Book of Abstracts

INTERNATIONAL CONFERENCE

IMAGING25

September 22 – 25, 2025
University of Milano-Bicocca, September 22, 2025 and
Villa Monastero, Varenna, Italy September 23-25, 2025

Organized by
- "Piero Caldirola" International Center for the Promotion of Science and ISPP, Italy
- Università degli Studi di Milano-Bicocca, Italy
- INFN Sezione di Milano-Bicocca, Italy
- Università della Calabria, Italy

We thank for the contribution:

International Conference on IMAGING25

September 22 – 25, 2025

Programme of September 22nd

Location: Aula Sironi, Department of Physics, building U2, University of Milano-Bicocca

Piazza della Scienza, 3 - 20126 Milano (Italy)

10.00 Introduction (Aula Sironi) Institutional greetings

10.15-11.00 Holé Clement (ESRF, France) Fluorescence and image registration

11.00-12.00 Nikolay Kardijlov (Helmholtz Centre Berlin for Materials and Energy, Germany) Neutron imaging data processing – basic principles, software tools and applications

12.00-14.30 Poster session and LUNCH

14.30-15.15 Hafiz Muhammad Fahad (Ludwig Maximilians University, Germany) Building AI solutions for Biomedical Imaging Challenges

15.20-16.05 Francesca Palermo (CNR, Italy) Image processing of Synchrotron Radiation tomography X-ray data

16.05-16.20 Break

16.20-17.00 Davide Tornotti (UNIMIB, Italy) Methods and Applications of Volumetric Data Analysis in Astrophysics

17.00-17.30 Alberto Bravin/Giulia Marcucci (UNIMIB, Italy) How to prepare a successful proposal for a Large-Scale Facility (X-rays, neutrons)

Closing of the session

IMAGING 2025

Villa Monastero, Varenna
September 23-25, 2025

DAY 1 - TUE 23 SEPT

Start	End			
09:00	10:00	*Registration and welcome coffee under the marquee (9:30-10.00)*		
10:00	10:20	*Welcome*	*Alberto BRAVIN, Daniela DI MARTINO*	

MORNING

Data processing, Artificial intelligence and new imaging applications

Start	End			Title
		Chairs:	*A. Bravin - M. Paganoni*	
10:20	10:50	*INVITED*	**J. BATENBURG, Uni Leiden**	Towards agentic imaging
10:55	11:15		**M. Brix**, Oulu	Photon Counting CT for coronary artery disease diagnosis: A Cost-Effectiveness Study in the Finnish Healthcare Context
11:20	11:40		**S. Lossano**, INFN Pisa	Real-time nanoscale imaging using deep learning super-resolution
11:45	12:05		**P. Lecoq**, Cern	Deployment of Nuclear Imaging Techniques to Low and Medium Income Countries
12:10	12:30	*Group Photo*		
12:30	14:30	*Lunch break (free)*		
		POSTER to be hung		

AFTERNOON

Imaging for cultural heritage (X-rays and neutrons)

Start	End			Title
		Chair:	*A. Fedrigo*	
14:30	15:00	*INVITED*	V. GONZALEZ, ENS Saclay	Multi-scale X-ray imaging to decipher the synthesis, use and alteration of historical inorganic pigments
15:05	15:35	*INVITED*	H. CASTILLO-MICHEL, ESRF	X-ray nano-spectroscopy at ESRF beamline ID21: Applications in life sciences
15:40	16:00		M. Cotte, ESRF	Cultural heritage at the European Synchrotron: improving experience far beyond the machine
16:00	16:30	*Coffee and POSTER SESSION opening*		
		Chairs:	*D. Di Martino*	
16:30	17:00	*INVITED*	A. FEDRIGO, ILL	Beyond the Surface: Neutron Imaging in Cultural Heritage Research
17:05	17:25		F. Salvemini, ANSTO	Advancing Cultural Heritage Science with Neutrons: 10 Years of ANSTO Contributions
17:30	17:50		A. Kaestner, PSI	What neutrons can tell about your sample
17:55	18:15		G. Marcucci, UNIMIB	At the edge of the Solar System: mapping the elemental distribution of meteorites through neutron resonance transmission imaging
18:20	18:40		C. Garagiola, UniTO	Application of an innovating laboratory-based phase contrast X-ray imaging system for the study and characterization of cultural heritage materials
18:45	19:05		G. Iori, SESAME, ETH	One year of non-destructive Synchrotron CT imaging of cultural heritage artifacts at SESAME BEATS
19:05		*Moving to the Welcome Party (on foot)*		
19:30		*Welcome Party*		

DAY 2 - WED 24 SEPT

MORNING

Imaging for astrophysics, homeland security and engineering, NEW IMAGING TECHNIQUES

Start	End			Title
		Chairs:	*J. Batenburg - A. Patera*	
09:00	09:30	*INVITED*	D. TORNOTTI, UNIMIB	Tomography imaging and data analysis techniques for volumetric data: applications in astrophysics
09:35	09:55		M. Riva, PoliMI	A wide-field Fourier-transform hyperspectral microscope for excitation spectroscopy
10:00	10:20		D. John, TUM	Material decomposition using modulation-based X-ray phase tomography
10:25	10:45		F.S. Maddaloni, UniMi, S.Raffaele	Preliminary investigation of spectral performances of a clinical Photon-counting Computed Tomography (PCCT) scanner
10:45	11:15	*Coffee break under the marquee*		
11:15	11:35		P. Perion, UniTS	A Dual-Detector X-ray Micro-Tomography System for simultaneous Spectral and Phase contrast Imaging
11:40	12:00		L. Brombal, UniTS	Modulation-based phase-contrast and hyperspectral imaging with Moench: a super-resolution direct-conversion hybrid detector
12:05	12:25		A. Gianoncelli, ELETTRA	Soft X-ray Microscopy Multimodal Imaging at TwinMic - Elettra
12:25	14:30	*Lunch break (free)*		

AFTERNOON

Biomedical imaging for diagnosis and therapy: techniques and achievements

		Chairs:	*L. Brombal - S. Donato*	
14:30	15.00	*INVITED*	**F. PALERMO, CNR Nanotec**	Advancing preclinical research on neurodegenerative diseases through X-ray imaging
15:05	15:35	*INVITED*	**R. MOKSO, Tec. Univ. Denmark**	Two clinical cases for laboratory phase contrast microCT
15:40	16:00		**S. Donato**, UniCal	Topological Mapping of Fat and Glycogen Distribution in Metabolic-Associated Fatty Liver Disease using micro- and nano-CT
16:05	16:25		**M. Croughan**, Monash	Directional dark-field x-ray image retrieval from a single sample image: with refinements and applications
16:25	16:55	*Coffee break under the marquee*		
16:55	17:15		**S. Rautio**, UniHelsinki	Metal segmentation and reconstruction of CBCT sinograms with 3D complex wavelets
17:20	17:40		**A. Olivo**, UCL	Three-dimensional hematoxylin and eosin (H&E) histology enabled by laboratory-based, multi-modal X-ray microscopy
17:45	18:05		**H. Allan**, UCL	Multiscale and extended field-of-view X-ray phase-contrast microtomography of soft tissues with a laboratory system
18:10	18:30		**C. F. Navarrete-Leon**, UCL	X-ray dark-field tomography of ex-vivo fibre-structured tissues in a compact laboratory system
18:35	18:55		**A. Rossi**, UCL	Novel fabrication methods for high-energy X-ray Phase Contrast Imaging
19:00	19:20		**M. Santini**, Univ. Bergamo	Estimation of tissues diffusion coefficients based on X-ray high-resolution radiographies
19:30		*Bus departure to Social Dinner*		
20:00		Social Dinner		

DAY 3 - THUR 25 SEPT

MORNING

Biomedical imaging for diagnosis and therapy: techniques and achievements

		Chairs:	*R. Menk - K. Morgan*	
09:15	9:45	*INVITED*	**E. VOCATURO, CNR Nanotec**	Innovative AI Solutions for Enhanced Diagnostic Accuracy in Medical Imaging
9:50	10:05		**F. Cognigni**, Zeiss	New Horizons in AI-Driven Workflows for X-ray Microscopy
10:10	10:30		**A. Patera**, CELLS	Hard X-ray imaging at the ALBA synchrotron: a dynamic, multimodal and multiscale experience
10:30	11:00	*Coffee break under the marquee and POSTER SESSION ending*		
11:00	11:20		**Y.Y. How**, TUM	In vivo 4D x-ray dark-field lung imaging in mice
11:25	11:45		**L. D'Amico**, Monash, Elettra	Investigation of ventilator-induced lung injury (VILI) using single-grid dark field
11:50	12:10		**S. Alloo**, Monash	Leveraging Intensity Flow for Image Reconstruction: Fokker-Planck X-ray Grating Interferometry
12:15	12:35		**L. Costello**, Monash	Zooming in on Lung Cancer: Region of Interest Diagnostic Imaging
12:40	13:00		**J.A. Pollock**, Monash	Low-Dose, High-Resolution CT of Infant-Sized Lungs via Propagation-Based Phase Contrast
13:00	13:30	*Awards and closing remarks*		

Intelligent Imaging for Scientific Discovery

K.J. Batenburg

Centrum Wiskunde & Informatica, Amsterdam, The Netherlands
Leiden Institute of Advanced Computer Science, Universiteit Leiden, Leiden, The Netherlands

Modern imaging technologies have transformed how we perceive the visible world, yet our ability to non-invasively explore the interior of objects—from human organs to historical artifacts—remains constrained. Current approaches to 3D interior imaging, such as CT and related modalities, often involve immobile and resource-intensive equipment, with meaningful insights arriving only after substantial post-processing and expert analysis.

This talk explores how a combination of classical Computational Imaging and Artificial Intelligence can change that paradigm. By embedding intelligence directly into imaging systems, we can envision scanners that not only acquire data, but also guide experiments, adapt acquisition strategies in real time, and collaborate with human experts as true research partners. Using cultural heritage as a motivating case, I will discuss how such intelligent imaging systems might shape the future of scientific discovery, and the broader implications of moving from static data acquisition to interactive, AI-driven exploration.

Photon Counting CT for coronary artery disease diagnosis: A Cost-Effectiveness Study in the Finnish Healthcare Context

M.A.K. Brix[1,2]*, M. Okkonen[3], T. Mäkelä[3], M. Nikki[2], M. Korhonen[4], M.T. Nieminen[1,2]

[1]*Research Unit of Health Sciences and Technology, University of Oulu, Oulu, Finland.*
[2]*Department of Diagnostic Radiology, Oulu University Hospital, Oulu, Finland.*
[3]*Department of Cardiology, Oulu University Hospital, Oulu, Finland.*
[4]*Department of Economics, Finance and Accounting, University of Oulu, Finland*
*Corresponding author: mikael.brix@oulu.fi

Photon-counting detector CT (PCD-CT) has shown promise in reducing downstream diagnostic testing burden in coronary artery disease (CAD) assessment compared to conventional energy-integrating detector CT (EID-CT). This benefit is due to PCD-CT's improved reclassification accuracy, referring to its ability to assign Coronary Artery Disease Reporting and Data System (CAD-RADS) grades more accurately. CAD-RADS is a standardized system that quantifies stenosis severity in coronary CT angiography and guides subsequent testing. The financial implications of the reduced number of follow-up examinations have not been addressed in European healthcare context.

In this study, costs for PCD-CT and EID-CT coronary CT angiographies were estimated using Monte Carlo simulations of 10,000 patients over a 10-year scanner lifespan. Finnish diagnostic pathways and cost structures were used. Two clinical scenarios were modeled: a guideline-based pathway emphasizing functional testing and a local practice where invasive coronary angiography (ICA) is the primary follow up. Previously reported CAD-RADS reclassification rates for PCD-CT and EID-CT were applied to direct downstream testing. Grades 0 to 2 require no follow up, while grades 3 to 5 will be further examined either using functional testing and/or ICA. Sensitivity analyses were conducted to evaluate the effects of including CAD-RADS 0 patients and of varying plaque composition assumptions, both of which have not been previously evaluated.

Significant reductions in downstream testing were observed with PCD-CT across both scenarios, corresponding to a 26.9% to 33.8% cost reduction. Despite a €1,500,000 cost premium with the PCD-CT scanner, break-even threshold of cumulative costs was achieved after 4,950 to 7,880 patients, depending on the scenario. Through sensitivity analyses, it was shown that the break-even threshold was strongly affected by underlying assumptions about patient demographics. When mixed plaque compositions were modeled or CAD-RADS 0 patients were included, the cost benefit threshold was delayed by 2,500 to 4,900 patients, in some cases exceeding the projected 10-year patient volume.

Substantial diagnostic and economic benefits can be realized with PCD-CT in high patient volume settings. However, cost effectiveness is highly dependent on reclassification accuracy and population demographics assumptions. Therefore, localized health economic assessments supported by sensitivity analyses are recommended before capital investment decisions are made.

Real-time nanoscale imaging using deep learning super-resolution

S. Lossano[1, *], S. Capaccioli[2,5], A. Catanzariti[2], F. Cella Zanacchi[2,5], E. Da Pozzo[3,5], F. Del Debbio[3], M.E. Fantacci[1,2,] F. Lizzi[1], R. Magrassi[4], D. Pisignano[2,5], C. Scapicchio[1] and A. Retico[1]

[1]*National Institute for Nuclear Physics (INFN), Pisa Division, Pisa, IT*
[2]*Department of Physics, University of Pisa, Pisa, IT*
[3]*Department of Pharmacy, University of Pisa, Pisa, Italy*
[4]*Istituto di Biofisica CNR, Genoa, Italy*
[5]*CISUP, Centro per l'Integrazione della Strumentazione dell'Universitá di Pisa, Pisa, Italy*
*Corresponding author: simone.lossano@pi.infn.it

In recent years, advancements in Super-Resolution Microscopy (SRM) have enabled fluorescence microscopy to achieve nanoscale detail, making it possible to observe cellular processes in live specimens. For example, techniques like Stochastic Optical Reconstruction Microscopy (STORM) can resolve structures smaller than 20 nm, yet acquisition times up to 90 minutes per image and difficulties with multicolor imaging make them less practical for real-time studies. To address these challenges, we adopted a deep learning approach by employing the Enhanced Super-Resolution Generative Adversarial Network (ESRGAN) to reconstruct high-resolution images from diffraction-limited ones [1]. This method significantly speeds up the data collection process and simplifies multicolor imaging complexities. Specifically, the network was trained to convert widefield (WF) diffraction-limited images—obtained in just seconds using a standard fluorescence microscope—into images that reproduce STORM-like images. This method achieves nanoscale imaging at four times the throughput of conventional fluorescence microscopy. The tool currently enables the detection of effects of FLASH radiotherapy on subcellular cytoskeletal characteristics and has already been applied to directly observe molecular motor movement as with dual-color STORM technique, greatly facilitating and accelerating the procedure. **Acknowledgments**: We acknowledge PNRR ECS00000017-THE Spoke 1 and Spoke 4 — CUP I53C21000350006, CUP I53C22000780001.

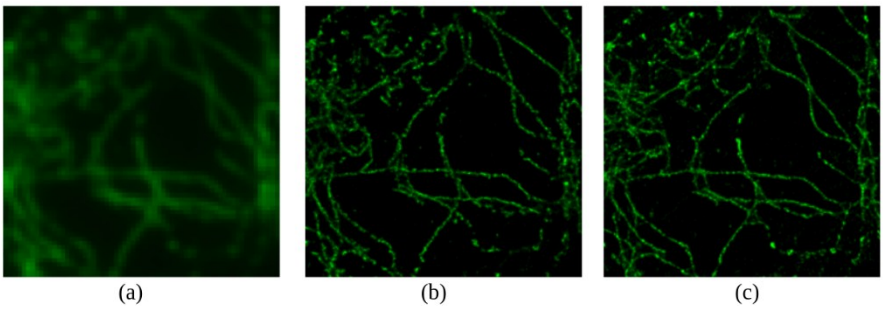

Figure 1 Cellular microtubules image detail: (a) Widefield (diffraction-limited) acquisition, (b) STORM acquisition, (c) AI-generated.

[1] S. Lossano *et al.*, *Mach. Learn.: Sci. Technol,* **6** 025001, doi : 10.1088/2632-2153/adc3e9

Deployment of Nuclear Imaging Techniques to Low- and Medium-Income Countries

P. Lecoq

CERN Honorary Member
European Academy of Sciences, Head of the Physics Division
Dr Honoris Causa Polytechnic University of Valencia, Spain

Nuclear Medical Imaging is at the forefront of molecular imaging diagnostic, theragnostic and treatment follow-up techniques for a number of diseases (cancer, neurodegenerative impairment, cardiovascular disorders, etc…), particularly in the rapidly growing context of personalised medicine. However, there is a dramatic unbalance for the access to molecular imaging diagnostic tools between highly developed and low- and medium-income countries (LCMIs).

Given the rapid adoption of new imaging technologies in high-income countries (HICs) to improve health outcomes, there are growing concerns around potential widening of disparities for the 66% of people worldwide without access to nuclear imaging. According to experts, low- to middle-income countries need to invest in imaging technology that focuses on local causes of death and disability, from cardiovascular disease to cancer. In a microsimulation based on 11 cancers, the Lancet Oncology Commission found that scaling up imaging technology in LMICs would significantly improve cancer survival and return $180 for every $1 invested [1].

Low-cost technologies designed specifically for LMICs can make huge strides toward addressing precise population health needs within the local context. This concept, dubbed “frugal innovation,” considers limited human resources and infrastructure and incorporating end-user feedback fromthe initial design stage. They are often portable, addressing the geographic barriers that often exist in LMICs, and are not intended to cheaply mimic high-end technology, but focus on intentionally addressing local health care needs while considering local challenges.

But the very fruitful cross-fertilisation between physics and medicine opens the way to the development of cost-effective and portable imaging approaches, allowing a better deployment of nuclear imaging modalities in low- and medium-income countries, with a huge economic impact and high return for each invested dollar. As presented in this talk, this ambitious goal is supported by the IAEA (International Atomic Energy Agency) and is in line with an initiative being prepared by the WHO (World Health Organisation) and the 3d out of 17 NATO sustainable goals for 2030: Good Heath and Well Being for everyone.

[1] H. Hricak et al., “Medical imaging and nuclear medicine: a Lancet Oncology Commission”. Lancet Oncol 2021; 22:136-72.

Multi-scale X-ray imaging to decipher the synthesis, use and alteration of historical inorganic pigments

Victor Gonzalez

Université Paris-Saclay, ENS Paris-Saclay, CNRS, PPSM, 91190, Gif-sur-Yvette, France

Omnipresent in paintings since the antiquity, inorganic pigments are key materials of art history. Collecting accurate chemical information on them is essential to achieve a better understanding of ancient pictorial practices, as well as to develop new conservation strategies.

However, this objective faces several scientific challenges. First, pigments were obtained in the past following complex chemical syntheses, whose parameters are not always known to us. Secondly, painters combined these materials in variable formulations and applied these formulations with their own unique artistic techniques, resulting in a strong heterogeneity of the hybrid [pigment(s) + binder] paint systems. Finally, paintings are dynamic objects: chemical interactions within paint layers can result in the *in situ* formation of non-original organometallic and/or inorganic compounds. The presence of these neo-formed materials can threaten the optical and/or physical integrity of artworks. This communication will present recent research aimed at deciphering the past synthesis, formulation by artists, and potential alteration mechanisms of historical pigments. A special focus will be put on the advantages of multi-scale chemical imaging to tackle the chemical complexity of the composite paint systems. At the micro-scale, the analytical power of synchrotron radiation, notably using structural analysis via X-ray Powder Diffraction (XRPD), enables them to discriminate between the multiple inorganic compounds present in paint layers, and to provide detailed information on their composition and microstructure. At the macroscale, the development of X-ray based chemical imaging prototypes enables the charting of crystalline species on the entire surface of historical paintings. The talk will illustrate the complementarity of structural data collected at the multi-scale on carefully designed model samples, historical paint fragments and entire artworks. The case of lead-based pigments and their associated alteration products will be specifically discussed.

X-ray nano-spectroscopy at ESRF beamline ID21: Applications in life sciences

H. Castillo-Michel

European Synchrotron Radiation Facility, Grenoble, France

ID21 is a beamline dedicated to X-ray fluorescence (XRF) mapping and X-ray absorption spectroscopy (XAS) in the tender X-ray range (2-11keV), this energy range allows detecting important nutrient elements (P, S, K, Ca, Mn, Fe, Cu, Zn) as well as rare earths and pollutants (Cd, Ag, Ce, La, Gd) in biological and environmental samples. A brand-new X -ray nanoscope is now in operation at the beamline. It offers enhanced capabilities for nano-XRF mapping and nano XAS. This new state-of-the-art instrument offers higher lateral resolution (down to 100 nm) with better XRF detection capacities (sub-ppm), higher acquisition speed, an improved cryogenic sample environment, preserving user-friendliness thanks to a new graphical user interface. Cryo-fixed biological samples can better cope with intense X-ray beams and the elemental distributions, chemical states, and sample morphologies are close to the in-vivo state under frozen-hydrated conditions. This presentation will highlight the present capabilities at ID21, and some examples of the research done at ID21 will be used to illustrate sample preparation protocols, data acquisition, and data analysis strategies.

Cultural heritage at the European Synchrotron: improving experience far beyond the machine

M. Cotte,[1,2]* C. Holé[1], G. Robertson[1], S. Delcamp[1], M. Bodin[1], V. Gonzalez[3], F. Vanmeert[4], L. Monico[5,6,7], Ida Fazlic[4], C. Dejoie[1], M. Burghammer[1], Wout de Nolf[1], L. Huder[1], E. Gutierez Fernandez[2], S. Fisher[1], H. Castillo-Michel[1], M. Salomé[1], V. Fernandez[1], P. Tafforeau[1], L. Paolasini[1]

[1]*European Synchrotron Radiation Facility France*
[2]*Laboratoire d'Archéologie Moléculaire et Structurale, CNRS UMR 8220, Sorbonne Universités, France*
[3]*Université Paris-Saclay, ENS Paris-Saclay, CNRS, PPSM, 91190, Gif-sur-Yvette, France*
[4]*Rijksmuseum, Amsterdam, Netherlands*
[5]*CNR-SCITEC, Via Elce di Sotto 8, 06123 Perugia, Italy*
[6]*Centre of Excellence SMAArt, University of Perugia, Via Elce di Sotto 8, 06123 Perugia, Italy*
[7]*Antwerp X-ray Imaging and Spectroscopy laboratory (AXIS) Research Group, NANOLab Centre of Excellence, University of Antwerp, Belgium*
*Corresponding author: cotte@esrf.fr

In 2019, the European Synchrotron's core machine was completely dismantled to install a revolutionary machine (EBS: Extremely Brilliant Source) producing a much brighter X-ray source. This upgrade has dramatically not only improved the properties of the X-ray beam (e.g. increase in brightness translating into higher flux, smaller beams and faster acquisitions) but also triggered several projects to improve the user experience, upstream and downstream data collection. As far as the cultural heritage community, this has motivated the implementation of a facilitated community access for structural analyses of historic materials (known as "BAG" access [1]). Access is granted every six months to two X-ray powder diffraction (XRPD) beamlines (ID13 for µXRPD 2D mapping and ID22 for high angular resolution XRPD) and beamtime is shared by a network of more than 120 international collaborators. The high throughput (>200 samples analysed per experiment) has motivated the creation of a dedicated database to make the data FAIR and facilitate its re-use by anyone (project "SHARE", funded by the OSCARS European Call). In parallel, the X-ray nano-spectroscopy beamline, ID21, has just been refurbished and offers unprecedented performance for 2D nano-XRF mapping, nano-XANES, possibly combined for hyper-spectral XRF mapping, in the 2.1-10 keV energy range. Efforts are also being made to provide users with easy-to-use graphical interfaces for data acquisition and to automate data processing and analysis. Regarding X-ray computed tomography, a new flagship beamline, BM18, has been built and optimized for multiresolution phase-contrast imaging of large objects. Thanks to a wide beam of up to 30 cm horizontally and an energy of up to about 300 keV in filtered white beam, several large fossils and a dozen of music instruments have recently been successfully imaged. In summary, the last five years have been instrumental in revolutionizing the user experience at the ESRF and, as recent examples will show, the benefits to the cultural heritage community are enormous.

[1] M. Cotte, V. Gonzalez, F. Vanmeert, L. Monico, C. Dejoie, M. Burghammer, L. Huder, W. de Nolf, S. Fisher, I. Fazlic, C. Chauffeton, G. Wallez, N. Jiménez, F. Albert-Tortosa, et al., *Molecules*, **2022**. *27*(6): p. 1997.

Beyond the Surface: Neutron Imaging in Cultural Heritage Research

A. Fedrigo

Institut Max von Laue, Paul Langevin (ILL) 71, avenue des Martyrs, CS 20156 38042 Grenoble cedex 9, France

Cultural Heritage Research encompasses a large variety of objects and materials, as well as anything that has historic, artistic, anthropological, and natural significance.

Scientific investigation in the domain of Cultural Heritage has evolved from a discipline focused on conservation to a broader research field aimed at developing the understanding of our Cultural History. In this matter, of particular importance are materials that have been transformed through human activity, like metals. Scientific investigations can help understanding their evolution from raw material to finished artefact, their diffusion and use, likely degradation, and conservation in museum collections.

Non-destructive neutron techniques represent an invaluable tool in Cultural Heritage Research, most notably because ancient objects are irreplaceable and must be preserved and passed on to future generations. In this talk, I will give an overview of how neutron imaging can be useful to investigate ancient metallic artefacts, from improving our knowledge on the manufacturing processes, to understanding how they are degrading over time due to changes in the environment.

In addition, the combined use of X-ray and neutron imaging provides additional element-dependent information which is fundamental in case of multi-material objects. The talk will give an overview of some neutron imaging cases in the field of Cultural Heritage—and ancient metallurgy in particular, spanning from looted artefacts from Iron Age Iran to ancient Egyptian artefact.

Advancing Cultural Heritage Science with Neutrons: 10 Years of ANSTO Contributions

F. Salvemini*

Australian Nuclear Science and Technology Organisation (ANSTO), Lucas Heights, NSW 2234, Australia

*Corresponding author: filomena.salvemini@ansto.gov.au

The need for non-invasive analytical methods has challenged the boundaries of cultural heritage research, driven technological advancements, and led to the routine application of a wide range of scientific tools. At the same time, the diverse nature of culturally significant objects necessitates an interdisciplinary, multi-technique approach to their study. Neutron techniques have become a well-established analytical means for the non-invasive investigation of ancient artefacts. The fundamental properties of the neutron—lack of electric charge, deep penetration power into matter, and interaction with atomic nuclei rather than electron clouds—make it an ideal probe for examining the bulk of various materials, including metals, ceramics, and organic compounds. Neutron Diffraction (ND) and Neutron Imaging (NI) are powerful tools for characterizing the compositional and microstructural properties of ancient artefacts, both qualitatively and quantitatively. An integrated approach combining ND and NI has enabled researchers to uncover new insights into the technological practices of past cultures without the need for sampling or invasive procedures.

This paper highlights the most significant cross-disciplinary studies conducted at the Australian Nuclear Science and Technology Organisation (ANSTO), carried out in collaboration with Australian research institutions, universities, and international partners.

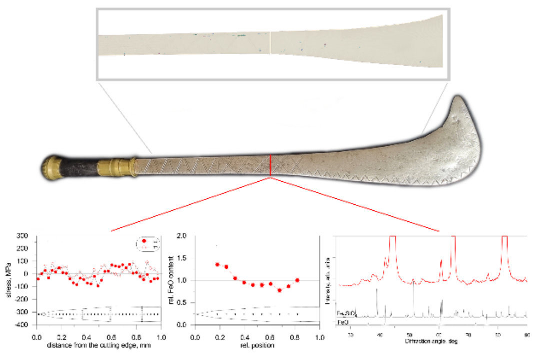

Figure 1 At the center, 19th century Dahomean swords. At the top, corresponding neutron tomography cross-section. At the bottom (from left to right), central line profiles of the longitudinal and transversal stress components, distribution of the FeO secondary phase, and experimental neutron full diffraction patterns [1].

[1] R. L. Anderson, F. Salvemini, M. Avdeev, V. Luzin (2025) An African Art Re-Discovered: New Revelations on Sword Manufacture in Dahomey. *Heritage*, **8(2)**, 62 https://doi.org/10.3390/heritage8020062.

What neutrons can tell about your sample

A. Kaestner

Center for Neutron and Muon sciences, Paul Scherrer Institut, Switzerland

Neutron imaging has become a well-established technique for non-destructively probing the interior of materials and observing dynamic processes. Originally rooted in traditional radiography and tomography, the field has evolved significantly, enabling insights into structures and phenomena that are often inaccessible with other methods, such as X-rays. This is particularly relevant for materials containing light elements, hydrogen-rich compounds, or complex assemblies with high-Z components.

At the Paul Scherrer Institut (PSI), we have played a pioneering role in advancing neutron imaging methodologies. Our efforts have contributed to the development of a broad suite of imaging techniques that allow for quantitative analysis of material composition and structural features well below the nominal pixel resolution of conventional radiographs.

Among these techniques are wavelength-resolved imaging, which enables Bragg edge imaging; dark-field imaging, which reveals ultra-small-angle scattering from microstructures; and correlative imaging approaches that combine neutron and X-ray modalities for comprehensive material characterization. These advanced methods are supported by PSI's state-of-the-art infrastructure, offering flexible beamline configurations and fully integrated experimental environments that facilitate complex, multi-modal investigations.

The continuing innovation in neutron imaging has opened new scientific frontiers across diverse research areas, from materials science and energy storage to geology and cultural heritage. We will present a selection of case studies demonstrating how our instrumentation and methodologies provide unique insights—ranging from the spatio-temporal mapping of water distribution root systems to the analysis of manufacturing techniques in ancient artifacts.

Through ongoing development and collaboration, PSI remains at the forefront of neutron imaging research, enabling breakthroughs that address both fundamental scientific questions and practical engineering challenges.

At the edge of the Solar System: mapping the elemental distribution of meteorites through neutron resonance transmission imaging

G. Marcucci[1,2*], M. Clemenza[1], M. Musa[3], M.P. Riccardi[3], F. Salvemini[4], A. Scherillo[2], D. Di Martino[1]

[1]*Dipartimento di Fisica "G. Occhialini", Università degli Studi di Milano-Bicocca and INFN Sezione di Milano-Bicocca, Milan, Italy*
[2] *STFC ISIS Neutron and Muon Source, Chilton-Didcot, United Kingdom*
[3]*Dept. of Earth and Environmental Science (DSTA), University of Pavia and INFN, Pavia Section, Pavia*
[4]*Australian Nuclear Science and Technology Organisation (ANSTO), Lucas Heights, Australia*

*Corresponding author: giulia.marcucci@unimib.it

Meteorites are a rare but valuable source of information about the earliest stage of the Solar System. These extraterrestrial rocks are directly linked to the solar system's evolution, and hypotheses about this remote process can be proposed through an analysis of their chemical compositions. Meteorites can be divided into three main categories: stony, iron and stony-iron meteorites. Stony meteorites consist mostly of silicate minerals and may contain small spheroidal grains (chondrules), while iron meteorites consist mainly of an iron-nickel alloy, being a source of metallic iron in ancient times. Conventionally, the investigation of the interior of a stone is carried out through thin sections, which allow the textures observation, the primary identification of the phases' distribution as well as some information about the impact parameters. However, this is an invasive method. Nowadays, the use of non-invasive nuclear techniques is becoming increasingly common across various fields and material types, proving to be highly effective when applied to meteorites. Our recent development of a new multidisciplinary non-destructive protocol for the analysis of stony meteorites [1] demonstrated the significant role of Neutron Resonance Transmission Imaging (NRTI) [2] in mapping the elemental distribution inside the bulk of these heterogeneous samples, exploiting the contrast enhancement that can be achieved. In particular, the detection and bulk mapping of trace elements, such as cobalt, can be reached with good accuracy thanks to the resonant way epithermal neutrons interact within the samples. Details of the NRTI technique will be provided, as well as a discussion of the results obtained through its application to a collection of chondrites and siderites provided by *Planetario e Osservatorio Astronomico G. Giacomotti* - Cà del Monte - Cecima (PV), Italy, in the framework of a collaboration between the Physics Department of Milano-Bicocca University and applied petrography group (DSTA) of Pavia University.

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Application of an innovating laboratory-based phase contrast X-ray imaging system for the study and characterization of cultural heritage materials

C. Garagiola[1,2]*, A. Re[1,2], E. Di Francia[1,2], L. Guidorzi[1,2], A. Lo Giudice[1,2], R. Boano[3], R. Giustetto[4], G. Ricchiardi[5], P. Cerello[2], E. Fiorina[2], M. Magalini[2], M. Marabotto[2], N. Mosco[2], L. Ramello[6,2], D. Trocino[2], D. Di Martino[7], G. Marcucci[7], L. Vigorelli[7], F. Pozzi[8], C. Ricci[8]

[1]*Dipartimento di Fisica, Università degli Studi di Torino, Torino, Italy*

[2]*INFN, sezione di Torino, Torino, Italy*

[3]*Dipartimento di Scienze della Vita e Biologia dei Sistemi, Università degli Studi di Torino, Torino, Italy*

[4]*Dipartimento di Scienze della Terra, Università degli Studi di Torino, Torino, Italy*

[5]*Dipartimento di Chimica, Università degli Studi di Torino, Torino, Italy*

[6]*Dipartimento per lo Sviluppo Sostenibile e la Transizione Ecologica, Università del Piemonte Orientale, Vercelli, Italy*

[7]*Dipartimento di Fisica "G. Occhialini", Università di Milano-Bicocca e INFN, sezione di Milano-Bicocca, Milano, Italy*

[8]*Centro per la Conservazione ed il Restauro dei Beni Culturali "La Venaria Reale", Venaria Reale (Torino), Italy*

* Presenting author: chiara.garagiola@unito.it

Phase-Contrast (PC) X-ray imaging is an effective technique for detecting low contrast details in weakly absorbing samples, as it provides high-quality information on micro-structural features [1], opening extremely interesting perspectives in the cultural heritage (CH) field, such as conservation, archaeology, archaeometry, anthropology, paleopathology.

The PITCH project, funded by MUR (PRIN2022 program), aims at designing, developing and characterising a laboratory Grating Interferometry (GI)-PC imaging setup based on a liquid-anode X-ray source, as well as at investigating and developing different data acquisition methods and algorithms for signal extraction and tomographic reconstruction. The system will be optimised for the study and characterisation of CH materials, both for radiographic and tomographic analyses.

For the refinement of the new setup and the development of reconstruction algorithms, a specific test object, i.e. a 3D printed cylinder with grids containing small samples of different materials related to the CH field, will be created. To optimise the instrument for CH materials, a selection of relevant materials for mock-up preparation used for preliminary tests has been made, including pigment layers, metallic yarns, textile material, leather, gilding on paper, parchment, cartonnage, barniz de Pasto, wood artifacts, shells and eggs from archaeological findings, pearls, mummified remains, animals preserved in formalin. Different sample geometries will be tested as well.

[1] M. Endrizzi, "X-ray phase-contrast imaging," *Nuclear Instruments and Methods in Physics Research A,* vol. 878, p. 88–98, 2018.

One year of non-destructive Synchrotron CT imaging of cultural heritage artifacts at SESAME BEATS

G. Iori[1,2*], P. Hans[1], N. M. E. Stucchi[3], L. U. Khan[1], G. Franceschin[3], A. Saadaldin[1,4], E. Possenti[5], G. L. Bonora[5], S. Al Khasoneh[6], H.-E. Mahnke[7] and G. Dardeniz[8]

[1]*SESAME – Synchrotron-light for Experimental Science and Applications in the Middle East, Allan, Jordan*
[2]*Institute for Biomedical Engineering, ETH Zürich and University of Zürich, Zürich, Switzerland*
[3]*Centre for Cultural Heritage Technology, Istituto Italiano di Tecnologia, Venezia, Italy*
[4]*Department of Mathematics, Faculty of Sciences, An-Najah National University, Nablus, Palestine*
[5]*Institute of Heritage Science, National Research Council, ISPC-CNR, Milan, Italy*
[6]*Sela for training and protection of heritage, Wadi Mousa, Petra, Jordan*
[7]*Ägyptisches Museum und Papyrussammlung, Staatliche Museen zu Berlin, Freie Universität Berlin, and Helmholtz-Zentrum Berlin, Germany*
[8]*Istanbul University, Faculty of Letters, Istanbul, Türkiye*

*Corresponding author: giiori@ethz.ch

This contribution highlights results from the first year of user operation of the synchrotron X-ray computed tomography (SXCT) beamline ID10-BEATS of SESAME for cultural heritage imaging research [1]. We will present modalities and results from experiments conducted on a variety of artworks and historical materials. Nano-CT using monochromatic light and propagation-based phase-contrast enhancement allowed to characterize the cementation production technology of faience microbeads from Central and Southwest Asia dating to 3000 BCE [2,3]. Pink-beam SXCT scans with energies higher than 70 keV were used to inspect strata-dependent cracks and microporosity in several centimeter-sized blocks of Roman mosaic mock-ups. Absorption-edge subtraction SXCT [4] of mock-up papyri scrolls enabled the identification and reconstruction of text written with carbon ink containing varying PbS concentrations (5 at% down to pure carbon) as well as with two red inks (minium and cinnabar). Using synchrotron phase-contrast SXCT and XRF, the composition (bulk and surface) and local alteration of a Roman glass fragment from Petra (Jordan) were analyzed. XRF complemented the SXCT results by identifying the glass as potash lime with Pb and Cu responsible for its dark green color, while revealing elevated Fe levels in the corrosion patina. In summary, SXCT imaging at SESAME BEATS is enabling the non-invasive, quantitative study of valuable archaeological specimens of different sizes and compositions and allows to test hypotheses about their manufacturing and degradation history, as well as develop novel restoration approaches. The opportunities for non-destructive examination and conservation of ancient materials provided by the first SXCT facility at the heart of Southwest Asia are vast.

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[3] G. Dardeniz et al. (2025) Tomography of Materials and Structures. 7:100056.
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Tomography imaging and data analysis techniques for volumetric data: applications in astrophysics

D. Tornotti

Dipartimento di Fisica "G. Occhialini", Università di Milano Bicocca e INFN, sezione di Milano Bicocca, Milano, Italy

Imaging has become a powerful and indispensable tool to extract physical information from scientific datasets across many disciplines. In astrophysics, integral field spectrographs are a prime example, as they deliver data cubes that combine spatial and spectral information of the observed sky. A notable case is the Multi Unit Spectroscopic Explorer (MUSE) at the Very Large Telescope: thanks to its large field of view and sensitivity, it has, among many achievements, revolutionized the study of the diffuse gas surrounding and connecting galaxies, beginning to unveil the gaseous backbone of the Universe — the Cosmic Web. In this talk, I will highlight the central role of such instruments and the associated challenges in analyzing these complex datasets. I will introduce the Python-based software SHINE, developed to extract astrophysical signals from galaxies and diffuse gas emission in three-dimensional data, and show how this approach enables precise measurements of structures in the circumgalactic and intergalactic gas, advancing our understanding of galaxy evolution and large-scale structure. Finally, I will briefly discuss how the upcoming generation of instruments and facilities, such as BlueMUSE and the Wide-Field Spectroscopic Telescope, will further expand both the scientific opportunities and the data analysis challenges in this research field.

A wide-field Fourier-transform hyperspectral microscope for excitation spectroscopy

M. Riva[1,*], A. Candeo[1], G. Valentini[1,2], G. Cerullo[1,2], C. Manzoni[2]

[1] *Dipartimento di Fisica, Politecnico di Milano, Piazza Leonardo da Vinci 32, I-20133 Milano, Italy*
[2] *Istituto di Fotonica e Nanotecnologie, IFN-CNR, Piazza Leonardo da Vinci 32, I-20133 Milano, Italy*

*Corresponding author: martina.riva@polimi.it

In fluorescence spectroscopy, the emission spectrum of a sample is typically measured by exciting the sample at a fixed wavelength. In contrast, excitation-resolved methods detect the wide-band emission while scanning the excitation wavelength. This approach provides complementary information to emission spectroscopy. Additionally, any spectral filtering is applied before the light reaches the sample, enabling the collection of all emitted photons. This results in a lower incident power for the same signal-to-noise ratio, thus reducing photobleaching, which mainly affects biological samples, as demonstrated by Favreau [1]. Another benefit is that excitation-resolved measurements can potentially address multi-labelling problems more effectively than emission-based approaches, especially when overlapping emission spectra are present in the field of view.

In microscopy, a few wide-field configurations have been reported to measure the excitation maps of samples, where a broadband source is filtered with thin-film [1] or acousto-optic [2] tunable filters. We use an alternative method for excitation-resolved microscopy based on the Fourier-transform approach, where all wavelengths of a broadband source excite the sample simultaneously, after passing through an interferometer, while the emission is collected by an imaging detector. White light from a halogen lamp is collimated through a common-path birefringent interferometer (*TWINS,* [3]) and then coupled into a microscope through a fiber, providing a uniform illumination of the sample. Fluorescence emission is detected with a monochrome camera during the interferometer scan, and the excitation spectrum is computed for all pixels through the Fourier transform of the emission signal.

This versatile illumination scheme can be easily coupled to a commercial optical microscope, providing excitation maps of various samples, from materials science to biology.

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[2] K. Chen, W. Li, and K. Xu (2022), “Super-multiplexing excitation spectral microscopy with multiple fluorescence bands”, *Biomed. Opt. Express* **13**, 6048–6060
[3] A. Candeo, B. Nogueira de Faria, M. Erreni, et al. (2019), “A hyperspectral microscope based on an ultrastable common-path interferometer,” *APL photonics,* **4**, 120802

Material decomposition using modulation-based X-ray phase tomography

D. John[*,1,2,4], D. Paganin[2], M.C. Zdora[2], L. M. Petzold[3], S. Baggio[1], J. Thalhammer[2,3], S. Alloo[2], J. Ahlers[2], J. Herzen[1], and K. Morgan[2]

[1]*Research Group Biomedical Imaging Physics, Technical University of Munich, Garching, Germany*
[2]*School of Physics and Astronomy, Monash University, Monash, Australia*
[3]*Chair of Biomedical Physics, Technical University of Munich, Garching, Germany*
[4]*Helmholtz-Zentrum Hereon GmbH, Hamburg, Germany*

*Corresponding author: dominik.john@tum.de

Material decomposition in X-ray imaging describes the separation of different materials within a sample based on their X-ray interaction properties [1], conventionally achieved using images taken at two X-ray energies [2]. An alternative method for material decomposition is to use attenuation and phase images, which can be obtained in a quantitative manner using modulation-based X-ray imaging. One major challenge in this approach is edge enhancement in the attenuation images due to coherent phase effects, which are not addressed by current phase-retrieval algorithms [3]. In an experiment at the Australian Synchrotron, we made use of Talbot array illuminators as a beam modulator [4] and the Unified Modulated Pattern Analysis for phase retrieval [5] to provide a proof of principle for material decomposition. First, we decompose a sample of known materials, focusing on areas away from interfaces, where edge enhancement effects are minimal (Fig. 1ab). Second, we introduce a modified Paganin filter [6] that incorporates prior knowledge about the sample composition to correct for the expected edge enhancement, allowing us to assess complementary phase and attenuation information on a highly structured, lead-stained mouse kidney (Fig. 1cd). Potential future applications of our research include advanced virtual histology and material identification in security settings.

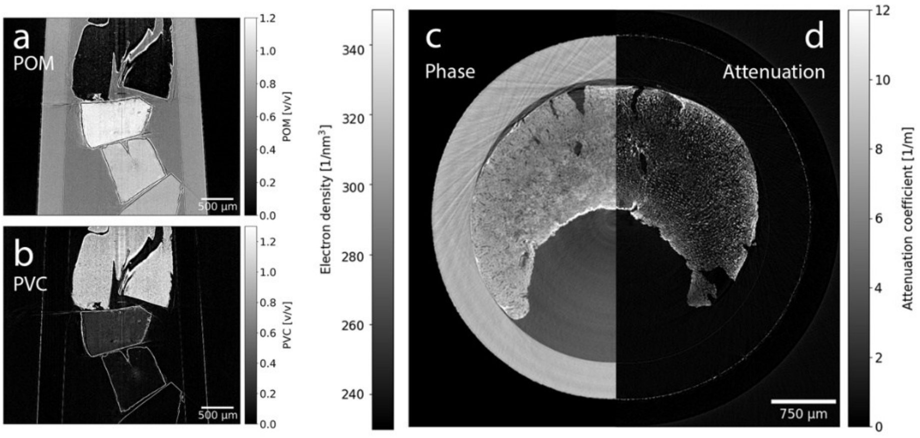

Figure 1 a,b: Example material decomposition. c,d: Stained mouse kidney, phase and attenuation.

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Preliminary investigation of spectral performances of a clinical Photon-counting Computed Tomography (PCCT) scanner

F.S. Maddaloni[1,2*], A. Loria[2], A. Sarno[1,3], A. Piai[2], C. Lenardi[1,3], A. Esposito[4], A. del Vecchio[2]

[1]*Università degli Studi di Milano, Dep. of Physics 'Aldo Pontremoli', Milan (Italy)*
[2]*Medical Physics Department, IRCCS San Raffaele Scientific Institute, Milan (Italy)*
[3]*INFN, sec. of Milan, Milan (Italy)*
[4]*Vita-Salute San Raffaele, Milan (Italy)*

*Corresponding author: francesca.maddaloni@unimi.it

PCCT represents a significant advancement in the actual CT technology. *Spectral analysis* is possible on the final reconstructed images.

This work investigates the spectral properties of the first clinically-approved PCCT scanner (Naeotom Alpha®, Siemens). We used a cylindrical phantom (TomoTherapy Cheese Phantom) with a 30 cm diameter, containing 20 cylindrical holes filled with 25 mL test tubes holding iodine solutions at concentrations ranging from 0 to 3.2 mg/mL in 0.2 mg/mL steps (Fig. 1(a)). Acquisitions were made using an abdominal protocol at 120 kV and 140 kV (analysis performed via Syngo.via®).

Attenuation was estimated at all the energies of the spectrum by means of measured HU values (Fig. 1(b)). The curves decrease exponentially with increasing energy. A linear regression of the measured iodine concentrations versus the nominal ones was made, obtaining a slope of 0.9683 and R^2 of 0.9885 (Fig. 1(c)). In conclusion, our PCCT scanner shows good performance in measuring iodine concentrations and attenuations, but other materials still have to be investigated for further clinical applications

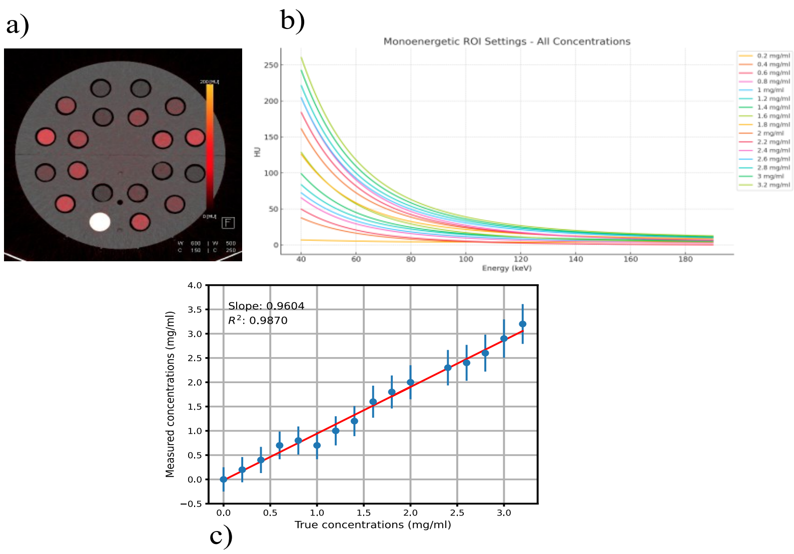

Figure 1: a) Section of the Cheese phantom represented in spectral mode; b) attenuation curves at various iodine concentrations; c) linear regression for measured concentrations

A Dual-Detector X-ray Micro-Tomography System for simultaneous Spectral and Phase contrast Imaging

P. Perion[1]*, L. Brombal[1], F. Brun[1], S. Donato[2], R.H. Menk[3], L. Sbuelz[4], F. Arfelli[1]

[1]*University of Trieste (Italy), and INFN Trieste (Italy)*
[2]*University of Calabria (Italy), and INFN Frascati (Italy)*
[3]*Elettra Sincrotrone Trieste (Italy), INFN Trieste (Italy), and Midsweden University (Sweeden)*
[4]*CNR – Istituto Officina dei Materiali (IOM) (Italy)*

*Corresponding author: paola.perion@phd.units.it

X-ray phase contrast imaging (XPCI) and spectral X-ray imaging (XSI) are being increasingly used in advanced imaging applications as their combination offers significant advantages for structural and compositional analysis [1]. In this contribution, we present a novel dual-detector imaging system for simultaneous XSI and XPCI, implemented at the SYRMEP beamline of the Elettra synchrotron. XPCI was performed using the beam tracking technique by adding an absorbing mask to the standard white beam setup, involving a lens-coupled detector with a 10μm pixel size. XSI was achieved by introducing a Laue crystal in the beam to diffract X-rays around silver's K-edge [2] and detecting them with photon-counting detector with a 60x52μm pixel size. It is important to note that the XSI setup is fully compatible with the beamline's standard white beam configuration. A test sample containing silver dilutions, chalk, a toothpick, microspheres, and nylon wires (see Fig.1a) was scanned. XPCI data provided absorption, (differential) phase, and dark field images, while XSI data, processed via a decomposition algorithm, yielded quantitative silver/water maps. Results demonstrate the potential of the system in providing complementary morphological and compositional information with quantitative accuracy.

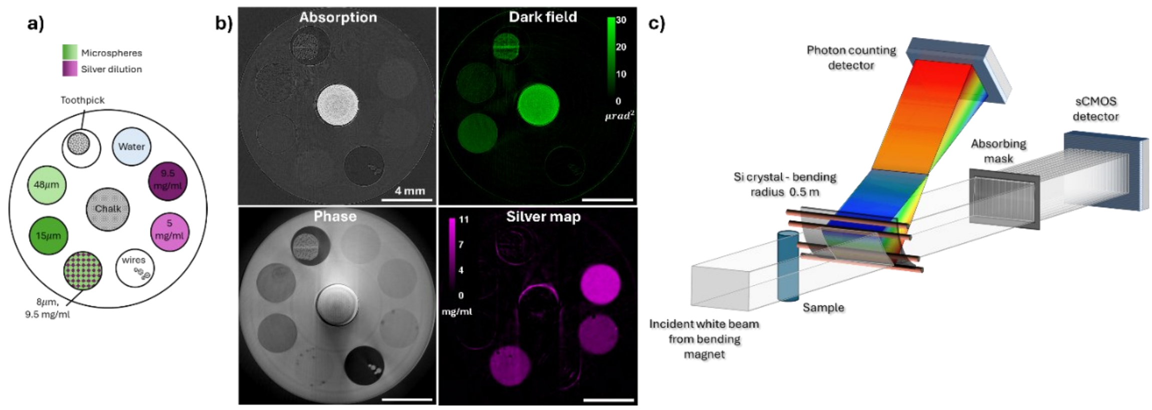

Figure 1 a) Sample sketch, b) Absorption, dark field, phase and silver map, c) Experimental setup

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Modulation-based phase-contrast and hyperspectral imaging with Moench: a super-resolution direct-conversion hybrid detector

L. Brombal[1]*, F. Arfelli[1], F. Brun[1], A.L. Coathup[1], R. Longo[1], P. Perion[1], A. Bergamaschi[2]

[1]*University of Trieste and INFN Trieste, Trieste, Italy*
[2]*Paul Scherrer Institute, Villigen PSI, Switzerland*

*Corresponding author: lbrombal@units.it

Moench is a small-pixel (25 µm) hybrid X-ray detector with single-photon counting capabilities [1]. As a charge-integrating device, it enables the measurement of the energy released by each photon. Additionally, by using the charge-sharing effect, the centroid of each event can be estimated with a spatial resolution finer than the pixel pitch, resulting in *super-resolved* images. These properties make Moench suitable for simultaneous modulation-based phase-contrast and (*hyper*)spectral imaging.

Super-resolution allows tracking of small local variations induced by the sample onto the pattern generated by the beam modulator (mask), enabling the extraction of X-ray attenuation, (differential) phase, and scattering properties. Meanwhile, the recorded pixel-by-pixel X-ray spectrum serves as input for spectral decomposition algorithms, enabling material-specific density mapping.

This study presents the first combination of spectral and phase-contrast imaging using Moench. Images were acquired at the PEPI Lab [2] using a conventional micro-focus X-ray tube operated at 50 kVp and 100 µA. Results (see Fig.1) obtained from a test object consisting of a bamboo stick stained with Ag and Mo solutions demonstrate the complementarity of the extracted signals, highlighting the potential of this technique for comprehensive material characterization.

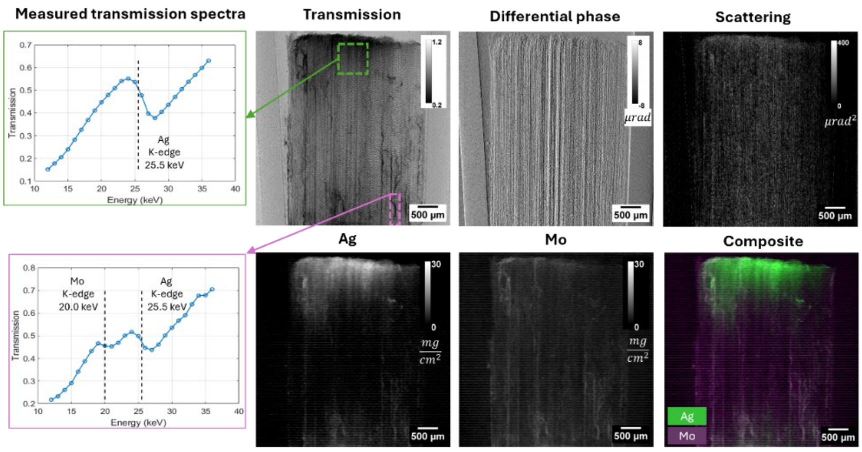

Figure 1 Transmission spectra within dashed ROIs (left); transmission, differential phase and scattering retrieved across the integral spectrum (top right); Decomposed Ag, Mo, and composite signals (bottom right)

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[2] Brombal, Luca, et al. "Pepi lab: a flexible compact multi-modal setup for x-ray phase-contrast and spectral imaging." Scientific Reports 13.1 (2023): 4206.

Soft X-ray Microscopy Multimodal Imaging at TwinMic - Elettra

A. Gianoncelli[1]*, V. Bonanni[1], A. Hafner[1], F. Guzzi[1], and G. Kourousias[1]

[1]*Elettra Sincrotrone Trieste, Trieste, Italy*

*Corresponding author: alessandra.gianoncelli@elettra.eu

Multimodal imaging is becoming an increasingly desirable and effective approach due to the integration of multiple complementary imaging techniques within a single instrument. Continuous advancements in detector technology and focusing systems, characterized by improvements in efficiency, speed, and compactness, progressively enable synchronous measurement of various signals originating from different phenomena. This approach provides simultaneous complementary information about the analyzed object. Although particularly critical in clinical medical fields — where multimodal imaging helps avoid repeated patient scans or exposures and reduces post-processing complexity arising from patient repositioning [1] — all imaging systems can substantially benefit from multimodal methodologies.

Indeed, the effectiveness of multimodal strategies has been demonstrated in various microscopy configurations. For example, in soft X-ray scanning microscopy, absorption and differential phase contrast (STXM) imaging can be effectively combined with X-ray Fluorescence (XRF) spectroscopy [2-4] or X-ray photoelectron spectroscopy [5]. Even portable systems increasingly incorporate multiple detectors to simultaneously collect diverse signals [6,7].

Here, we present the latest imaging advancements implemented at the TwinMic soft X-ray microscopy beamline [8] at Elettra Sincrotrone Trieste (Trieste, Italy), focusing on recent multimodal instrument developments and intelligent acquisition strategies illustrated through recent scientific results. Specifically, we highlight the newly developed in-vacuum X-AFM system that enables simultaneous topographic scans coupled with STXM and low-energy XRF imaging [9]. Additionally, we discuss the benefits provided by a novel Compressive Sensing acquisition approach [10].

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[6] A. Gianoncelli, J. Castaing, L. Ortega, et al (2008) X-Ray Spectrometry 37, 418.
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[10] G. Kourousias, F. Billè, et al. (2020) Sci Rep 10, 9990.

Advancing preclinical research on neurodegenerative diseases through X-ray imaging

F. Palermo[1], L. Massimi[1,2], M. Fratini [1,2], N. Marrocco[1], I. Bukreeva[1], A. Cedola[1]

[1]*Institute of Nanotechnology – CNR, Rome, Italy.*
[2]*NeuroImaging Lab, IRCCS Santa Lucia Foundation, Rome, Italy*

Preclinical research on neurodegenerative diseases increasingly relies on advanced imaging techniques to unravel complex structural and functional changes in the brain. Among these, X-ray–based imaging modalities, including micro-computed and phase-contrast X-ray tomography (XPCT), offer unprecedented opportunities to visualize neural tissue at high spatial resolution and in three dimensions without destructive sectioning. These approaches enable the detection of subtle alterations in brain microarchitecture, vascular networks, and cellular environments associated with different pathological conditions. In combination with multimodal approaches, XPCT yields complementary insights that support the identification of biomarkers, monitoring of disease progression, and evaluation of therapeutic interventions. By expanding the toolkit for non-invasive and quantitative assessment, X-ray imaging will help accelerate translational discoveries and deepen mechanistic understanding of neurodegenerative pathology.

Two clinical cases for laboratory phase contrast micro-CT

R. Mokso[1]*, A. Al-Khafaf[2], L. Mortensen[3], HM Kjaer[3], L Eriksen[4], C. Porsberg[4], T. Todsen[2]

[1]*Department of Physics & 3D Imaging Centre, Technical University of Denmark*

[2]*Department of Head and Neck surgery, Rigshospitalet, Copenhagen, Denmark*

[3]*Department of Computer Science, Technical University of Denmark*

[4]*Department of respiratory and infection diseases, Bispebjerg hospital, Denmark*

*rajmo@dtu.dk

Propagation based phase contrast tomography is the established method at synchrotron imaging beamlines, but laboratory microCT scanners are today also capable to offer this modality. At the 3D Imaging center at DTU we are exploring the potential of phase contrast microCT in the clical practice by optimizing the acquisition speed and resolution. I will present two clinical case studies in their pilot phase. The first study is directed towards the improvement of precision in cancer surgery by 3D assessment of surgical resections intraoperatively. The second case aims to detect and count abnormal clusters of cells in lymphoid tissue in cryo-biopsies from asthma patients.

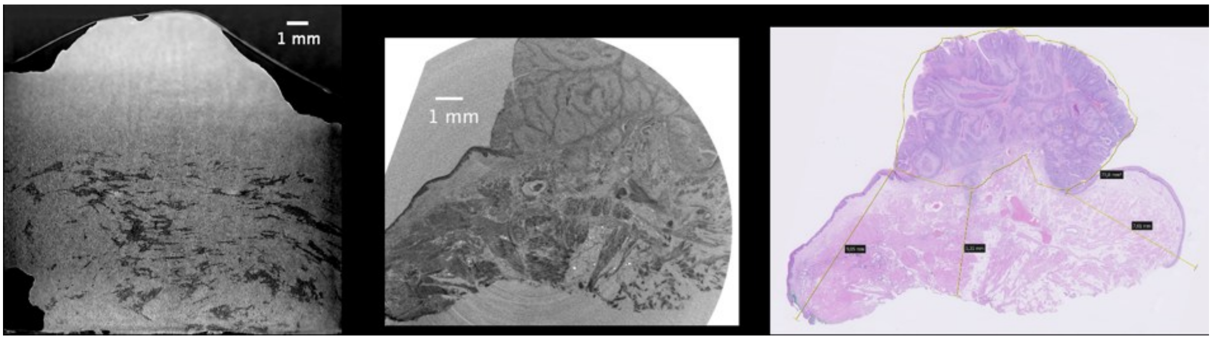

Figure.1: Images of excised tongue tumour. X-ray tomographic slice acquired directly after surgery of unstained, wet tissue (left), after paraffin embeddig (middle) and the corresponding histopathology slice with H&E staining.

Topological Mapping of Fat and Glycogen Distribution in Metabolic-Associated Fatty Liver Disease using micro- and nano-CT

S. Donato[1*], E. Longo[2], D. Bonazza[3], E. Giacomello[4], G. Tromba[2], S. Palmisano[4], P.J. Giraudi[5], N. Rosso[5]

[1]*Dept. Of Mathematics and Computer Science, Dept. of Physics, University of Calabria, Rende, Italy*
[2]*Elettra Sincrotrone Trieste S.C.p.A ., Trieste, Italy*
[3]*Surgical Pathology Unit ASUGI, Trieste, Italy*
[4]*Department of Medicine, Surgery and Health Sciences, University of Trieste, Trieste, Italy*
[5]*Fondazione Italiana Fegato ONLUS, MASLD Unit, Trieste, Italy*

*Corresponding author: Sandro.donato@fis.unical.it

Metabolic-associated fatty liver disease (MAFLD) [1] is one of the leading causes of liver cirrhosis and hepatocellular carcinoma worldwide [2]. It has emerged as a growing public health concern, driven by the rising global prevalence of obesity and type 2 diabetes. MAFLD reflects the hepatic manifestation of a heterogeneous, multisystemic disorder and imposes a significant clinical and economic burden [3]. MAFLD encompasses a spectrum of hepatic changes, ranging from simple steatosis (characterized by fat accumulation without significant inflammation or hepatocellular injury) to more advanced forms marked by inflammation, hepatocyte ballooning, and fibrosis [4,5]. While early-stage MAFLD is generally benign and reversible, approximately 20% of cases may progress to more severe stages, including non-alcoholic steatohepatitis, cirrhosis, and carcinoma.

In addition to lipid accumulation, altered glycogen metabolism plays a key role in the pathophysiology of MAFLD. Hepatic glycogen storage becomes dysregulated in response to insulin resistance [6], often leading to abnormal glycogen deposition patterns that may coexist with steatosis. This disrupted glycogen handling reflects broader metabolic dysfunction and may contribute to hepatocyte stress, particularly in the early stages of disease.

We performed micro-CT (2.5 µm pixel size) and nano-CT (50 nm pixel size) experiments, respectively at the SYRMEP (Trieste, Italy) and ID16A (Grenoble, France) beamlines, for studying the spatial and metabolic changes in MAFLD. Samples were obtained from patients undergoing bariatric surgery. Micro-CT provides 3D mapping of hepatic lobules and quantifies lipid droplets, while nano-CT captures detailed subcellular structures, including lipid droplet organization. Together, these techniques, alongside histology, can offer valuable insights into the progression and metabolic alterations of MAFLD.

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Directional dark-field x-ray image retrieval from a single sample image: with refinements and applications

M. K. Croughan[1, *], Y. Y. How[1], D. M. Paganin[1], S. J. Alloo[1], J. N. Ahlers[1], S. A. Harker[2], A. Pennings[3], K. S. Morgan[1]

[1]*School of Physics and Astronomy, Monash University, Wellington Road, Clayton 3800, Australia*
[2]*Frankston Hospital, 2 Hastings Rd, Frankston 3199, Australia*
[3]*School of Physics, The University of Melbourne, Swanston St & Tin Alley, Parkville 3010, Australia*
*Corresponding author: Michelle.Croughan@monash.edu

Directional dark-field x-ray imaging is sensitive to unresolved anisotropic scattering from small sample microstructures [1]. Measuring this signal provides sub-pixel information with less radiation dose than typically required to directly resolve those features. Thus, if directly resolving sample microstructure is not possible due to time, equipment or dose limitations, then dark-field x-ray imaging could retrieve microscale information over a macroscropic field of view. Here we focus on the single-grid technique [2,3], showing quantitative retrieval of the directional dark field [4].

Single-grid dark-field imaging, and adjacent techniques such as speckle-based imaging, often measure the dark field as a blurring of the x-ray intensity in the image. Thus, other forms of blur introduced into the image (e.g. blur due to the detector's finite resolution) and large intensity gradients (e.g. phase-contrast fringes) can result in artefacts in the retrieved directional dark-field image. We present a correction technique to remove these artefacts and significantly improve the quality of the retrieved image [5], with an example shown in Figure 1.

Importantly, as single-grid imaging only requires one sample exposure, it allows for low-dose and fast dynamic imaging. This can be advantageous for dose-sensitive and/or moving samples such as small animals in medical research or items moving along a conveyor belt in industry. This also indicates potential for fast data collection for techniques such as directional dark-field tomography.

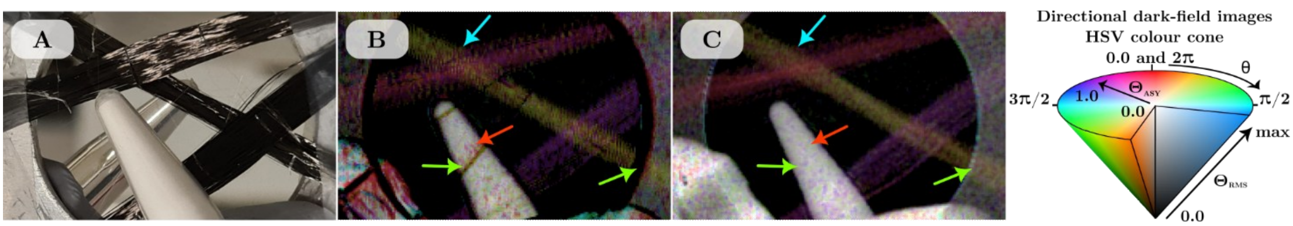

Figure 1 A) Dark-field phantom made of a tube of water, a tube of 6 μm PMMA microspheres, and three carbon fibre bundles. B) Standard directional dark-field reconstruction using Croughan 2023 [4]. C) Improved reconstruction using Croughan 2024 [5]. The image colour is the dominant scattering direction θ, the saturation is the scattering asymmetry Θ_{ASY}, and the brightness is the scattering strength Θ_{RMS}.

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Metal segmentation and reconstruction of CBCT sinograms with 3D complex wavelets

S. Rautio*

Univeristy of Helsinki

*Corresponding author: siiri.rautio@helsinki.fi

Metal objects pose a significant challenge in cone-beam X-ray computed tomography (CBCT), as they attenuate X-rays much more strongly and non-uniformly than biological tissues. This results in inconsistent X-ray projections that produce severe streaking and shading artifacts in the reconstructed images, degrading image quality and hindering accurate medical analysis.

We propose a method for sinogram-domain metal segmentation based on 3D complex wavelets. In 3D, complex wavelet coefficients encode directional information in 28 directions, and we can utilize geometrical knowledge of the sinogram to extract the wavefront set of the metals. Based on this, we can form the singular support of the metals in the sinogram and use this information to perform the segmentation. We demonstrated the method with experimental CBCT data.

In the full metal artefact reduction pipeline, the next steps would involve inpainting the metals in the sinogram and reconstructing the metals separately.

Three-dimensional hematoxylin and eosin (H&E) histology enabled by laboratory-based, multi-modal X-ray microscopy

M. Esposito[1], A. Astolfo[1], Y. Zhou[2], A. Teplov[3], I. Buchanan[1], O. Makarova[4], M. Endrizzi[1], C.-M. Tang[4], Y. Yagi[3], P.D. Lee[2], C. Walsh[2], J.D. Ferrara[5], A. Olivo[1]*

[1]*UCL Dept Medical Physics and Biomedical Engineering, Malet Place, Gower St, London WC1E 6BT UK*
[2] *UCL Dept Mechanical Engineering, Malet Place, Gower St, London WC1E 6BT UK*
[3]*Dept of Pathology, Memorial Sloan Kettering Cancer Center, New York, NY 10065, USA*
[4]*Creatv Microtech, Potomac, MD 20854 and Chicago IL 60612, USA*
[5]*Rigaku Americas, 9009 New Trails Drive, The Woodlands, TX 77381, USA*

*Corresponding author: a.olivo@ucl.ac.uk

We have developed an X-ray microscope based on structuring of the X-ray beam with free-standing gold masks [1]. Unlike standard X-ray instruments where resolution is determined by the source focal spot and detector point spread functions, in our instrument this is entirely driven by the apertures in the beam structuring mask [2]. This has two important consequences: 1) the resolution is a user-driven parameter that can be changed simply by swapping masks 2) resolution and voxel size are one and the same thing, unlike conventional systems where *real* resolution is often several voxel sizes. An additional advantage of beam structuring is it provides ready and *simultaneous* access to phase and scatter images as well as attenuation ones. Since resolution in phase and attenuation images is in our case of 1 micron, the scatter channel is sensitive to nanometric features (e.g. the extra-cellular matrix). Our recent combination of the microscope with CT acquisition and reconstruction enabled crisp 3D images of unstained tissue blocks where cells and nuclei are clearly visible; indeed, in one of our "standards" scans the latter have a signal-to-noise ratio of approximately 20 which makes their segmentation straightforward, with automatic extraction of key parameters such as size, asymmetry, etc. X-ray images are sufficiently information rich that, by training an AI algorithm on H&E slides, it is possible to convert our X-ray datasets into H&E ones (Fig. 1). This allows the creation of truly 3D H&E blocks, without all the issues associated with current practice (time and cost of slicing entire blocks, cutting artifacts, difference between in plane and off-plane resolution, etc). 3D blocks allow the interpretation of abnormalities in the context of the surrounding tissue architecture.

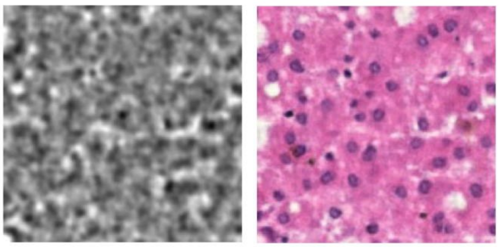

Figure 1 Example X-ray microscopy cell map (left) converted into H&E via machine learning (right)

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Multiscale and extended field-of-view X-ray phase-contrast microtomography of soft tissues with a laboratory system

H. Allan[1,2,*], A. Doherty[1,2], C. Navarrete-León[1,2], A. González-Grajales[1,2], A. Szmul[3], J. Jacob[3,4], M. Endrizzi[1,2]

[1]*Department of Medical Physics and Biomedical Engineering, University College London, London, UK*
[2]*X-ray Microscopy and Tomography Laboratory, The Francis Crick Institute, London, UK*
[3]*Hawkes Institute, University College London, London, UK*
[4]*UCL Respiratory, University College London, London, UK*

*harry.allan.21@ucl.ac.uk

We demonstrate a system and methodology for X-ray phase-contrast imaging based at the UK's National research facility for lab-based X-ray Computed Tomography [1]. The system is capable of multi-contrast imaging (attenuation, phase, dark field), across a range of length scales. Non-destructive multi-scale and multi-contrast imaging of the same sample can be achieved, utilising techniques based on free-space propagation and beam-tracking [2]. In particular, we report on developments allowing a doubling of the effective field-of-view of the system [3], enabling imaging of samples over 7 cm in diameter, at resolutions of tens of microns. These large overview scans can be followed by targeted high-resolution local zooms of the tissue, as highlighted in figure 1 for a resected human lung sample. We have focused on these developments at a laboratory source with the aim of facilitating a widespread adoption of volumetric imaging of soft tissue samples, enabling valuable applications such as intraoperative imaging and the routine application of virtual histology.

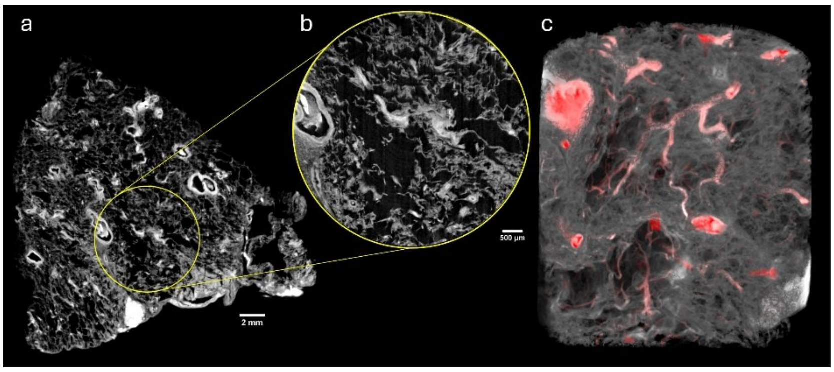

Figure 1 Free-space propagation-based X-ray phase-contrast microtomography of resected human lung tissue. A large field-of-view overview scan is acquired first (a), followed by a targeted zoom at higher resolution using local tomography in the same system (b). The resultant volumetric datasets allow further analysis, including segmentation of the vascular tree (c).

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X-ray dark-field tomography of ex-vivo fibre-structured tissues in a compact laboratory system

C. Navarrete-León*[1,2], A. González-Grajales[1,2], A. Parmenter[1,3], H. Allan[1,2], A. Doherty[1,2], S. Cipiccia[1], C. K. Hagen[1], D. Bate[4], A. Olivo[1], M. Endrizzi[1,2]

[1]*Dep. of Medical Physics and Bioengineering. University College London, Gower St, WC1E 6BT London, UK*
[2]*X-ray Microscopy and Tomography Lab, The Francis Crick Institute, 1 Midland Road, London, NW1 1AT, UK*
[3]*Dep. of Mechanical Engineering. University College London, Gower St, WC1E 6BT London, UK*
[4]*Nikon X-Tek Systems Ltd, Tring, Herts, HP23 4JX, UK*

*Corresponding Author: carlos.leon.17@ucl.ac.uk

X-ray dark-field imaging is a promising technique that detects small-angle x-ray scattering to generate contrast from structural variations unresolved by the imaging system's spatial resolution, enabling microstructural characterisation without the need for high-resolution imaging. Here, we demonstrate its application for non-destructive structural characterisation of ex-vivo fibre-structured tissues in both 2D and 3D. We use two-directional beam-tracking (2DBT), an approach that enables simultaneous absorption, refraction, and scattering imaging from a single x-ray exposure, and allows directional scattering measurements for characterising anisotropic structures within a sample [1,2]. Using a compact laboratory-based setup, we show that dark-field tomography highlights regions with sub-resolution (<~20μm) structural organisation in biological tissues, including myocardial fibres in a rat heart and radial-tie fibres in a porcine meniscus. This approach provides an opportunity for structural characterisation within a larger field of view (~2-3 cm), offering a promising route toward accessible, laboratory-based studies of ex-vivo fibre-structured tissue organisation, with potential applications in cardiovascular and musculoskeletal research.

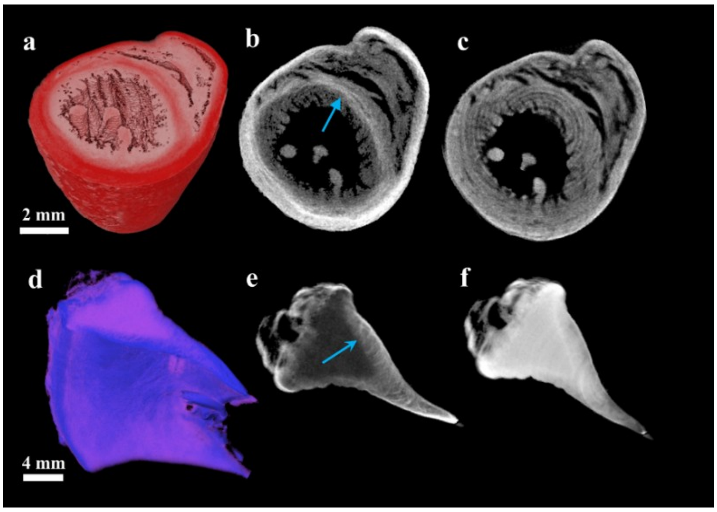

Figure 1 Dark-field and attenuation tomography of a rat heart (a–c) and porcine meniscus (d–f). Volume renderings (a, d) and axial slices (b, e) of dark-field tomography reconstructions, along with corresponding attenuation slices (c, f). The dark-field signal reveals circumferentially oriented fibres that are not clearly visible in attenuation, including those in the mid-myocardium of the heart and those emanating from the superficial layer of the meniscus, as indicated by the arrows.

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Novel fabrication methods for high-energy X-ray Phase Contrast Imaging

A. Rossi[1]*, D. Josell[2], I. Papakonstantinou[1], A. Olivo[3]

[1] *Photonic Innovations Lab, Department of Electronic & Electrical Engineering, University College London, Torrington Place, London, WC1E 7JE UK*
[2]*Materials Science and Engineering Division, National Institute of Standards and Technology, Gaithersburg, MD, 20899 US*
[3]*Department of Medical Physics and Biomedical Engineering, University College London, Gower Street, London, WC1E 6BT UK*

*alessandro.rossi.20@ucl.ac.uk

X-ray Phase Contrast Imaging (XPCI) enhances sensitivity in X-ray imaging, revealing details invisible to conventional radiography, with promising applications across multiple fields. Most XPCI methods rely on gratings, but fabrication limitations—especially for low periods or extreme thickness and aspect ratios—restrict phase sensitivity, resolution, and usable beam energy [1,2]. Specifically, current gratings fail to efficiently modulate higher energy beams (> 100 keV) due to insufficient thickness and, consequently, low absorption.

This talk presents the fabrication of the thickest-ever X-ray absorption gratings (500 µm, Fig. 1a), or masks, demonstrating enhanced phase sensitivity in an Edge Illumination (EI) setup at 160 kVp (Fig. 1b) [2]. Additionally, I will share ongoing, unpublished results on > 700 µm-thick masks designed for testing at 225 kVp, a standard voltage for industrial non-destructive testing (NDT), potentially enabling XPCI adoption in high-energy NDT as it appears from preliminary simulations (Fig. 1c). These masks are fabricated using maskless lithography, Deep Reactive Ion Etching, and Bi-mediated Au superconformal filling. Finally, I will present biomedical images obtained with microfluidic gratings produced through an alternative, cheaper, and faster approach, which could replace the state-of-the-art solid-state fabrication protocol.

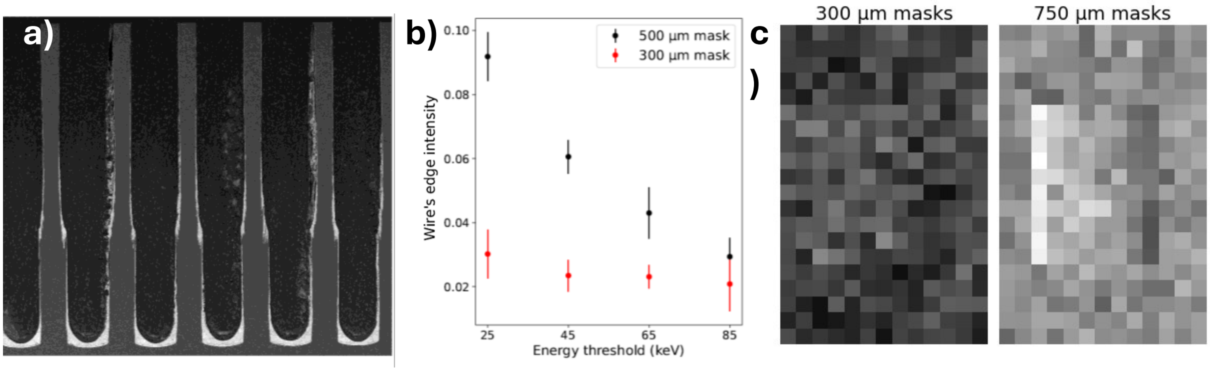

Fig 2. a) Cross-section of 500 µm masks with bottom-up Au plating at the initial stage; b) improved phase sensitivity measured with 500 µm masks (black) over 300 µm masks (red); c) simulation of a 40 µm inclusion in Cu made visible by thicker masks.

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Estimation of tissues diffusion coefficients based on X-ray high-resolution radiographies

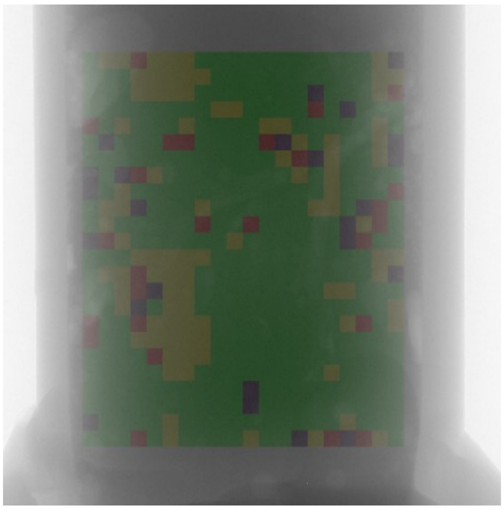
M. Santini[1]*, S. Fest-Santini[1], E. Medolago, C. Sirtoli, G. E. Cossali[1]

[1] *Department of Engineering and Applied Sciences, University of Bergamo, Viale Marconi 5, 24044 Dalmine (BG), Italy*

*Corresponding author: maurizio.santini@unibg.it

The examination of a sample of biological tissues constitutes a pivotal step in the diagnosis of numerous pathologies. A series of histological treatments, which are based on solvents diffusion in the specimen, are required and the duration of each phase is determined by empirical timing. A methodology for estimating the diffusion coefficient in biological material was previously implemented (Santini et al., 2024), solving the diffusion equation in cylindrical coordinates. The method was based on the analysis of the time-dependent concentration profile in the fan beam plane known from X-ray high-resolution radiographs, in which the intensity of the attenuation of the ionizing beam is proportional to the concentration of the solvent diffusing within the histological specimen. This method is now extended to the whole X-ray cone beam, and the three-dimensional diffusion equation is solved. The results of the variability of the diffusion coefficient within a biological sample are shown in Figure 1, indicating the underlying differences in the sample morphology.

Figure 3: colour map of the diffusion coefficient. The colours are indicative of the deviation from the global average value of the diffusivity in each ROI. In particular, green corresponds to values of D belonging to the interval $[\bar{D}-\sigma, \bar{D}+\sigma]$, yellow corresponds to D belonging to $[\bar{D}-1.5\sigma, \bar{D}-\sigma) \cup (\bar{D}+\sigma, \bar{D}+1.5\sigma]$, red corresponds to D belonging to $[\bar{D}-2\sigma, \bar{D}-1.5\sigma) \cup (\bar{D}+1.5\sigma, \bar{D}+2\sigma]$ and purple corresponds to D belonging to $[D_{min}, \bar{D}-2\sigma) \cup (\bar{D}+2\sigma, D_{max}]$. Where $\bar{D}$, σ, D_{max} and D_{min} are respectively the mean, the standard deviation, the minimum and maximum values of the diffusion coefficient



Keywords: *diffusion coefficient, porous media, X-ray radiography, histological tissue, three-dimensional Diffusion equation*

Santini M., Fest-Santini S., Cossali G.E., Casatta N. Lupo C. A novel methodology for the diffusion coefficient determination in porous media by X-ray high-resolution radiographies, Eur. Phys. J. Plus (2024) 139:696

Innovative AI Solutions for Enhanced Diagnostic Accuracy in Medical Imaging

E.Vocaturo

NANOTEC National Research Council, Rende (CS), Italy

Artificial Intelligence (AI) is catalyzing an unprecedented transformation in the healthcare landscape, enabling more accurate, timely, and interpretable disease diagnoses through the use of advanced deep learning and machine learning techniques. Despite significant progress, the clinical integration of AI-based diagnostic solutions remains limited, primarily due to concerns regarding model transparency and reliability.

In this talk, synthesizes findings from our various AI applications in medical imaging are presented —brain tumor detection [1], lung disease assessment [2], breast cancer diagnosis [3] and melanoma classification [4] highlighting the benefits of hybrid and explainable methodologies in diverse diagnostic contexts. Our results emphasize the excellence of deep learning models in the feature extraction process, synergistically combined with handcrafted features and machine learning classifiers to enhance diagnostic accuracy. Explainability is ensured through a multi-level analytical framework that employs techniques such as Grad-CAM, LIME, SHAP, Permutation Feature Importance, and Partial Dependence Plots, thus providing interpretable and actionable insights to clinicians. The proposed frameworks have achieved state-of-the-art performance across various medical imaging tasks, with F1-scores exceeding 90% and AUC values nearing 0.97. By integrating AI solutions into radiologists' workflows as a decision support system, this research fosters a paradigm shift towards explainable and clinically reliable AI applications. Future research directions will focus on developing robust, domain-adaptable architectures to further bridge the gap between AI advancements and their practical implementation in the medical field.

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New Horizons in AI-Driven Workflows for X-ray Microscopy

F.Cognigni

Carl Zeiss SpA, Milan, Italy

X-ray Microscopy (XRM) has become an essential tool for the non-destructive and multiscale investigation of materials and biological specimens. However, the ever-increasing size and complexity of datasets, combined with the demand for higher throughput and quality, are pushing traditional workflows to their limits. In this talk, we will explore how artificial intelligence (AI) is reshaping XRM workflows, enabling faster, more reliable, and comprehensive insights from acquisition to 3D image analysis.

We will present recent advances in AI-driven reconstruction algorithms, such as deep learning–based approaches for noise reduction, artifact correction, and super-resolution, which allow high-quality 3D volumes to be generated from reduced acquisition times and lower radiation doses. Furthermore, we will demonstrate how semantic and instance segmentation models facilitate automated identification of relevant structures, accelerating quantitative analysis and minimizing user bias.

By highlighting concrete case studies from both materials science and life sciences, this presentation will show how AI-powered XRM workflows are expanding the frontiers of non-destructive imaging offering researchers unprecedented efficiency, scalability, and depth of understanding.

Hard X-ray imaging at the ALBA synchrotron: a dynamic, multimodal and multiscale experience

A. Patera[1*], F. Cova[1], V. Bouffetier[1], L. Ribó[1], S. Wohl[1], A. Mittone[2], J. Nicolás[1], J. Juanhuix[1]

[1]*Alba Synchrotron light source, Carrer de la llum 2-26, 08290 Cerdanyola del Vallès, Spain*
[2]*Argonne National Laboratory, 9700 S Cass Ave, Lemont, IL 60439, USA*

*Corresponding author: apatera@cells.es

The new FaXToR beamline at ALBA, brought into user operation in 2025, is dedicated to fast X-ray micro-CT in the hard X-ray range to accomplish a wide number of applications, from material to life sciences, to cultural heritage and paleontology [1]. Trends in life sciences strongly push towards multiscale and multimodal capabilities from the cell up to the tissue level and from tissues to whole organism. Additionally, *ex-vivo* imaging requiring a combination of dynamic high-resolution capabilities is in growing demand. Similarly, the material science community is mostly interested into operando and multiscale experiments, in which the sample can be subjected to external stimuli, such as heating, stress (tension/compression), electric/magnetic fields, etc. In response to these trends, the sample dynamic scan can be followed with a time scale up to 20 tomo per second, while focusing in regions of interest with a higher level of details. Phase-contrast imaging is feasible in free space propagation at first and then with grating interferometry, enhancing its performance in soft matter visualization. Overall, FaXToR is now open to a large user community offering a flexible design capable of performing morphological and dynamic studies at the micron scale in large volumes.

The beamline is fed by a short in-vacuum multipole wiggler and provides both filtered white and monochromatic beam with energies ranging from 10 to 70 keV and maximum beam size of 35×12 mm^2 (HxV) at the sample stage. It is equipped with four detectors, two of them working simultaneously: namely, a fast-streaming camera with a resolution of 1MP and capable of acquiring up to 5000 images per second, and three higher resolution cameras between 4 and 7 MP. The fast-streaming camera is used for dynamic tomography acquisition, requiring on-the-fly 3D reconstruction and visualization system, which is a challenging task since the beamline envisages a high data throughput of around 100 Gb/s that needs to be processed in quasi real time. A proper infrastructure that can handle this amount of data foresees an ultra-fast storage system coupled with CPU and GPU nodes equipped with state-of-the-art cards to perform the data processing.

Herein, we will provide an overview of the beamline capability and its first glance into user operation.

[1] Mittone A et al 2022 J. Phys. Conf. Series 2380 012035

In vivo 4D x-ray dark-field lung imaging in mice

Y.Y. How[1*], N. Reyne[2], M. K. Croughan[1], P. Cmielewski[2], D. Batey[3], L. F. Costello[1], R. Smith[2], J. N. Ahlers[1], M. Cholewa[4], M. Kolodziej[5], J. Duerr[6], M. A. Mall[6], M. J. Kitchen[1], M. Asselin-Labat[3], D. M. Paganin[1], M. Donnelley[2], K. S. Morgan[1]

[1]*School of Physics and Astronomy, Monash University, Australia* [2]*Adelaide Medical School and Robinson Research Institute, University of Adelaide, Australia* [3]*Personalised Oncology Division at Walter and Eliza Hall Institute of Medical Research, Australia* [4]*Department of Biophysics, Uniwersytet Rzeszowski, Poland* [5]*Institute of Medical Sciences, College of Medical Sciences, Uniwersytet Rzeszowski, Poland* [6]*Department of Pediatric Respiratory Medicine, Immunology and Critical Care Medicine, Charite-Universitatsmedizin Berlin, Germany*

*Corresponding author: ying.how1@monash.edu

X-ray dark-field imaging is useful in visualising the health of lungs since the many tiny air sacs, or alveoli, cannot be individually resolved, but do create a strong dark-field signal. However, achieving time-resolved tomographic (i.e. 4D) x-ray dark-field imaging is challenging since multiple sample exposures have typically been required to extract the dark-field signal.

Here, we present the first *in vivo* 4D x-ray dark-field lung imaging in mice. This is achieved by synchronizing the data acquisition process of a single-exposure grid-based imaging approach [1-4] with the breath cycle [5]. The short data acquisition time per dark-field projection makes this approach appropriate for 4D imaging since it minimizes motion blur, the total time required, and the associated radiation dose. Images were captured of both healthy and diseased mice, specifically models of emphysema and lung cancer, where a change in the size of the alveoli is expected.

The results demonstrate that the 4D dark-field signal reveals how the size of the alveoli from different parts of the lungs changes throughout a breath cycle, as shown in Figure 1. By quantifying the dark-field signal, this technique could be used to perform functional lung imaging that allows the assessment of both global and regional lung conditions where the size of the alveoli is affected.

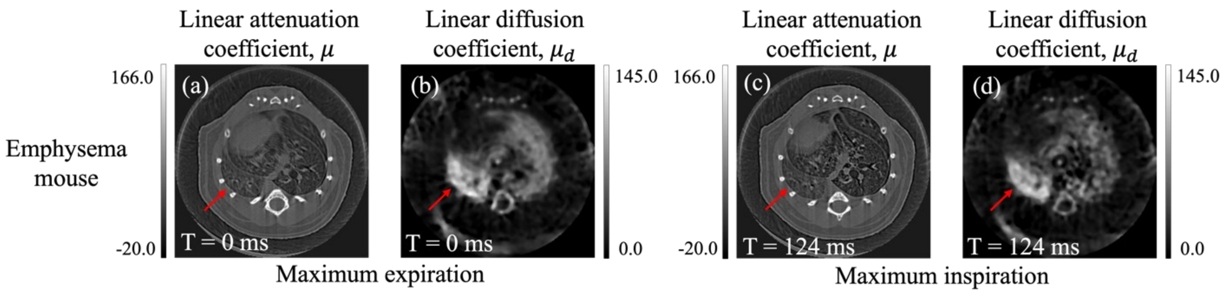

Figure 1. CT slices at maximum expiration/inspiration (T = 0 ms/124 ms) using (a) & (c) the attenuation and (b) & (d) dark-field signal extracted. The dark-field images highlight the back-left lobe (see red arrow) of the lungs, where the alveoli are a different size to the other lobes, not apparent from panels (a) and (c).

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Investigation of ventilator-induced lung injury (VILI) using single-grid dark field

L. D'Amico[1,2*], N. Reyne[3,4], S. Bayat[5], Y.Y. How[1], L. Costello[1], R. Smith[3,4], M. Kitchen[1], M. Donnelley[3,4], K. Morgan[1]

[1] *School of Physics and Astronomy, Monash University, Victoria, Australia*
[2]*Elettra-Sincrotrone Trieste S.C.p.A, Trieste, Italy*
[3]*Adelaide Medical School & Robinson Research Institute, University of Adelaide, South Australia,Australia*
[4]*Respiratory Medicine, Women's & Children's Hospital Adelaide,South Australia, Australia*
[6]*Department of Pulmonology and Physiology, CHU Grenoble Alpes, Grenoble, France*
*Corresponding author: lorenzo.damico@monash.edu

Mechanical ventilation (MV) is an essential life support measure for patients with acute respiratory failure. While MV helps patients breathe, it can also damage the lungs, leading to ventilator-induced lung injury (VILI). However, the physiology of VILI and acute respiratory conditions is still unclear, especially due to the poorly understood mechanism of VILI at a microscale. In recent decades, the combination of synchrotron radiation (SR) sources and propagation-based phase contrast x-ray imaging (PBI) has enable high-resolution computed tomography. However, the spatial resolution that PBI can achieve is still bound by the detector pixel size and motion blur during the breath, limiting how well this approach can reveal the VILI mechanism. Here, we present a novel approach based on single-grid dark-field 4D tomography, which allows decoupling from the detector resolution, since the small-angle x-ray scattering (SAXS) generated by the air-tissue interfaces, can reveal the presence of the structures beneath than the detector resolution. The sensitivity of the dark field signal to the size and number of alveoli allows sensitive information to be generated about the pulmonary structure (Fig. 1), e.g. the airspace enlargement.

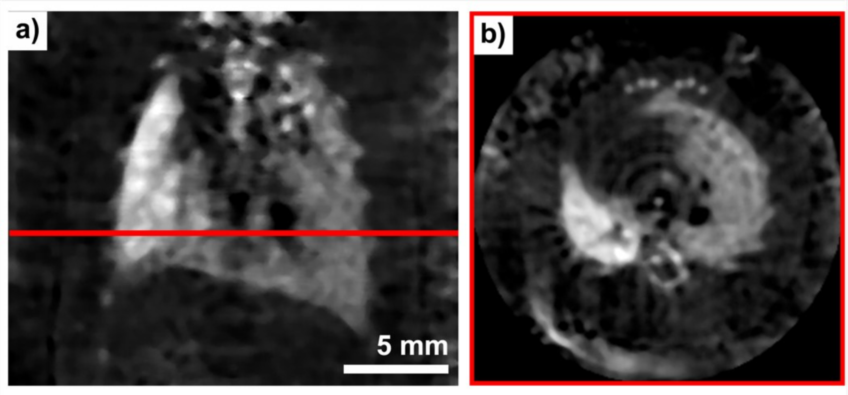


Figure 1: Coronal a) and axial b) dark-field CT slices of a breathing mouse, using the dark field setup and algorithm described in [1] .a) 2D coronal slice of the lung showing the higher dark-field signal (brighter area) in the left lobe, pointing at the healthy condition of the organ, while the right part, shows a lower signal, depicting injuries of the alveoli. b) 2D dark-field slice reconstructed using the algorithm presented in [1]. The slice was reconstructed at the height indicated with red line.

[1] Y. Y, How et al., 2024, In vivo 4D x-ray dark-field lung imaging in mice, arXiv.2411.14669

Leveraging Intensity Flow for Image Reconstruction: Fokker-Planck X-ray Grating Interferometry

S. J. Alloo[1*], F. Schaff[2,3], and K. S. Morgan[1]

[1]*School of Physics and Astronomy, Monash University, Australia.* [2]*School of Natural Sciences, Technical University of Munich (TUM), Germany,* [3]*Munich Institute of Biomedical Engineering, TUM, Germany,*

*Corresponding author: samantha.alloo@monash.edu

Grating interferometry is an established imaging technique for phase and dark-field X-ray imaging, suitable for large-area applications, with human scanners currently being developed [1]. While conventional radiography reveals structural differences in attenuation (e.g., bones vs. soft tissue), phase and dark-field images provide complementary information–distinguishing weakly attenuating materials (e.g., fat vs. muscle) and visualizing otherwise-invisible structures (e.g., lung alveoli), respectively. Extracting these additional channels requires a suitable image retrieval method.

Since the first demonstration of grating-interferometry in 2008 [2], image retrieval methods have relied on pixel-wise analysis across grating steps, treating each pixel independently, without taking into account the intensity at neighboring pixels and pixel-to-pixel flow of intensity. We propose a new approach based on the Fokker-Planck equation [3,4], which has shown promise in other multimodal X-ray imaging techniques [5,6]. This method integrates the spatial dynamics of intensity, enabling stable image retrieval even under noisy conditions, producing smooth multimodal images.

We present the first implementation of Fokker–Planck-based image retrieval for grating-interferometry data, summarized in Fig. 1. Our approach aggregates experimental data across grating steps to construct a single image containing the entirety of the attenuation, phase, and dark-field information. This methodology has the potential to reduce radiation dose [7]–particularly valuable for ongoing lung imaging studies [8]–and potentially offers improved robustness for large-scale systems where precise grating stepping is challenging, such as the human-size tomography scanner [1].

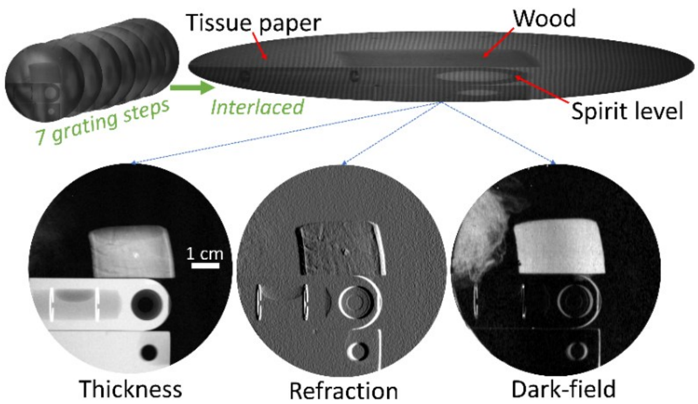


Figure 4 Demonstration of Fokker–Planck-based grating interferometry. Experimental data across grating steps is interlaced and used within our Fokker–Planck

[1] Viermetz, M., *et al.* (2022). *IEEE Trans. Med. Imaging*, **42**(1), 220-232. [2] Pfeiffer, F., *et al.* (2008). *Nat. Mater*. **7**, 134-137. [3] Paganin, D. M., & Morgan, K. S. (2019). *Sci. Rep*. **9**(1), 17537. [4] Morgan, K. S., & Paganin, D. M. (2019). *Sci. Rep*. **9**(1), 17465. [5] Ahlers, J. N., *et al.* (2024). *Optica*, **11**(8), 1182-1191. [6] Alloo, S. J., *et al.* (2025). *Opt. Express*, **33**(2), 3577-3600. [7] Beltran, M. A., *et al.* (2023). *Optica*, **10**(4), 422-429. [8] Willer, K., *et al.* (2021). *The Lancet Digital Health*, 3(11), e733-e744.

Zooming in on Lung Cancer: Region of Interest Diagnostic Imaging

L. Costello[1], L. D'Amico[1], M. Donnelley[2,3], D. Parsons[2,3], R. Smith[2,3], D. Hausermann[4], M. Kitchen[1], and K. Morgan[1].

[1]*Monash University, School of Physics and Astronomy, Australia, VIC, 3800*
[2]*University of Adelaide, Adelaide Medical School, Adelaide, SA, 5000*
[3]*Women's and Children's Hospital, Adelaide, SA, 5000*
[4]*ANSTO, Australian Synchrotron, Clayton, VIC, 3168*

*Corresponding author: lucy.costello@monash.edu

Lung cancer is one of the deadliest cancers worldwide. At present, conventional lung imaging has limited resolution and contrast, which can make it difficult to properly visualise and characterise early-stage lung tumours. Here we use Phase Contrast CT (PC-CT) to exploit x-ray refraction and improve lung contrast. We couple PC-CT with the idea of "zooming-in" to a suspicious area of the lungs to take a high-resolution Region of Interest (ROI) CT at the Australian Synchrotron's Imaging and Medical Beamline (IMBL), where the illuminated area is only 2% of the whole-lung CT slice.

The aim of this research is to advance clinical lung cancer diagnostics using human-sized lungs (from large animals), determining if ROI PC-CT is feasible, particularly at the high x-ray energies required to penetrate a human chest, and if ROI PC-CT can provide improved visibility of millimetre-sized lung features. Imaging parameters were varied to determine optimal settings and ROI PC-CT was achieved [1]. ROI scans captured a field of view of ~3.8cm with a resolution less than 0.1mm, resolving individual alveoli (Fig. 1). Our comparisons to clinical MRI and CT show PC-CT image quality to be far superior.

This novel approach could provide advantages for radiomics and the characterization of early-stage tumours to determine a treatment plan, and potentially reduce the need for painful biopsies.

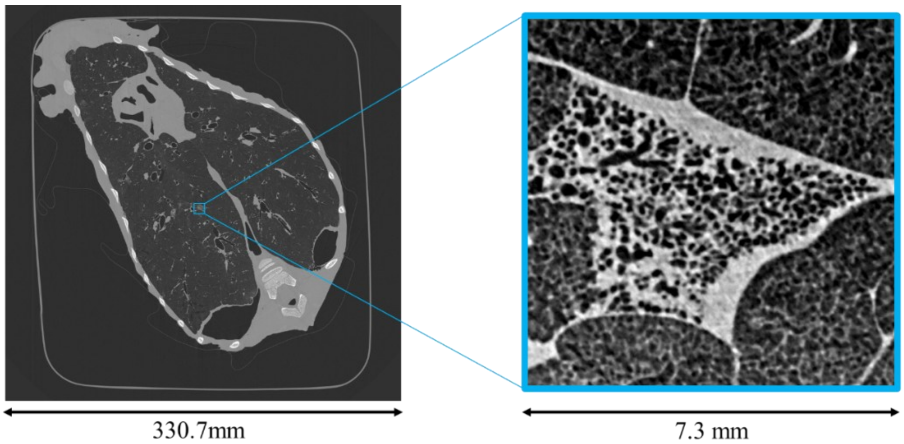


Figure 1. Whole calf thorax (left) and the corresponding region-of-interest image (right), which was captured with a narrowed beam and a higher-resolution detector, but without any changes to the sample.

[1] L. Costello et al., (2025) Evaluating the feasibility of region-of-interest x-ray phase contrast imaging for lung cancer diagnostics. *Scientific Reports*, under review.

Low-Dose, High-Resolution CT of Infant-Sized Lungs via Propagation-Based Phase Contrast

J. A. Pollock[1], K. Morgan[1], L. C. P. Croton[1], E. J. Pryor[23], K. J. Crossley[23], C. J. Hall[4], D. Häusermann[4], A. Maksimenko[4], S.B. Hooper[23], M. J. Kitchen[1]

[1]*School of Physics and Astronomy, Monash University, Clayton, VIC, Australia*
[2]*Ritchie Centre, Hudson Institute of Medical Research, Clayton, VIC, Australia*
[3]*Department of Obstetrics and Gynecology, Monash University, Clayton, VIC, Australia*
[4]*ANSTO, based at the Imaging and Medical Beamline of the Australian Synchrotron, Clayton, VIC, Australia*

*Corresponding author: James.pollock@monash.edu

Many lung conditions require precise visualization for diagnosis and treatment. Infants, particularly those born pre-term, may experience further complications due to lungs being among the last organs to develop in-utero. Most conditions, such as emphysema, bronchopulmonary dysplasia and hypoxia, may be readily diagnosed through volume reconstruction methods like Computed Tomography (CT). However, exposure to ionising radiation introduces long-term risk, especially in high resolution scans. Phase contrast X-ray techniques, by exploiting the phase information of X-rays, may be leveraged to allow safe improvements to image resolution. In particular, propagation-based phase-contrast imaging requires minimal adaption of existing medical systems and has already been demonstrated to provide large dose reductions over absorption X-ray imaging [1]. Our study, published in *Scientific Reports* [2], presents an optimization of propagation-based phase contrast CT for paediatric imaging in large animal lamb models at the Australian synchrotron. Noise-limited spatial resolution was measured using Fourier ring correlation [3] to assess the dominant effect of Poisson noise on resolution at very low doses, while dosimetry was performed through Monte Carlo simulation. The resulting CT images demonstrate superior resolution to existing high resolution CT systems while preserving dose to be within or less than current Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) guidelines for infant chest CT exposure (<2.5mSv effective dose).

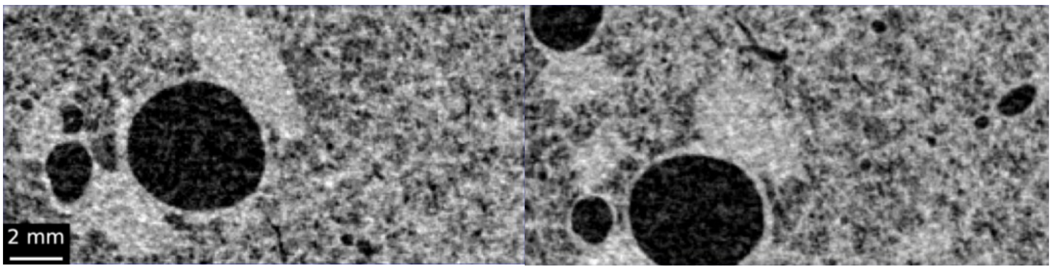


Figure 1 Example lung CT sections recorded at effective doses of 0.63 mSv (left) and 0.99 mSv (right).

[1] M. J. Kitchen, G. A. Buckley, T. E. Gureyev, M. J. Wallace, N. Andres-Thio, K. Uesugi, N. Yagi, and S. B. Hooper. *Scientific Reports*, 7(1):15953, November 2017.

[2] J. A. Pollock, K. Morgan, L. C. P. Croton, E. J. Pryor, K. J. Crossley, C. J. Hall, D. Häusermann, A. Maksimenko, S. B. Hooper, M. J. Kitchen. *Scientific Reports*, 7(1):15953, … 2025.

[3] M. van Heel and M. Schatz. *Journal of Structural Biology*, 50 151(3):250–262, September 2005

POSTER SESSION 1

September 22nd, 12:00-14:30

P1.1	Jannis Ahlers Monash University (AUS)	High-speed X-ray dark-field imaging via spectral information
P1.2	Michela Ascolese Milano-Bicocca University (IT)	First results of phase contrast microCT imaging with the Zeiss-Versa laboratory source
P1.3	Federico Camponovo INFN - Milano-Bicocca section (IT)	Explainability methods with X-CAM visualization in Jet Tagging
P1.4	Simone Caputo Milano-Bicocca University (IT)	Deep learning begins with segmentation: a method for brain vascular mapping in phase-contrast microCT
P1.5	Matteo Cataldo INFN - Milano-Bicocca section (IT)	Compositional and morphological study of a Nuragic bronze figurine with neutron diffraction and neutron tomography
P1.6	Maria Caterina Crocco Universty of Calabria and STAR RI (IT)	Multilevel evaluation of PSELT in cardiovascular disease
P1.7	Hafiz Muhammad Fahad Ludwig Maximilians University (GER)	Patch-Based U-Net Segmentation of Human Brain Tissue in Synchrotron Nano-CT Imaging
P1.8	Hafiz Muhammad Fahad Ludwig Maximilians University (GER)	DAPHNE4NFDI: FAIR data workflow and solutions for the X-ray imaging and CT use case
P1.9	Tero Hyvärinen University of Oulu (FIN)	Automatic Exposure Control in Cone Beam Computed Tomography
P1.10	Dinidu Prabhath Jyakody Arachchilage University of Oulu (FIN)	A hybrid approach combining dual-energy decomposition and inpainting for metal artefact reduction in dentomaxillofacial CBCT
P1.11	Werneri Lindberg ETH Zürich (CH)	Adapting X-ray dark-field imaging for clinical practice: a path towards enhanced disease characterization in routine healthcare
P1.12	Giusto Lo Bue University of Pavia (IT)	Neutron tomography for non-destructive imaging of microplastics in bio-engineered marine habitats
P1.13	Giulia Marcucci Milano-Bicocca University (IT)	The INFN CHNet_BRONZE project: quantitative optimisation of advanced neutron imaging for archeometallurgical applications
P1.14	Giulia Marcucci Milano-Bicocca University (IT)	The normalisation workflow and post processing pipeline for neutron resonance transmission imaging at the INES beamline
P1.15	Samuel Onnela University of Oulu (FIN)	Signal-to-equivalent Thickness Calibration improves soft tissue contrast with diagnostic CBCT
P1.16	Tahseen Sana Milano-Bicocca University (IT)	Characterization of the performances of the Zeiss-Versa 610

P1.17	Sobhan Sheikhi Milano-Bicocca University (IT)	Evaluation of Therapeutic Strategies to Slow Down Neurodegeneration in Experimental Models of Spinocerebellar Ataxia Type 1 by Multiscale X-ray Phase-Contrast Micro-CT
P1.18	Luisa Vigorelli Milano-Bicocca University (IT)	Python-based software for X-ray phase contrast tomographic reconstruction in the framework of the PITCH project for Cultural Heritage analysis
P1.19	Luisa Vigorelli Milano-Bicocca University (IT)	High-resolution neutron tomography for the study of a golden filigree from the Chiaravalle Cross

P1.1

High-speed X-ray dark-field imaging via spectral information

J.N. Ahlers[1]*, K.M. Pavlov[2,3,1], M.J. Kitchen[1], C. Hall[4], K.S. Morgan[1]

[1]*School of Physics and Astronomy, Monash University, Clayton, VIC 3800, Australia*
[2]*School of Physical and Chemical Sciences, University of Canterbury, Christchurch 8140, New Zealand*
[3]*School of Science and Technology, University of New England, Armidale NSW 2351, Australia*
[4]*Australian Synchrotron, ANSTO, Clayton, VIC 3168, Australia*

*Corresponding author: jannis.ahlers@monash.edu

Dark-field X-ray imaging is a burgeoning technique sensitive to the scattering of X-rays from the sample's microstructure below the resolution limit. Dark-field imaging usually relies on a reference structured illumination to analyse such scattering. However, most synchrotron imaging is done using simple propagation-based imaging (PBI); the sample is placed in the un-structured beam, and the diffracted wavefield is imaged some propagation distance downstream from the sample. The recent development of a Fokker–Planck model for dark-field intensity diffusion has enabled the reconstruction of dark-field signals from straightforward PBI [1,2,3]. We present a method for dark-field retrieval from dual-energy PBI [4] and its use for dynamic imaging of changing samples (see Figure 1) at the Imaging and Medical Beamline (IMBL) of the Australian Synchrotron using a principal and third monochromator harmonic in combination with an energy-discriminating photon-counting detector [5]. We discuss the quantitative interpretation of Fokker–Planck-based dark-field retrieval and present current progress on iterative methods for dark-field reconstruction from PBI data.

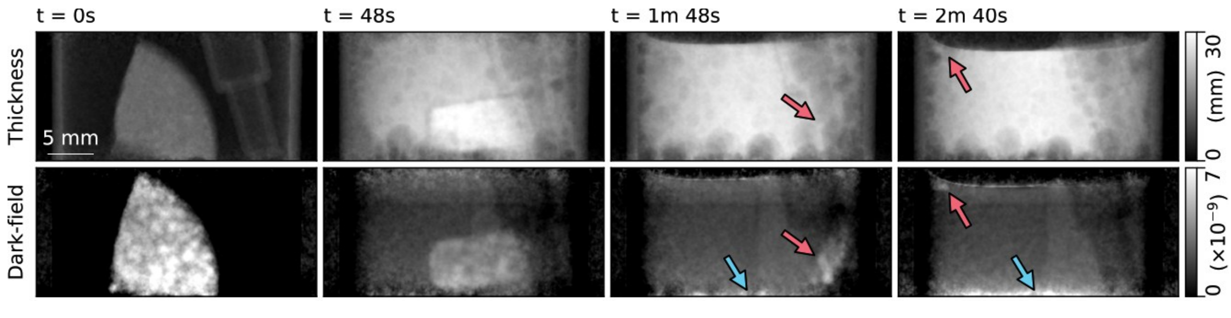


Figure 1 Dissolution of a piece of an effervescent tablet in water. The water quickly dissolves the tablet, making it difficult to distinguish from the surrounding solution in the attenuation image (top row); in contrast, the remnant of the tablet can be clearly distinguished in the dark-field image (bottom row).

[1] D.M. Paganin & K.S. Morgan (2019). *Scientific Reports*, **9**, 17537.
[2] K.S. Morgan & D.M. Paganin (2019). *Scientific Reports*, **9**, 17465.
[3] T.A. Leatham, D.M. Paganin, K.S. Morgan (2023). *IEEE Transactions on Medical Imaging*, **42**, 1681–1695.
[4] J.N. Ahlers, K.M. Pavlov, M.J. Kitchen, K.S. Morgan (2024). *Optica*, **11**, 1182–1191.
[5] J.N. Ahlers, K.M. Pavlov, M.J. Kitchen, S.A. Harker, E.J. Pryor, J.A. Pollock, M.K. Croughan, Y.Y. How, M.C. Zdora, L.F. Costello, D. O'Connell, C. Hall, K.S. Morgan (2025). *Optics Letters*, **50**, 2171–2174.

P1.2

First results of phase contrast microCT imaging with the Zeiss-Versa laboratory source

M. Ascolese[1]*, T. Sana[1], S. Caputo[1], F. Cognigni[2], F. Biancardi[2], G. Cavaletti[3], A. Bravin[1]

[1]*Dipartimento di Fisica "G. Occhialini", Università degli Studi di Milano-Bicocca, Building U2 Piazza della Scienza, 3, 20126 Milano (MI), Italy*
[2]*ZEISS Research Microscopy Solutions, Via Varesina, 162, 20156 Milano (MI), Italy*
[3] *Dipartimento di Medicina e Chirurgia, Università degli Studi di Milano-Bicocca, Building U18 20854 Vedano al Lambro (MB), Italy*

*Corresponding author: michela.ascolese@unimib.it

A Zeiss Xradia Versa 615 microscopy system has been recently installed at the University of Milano-Bicocca, to serve the scopes of the Anthem1 project. This new instrument can perform radiographs and microtomographies at the submicrometric resolution both exploiting the traditional absorption contrast and propagation-based phase-contrast-generated maps (PBI). PBI is able to visualize the tiny refraction of X-rays inside the specimens, generating an edge enhancement that improves the detail visibility.

We will present here the results of the first images acquired in both radiography and tomography modes, comparing the absorption-based and the phase-contrast images in a portfolio of phantoms and biological samples.

[1] Anthem – AdvaNced Technology for Human centEred Medicine, Piano Nazionale Complementare al PNRR

P1.3

Explainability methods with X-CAM visualization in Jet Tagging

F. Camponovo[1*], M. Monteleone[3], L. Cederle[3], F. Camagni[3], P. Govoni[1,2], S. Gennai[1], C. Paganelli[3]

[1] *INFN sezione di Milano-Bicocca, Milano, Italy*
[2] *Università degli studi di Milano-Bicocca, Milano, Italy*
[3] *Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano, Milano, Italy*
*federico.camponovo@mib.infn.it

Jet tagging is a fundamental task in high-energy physics, which can be effectively approached as an image classification problem. By representing jet events as 2D images in the ($\boldsymbol{\varphi}$, η) plane, deep learning models can analyze and classify different types of jet events based on their underlying physical processes. Explainability in these models is crucial for facilitating the data analysis review process.
This work explores explainability X-CAM methods like Score-CAM and Grad-CAM, in the context of jet classification using a simple pretrained VGG-16 network. This study is intended to complement the work in [1], providing a comparative analysis of classification techniques based on Visual Transformers and attention maps as an explainability tool.
The study is based on the JETCLASS dataset, focusing on two jet tagging tasks: distinguishing signal from background and differentiating between different signal types. A pre-trained VGG-16 model is employed to perform binary classification tasks with fine tuning, in order to refine high level features; by computing the centroids of each jet within the image and defining regions of interest (ROIs) around their barycenters, we have analyzed the model's decision-making process.
Our comparative study with Visual Transformer-based classification techniques has revealed a significant difference in the degree of attention across different deep learning paradigms. While Grad-CAM and Score-CAM exhibited a relatively low average attention of about 30 – 40% in the ROIs, the attention maps from Visual Transformers demonstrated a much higher focus on the same areas, reaching attention levels of 80 – 85%. These findings highlight how different architectures process spatial information differently, offering valuable insights into the interpretability of deep learning models in high-energy physics. Given the robustness of the data in this domain, our study could also contribute to a deeper understanding of explainability tools in other fields where interpretability is crucial, such as medical imaging.

[1] M.Monteleone, F. Camponovo, L.Cederle F. Camagni, P. Govoni, S. Gennai, C. Paganelli (2025), Investigating Explainable Jet Tagging with Pretrained Vision Transformers and Attention Mechanism, in preparation.

P1.4

Deep learning begins with segmentation: a method for brain vascular mapping in phase-contrast micro-CT

S. Caputo[1*], H. M. Fahad[2], E. Rothaemel[2], S. Gerevini[1,3], A. Gianatti[1,3], G. Cavaletti[1], F. Pagni[1], A. Mittone[4], M. Eckermann[5,6], P. Coan[2], A. Bravin[1,7]

[1] *University of Milano-Bicocca, Milan, Italy*
[2] *Ludwig Maximilians University, Munich, Germany*
[3] *ASST Papa Giovanni XXIII, Bergamo, Italy*
[4] *Argonne National Laboratory, Illinois, USA*
[5] *European Synchrotron Radiation Facility, Grenoble, France*
[6] *University of Bern, Bern, Switzerland*
[7] *University of Calabria, Arcavacata di Rende, Italy*

*Corresponding author: s.caputo19@campus.unimib.it

Phase-contrast X-ray microtomography (micro-CT) is a powerful tool for non-destructive analysis of biological samples. We will report here the procedures used for the characterization and segmentation of micro-CT images of human brain samples prepared in paraffin blocks using the standard histological workup. Accurate segmentation of the datasets is critical for quantitative morphometric analysis and structural mapping at the microscale [1]. In this work, we describe the implementation of a deep learning framework based on a U-Net architecture [2] to segment the vascular network in volumes, composed of 2048x2048x2048 voxels, acquired at the BM5 beamline of the European Synchrotron Radiation Facility (Grenoble, France). Particular care was devoted to the preparation of training datasets, as the performance of deep learning segmentation models is highly dependent on the quality, diversity, and representativeness of the training data. Two types of approaches were used in this work, one optimized for large-and-medium-size vessels and the other for capillaries. Manual segmentation of large vessels was performed using commercial image analysis software such as “3D slicer” and “ImageJ” via the standard tools available in the software itself; this implementation was simple and relatively low time-consuming due to the exiguous number of large vessels in the analyzed tissues. To segment the capillaries, which are present in dozens in each slice, we used instead a semi-automatic approach combining the above-mentioned commercial software with home-made python codes to perform data binning, detail labelling, and interpolation operations; the separation of these procedures permitted to speed up the segmentation processing of these very large volumes of data. We will present here the two methods and the results of the segmentation of the vascular network in the examined brain specimens.

[1] G. Litjens et al. (2017). *Medical Image Analysis*, **42**, 60–88. [2] O. Ronneberger, P. Fischer, T. Brox (2015) U-Net: Convolutional networks for biomedical image segmentation. In *International Conference on Medical Image Computing and Computer-Assisted Intervention (MICCAI)*, Springer, 234–241.

P1.5

Compositional and morphological study of a Nuragic bronze figurine with neutron diffraction and neutron tomography

P. Oliva[1], S. Britto[2], N. Canu[3], M. Cataldo[4*], M. Clemenza[4], G. Marcucci[4,5,2], A. Scherillo[2], V. Sipala[6]

[1]*Università di Pisa*

[2]*ISIS Neutron and Muon Source, Didcot, UK*

[3]*Sopraintendenza Archeologia, Belle arti e Paesaggio per le province di Sassari e Nuoro*

[4]*INFN Sezione Milano Bicocca*

[5]*Università degli Studi di Milano Bicocca*

[6]*Università degli Studi di Sassari*

*Corresponding author: matteo.cataldo@mib.infn.it

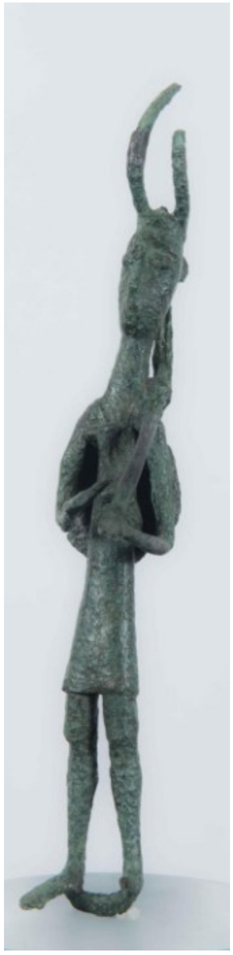


Fig. 1 – Nuragic bronze statuette

Nuragic figurines are rare and unique examples of the mastery achieved by Sardinian craftsmen in the early Iron Age. Made of bronze, they represent a wide variety of figures, from warriors, animals, and divinities to votive boats. These artefacts were most likely cast using the lost wax technique: the shapes were moulded with relative ease, and even complex figures could be represented. However, the manufacturing process wasn't always a single solution: in some cases, the parts of the model were moulded separately and then assembled in a second place. The analytical study of these artefacts can help to understand the specific casting methods and to evaluate the techniques implemented by Sardinian craftsmen to produce such complex objects. Many methods can be used to characterise these materials, but in recent years, neutron diffraction (ND) and neutron imaging (NI) have proven to be among the most effective methods for non-invasive studies [1-2]. ND and NI provide quantitative and morphological information that can be the key to understanding the casting processes. In this work, the results of the analysis of a bronze figurine will be reported. The statuette represents a Nuragic warrior with a horned helmet and a shield on his back (Fig. 1), and it is owned by the *Soprintendenza Archeologia Belle Arti e Paesaggio per le province di Sassari e Nuoro* (Sassari, Italy). The results of the analysis show that the warrior was cast as a single piece of bronze, in agreement with archaeological assumptions (driven by the presence of possible casting channels under the warrior's feet). Moreover, diffraction studies reveal strong texture effects on each measured area, indicative of cold working. Finally, unlike other measured samples, this figurine has very limited porosity, testifying to the high level of control achieved in this manufacturing process.

[1] A. Depalmas et al. (2021) *Archaeol and Anthropol Sci,* **13**, 101 [2] F. Cantini et al. (2024) *J. of Archaeol. Sci Rep,* **60**, 104801

P1.6

Multilevel evaluation of PSELT in cardiovascular disease

M.C. Crocco[1,2,3*], C. Rocca[4], A. De Bartolo[4], R.C. Barberi[1,2,3], T. Angelone[4], R.G. Agostino[1,2,3], R. Guzzi[1,3] and V. Formoso[1,2,3]

[1]*Department of Physics, University of Calabria, Rende, 87036, CS, Italy*
[2]*STAR Research Infrastructure, University of Calabria, Rende, 87036, CS, Italy*
[3]*CNR Nanotec, Rende, 87036, CS, Italy*
[4]*Department of Biology Ecology and Earth Sciences, University of Calabria, Rende, 87036, CS, Italy*

*Corresponding author: mariacaterina.crocco@unical.it

Cardiac lipotoxicity is a key factor in cardiovascular complications associated with obesity. Selenoprotein T (SELENOT) has been shown to play a key role in cardiomyocyte differentiation and protection. In this study, the protective potential of a peptide fragment (PSELT) derived from the redox-active domain of SELENOT, was explored to understand the mechanisms by which this peptide could defend cardiomyocytes and the heart from cardiovascular complications. The properties of PSELT were analyzed using attenuated total reflection Fourier transform infrared spectroscopy (ATR-FTIR) and X-ray microtomography (μ-CT), on two distinct levels: cellular and whole organ (rat heart). To simulate cardiac lipotoxicity, H9C2 cardiac cells were exposed to palmitic acid (PA), while global ischemia was induced in *ex-vivo* rat hearts. Experimental results showed that treatment with PSELT significantly reduced cardiac damage. According to spectroscopic analysis at the cellular level, the peptide reduced the alterations at the level of macromolecules and regulated the membrane fluidity altered by PA [1]. In addition, μ-CT confirmed, at the whole-organ level, the efficacy of PSELT in contrasting ischemic damage, also highlighting the excellent ability of this technique in obtaining virtual three-dimensional histological images.

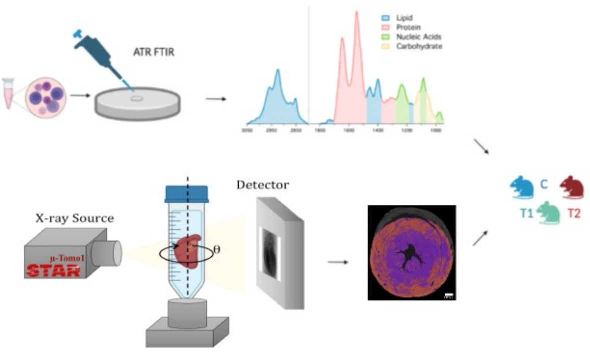


Figure 1 Graphical abstract.

[1] C. Rocca, A. De Bartolo, R. Guzzi, M.C. Crocco, et al. (2022). *Cells*, **12** (7):1042.

P1.7

Patch-Based U-Net Segmentation of Human Brain Tissue in Synchrotron Nano-CT Imaging

H. M. Fahad*[1], E. Rothaemel[1], S. Caputo[2], M. Ascolese[2], T. Sana[2], S. Gerevini[2,3], A. Gianatti[2,3], G. Cavaletti[2], F. Pagni[2], A. Mittone[4], M. Eckermann[5,6], A. Bravin[2,7], P. Coan[1]

[1] *Ludwig Maximilians University, Munich, Germany*
[2] *University of Milano-Bicocca, Milan, Italy*
[3] *ASST Papa Giovanni XXIII*
[4] *Argonne National Laboratory*
[5] *European Synchrotron Radiation Facility, Grenoble, France*
[6] *University of Bern, Bern, Switzerland*
[7] *University of Calabria, Arcavacata di Rende, Italy*
*Corresponding author: h.fahad@lmu.de

Synchrotron-based X-ray computed tomography (CT) is a state-of-the-art imaging technique that enables exceptionally detailed visualization and high contrast of micro- and nano-scale structures within biological tissues and materials. In this study, imaging data were acquired at the ID16A beamline of the European Synchrotron (ESRF, France). Thanks to the high brilliance of the photon beam and the advanced capabilities of the experimental setup, nano-scale X-ray tomography on human brain tissues was successfully performed. High-resolution segmentation of these complex structures is crucial for characterizing cellular and vascular morphology and revealing and studying possible alterations in pathological conditions. However, the size and complexity of the resulting volumetric datasets present significant computational challenges. To address this latter point, we developed a machine learning-based segmentation pipeline using the U-Net architecture, adapted to process image patches that fit within GPU memory limits without compromising contextual information. Initially, training datasets were generated through manual annotation of representative regions, focusing on cellular and vascular features, using the Dragonfly image processing tool. Several preprocessing steps were performed, including histogram normalization to standardize intensity distributions across samples, and bilateral filtering to reduce noise while preserving important edge information—crucial for distinguishing cellular and vascular boundaries. Model performance was assessed using the Jaccard coefficient, a widely used similarity metric in image segmentation tasks. The complete dataset was divided into three parts: training, validation, and test sets, to thoroughly evaluate model performance. The trained model was applied to synchrotron nano-CT datasets of human brain tissue, resulting in a high-accuracy segmentation of both cellular structures and vasculature, achieving 87% and 96% accuracy, respectively. These results underscore the model's capability to resolve fine anatomical features, demonstrating its potential for large-scale biomedical imaging analysis. Overall, this framework offers a robust and scalable solution for deep learning-based segmentation of high-resolution 3D imaging data.

P1.8

DAPHNE4NFDI: FAIR data workflow and solutions for the X-ray imaging and CT use case

H. M. Fahad*[1], M. Osterhoff[2], S. Köster[2], H. Görzig[3], P. Coan[1]

[1] *Ludwig Maximilians University, Munich, Germany*
[2] *Georg-August-Universität Göttingen, Göttingen, Germany*
[3] *Helmholtz-Zentrum Berlin, Berlin, Germany*

*Corresponding author: h.fahad@lmu.de

DAPHNE4NFDI is one of the twenty-six consortia within the National Research Data Infrastructure (NFDI), funded by the German Research Foundation (DFG). DAPHNE4NFDI focuses on research involving photons and neutrons at large-scale facilities, aiming to provide open access to experimental data, integrate user-oriented solutions, and support a comprehensive scientific infrastructure. The project is a collaboration between seven research institutions, eleven universities from various scientific disciplines, and several international partners—including the DESY (D) laboratories, the Ludwig Maximilians University - LMU (D), and the European Synchrotron Radiation Facility - ESRF (F). Advances in synchrotron imaging and computed tomography (CT) now allow non-invasive, high-resolution 3D visualization of samples, including biological tissues, surpassing traditional methods. These innovations generate large volumes of data, necessitating tailored solutions for data capture, management, storage, and the creation of repositories for processed data and analysis code. Such solutions are able to enhance transparency and promote data reuse in biomedical research. Our LMU team has been collaborating closely with scientists and IT experts from various synchrotron facilities and has established a consistent vocabulary, along with a comprehensive list of metadata parameters applicable across different imaging beamlines. Currently, implemented or ongoing metadata recording efforts are primarily focused on capturing parameters up to the data acquisition phase. In collaboration with ESRF's IT experts, we are now working to extend this list to include comprehensive post-processing metadata—at least up to the CT data reconstruction stage, which is common to all CT experiments. Catalogues are essential for effective data management in scientific experiments, ensuring that data are organized, preserved, and aligned with the FAIR principles. Our LMU team is currently finalizing the installation of SciCAT, aiming to its integration with the existing catalog system to enhance overall data management. Through collaboration among user groups, scientists, and IT experts at synchrotron facilities, the LMU team is actively developing a general FAIR data workflow for synchrotron imaging and CT experiments.

P1.9

Automatic Exposure Control in Cone Beam Computed Tomography

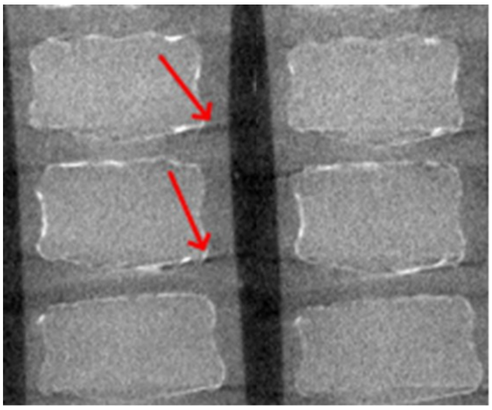
T. Hyvärinen[1*], S. Onnela[1*], M. Brix[1,2], T. Liimatainen[1,2], M. Hanni[1,2,3]

[1] *Research Unit of Health Sciences and Technology, University of Oulu, Oulu.*
[2] *Department of Diagnostic Radiology, Oulu University Hospital, 90220 Oulu, Finland*
[3] *Medical Research Center Oulu, University of Oulu and Oulu University Hospital, Oulu, Finland.*

*Corresponding author(s): tero.hyvarinen@oulu.fi, samuel.onnela@oulu.fi

Cone Beam Computed Tomography (CBCT) is a widely used X-ray imaging technique. Though considered a low-dose modality, it can result in significant cumulative doses, for example in CBCT-based radiation therapy patient positioning.

This study shows that tube current adjustment based on phantom attenuation reduces radiation dose with minimal effect on image quality. An anthropomorphic phantom was imaged with a diagnostic head-neck CBCT device with varying dose levels. The phantom was modeled as an elliptic cylinder based on scout images. A separate signal-to-equivalent thickness method was used to choose the sufficient dose level for optimal image quality. The optimal projections were combined to simulate dynamic tube current modulation. The modulated image (Fig. 1) exhibited both reduced radiation dose and improved image quality compared to the image reconstructed from projections with a constant current setting.



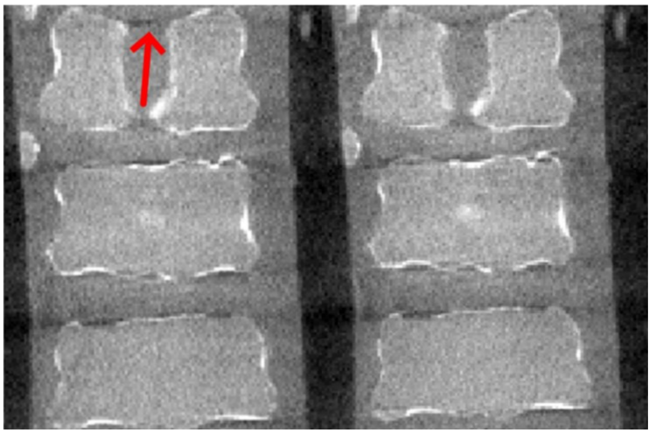


Figure 1 Modulated images (rightmost) have reduced beam hardening-related artefacts with lower dose. Noise remained consistent while the radiation dose could be reduced by 5–17%. Signal-to-noise ratio (SNR) varied by ±1% compared to the unmodulated image, depending on the slice. The study concludes that adjusting tube current based on anatomical variations can effectively reduce radiation dose in CBCT imaging with minimal to positive impact on image quality.

P1.10

A hybrid approach combining dual-energy decomposition and inpainting for metal artefact reduction in dentomaxillofacial CBCT

D. Jayakody[1]*, H. Agrawal[2], E. Räinä[1], A. Sipola[4], R. Näpänkangas[4], S. Ylisiurua[1,3], M.T. Nieminen[1,3], M. Brix[1,3]

[1]*Research Unit of Health Sciences and Technology, University of Oulu, Aapistie 5A, Oulu, Finland.*
[2]*Research and Technology, Planmeca Oy, Asentajankatu 6, FI-00880 Helsinki, Finland.*
[3]*Department of Diagnostic Radiology, Oulu University Hospital, Kajaanintie 50, Oulu, FI-90220, Finland.*
[4]*Department of Oral and Maxillofacial Surgery, Oulu University Hospital, Kajaanintie 50, Oulu,Finland.*

*Corresponding author: Dinidu.jayakodyarachchilage@oulu.fi

Cone-beam computed tomography (CBCT) is frequently used in dentomaxillofacial imaging and orthopedic studies. However, diagnostic accuracy is often compromised by dense bone structures and dental restorations, which generate beam hardening and metal artifacts [1]. In this work, a dual-energy (DE) CBCT-based projection domain material decomposition (MD) approach [2], and virtual monochromatic imaging (VMI) technique was used. The key technical contribution of this work is the integration of the VMI technique with the vendor's metal artifact reduction (MAR) pipeline to mitigate beam hardening artifacts.

Six commonly used dentomaxillofacial implant and prosthetic materials were extracted during routine dental procedures and placed in a 3D-printed gelatin-filled mold. A CBCT scanner (Viso G7, Planmeca group) was used to image phantoms at 80 kV and 120 kV. An internally developed polychromatic projection-domain MD algorithm processed the DE acquisitions into water and iron basis materials. VMIs at 200 keV were created, and vendor's inpainting-based MAR algorithm was subsequently applied (VMI+MAR). For comparison, 100 kV acquisition (routine protocol) with and without MAR was used to assess VMI performance. The dose-area products of the DE and routine acquisitions were matched (relative error of 5.4%).

Vendor's MAR reduced metal artifacts, however, some artifacts remained. VMI alone substantially reduced artifacts, though some traces of the original artifacts were still present. The VMI + MAR method yielded superior performance allowing mitigation of artifacts seen in the VMI reconstruction. Furthermore, the method successfully recovered the internal structures of the used prosthetic and implant materials. Our findings indicate that DE-based CBCT, combined with MD and VMI technique, clearly reduced the metal artifacts in CBCT. Additionally, combining the VMI technique with an inpainting MAR produced a particularly effective artifact reduction technique, yielding previously unreported performance improvement with CBCT.

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P1.11

Adapting X-ray dark-field imaging for clinical practice: a path towards enhanced disease characterization in routine healthcare

W. Lindberg[1,2], H. Richter[3], F. Alfayez[4], K. Pratama[5], O. Bonny[6], D. Terebenec[2], R. Rossi[1], A. Neels[2,7], R. Zboray[2,8,*]

[1]*Department of Health Sciences and Technology, ETH Zürich, CH-8092, Zürich*
[2]*Center for X-ray Analytics, Empa, CH-8600, Dübendorf*
[3]*Diagnostic Imaging Research Unit (DIRU), Vetsuisse Faculty, University of Zürich, CH-8057, Zürich*
[4]*Department of Materials, ETH Zürich, CH-8049, Zürich*
[5]*Mechanics of Materials and Nanostructures, Empa, CH-3603, Thun*
[6]*HFR Fribourg Cantonal Hospital, CH-1752, Fribourg*
[7]*Department of Chemistry, University of Fribourg, CH-1700, Fribourg*
[8]*ARTORG Center, University of Bern, CH-3012, Bern*

*Corresponding author: robert.zboray@empa.ch

Current imaging modalities lack the sensitivity needed for accurate disease characterization, limiting effective patient management. In light of these challenges, X-ray dark-field imaging provides valuable contrast by detecting variations in scattering from biological structures, offering proven clinical benefits in the lung [1], bone [2], urinary stone [3]-[6], and early-stage diseases [7]-[10]. However, these advanced imaging techniques have predominantly been employed in synchrotron facilities or specialized equipment, where high-quality imaging can be achieved under controlled conditions. The challenge lies in adapting dark-field imaging for lab-based X-ray systems commonly found in clinical environments, where such conditions are not readily achievable.

The purpose of this study is to integrate X-ray dark-field imaging into standard radiography and computed tomography with minimal modifications to existing equipment. Practical adaptations of Fokker Planck and speckle-based X-ray imaging help bridge the gap, translating the proven advantages of dark-field imaging from research into everyday clinical use, thereby making advanced diagnostic techniques more accessible and applicable in routine healthcare.

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P1.12

Neutron tomography for non-destructive imaging of microplastics in bio-engineered marine habitats.

G. Lo Bue [1]*, M. Musa[1], A. Kaestner[2], D. Di Martino[3], M. Busi, S. Azad[2], M. P. Riccardi[1], N. Mancin[1]

[1]*Dipartimento di Scienze della Terra e dell'Ambiente, Università di Pavia, Via Ferrata, 9 – 27100 Pavia, Italia.*
[2] *PSI Center for Neutron and Muon Sciences, 5232 Villigen PSI, Switzerland*
[3] *Dipartimento di Fisica "G. Occhialini", Università degli Studi di Milano Bicocca, Piazza della Scienza, 3 - 20126 Milano, Italia.*

*Corresponding author: giusto.lobue01@universitadipavia.it

Microplastics (MPs) are pervasive pollutants posing a planetary boundary threat due to their persistence and ability to enter food webs and sedimentary records. Many benthic organisms utilize available grains picked from the substrate for the building of their agglutinated tubes. Among these organisms, Sabellariid polychaetes exhibit a gregarious way of life, where individuals build tubes close together, resulting in the formation of extensive arenaceous bioconstructions (reefs) along European coasts. These dynamic engineered reefs play vital roles as nutrient sinks, biodiversity hotspots and protection from the coastal erosion [1]. An increasing amount of microplastics accumulated among sedimentary granules could enter these bioengineered habitats with effects still unknown. Recently MPs abundance in Mediterranean *Sabellaria spinulosa* reefs has been quantified, but the methods involved sample destruction via digestion and density separation, causing crucial data loss regarding MPs spatial distribution within the reef structure [2].

Building on prior work using non-destructive imaging for MPs in sediment [3], we applied neutron tomography to investigate *S. spinulosa* bioconstruction samples. Portions collected from the Torre Mileto (Apulia) reef were exposed in two experimental tanks for one month: one contaminated with known MPs (Polyethene terephthalate up to 2mm), another serving as a control. Analyses were conducted at the ICON neutron imaging facility (Paul Scherrer Institut) [4]. Unlike sediment sample, bioconstruction sample have added complexity due to the organic matrix binding the grains and organic worm remains potentially interfering with MP identification. Nevertheless, our initial results strongly suggest neutron tomography offers high potential for the non-destructive detection of MPs within these challenging, complex matrices. Further validation is underway to confirm the full efficacy of this innovative approach.

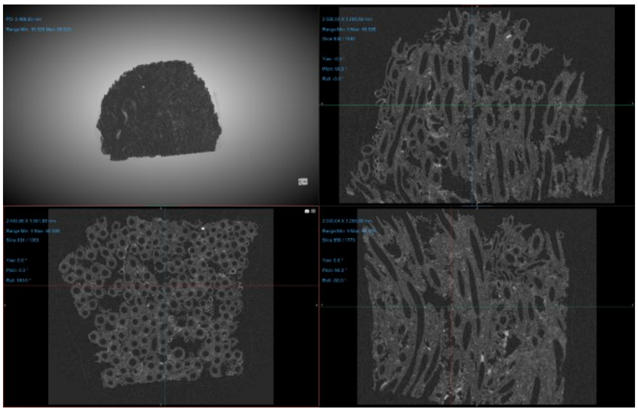

Figure 1 Neutron reconstruction of the sample within the Dragonfly software environment, illustrating the processed sample volume (top left) and orthogonal views (bottom left, top right, bottom right).

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P1.13

The INFN CHNet_BRONZE project: quantitative optimisation of advanced neutron imaging for archeometallurgical applications

G. Marcucci[1,2]*, M. Clemenza[1], L. Vigorelli[1], F. Grazzi[3], A. Re[4,5], M. Marabotto[5], M. Dematteis[4,5], D. Di Martino[1]

[1]*Dipartimento di Fisica "G. Occhialini", Università degli Studi di Milano-Bicocca and INFN Sezione di Milano-Bicocca, Milano, Italy*
[2]*STFC ISIS Neutron and Muon Source, Chilton-Didcot, United Kingdom*
[3]*CNR, Istituto di Fisica Applicata Nello Carrara, and INFN Sezione di Firenze, Firenze, Italy*
[4]*Dipartimento di Fisica, Università degli Studi di Torino, Torino, Italy*
[5]*INFN Sezione di Torino, Torino, Italy*

*Corresponding author: giulia.marcucci@unimib.it

The study of historical metallurgy, particularly bronze and copper alloys, plays a crucial role in understanding the artistic and technological advancements of past civilisations. Mastering these metallurgical processes required extensive knowledge, including the smelting of various metals (such as copper, tin, and lead), the selection of the alloy composition, and the preparation of casting moulds. Conventional archaeometallurgical investigations often rely on destructive techniques, such as metallographic analysis and scanning electron microscopy, which can compromise the integrity of cultural artefacts. To address the need for non-invasive investigations, the CHNet_BRONZE project, funded by INFN, focuses on the quantitative optimisation of neutron-based absorption and scattering methods [1], which can provide valuable information on the elemental and phase composition, texture, microstructure, and morphology of ancient metallic artefacts. The integration of advanced bulk analysis methods includes Neutron Resonance Transmission Imaging (NRTI), which enables the generation and quantitative analysis of bidimensional elemental maps for heritage science studies [2]. NRTI is a time-of-flight radiographic technique exploiting epithermal neutrons for 2D (and potentially 3D) mapping of the bulk elemental and isotopic distributions. No sample preparation is required. NRTI reveals the fraction of the neutron beam that passes through the sample without any interaction, and it is based on the presence of resonance peaks in the cross sections of neutron-induced reactions. These structures appear at energies specific to each nuclide, acting as fingerprints for the nuclide. Moreover, the resonance intensity can provide quantitative information about these isotopes. The quantitative optimisation of NRTI is under development at the ISIS Neutron and Muon Source (UK), using a set of Cu-based reference alloys characterised by metallurgical features and microstructure similar to ancient bronze artefacts and whose chemical composition is ascribed to the material classes Cu-Sn, Cu-Zn, Cu-Pb, Cu-Sn-Pb, Cu-Zn-Pb, and Cu-Sn-Zn-Pb.

[1] M. Marabotto, et al. (2025), submitted to *Il Nuovo Cimento C*
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P1.14

The normalisation workflow and post-processing pipeline for neutron resonance transmission imaging at the INES beamline

G. Marcucci[1,2]*

[1]*Dipartimento di Fisica "G. Occhialini", Università degli Studi di Milano-Bicocca and INFN Sezione di Milano-Bicocca, Milano, Italy*
[2]*STFC ISIS Neutron and Muon Source, Chilton-Didcot, United Kingdom*

*Corresponding author: giulia.marcucci@unimib.it

Neutron Resonance Transmission Imaging (NRTI) is an energy-dependent method based on event-mode acquisition of time-of-flight (ToF) radiographies over a white neutron beam. NRTI enables distinguishing and mapping with enhanced contrast elements and isotopes within a sample that would be undetectable or indistinguishable using conventional imaging methods [1-2]. Currently, NRTI is not readily available as an in-suite technique within large-scale facilities.

The acquisition system crucially differentiates NRTI from conventional neutron tomography. Each pixel of the neutron detector records full ToF spectra. With a total of 128 x 128 pixels, this method generates 16,384 spectra per run, resulting in large-scale event-mode datasets. The presence of an upstream beamline and the intrinsic variations in neutron flux also need to be taken into account when developing acquisition and normalisation procedures.

The growing adoption of NRTI within the ISIS users community highlights the need for a robust and reproducible data normalisation workflow, within the perspective of a quantitative optimisation of the technique.

The proposed workflow for NRTI data processing is currently adapted from standard practices in neutron imaging (open-beam referencing and incident flux monitoring) and represents a first step towards its end-user standardisation. The core difficulty is to balance the need for high signal-to-noise ratios in the spectral domain (for quantitative accuracy) with the constraints of time-intensive acquisitions, which—depending on the target isotopes—can span multiple days.

Additionally, a FAIR-oriented approach to acquisition, normalisation, and post-processing is increasingly essential; in this workflow, it is supported by the use of the Mantid software (license-free), NeXus data format, and Python-based tools. Future work will focus on integrating AI-based methods to enhance signal statistics and reduce acquisition times, alongside Monte Carlo simulations to optimise the imaging pipeline for quantitative elemental and isotopic analysis.

[1] G. Marcucci, et al. (2024) *The European Physical Journal Plus*, **139**, 475. https://doi.org/10.1140/epjp/s13360-024-05222-y
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P1.15

Signal-to-equivalent Thickness Calibration improves soft tissue contrast with diagnostic CBCT

S. Onnela[1*], S. Ylisiurua[1,2], A. Meaney[3], S. Siltanen[3], M. Nieminen[1,2], M. Brix[1,2]

[1]*Research Unit of Health Sciences and Technology, University of Oulu*
[2]*Department of Diagnostic Radiology, Oulu University Hospital*
[3]*Department of Mathematics and Statistics, University of Helsinki*

*Corresponding author: samuel.onnela@oulu.fi

Cone beam computed tomography (CBCT) X-ray imaging suffers from poor soft-tissue contrast, Hounsfield Unit (HU) instability, and beam hardening -related artifacts. This study aims to alleviate these issues by utilizing an acrylic-based signal-to-equivalent thickness calibration (STC) method [1,2]. Previously, the STC method showed deteriorated image quality in large field-of-views (FOVs), limiting its generalizability.

We extended the method by creating scatter intensity images from small-FOV images and subtracting them from the primary calibration images. A spectral CT phantom was scanned with varying tissue inserts and scattering conditions. Projection data underwent flat field (FF) and STC corrections before Feldkamp-Davis-Kress reconstruction. Image quality was compared between methods based on target contrast and HU values with helical CT serving as a benchmark.

Compared to vendor-calibrated and FF-corrected images, the scaled STC method enhanced soft tissue contrast by 6 to 13 HU for blood, liver, brain, muscle, and lymph tissues. Contrast enhancement was observed for iodine, calcium hydroxyapatite, lung and adipose in comparison to vendor's but not FF images, across all FOVs. Linear regression analysis across all tissue implants, FOVs and with or without a scattering mantle yielded fidelity and intersection of 0.833 and 1.9 HU, respectively, for scaled STC, when the other methods' results varied from 0.781 to 0.803 and –44 to –25 HU.

The study shows the feasibility of STC in enhancing soft tissue contrast and HU value fidelity in diagnostic CBCT. Additionally, we have also demonstrated that low-scattering images can be used for scattering reduction in the STC method itself, improving the existing method.

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P1.16

Characterization of the performances of the Zeiss-Versa 610 microtomographic system

T. Sana[1]*, M. Ascolese[1], G. Cavaletti[1], M. Bossi[1], A. Bravin[1,2]

[1] *University of Milano-Bicocca, Milan, Italy*
[2] *University of Calabria, Arcavacata di Rende, Italy*

*Corresponding author: t.sana@campus.unimib.it

An Xradia Zeiss-Versa 610 X-ray microtomographic system has been recently installed in the Milano-Bicocca University's laboratories to serve the AdvaNced Technology for Human centEred Medicine (Anthem) project. The overall scope of the project is to perform non-destructive 3D virtual histology of human biopsies, to support and complement with 3D visualization and quantification, the diagnosis made using conventional histology workup.
The Xradia Versa is aimed at realizing microCT scans at submicrometric resolution and can host samples up to 50 mm in size. The system is equipped with a phase contrast capability, to convert the phase variations of the X-ray beam penetrating the sample into amplitude variations, thus enhancing the signal arising from the interfaces present within the sample.
The tomography system is equipped to perform multiscale tomography permitting to analyse first the overall morphology of the sample at low resolution and then focus on a selected region of interest at higher spatial resolution.
We report here the early results of the characterization of the system in terms of effective spatial resolution, minimum contrast, data acquisition time to perform a full tomography in different experimental conditions.

P1.17

Evaluation of Therapeutic Strategies to Slow Down Neurodegeneration in Experimental Models of Spinocerebellar Ataxia Type 1 by Multiscale X-ray Phase-Contrast Micro-CT

S. Sheikhi[1]*, HM. Fahad[2], F. Liberatore[3], S. Caputo[1], S. Notartomaso[3], R. P. Ginerete[3], V. Bruno[3,4], A. Bravin[1,5], P. Coan[2,6], G. Battaglia[3,4]

[1] *Department of Physics "G. Occhialini," University Milano Bicocca, Milano, Italy*
[2] *Department of Physics, Ludwig-Maximilians University, Munich, Germany*
[3] *Department of Molecular Pathology, IRCCS Neuromed Institute, Pozzilli, Italy*
[4] *Department of Physiology and Pharmacology, Sapienza University, Roma, Italy*
[5] *Department of Physics, University of Calabria, Arcavacata di Rende, Italy*
[6] *Department of Radiology, Ludwig Maximilians University, Munich, Germany*

*Corresponding author: sobhan.sheikhi@unimib.it

Spinocerebellar ataxia type 1 (SCA1) is a neurodegenerative (autosomal dominant) pathology that mainly affects the cerebellum and induces progressive motor deficits. This rare dysfunction is a polyglutamine-dominantly inherited genetic disease caused by an increase in the number of CAG repeats in the ATXN1 gene leading to an expanded polyQ tract in the ataxin-1 protein [1]. This study investigates the potential of selected senolytic drugs in an experimental model of SCA1. We utilized a high-sensitivity microscopic approach based on X-ray phase-contrast micro-CT (X-PCI-CT) for multiscale, postmortem, label-free, three-dimensional virtual histology of formalin fixed, paraffin-embedded healthy and SCA1 mice cerebella. By acquiring datasets at 3^3 μm^3 for full organ coverage and 0.3^3 μm^3 for analysing selected regions, we gathered a comprehensive depiction of the morphology of the examined tissues, including metrics of Purkinje cell density, neuroinflammation markers, and vascular networks. The X-PCI-CT high-resolution data collected in this pilot experiment demonstrate the capability of the method to reveal morphological changes caused by disease or treatment. While a thorough quantitative assessment is still in progress, our qualitative observations suggest that the treatment might be able to decrease neurodegenerative changes through the preservation of cerebellar microstructure and to reduce the senescence-associated markers. Correlative methods utilizing biochemical and immunohistochemical findings will clarify the impacts of treatment-related neuroinflammation and cellular senescence.

This study shows the suitability of advanced multiscale imaging as a tool to evaluate the effects of pharmacological treatments in preclinical models and specifically to evaluate novel and translational approaches for disease management in SCA1.

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P1.18

Python-based software for X-ray phase contrast tomographic reconstruction in the framework of the PITCH project for Cultural Heritage analysis.

L. Vigorelli[1]*, G. Marcucci[1], D. Di Martino[1], A. Re[2,3], E. Di Francia[2,3], A. Lo Giudice[2,3], L. Guidorzi[2,3], C. Garagiola[2,3], D. Trocino[3], P. Cerello[3], E. Fiorina[3], M. Magalini[3], M. Marabotto[3], N. Mosco[3], L. Ramello[4,3], R. Boano[5], R. Giustetto[6], G. Ricchiardi[7], F. Pozzi[8], C. Ricci[8]

[1]*Dipartimento di Fisica "G. Occhialini", Università di Milano Bicocca e INFN, sezione di Milano Bicocca, Milano, Italy*

[2]*Dipartimento di Fisica, Università degli Studi di Torino*

[3]*INFN, sezione di Torino, Torino, Italy*

[4]*Dipartimento per lo Sviluppo Sostenibile e la Transizione Ecologica, Università del Piemonte Orientale, Vercelli, Italy*

[5]*Dipartimento di Scienze della Vita e Biologia dei Sistemi, Università degli Studi di Torino, Torino, Italy*

[6]*Dipartimento di Scienze della Terra, Università degli Studi di Torino, Torino, Italy*

[7]*Dipartimento di Chimica, Università degli Studi di Torino, Torino, Italy*

[8]*Centro per la Conservazione ed il Restauro dei Beni Culturali "La Venaria Reale", Venaria Reale (Torino), Italy*

*Corresponding author: luisa.vigorelli@unimib.it

Over the last few decades, X-ray imaging has improved significantly as a high-resolution and non-invasive tool, detecting internal structures of samples in different fields. While the conventional absorption contrast method is particularly beneficial for characterising medium-density samples, but not for low-Z materials, Phase Contrast (PC) X-ray imaging is an effective technique for detecting low contrast details in weakly absorbing samples. PC is based on the observation of the interference pattern between diffracted and non-diffracted waves caused by spatial variations in the real component of the refractive index introduced by a sample placed in the wave path. As such, it has great potential in many fields of application, delivering high-quality information on microstructural characteristics. An X-ray Grating Interferometry (GI) laboratory setup based on a Metaljet X-ray source is being developed at the University of Turin within the scope of the PITCH project (funded by MUR, PRIN2022 program), focused on the analysis of Cultural Heritage materials. In this framework, Python-based codes for extraction of signals (absorption, differential phase and dark field) and computed tomography (CT) reconstruction are being finalised. Two different methodologies can be adopted for signals extraction from raw data (sine-fitting or Fourier-transform), while for CT reconstruction both traditional and modified reconstruction algorithms are implemented. In particular, the ASTRA-Toolbox algorithms for cone beam geometry can be used for absorption signal CT, while a customised one with a different type of filter (e.g. Hilbert transform) is implemented for differential phase contrast. The final software will be built as a web application using different tools (e.g. Solara) to provide a user friendly and ready-to-use interface, starting from the acquired raw data to return the three reconstructed volumes.

P1.19

Study of golden filigree from the 13th century Chiaravalle Cross through high-resolution Neutron Tomography.

L. Vigorelli[1*], Filomena Salvemini[2], Giulia Marcucci[1], Costanza Cucini[3], Maria Pia Riccardi[4], Klaud Jakubowski[2], Mitra Safavi-Naeini[2], Daniela Di Martino[1]

[1]*Dipartimento di Fisica "G. Occhialini", Università degli Studi di Milano-Bicocca and INFN Sezione di Milano-Bicocca, Piazza della Scienza 3, 20126 Milan, Italy*
[2]*Australian Nuclear Science and Technology Organisation (ANSTO), Lucas Heights, Australia*
[3]*IRAMAT, UMR 7065, CNRS, Université de Technologie Belfort Montbéliard, 90010 Belfort Cedex, France*
[4]*Dipartimento di Scienze della Terra e dell'Ambiente and Arvedi Laboratorio– sede di Pavia, Università degli Studi di Pavia, via Ferrata 9, 27100 Pavia, Italy*

*Corresponding author: luisa.vigorelli@unimib.it

The Chiaravalle Cross, a medieval processional cross from Chiaravalle Abbey (Milan, Italy), is a complex jewellery masterpiece attributed to the Venetian production (13th century), realised and decorated with silver and gold laminas, filigrees, gems and other precious materials, requiring various manufacturing techniques[2]. In this work, the analysis conducted on one small filigree fragment (a "rosette" decoration, realised with a wrapped twisted wire, joined with another twisted wire), using neutron tomography (NT) is presented. The study was performed at the DINGO neutron imaging station (ANSTO facility, Sydney); given the very small dimension of the sample, the innovative Neutron Microscope detector, developed by PSI[2], was used to achieve a better spatial resolution (~5 µm), coupling a CMOS camera with a high-numerical aperture objective to achieve a wider field of view. The NT reconstructions enabled the investigation of microstructural features of the filigree (down to ~5 µm), in particular of the "rosette" decoration, where the inner arrangement of the twisted wire, the weld joint and porosity are highlighted thanks to different materials attenuation coefficient. A comparison of the neutron and SEM images obtained from previous analysis can be attempted by visualising the sample in the same spatial direction. In this case, the inner morphology of the spiral can be better appreciated and three-dimensionally tracked from the resulting tomographic reconstruction. Moreover, the square section of the twisted wire is observed in CT slices, confirming the initial hypothesis of the experts. A validated Geant4 Monte Carlo model of Dingo is currently used to simulate experimental neutron attenuation values (in order to better compare SEM and NT results). This study demonstrates how non-invasive neutron imaging techniques coupled with new innovative instrumentation can be used as a valuable alternative to traditional invasive microscopic methods.

[1] G. Benati and D. Di Martino, La Croce di Chiaravalle. Approfondimenti storico-scientifici in occasione del restauro. BookTime, Milano, 2017
[2] P. Trtik et al. (2015) Improving the spatial resolution of neutron imaging at Paul Scherrer Institute–the neutron microscope project. *Phys Procedia*, **69**, 169–176

POSTER SESSION 2

September 23rd - September 25th

P2.1	Kim Bazot INSERM Grenoble	X-ray modulation-based imaging for oral healthcare
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P2.3	Rémi Dupraz-Roget INSERM Grenoble	X-ray phase recovery algorithm using deep learning with introduction of Fresnel propagation in the loss function
P2.4	Mateus Gruener Lima Martin Luther University Halle-Wittemberg	Intermittent in-situ mechanical testing of gecko-like dry adhesive surfaces with synchrotron X-ray nano-computed tomography
P2.5	Samy Kefs INSERM Grenoble	A universal single exposure Omnidirectional Darkfield retrieval
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P2.8	Nicole Marrocco CNR Nanotec - Roma3	Phase-contrast X-ray tomography for studying the role of the intestine in murine models of Alzheimer's disease
P2.9	Jana Matouskova Praha University	Neutron Imaging in Cultural Heritage Research at the TRIXIE Instrument
P2.10	Daniele Rusconi University of Bergamo	Weak Supervision: A Solution for Image Segmentation in Challenging Datasets

P2.1

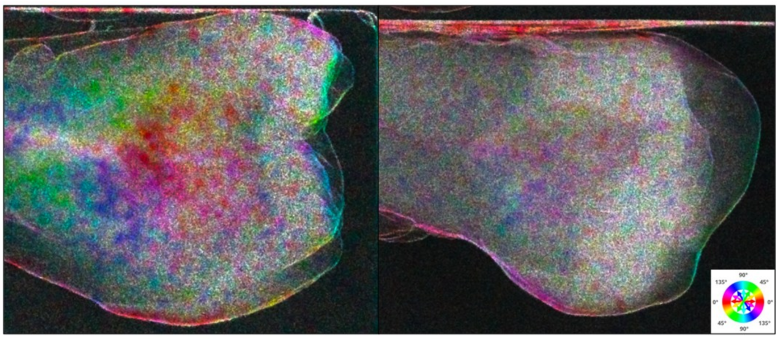
X-ray modulation-based imaging for oral healthcare

K. Bazot[1]*, C. Capdeville[2], J. Minvielle Moncla[3], C. Guissard[3], P. Kemoun[3], M. Wiart[2], F.R. Rozzi[4,5], P. Monsarrat[3], B. Salmon[5,6], E. Brun[1]

[1]*Strobe laboratory, Université Grenoble Alpes INSERM, France*
[2]*CARMEN-IRIS laboratory – CNRS – Université Lyon 1, France*
[3]*RESTORE laboratory - INSERM - CNRS - EFS - Université de Toulouse, France*
[4]*UMR 7206 Ecoanthropologie, MNHN-CNRS-UPCité, Musée de l'Homme, Paris, France*
[5] *UMR 1333 Oral Health, Université Paris Cité, INSERM, Montrouge, France*
[6]*Dental Medicine Department, Bretonneau University Hospital, AP-HP, Paris, France*
*Corresponding author: kim.bazot@inserm.fr

Chronic inflammatory diseases represent a major burden in our ageing societies. Many of them involve damage to both connective and mineralized tissues, including teeth and tooth supporting tissues (periodontium) involved in periodontitis, an age-related disease. Similarly, several genetic disorders affect calcium and phosphate homeostasis, leading to impaired dental and periodontal structures. For earlier identification of these pathologies, we propose a new imaging modality capable of monitoring subtle changes in both hard and soft tissues. We propose to develop and implement the X-ray imaging methodology, called Modulation-Based Imaging, that will allow Phase Contrast and Dark-field Imaging using X-ray devices compatible with oral medicine for the first time.

We present here, the very first results of Modulation Based imaging developed at the Soleil synchrotron as an oral tissues phase contrast and dark-field imaging proof of concept. As already shown by [1] or [2], x-ray dark-field imaging allows to obtain information on tooth cracks and dentinal tubules that are not visible on absorption images. In this study, dark-field imaging allows for instance to highlight the decrease of dentinal tubules quantity in a tooth with altered ultrastructure in the dentinogenesis imperfecta pathology compared to a healthy tooth (Figure 1).



Control Dentinogenesis imperfecta

Figure 1 Comparison of directional dark-field signals of a tooth with ultrastructure alteration (dentinogenesis imperfecta) and a healthy tooth as a control. Directional dark-field signal in dentinogenesis imperfecta is weaker and the dentin structure reveals fewer principal orientations than in a control tooth.

[1] C. Jud, et al. (2021) *Sci Rep* **11**, 14017. https://doi.org/10.1038/s41598-021-93393-4 [2] T. H. Jensen, et al. (2010) *Phys. Rev. B,* **82**, 214103. https://doi.org/10.1103/PhysRevB.82.214103

P2.2

Molecular X-ray Phase-Contrast Tomography (mXPCT): proof-of-concept in a murine model of cerebral inflammation

C. Capdeville[1], E. Longo[2], L. Langbour[1], M. Wiart[1], E. Brun[3], F. Chauveau[4*]

[1]*Univ. Lyon, CarMeN Laboratory, INSERM, INRA, INSA Lyon, Univ Lyon 1, Lyon, France*
[2] *Elettra-Sincrotrone Trieste SCpA, Italy*
[3]*Univ. Grenoble Alpes, INSERM UA7 STROBE, Grenoble, France*
[4] *Univ. Lyon, Lyon Neuroscience Research Center, CNRS, INSERM, Univ Lyon 1, Lyon, France*

*Corresponding author: fabien.chauveau@cermep.fr

Moving from virtual histology to virtual immunohistochemistry requires the ability to design customized contrast agents for X-rays. Building on the expanding field of molecular MRI [1], this study tested the use of iron oxide microparticles and gold nanoparticles, functionalized with antibodies targeting the vascular endothelium, to obtain a high-resolution 3D volume of the resulting molecular staining detected with XPCT.

Several contrast agents were obtained through the combination of antibodies against adhesion proteins (P-selectin, Icam-1, VCAM-1) with commercial micro-sized particles of iron oxide (MPIO) or 100nm NHS-activated gold nanoparticles. The animal model consisted of a unilateral intrastriatal infusion of 1 µl of lipopolysaccharide (LPS) at 1µg/µl. Contrast agents (typically 2.5×10^{8} particles in 200µl) were injected intravenously and euthanized after one hour, with intracardiac perfusion and fixation in formaldehyde. XPCT was performed on the SYRMEP beamline at ELETTRA and repeated after varying the concentration of ethanol (30-50-70%) to optimize the respective contrasts from the agent and the surrounding brain tissue. Vessels were detected around the site of LPS injection (Fig. 1, red dotted area), consistent with an upregulation of targeted adhesion proteins.

mXPCT enables the detection of vascular targets. Combined with K-edge subtraction tomography, this approach has the potential to provide a 3D ex vivo quantitation in an intact volume.

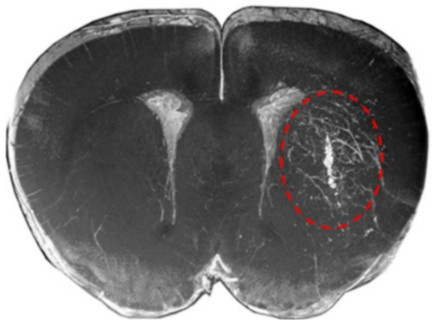


Figure 1: Whole-brain tomography from a mouse injected with an antibody against P-selectin coupled to gold nanoparticles. Red dotted area highlights the area of vascular inflammation.

[1] Gauberti M, et al. (2018) Molecular Magnetic Resonance Imaging of Endothelial Activation in the Central Nervous System. *Theranostics*, **8**(5), 1195-1212. doi:10.7150/thno.22662

P2.3

X-ray phase recovery algorithm using deep learning with introduction of Fresnel propagation in the loss function

R. Dupraz-Roget[1], K. Mom[1], J.M. Letang[3], S. Rit[3], E. Brun[2]*, M. Langer[1]

[1] *TIMC (Translational research and Innovation in Medicine and Complexity)*
[2] *STROBE (Synchrotron Radiation for Biomedicine)*
[3] *CREATIS (Biomedical imaging lab)*

*Corresponding author: emmanuel.brun@inserm.fr

X-rays are strongly attenuated by bones and weakly by soft tissues, creating high contrast between these two types of structures. However, this method has difficulty distinguishing structures of comparable density, such as those located within soft tissue [1] or bone [2]. Phase retrieval (PR) methods address this issue by recovering phase information. Yet, these approaches are often affected by noise and rely on limiting assumptions.

In recent years, new AI-based methods have emerged [3] to tackle this highly nonlinear problem. Here, we propose a neural network that uses the intensity measured on the sensor as an input to estimate the absorption and phase at the sample output. To improve the reconstruction accuracy, we have introduced the Fresnel propagator into the loss function.

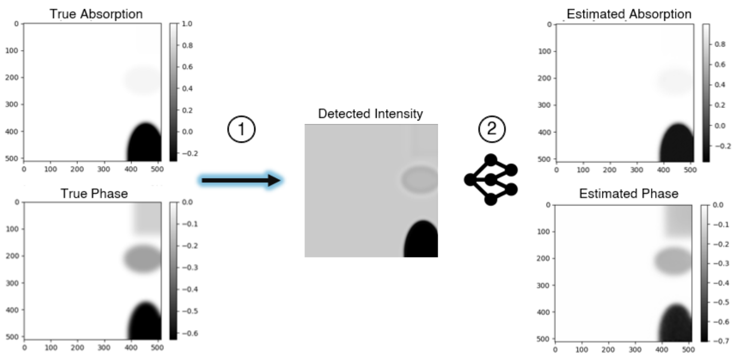


Figure 1: Pipeline from a random sample field (absorption + phase) that propagates to the detector (1), then the neural network reconstructs the absorption and phase (2).

As can be seen in Fig. 1, the quantitative reconstructed absorption and phase maps (right) are very similar to their theoretical values (left), which translates into a very low NMSE < $1e^{-5}$ and SSIM > 0.99. Unlike many PR, our approach provides quantitative phase information from only one measurement, and is not limited by physical assumptions (propagation distance, sample composition, …). However, like all AI models, it requires a large volume of data and suffers from a lack of generalizability.

[1] H. Rougé-Labriet, et al. (2020) *Scientific reports*,**10**(1), 1911.
[2] M. Langer, et al. (2012) *Plosone*, **7**, 35691
[3] K. Mom, M. Langer, B. Sixou (2023) *Opt. Lett.* **48**(5), 1136-1139.

P2.4

Intermittent in-situ mechanical testing of gecko-like dry adhesive surfaces with synchrotron X-ray nano-computed tomography

M. Gruener Lima[1,2,3*], A. Thormann[2], S. Flenner[4], I. Greving[4], J. M. S. e Silva[2,3]

[1]*Applied Nuclear Physics Research Group, State University of Londrina, Rodovia Celso Garcia Cid, PR-445, Km 380, Londrina - PR, 86057-970, Brazil*
[2]*Fraunhofer Institute for Microstructure of Materials and Systems IMWS, Walter-Hülse-Straße 1, 06120 Halle (Saale), Germany*
[3]*Institute of Physics, Martin Luther University Halle-Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle (Saale), Germany*
[4]*Institute of Materials Physics, Helmholtz-Zentrum Hereon, Max-Planck-Straße 1, 21502 Geesthacht, Germany*

*Corresponding author: mateus.gruener@uel.br

Relying solely on charge interactions rather than chemical adhesives, gecko-inspired surfaces exhibit notable strength, reversibility, and reusability [1]. Consequently, they hold significant potential for applications in cultural heritage preservation and archaeometry studies [2]. A comprehensive understanding of their mechanical behavior is essential. In this study, thermoplastic polyurethane (TPU)-based cone-shaped structures (Fig. 1a and b) were analyzed using nano-computed tomography and in-situ mechanical testing. Six scans were conducted under varying load conditions (Fig. 1c and d). The results offer valuable insights into their compression and adhesion mechanisms, reinforcing their suitability for conservation and restoration of fragile artifacts. Digital Volume Correlation analysis quantitatively supports these findings and reveals the redistribution of forces across the surface.

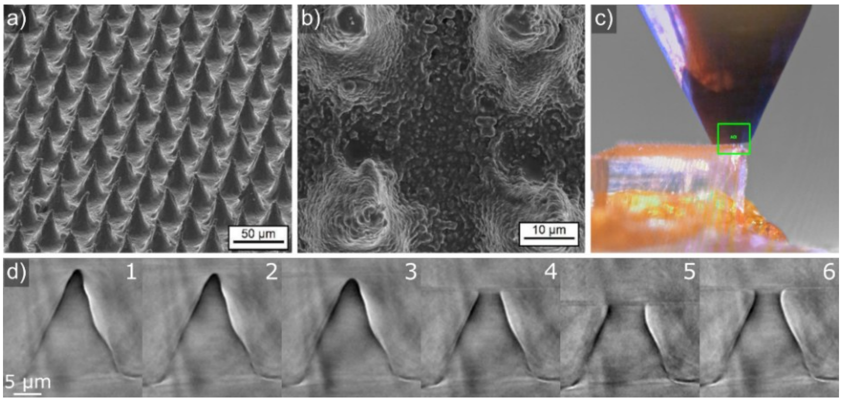


Figure 1 a) and b) Scanning Electron Microscopy images of a gecko-like surface at different scales. c) Experimental setup for in-situ compression and nano-CT scanning. d) Reconstructed slices of the same tip at six different load steps (1–6).

[1] I.G. Shuttleworth (2020). *Results in Materials*, **6**, 100080.
[2] J. Olender, J. Perris, Y. Xu, C. Young, D.M. Mulvihill, & N. Gadegaard. (2023). *Journal of Adhesion Science and Technology*, **37**(6), 1091–1116.

P2.5

A universal single exposure Omnidirectional Darkfield retrieval

S.Kefs[1]*, P.Lhuissier[2], S.Rolland Du Roscoat[3], E. Brun[1]

[1] *Univ Grenoble Alpes, INSERM UA7 Strobe,Grenoble France*
[2]*SIMAP, CNRS, Univ. Grenoble Alpes, France*
3 3SR, Université Grenoble Alpes, CNRDS, G-INP, France

*Corresponding author: samy.kefs@inserm.fr

X-ray dark-field Imaging techniques based on phase gratings, grids or modulation masks, whether typically require multiple exposures of the sample to retrieve absorption, phase and darkfield information, either explicitly or implicitly [1,2]. A major challenge lies in reducing the number of acquisitions to lower the dose, accelerate imaging and simplify experimental setups. This would pave the way for dynamic applications or *in vivo* imaging. The method presented here allows, from a single exposure of the sample and without prior assumptions about the type of modulation (random or structured, binary or intensity), to retrieve both directional darkfield and absorption signals.
Assuming that the phase shift induced by the sample remains below the pixel size, it becomes possible to retrieve qualitative and quantitative information on the loss of visibility of the modulation pattern by statistically comparing the reference and the sample images. This visibility loss is directly related to (ultra) small-angle scattering caused by internal microstructures within the material. By repeating this analysis across multiple local orientations, it becomes possible to reconstruct the directional component of the darkfield signal. This approach enables the estimation of scattering intensity in each direction, and the derivation of the precise geometric parameters such as the orientation, eccentricity, and the area of the scattering cone (figure 1). As a result, a complete mapping of scattering anisotropy can be obtained, enabling a refined interpretation of internally oriented structures within the sample.

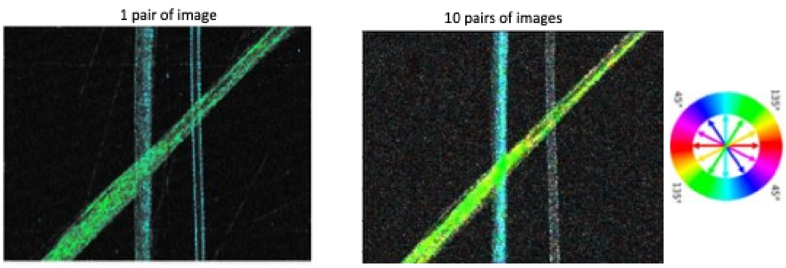


Figure 5 Results of directional dark-field retrieval obtained using a laboratory source of 2 carbon fiber bundles and a nylon wire (right). HSV representation of darkfield signal properties: the orientation is based on intensity of the darkfield signal.

[1] R. Celestre et al. (2025) *J. Synchrotron Rad.*, **32**, 180-199. doi: 10.1107/S1600577524010117. [2] C. Magnin, et al (2023) *Opt. Lett.*, **48**, 5839-5842. doi: 10.1364/OL.501716.

P2.6

Current Quantum Computing Algorithms for Practical Computational Imaging

G. Kourousias[1,2,3]*, S. Carrato[2], R. Pugliese[1], P. Dimitrakis[3]

[1]*Scientific and Quantum Computing Unit "SciQC", Elettra Sincrotrone Trieste, Italy*
[2]*Image Processing Laboratory, Department of Engineering and Architecture, University of Trieste, Italy*
[3]*Institute of Quantum Computing and Quantum Technology, NCSR "Demokritos", Athens, Greece*

*Corresponding author: george.kourousias@elettra.eu

Quantum Computing (QC) is emerging as a paradigm shift that transcends mere speed improvements. Although rapid progress is being made in both hardware and software, existing quantum algorithms have the potential to transform conventional computational imaging methods. In particular, algorithms such as the Quantum Approximate Optimization Algorithm (QAOA) [1], the Quantum Fourier Transform (QFT) [2,3], and the Grover's algorithm [4] offer promising avenues for enhancing image reconstruction and analysis.

We highlight how these algorithms can be deployed in X-ray imaging applications, including computed tomography (CT) [5], coherent diffraction imaging (CDI), and ptychography. Such implementations not only improve these modalities but also demonstrate the broader applicability of quantum methods to other computational imaging techniques and related disciplines – especially in the realm of artificial intelligence through quantum machine learning (QML) [6].

This work presents current frameworks including QisKit, PennyLane, and CUDA-Q that enable the implementation of these algorithms on both simulated and experimental quantum hardware. Moreover, we address the significant limitations inherent in today's quantum computing field, such as data encoding challenges, noise, and scalability issues. Despite these hurdles, our findings suggest that QC can serve as an early adopter for practical computational imaging, paving the way for novel approaches in image processing and analysis.

[1] E. Farhi, J. Goldstone, S. Gutmann (2014) A Quantum Approximate Optimization Algorithm. *arXiv preprint* arXiv:1411.4028. https://doi.org/10.48550/arXiv.1411.4028

[2] M.A. Nielsen, I.L. Chuang (2000) *Quantum Computation and Quantum Information* (ed.). Cambridge, Cambridge University Press. ISBN: 978-0521635035

[3] D.R. Musk (2020) A comparison of quantum and traditional Fourier transform computations. *Computing in Science & Engineering*, **22**(6), 103–110. https://doi.org/10.1109/MCSE.2020.3023979

[4] L.K. Grover (1997) Quantum mechanics helps in searching for a needle in a haystack. *Physical Review Letters*, **79**(2), 325–328. https://doi.org/10.1103/PhysRevLett.79.325

[5] K. Dremel, et al. (2025) Utilizing Quantum Annealing in Computed Tomography Image Reconstruction. *IEEE Transactions on Quantum Engineering*. https://doi.org/10.1109/TQE.2025.3549305

[6] M. Cerezo, G. Verdon, H.Y. Huang, L. Cincio, P.J. Coles (2022) Challenges and opportunities in quantum machine learning. *Nature Computational Science*, **2**(9), 567–576. https://doi.org/10.1038/s43588-022-00311-3

P2.7

Material-separating regularizer for multi-energy x-ray tomography

S-M. Latva-Äijö*

University of Helsinki

Corresponding author: salla.latva-aijo@helsinki.fi

Dual-energy X-ray tomography is considered in a context where the target under imaging consists of two distinct materials. The materials are assumed to be possibly intertwined in space, but at any given location there is only one material present. Further, two X-ray energies are chosen so that there is a clear difference in the spectral dependence of the attenuation coefficients of the two materials.

A novel regularizer is presented for the inverse problem of reconstructing separate tomographic images for the two materials. A combination of two things, (a) non-negativity constraint, and (b) penalty term containing the inner product between the two material images, promotes the presence of at most one material in a given pixel. A preconditioned interior point method is derived for the minimization of the regularization functional.

Numerical tests with digital phantoms suggest that the new algorithm outperforms the baseline method, Joint Total Variation regularization, in terms of correctly material-characterized pixels. While the method is tested only in a two-dimensional setting with two materials and two energies, the approach readily generalizes to three dimensions and more materials. The number of materials just needs to match the number of energies used in imaging.[1]

[1] J. Gondzio, M. Lassas, S.M. Latva-Äijö, S. Siltanen, F. Zanetti (2022) Material-separating regularizer for multi-energy x-ray tomography. *Inverse Problems*, **38**(2), 025013.

P2.8

Phase-contrast X-ray tomography for studying the role of the intestine in murine models of Alzheimer's disease

F. Palermo[1], N. Marrocco[1,2,*], C. Balducci[3], A. Cedola[1]

[1]*CNR-Nanotec Rome c/o Phys.Dip. SAPIENZA University, Italy*
[2]*Roma Tre University, Dip. Scienze, Italy,*
[3]*Istituto di Ricerche Farmacologiche Mario Negri IRCCS, Milan, Italy*

*Corresponding author: nicole.marrocco@uniroma3.it

Alzheimer's disease (AD) is a complex neurodegenerative disorder affecting millions of people worldwide. Recent studies [1] highlight a strong link between intestinal alterations and neuroinflammatory conditions in AD, emphasizing the gut-brain axis's critical role. Phase-Contrast X-Ray Tomography (XPCT), a non-invasive 3D imaging technique [2], provides high-resolution visualization of soft tissues, offering new insights into AD-related structural changes. This study aimed to characterize the intestines of murine AD models, comparing sporadic (SAMP8) and familial (APP/PS1) variants with controls.

Using XPCT at the European Synchrotron Radiation Facility (ESRF) and Sincrotrone Soleil, samples were measured with micrometric and nanometric resolution. Intestines of AD models and controls were analyzed qualitatively and quantitatively, focusing on villi length, crypt depth and follicular volume.

This study revealed significant intestinal morphological changes in AD murine models, offering new perspectives on the interaction between neurodegeneration and intestinal alterations, potentially leading to new diagnostic and therapeutic markers for AD.

The application of micro- and nano-XPCT to different AD mouse models has revealed significant changes in villi and crypt structures, as well as cellular modifications in Paneth and goblet cells. Additionally, telocytes, neurons, erythrocytes, and mucus secretion by goblet cells have been identified within the gut cavity. These structural alterations in the gut may provide insights into the progression from dysbiosis to neurodegeneration and cognitive decline [3].

[1] S. Chandra et al. (2023) The gut microbiome in Alzheimer's disease: what we know and what remains to be explored. *Molecular Neurodegeneration*, **18**(1), 9.
[2] L. Massimi et al. (2018) Exploring Alzheimer's disease mouse brain through X-ray phase contrast tomography: From the cell to the organ. *NeuroImage*, **184**, 490–495.
[3] F. Palermo, et al. (2025) Investigating gut alterations in Alzheimer's disease: In-depth analysis with micro- and nano-3D X-ray phase contrast tomography. *Science Advances*, **11**, eadr8511.

P2.9

Neutron Imaging in Cultural Heritage Research at the TRIXIE Instrument

J. Matouskova[1*], E. Frame[1]

[1]*Czech Technical University, V Holešovičkách 2, Prague, Czech Republic*

*Corresponding author: jana.matouskova@fjfi.cvut.cz

Non-destructive and non-invasive investigations of cultural heritage objects are essential for uncovering their structure, composition, provenance, and restoration history without causing damage. While X-ray imaging is widely used in museums and laboratories, it has limitations when image contrast or transmission is insufficient for certain materials or dimensions.

Neutron imaging offers a valuable alternative, as it interacts with matter differently, often revealing details that X-rays cannot detect. This makes it particularly useful for analyzing composite objects, hidden structures, and organic materials encased in metal. As a result, neutron imaging has become an important tool in cultural heritage research.

The TRIXIE instrument, located at the LVR-15 research reactor near Prague in the Czech Republic, is used for multidisciplinary research, including studies in cultural heritage. Neutron imaging at the TRIXIE instrument has been employed to examine various historical artifacts, such as Asian votive statues, medieval weights, and historical bullets. These investigations have provided valuable insights into casting techniques, authenticity, and manufacturing processes, aiding researchers in the understanding and preservation of these objects.

P2.10

Weak Supervision: A Solution for Image Segmentation in Challenging Datasets

D. Rusconi

University of Bergamo

Accurate segmentation of renal glomeruli in X-ray μCT is highly challenging due to their small size, low contrast, and indistinct boundaries, which make reliable manual annotation difficult and time-consuming.

Conventional CNN-based approaches, such as U-Net, require large, high-quality labeled datasets and therefore struggle in this context. To overcome this limitation, we investigated a weakly supervised strategy built upon the transformer-based UNETR architecture from Hatamizadeh et al.

Starting from a UNETR model obtained via transfer learning, the network was then adapted to operate with approximate annotations of high-resolution μCT images of rat kidneys. This weak supervision enabled the model to exploit approximate labels while maintaining competitive performance.

Despite the constraints of sparse and imprecise ground truth, the method achieved encouraging segmentation results, demonstrating that weak supervision can serve as a viable solution to the scarcity of reliable annotations in medical image analysis.