Joint BRSG and Medical Physics Meeting – Friday 17th April 2026

Institute of Physics, 37 Caledonian Road, London N1 9BU, UK

Programme

9:30 - 10:00 Refreshments / Arrivals

10:00 - 10:10 Opening remarks / Welcome

10:10 - 10:50 Geoffrey Bodenhausen - Long-lived states in solution-state NMR: from drug screening to silent spin waves

10:50 - 11:05 Steven Parnell - Spin precession of neutrons as a mechanism of probing effects of antibiotics on bacteria

11:05 - 11:20 Wing Ying Chow - Biomolecular solid-state NMR for ensembles of structures with relevance to health and disease

11:20 - 11:40 Coffee/Tea Break

11:40 - 12:05 Ozlem Ipek – Multinuclear clinical MRI coil development at 7 Tesla

12:05 - 12:20 Muhammad Suhaib Shahid - Dynamic mastication using Upright MRI: Visualisation of internal oral features, its potential association with BMI and AI

12:20 - 12:35 Marco Muccio - Optimizing MRI Acquisition for Spinal Cord Imaging

12:35 - 1:00 Stephen Wimperis - Multiple-quantum ^{23}Na MRI: methods old and new

1:00 - 2:00 Lunch

2:00 - 2:20 Catriona Rooney - Stable electron-irradiated [1-13C]alanine radicals for metabolic imaging with Dynamic Nuclear Polarisation

2:20 - 2:35 Kirsten Buniak - Exploiting Fast Field-Cycling NMR Relaxometry to Differentiate Sickle Cell Hemoglobin from Hemoglobin A

2:35 - 2:50 Luis Simbari - Solid-state MAS NMR and Dynamic Nuclear Polarization of nitroxide-templated metal halide perovskites

2:50 - 3:15 Jessica Winfield - Diffusion MRI in Cancer

3:15 - 3:40 Coffee/Tea Break 2

3:40 - 4:05 Melanie Britton - Through the Chemical Microscope, what MRI can tell us about spatially heterogeneous materials and processes

4:05 - 4:20 Menglu Wu - First in-vivo quantification of human brain potassium at 7T using a custom-built $^{39}K/^{1}H$ head coil

4:20 - 5:00 Ilya Kuprov - The exponential complexity scaling wall and how it fell in Magnetic Resonance (via video link)

5:00 - 5:10 Closing remarks

Long-lived states in solution-state NMR: from drug screening to silent spin waves

Geoffrey Bodenhausen[1]

[1]École Normale Supérieure, Paris, France

Long-lived states (LLS), or more precisely imbalances of populations of spin states belonging to different irreducible representations of the symmetry group of a spin system, have lifetimes that can greatly exceed the usual spin-lattice relaxation times, as has been shown by Malcolm Levitt and his group in Southampton. The lifetimes of LLS are exquisitely sensitive to perturbations of the symmetry, which occur when an achiral molecule weakly binds to a chiral partner such as a protein. This implies that long-lived states can be useful for drug screening. Long-lived states can be excited not only for pairs of chemically inequivalent nuclei such as carbon-13, but also for pairs of chemically equivalent but magnetically inequivalent protons as occur in aliphatic chains. In such systems, one can indirectly observe spin waves that propagate along a chain of CH2 groups. LLS methods can be combined with various hyperpolarization methods, such as dissolution and bullet dynamic nuclear polarization (d-DNP and b-DNP) or chemically induced dynamic nuclear polarization (CIDNP) to boost the sensitivity.

Spin precession of neutrons as a mechanism of probing effects of antibiotics on bacteria

Steven Parnell[1]

[1]Isis Pulsed Muon and Neutron Source, Rutherford Appleton Laboratory, Chilton, Oxfordshire, UK

It is well known that growing resistance to current antibiotics is leading to a need to search for new drugs. Changes in the overall bacteria size and shape and also within the cell wall in the peptidoglycan layer are expected, these changes are on very different length scales (nm vs microns) and often require complex preparation to view with microscopy.

So, we have asked the question, can we look at the structure of such bacteria using scattering techniques? In principle these methods allow us to study systems in-situ.

We present an initial investigation using scattering techniques which utilise neutron spin echo to encode the scattering angle and allow us to probe across this whole length scale range in dead bacteria. We show initial results showing measurement of the bacteria size and also effects upon the internal structure, moreover we also find some changes in this behaviour dependent upon the optical density showing differences between the exponential and rest phases.

Biomolecular solid-state NMR for ensembles of structures with relevance to health and disease

Wing Ying Chow[1], Ananya Singh[1], Abi Hession[1], Sabeeha Malek[2], Kacper Barbiarz[1], Teresa Massam-Wu[2], Paul Brighton[2], Darius Koester[1], Andrew Blanks[2], Mohan Balasubramanian[2]

[1]Department of Physics, University of Warwick,
[2]Warwick Medical School, University of Warwick, UK

Biography:
Ying carried out her PhD at Cambridge with Melinda Duer on solid-state NMR of cellular models of bone, then postdoc-ed in the labs of Hartmut Oschkinat in Berlin, Sabine Hediger and Gaël De Paëpe in Grenoble, working on solid-state NMR and DNP of various biological systems. She returned to the UK in 2022 and is now Associate Professor in Physics at the University of Warwick.

Solid-state NMR offers unique advantages for probing hydrated extracellular matrices in a range of biological settings. I will illustrate this with some examples of recent applications, from the cell wall of fungal organisms to cell culture models of disease. By focusing on the extracellular matrix, the functional end product, our work complements imaging (microscopy), biochemical, and genetic approaches.

Multinuclear clinical MRI coil development at 7 Tesla

Ozlem Ipek[1,2]

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[2]London Collaborative Ultra high field System (LoCUS), King's College London, UK

This talk presents a novel radiofrequency coil architecture enabling multi-nuclear MRI and spectroscopy of both hydrogen (^{1}H) and X-nuclei (^{2}H, ^{23}Na, ^{31}P, ^{39}K). At 7-Tesla field strength, simultaneous acquisition of high-resolution structural and metabolic information is highly desirable, yet no commercial coil currently provides high-quality ^{1}H/X-nuclei imaging within a single setup. Existing multi-nuclear workflows require swapping coils or compromising performance, effectively doubling scan time, cost, and workflow disruption. These limitations hinder broader clinical adoption of multi-nuclear MRI despite its clear potential for advancing metabolic and functional assessment.

Our laboratory is developing integrated parallel-transmit ^{1}H coil arrays combined with dedicated X-nuclei designs to support at least two multi-nuclear operating frequencies within one system. We are engineering solutions tailored for brain, extremity, cardiac, and torso imaging, with the goal of enabling efficient, high-performance structural and metabolic MRI/S in a single examination. This technology aims to remove key barriers to clinical translation and unlock the full diagnostic value of multi-nuclear imaging.

Dynamic mastication using Upright MRI: Visualisation of internal oral features, its potential association with BMI and AI

Muhammad Suhaib Shahid[1], Arthur Harrison[2], Olivier E Mougin[2], Gleb Yakubov[3], Galina Pavlovskaya[2]

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[2]Sir Peter Mansfield Imaging Center, University of Nottingham,
[3]School of Food Science and Nutrition, University of Leeds, UK

This study reports the first development of a dynamic upright MRI protocol to visualise mastication in a physiologically relevant seated posture and examine its potential association with body mass index (BMI). Mastication is a complex biomechanical process requiring coordinated activity of the teeth, jaw, tongue, and saliva. While previous research has linked higher BMI to altered chewing speed, a clear anatomical explanation for these differences has not been established.

Thirty-five healthy adult volunteers with contrasting BMI histories participated in this study. Imaging was performed on a 0.5T ASG Paramed open MRI scanner, enabling upright positioning to replicate natural eating conditions. Both head and neck coils were assessed, with the neck coil providing optimal contrast and coverage. Participants undertook controlled chewing cycles using a banana sample while a rapid 2D gradient-echo sequence (TR/TE 5.7/1.2 ms; 200 frames at 2.6 Hz; 77-second acquisition) captured dynamic image series. The images were reconstructed into video sequences for qualitative evaluation of bolus formation, occlusal contact, tongue–palate interaction, jaw kinematics, and swallow progression.

The optimised protocol successfully visualised successive stages of mastication, including food preparation, bite progression, jaw closure, bolus consolidation, and swallowing. Preliminary comparisons suggest that individuals with higher BMI histories exhibit reduced craniovertebral angle and more advanced bolus progression at swallow, potentially reflecting differences in oral cavity geometry, posture, or soft-tissue compliance influencing masticatory efficiency.

Although currently limited by qualitative assessment, this proof-of-concept study demonstrates the feasibility and capability of upright dynamic MRI to characterise the “anatomy of mastication” in vivo. The approach establishes a platform for future quantitative investigations of how anatomical variation, eating behaviour, and posture interact in obesity and metabolic health. Integration of deep learning–based analysis will enable automated feature extraction, motion tracking, and generative modelling, supporting classification of masticatory patterns and exploration of their health associations.

Optimizing MRI Acquisition for Spinal Cord Imaging

Marco Muccio[1], Damian Tyler[1], James Grist[1]

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Spinal cord MRI is central to diagnosing and monitoring of several neurological diseases and injuries, yet it remains technically challenging because of the cord's small size, heterogeneous surroundings, and sensitivity to respiratory, vascular, and cerebrospinal fluid motion. The spinal cord is particularly relevant in multiple sclerosis (MS), where recent diagnostic criteria incorporate spinal lesions which correlate strongly with disability and prognosis [1,2]. Nevertheless, spinal MRI remains comparatively underdeveloped relative to brain imaging.

This study aimed to optimize MRI sequences sensitive to MS pathophysiology to inform improvements in clinical spinal protocols. Five healthy volunteers (mean age ~25 years; three males) were scanned on a 3 T GE system using head and chest coils. Acquisitions included routine contrasts (T1-weighted, T2-weighted, proton density) and advanced techniques such as T2* mapping, white-matter-null, magnetization transfer ratio, and diffusion tensor imaging.

Optimization focused on improving resolution, signal-to-noise ratio, and robustness to motion. Dynamic local shimming and saturation bands around the field of view consistently improved image quality across sequences. Dividing acquisitions into two cervical blocks enabled better compensation for spinal curvature and more accurate axial orientation. For motion-sensitive sequences, PROPELLER approaches minimized motion effects, while cardiac-triggered (ECG and pulsoxymeter) T2* mapping minimized pulsatility artifacts (ghosting in phase encoding direction) by synchronizing acquisition to the cardiac cycle.

Ongoing work will assess repeatability, compare reconstruction strategies, and refine a clinically-feasible comprehensive spinal MRI protocol to be investigated in MS patients, with the goal of enabling earlier diagnosis, differential diagnosis, treatment monitoring, and ultimately improve patient care.

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Multiple-quantum ^{23}Na MRI: methods old and new

Stephen Wimperis[1]

[1]Department of Chemistry, Lancaster University, Lancaster, UK

Multiple-quantum NMR techniques have become essential tools in the study of spin I = 3/2 nuclei, such as ^{7}Li, ^{23}Na, ^{39}K and ^{87}Rb. For example, in purely isotropic liquids or biological systems, triple-quantum filtered 23Na NMR can be used to separate the signal from ions experiencing slow dynamics from that of sodiums experiencing very fast dynamics. In most heterogeneous biological systems a further, non-isotropic ion environment is encountered, where the sodium ions interact with ordered molecular structures and hence exhibit a distribution of quadrupolar splittings in the ^{23}Na NMR spectrum. This pool of ions can be selectively detected using a double-quantum filtration NMR technique where one or more of the radiofrequency pulses in the filtration step have a 54.7° (or "magic angle") flip angle.

Multiple-quantum techniques have also been used in ^{23}Na MRI with the aim of obtaining a novel source of image contrast. In early demonstrations, many of the proposed methods used the same radiofrequency pulse sequences applied in NMR spectroscopy. Subsequently, concerns over the specific absorption rate (SAR) of radiofrequency energy led to an interest in methods where a reduced number of pulses was used. Such "reduced" techniques have been applied both in triple-quantum filtered ^{23}Na MRI and also, much more recently, in "magic angle" double-quantum filtered ^{23}Na MRI where the aim is to selectively image sodium ions in ordered environments.

In this talk, I will discuss some of the problems inherent in these "reduced" multiple-quantum ^{23}Na MRI methods and demonstrate partial solutions, in particular for the imaging of sodium ions in ordered environments. Methods for boosting the sensitivity of such experiments will also be suggested.

Stable electron-irradiated [1-^{13}C]alanine radicals for metabolic imaging with Dynamic Nuclear Polarisation

Catriona Rooney[1,2]

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Dissolution dynamic nuclear polarisation (dDNP) enables >10^4-fold signal enhancement in metabolic MRI by generating hyperpolarised injectable solutions of ^{13}C-labelled metabolites. Conventional dDNP has not yet seen widespread clinical adoption. The technique relies on exogenous radical polarising agents to enable the build-up of nuclear polarisation, but these radicals must be removed prior to injection.

In this work, an alternative strategy was explored in which ultrahigh-dose electron irradiation generates nonpersistent radicals directly within [1-^{13}C]alanine. Our findings showed that these radicals are stable for months in the solid state at room temperature, with concentrations tuneable by irradiation dose, yet spontaneously quench upon dissolution, eliminating the need for post-polarisation filtration.

Despite the absence of conventional radical additives, nuclear polarisation levels of ~17% were achieved, comparable to trityl-based sample mixtures (19%) and, following dissolution, a longer T1 (77 s) at 1.4 T. However, the underlying polarisation process is not yet fully understood in this system.

Ultimately, we believe this approach could enable centralised sample preparation, storage, and distribution, allowing ready-to-use clinical samples to be deployed on demand and reducing the need for on-site pharmacy facilities with sterile compounding capability. This may address a key practical and regulatory barrier to scalable clinical dDNP.

Exploiting Fast Field-Cycling NMR Relaxometry to Differentiate Sickle Cell Hemoglobin from Hemoglobin A

Kirsten Buniak, David Faux, Manuel Arsenio Lores Guevara, Remi Kogon, Nestor Juan Rodriguez de la Cruz

Hemoglobin S (HbS) is the primary protein within the red blood cells of patients suffering Sickle cell anemia (SCA). SCA is a serious blood disorder that can lead to widespread organ damage and even death. Current diagnostic tests have their limits, whether it is due to cost, reliability, time constraints, staffing, or ability to distinguish between different cell types. In search of better alternatives, many new techniques are being explored. This study investigates fast field-cycling nuclear magnetic resonance (FFC NMR) relaxometry as a low magnetic field alternative for distinguishing HbS from HbA. Five blood samples from healthy individuals and two samples from patients with sickle cell disease (SCD) were processed by classical methods. Each HbA and HbS sample was subject to repeat measurements of the frequency-dependent relaxation rate R_1 (f). Each NMR dispersion (NMRD) profile was analyzed using the 3-Tau Model (3TM) providing seven physically meaningful fit parameters per sample. The Fe(III) content was important for defining the shape and form of the NMRD profiles. The surface water dynamic time constant τ_l and desorption time constant τ_d for HbS were found to be approximately half those for HbA. The bulk water dynamic correlation time τ_b was found to be linked to HbS polymerization and directly related to viscosity. Protein dynamics do not contribute significantly to NMRD profiles. The 3TM analysis of NMRD profiles allows HbA and HbS to be clearly distinguished. FFC NMR shows promise as a diagnostic technique for blood conditions such as SCD, leukemia and conditions that lead to the thickening of blood.

Solid-state MAS NMR and Dynamic Nuclear Polarization of nitroxide-templated metal halide perovskites

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[2]Aix-Marseille Université, France

Biography:
Luis Simbari is a chemistry PhD student at the University of Birmingham. He graduated from the University of East Anglia and works with solid-state NMR and mechanochemistry for the discovery of new optoelectronic materials among other solid state chemistry applications.

Metal halide perovskites are a rapidly developing class of semiconductors, widely known for their applications in solar cells. Solid-state NMR has already delivered significant atomic-level insights into these materials, notably on their local structure, ion dynamics, and speciation of dopants. In device architectures, halide perovskites are used as thin films and studying them with MAS NMR in this form is a challenge due to their limited mass. Dynamic Nuclear Polarization (MAS DNP) would be the ideal solution, but its application to this class of solids has been largely limited to fully inorganic perovskites (Mishra et al. J. Phys. Chem. C 2023, 127, 11094–11102) owing to the challenges associated with hyperpolarization transfer efficiency through 1H-1H spin diffusion in the organic-inorganic materials when exogenous polarizing agents are used (Hanrahan et al. Chem. Mater. 2018, 30, 7005–7015).

Here, we proposed another approach: incorporating polarizing agents directly into the structure of metal halide perovskites to provide an endogenous source of polarization. We present the synthesis and full characterization (XRD, EPR, MAS NMR, MAS DNP) of hybrid halide perovskite materials incorporating ammonium-nitroxide radicals. We use the radical concentration dependent Paramagnetic Relaxation Enhancements of 1H T1 relaxation as atomic-level evidence for the incorporation of the nitroxides into the halide perovskite structures. We anticipate that this approach will enable MAS DNP on mass limited samples, such as µg-level single thin films.

Diffusion MRI in Cancer

Jessica Winfield[1,2]

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[2]The Institute of Cancer Research, London, UK

Diffusion-weighted MRI (DW-MRI) is a well-established technique in cancer imaging. DW-MRI is used for tumour detection, characterisation and response assessment across a wide variety of tumour types and anatomical sites. DW-MRI is non-invasive and provides functional information about the whole tumour volume, making DW-MRI particularly well-suited to serial measurements during the course of treatment as well as for clinical research.

This talk will discuss current clinical applications of DW-MRI and topics of ongoing clinical research in oncology. We will describe common clinical uses of DW-MRI including prostate, breast and whole-body imaging and will discuss acquisition methods employed routinely on clinical MRI scanners. We will describe some areas of clinical research in oncology including biophysical models, histological validation studies and ongoing developments in image acquisition. Finally we will discuss some of the remaining challenges and future directions.

Through the Chemical Microscope, what MRI can tell us about spatially heterogeneous materials and processes

Melanie M. Britton[1]

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Nuclear Magnetic Resonance (NMR) spectroscopy is the pre-eminent analytical technique used to determine molecular structure and dynamics of molecules. When NMR experiments are performed in the presence of magnetic field gradients, the NMR signal becomes spatially-dependent, resulting in magnetic resonance imaging (MRI), which is now fully-established in biomedical research and clinical diagnosis. These contrasting techniques demonstrate the versatility of magnetic resonance to provide an integrated, non-destructive view of the structure, dynamics and function in molecular systems; where spectroscopic information, at the atomic level, can be integrated with relaxation and diffusion data to characterise systems across mesoscopic and macroscopic length scales. The synergy between these modalities enables MR techniques to probe a broad range of systems, many of which not accessible via other analytical techniques. In this talk, I will present examples showing how MRI is able to visualize composition, transport and reaction to study spatially-heterogeneous chemical systems in a diverse range of applications, including electrochemical, consumer products and complex fluids. Furthermore, I will demonstrate how the exchange of approaches between solution-state, solid-state and imaging disciplines can unlock new insight and technical capabilities.

First in-vivo quantification of human brain potassium at 7T using a custom-built $^{39}K/^{1}H$ head coil

Menglu Wu,[1,2] Jon O. Cleary,[2,3] Philippa Bridgen,[2,3] David W. Carmichael,[1,2] Özlem Ipek[1,2]

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Quantitative potassium (^{39}K) imaging of the human brain could provide a non-invasive biomarker of ionic homeostasis and tissue viability [1,2], but remains challenging because of the low gyromagnetic ratio (~22 times lower than proton) and rapid transverse relaxation. Clinical feasibility of ^{39}K quantification has recently been demonstrated with a commercial coil in skeletal muscle [3]. Here we demonstrate, to our knowledge, the first in-vivo quantification of brain potassium at 7T using a custom-built $^{39}K/^{1}H$ head coil.

A custom 7 T head coil was developed, consisting of an 8-rung low-pass ^{39}K birdcage resonator (13.9 MHz) integrated with eight ^{1}H centre-shortened dipoles (297.2 MHz). The design was validated in phantom experiments and electromagnetic simulations. Human simulations were then performed in Duke and Ella models to estimate specific absorption rate (SAR) for safety factor estimation. Two healthy volunteers were scanned on a 7T MR scanner (MAGNETOM Terra.X, Siemens Healthineers, Germany). Six external reference tubes containing known KCl concentrations (100–300 mM) were positioned around the head for calibration. Anatomical ^{1}H images were acquired with 3D GRE, and ^{39}K images with 3D UTE (8.5 mm isotropic, acquisition time 14 min, averaged across three acquisitions). Voxel-wise potassium concentration maps were generated by linear calibration from the reference-tube signal.

The integrated coil enabled successful acquisition of co-registered ^{1}H anatomical and ^{39}K brain images in both volunteers. Estimated whole-brain potassium concentrations were 60.1±7.5mM and 55.1±11.5mM, consistent with the expected physiological range [4,5]. These results establish the technical feasibility of in-vivo human brain ^{39}K quantification at 7 T and provide a foundation for future studies of neurological disease and metabolic dysfunction. Further investigation will evaluate reproducibility across sessions and refine calibration methods to reduce inter-subject variability. Further optimisation of pulse sequences and image processing may improve SNR and spatial resolution, facilitating translation toward patient studies.

References

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The exponential complexity scaling wall and how it fell in Magnetic Resonance

Ilya Kuprov[1]

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This lecture presents a mathematical and historical overview of a major recent development in magnetic resonance theory and software: the adoption of incomplete basis sets and the resulting improvement in the efficiency of numerical simulations from exponential complexity scaling to low-order polynomial scaling, whereupon time domain simulations (including accurate treatment of relaxation, chemical kinetics, and spatial transport) of biological systems with hundreds of interacting spins have become feasible.

Magnetic resonance simulations used to be hard because the dimension of the density matrix goes at least as 2^n with the number of spins — hence the exponential complexity scaling. Some corners can be cut using symmetries, conservation laws, and sparse array storage, but this does not solve the fundamental scaling problem. DMRG-type methods likewise cannot handle long-range time evolution of irregular polycyclic dissipative interaction networks that are common in biological spin systems. Until 2007, the problem stood unsolved.

This has changed in 2007 with the introduction of restricted state spaces [1] and their special case later called low correlation order approximation [2]. It turned out that most of the quantum mechanical state space of weakly interacting dissipative spin systems at room temperature is dynamically unreachable [3], and local reduced basis sets [4] are an excellent approximation. It was later shown that these methods sometimes work in solid-state magnetic resonance [2,5], where the powder averaging operation makes the dynamics effectively dissipative [6]. The mathematics of state space restriction is complicated (the dynamical manifold is not only a linear space, but also a Lie algebra [7]), but a convenient software implementation now exists [8] that covers the whole of magnetic resonance spectroscopy and imaging. At the time of writing, over 20 years of work has gone into a variety of numerical efficiency tweaks [9].

There are still cases (for example, crystalline solids at low temperatures) where the complexity of spin dynamics simulations scales exponentially, but in the daily life of a magnetic resonance spectroscopist such systems are few and far between; as of 2026, the Spinach package [8] would run most real-life magnetic resonance simulations on a good laptop.

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