being introduced. Please contact the Facility manager if you need an account on the 500 or 600 MHz machines. Please note, that on the 600 MHz machine only the NMR Superuser account can be used for imaging.

We would like to remind you of the Christmas closedown (21st of December till 4th of January) of the facility and plan your experiments accordingly.

Please note, that Dr Mikhail Zubkov will be leaving the position of the BMRF Facility Manager on 2nd December. After this date please contact Dr Allan Torres (a.torres@westernsydney.edu.au) or Prof. Bill Price (w.price@westernsydney.edu.au) on BMRF related matters.

Student Profile



Aleksandra Bjelosevic

Aleksandra Bjelosevic completed her B.Sc. (Honours) in 2014 at Western Sydney University.

She is currently in the second year of her PhD at Western Sydney under the supervision of Prof. Janice R. Aldrich-Wright, Dr Allan Torres and Dr Ming Wu. Her research interests include the development of multi-dentate ligands and metal complexes of those ligands with anticancer and antibacterial activity. Aleksandra has undertaken research at the University of Aarhus, Denmark to measure the melting profiles by Synchrotron Radiation Circular Dichroism spectra of several types of Quadraplex DNA to characterise them for a group project. She has also attend a CD and LD workshop at Warwick University, UK.

Her work probes the influence of multi-dentate ligands on both cellular and bacteria cytotoxicity and will eventually be submitted for publication in a high-impact journals.

Separation from Chaos

The ability to separate molecules, ions and particles is of great importance to chemical analysis and purifications as well as several industrial processes (e.g., pharmaceuticals/medical, mining, electroplating, agriculture, desalination, etc). Traditional separation methods are batch procedures (e.g., filtration, column chromatography) and can be complex and expensive. Continuous flow separation/ continuous flow concentration technologies offer alternatives and expansions to current approaches. One novel way to separate molecules is to use their own random motion, i.e., diffusion, against and this is precisely what a Brownian ratchet does. Separation in a Brownian ratchet device occurs at an angle to the direction of the flow allowing for continuous injection, collection, analysis/monitoring, and is well suited to 'in-line' processes or for pre-concentrators. Figure Z depicts common separation approaches and shows the general operation of a ratchet device. In a geometric (2D) Brownian ratchet molecules in a mixture are forced through a periodic array of obstacles which are asymmetric with respect to the flow direction. Between the rows of obstacles the molecules diffuse and the particle distribution broadens so that when they enter the next row of obstacles the particle distribution is rectified by the obstacle shape/arrangement – but the asymmetry gives net transport in a direction at an angle to the flow. Since diffusion is related to molecular size, different molecules in a mixture may be separated via differences in their Brownian motion and hence their net transport. Alternatively, if a dilute solution is added along the top edge of the array then the solute would be concentrated at the bottom corner of the array.

WHAT DOES A TEARY-EYED, JOYFUL SANTA SAY ABOUT CHEMISTRY? HOH, HOH, HOH!

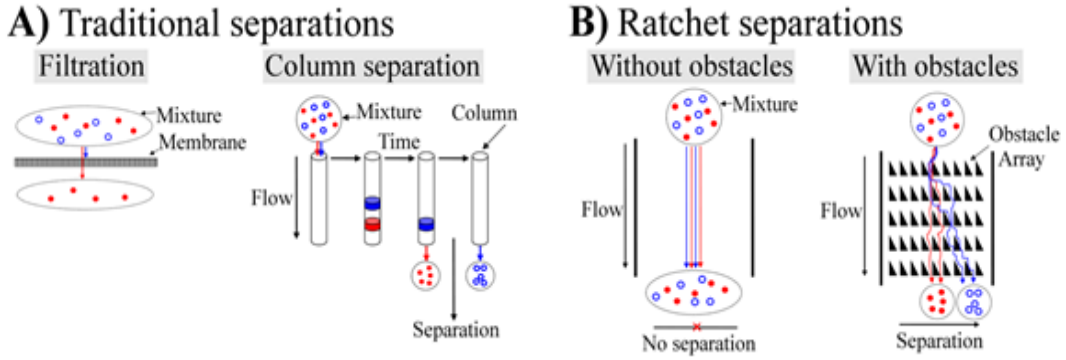
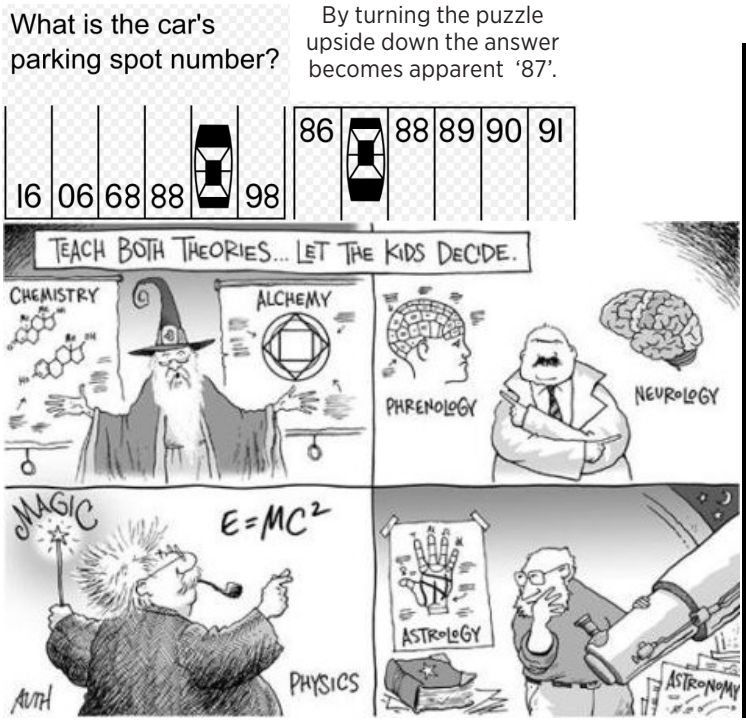
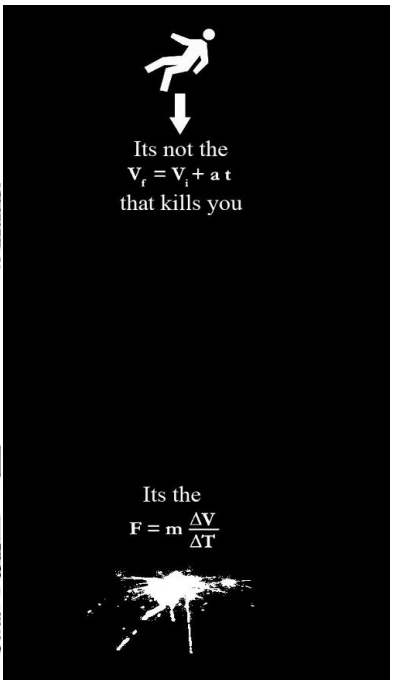


Figure Z Schematics of different separation methods. A. Traditional separations such as membrane filtrations and column separations, separate mixtures in the flow direction. Filtrations prevent molecules/particles of a certain size in the mixture passing through and in column separations a small amount of the mixture is added at a time followed by collection of each component separately. B. Ratchet separations may use an array of obstacles combined with diffusion or flow lanes to separate molecules at an angle to the flow. Without the obstacles there is no separation and the molecules co-elute and broaden due to diffusion. With the obstacle array there is separation at an angle to the flow.





MY NEW THEORY ON INERTIA DOESN'T SEEM TO BE GAINING MOMENTUM,

WELL; MY NEW THEORY ON GRAVITY JUST HASN'T GOTTEN OFF THE GROUND.

NANOSCALE ORGANISATION AND DYNAMICS

Professor William S. Price
Group Leader
- Medical Physics, MRI, NMR and diffusion

Professor Janice Aldrich-Wright
Lecturer
- Potent in-vivo cytotoxic agents

Professor Annemarie Hennessy
Dean of Medicine
- Preeclampsia

Assoc. Prof. Gary Dennis
Director Research School of Science and Health
- Polymer and surface chemistry

Dr Tim Stait-Gardner
National Imaging Facility Fellow
- MRI and quantum physics

Dr Allan Torres
Research Instrumentalist
Senior Lecturer
- NMR and MRI

Dr Gang Zheng
Lecturer
- NMR pulse sequence development

Dr Scott Willis
Post Doctoral Fellow
- NMR and MRI diffusion measurements

Dr Abhishek Gupta
Post Doctoral Fellow
- MRI contrast agent development and NMR relaxation

Dr Mikhail Zubkov
Biomedical Magnetic Resonance Facility Manager
- Modified diffusion sequences

THE SCIENCE OF TODAY IS THE TECHNOLOGY OF TOMORROW - EDWARD TELLER

Group Meetings

NANOSCALE RESEARCH / GRANT MEETINGS

Nanoscale Research/Grant Meetings are held monthly at Campbelltown with the next one to be held in February.

PROFESSOR WILLIAM PRICE'S LAB GROUP

Meet every Friday at 09:30 am in CA 21.1.65

BMRF USERS MEETING

February / May / August / November

PROFESSOR JANICE ALDRICH-WRIGHT'S LAB GROUP

Group meet every Friday at 10:00 am in 21.G.23

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