IASIM-2026

Conference on spectral imaging

June 14–17, Umeå, Sweden

BOOK OF ABSTRACTS

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INSTITUTIONAL SUPPORT

MAL – Environmental Archaeology Lab – Umeå University

Department of Historical, Philosophical and Religious Studies – Umeå University

TECHNICAL SUPPORT

Nordic Congress - Umeå

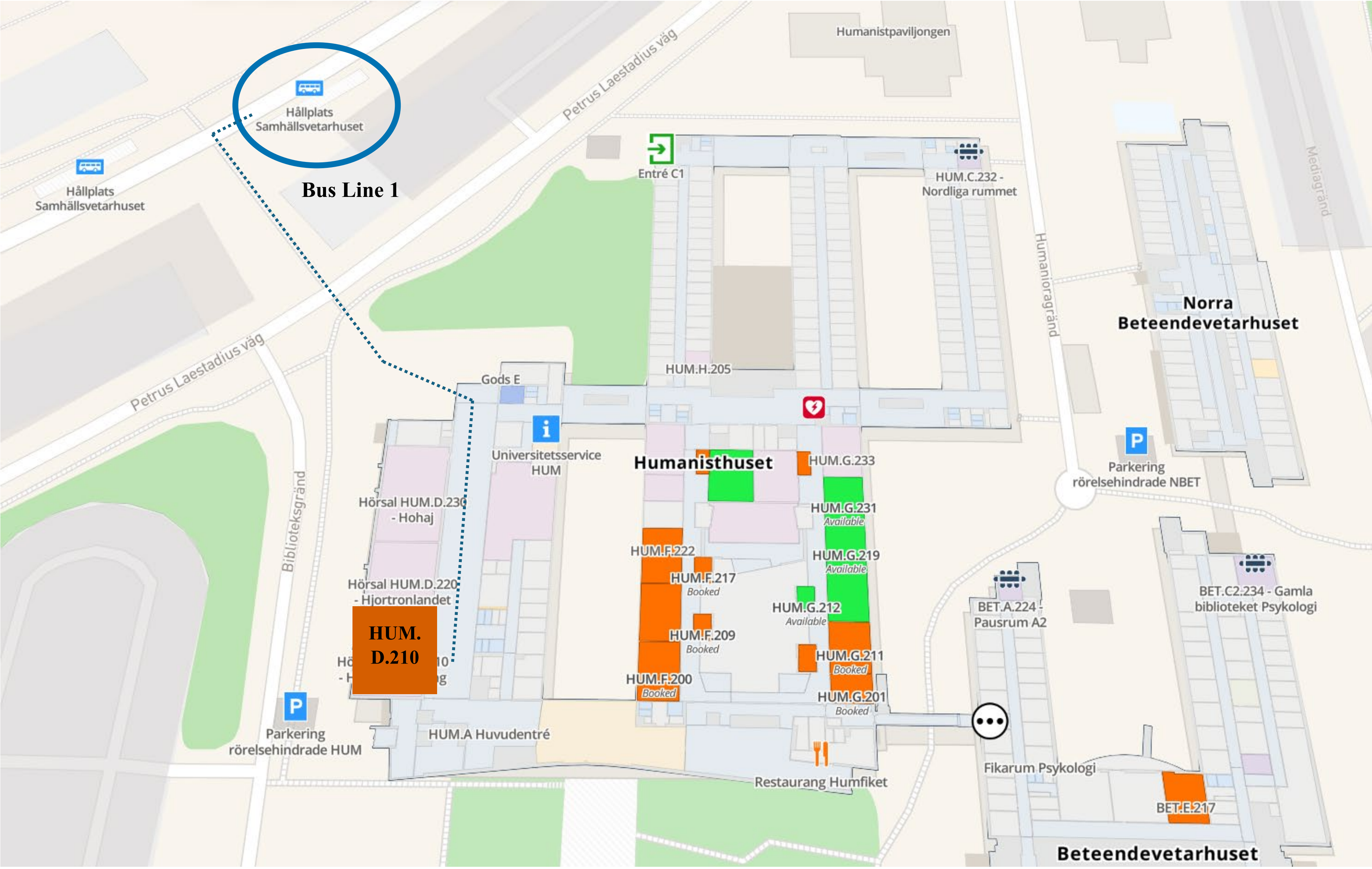
INDEX

Saturday & Sunday Workshops: Humanities Building (Humanisthuset), Entrance on Floor 2 – use stairs to go down to Floor 1 for HUM.J.118

Registration table for Saturday and Sunday (WEEKEND ONLY)

Saturday & Sunday Workshops: Humanities Building (Humanisthuset), Floor 1 – room HUM.J.118

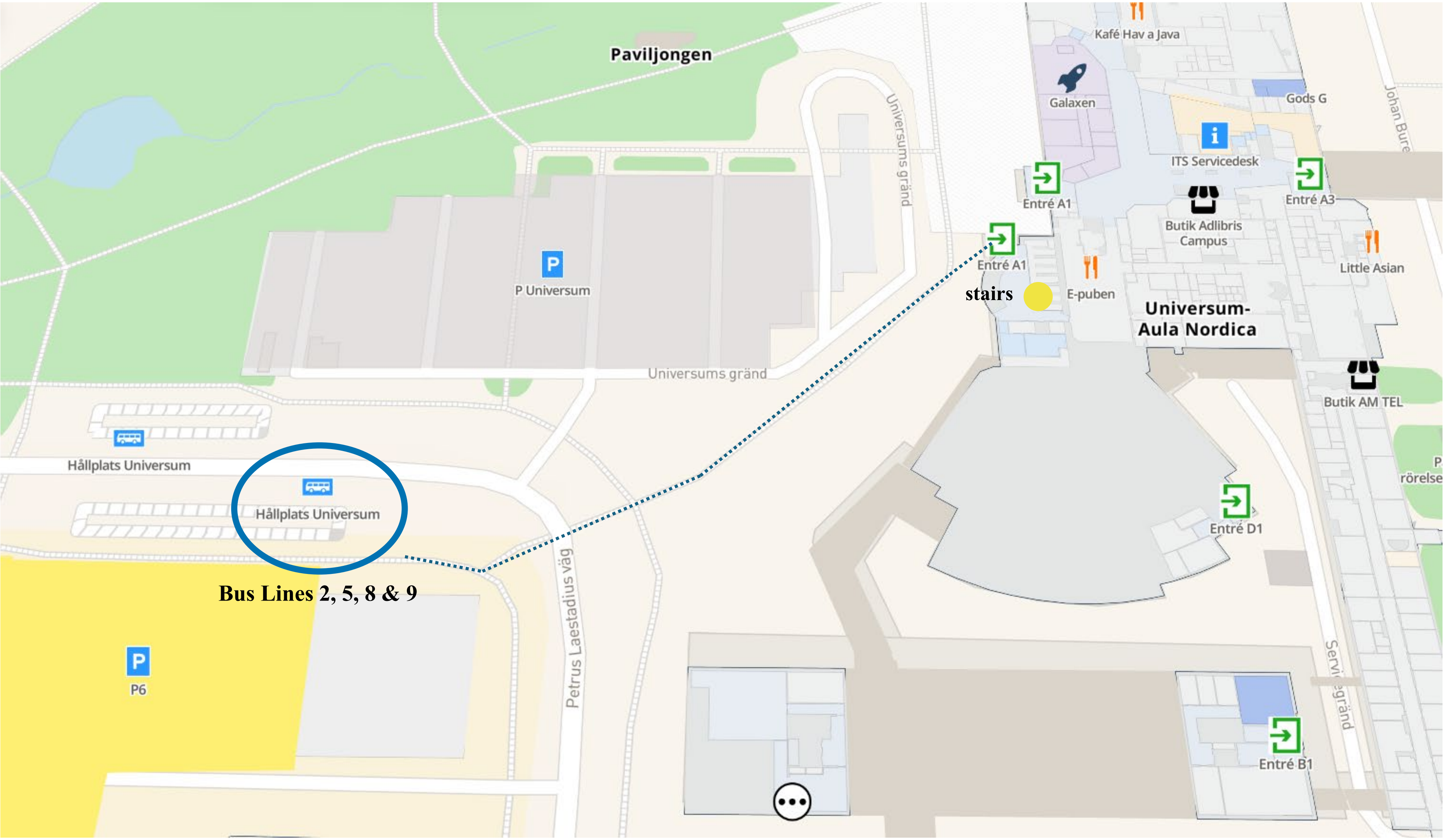
Sunday Opening Session: Humanities Building (Humanisthuset), Floor 2 – room HUM.D.210



Monday, Tuesday & Wednesday: Universum Building, Floor 2 – use stairs up to Floor 3 for Aula Nordica

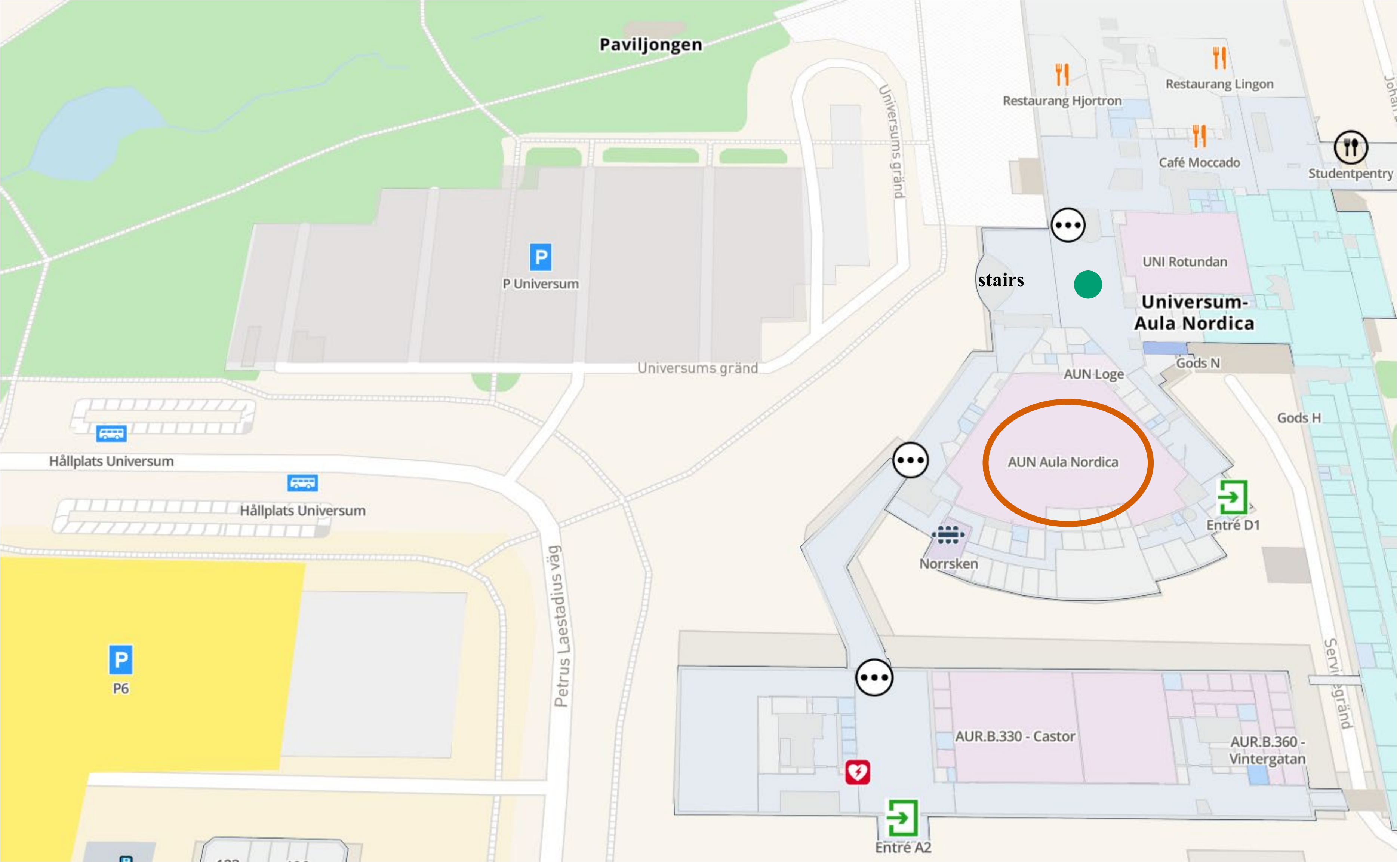
Access to conference venue with a cloakroom available

Registration table for Monday, Tuesday & Wednesday MORNINGS ONLY

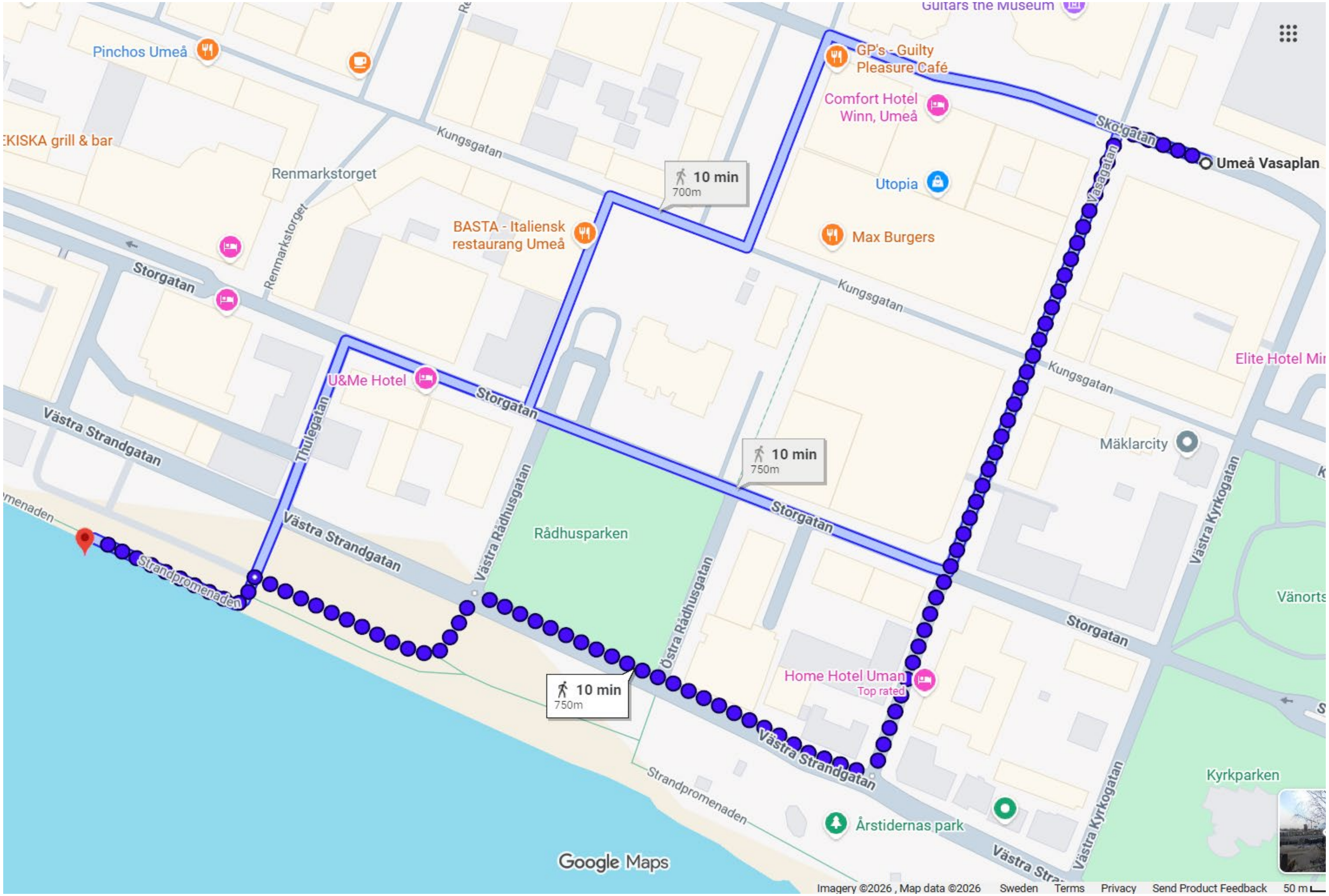


Monday, Tuesday & Wednesday: Universum Building, Floor 3, Aula Nordica

● Area for coffee breaks, lunch, poster sessions and sponsors exhibitions



Conference dinner – Tuesday – Sjöbris - Kajen 10, 903 26 Umeå



IASIM 2026 Full Programme

	IASIM Day 0 Saturday, 13th June	**IASIM Day 1** Sunday, 14th June	**IASIM Day 2** Monday, 15th June	**IASIM Day 3** Tuesday, 16th June	**IASIM Day 4** Wednesday, 17th June
08:00			REGISTRATION	REGISTRATION	REGISTRATION
08:30	REGISTRATION	REGISTRATION		Plenary Lecture 2: Prof. Giorgia Sciutto	Plenary Lecture 4: Prof. Martina Marchetti-Deschmann
09:00	Workshop 1: Giulia Gorla – “Understanding complex hyperspectral datasets: from scratch to answers”	Workshop 3: Qtechnology – “From data to deployment: turning hyperspectral ideas into working applications”			
09:10			Plenary Lecture 1: Assoc. Prof. William Lindberg		
09:30				Vital *et al.*	Gorla *et al.*
09:50				Pourahmadi *et al.*	Amato *et al.*
10:10			Santiago *et al.*	Iturrioz & Amigo	Ronda *et al.*
10:30			COFFEE BREAK / SPONSOR EXHIBITIONS / POSTERS		
11:00			Awais *et al.*	Gowen *et al.*	Oliveri *et al.*
11:20			Coloma *et al.*	Lufu & Williams	Duponchel *et al.*
11:40			Reis *et al.*	Najafabadi *et al.*	Sicre-Conesa *et al.*
12:00			PREDIKTERA	LIGHTNOVO	Scherzer *et al.*
12:05				LUNCH / SPONSOR EXHIBITIONS / POSTERS	
12:10			LUNCH / SPONSOR EXHIBITIONS / POSTERS		
12:20					CONFERENCE CLOSURE
13:00	Workshop 2: Anna de Juan Capdevila *et al.* – “Image unmixing. Linking space and chemistry of hyperspectral image components”	Workshop 4: Prediktera – “Practical Considerations for Outdoor Hyperspectral Imaging: From Data Acquisition to Processing”			
13:40			Duma *et al.*	Plenary Lecture 3: Dr. Juan Antonio Fernández Pierna	
14:00			Medina-García *et al.*		
14:20			Sarr *et al.*		
14:40			Lorin *et al.*	Fatchurrahman *et al.*	
15:00			QTECHNOLOGY	SPECIM	
15:05			COFFE BREAK / SPONSOR EXHIBITIONS / POSTERS		
15:50			Martinelli *et al.*	Hansen *et al.*	
16:00					
16:10			Tauler *et al.*	Chen *et al.*	
16:30			Sihvonen *et al.*	Peiris *et al.*	
16:50		CONFERENCE OPENING	Tighineanu *et al.*	Williams *et al.*	
17:00					
17:10		Jim & Paul Award Plenary Lecture: Dr. Cristina Malegori		Villarruel *et al.*	
17:30					
18:00					
18:30					
19:00		WELCOME EVENT (drinks & appetizers)		CONFERENCE DINNER	
20:00					
21:00					
22:00					

IASIM Day 0 – Saturday, 13th June 2026

HUM.J.118, Humanisthuset, 1st Floor, Umeå University

8:30 – 9:00	Registration – Humanisthuset Entré B1 (Floor 2)
9:00 – 12:00	Workshop 1 by **Giulia Gorla** – *Understanding complex hyperspectral datasets: from scratch to answers*
12:00 – 13:00	Break – FOOD NOT PROVIDED
12:30 – 13:00	Registration – Humanisthuset Entré B1 (Floor 2)
13:00 – 16:00	Workshop 2 by **Rodrigo Rocha de Oliveira** & **Adrián Gómez Sánchez** – *Image unmixing (Multivariate Curve Resolution). Linking space and chemistry of hyperspectral image components*

IASIM Day 1 – Sunday, 14th June 2026

HUM.J.118, Humanisthuset, 1st Floor, Umeå University

8:30 – 9:00	Registration – Humanisthuset Entré B1 (Floor 2)
9:00 – 12:00	Workshop 3 by **Qtechnology** – *From data to deployment: turning hyperspectral ideas into working applications*
12:00 – 13:00	Break – FOOD NOT PROVIDED
12:30 – 13:00	Registration – Humanisthuset Entré B1 (Floor 2)
13:00 – 16:00	Workshop 4 by **Prediktera** – *Practical considerations for outdoor hyperspectral imaging: from data acquisition to processing* *

* this workshop has been planned to be held outdoors, depending on weather conditions – meeting point still in Hum.J.118

IASIM Day 1 – Sunday, 14th June 2026

HUM.D.210, Humanisthuset, 2nd Floor, Umeå University

16:30 – 17:00	Opening Session
17:00 – 18:00	Jim & Paul Award Plenary Lecture by Dr. **Cristina Malegori**

IASIM Day 1 – Sunday, 14th June 2026

Brashörnan, Universum, 3rd Floor, Umeå University

19:00 – 21:00	Welcome event (drinks & appetizers)

IASIM Day 2 – Monday, 15th June 2026

Aula Nordica, Universum, 3rd Floor, Umeå University

8:00 – 9:10	Registration
Session 1: Environment	
9:10 – 10:10	Plenary Lecture by Assoc. Prof. **William Lidberg** *Unveiling New Horizons in Forest Floor Remote Sensing*
10:10 – 10:30	**Carlos Martín Santiago**, Jose Manuel Amigo Rubio, Enmanuel Cruz Muñoz, Davide Ballabio, Arantza Aldezabal Roteta, Kepa Castro Ortiz de Pinedo *Remote sensing and chemometrics for grassland management: when did they cut?*
10:30 – 11:00	Break / Sponsor Exhibitions / Posters
11:00 – 11:20	**Muhammad Awais**, Michael Altgen, Kristian Hovde Liland, Lone Ross, Arnkell Jonas Petersen, Thomas Kringlebotn Thiis, Ingunn Burud *From laboratory to field: hyperspectral imaging predicts fire classification of treated wood*
11:20 – 11:40	Giulia Gorla, **Leire Coloma**, Markel Sanchez-Goyenaga, Fernando Alberquilla, Julene Aramendia, José Manuel Amigo, Gorka Arana, Juan Manuel Madariaga *Hyperspectral imaging for meteorite analysis: advantages and limitation of combining multiple techniques*
11:40 – 12:00	**Marco S. Reis**, Eugeniu Strelet, Ivan Castillo *Image-based monitoring of EPS in wastewater bioreactors*
12:00 – 12:10	Sponsors Talk: **Prediktera**

12:10 – 13:40	Lunch / Sponsor Exhibitions / Posters
13:40 – 14:00	**Zina-Sabrina Duma**, Tenzin Tsering, Tuomo Soininen, Arto Koistinen, Tuomas Sihvonen, Sara Heikkinen, Satu-Pia Reinikainen *A multi-level framework for FT-IR spectral imaging of microplastics*
14:00 – 14:20	**Miriam Medina-García**, Carlos Martín-Santiago, Unai Famoso-Rodríguez, Jon Ander Iturrioz-Aguirre, Ainara Gredilla, Leire Kortazar, Jose Antonio Carrero, Luis Ángel-Fernández-Cuadrado, Alberto de Diego, Mathieu Marmion, José Manuel Amigo, Giulia Gorla *Assessing the true potential of SWIR-HSI and LWIR-HSI for microplastics identification in beach monitoring*
14:20 – 14:40	**Papa Masserigne Sarr**, Dr Noémie Caillol, Dr Franck Baco-Antoniali *Developing quantitative textile composition models using hyperspectral imaging and chemometric*
Session 2: Spectroscopy	
14:40 – 15:00	**Arthur Lorin**, Maxime Istasse, Damien Vincke, Antoine Deryck, Juan Antonio Fernández Pierna, Paul Vanabelle *Hyperspectral data cube compression using video coding algorithms*
15:00 – 15:05	Sponsors Talk: **Qtechnology**
15:05 – 15:50	Break / Sponsor Exhibitions / Posters
15:50 – 16:10	**Elisabetta Martinelli**, Marcos Alonso, Giulia Gorla, Daniela Comelli, José Manuel Amigo *Investigation towards high-fidelity hyperspectral imaging with robot-assisted fibre scanning*
16:10 – 16:30	**Romà Tauler**, Chenxi Peng, Carme Bèdia, Anna de Juan *Three-way ROIMCR: a new framework for analysing ion mobility mass spectrometry hyperspectral imaging data*

16:30 – 16:50 **Sihvonen T**, Vitale R., Gómez-Sánchez A., Duma Z-S., Ruckebusch C., Reinikainen S.P.
Selfsharpening: an image fusion method for spectral microscopy data

16:50 – 17:10 **Petru Tighineanu**, Matthias Kayser, Ruyu Wang, Murat Bayram, Daniella Gal, Alexander Qualmann, Abhishek Dani
Zero-shot learning for hyperspectral imaging in manufacturing

IASIM Day 3 – Tuesday, 16th June 2026

Aula Nordica, Universum, 3rd Floor, Umeå University

8:00 – 8:30	Registration
Session 3: Cultural Heritage	
8:30 – 9:30	Plenary Lecture by Prof. **Giorgia Sciutto** *Are spectral imaging and chemometrics the next frontier of Cultural Heritage diagnostics?*
9:30 – 9:50	**Ana Vital**, **Anne Mirich**, Johan Linderholm *The potential of hyperspectral imaging for archaeological studies*
9:50 – 10:10	**Baharan Pourahmadi**, Simon Valsøe Wadowski, Mads Toudal Frandsen *Restoration of hidden text in book bindings via spectral imaging and blind super-resolution*
10:10 – 10:30	**Jon Ander Iturrioz**, José Manuel Amigo *3D-hyperspectral mapping of small cultural heritage objects. Fusion of SWIR-HSI and Low-Cost 3D scanning for material analysis. The example of a Nubian dagger.*
10:30 – 11:00	Break / Sponsor Exhibitions / Posters
Session 4: Food Quality and Safety	
11:00 – 11:20	S. Somani, E. Achata Gonzales, **Aoife Gowen** *Data fusion and variable selection for enhanced classification of age and viability in cabbage seeds using spectral imaging data*

11:20 – 11:40	**Robert Lufu**, Paul James Williams *Real-time identification of clean and defective maize grains for smart sorting using SWIR hyperspectral imaging technology*
11:40 – 12:00	**Ayoub Fathi Najafabadi**, Maria Matloob, Danial Fatchurrahman, Giancarlo Colelli, Maria Lusia Amodio *Assessing the quality of packaged cherry tomatoes using two hyperspectral imaging systems*
12:00 – 12:05	Sponsors Talk: **Lightnovo**
12:05 – 13:40	Lunch / Sponsor Exhibitions / Posters
13:40 – 14:40	Plenary Lecture by **Dr. Juan Antonio Fernández Pierna** *NIR hyperspectral imaging for advancing food safety and quality assessment*
14:40 – 15:00	**Danial Fatchurrahman**, Lucia Russo, Maria Luisa Amodio, Giancarlo Colelli *Spectral information combined with physical attributes for the prediction of blackheart defective pomegranate (Punica granatum L.) fruit*
15:00 – 15:05	Sponsors Talk: **Specim**
15:05 – 15:50	Break / Sponsor Exhibitions / Posters
15:50 – 16:10	**Marcus Hoff Hansen**, Wenche Emblem Larssen, Silje Ottestad, Jørgen Lerfall *Industrial hyperspectral imaging as a tool for measurement of texture and related parameters in Atlantic cod (Gadus morhua L.) fillets*

16:10 – 16:30 **Yangyue Chen**, Zsanett Bodor, Daniel Mörlein
Prediction of pork loin quality using near-infrared hyperspectral imaging

16:30 – 16:50 **Clara Peiris**, Giulia Gorla, Josep Comaposada, Begonya Marcos, José Manuel Amigo
Matrix effect on hyperspectral images when detecting and identifying microplastics in food matrices

16:50 – 17:10 J. Schreuder, D. Rip, **P.J. Williams**
Rapid serotyping of Listeria monocytogenes with a handheld VNIR hyperspectral imaging camera

17:10 – 17:30 **Fernando D. Villarruel**, Tigran Soghomonyan, Federico A. O. Rasse-Suriani, Fernando S. García Einshlag, Narine Sarvazyan
Multi-excitation fluorescence hyperspectral imaging for detection of radiofrequency ablation lesions: a PLS-DA approach

19:00 – 22:00 Conference Dinner at **Sjöbris**
Kajen 10, 903 26 Umeå

IASIM Day 4 – Wednesday, 17th June 2026

Aula Nordica, Universum, 3rd Floor, Umeå University

8:00 – 8:30	Registration

Session 5: Spectroscopy	
8:30 – 9:30	Plenary Lecture by Prof. **Martina Marchetti-Deschmann** *Imaging Mass Spectrometry as Another Dimension in Spectral Imaging for Assessing Skin Aging*

9:30 – 9:50 **G. Gorla**, R. Goyetche, P.J. Rodríguez Grasa, E. Garrote, J. M. Madariaga, J. M. Amigo
Information in hyperspectral imaging: how unsupervised models shape anomaly detectability

9:50 – 10:10 **Federica Amato**, Jon Ander Iturrioz, Giulia Gorla, Marcos Alonso Nieto, Daniel Maestro-Watson, Beñat Urtasun Marcoc, Gorka Arana, Juan Manuel Madariaga, José Manuel Amigo
3D-HSI-SWIR. 3D integration of SWIR hyperspectral imaging (HSI-SWIR) with a modified structure-from-motion (SFM) approach

10:10 – 10:30 **Lucía Ronda**, Danylo Komisar, Andrii Kutsyk, Gohar Soufi, Ditte Rask, Thomas Emil Andersen, Oleksii Ilchenko
Handling complex Raman data for bacterial identification without cultivation: a chemometric pipeline

10:30 – 11:00	Break / Sponsor Exhibitions / Posters

11:00 – 11:20 **Paolo Oliveri**, Cristina Malegori, Sara Gariglio, Eugenio Alladio, Giorgia Sciutto
Chemometric insights on the penetration depth of near infrared radiation in spectral imaging configurations: the INSIDE research project

11:20 - 11:40	**Ludovic Duponchel**, Ruggero Guerrini, Federico Marini, Nicolas Herreyre, Vincent Motto-Ros *Beyond the spectral cube: integrating visible imaging into LIBS data analysis*
11:40 – 12:00	**A. Sicre-Conesa**, A. Gómez-Sánchez, R. Vitale, A. de Juan, C. Ruckebusch *Exploring deconvolution MCR-ALS (DMCR-ALS) applied for spectral image unmixing analysis*
12:00 – 12:20	Olesya Daikos, Evgeny Lugovoy, **Tom Scherzer**, Kay-Antonio Behrend, Markus Rohdenburg, Jonas Warneke *Microspectral Imaging of* $[B_{12}Cl_{12}]^{2-}$ *and* $[Ru(bpy)_3]^{2+}$ *Ionic Layers Deposited by Ion Soft Landing*
12:20 – 13:00	Closing Session

IASIM-2026

Conference on spectral imaging

June 14–17, Umeå, Sweden

DAY 2 – Monday, June 15th 2026

ORAL PRESENTATION ABSTRACTS

REMOTE SENSING AND CHEMOMETRICS FOR GRASSLAND MANAGEMENT: WHEN DID THEY CUT?

Carlos Martín Santiago[1,2], José Manuel Amigo Rubio[1,3,4], Enmanuel Cruz Muñoz[2], Davide Ballabio[2], Arantza Aldezabal Roteta[1], Kepa Castro Ortiz de Pinedo[1]

[1] University of the Basque Country, Faculty of Science and Technology, Leioa, Spain

[2] University of Milano-Bicocca, Department of Earth and Environmental Sciences, Milan, Italy

[3] Ikerbasque, Basque Foundation for Sciences, Bilbao, Spain

[4] HYPER-Tools S.L., Edificio Rectorado, Barrio Sarriena S/N, Leioa – 48940, Spain

Grasslands are vital ecosystems that provide essential material resources and non-material benefits, while also serving as significant carbon sinks [1]. Despite their ecological importance, the global degradation of grasslands poses a serious threat: at least 49% of these ecosystems have been degraded to some extents [2]. To address this issue, the European Commission protects these ecosystems through the Habitat Directive, which requires Member States to submit comprehensive reports every six years on the conservation status of different habitats.

However, grassland monitoring faces two major challenges. First, the majority of the grasslands lie outside the Natura 2000 network, making them difficult to monitor. Second, most of the grasslands are privately owned, further complicating direct access for assessment. These limitations make remote sensing – particularly satellite imagery combined with remote sensing – a reliable and practical solution for tracking grassland management over time.

This study compiles Sentinel-2[3] imagery from 2022 to train a classification model for predicting the grassland status in Bilbao (Spain). The model is trained using data from known reference sites and validated through field data. Preliminary results demonstrate the model's strong performance, enabling effective distinction of grassland management (cut vs. non-cut) across seasons.

References

[1] Bardgett, R. D.; Bullock, J. M.; Lavorel, S.; Manning, P.; Schaffner, U.; Ostle, N.; Chomel, M.; Durigan, G.; L. Fry, E.; Johnson, D.; Lavallee, J. M.; Le Provost, G.; Luo, S.; Png, K.; Sankaran, M.; Hou, X.; Zhou, H.; Ma, L.; Ren, W.; Li, X.; Ding, Y.; Li, Y.; Shi, H. Combatting Global Grassland Degradation. Nat Rev Earth Environ 2021, 2 (10), 720–735.

[2] Gang, C.; Zhou, W.; Chen, Y.; Wang, Z.; Sun, Z.; Li, J.; Qi, J.; Odeh, I. Quantitative Assessment of the Contributions of Climate Change and Human Activities on Global Grassland Degradation. Environ Earth Sci 2014, 72 (11), 4273–4282.

[3] Sentinel-2 - Missions - Sentinel Online. Sentinel Online. https://copernicus.eu/missions/sentinel-2 (accessed 2025-06-21).

FROM LABORATORY TO FIELD: HYPERSPECTRAL IMAGING PREDICTS FIRE CLASSIFICATION OF TREATED WOOD

Muhammad Awais[1,2], Michael Altgen[3], Kristian Hovde Liland[1], Lone Ross[3], Arnkell Jonas Petersen[1], Thomas Kringlebotn Thiis[1], Ingunn Burud[1]

[1] Norwegian University of Life Sciences, Faculty of Science and Technology, Ås, Norway

[2] Aalto University, Department of Bioproducts and Biosystems, Espoo, Finland

[3] Norwegian Institute of Bioeconomy Research, Department of Wood Technology, Ås, Norway

Wooden façades on multi-storey buildings often require fire-retardant treatments to meet fire safety regulations, yet the progressive loss of these treatments under outdoor weathering necessitates non-invasive monitoring solutions. This study evaluates short-wave infrared hyperspectral imaging combined with canonical partial least squares linear discriminant analysis (CPLS-LDA) for classifying fire-retardant-treated wood into estimated fire performance categories under both laboratory and field conditions. Scots pine sapwood samples impregnated with a phosphorus-based fire retardant at varying loading levels (0, 12, 36% solution solid content) were subjected to repeated leaching cycles. Fire performance categories were estimated based on heat release rate and time-to-ignition thresholds derived from mass-loss calorimetry, supported by elemental (X-ray fluorescence, inductively coupled plasma optical emission spectroscopy) and thermal analyses confirming progressive fire-retardant loss.

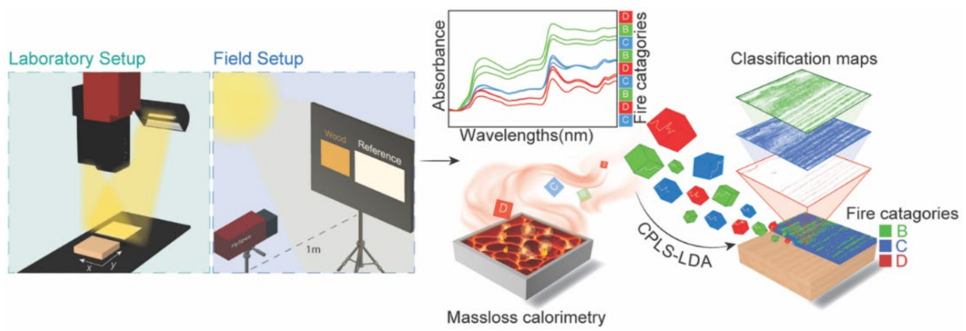


Fig. 1. Hyperspectral imaging workflow for predicting fire performance categories in lab and field setups.

The classification approach was tested under two imaging configurations: (1) a controlled laboratory setup with artificial illumination and a short working distance, and (2) an outdoor field setup at 1 m working distance under direct sunlight using a tripod-mounted camera. Separate classification models were trained for each configuration, achieving 96% and 79% test-set accuracy for laboratory and field conditions, respectively. Pixel-wise spatial classification maps from both setups revealed heterogeneous fire-retardant distributions and progressive changes in category assignments across leaching cycles, providing spatial information unattainable by conventional point-measurement techniques. These results show that hyperspectral imaging offers a practical pathway toward non-destructive, spatially resolved monitoring of fire safety in wooden construction.

HYPERSPECTRAL IMAGING FOR METEORITE ANALYSIS: ADVANTAGES AND LIMITATIONS OF COMBINING MULTIPLE TECHNIQUES

Giulia Gorla[1], **Leire Coloma**[1], Markel Sanchez-Goyenaga[1], Fernando Alberquilla[1], Julene Aramendia[1], José Manuel Amigo[1,2,3], Gorka Arana[1], Juan Manuel Madariaga[1]

[1] Department of Analytical Chemistry, Faculty of Science and Technology, University of the Basque Country (UPV/EHU), Barrio Sarriena s/n, 48940 Leioa, Spain

[2] IKERBASQUE, Basque Foundation for Science, Plaza Euskadi, 5, 48009 Bilbao, Spain

[3] HYPER-Tools S.L., EHU, Barrio Sarriena s/n, 48940 Leioa, Spain

Meteorites offer unique insights into the formation and evolution of the Solar System, including planetary differentiation and the composition of bodies such as Mars and Moon. Comprehensive chemical and mineralogical characterization is challenging due to the complex, heterogeneous nature of these materials and their limited availability, necessitating multiple complementary analytical techniques. Non-destructive methods are particularly valuable, allowing detailed analysis without altering these rare specimens. Commonly employed approaches include Raman and near-infrared (NIR) spectroscopy [1] and X-ray fluorescence (XRF) [2]. In the present study, hyperspectral images were acquired using μ-Raman spectroscopy, μ-NIR spectroscopy, and μ-EDXRF spectrometry, to analyze different meteorites from Mars and the Moon. The data obtained from each technique were analyzed through Principal Component Analysis (PCA) and Multivariate Curve Resolution (MCR), testing different pre-processing approaches such as scattering correction and derivative transformations. A multiblock approach was also evaluated to facilitate the interpretation of the results and to identify the mineral phases present in the samples. This approach enabled a detailed evaluation of the complementary techniques, highlighting both the advantages and limitations of performing full-face mapping with each method and the challenges of comparing the resulting datasets.

References

1. I. Gyollai, et al. Raman–Infrared Spectral Correlation of an Artificially Space-Weathered Carbonaceous Chondrite Meteorite, Minerals. 14 (2024) 288.

2. I. Allegretta, et al. Macro-classification of meteorites by portable energy dispersive X-ray fluorescence spectroscopy (pED-XRF), principal component analysis (PCA) and machine learning algorithms, Talanta. 212 (2020) 120785.

IMAGE-BASED MONITORING OF EPS IN WASTEWATER BIOREACTORS

Marco S. Reis[1], Eugeniu Strelet[1], Ivan Castillo[2]

[1] University of Coimbra, CERES, Department of Chemical Engineering, Coimbra, Portugal

[2] The Dow Chemical Company, Lake Jackson, USA

Industry 4.0 has driven the rise of accessible image-based monitoring tools [1]. This study focuses on a Wastewater Treatment Plant (WWTP) bioreactor, aiming to estimate and monitor Extracellular Polymeric Substances (EPS), which are key to cell aggregation and floc formation [2]. Currently, EPS assessment relies on offline microscopic inspections performed by specialists, leading to delays in feedback and limited sampling capability.

To overcome these limitations, we propose a fast and reliable image-based methodology to estimate EPS concentration while extracting descriptors for identifying normal and deviating operational conditions. The approach integrates digital image processing [3] with chemometric techniques. It involves grayscale transformation, object segmentation, and subsequent extraction of statistical features, which are analyzed using multivariate methods to classify image quality and monitor reactor performance.

The developed model achieved a coefficient of determination (R2) of 0.95 and a root mean square error (RMSE) of 0.98%. This accuracy allowed the method to be applied to an image database for tracking both intra- and inter-sample variability through X-bar and R Shewhart control charts [4]. The proposed methodology effectively detected low-quality images and identified meaningful features that distinguish between stable and deviating reactor operation periods, offering a valuable tool for real-time process monitoring in wastewater treatment.

References

1. Reis, M. S. (2014), Multivariate image analysis, in ‘Mathematical and Statistical Methods in Food Science and Technology’, John Wiley & Sons, Ltd., chapter 12, pp. 201–218

2. Liu, Y. & Fang, H. H. P. (2003), ‘Influences of Extracellular Polymeric Substances (EPS) on Flocculation, Settling, and Dewatering of Activated Sludge’, Critical Reviews in Environmental Science and Technology, 33(3), 237-273

3. Gonzalez, R. C., Woods, R. E. & Eddins, S. L. (2009), Digital Image Processing Using Matlab, 2nd ed, Gatesmark Publishing.

4. Montgomery, D. C. (2013), Introduction to Statistical Quality Control, 7th ed, John Wiley & Sons, Inc.

A MULTI-LEVEL FRAMEWORK FOR FT-IR SPECTRAL IMAGING OF MICROPLASTICS

Zina-Sabrina Duma[1], Tenzin Tsering[2], Tuomo Soininen[2], Arto Koistinen[2], Tuomas Sihvonen[2], Sara Heikkinen[1], Satu-Pia Reinikainen[1]

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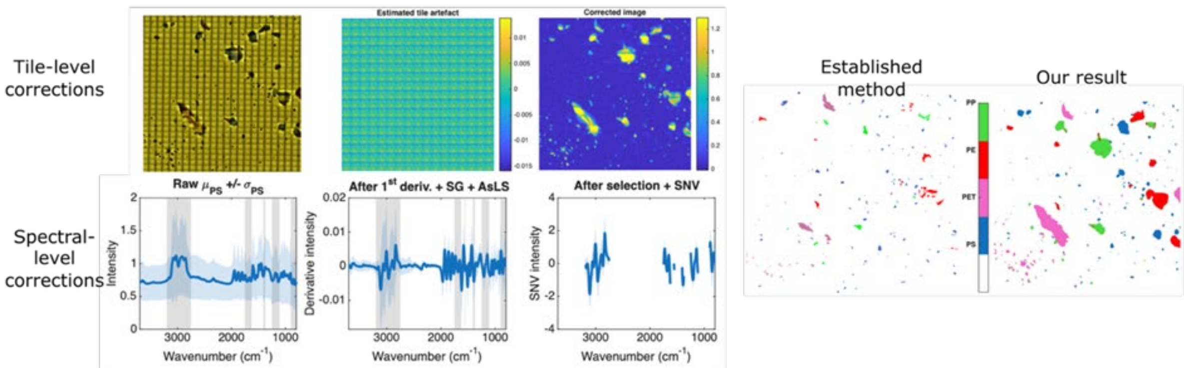
Spectral imaging offers chemically specific and spatially resolved microplastic analysis, but routine application is limited by high data volume, acquisition artefacts, spectral variability, and misclassification of chemically similar polymers. We propose a multi-level framework for FT-IR spectral imaging that combines image-level, tile-level, and spectral-level corrections with scalable identification strategies. Principal component analysis was used to detect and remove acquisition-related image variation, while a background-based tile correction reduced spatial artefacts. Spectral preprocessing included baseline correction, smoothing, derivatives, normalization, and wavelength selection, after which only particle spectra were retained. For scalable identification, clustering was performed on particle spectra and spectral library matching was applied to cluster centroids instead of individual pixels. This reduced computational cost while improving spatial coherence of particle maps. Among twelve evaluated matching strategies, a sign-invariant derivative-based cosine similarity method correctly classified the plastic types. Along with the semi-supervised centroid matching identification, the framework looks at supervised classification methods as well. Along with traditional supervised classification, the kernel-based variants of established methods are added to better address nonlinear class boundaries and confusable polymer pairs. The results show that multi-level correction combined with centroid-based matching provides a robust and efficient strategy for spectral-imaging-based microplastic identification.

Graphical abstract:



ASSESSING THE TRUE POTENTIAL OF SWIR-HSI, MWIR-HSI AND LWIR-HSI FOR MICROPLASTICS IDENTIFICATION IN BEACH MONITORING

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The increasing presence of microplastics (MPs; sizes ranging from 5 mm to 1 µm) in coastal environments calls for robust monitoring strategies to identify diverse polymer types under realistic field conditions. Short-wave infrared (SWIR) hyperspectral imaging (SWIR-HSI) is the most commonly used approach for this purpose. However, the reliability of reflectance-based measurements is strongly influenced by particle shape, surface texture, and colour. Moreover, it critically depends on the degree and pathway of environmental ageing, as different weathering processes can significantly alter the spectral response of certain MPs [1]. In this study, MPs from multiple beaches along the Biscay coast were analysed using SWIR-HSI (Specim, 0.95–2.5 µm), Specim FX50 (MWIR, 2.7–5.3 µm) and Specim FX120 (LWIR, 7.7–12.3 µm) cameras. The Mid-Infrared-HSI (MWIR-HSI) is particularly effective for detecting dark polymers that strongly absorb in the SWIR region. At the same time, the Long-wave-Infrared-HSI (LWIR-HSI) domain provides chemical contrast based on thermal emissivity rather than reflectance, allowing the identification of highly absorbing or weathered plastics. Polymer assignments were validated by portable Raman spectroscopy (532 and 785 nm excitation) and benchtop ATR-FTIR (4000–500 cm^{-1}). Results show that colour, weathering and surface fouling significantly affect spectral signatures, impacting classification performance. Variability in sampling location, particle size, shape and degradation further influences model reliability. This work demonstrates the need for multi-modal validation and defines the operational limits of infrared hyperspectral imaging for routine beach monitoring.

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Acknowledgements

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DEVELOPING QUANTITATIVE TEXTILE COMPOSITION MODELS USING HYPERSPECTRAL IMAGING AND CHEMOMETRIC

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The recycling of textile waste requires fast, accurate, and automated sorting solutions capable of handling heterogeneous materials, fiber blends, and strong visual variability. Conventional mechanical or manual sorting methods often fail to meet these challenges. Hyperspectral imaging (HSI), combined with chemometric analysis, offers a non-destructive and spatially resolved approach for textile identification and classification based on chemical composition rather than appearance [1].

This study is part of the European Solstice project, it investigates the use of short-wave infrared (SWIR, 1000–2500 nm) hyperspectral imaging coupled with multivariate data analysis for textile characterization and sorting. The main objective is to discriminate textiles according to chemical composition, including complex blended and multi-material structures, and to develop models for predicting polyester (PES) and cotton contents independently of their color or texture [2,3].

Hyperspectral images were acquired using a Specim SWIR camera under conveyor-based conditions. A diverse dataset of reference textile samples covering natural, synthetic, and technical fibers was analyzed on both sides of each sample. Spectral preprocessing, including Standard Normal Variate (SNV) correction and Savitzky–Golay first derivative, was applied to reduce scattering effects and enhance material-specific spectral features. Exploratory analysis was performed using Principal Component Analysis (PCA), while Partial Least Squares (PLS) regression models were developed for quantitative composition prediction [4].

The results demonstrate high-quality and reproducible spectral acquisitions with low noise levels. PCA revealed well-defined clusters corresponding to textile material types, showing clear separation between different fibers and good consistency between most sample faces for which they were consistent and not so much when they were not.

A key outcome is the ability of SWIR-HSI to detect minor components in blended textiles, such as a Lurex thread representing approximately 1% of the total composition, confirming the high sensitivity of the technique [1]. PLS regression models provided promising predictions of PES and cotton contents, with predicted values close to the nominal compositions, despite slight overestimations attributed to uncertainties in label-based reference data. Limitations were observed for dark-colored textiles due to low reflectance, a known constraint of reflectance-based HSI systems [2].

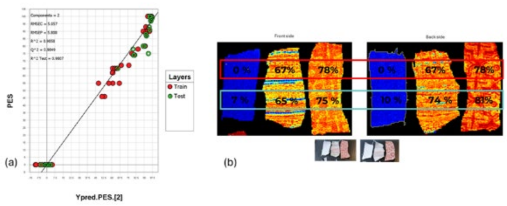

Figure: (a) PLS regression applied to the data and prediction of PES; (b) content reference values in red and predicted values in green.

Overall, this work confirms the strong potential of SWIR hyperspectral imaging combined with chemometrics for automated textile quantitative composition determination. The approach aligns with Process Analytical Technology (PAT) principles and represents a robust pathway toward smarter, more efficient textile recycling processes.

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HYPERSPECTRAL DATA CUBE COMPRESSION USING VIDEO CODING ALGORITHMS

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Hyperspectral imaging produces data cubes made of many contiguous spectral bands, which creates major storage and transmission constraints in remote sensing, industrial inspection, and scientific imaging. This work studies a simple compression strategy in which the spectral cube is treated as an ordered image sequence, allowing standard video coders to reuse the strong correlation between neighboring bands. We implement this HSI-as-video idea in a reproducible workflow that loads hyperspectral cubes, converts bands to image sequences, encodes them with video codecs such as AV1 [2], reconstructs the cube, and records machine-readable experiment artifacts for later comparison.
Experiments on the Indian Pines dataset [3] show that this approach can achieve a file size reduction of up to 500x while preserving spectral fidelity with negligible impact on downstream classification tasks after reconstruction. Beyond compression efficiency, it also benefits from the speed and maturity of modern video coding pipelines, which makes it more attractive for time-sensitive applications, including field and onboard processing. In our experiments, processing speed increased by up to 20x compared to the recommended standard [1]. Overall, these results suggest that reusing video coding algorithms is a simple and effective way to compress hyperspectral data while balancing storage reduction, encoding speed, and spectral fidelity. These preliminary results suggest that video compression algorithms could be a replacement to the current standard [1] for hyperspectral image compression.

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INVESTIGATION TOWARDS HIGH-FIDELITY HYPERSPECTRAL IMAGING WITH ROBOT-ASSISTED FIBER SCANNING

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Hyperspectral imaging (HSI) is a powerful technique for the non-invasive characterization of materials, yet achieving broad spectral coverage, high spectral resolution, and flexible spatial sampling remains a fundamental challenge due to inherent hardware trade-offs [1]. Here we present a system coupling a single optical fiber to an ASD FieldSpec 4 spectroradiometer mounted on a Stäubli TX-60 robotic arm, targeting industrial inspection and quality control applications. This system combines full spectral coverage from 350 to 2500 nm with sub-8 nm spectral resolution and programmable point-by-point acquisition over user-defined regions of interest. Spatial resolution is inherently constrained by fiber properties, and the effects of scan overlap and reconstruction strategy on both spatial resolution and spectral fidelity are investigated. Overlap controls sampling redundancy, a key parameter in accurate hyperspectral reconstruction. We compare several reconstruction algorithms, from Gaussian-weighted averaging adapted to the fiber point spread function, to an inverse problem formulation with spatial regularization. Validation is carried out on flat surfaces using a designed plastic calibration target, engineered to deliver strong color contrast in the visible and distinctive spectral features in the infrared. Results reveal the optimal combination of overlap and reconstruction strategy that maximizes both spatial resolution and spectral fidelity, providing practical guidelines for fiber-based robotic HSI.

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THREE-WAY ROIMCR: A NEW FRAMEWORK FOR ANALYZING ION MOBILITY MASS SPECTROMETRY HYPERSPECTRAL IMAGING DATA

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Ion Mobility Mass Spectrometry Imaging (IMS–MS/MS-imaging) [1] is a powerful technique for the in-depth analysis of complex biological samples. However, the large, multiway datasets it produces are challenging to interpret. This work introduces the Regions-Of-Interest–based Multivariate Curve Resolution (ROIMCR) [2] strategy to address this challenge. Unlike conventional methods that condense ion mobility data into a single collision cross-section (CCS) value [3], ROIMCR retains the full ion mobility profile, enabling a more comprehensive and accurate analysis. The core of the approach is a three-way data formulation, using either a bilinear or trilinear multivariate curve resolution model. This framework simultaneously resolves the three key components of the dataset: the spatial distribution of compounds (x-y images), their ion mobility profiles, and their mass spectra (both MS1 and MS2). By enforcing chemically consistent solutions across these three data directions, the model produces interpretable component profiles with high performance. Compound annotation is then achieved by directly comparing these resolved profiles—specifically drift time and tandem mass spectra—against reference libraries [4]. The effectiveness of three-way ROIMCR was validated on two distinct datasets: first, a synthetic mixture of four analytes designed to test its ability to resolve overlapping spatial and spectral features, and second, an experimental dataset mapping lipid constituent's distribution across different layers of skin (dermis to epidermis) exposed to air pollution extracts. In summary, the proposed three-way MCR framework offers an accurate, scalable, and chemically meaningful solution for the analysis of high-dimensional IMS–MS/MS hyperspectral images.

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SELFSHARPENING: AN IMAGE FUSION METHOD FOR SPECTRAL MICROSCOPY DATA

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In optical microscopy, it is common to employ deconvolution for image superresolution [1]. However, for spectroscopic images, processing each image channel in this way might be computationally costly or, for noisy channels, distort the results. We propose to use selfsharpening, an approach derived from standard pansharpening, to overcome this limitation.

Pansharpening is a data fusion strategy, originated in remote sensing, that combines a high-spatial but low-spectral-fidelity image with a low-spatial but high-spectral-fidelity image [2]. In selfsharpening, the high-resolution image is first produced by a standard deconvolution method from, for example, the mean of the spectral image. Then, a classical pansharpening method is applied to sharpen the original spectral image. This will have the benefit that, as the deconvolution is computed only on the mean image, much of the random noise in the image is cancelled out by averaging, thus not corrupting the results.

The proposed methodology is studied utilising synthetic and real microscopy imaging data. In addition to the enhanced resolution of the images, the effect of selfsharpening on their multivariate curve resolution analysis is studied [3]. The suitability of diverse pansharpening methods for the task is also compared and discussed.

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ZERO-SHOT LEARNING FOR HYPERSPECTRAL IMAGING IN MANUFACTURING

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Hyperspectral imaging (HSI) has emerged as a powerful modality for anomaly detection in product manufacturing [1, 2], enabling detection of subtle defects and surface contamination often undetected in RGB imaging. At the same time, hyperspectral data often exhibits significant variability across cameras, illumination conditions, and acquisition setups, leading to domain shifts that degrade the performance and transferability of data-driven models.

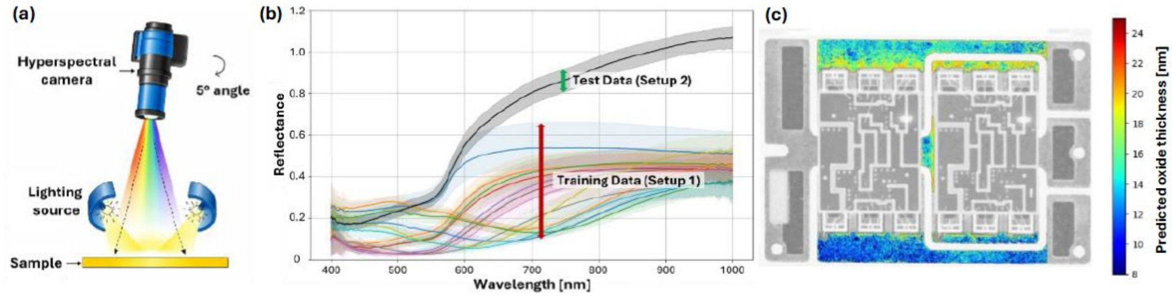

Fig. 1: (a) Sketch of our camera setup. (b) Visualization of the apparent heterogeneity between train and test datasets. (c) Model prediction with documented RMSE to ground truth of 3.4 nm.

In this work, we show that simple transformations can make HSI data inherently robust to domain shifts allowing for label-free, zero-shot learning across setups. Our application domain is surface quality assessment of power electronic products, where we employ HSI for early defect detection. We demonstrate how combining simple data-processing steps with generic machine-learning models can yield surprisingly robust and generalizable models across setups, see Fig. 1. For instance, a model trained to predict oxide thicknesses can produce strong zero-shot generalizability on setups with markedly different raw-data distributions.

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IASIM-2026

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DAY 3 – Tuesday, June 16th 2026

ORAL PRESENTATION ABSTRACTS

THE POTENTIAL OF HYPERSPECTRAL IMAGING FOR ARCHAEOLOGICAL STUDIES

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Chemical analysis of archaeological samples creates historical context and deepens the understanding of a location's purpose and history. Items related to cultural heritage, however, must remain in their found state and cannot be damaged or modified. A solution is to scan artifacts in a non-destructive way using hyperspectral imaging (HSI) with a near-infrared (NIR) source.

This work has employed a near-infrared (NIR) hyperspectral camera with a moving sample table to scan flint pieces, soils, and pieces of historical charcoal. By combining HSI with principal component analysis (PCA), a statistical relationship can be made between imaging and chemical spectra. This technique allows for a quick and reliable distinction between classes of archaeological items (e.g. flint vs. charcoal vs. soil), as well as the identification of similarities and differences between samples within the same class. One case in point is the comparison of pristine and semi-charred wood. PCA results (Fig. 1a) show a negative correlation between charred and pristine wood along PC2, indicative of chemical differences (Fig. 1b). Despite the retention of the tree rings on the charred specimen, the chemical change from the wood's use in a tar pit is captured by the HSI-NIR.

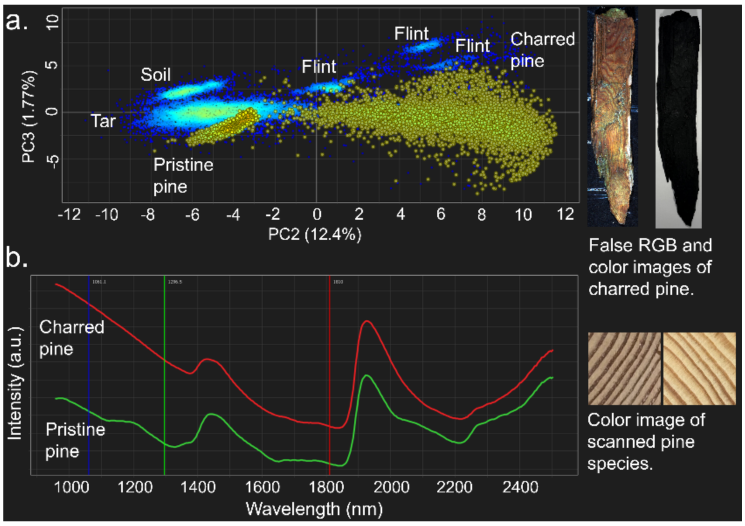

Figure 1. HSI-NIR results for flints, wood, charred wood, and soil samples. A) highlighted in yellow on the PCA map are the NIR results from pristine pine, and semi-charred wood collected from a historical tar pit in Degersjön (Sweden); B) the average NIR spectra of pristine pine and semi-charred wood.

Preliminary results from the analysis of flints show differences between white and blue patinated areas, and the remaining cortex on certain flakes. As a result, HIS-NIR has shown to be useful for identifying heterogeneities within samples with wide applications in cultural heritage.

RESTORATION OF HIDDEN TEXT IN BOOK BINDINGS VIA SPECTRAL IMAGING AND BLIND SUPER-RESOLUTION

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Manuscript fragments reused in historical bookbindings preserve a "hidden library" of pre-modern texts, yet their recovery is hindered by layered materials, chemical treatments, and complex optical degradation. This work presents a unified framework combining spectral imaging and physics-aware deep learning–based restoration.

Using case studies from the Herlufsholm Collection at the University Library of Southern Denmark (vols. 24.1 and 250.8), we evaluate Multispectral Imaging (MSI), Hyperspectral Imaging (HSI), and Ultraviolet (UV) illumination. While HSI (up to 1700 nm) improves spectral penetration, and MSI preserves spatial detail, we show that overlaid materials introduce spatially variant blur due to light diffusion, which cannot be captured by standard degradation models [1].

To address this, we formulate the problem as blind text image super-resolution and adapt generative models to historical Latin scripts (Fig. 1). This reduces Character Error Rate (CER) from 88.04% to 35.54%, enabling partial recovery of previously unreadable text [2].

We further model the physical degradation process in layered substrates to bridge the domain gap between synthetic training data and real fragments. This integration of imaging physics and generative modelling supports more reliable, evidence-based restoration of obscured historical texts.

a) b)

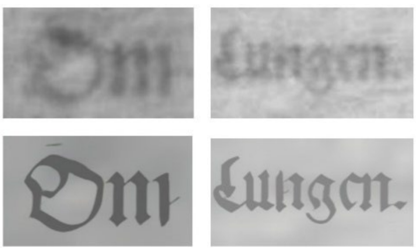

Fig. 1 Qualitative performance of the proposed model on degraded text images extracted from the fragment on Herlufsholm 24.1. The figure shows a) the low-resolution inputs and b) the super-resolved outputs.

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3D-HYPERSPECTRAL MAPPING OF SMALL CULTURAL HERITAGE OBJECTS. FUSION OF SWIR-HSI AND LOW-COST 3D SCANNING FOR MATERIAL ANALYSIS. THE EXAMPLE OF A NUBIAN DAGGER.

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The analysis of cultural heritage objects often requires integrating complementary sensing modalities to capture both material composition and spatial structure. In this work, we present a novel framework that fuses short-wave infrared hyperspectral imaging (SWIR-HSI) with 3D geometry acquired using a low-cost structured-light scanner (Creality CR-Scan), enabling the generation of fully registered 3D hyperspectral models.

SWIR-HSI is used to capture spectral signatures associated with different materials and degradation processes, such as corrosion products, mineral inclusions, and surface alterations. A dedicated co-registration pipeline is developed to align hyperspectral data with the 3D mesh, combining geometric calibration and feature-based matching. Chemometric models, including PCA and spectral unmixing (Multivariate Curve Resolution - MCR), are used to identify and map relevant chemical and structural features.

The methodology is validated on small-scale archaeological artefacts, including a Nubian dagger, where complex geometries and heterogeneous surface conditions pose significant analytical challenges. The resulting 3D hyperspectral maps enable intuitive visualisation and precise localisation of corrosion patterns and compositional heterogeneities, surpassing traditional 2D analysis. The use of an accessible 3D scanner further demonstrates the feasibility of low-cost, high-impact multimodal systems for heritage diagnostics.

DATA FUSION AND VARIABLE SELECTION FOR ENHANCED CLASSIFICATION OF AGE AND VIABILITY IN CABBAGE SEEDS USING SPECTRAL IMAGING DATA

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Most methods currently used to determine the viability of seeds are destructive and time-consuming. This research investigates the performance of non-destructive spectral imaging for the assessment of naturally aged cabbage seeds from different harvest years. Spectral images of the seeds were captured in the Visible-Near infrared (VNIR, 400-1000 nm) and Short-Wave Infrared (SWIR, 900-2500 nm) ranges, and multivariate calibration models were developed to classify seeds according to age and viability. Six independent trials were carried out, and models developed using partial least squares discriminant analysis generally out-performed other multivariate techniques. Three variable selection techniques were evaluated and compared: random variable selection, uninformative variable elimination[1] and ensemble Monte Carlo variable selection[2]. Overall, models developed to predict age were more successful than those constructed to predict viability, and models developed using the SWIR wavelength were more accurate than those developed on the VNIR range. Fusion of the spectral ranges improved classification accuracy considerably (by ~ 10%), and variable selection approaches showed that model performance could be maintained using less than 10% of the original wavelengths.

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REAL-TIME IDENTIFICATION OF CLEAN AND DEFECTIVE MAIZE GRAINS FOR SMART SORTING USING SWIR HYPERSPECTRAL IMAGING TECHNOLOGY

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Traditional grain sorting methods are often labor-intensive, time-consuming, and prone to subjectivity, limiting their efficiency in large-scale operations. This study presents the development of a real-time grain classification system for the rapid identification of clean and defective maize kernels using a short-wave infrared (SWIR) hyperspectral imaging linescan camera (Hyspex SWIR-384 Norsk Elektro Optikk, Norway). Spectral data were acquired from both clean and defective maize kernels, with defects including heat damage, insect damage, frost damage, discoloration, breakage, sprouting, and Fusarium contamination. Pre-processing of spectral data was performed using Savitzky–Golay second derivative filtering and standard normalization techniques to enhance spectral features and reduce noise. Wavelength selection methods were subsequently applied to minimize data dimensionality and computational complexity. Partial least squares discriminant analysis (PLS-DA) was employed to develop classification models for distinguishing between clean and defective grains. The developed model achieved classification accuracies exceeding 95%, demonstrating high sensitivity and reliability in defect detection. Notably, the highest classification performance was observed for Fusarium-infected, heat-damaged, insect-damaged, and sprouted kernels. The results highlight the significant potential of SWIR hyperspectral imaging as a transformative technology for intelligent grain sorting and quality assurance. The proposed system enables rapid, automated, and high-throughput inspection, offering a scalable solution for modern grain supply chains.

Keywords: Hyperspectral imaging; SWIR; Maize kernels; Defect detection; PLS-DA; Grain sorting; Postharvest quality

ASSESSING THE QUALITY OF PACKAGED CHERRY TOMATOES USING TWO HYPERSPECTRAL IMAGING SYSTEMS

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Growing interest in non-destructive quality assessment has accelerated the adoption of hyperspectral imaging (HSI) in postharvest and commercial applications1. Two HSI operating in the VIS–NIR and NIR range using Specim V10 spectrograph for VIS-NIR and Specim N17E spectrograph for NIR, and Headwall system, integrating in one scanning system MV.C VNIR and MV.C NIR sensors, were used to evaluate the quality of packaged and non-packaged cherry tomatoes from the market. Physicochemical attributes including firmness, total soluble solids (TSS), pH, titratable acidity, and vitamin C content were measured as reference parameters. Partial Least Squares Regression (PLS-R) models were developed to assess tomato quality across all spectral datasets. Standardization and calibration-transfer techniques2 were evaluated to address spectral differences between instruments, enabling models built with Specim spectra to be applied to Headwall measurements (Fig. 1 A and B).

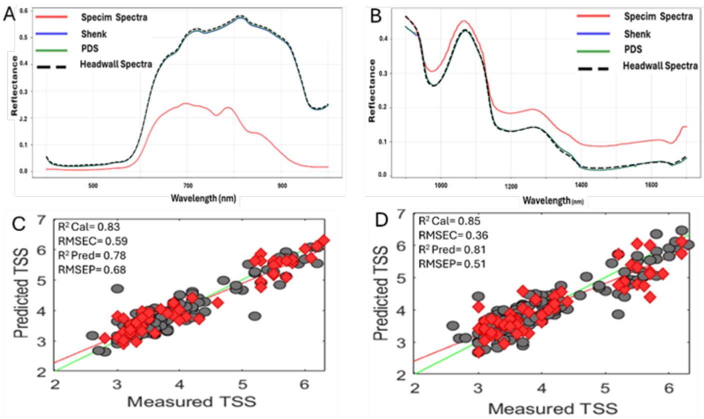

Fig. 1. Raw and calibrated spectra acquired with Specim and Headwall systems in the VIS–NIR (A) and NIR (B) ranges. Standardization was performed using mean spectra. Prediction plots for TSS measured in VISNIR (C) and NIR (D).

Instrument variability and packaging affected model performance, with the Headwall system and NIR range yielding more accurate predictions, especially for the TSS (Fig. 1 C and D). Spectral standardization, particularly PDS, improved transferability, and combining datasets enhanced accuracy. Overall, reliable cross-system prediction was achieved, supporting large-scale HSI-based quality assessment.

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SPECTRAL INFORMATION COMBINED WITH PHYSICAL ATTRIBUTES, FOR THE PREDICTION OF BLACKHEART DEFECTIVE POMEGRANATE (PUNICA GRANATUM L.) FRUIT

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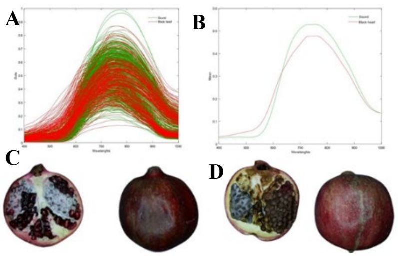
Blackheart internal defect is a major pre-harvest disease affecting global pomegranate production. Distinguishing defective fruit externally is challenging, typically requiring expert assessment. This study aimed to develop a non-destructive classification method for blackheart detection. We evaluated 903 pomegranates (543 defective, 360 sound) using visible-near-infrared (Vis-NIR, 400–1000 nm) hyperspectral reflectance imaging and conventional measurements of physical attributes (weight, volume, density). Image processing extracted morphological (circularity, sphericity, projected surface, perimeter), colorimetric (RGB, Lab*), and Grey Level Co-occurrence Matrix (GLCM)2 textural parameters.



Raw spectra (A) and mean spectra (B) acquired in reflectance mode over the VIS-NIR range and classified as Sound (green) or Black Heart (red). Representative images of Sound (C) and defective Black Heart (D) pomegranates.

A baseline Partial Least Squares Discriminant Analysis (PLS-DA)3 model utilising only conventional and image-derived attributes achieved classification accuracies of 80% (calibration) and 85% (prediction). To enhance classification performance, spectral reflectance intensities at five key wavelengths (450, 550, 570, 610, and 675 nm) were integrated into the model. The inclusion of these targeted spectral variables significantly improved the PLS-DA model, yielding 88% accuracy for both calibration and prediction datasets. These results demonstrate that combining optical spectral signatures with physical and image-derived morphological and textural features provides a rapid, reliable, and non-invasive approach for detecting blackheart in pomegranates. thereby improving postharvest quality control.

Disclosure Statement: The diagnostic approach and methodologies described in this work are the subject of an Italian patent application (Deposit No. 102025000032317) pending before the Ministero delle Imprese e del Made in Italy - Ufficio Italiano Brevetti e Marchi (UIBM).

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INDUSTRIAL HYPERSPECTRAL IMAGING AS A TOOL FOR MEASUREMENT OF TEXTURE AND RELATED PARAMETERS IN ATLANTIC COD (*GADUS MORHUA L.)* FILLETS

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The texture of Atlantic cod (Gadus morhua L.) fillets is an important quality parameter regarding both the processing of fillet products and the consumer. The firmness and cohesiveness of cod fillets may vary drastically and in extreme cases the fillet can fall apart during processing causing revenue and food loss [1]. Some of the textural variability is related to the spawning cycle of Atlantic cod, where the growth of gonads decreases protein and increases water content in the muscle tissue [2]. This is also interlinked with feeding and growth of the fish, as heavy feeding and fast growth in the summer months is reported to reduce the firmness of the fillet [3], while starvation strengthens connective tissue leading to a firmer fillet [4].

In recent years a commercial HSI instrument have become available which is specifically tailored towards the fishing industry called Maritech Eye™ (Maritech AS, Molde, Norway). Maritech Eye makes it possible to monitor physiochemical parameters of fish in the production line. However, there are currently no known models for measuring texture or texture relevant parameters in Atlantic cod from HSI images. Therefore, this research focused on testing representative parameters to cod fillet texture and their measurability with industrial HSI.

Three rounds of samplings were conducted from commercial Norwegian trawlers in the Barents Sea during January, February, and October of 2025. The first round consisted of 47 cod fillets analyzed on land. The second and third samplings consisted of 87 and 60 fish respectively and were filleted and partially analyzed on board the trawlers to collect biological relevant data and NIR measurements of fresh pre-rigor fillets. On landfall, the fillet samples were scanned with Maritech Eye at industrial speed (0.5 m/s) and fillet texture, water content, ash content, water holding capacity (WHC) and amino acid sequence of the loin were measured.

Results showed significant differences in multiple parameters between the samples caught in February and October including physical measurements of fillet firmness, total and individual amino acids related to texture and WHC. The results of this study are coherent with the results in literature, with better texture in the samples from the winter months and poorer texture in the samples from October. Remaining work will explore the signal spectra collected with HSI and handheld NIR instrument to identify any seasonal variance relevant to the texture of cod fillets in the spectra. After which calibration of a predictive model will be conducted using conventional and neural-net based chemometric approaches.

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PREDICTION OF PORK LOIN QUALITY USING NEAR-INFRARED HYPERSPECTRAL IMAGING

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Traditional pork quality assessment relies on destructive physical and chemical analyses, which are difficult to integrate into the pig production chain. This study aims to investigate the feasibility of near-infrared hyperspectral imaging (NIR-HSI) as a rapid, multivariate approach for online pork quality assessment.

To this end, loin samples (Longissimus thoracis et lumborum) from 526 pigs stemming from two production systems (organic vs. conventional) were collected between 2025 and 2026. Quality traits of the loins were determined at the slaughterhouse and in the laboratory, including pH at 45 min and 24 h postmortem (p.m.), electrical conductivity at 24 h p.m., drip loss, color before (L*1, a*1, b*1) and after storage (L*2, a*2, b*2), cooking loss, and shear force. Hyperspectral data were acquired from an adjacent loin slice in the laboratory about 32 h p.m. in the near-infrared range (936–1720 nm) using a line-scan camera and a moving sample stage. A U-Net model was applied for segmentation, and mean spectra were obtained from the central region of each loin chop. The dataset was divided into calibration (80%) and prediction (20%) sets using the Kennard–Stone algorithm. Partial least squares regression (PLSR) models were developed with different preprocessing combinations.

The results show that the coefficients of determination in the prediction set (R^2P) for L*1, L*2, a*1, and a*2 reached 0.82, 0.72, 0.74, and 0.80, respectively, with corresponding residual predictive deviation (RPD) values of 1.67, 1.83, 1.97, and 2.23. Moderate to limited predictive performance was observed for other traits, including pH24 h p.m. ($R^2P = 0.67$), drip loss ($R^2P = 0.44$), cooking loss ($R^2P = 0.46$) and b*2 ($R^2P = 0.48$).

Overall, the results demonstrate the potential of NIR-HSI as a rapid on-line method for assessing pork color, while the prediction of more complex traits remains challenging. As part of the ongoing project, further chemical analyses will be conducted to investigate the feasibility of predicting proximate composition (e.g., fat content). Future work will focus on developing classification models based on comprehensive quality indicators.

This work is part of the GlasSchwein project, funded by the German Federal Office for Agriculture and Food (Project ID: 28DI107B23)

MATRIX EFFECT ON HYPERSPECTRAL IMAGES WHEN DETECTING AND IDENTIFYING MICROPLASTICS IN FOOD MATRICES

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Near-infrared hyperspectral imaging (HSI) has shown potential for rapid screening of MPs in complex matrices [1]. However, the impact of the matrix effect, a limitation in destructive techniques such as mass spectroscopy [2], has not been fully studied. Hence, the objective of this study was to evaluate the matrix effect of different food matrices (sea salt and fish) on the detection and identification of polyethylene terephthalate (PET), polystyrene (PS), polypropylene (PP) and low-density polyethylene (LDPE) microparticles (MPs).

PET, PS, PP, and LDPE microparticles (0.3-2.4 mm) were used to contaminate the surfaces of two types of food matrices: sea salt (coarse, 460-2210 µm; fine, 135-480 µm) and gilt-head bream filets (whole and ground). Hyperspectral images were acquired using a push-broom Specim SWIR camera (928–2524 nm) equipped with an OLES30 lens. Spectral data were processed and modelled using MIA Toolbox 9.1 and a custom script developed in Matlab R2024b. Different preprocessing strategies, partial least squares discriminant analysis (PLS-DA) and multivariate curve resolution (MCR) were compared to detect and identify MPs. For sea salt, PLS-DA and MCR successfully detected and identified all PET, PS, PP and LDPE MPs studied. Although spectra revealed some matrix influence, it did not hinder polymer identification. For fish filets, both models accurately detected and identified all studied polymers in whole and ground gilt-head bream over the 0.5-2.4 mm range. However, MPs of 0.3 mm were not detected, likely due to decreased polymer peak intensities and matrix effects. Overall, the results highlight the potential of hyperspectral imaging as a non-destructive approach for detecting MPs in sea salt and fish fillet, and they also demonstrate the impact of matrix effects, which can limit MP detection.

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RAPID SEROTYPING OF *LISTERIA* MONCYTOGENES WITH A HANDHELD, VNIR HYPERSPECTRAL IMAGING CAMERA

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A handheld visible–near infrared (VNIR) hyperspectral imaging camera was evaluated for the differentiation of *Listeria* species (*Listeria monocytogenes*, *Listeria ivanovii* and *Listeria innocua*) and for the serotyping of *L. monocytogenes* (1/2a and 4b) from pure cultures grown on agar. The aim was to assess the potential of portable hyperspectral imaging for pathogen discrimination, despite its lower spectral resolution and higher sensitivity to noise compared to laboratory-based systems.

A total of 555 hyperspectral images were collected from pure cultures across seven sampling campaigns. Partial Least Squares Discriminant Analysis (PLS DA) models were developed using 65% of the samples for training (approximately 90 samples per class) and 35% for validation (approximately 50 samples per class). Using a reduced wavelength model, an overall validation classification accuracy of 74.5% was achieved for discrimination between Listeria isolates (*L. monocytogenes* 1/2a, *L. monocytogenes* 4b, *L. ivanovii* and *L. innocua*).

For L. monocytogenes serotyping, a two class PLS DA model achieved a validation classification accuracy of 90% when distinguishing between serotypes 1/2a and 4b. Variable Importance in Projection (VIP) analysis was used to identify wavelengths contributing to discrimination, with relevant features primarily located in the visible region. Notably, absorption regions used to differentiate *L. monocytogenes* serotypes were confined to the visible range (480–525 nm, 540–560 nm, 610 nm and 690 nm), despite the colonies appearing visually and morphologically indistinguishable on brain heart infusion agar.

These results demonstrate that handheld VNIR hyperspectral imaging can distinguish between *Listeria* species and *L. monocytogenes* serotypes under controlled experimental conditions and highlight its potential as a rapid, non-destructive approach for microbial differentiation.

MULTI-EXCITATION FLUORESCENCE HYPERSPECTRAL IMAGING FOR DETECTION OF RADIOFREQUENCY ABLATION LESIONS: A PLS-DA APPROACH

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Atrial fibrillation treatment via radiofrequency ablation (RFA) lacks direct lesion visualization during surgery. This inability to visualize lesion formation in real time often leads to incomplete treatment and high rates of arrhythmia recurrence. Fluorescence hyperspectral imaging (fHSI) shows promise for RFA lesion detection, but cross-sample generalizability remains poorly characterized. We explored multi-excitation fHSI (ME-fHSI) to leverage the fluorescence signatures of endogenous biomarkers, such as NADH and collagen, and improve the biochemical contrast between healthy and ablated tissue. We applied Partial Least Squares-Discriminant Analysis (PLS-DA) for cross-sample classification of ablated versus non-ablated cardiac tissue in a bovine model. ME-fHSI datasets from bovine left atrial tissues with localized RFA lesions were acquired (λexc: 360-390 nm, λem: 420-720 nm, 10 nm steps), and TTC histology was used to create their ground truth masks. PLS-DA models were evaluated under Leave-One-Out (LOO) cross-validation schemes (training on seven images and testing on one).

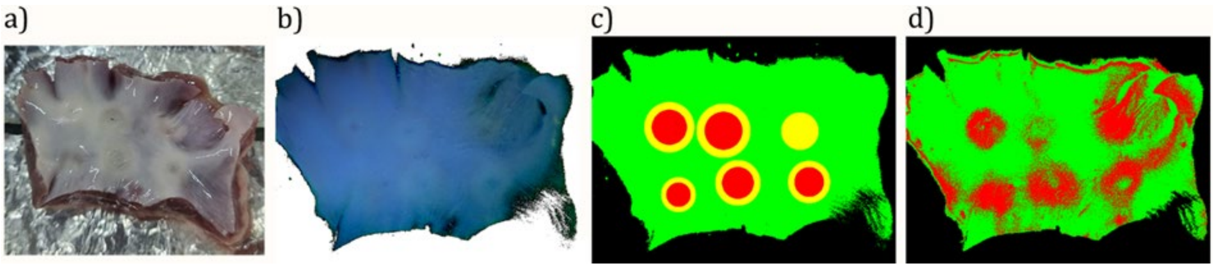

Fig. 1. a) Left atrial bovine tissue sample with six localized RFA lesions, b) RGB representation of one fHSI cube (λexc = 380 nm) after preprocessing, c) ground truth mask obtained from TTC histology and d) PLS-DA prediction generated from the full ME-fHSI dataset.

Despite high inter-sample variability, the PLS-DA approaches achieved a mean balanced accuracy of ~0.7, demonstrating the feasibility of a generalized classification model across different cardiac specimens. Future work on signal optimization and data pretreatment is required to achieve the performance levels necessary for intraoperative use.

IASIM-2026

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DAY 4 – Wednesday, June 17th 2026

ORAL PRESENTATION ABSTRACTS

INFORMATION IN HYPERSPECTRAL IMAGING: HOW UNSUPERVISED MODELS SHAPE ANOMALY DETECTABILITY

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Anomaly detection is an important task in hyperspectral imaging, where the identification of rare or subtle spectral–spatial events is required in applications such as material characterisation, quality control, environmental monitoring, and industrial inspection [1]. Within this framework, anomalies can be interpreted as signal components that are difficult to encode efficiently in low-dimensional latent spaces since excessive compression may suppress small but potentially relevant information. This limitation is particularly relevant in hyperspectral imaging, where meaningful spectral signatures may correspond to low-energy variations or localised spatial structures. Consequently, model evaluation should consider not only reconstruction accuracy but also the type of information preserved or discarded during representation learning [2]. In this work, several unsupervised modelling approaches are compared to investigate their behaviour across varying levels of spectral–spatial complexity. The analysis considered datasets with diverse structural characteristics, including smooth spectral variability, mixed spectral–spatial patterns, and heterogeneous imaging structures. The methods evaluated represent distinct paradigms of information compression, deterministic variance-based projections, probabilistic noise-aware formulations, nonlinear manifold learning, neural latent-space reconstruction, and emerging quantum encoding strategies, thereby enabling a systematic investigation of how different representational assumptions shape anomaly detectability in hyperspectral data. Overall, anomaly detection in hyperspectral imaging is closely related to representation learning and information compression. The detectability of anomalies depends on how information is encoded, preserved, and approximated within latent spaces. Comparing unsupervised models with underlying assumptions that differ across datasets of varying complexity highlights how scenario-specific factors interact with model characteristics, providing critical guidance for selecting or designing unsupervised tools that reliably capture subtle or rare anomalies.

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3D-HSI-SWIR. 3D INTEGRATION OF SWIR HYPERSPECTRAL IMAGING (HSI-SWIR) WITH A MODIFIED STRUCTURE-FROM-MOTION (SFM) APPROACH

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The integration of localized chemical information from Short-Wave Infrared Hyperspectral Imaging (HIS-SWIR) has so far remained inherently limited to two-dimensional (2D) representations [1]. Accurate three-dimensional (3D) spatial reconstruction with chemical maps remains a challenge in Cultural Heritage (CH), hindered by spatial misalignment, differences in resolution, scale, and depth, as well as intrinsic limitations in combining line-scan spectral data with conventional imaging pipelines [2-3].

In this study, we present an advanced 3D-HSI-SWIR framework that integrates hyperspectral imaging in the 996–2505 nm range with 3D reconstruction through a modified Structure-from-Motion (SfM) approach. The proposed method maps spectral information into a unified 3D metric space, where each spectrum is directly associated with coherent spatial coordinates, thereby enabling simultaneous chemical and geometric analysis.

A simulated artwork, selected for its complex morphology, was used as a validation case study alongside a calibrated palette. The samples were coated and painted with 11 historically relevant white pigments to ensure realistic material conditions. The samples were scanned using a SWIR line-mapping hyperspectral camera equipped with a rotary system, which acquired multiple datasets from different viewpoints. As a validation method for the 3D reconstruction, images were acquired by a pinhole camera using stereo vision techniques, enabling volumetric reconstruction through multi-view stereo (MVS) pipelines. A modified SfM pipeline was developed to operate with the line-scan hyperspectral system with negligible reprojection errors, incorporating a pre-calibration pattern of the line-scan sensor, radial distortion correction, and constrained optimisation of intrinsic parameters for the SfM algorithm.

Classification models were performed using Hierarchical Partial Least Squares Discriminant Analysis (PLS-DA), to identify chemical components, thereby enabling accurate localisation of the pigments on the 3D surface [4-5]. The final output is a cohesive 3D hyperspectral model that accurately represents both geometric features and material composition and can be interactively visualised on open-source platforms, delivering reliable chemical mapping across the 3D surface.

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HANDLING COMPLEX RAMAN DATA FOR BACTERIAL IDENTIFICATION WITHOUT CULTIVATION: A CHEMOMETRIC PIPELINE

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This study explores the feasibility of culture-independent bacterial identification and highlights the critical role of chemometric methods in enabling this transition.

The identification of bacterial pathogens remains a challenge in clinical diagnostics, where current standard methods rely on time-consuming cultivation steps prior to analysis. Raman spectroscopy offers a fast, label-free alternative, enabling direct investigation of clinical samples without prior cultivation (see Fig. 1). However, such no-cultivation datasets are highly complex, with high spectral variability, low signal-to-noise ratios, class imbalance, and mixed bacterial populations [1].

In this work, we present a chemometric pipeline for the analysis of Raman spectral maps acquired from heterogeneous patient-derived samples. Outlier detection is performed using signal-to-noise ratio (SNR) filtering and interquartile range (IQR) analysis. Spectral preprocessing includes low-pass filtering, baseline correction using asymmetric least squares (AsLS), and z-score normalization. To address data imbalance and limited patient availability, data augmentation techniques are applied to generate synthetic spectra. Finally, different classification strategies are evaluated for bacterial identification under these challenging conditions (see Fig. 1.d).

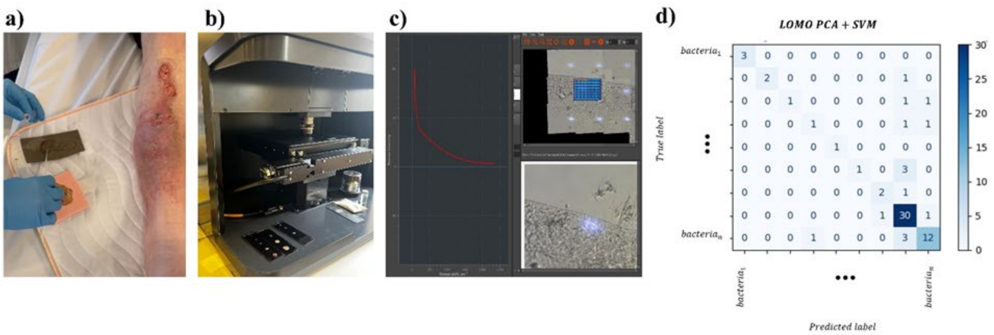

Fig. 1. Workflow of Raman data acquisition from clinical samples: (a) wound sampling, (b) measurement setup in the Raman microscope, (c) example of acquired spectral map and corresponding spectra and (d) final confusion matrix for preliminary results with PCA

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CHEMOMETRIC INSIGHTS ON THE PENETRATION DEPTH OF NEAR INFRARED RADIATION IN SPECTRAL IMAGING CONFIGURATIONS: THE INSIDE RESEARCH PROJECT

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The two-year research project INSIDE, funded by the Italian Ministry of Universities and Research – MUR as a frame for the "PRIN 2022" call, involved three Italian universities: Genova, Bologna and Torino. The project was aimed at understanding the contribution of penetration of near-infrared (NIR) radiation in pushbroom imaging systems [1], exploring the possibility of exploiting such a property for the characterization of samples beyond the surface [2]. In fact, understanding how deeply NIR radiation penetrates into matter is essential for interpreting spectral imaging data, yet comprehensive assessments of penetration depth remain limited. Although NIR imaging is traditionally considered as a surface analytical technique, subsurface contributions may affect spectral profiles, challenging this assumption. The present study presents a systematic and quantitative investigation of NIR penetration (in the 1000-2500 nm spectral range) in a controlled imaging setup using multilayer polymeric samples manufactured by 3D printing. The robustness of the proposed strategy arises from the use of designed ad-hoc samples, two independent instruments and multiple complementary chemometric methods converging toward consistent results. Overall, the present work challenges the conventional surface-limited view of NIR spectral imaging and provides a robust framework for investigating NIR penetration, supporting the development of depth-resolved and potentially tomographic imaging approaches in the near-infrared range.

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BEYOND THE SPECTRAL CUBE: INTEGRATING VISIBLE IMAGING INTO LIBS DATA ANALYSIS

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Spectroscopic imaging is now more than ever at the heart of analytical chemistry. It enables us to thoroughly investigate complex samples by combining, in a single acquisition, molecular or elemental spectral analysis with spatial information. Over time, each spectroscopic technique has developed its own imaging modality, typically through the combination of a spectrometer and a microscope or another focusing system. Without being exhaustive, we can cite infrared, Raman, MALDI, and LIBS imaging, each offering unique characteristics in terms of spatial resolution, sensitivity, speed, and chemical insight. The sheer volume of spectra generated by these instruments quickly led us to develop chemometric approaches to explore and extract the most unbiased chemical information possible. In fact, it is now quite rare to see published work in spectroscopic imaging without an accompanying chemometric component. One might assume, then, that everything is progressing optimally. However, the results we will present in this work stem from an observation that applies broadly across all spectroscopic imaging techniques. Most of these instruments are also capable of acquiring a visible image of the sample under investigation. This is often used to observe the precise area to be analyzed or to ensure the optical system is correctly aligned for spectral acquisition. Yet despite the rich information contained in these visible images, they are rarely used in subsequent data processing, only the spectroscopic data are typically exploited. The aim of this presentation is to demonstrate how data fusion between a visible image and the spectroscopic data cube can significantly enhance sample exploration. We will introduce aspects related to image registration as well as colorimetric space transformations. To illustrate our approach, we will focus on the characterization of an ancient mortar using LIBS imaging (fig.1).

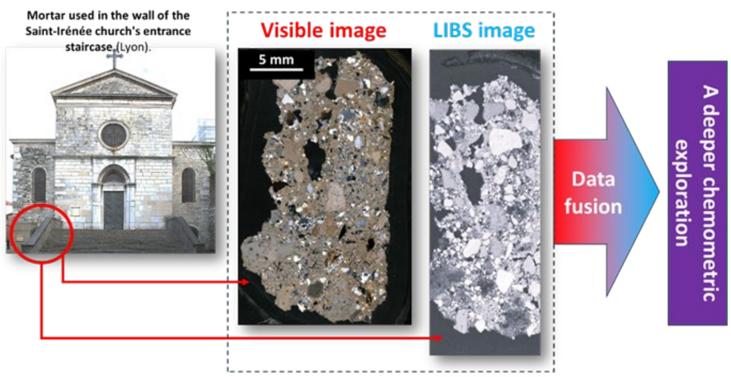

Fig. 1. The fusion of a visible image with LIBS hyperspectral data for a finer exploration of a complex heritage sample.

EXPLORING DECONVOLUTION MCR-ALS (DMCR-ALS) APPLIED FOR SPECTRAL IMAGE UNMIXING ANALYSIS

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In many fields such as process monitoring, biomedical or environmental surveillance, spectral image unmixing is commonly used to characterize complex systems. Sometimes, these applications demand imaging conditions, like fast acquisition rates, that can worsen the quality of the measured signal [1]. This can severely hinder unmixing performance and the accurate recovery of pure component spectral profiles. To address this limitation, spatial kernels can be applied for "binning" pixels and average their corresponding signals (thus improving SNR) to allow better signal extraction when bilinear decomposition methods are applied. However, convolution with kernels reduces the spatial resolution of the original image and may also affect the unmixing model because of rotational ambiguity [2].

In this work, we explore the capability of a new spectral image unmixing protocol, called Deconvolution Multivariate Curve Resolution (DMCR), based on the traditional MCR - Alternating Least Squares (MCR-ALS) algorithm [3], to overcome this problem. The strategy takes advantage of the fact that kernel convolution is a linear shift-invariant operation that can be written as a matrix multiplication and be introduced in the original MCR model. This matrix being known, the spatial resolution of the original image can be recovered while taking advantage of signal averaging. As a consequence of the deconvolution step, the rotational ambiguity is not increased even if binning and blurring operations are carried out as initial steps of the analysis.

Compared with standard unmixing protocols, this method aims at improving the recovered spectral profiles by smoothing/averaging the collected signal, without compromising the quality of the recovered pure contribution maps.

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MICROSPECTRAL IMAGING OF $[B_{12}Cl_{12}]^{2-}$ AND $[Ru(bpy)_3]^{2+}$ IONIC LAYERS DEPOSITED BY ION SOFT LANDING

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Ion soft landing is a preparative mass spectrometry technique that allows deposition of intact polyatomic ions with well-defined composition and charge state on surfaces in high vacuum. The deposition of large numbers of ions onto substrates has enabled fabrication of novel functional layers, which might be interesting for future applications in energy storage, catalysis, soft materials, or biology. Microspectral imaging was used to detect, locate and analyze the deposited ionic layers. In the present investigation, we used mainly two molecular ions: $[B_{12}Cl_{12}]^{2-}$ and $[Ru(bpy)_3]^{2+}$. They were deposited either individually, side by side or one upon the other on gold-plated substrates, which enables measurements in reflection. Spectral imaging was carried out with a FPA detector (64x64 pixels). Successive scanning of the surface with the FPA detector allows imaging of areas up to square millimeters und thus to capture large parts of the structures deposited by ion soft landing. At the end, spectral images based on up to $3x10^5$ spectra were recorded.

In case of layers formed by deposition of one ion type, the deposited layers were found to have volcano-like ring structures. Other compounds formed within the layer due to charge-balancing reactions either in vacuo or later by reactions with air were found to contain NH and/or OH groups. These compounds show a characteristic distribution, which apparently depend on the inner and outer slopes of the formed layer.

While the rapid alternation of anion and cation deposition (submonolayer to a few multilayers per cycle) in layers of 10-100 nm thickness leads to the formation of a charge-balanced molecular salt, which incorporates reduced amounts of contamination, this study investigated the case of changing polarity after ion amounts far above the monolayer were deposited and total layer thicknesses above multiple 100 nm were reached. The formation of island structures was observed, which point to a phase separation of the deposited substances under these deposition conditions.

IASIM-2026

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POSTER ABSTRACTS

Poster #1

HYPERSPECTRAL IMAGING APPLICATIONS IN KOREAN CULTURAL HERITAGE: FROM OBJECTS TO SITES

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The National Research Institute of Cultural Heritage (NRICH) was established as a government agency to provide systematic research of Korean cultural heritage. The organization has been responsible for comprehensive, government-sponsored efforts in surveying, researching, and developing Korea's cultural heritage [1]. The Conservation Science Division employs advanced technologies for scientific analysis to reconstruct and reveal aspects of ancient lifestyles. Building on this analytical foundation, the division contributes the long-term value of cultural heritage by offering critical policy support, including scientific evaluations of state-designated objects and providing data to inform official heritage designations.

Since 2014, the Division has employed hyperspectral imaging for heritage analysis, beginning with an investigation of the stone wall foundation of Sungnyemun Gate as part of the Monitoring of Prioritized National Heritage. Hyperspectral imaging has since been extended to a variety of outdoor stone heritage sites. Data were primarily acquired using a Visible and Near-Infrared (VNIR, 400–1,000 nm) sensor, and the Normalized Difference Vegetation Index (NDVI) was applied to assess the vitality of surface vegetation. In 2024, the analytical scope was further expanded through the integration of a Near-Infrared (NIR, 900–1,700 nm) sensor, enabling the assessment of both vegetation and moisture distribution on outdoor heritage sites. For movable heritage objects, Short-Wavelength Infrared (SWIR, 1,000–2,500 nm) sensor, introduced in 2017 has been primarily used to detect underdrawings and analyze pigment compositions in traditional paintings.

This study highlights the pivotal role of hyperspectral imaging as a tool for the scientific analysis of Korean Cultural Heritage. By bridging the gap between technical analysis and Cultural Heritage designation policy, hyperspectral imaging enhances the objectivity of value assessments and establishes a sustainable foundation for the long-term conservation of Korea's national heritage.

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Poster #2

APPLICATION OF HYPERSPECTRAL IMAGE–DERIVED SPECTRAL INDICES (NDVI, NDII) FOR MONITORING AND CONSERVATION MANAGEMENT OF OUTDOOR STONE CULTURAL HERITAGE IN KOREA: AN INTERANNUAL COMPARISON (2024–2025)

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Outdoor stone cultural heritage is subjected to repeated cycles of moisture fluctuation and biotic cover formation driven by climate and site-specific conditions, which are key factors contributing to long-term surface deterioration. However, one-time assessments cannot explain why deterioration recurs at particular locations. This study aims to identify spatial recurrence patterns of vulnerable zones through short-term, multi-seasonal observations and to apply these insights to conservation management strategies.

The analysis focuses on four heritage sites: Cheomseongdae Observatory; the rock-carved Standing Buddha Triad in Seoak-dong, Gyeongju; the rock-carved Buddha Triad in Yonghyeon-ri, Seosan; and the Petroglyphs of Cheonjeon-ri in Ulju. While Visible and Near-Infrared (VNIR) data have been collected at each site overmultiple years, Near-Infrared (NIR) data have only been available since 2024. Consequently, this study focuses on data from 2024 to 2025.

To assess biotic cover, the Normalized Difference Vegetation Index (NDVI) was calculated from VNIR data, while the NIR-based Normalized Difference Infrared Index (NDII) was used to interpret surface moisture conditions. Both indices were integrated within a cross-analysis framework linking biotic activity to moisture retention and movement, emphasizing the consistency of spatial distribution patterns rather than absolute index values.

Results indicate that signals from both indices repeatedly concentrated in specific zones across all sites. These zones corresponded closely with microcracks, bedding planes, and shading conditions influenced by solar geometry. The findings demonstrate that short-term, repeated observations can effectively identify recurrent vulnerable zones, providing a basis for preventive conservation management strategies.

Poster #3

PIPELINES FOR MERGING PUSH-BROOM HSI-SWIR HYPERSPECTRAL IN SITU ACQUISITION OF LARGE-SCALE ARTWORKS

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Cultural heritage (CH) materials are inherently heterogeneous and often altered by degradation and past restorations, complicating their interpretation. In this context, hyperspectral imaging (HSI) provides a powerful non-invasive tool by combining spatial and spectral information into a single data cube, enabling chemical mapping and supporting point-based analyses of targets [1]. However, in situ investigation of large artworks using the bush-broom system remains challenging, as their dimensions prevent single-frame acquisition. Consequently, analyses are often limited to small, non-representative areas that may not capture the full compositional variability of the object.

Here, we present the results from an ongoing hyperspectral study of an 18th-century embossed and polychromed guadamecí altar frontal, preserved at the Museum of Sacred Art in Bilbao [2]. Due to its size (92 × 223 cm), the surface had been scanned as a structured mosaic of partially overlapping sections using a SWIR push-broom camera (1000–2500 nm, SPECIM), generating approximately 60 captures, with the white standard reference placed at different positions within the field of view Fig.1-b. The acquisition geometry, involving angular motion of the camera, introduced scan-geometry distortion and distance-dependent radiometric variability (Fig.1- a). Also, due to the small size and uneven illumination of the Spectralon reference in each frame, we investigated how the selected row for reflectance correction affected the conversion to pseudo-absorbance and subsequent analysis. Therefore, a dedicated radiometric workflow was implemented, creating a composite white reference by selecting and concatenating the brightest Spectralon row from each capture to compensate for distance-dependent radiance falloff and illumination-angle variability. This not only ensures consistent reflectance but also narrows the dataset to 13 sub-hypercubes.

Subsequently, three reconstruction strategies were evaluated for merging partially overlapping hyperspectral sub-cube: i) a fully manual Crop&Concat approach, which preserves spectral integrity since no interpolation is applied, but it is extremely time-consuming (~days) and suffers for lack of geometric consistency; ii) a ManuImgReg reconstruction, which improves spatial alignment through semi-manual feature-based image registration, enabling gull reconstruction in approximately 5 hours with minimum interpolation effects; iii) finally the fully AutoImagReg pipeline, which performs feature detection in selected areas and geometric alignment without operator intervention, leading to a rapid reconstruction of the complete dataset in less than an hour.

Principal Component Analysis (PCA) of the reconstructed dataset yielded consistent loading patterns and score images across all fusion strategies, indicating that the spectral information and the underlying chemical variability are largely preserved. At the same time, MCR resolved overlapping spectral signatures to support the mapping of pigments, coatings, restoration overpaints and degradation products [3].

Overall, the proposed workflows enable reliable reconstruction of large in-situ line-scanned hyperspectral datasets while preserving the spectral integrity of CH.

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Poster #4

ASSESSMENT OF LAKE ENVIRONMENTAL CONDITIONS USING IN SITU MEASUREMENTS AND LANDSAT 8–9 SATELLITE IMAGERY

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Remote sensing is a widely utilized methodology in environmental monitoring due to its extensive coverage from a single image. In this study, multispectral imagery from the Landsat 8 and 9 satellite systems is combined with in situ measurements collected from Lake Vesijärvi in southern Finland. The integration of ground-truth observations with satellite imagery yields a calibration dataset that links spectral information to water-quality parameters. This dataset is used to develop and calibrate regression models for estimating Chlorophyll-a (Chl-a) and turbidity concentrations across the entire lake. The resulting models enable spatially continuous assessment of these key indicators of lake water quality.

In environmental monitoring, numerous satellite band–based indices have been proposed, including the Normalized Difference Turbidity Index (NDTI) [1], Normalized Difference Water Index (NDWI) [2], Normalized Difference Vegetation Index (NDVI) [3], and a proxy index for coloured dissolved organic matter (CDOM) [4] derived from multispectral bands. In this study, these indices are used in conjunction with Chl-a and turbidity concentrations estimated from regression models to characterize the spatial and temporal variability of lake water quality. Together, they provide complementary, comprehensive information on the lake's ecological condition.

These indices and concentration maps are compared using correlation and seasonality analysis methods. The aim of this study is to describe the environmental conditions in the middle of Lake Vesijärvi.

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Poster #5

ON THE USE OF HYPERSPECTRAL IMAGES TO STUDY MINERAL ALTERATION PROCESSES RELEVANT TO MARS

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On Mars, primary minerals such as pyroxene and olivine dominate both Martian meteorites and several regions of the Martian surface, as detected by multiple rover and orbital missions [1]. These primary minerals can undergo alteration processes leading to the formation of secondary phases such as clay minerals, which have also been identified on the Martian surface and provide important evidence of past aqueous environments. The study of terrestrial analogues plays a key role in improving the interpretation of data obtained from planetary missions. Hyperspectral spectroscopy is a powerful non-destructive tool for identifying and characterizing mineralogical compositions relevant to planetary exploration. To characterize their mineralogical composition and spectral properties, the samples were analyzed using a combination of non-destructive hyperspectral techniques commonly applied in planetary science, including micro-Raman spectroscopy, micro-near-infrared (μ-NIR) spectroscopy, and micro energy-dispersive X-ray fluorescence (μ-EDXRF). In this work, several rock samples collected from beaches in San Diego (California), specifically Black's Beach (La Jolla), San Elijo Beach, and Torrey Pines State Beach, were investigated as potential Martian analogues. These rocks experienced significant alteration under tropical climatic conditions millions of years ago [2], potentially comparable to environmental conditions that may have existed on early Mars when liquid water was present at the surface. The techniques used in this study enable the identification of the spatial distribution and mineralogical associations within the samples, providing insights into the interactions between mineral phases during alteration processes. The analyses revealed that these rocks are predominantly composed of alteration minerals such as kaolinite and smectite (with other minor minerals), likely formed through pedogenic alteration of primary minerals such as plagioclase, pyroxene and olivine. Similar alteration processes may have occurred on Mars, leading to the formation of comparable mineral assemblages that have been detected in several geologic units of Jezero crater.

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Poster #6

ESTIMATION OF NEEDLE AND WAX CONTENT IN SPRUCE FOREST RESIDUES USING HYPERSPECTRAL NIR IMAGING

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Spruce needle wax is an increasingly valuable natural resource due to its antimicrobial properties and high hydrophobicity [1, 2]. It offers a sustainable, biodegradable alternative to synthetic chemicals and microplastics in various high-value applications, including cosmetics, dermatological treatments, and protective coatings for textiles and paper. To facilitate the industrial extraction of these waxes, it is essential to develop efficient methods for separating and quantifying needle content within forest residues.

This study evaluates the use of hyperspectral Near-Infrared (NIR) imaging to estimate the concentration of needles and wax in residues following Gravimetrical separation. Samples were collected from spruce trees harvested in both spring and winter. The material was processed in a multiblade shaftmill and subsequently separated using a Windsifter, which divides the residue into an accept fraction, containing primarily needles, and a reject fraction. To optimize the separation process, nine different machine settings were tested.

To develop a robust predictive model, pure fractions of needles, bark, and wood were manually collected from various heights of the sampled trees. These materials were freeze-dried and milled to 1 mm. A calibration space was established using an I-optimal design consisting of 40 blended samples. Both the design mixtures and the Windsifter accept fractions have been analyzed using a HySpex SWIR-640 camera. The resulting calibration model will be applied to predict the concentration of needles and wax within the accept fraction, providing a precise means to evaluate the efficiency of the mechanical separation process.

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Poster #7

ADDRESSING THE SPECTRAL BLIND SPOT: MULTISENSOR IMAGING FOR DARK TEXTILE SORTING

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The transition towards a circular textile economy requires reliable fibre identification technologies capable of operating under real industrial conditions. While spectroscopic techniques have demonstrated interesting performance for light-colored materials [1], dark textiles remain a major bottleneck in automated sorting systems. This work evaluates the challenges associated with dark textile identification and explores the potential of multisensor strategies combining spectroscopic and hyperspectral imaging approaches. A representative dataset including pure and blended textiles was analysed. Hyperspectral imaging measurements were performed across multiple spectral domains using Specim FX17 (NIR, 0.9–1.7 μm), LLA KUSTA1.9MSI (NIR, 1.32–1.9μm), Specim FX50 (MWIR, 2.7–5.3 μm), Specim FX120 (LWIR, 7.7–12.3 μm), and Specim SWIR (SWIR, 0.95–2.5 μm). The MWIR range, particularly relevant for black polymer discrimination, provides access to fundamental vibrational absorptions that are less affected by pigmentation. The LWIR thermal hyperspectral domain enables chemical imaging based on emissivity differences rather than reflected light, offering a promising alternative for highly absorbing materials. Complementary spectroscopic techniques, including portable Raman spectroscopy (532 and 785 nm excitation), benchtop ATR-FTIR (4000–500 cm-1), and DRIFT (4000–500 cm-1) configurations, were used to analyse the samples and evaluate industrial feasibility. The findings define instrumental limits and provide a framework for integrated spectral imaging platforms that can address one of the major technological barriers to automated textile recycling. The results suggest that relying on a single analytical modality may not be sufficient for the immediate and universal identification of dark textiles.

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Poster #8

SWIR HYPERSPECTRAL IMAGING FOR MINERAL SORTING IN FINE CONSTRUCTION AND DEMOLITION WASTE

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Efficient recycling of construction and demolition waste (CDW) requires advanced detection strategies capable of resolving complex mixtures of materials at the fine scale of particles. In particular, the so-called gray fraction, which comprises sand-sized particles up to 3 cm, presents significant challenges due to its heterogeneous composition and variable moisture conditions. This work explores the use of shortwave infrared hyperspectral imaging (SWIR-HSI) for the characterization and classification of this fraction, with particular attention to key mineralogical components, including carbonates (cement paste), silicates (natural aggregates), and mixed phases. A key aspect of the study is the evaluation of the spectral variability induced by humidity and dirt (common states of this type of materials in the stockpiles of waste management plants), comparing dry, wet, dirty and clean states, so that the loss and/or modification of the signal due to dirt or moisture in these can be evaluated. Hyperspectral datasets are acquired under controlled laboratory conditions (having prepared controlled sets of material) and processed by chemometrics. Spectral preprocessing strategies (e.g., SNVs or derivatives) are evaluated to improve robustness against moisture-induced variability. Classification models, including the PLS-DA, are developed to enable reliable identification of materials through particle size and environmental conditions. The results demonstrate that SWIR-HSI provides distinctive spectral signatures for mineral separation even at small scales, while humidity introduces spectral distortions that need to be explicitly modeled. The proposed framework enables accurate sorting and paves the way for sensor-based real-time sorting systems for fine fractions of CDW.

Poster #9

HYPERSPECTRAL IMAGING AND CHEMOMETRIC MODELING FOR PREDICTING ESSENTIAL OIL CONTENT DISTRIBUTION IN CARAWAY SEEDS (*CARUM CARVI*)

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Growing conditions in Finland result in caraway (*Carum carvi*) seeds with high, but variable essential oil content [1, 2], creating a need for rapid, non-destructive methods for both quantitative analysis and characterization of sample heterogeneity.

A total of 200 caraway seed samples, covering a wide range of essential oil concentrations, were analyzed using a NIR hyperspectral imaging system. Reference concentrations of limonene ($C_{10}H_{16}$) and carvone ($C_{10}H_{14}O$) for each sample were determined by accredited laboratory methods for each sample. Hyperspectral imaging provides thousands of spectra per sample, enabling pixel-level analysis of chemical variability, in contrast to conventional NIR spectroscopy which yields a single averaged spectrum per sample [3]. Principal component analysis (PCA) was applied to capture major sources of spectral variance, visualize spatial patterns, and enable comparison and clustering of samples. PCA score images were used to assess intra-sample heterogeneity.

Partial least squares (PLS) regression models were subsequently developed using two strategies: (i) pixel-wise modelling, where individual pixel spectra were related to bulk reference values, and (ii) object-wise modelling, where spectra were averaged per sample to represent bulk measurements. This comparison enables evaluation of the added value of spatially resolved modelling.

Preliminary results show that hyperspectral imaging reveals pronounced intra-sample heterogeneity and enables clear differentiation between samples through PCA. Pixel-wise PLS modelling provides spatially resolved prediction of chemical composition, while object-wise models yield robust bulk estimates. These results demonstrate the advantage of HSI over conventional NIR spectroscopy by combining spatial resolution with quantitative predictive capability.

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Poster #10

NEAR-INFRARED HYPERSPECTRAL IMAGING (NIR-HSI) AS A SUPPORT TOOL IN THE DESIGN OF NEW HYBRID MEAT PRODUCTS

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The growing demand for sustainable and nutritionally balanced food products has increased the interest in hybrid meat formulations, in which animal-derived ingredients are partially replaced by plant-based alternatives [1]. However, ensuring consistent quality and traceability throughout the production chain of such novel matrices remains a significant analytical challenge. This study investigates the potential of hyperspectral imaging (HSI) as an environmentally friendly analytical technique to assess quality throughout the production chain of hybrid sausage.

For that, sausages were measured using a Specim FX17 camera (900-1700nm) at three key stages of their manufacturing process (mixture, boiled, and final cooked product). Different signal pre-processing methods were assessed in combination with various multivariate analysis methods (PCA, HCA, K-means) to evaluate the capacity of the proposed approaches to determine product quality along the production chain. Specifically, the study addressed sample-to-sample reproducibility across batches and replicates, measurement repeatability, and the evolution of compositional distribution across the different processing stages, evaluated across multiple sausage formulations.

The results demonstrate the potential of NIR-HSI as a rapid, non-destructive quality-monitoring approach, contributing to a deeper understanding of hybrid meat production processes and paving the way for its integration as an analytical tool in the development of next-generation meat products.

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Acknowledgements

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Poster #11

HYPERSPECTRAL IMAGING FOR NON-DESTRUCTIVE QUALITY PREDICTION AND AUTOMATED HARVEST DECISION OF TABLE GRAPES

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This study explores a dual-range hyperspectral imaging (HSI) system operating in the VNIR (400–1000 nm) and NIR (900–1700 nm) ranges as a non-destructive method for predicting the quality of intact 'Italia' grape clusters and automating harvest decisions. Approximately 250 clusters were collected weekly over five harvest dates from a vineyard in Foggia, Italy, covering various maturity stages. Clusters were scanned with an integrated Headwall system, and six quality traits i.e. total soluble solids (TSS), titratable acidity (TA), maturity index, total phenolic content (TPC), antioxidant activity (AOX), and firmness, were measured destructively. Spectral data underwent preprocessing and five modelling approaches were compared: Partial Least Squares regression (PLS), Support Vector Regression (SVR), Random Forest (RF), Gradient Boosting Regression (GBR), and an ensemble model. Model performance was evaluated with 10-fold cross-validation using metrics like R^2 and RMSE.

In the VNIR range, TPC and AOX were predicted with high accuracy (RPD up to 2.91 and 2.60, respectively) using RF and ensemble methods. TSS had satisfactory results (RPD = 1.92), while TA (RPD up to 1.93) and maturity index (RPD up to 1.78) showed acceptable performance; firmness was the most challenging parameter (RPD < 1.70). In the NIR range, TSS prediction improved significantly (RPD = 2.30 via PLS), alongside strong performances for TPC, AOX, and TA (RPDs up to 2.18, 2.46, and 2.02, respectively). Quality values were integrated into a harvest decision framework, classifying clusters as not ready, ready, or overripe based on TSS, TA, maturity index, TPC, AOX, and firmness thresholds. These findings show that dual-range HSI with ensemble or PLS modelling enables rapid, non-invasive quality assessment of grape clusters for data-driven harvest scheduling in precision viticulture.

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Poster #12

HYPERSPECTRAL IMAGING OF REINDEER CARCASS FOR GRADING PURPOSES

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Carcass grading is a process used to classify meat based on the quality and the yield, focusing on maturity, marbling, fat thickness, and muscling. In the EU, the EUROP system originally designed for beef is used [1]. This system has been automated using Video Image Analysis (VIA). While significant development has been made for beef grading, this is not the case for reindeer meat, due to the smaller scale and limited geographical distribution of production. However, this industry is very important in Nordic countries, due to its cultural significance and economic value for indigenous communities.

Currently, reindeer carcass grading adopts the EUROP system and is performed manually by a reindeer meat inspector, which is error-prone. In this study, the development of an automated reindeer-specific carcass grading system is investigated using both classical and contemporary methods, including an AI-based data pipeline. Hyperspectral imaging (HSI) is explored for this purpose due to its potential [2]. HSI data of reindeer carcasses are acquired and analyzed. Camera parameters, lighting conditions, and carcass positioning are systematically evaluated to obtain HSI data suitable for grading purposes. The results are discussed, and recommendations are provided to enable effective reindeer carcass grading using this technology.

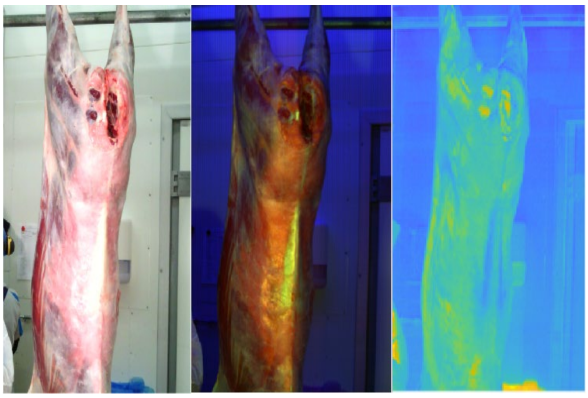

Fig. 1. Reindeer dressed carcass images in RGB (L), HSI (M) and HSI-osavi (R) formats.

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Poster #13

COMPARISON BETWEEN A SHORT-RANGE AND A WHOLE-RANGE NIR HYPERSPECTRAL CAMERA TO DETECT AND IDENTIFY MICROPLASTICS

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Microplastics (MPs; 1-5,000 µm) have entered the food chain. Sea salt is a commonly used condiment; therefore, consuming contaminated sea salt could pose a risk to human health [1]. Standardized, high-throughput analytical methods for MPs analysis remain limited. Near-infrared hyperspectral imaging (HSI) has shown potential for rapid screening of MPs in complex matrices [2]. Broader NIR coverage provides maximal chemical information, but it remains unclear if shorter-range, more economic systems can deliver comparable performance. Hence, this study seeks to evaluate the viability of using a short-wave NIR HSI camera, compared with a full-range one, to analyse polyethylene terephthalate (PET), polystyrene (PS), polypropylene (PP), and low-density polyethylene (LDPE) MPs in sea salt.

Coarse (460-2210 µm) and fine (135-480 µm) salt were artificially contaminated with PET, PS, PP, and LDPE MPs (0.1-2.4 mm). A push-broom Specim FX17 (935-1720 nm) and SWIR (928-2524 nm) cameras were used using two lenses: FOV38 or OLES30 for larger MPs (0.3-2.4 mm), and OLESMACRO for smaller MPs (0.1-0.8 mm). Spectral data were analysed using MIA Toolbox 9.1. Different preprocessing strategies were applied, and partial least squares discriminant analysis models were calculated. Similar calibration results were obtained with both cameras, with high sensitivities and specificities (>0.99) and classification errors near 0. In prediction, all MPs studied were detected and identified using both systems. Analysis of variable importance in projection (VIP) revealed comparable significant wavelength regions. These findings provide insight into the minimum spectral range required for reliable MPs analysis in food matrices. Also, the macro lens enabled a reduction in detection limit to 100 µm.

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Poster #14

RECONSTRUCTION OF PROTEIN COMPONENTS – COMPUTATIONAL DECOMPOSITION OF MODEL VACCINE SPECTRA

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Vaccines play a key role in public health and epidemic control with millions of doses being applied every year. To ensure their efficacy and safety, their quality is strictly controlled by legally required batch release testing. These tests verify the presence of the active pharmaceutical ingredients (API), such as antigenic proteins. However, vaccine compositions are complex, often including various excipients to stabilize the pH level and/or preservatives. Additionally, proteins are often adsorbed to adjuvants to elicit a stronger immune response. This complex formulation makes a targeted detection of the API an elaborate process.

Raman spectroscopy is a non-destructive, fast method to study the chemical composition of biomedicines as their unique Raman spectral fingerprint is sensitive to the structure of proteins and their side chain. The potential of this method as an alternative batch release testing method is evaluated using model vaccines with known components and well-defined concentrations. Computational unmixing of the full product spectra is challenging due to similarities in protein spectra, the potential dominance of excipient spectra and often sample heterogeneity. In this study, we show the importance of visualization to guide data standardization and analysis. Different machine learning algorithms like principal component analysis (PCA) and non-negative least square regression (nnls) are tested for their capacity to differentiate various proteins on the basis of their spectral contribution. Our findings show the potential of the method to recover and quantify component spectra from Raman spectra of full products. This allows to advance the quality control of vaccines.

Poster #15

ADVANCING QUALITY CONTROL OF ALUMINUM ADJUVANTED VACCINES WITH RAMAN SPECTRAL IMAGING AND MACHINE LEARNING

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Vibrational spectroscopy is an established, non-invasive tool for quality and process control, yet its application to vaccine formulations remains challenging [1]. Low antigen concentrations and strong matrix interferences hinder reliable spectral interpretation, particularly in aluminum adjuvanted systems. Integrating Raman spectroscopy with machine-learning analysis enables reliable identification and quantification of components in these complex systems [2]. A model system comprising a representative protein antigen and aluminum hydroxide ($Al(OH)_3$) as the adjuvant was employed. This controlled setup enabled systematic investigation of protein–adjuvant interactions and supported the development of analytical strategies applicable to real vaccine formulations. Raman spectra were acquired from mixtures across varying concentration ratios, providing a robust dataset for calibrating and validating prediction models. Importantly, all benchmarking considered the inherent spatial heterogeneity of vaccine samples by employing Raman spectral imaging, ensuring that model performance reflected realistic sample variability. Component identification and quantification were then benchmarked using both classical and modern unmixing and regression approaches, including PLSR, MCR-ALS, and deep-learning autoencoder models.

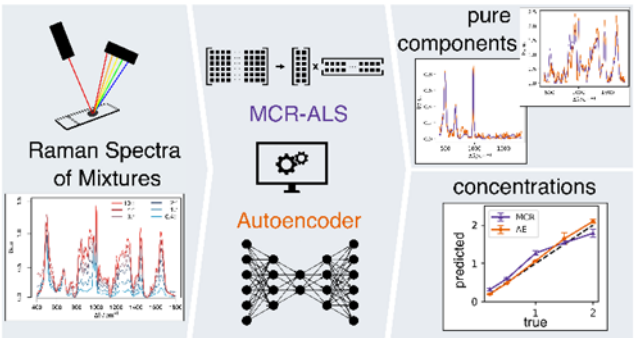

Fig. 1. Identifying and Quantifying Components in a Model Vaccine

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Poster #16

3D MICRO-RAMAN IMAGING OF DRIED PLASMA DROPS: SPECTRAL AND CHEMOMETRIC LIMITATIONS FOR CAR-T TREATMENT MONITORING

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Monitoring molecular changes in patient biofluids during cancer therapy is a key objective in biomedical research, particularly for advanced treatments such as CAR-T therapy [1]. Raman spectroscopy has emerged as a promising label-free technique to probe biochemical composition in complex matrices like plasma [2], but most studies rely on punctual measurements that capture only a small portion of the sample. In this study, 3D micro-Raman spectroscopy with 532 nm excitation was used to analyse dried plasma drops from ten CAR-T–treated patients (five men, five women) at three timepoints: before therapy, 10 days, and 1-month post-infusion. Each drop was mapped on a 20 × 20 spatial grids with five depth layers separated by 1 µm, producing ~16,000 spectra. Principal component analysis (PCA) was first used to identify the main sources of spectral variance and to visualize spatial patterns associated with the drying process. Subsequently, multivariate curve resolution (MCR) was explored to obtain chemically interpretable spectral signatures together with their corresponding spatial distribution maps. These approaches reveal compositional gradients across the drop and localized regions enriched in characteristic plasma components. Importantly, the results also highlight several practical limitations and challenges inherent to dried biofluid analysis: sample heterogeneity, uneven distribution of analytes, and the influence of drop morphology can affect both sampling and measurement. Additionally, instrumental factors such as the focusing system may further contribute to variability. Despite these challenges, hyperspectral Raman imaging combined with chemometric decomposition provides valuable insight into spatial metabolite organization and supports the development of robust analytical workflows for complex biomedical hyperspectral datasets.

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Poster #17

IDENTIFICATION OF COCAINE THROUGH SEALED PACKAGING USING SPECTROSCOPIC AND HYPERSPECTRAL DATA

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The forensic analysis of illicit drugs increasingly requires non-destructive methodologies capable of preserving evidentiary integrity while ensuring operator safety. In this work, Fourier Transform Near-Infrared (FT-NIR) spectroscopy and Near-Infrared Hyperspectral Imaging (NIR-HSI) were investigated as complementary tools for the analysis of cocaine through sealed polyethylene packaging [1]. Twenty-four cocaine samples from four independent seizures and six common cutting agents were analyzed without opening the evidence bags. Chemometric processing combined exploratory, classification, and regression approaches. Principal Component Analysis (PCA) revealed a clear separation between cocaine and adulterants, while Soft Independent Modelling of Class Analogy (SIMCA) was applied as a one-class strategy for cocaine authentication. Using second-derivative FT-NIR spectra, the optimized SIMCA model achieved 100% sensitivity and 100% specificity on an independent test set. Quantitative determination of cocaine content was performed using Partial Least Squares (PLS) regression, yielding an independent-test coefficient of determination (R^2) of 0.95 and a prediction error (RMSEP) of 2.40%. To complement bulk measurements, NIR-HSI data were analyzed at the pixel level. SIMCA models developed on approximately 32,000 pixel spectra achieved sensitivities above 94% while maintaining 100% specificity. Application of the models to complete hyperspectral images enabled selective identification of cocaine-containing regions while simultaneously rejecting pixels associated with adulterants, packaging materials, and background, without prior image segmentation. The results demonstrate that the integration of FT-NIR spectroscopy, hyperspectral imaging, and class-modelling techniques provides a rapid, robust, and fully non-destructive framework for forensic drug screening, combining accurate authentication, quantitative analysis, and spatially resolved chemical information.

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Poster #18

PROOF-OF-CONCEPT ACTIVE HYPERSPECTRAL IMAGING FOR MDMA DETECTION

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Active hyperspectral imaging (AHI) systems are not yet widely commercial. A low-cost supercontinuum light source, push-broom AHI system [1] is being evaluated to support harmonized drug-related investigations across the EU (https://www.narcosis-project.eu/), focusing on illegal tablet analysis. This study examines detection performance, spectral profile extraction via curve resolution, and MDMA tablet characterization, aiming to extract reliable spectral data for a shared database. The AHS system covers the 1350–1650 nm spectral range. A dataset of 283 MDMA tablets with qualitative information, provided by the Instituto Nacional de Toxicología y Ciencias Forenses (Barcelona, Spain), was analyzed. All MDMA tablets exhibited the characteristic NIR absorption bands at ~1490 nm and ~1570 nm, with high-MDMA-content tablets showed strong agreement with a reference spectrum [2] (Pearson = 0.92; SAM = 0.25). Lower-content tablets showed reduced similarity (SAM = 0.70 ± 0.03; Pearson = 0.31 ± 0.07), likely due to variability from excipients. PCA did not reveal distinct clusters or trends associated with MDMA content, although key MDMA-related features were evident in the loadings of the first and second principal components. MCR-ALS, applied after standard preprocessing, enabled recovery of MDMA spectral profiles. Distribution maps agreed with semi-quantitative information available. Initial tests demonstrate that MDMA compounds are a viable example of PS detectable with this camera, and a spectral library is currently under development. MCR-ALS showed promising results in recovering MDMA spectral profiles, though further research is needed to identify all the major cutting agents; as one of the first applications of an AHS system in forensic analysis, this approach highlights its potential as a lower-cost solution for broader hyperspectral imaging use.

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Poster #19

Investigation of $[B_{12}Cl_{12}]^{2-}$ and $[Ru(bpy)_3]^{2+}$ Ionic Layers Deposited by Ion Soft Landing by Infrared Microspectroscopic Imaging

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Ion soft landing enables the deposition of thin layers of mass-selected polyatomic ions with well-defined composition and charge state from the gas phase. In the present study, two types of ions – a dication and a dianion – were deposited. So far, only very few data about the precise spatial distribution of such ions as well as possible reactive species formed during the deposition process were available. Infrared microspectroscopic imaging was shown to have immense potential to provide such data, which are also relevant for a better understanding of the underlying processes. In contrast to typical layers made by ion soft landing, which have a thickness of a few nanometers, the two polyatomic ions were deposited as rather thick layers with a thickness of some microns in the present study in order to make them detectable by IR spectroscopy. The two types of ions were deposited either individually or together in order to be able to study the interaction of the various species.

IR microspectral imaging was carried out with a focal plane array (FPA) detector with 64x64 pixels. Structures deposited to gold-coated silicon by ion soft landing with dimensions in the order of square millimeters were imaged by consecutive scanning of the surface with the FPA detector, which finally results in images consisting of up to several hundred thousand spectra.

The thick layers characterized in the present work were found to show several effects, which are different from those in the thin layers mentioned above. While the rapid alternation of anion and cation deposition in the latter (typically resulting in submonolayers) leads to the formation of a charge-balanced molecular salt, specific charge-balancing reactions are required in case of changing polarity after deposition of ion amounts far above the monolayer, which occur either in vacuo or after removal from UHV by reactions with air and result in species that contain NH and/or OH groups. These species show a characteristic distribution, which is apparently related to the inner and outer slopes of the volcano-like ring structure formed by polyatomic ions.

Poster #20

ASSESSING THE IMPACT OF VARIABLE ILLUMINATION AND WHITE REFERENCE NORMALIZATION ON MULTISPECTRAL IMAGING PERFORMANCE

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With advances in sensor technology, multispectral imaging is gaining widespread adoption across diverse applications [1]. However, in real-world scenarios, uncontrolled variations in external illumination, including changes in ambient light intensity, spectral composition, and shadowing, introduce variability that can significantly impact the consistency and reliability of acquired spectral data [2]. This study evaluates the consistency of data generated by a novel miniaturized multispectral camera (Spectricity S1-EVK2) under varying illumination conditions and investigates the influence of white reference placement on the normalized spectral response. Multispectral imaging was conducted across three distinct lighting environments: (1) low-intensity indoor ambient illumination, consisting of weak natural daylight entering through windows combined with overhead LED lighting, with acquisitions performed both with the ceiling illumination enabled and disabled to assess its influence; (2) controlled laboratory illumination, where imaging was carried out in a dark room using fixed-position light sources with controlled intensity and no ambient light interference; and (3) outdoor direct daylight illumination, representing fully uncontrolled conditions under natural sunlight. The spectral power distribution (SPD) of the ambient illumination was measured for each setup using a calibrated spectrometer.

The results show that uniform illumination is essential for achieving consistent and repeatable multispectral measurements, as it reduces sensitivity to white-reference placement. The multispectral system maintained good spectral consistency across both controlled and uncontrolled environments, with a high level of agreement with spectrometer-based measurements. Overall, the proposed multispectral system does not require strictly controlled laboratory conditions to achieve reliable spectral performance, provided that illumination uniformity is maintained and appropriate normalization is applied.

These findings provide a foundational understanding of system behavior under realistic illumination conditions, supporting more robust integration of multispectral sensors into everyday consumer devices, facilitating reliable operation in practical, real-world use cases.

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Poster #21

DIMENSIONALITY REDUCTION OF MULTI-EXCITATION FLUORESCENCE IMAGING OF PEPSIN-DIGESTED COLLAGEN SCAFFOLDS

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Multi-excitation hyperspectral imaging (ME-HSI) creates a 4D dataset by varying the excitation wavelength of an emission-based HSI acquisition, which improves the discrimination of materials that contain mixed fluorophores. The resulting cubes are rich but can potentially be highly redundant, and band selection methods developed for 3D HSI [1] usually fail to capture the nonlinear cross-excitation correlations specific to ME-HSI. In prior work we introduced a deep-learning framework that addresses this gap in three stages: (1) a 3D convolutional autoencoder [2] with parallel excitation branches learns a unified latent representation of the 4D cube, (2) perturbation-based attribution traces reconstruction sensitivity to individual excitation–emission wavelength pairs, and (3) Maximum Marginal Relevance (MMR) selection balances informativeness with spectral diversity [3]. Here we extend the framework to a new, chemical sample, applying the enhanced framework on pepsin-digested collagen scaffolds with three crosslinker concentrations (0.002%, 0.0075%, 0.013%), imaged at six excitations (310–400 nm) with emissions 420–720 nm (10 nm step), yielding 158 excitation–emission band pairs per pixel.

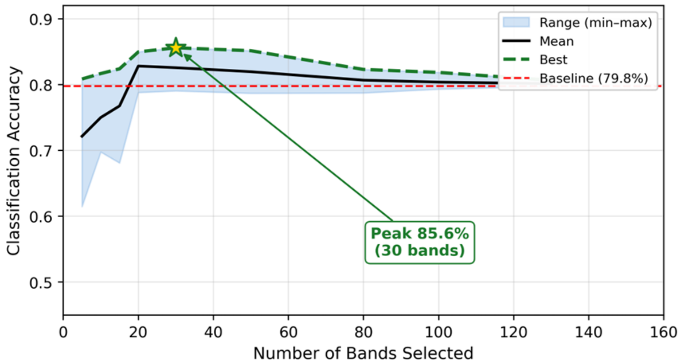

Fig. 1. Classification accuracy (KNN, k=5) versus number of selected bands across 432 configurations on the pepsin-digested collagen dataset. Blue band = min–max range; black = mean; green dashed = best per band count; red dashed = full-spectrum baseline (79.8%). Peak accuracy (85.6%) is reached at 30 bands - 81% data reduction.

Across 432 configurations, every band count between 5 and 130 exceeded the 158-band KNN baseline of 79.8%; peak accuracy reached 85.6% with 30 bands (81% compression, Fig. 1). The same selected wavelengths were evaluated with nine additional classifiers (LDA, linear and RBF SVM, random forests, gradient boosting, MLP). Linear Discriminant Analysis achieved 84.6% with only 5 bands (97% reduction) and 92.5% with 50 bands (68% reduction); all ten classifiers matched or exceeded their own baselines at 30–50 bands, confirming that the selected wavelengths carry classifier-independent discriminative information. These results demonstrate that the framework is generalizable, enabling shorter acquisitions with no loss of discriminative power and autonomous, unsupervised information detection pipeline.

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Poster #22

DEVELOPMENT OF HYPERSPECTRAL MICROSCOPY SYSTEM IN VIBLE TO SHORT-INFRARED RANGE

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Hyperspectral microscopy (HSM) enables analysis of spectral features in microstructures [1]. Most commercial systems are limited to either the visible–near-infrared (VNIR, 400–1000 nm) or short-wave infrared (SWIR, 900–1700 nm) range. Recent advances in camera technology have produced sensors sensitive across 450–1700 nm, enabling single-scan acquisition over the full spectral range [2]. However, most commercial microscopes employ optics coated for only VNIR or SWIR operation, highlighting the need for microscope systems designed with broadband, uncoated optics.

We developed and characterized a custom line-scan hyperspectral microscope covering the 450–1700 nm spectral range. The system is based on a reflective microscope objective, a broadband tube lens, and both epi-illumination and transmission illumination paths constructed from commercially available stock optics from Thorlabs and Edmund Optics. Hyperspectral data acquisition is achieved using a VisSWIR Oculus spectrograph (Newtec) and a motorized microscope stage (Thorlabs). Optical performance, including spectral and spatial resolution, was evaluated experimentally and compared against optical simulations conducted in Zemax.

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Poster #23

MITIGATING REFLECTANCE ARTIFACTS IN MULTI-EXCITATION HSI VIA EXCITATION-SPECIFIC PRINCIPAL COMPONENT ANALYSIS

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Hyperspectral imaging (HSI) under multiple excitation wavelengths offers a powerful approach for characterizing collagen-based biomaterials. However, because fluorescence emission is inherently three to five orders of magnitude weaker than reflected light, minor imperfections in the excitation source or the presence of ambient light can introduce reflectance artifacts that dominate the signal [1]. Existing methods aimed at removing reflectance are highly limited, requiring specialized high-frequency, broad-spectrum illumination sources and samples with smooth absorption spectra [2]. In this work, we addressed this limitation by integrating excitation-specific principal component analysis (PCA).

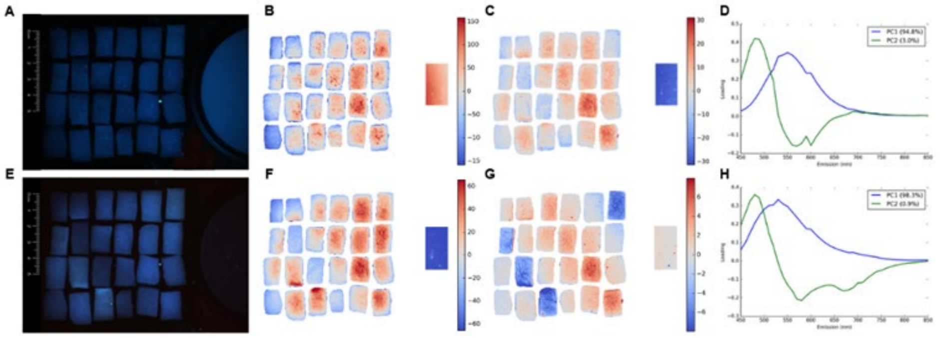

Fig. 1. Representative hyperspectral renderings and PCA results for the 340 nm (top row) and 385 nm (bottom row) excitation datasets. (A, E) RGB-style renderings of the hyperspectral cubes. (B, C, F, G) PC1 and PC2 score maps. (D, H) Corresponding loading plots.

By examining the spectral loadings of each component relative to a white standard, we identified and extracted the components most representative of true fluorescence emission. These selected PCA scores were then utilized as features in classification models. The results demonstrated that the PCA-based, dimensionality-reduced feature representation produced superior class separation compared to the original full HSI data.

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Poster #24

EVALUATING SUB-PIXEL SHIFTING APPROACHES FOR SPATIAL RESOLUTION ENHANCEMENT IN LINE-SCANNING HYPERSPECTRAL SYSTEMS

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Pushbroom hyperspectral cameras offer high spectral resolution but are inherently limited in spatial resolution by their detector pitch and optics. This work investigates super-resolution strategies based on sub-pixel shifting (SPS) for pushbroom line-scanning systems, exploiting the scanning nature of the acquisition to introduce controlled sub-pixel displacements without reducing the field-of-view or light throughput [1,2]. Multiple SPS configurations and reconstruction methods are evaluated on a Specim SWIR 3 hyperspectral camera, varying scanning speed and acquisition parameters to systematically control sub-pixel displacements and determine the most effective experimental settings. Spatial resolution improvement is assessed quantitatively using a USAF 1951 resolution target, while spectral fidelity is validated on real plastic samples, to verify that the reconstruction process preserves the spectral signatures of the materials. The findings offer practical guidelines for implementing hardware-free super-resolution in pushbroom hyperspectral imaging systems.

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Poster #25

STAR: 10× SNR ENHANCEMENT VIA AUTOMATIC FIXED-PATTERN NOISE COMPENSATION IN CCD SPECTROSCOPY

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We present a practical method to improve signal-to-noise ratio (SNR) in CCD-based spectroscopy for detecting low-concentration analytes. Applicable to any cooled-CCD spectroscopic technique - Raman, NIR, fluorescence, absorption - the method addresses fixed-pattern noise (interference fringes and pixel-to-pixel QE variation), which persists after cooling and extended exposure and cannot be reliably removed by post-processing.

The Sensor Tilt Arifact Removal (STAR) method involves tilting the detector around the diffraction grating axis during acquisition, physically averaging out fringe and QE variation effects. Applied to glucose detection in water with Raman spectroscopy, this yielded an 11-fold SNR increase. This allows to see glucose peaks below 1mM concentration with naked eye, which was not possible before.

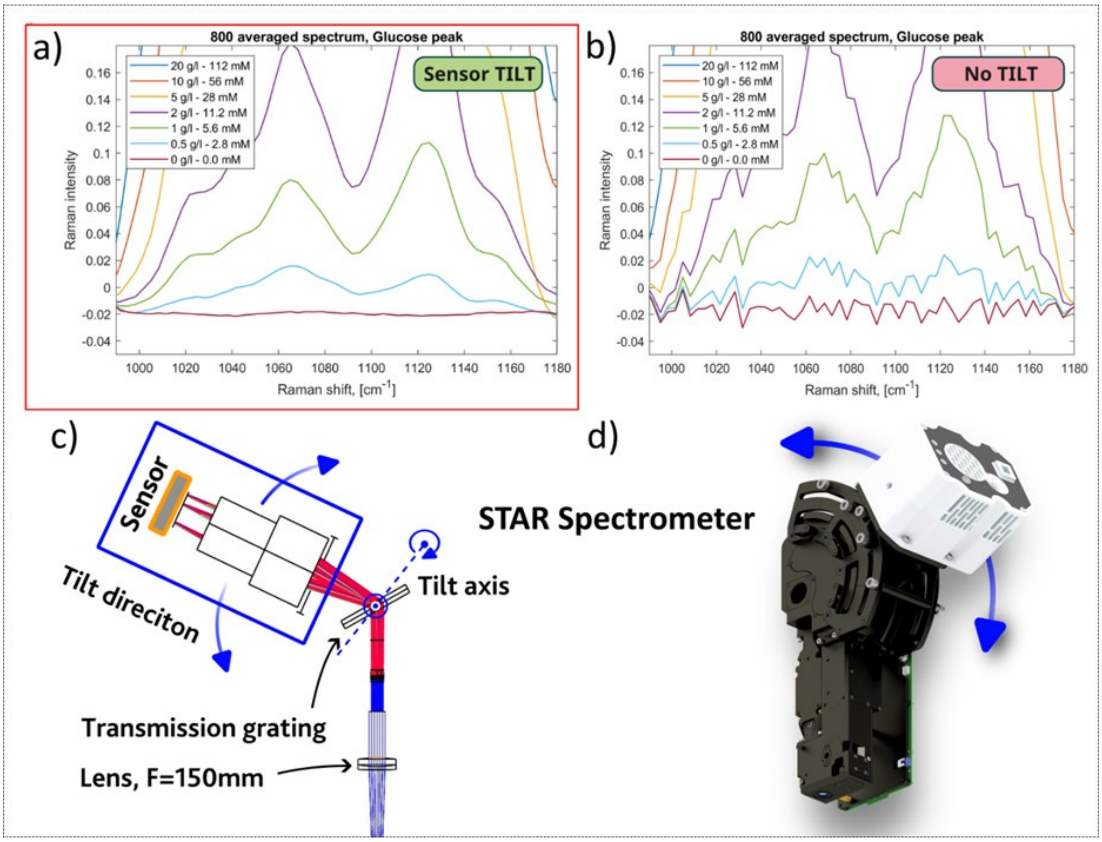

Fig. 1. Raman spectra of glucose in aqueous solutions measured with 532 nm laser, 4-second exposure time. (a) Spectra acquired without detector tilt. (b) Spectra acquired without detector tilt for different glucose concentrations. (c) Sensor Tilt Arifact Removal spectrometer schematics and (d) outlook.

Poster #26

INSIDE – IN-DEPTH CHEMICAL MAPPING: EXCEEDING PENETRATION LIMITS?

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The research project INSIDE investigates the penetration depth of incident near-infrared (NIR) radiation coupled with hyperspectral imaging (HSI). After extensive bibliographic research [1], the first insights about this project [2] were focused on the investigation of penetration depth up to 1 cm. The present research line is aimed at continuing the same investigation but on higher samples, with the aim of stressing the penetration depth concept, exceeding what is generally considered a reasonable limit.
To this aim, ad hoc samples in the shape of 1×1×3 cm and 1×1×5 cm (square base × height) parallelepipeds were designed and built employing a multi-material 3D printer, resulting in specimens composed with strata of different thickness of polymers with distinct spectral signatures. In particular, glucose-modified polyethylene terephthalate (PETG) and polylactic acid (PLA) were employed. The samples were then analysed via a NIR-HSI camera (Specim, Finland) in the 1000-2500 nm spectral range, and the obtained spectra were submitted to data processing.
In particular, the data matrices (both on a pixel-level and on an image-level) underwent exploratory analysis, with a focus on data preprocessing and its contribution in highlighting physical and chemical information, separately. Subsequently, the amount of different components in terms of height in mm of the considered polymer was quantified, and the precision of the quantification in terms of root mean square error in prediction was determined.

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Poster #27

DATA-DRIVEN CRYSTAL ORIENTATION MAPPING FROM POLARIZED RAMAN SPECTROSCOPY USING QRICO-NET

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Quantitative Raman Imaging for Crystal Orientation (qRICO) maps crystallographic orientations in polycrystalline materials using polarized Raman microscopy [1], without sample preparation and applicable to both 2D and 3D mapping. Conventional qRICO requires explicit knowledge of Raman tensor elements, limiting its applicability. qRICO-Net replaces this analytical framework with a data-driven model trained on polarized Raman spectra paired with EBSD orientation maps as ground-truth labels. Convolutional layers extracts spectral features from the per-pixel polarisation-channel-wavenumber tensor, and a residual multilayer perceptron regresses a 6D rotation vector projected onto SO(3), trained with a symmetry-aware misorientation loss. This design bypasses the need for explicit Raman tensor knowledge entirely. We demonstrate qRICO-Net on Sb_2S_3, a quasi-one-dimensional solar absorber whose efficiency depends critically on grain orientation. Predicted maps (Fig. 1a) agree closely with EBSD (Fig. 1b), with a mean misorientation of 9 degrees (Fig. 1c). Data-driven qRICO could become a broadly applicable orientation mapping tool for polycrystalline thin films, enabling microstructure optimisation in optoelectronic devices.

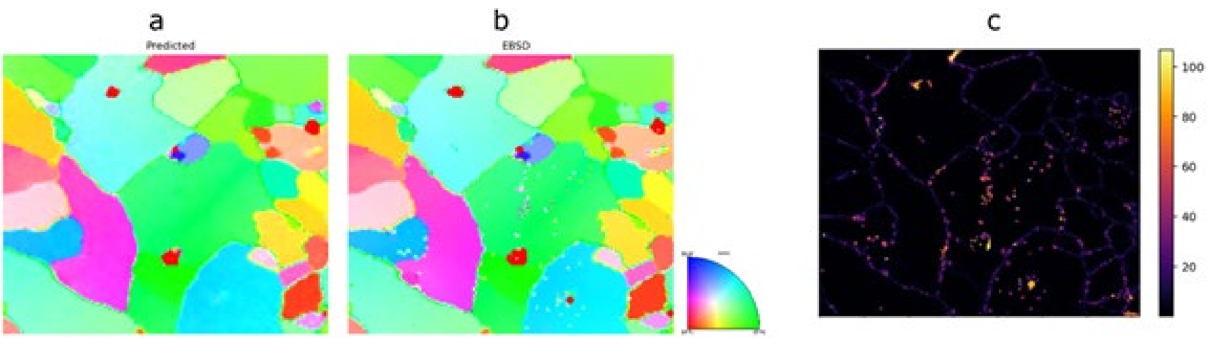

Fig. 1. Predicted qRICO-Net (a) and EBSD orientation maps (b) of the surface of a polycrystalline Sb2S3 and misorientation map between qRICO-Net and EBSD data (c).

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