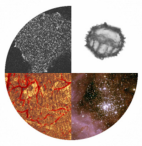
Book of Abstracts

SFB Conference
"Tomography Across the Scales"

June 16–21, 2025
Bifeb, Strobl, Austria



SFB Tomography
Across the Scales

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Preface

This booklet contains the abstracts of the presentations that will be given at the *SFB Conference "Tomography Across the Scales"*. The event brings together researchers, students, and professionals to discuss the latest developments in the field of tomography.

Scientific Committee

Otmar Scherzer, University of Vienna (Austria)
Ronny Ramlau, RICAM and Johannes Kepler University, Linz (Austria)
Wolfgang Drexler, Medical University of Vienna (Austria)
Peter Elbau, University of Vienna (Austria)
Monika Ritsch-Marte, Medical University of Innsbruck (Austria)
Gerhard Schütz, Technische Universität Wien (Austria)
Gabriele Steidl, Technische Universität Berlin (Germany)
Glenn van de Ven,University of Vienna (Austria)

Local Committee:

Sonia Foschiatti, University of Vienna (Austria)
Min Hadler, University of Vienna (Austria)

Funded by:

FWF Der Wissenschaftsfonds.

DFG Deutsche Forschungsgemeinschaft

Practical information for Participants

- **Reception**: Located in the **Haupthaus** (see the Lageplan below).
  - On **Monday June 16**, the reception is open **up to 18:00**;
  - On the **other days**, it is open until **15:30**.
- **Bifeb shuttle service:** From **8:00 to 15:00**, you can ask for the **bifeb shuttle service**. Call: +43 06137 6621.
- **Strobl taxi service:** Call: +43 01637 7367 (Riedl).
- The **seminar room** where the presentations will take place is the **Bürglsaal**, located in the **Bürglhaus**.
- **Meals:** served in the **Haupthaus** (first floor).
  - **Breakfast:** from 07:30 to 09:00;
  - **Lunch:** from 12:30 to 14:00 (three options: meat, vegetarian, vegan);
  - **Dinner:** from 18:00 to 19:30 (two options: vegetarian, vegan).

Figure 1: How to arrive at Bifeb (Bundesinstitut für Erwachsenenbildung) from the Bus station and the map of the houses at bifeb.

Session overview

Time	Chair(s)	Session
Tuesday, June 17		
09:00 – 12:30	Otmar Scherzer & Peter Elbau	Inverse Problems, Part 1
14:00 – 18:00	Glenn van de Ven	Astrophysics
19:30 – 20:30	Meeting of the Principal Investigators	
Wednesday, June 18		
09:00 – 12:30	Wolfgang Drexler	Medical Imaging
14:00 – 18:00	Gabriele Steidl	Mathematical Imaging
19:30 – 20:30	Meeting of the SFB members	
Thursday, June 19		
09:00 – 12:30	Monika Ritsch-Marte	Optical Tomography
14:00 – 17:30	Afternoon Activity: Excursion in the surroundings of Wolfgangsee	
Friday, June 20		
09:00 – 12:30	Ronny Ramlau	Inverse Problems, Part 2
14:00 – 18:00	Gerhard Schütz	Super-resolution Microscopy

Program Overview

Tuesday, June 17

Morning Session: Inverse Problems, Part 1

Chair: Otmar Scherzer & Peter Elbau

- **09:00–09:35** Alexander Katsevitch
  Statistical microlocal analysis
- **09:45–10:20** Peter Elbau
  TBA
- **10:30–11:00** Break
- **11:00–11:35** Eric Todd Quinto
  Spherical Radon transforms with smoothly varying radii and applications to tomography
- **11:45–12:20** Tanja Tarvainen
  Utilising Monte Carlo method for light transport in optical tomography
- **12:30–14:00** Lunch

Afternoon Session: Astrophysics

Chair: Glenn van de Ven

- **14:00–14:35** Ling Zhu
  A triaxial and vertically oriented dark matter halo of the Milky Way shaped by minor mergers
- **14:45–15:20** Tobias Buck
  Inverse Modelling of Galaxies Across Scales: From Simulations to Observations with Modern Computational Tools
- **15:30–15:55** Victoria Laidlaw
  Mathematical methods for wide field of view adaptive optics in ophthalmology
- **16:00–16:30** Break

- **16:30–17:05** Sebastian Kamann
  Focusing on the stars: The crucial role of adaptive optics in astronomy
- **17:15–17:40** Stefanie Reiter
  Collecting fossil records of galaxy formation
- **18:00–19:30** Dinner
- **19:30–20:30** Meeting of the Principal Investigators

Wednesday, June 18

Morning Session: Medical Imaging

Chair: Wolfgang Drexler

- **09:00–09:25** Prashin Jethwa
  Comparing Algorithms for Galaxy Reconstructions
- **09:30–09:55** Elisabeth Brunner
  Longitudinal AO-OCT imaging of the retina in diabetic eyes using the P-WFS
- **10:00–10:25** Lisa Krainz
  Quantitative Optical Coherence Elastography Facilitating Axial and Lateral Sample Deformation
- **10:30–11:00** Break
- **11:00–11:25** Ekaterina Sherina
  On the Intensity-based Inversion Method for Quantitative Optical Coherence Elastography
- **11:30–11:55** Leopold Veselka
  Parameter identification in quantitative optical coherence tomography
- **12:00–12:25** Cristobal Villalobos
  A Gauss-Green formula approach for refractive index recovery from OCT
- **12:30–14:00** Lunch

Afternoon Session: Mathematical Imaging

Chair: Gabriele Steidl

- **14:00–14:35** Luca Calatroni
  Seeing through light beyond space and time: advances in fluorescence microscopy image reconstruction
- **14:45–15:20** Matthias Beckmann
  On Modulo Radon Transform Based Tomography
- **15:30–16:00** Break

- **16:00–16:35** Florian Faucher
  Quantitative inverse problem in ultrasound imaging for viscoelastic anisotropic media
- **16:40–17:05** Michael Quellmalz
  Fast and Accurate Approximation of High-Dimensional Radial Kernels via Slicing
- **17:10–17:35** Christian Wald
  Modeling Molecule and Cluster Movements via generative modeling and SDEs
- **18:00–19:30** Dinner
- **19:30–20:30** Meeting of the SFB members

Thursday, June 19

Morning Session: Optical Tomography

Chair: Monika Ritsch-Marte

- **09:00–09:35** Olivier Haeberlé
  Optical microtomography: challenges for improved resolution and functionalization
- **09:45–10:20** Jeroen Kalkman
  Advancements in large scale optical tomography
- **10:30–11:00** Break
- **11:00–11:25** Mia Kvåle Løvmo
  Optical Tomography by Rotation in Acoustofluidic Platforms
- **11:30–11:55** Denise Schmutz
  When Do Measurements Reveal How a Sample Rotates? The Challenge of Uniqueness in Rigid Motion Reconstruction
- **12:00–12:25** Christina U. Strohmenger
  Phase Retrieval Using the Transport of Intensity Equation
- **12:30–14:00** Lunch

Afternoon Session

- **14:00 – 17:30:** Excursion in the surroundings of Wolfgangsee
- **18:00–19:30** Dinner

Friday, June 20

Morning Session: Inverse Problems, Part 2

Chair: Ronny Ramlau

- **09:00–09:35** Raymond H. Chan
  PiLocNet: Physics-informed neural network on 3D localization with rotating point spread function
- **09:45–10:20** Ha Pham
  Numerical computation of wave oscillations for helioseismology: from radially symmetric models to differential rotation
- **10:30–11:00** Break
- **11:00 – 11:25** Simon Hubmer
  The SCD Semismooth Newton method for the efficient minimization of Tikhonov functionals*
- **11:30 – 11:55** Yutong Wu
  The inverse problem of wavefront reconstruction for atmospheric tomography in Adaptive Optics
- **12:00 – 12:25** Ioannis Martikos
  Extracting Features from Galaxy Orbit Distributions
- **12:30–14:00** Lunch

Afternoon Session: Super-resolution Microscopy

Chair: Gerhard Schütz

- **14:00–14:35** Ingo Gregor
  Structure and Dynamics of Lipid Bilayers
- **14:40 – 15:05** Montse Martinez Lopez
  Fluorophore dipole orientation characterization
- **15:10 – 15:35** Yakun Dong & Zheyi Yang
  Algebraic circle fitting algorithms for 2-dimensional noise correlated case with application to size oligomeric biomolecules on cryo single molecule localization microscopy
- **10:30–11:00** Break & Group Meetings

- **18:00–19:30** Closing Dinner

Abstracts

Tuesday, June 17

Morning Session: Inverse Problems Part 1

Chair: Otmar Scherzer & Peter Elbau

Statistical microlocal analysis

Alexander Katsevich[1]

Joint work with: Anuj Abhishek[2], James W. Webber[3]

Affiliation: [1]University of Central Florida (US), [2]Case Western Reserve University (US), [3]Cleveland Clinic (US)

Time: Tuesday, June 17, 09:00 – 09:35

Abstract:

In many imaging applications it is important to assess how well the edges of the original object f are resolved in an image f_{rec} reconstructed from data g. In the talk we consider X-ray Computer Tomography (CT). Let $g = Rf$ be the Radon transform data in the plane. Conventional microlocal analysis provides conditions for edge detectability based on scanner geometry in the case of continuous, noiseless data, but does not account for noise and finite data step size. We develop a novel technique, Statistical Microlocal Analysis (SMA), which uses the statistical hypothesis testing framework to determine if an image edge (singularity) in f is detectable from f_{rec} and quantify edge detectability using the statistical power of a test. SMA is the first extension of classical microlocal analysis theory to account for practical measurement imperfections, such as noise and finite data step size, at the highest possible resolution compatible with data.

TBA

Peter Elbau

Affiliation:

Time: Tuesday, June 17, 09:45 – 10:20

Abstract:

Spherical Radon transforms with smoothly varying radii and applications to tomography

Eric Todd Quinto[1]

Joint work with: James W. Webber[2]

Affiliation: [1]Tufts University (US); [2]Cleveland Clinic (US)

Time: Tuesday, June 17, 11:00–11:35

Abstract:

We will analyze a spherical Radon transform which integrates a function over spheres in Euclidean space with arbitrary centers, y, and radii $r(y)$ that vary smoothly with y. We prove conditions under which the normal operator is an elliptic pseudodifferential operator. This gives us Sobolev regularity and stability of inversion. We apply it to problems including Compton Scatter Tomography and Ultrasound Reflection Tomography.

Utilising Monte Carlo method for light transport in optical tomography

Tanja Tarvainen

Affiliation: University of Eastern Finland (Finland)

Time: Tuesday, June 17, 11:45 – 12:20

Abstract:

We study the inverse problem in optical tomography when the forward solution is approximated with the Monte Carlo method for light transport. In the approach, paths of photons are simulated when they undergo absorption and scattering events in a scattering medium. In the inverse problem of optical tomography, distributions of absorption and scattering parameters are estimated. Now, due to the stochastic nature of the forward operator, the search direction of a minimisation algorithm for solving these estimates is also stochastic.

Afternoon Session: Astrophysics

Chair: Glenn van de Ven

A triaxial and vertically oriented dark matter halo of the Milky Way shaped by minor mergers

Ling Zhu

Affiliation: Shanghai Astronomical Observatory (China)

Time: Tuesday, June 17, 14:00 – 14:35

Abstract:

The 3D shape of the Milky Way's dark matter (DM) halo is crucial for understanding its formation history, yet it remains debated, despite the large effects made on it. LAMOST and Gaia observations provide us a sample of halo stars with full 6D phase-space measurements. By adopting a single basic assumption— that the smooth stellar halo is stationary— we circumvent limitations of previous dynamical models, enabling a direct constraint on the 3D DM distribution. Our findings show that the Milky Way DM halo is triaxial and vertically oriented (qDM = Z/X = 0.92±0.08, pDM = Y/X = 0.8 ± 0.2). Notably, there is a significant correlation between the 3D shape of the DM halo and the configuration of the satellite galaxy system in the halo, as revealed by TNG50 simulations. The distinctive orientation of the Milky Way's DM halo corresponds with its unusually vertically aligned satellite galaxy system. Supported by its TNG50 analogues, the Milky Way DM halo may have retained this shape for a long time, while the disk has been flipped by about $\sim 90^\circ$ by a minor merger. With the 3D shape/orientation of the DM halo uncovered in this work, we establish the first coherent scenario connecting the DM halo's shape to the Milky Way's merger history.

Inverse Modelling of Galaxies Across Scales: From Simulations to Observations with Modern Computational Tools

Tobias Buck

Affiliation: Heidelberg University (Germany)

Time: Tuesday, June 17, 14:45 – 15:20

Abstract:

Understanding how galaxies form and evolve is a central goal in astrophysics. With the advent of high-resolution simulations and integral field unit (IFU) spectroscopy, we now have unprecedented access to both the theoretical and observational structure of galaxies across cosmic time. However, bridging these two domains—inferring the underlying dynamical and structural properties of real

galaxies from observational data—poses a complex inverse problem.

In this talk, I will present a new computational framework for solving this inverse problem, developed in the context of the NIHAO-UHD simulations and applied to IFU data from the GECKOS survey. Our approach combines classical galaxy modelling techniques—such as distribution function fitting, Schwarzschild orbit superposition, and made-to-measure methods—with modern tools from scientific computing and machine learning.

At the core of this framework are our open-source software packages: RUBIX, Odisseo, and jf1uids. These tools leverage the JAX ecosystem for automatic differentiation and hardware acceleration, enabling efficient gradient-based optimization and scalable inference. I will show how this modular and physics-informed approach allows us to extract physical parameters of galaxies—such as their mass distribution and orbital structure—directly from IFU data. This work lies at the intersection of astrophysics, applied mathematics, and computational science, and I will highlight the broader relevance of these inverse modelling techniques across disciplines dealing with complex, high-dimensional data.

Mathematical methods for wide field of view adaptive optics in ophthalmology

Victoria Laidlaw[1]

Joint work with: Elisabeth Brunner[2], Wolfgang Drexler[2], Michael Pircher[2] and Ronny Ramlau[1,3]

Affiliation: [1]JKU Linz (Austria), [2]Medical University of Vienna (Austria), [3]RICAM, Linz (Austria)

Time: Tuesday, June 17, 15:30 – 15:55

Abstract:

Adaptive optics (AO) assisted retinal imaging plays a crucial role in the investigation of vision-threatening eye diseases by visualising the human living retina at cellular and sub-cellular level. An obstacle to widespread clinical use of AO technology is its small field of view (FoV) which prohibits fast screening of large areas of the retina and complicates revisiting the same retinal locations.

In this talk we investigate how mathematical methods can be used to extend the FoV of standard AO ophthalmoscopes. Based on a theoretical analysis we develop a mathematical framework to determine the optimal system design and corresponding control algorithms for AO supported retinal imaging.

It is demonstrated with a software-based AO ophthalmoscope model how the currently available FoV can be doubled. The optimal system design is experimentally realized.

Focusing on the stars: The crucial role of adaptive optics in astronomy

Sebastian Kamann

Affiliation: Liverpool John Moores University (UK)

Time: Tuesday, June 17, 16:30 – 17:05

Abstract:

With a primary mirror measuring almost 40 meters in diameter, the upcoming Extremely Large Telescope will enable astronomers to look deeper into the universe than hitherto possible. A key technique to tap the full potential of this unique facility is adaptive optics: High frequency deformations of the telescope's mirror that compensate for the turbulence of the atmosphere and increase the achieved spatial resolution by an order of magnitude. In my talk, I will present some of the science cases that are enabled by adaptive optics, namely the search for black holes in star clusters and the study of individual stars in distant galaxies. Successfully addressing such science cases requires precise predictions of the image quality achieved in each observation. My talk will also highlight our efforts to make such predictions via atmospheric tomography and to verify them using simulated as well as observational data.

Collecting fossil records of galaxy formation

Stefanie Reiter

Affiliation: University of Vienna (Austria)

Time: Tuesday, June 17, 17:15 – 17:40

Abstract:

We use a triaxial implementation of an orbit-based dynamical modelling method to recover the internal structure of spectroscopically observed galaxies and to disentangle their individual dynamical components, which contain information on the galaxies' formation histories. To inform our analysis of the resulting orbit distributions, I am working with TNG50, a new generation of cosmological simulations with high enough resolution to analyze the stellar components of individual simulated galaxies in a similar way as in the dynamical models of observed galaxies. We aim to use the orbit distributions of TNG50 galaxies to construct physically motivated priors to inform and speed up our dynamical modelling. In this talk, I will discuss our selection of relevant features in the orbit distributions and current plans to use them for prior construction.

Wednesday, June 18

Morning Session: Medical Imaging

Chair: Wolfgang Drexler

Comparing Algorithms for Galaxy Reconstructions

Prashin Jethwa

Affiliation: University of Vienna (Austria)

Time: Wednesday, June 18, 09:00 – 09:25

Abstract:

I'll present recent work comparing two algorithms for reconstructing galaxy properties from observational data - PNKR and BayesLOSVD - highlighting their particular strengths and weaknesses before summarising the lessons learned for the future.

Longitudinal AO-OCT imaging of the retina in diabetic eyes using the P-WFS

Elisabeth Brunner[1]

Joint work with: Laura Kunze, Victoria Laidlaw[2], Wolfgang Drexler[1], Ronny Ramlau[2,3], Andreas Pollreisz, Michael Pircher[1].

Affiliation: [1]Medical University of Vienna (Austria), [2]RICAM, Linz (Austria), [3]JKU Linz (Austria)

Time: Wednesday, June 18, 09:30 – 09:55

Abstract:

Over the course of 1 year, seven patients suffering from diabetic retinopathy were repeatedly imaged with our P-WFS-based AO-OCT system to investigate in vivo the activation state and density of human retinal microglia, offering insights into the disease's inflammatory dynamics. Diabetic lesions were examined with this high-resolution technique and compared to results from conventional imaging methods. Additionally, we conducted a retrospective analysis to introduce quantitative metrics for assessing AO-OCT image quality and explored possible relationships with parameters from the system's P-WFS.

Quantitative Optical Coherence Elastography Facilitating Axial and Lateral Sample Deformation

Lisa Krainz

Affiliation: University of Vienna (Austria)

Time: Wednesday, June 18, 10:00 – 10:25

Abstract:

Quantitative Optical Coherence Elastography (OCE) offers high-resolution stiffness mapping but often suffers from limited accuracy due to oversimplified handling of strain and stress. We developed an OCE system capable of capturing both axial and lateral sample deformations, enabling the derivation of high-fidelity strain maps. Comparative analysis across multiple phantoms demonstrates that stiffness reconstruction is most accurate when using an intensity-based inversion method, whereas strain-map-based and uniaxial approaches yield significantly less reliable results.

On the Intensity-based Inversion Method for Quantitative Optical Coherence Elastography

Ekaterina Sherina

Affiliation: University of Vienna (Austria)

Time: Wednesday, June 18, 11:00 – 11:25

Abstract:

Elastography, as an imaging modality in general, aims at mapping the mechanical properties of a given material sample. For estimating the values of stiffness and strain quantitatively, we look at Elastography from the perspective of Inverse Problems. In particular, we start with theoretical ideas on how to perform Elastography and continue all the way to implementing Optical Coherence Elastography (OCE) as an imaging modality in practice. Furthermore, we discuss inversion methods for estimating strain and stiffness from optical coherence imaging data, and validate the reconstruction results against the ground truth for 12 silicone elastomer phantoms. In addition, we present a convergence analysis of the intensity-based inversion method for evaluating material parameters.

Parameter identification in quantitative optical coherence tomography

Leopold Veselka[1]

Joint work with: Lisa Krainz[2], Leonidas Mindrinos[3], Wolfgang Drexler[2], and Peter Elbau[1].

Affiliation: [1]Faculty of Mathematics, University of Vienna (Austria), [2]Medical University of Vienna (Austria), [3]Agricultural University of Athens (Greece)

Time: Wednesday, June 18, 11:30 – 11:55

Abstract:

Optical coherence tomography (OCT) is a non-invasive imaging technique providing highly resolved images of the inner structure of biological tissues that are based on the interferometric measurement of backscattered light. In this talk we discuss the related direct and inverse scattering problem with focus on the extraction of optical properties from experimental OCT measurement data. The applicability of the method is tested with numerical experiments for simulated and experimental data.

A Gauss-Green formula approach for refractive index recovery on OCT

Cristóbal Villalobos Guillén

Affiliation: University of Vienna (Austria)

Time: Wednesday, June 18, 12:00 – 12:25

Abstract:

We are interested in the recovery the refractive index of tissue by use of OCT (optical coherence tomography). In order to model the behavior of light as it passes through different media, Snell and Fresnel equations are used in the case of planar interfaces. Based on these equations, Drexler, Elbau, Krainz and Veselka have developed an inversion technique to obtain the refractive index from OCT measurement. In this talk, we will go through a generalization of their work to the case of non-planar interfaces, using the Gauss-Green formula and the equations of light on the frequency domain instead of Snell/Fresnel equations. We will touch on the limitations of this approach and show some preliminary results.

Afternoon Session: Mathematical Imaging

Chair: Gabriele Steidl

Seeing through light beyond space and time: advances in fluorescence microscopy image reconstruction

Luca Calatroni

Affiliation: University of Genoa (Italy)

Time: Wednesday, June 18, 14:00 – 14:35

Abstract:

The diffraction limit of light restricts the spatial resolution of standard optical microscopes to approximately 200 nm. To overcome this barrier and reveal structures of critical importance in fields such as biology and materials science, two main strategies are employed: improving hardware and acquisition protocols—which can be costly and potentially damaging to samples—or developing advanced image reconstruction methods that extract useful information from existing data.

The latter approach leverages physical priors, such as knowledge of physical models and noise distributions, along with structural or temporal prior assumptions about the sample. Recent advances in machine learning and deep learning further enable the creation of interpretable, model-aware data-driven methods, where physical models are enriched by insights learned from data.

In this talk, I will present a journey through the physical principles and mathematical models behind modern fluorescence microscopy reconstruction techniques. Topics will include ℓ_0-sparse optimization for Single Molecule Localization Microscopy (SMLM) and fluctuation-based super-resolution, the use of Continuous Hidden Markov Models to describe dynamic fluctuation phenomena, and model-aware deep learning methods for image reconstruction in Image Scanning Microscopy (ISM).

On Modulo Radon Transform Based Tomography

Matthias Beckmann

Affiliation: University of Bremen (Germany)

Time: Wednesday, June 18, 14:45 – 15:20

Abstract:

In this talk we introduce a new single-shot approach to high dynamic range tomography based on the Modulo Radon Transform (MRT), a novel generalization of the conventional Radon transform. We discuss how to recover a function from given MRT samples and show mathematical recovery guarantees and error estimates for target functions from Sobolev spaces of fractional order. Our

theoretical results are illustrated by numerical simulations and prototype modulo ADC based hardware experiments, where we report image recovery from measurements 10 times larger than the sensor's dynamic range while benefiting with lower quantization noise.

Quantitative inverse problem in ultrasound imaging for viscoelastic anisotropic media

Florian Faucher[1]

Joint work with: Otmar Scherzer[2]

Affiliation: [1]Team Makutu, Inria (France), [2]University of Vienna (Austria)

Time: Wednesday, June 18, 16:00 – 16:35

Abstract:

We consider the quantitative inverse problem for reconstructing physical properties in viscoelastic anisotropic media using wave data-sets. The time-harmonic formulation of the anisotropic elastic wave equations is used to facilitate handling different models of viscosity. The system is discretized with the hybridizable discontinuous Galerkin (HDG) method which employs static condensation to reduce the computational cost, although requiring non-trivial stabilization term for efficiency. The nonlinear inversion algorithm is performed following a minimization process in which the model parameters are iteratively updated. We carry out reconstructions with attenuation model uncertainty, and emphasize the importance of considering anisotropy in the model with synthetic experiments for ultrasound imaging.

Fast and Accurate Approximation of High-Dimensional Radial Kernels via Slicing

Michael Quellmalz

Affiliation: Technische Universität Berlin (Germany)

Time: Wednesday, June 18, 16:40 – 17:05

Abstract:

The fast computation of large kernel sums arises as a subproblem in any kernel method, including kernel density estimation, electrostatic particle simulation or gradient flows. We approach the problem by slicing, which relies on projections to one-dimensional subspaces via an adjoint Radon transform combined with fast Fourier summation. Numerical examples demonstrate that our slicing approach outperforms existing methods like random Fourier features on standard test datasets.

Modeling Molecule and Cluster Movements via generative modeling and SDEs

Christian Wald

Affiliation: TU Berlin (Germany)

Time: Wednesday, June 18, 17:10 – 17:35

Abstract:

We are interested in modeling the dynamic behavior of molecule clusters as well as single molecules in T-cells. To this end, we use flow matching techniques in order to learn trajectories directly as well as learning SDE parameters for modeling the movement dynamics. Both methods allow for a computation of a likelihood of given trajectories.

Thursday, June 19

Morning Session: Optical Tomography

Chair: Monika Ritsch-Marte

Optical microtomography: challenges for improved resolution and functionalization

Olivier Haeberlé

Affiliation: Université de Haute-Alsace, Mulhouse (France)

Time: Thursday, June 19, 09:00 – 09:35

Abstract:

Optical microtomography techniques present advantages compared to classical or holographic and even fluorescence microscopy, but are still limited on many aspects. Delivered images present an anisotropic resolution, which can alter measurements of physical quantities, and while the index of refraction is an interesting contrast in itself, it lacks chemical sensitivity. Ways however do exist to circumvent these drawbacks, representing promising research axes to improve the technique.

Advancements in large scale optical tomography

Jeroen Kalkman

Affiliation: TU Delft (Netherlands)

Time: Thursday, June 19, 09:45 – 10:20

Abstract:

I will present advancements in large scale optical tomography. First, I will discuss the application of large-scale optical diffraction tomography for phase imaging of optically cleared non-scattering tissue samples, such as clinically relevant tissues and entire zebrafish. Second, I will discuss optical tomography of highly scattering media using optical coherence projection tomography that uses transmission spectral interferometry for temporal light gating, phase estimation, and amplitude determination.

Optical Tomography by Rotation in Acoustofluidic Platforms

Mia Kvåle Løvmo

Affiliation: Medical University of Innsbruck (Austria)

Time: Thursday, June 19, 11:00 – 11:25

Abstract:

To unlock the full potential of 3D in vitro models for biomedical research, new methods are required for handling and analyzing developing samples in a non-invasive and controlled manner. To meet this demand, we have developed acoustofluidic platforms compatible with Optical diffraction Tomography or Optical Coherence Tomography. We acquire multi-angle views by acoustic rotation of the object, and reconstruct the objects precise motion and 3D structure jointly by a model-based optimization algorithm.

When Do Measurements Reveal How a Sample Rotates? The Challenge of Uniqueness in Rigid Motion Reconstruction

Denise Schmutz

Affiliation: University of Vienna (Austria)

Time: Thursday, June 19, 11:30 – 11:55

Abstract:

We investigate the problem of recovering an unknown time-dependent rotational motion from parallel-beam measurements, motivated by imaging scenarios where the sample rotates in an imperfectly controlled manner during data acquisition. The central questions we address are: under what conditions on the motion and the object can the rotation be uniquely determined via the infinitesimal common line method, and how frequently does non-uniqueness arise for a generic object?

Phase Retrieval Using the Transport of Intensity Equation

Christina U. Strohmenger

Affiliation: University of Vienna (Austria)

Time: Thursday, June 19, 12:00 – 12:25

Abstract:

In this talk we explore a PDE-based method for solving the phase retrieval problem. We will

derive the Transport of Intensity Equation from the paraxial approximation of the optical wave and discuss the performance of the method based on examples.

Friday, June 20

Morning Session: Inverse Problems, Part 2

Chair: Ronny Ramlau

PiLocNet: Physics-informed neural network on 3D localization with rotating point spread function

Raymond H. Chan

Affiliation: Lingnang University (Hong Kong)

Time: Friday, June 20, 09:00 – 09:35

Abstract:

We consider the 3D localization problem of the point spread function (PSF) engineering and propose a novel framework based on the physics-informed neural network (PINN), namely PiLocNet, to solve this problem.

Our PiLocNet combines deep learning and variational methods, which enhances the black box neural networks by employing the known physics information of the forward process into the framework as the data fitting term. In the meantime, it incorporates the regularization terms from the variational method that best fits the noise model. This work focuses on the single-lope PSF, while it is widely applicable to other PSFs or other imaging problems.

Numerical computation of wave oscillations for helioseismology: from radially symmetric models to differential rotation

Ha Pham[1]

Joint work with: Florian Faucher[1], Damien Fournier[2], Lola Chabat[1], Laurent Gizon[2], Hélène Barucq[1]

Affiliation: [1]Team Makutu, Inria (France), [2]Max-Plank Institute (Germany)

Time: Friday, June 20, 09:45 – 10:20

Abstract:

Helioseismology infers the interior of the Sun from oscillations which are continuously excited by near-surface turbulent convection and observed in the photosphere. Global helioseismology reconstructs global structures from free oscillations which manifest as ridges in power spectrums of

Dopplergrams. On the other hand, techniques in local helioseismology, e.g. time-distance helioseismology and far-side helioseismic holography, are based on correlation of Dopplergrams to reconstruct local perturbations (e.g. in flow and sound speed). After choosing a mathematical equation together with boundary conditions to model oscillations, for global seismology, an eigensolver needs to be constructed, while for correlation-based techniques, be this qualitative or quantitative, Born approximation or iterative, a wave solver to compute Green's kernel is required. In this talk, I will give an overview of various Green's kernels we have obtained. These results are achieved with in-house software Hawen, which solves scalar and vector equations modeling solar waves, for backgrounds ranging from radially symmetric standard models with or without Cowling approximation, to differential rotation. The equations with radially symmetric backgrounds are solved in 1D via spherical harmonics decomposition, the ones with differential rotation in 2D via azimuthal decomposition, and general backgrounds without flow and rotation in 3D. These direct solvers serve as essential steps towards inversion, in particular full-wave form inversion. As a first validation, our power spectrums computed for model S show ridges in agreement with HMI observation. Secondly, in simulations with realistic differential rotation, our spectrums reproduce the observed splitting in azimuthal modes due to rotation.

The SCD Semismooth* Newton method for the efficient minimization of Tikhonov functionals

Simon Hubmer[1]

Joint work with: Helmut Gfrerer[2], Ronny Ramlau[1,3]

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Time: Friday, June 20, 11:00 – 11:25

Abstract:

We consider the efficient numerical minimization of Tikhonov functionals with nonlinear operators and non-smooth and non-convex penalty terms, which appear e.g. in variational regularization. For this, we consider a new class of SCD semismooth* Newton methods, which are based on a novel concept of graphical derivatives, and exhibit locally superlinear convergence. We present a detailed description of these methods, and provide explicit algorithms in the case of sparsity (ℓ_p, $0 \leq p < \infty$) and TV penalty terms. The numerical performance of these methods is then illustrated on a number of tomographic imaging problems.

The inverse problem of wavefront reconstruction for atmospheric tomography in Adaptive Optics

Yutong Wu[1]

Joint work with: Roland Wagner[1], Ronny Ramlau[1,2]

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Time: Friday, June 20, 11:30 – 11:55

Abstract:

We present a tomographic algorithm for wavefront phase reconstruction in Adaptive Optics using wavefront gradient measurements from multiple wave- front sensors. The method leverages the ESO atmospheric layer model and guide star to reconstruct the turbulence structure. Guided by Kolmogorov's turbulence theory, we model atmospheric reconstruction in the Sobolev space $H^{11/6}$, and an $H^2 - L^2$ regularization is introduced to stabilize the inversion.

Extracting Features from Galaxy Orbit Distributions

Ioannis Martikos

Affiliation: University of Vienna (Austria)

Time: Friday, June 20, 12:00 – 12:25

Abstract:

We analyze orbit distributions of galaxies derived from cosmological simulations. Wavelet decomposition is used to enhance interpretability and extract multiscale features. The reconstructed representations aim to preserve key orbital structures while reducing noise and dimensionality. These filtered distributions serve as informed priors for regularizing the inverse problem of orbit modeling in observed galaxies.

Afternoon Session: Super-resolution Microscopy

Chair: Gerhard Schütz

Structure and Dynamics of Lipid Bilayers

Ingo Gregor

Joint work with: Tao Chen[1], Jörg Enderlein[1]

Affiliation: [1]3rd Institute of Physics, Georg-August-University, Göttingen (Germany)

Time: Friday, June 20, 14:00 – 14:35

Abstract:

Plasma membranes host numerous proteins and lipids that are essential for cellular functions. The intricate composition and inherently active, nonequilibrium nature of native plasma membranes is driven by energy-dependent processes such as lipid recruitment, active transport, and cytoskeletal remodeling. These pose significant challenges for isolating and studying individual components in these membranes. Supported lipid bilayers (SLBs) provide a valuable bottom-up alternative as simplified but versatile membrane models. These biomimetic systems have become well-established in a wide range of biophysical and biological studies. Despite their extensive application, the experimental investigation of their properties is quite limited. Our study introduces GIET-lsFLCS to study the structure and dynamic properties of SLBs, offering detailed insights in a leaflet-specific manner. This information not only deepens the fundamental knowledge of membrane biophysics but also paves the way for studying lipid interactions in complex biological systems.

Epithelial cadherin (E-cad) mediated cell-cell junctions are fundamental for the formation and maintenance of tissues and organs. In this study, we investigate variations in intermembrane distance during adhesion between two model membranes adorned with E-cad. By correlating the measured intermembrane distances with the distinct E-cad junction states, we probed the dynamic behavior and diversity of E-cad junctions across different binding pathways. Our observations led to the identification of a transient intermediate state and enabled a detailed analysis of its kinetics. We discovered that the formation of the X-dimer leads to significant membrane displacement, subsequently impacting the formation of other X-dimers. The dynamics of E-cad-modified membranes and resultant changes in intermembrane distance provide insights on the assembly of E-cad junctions between cells, elucidating a key step of tissue and organ development.

References:

- Karedla, N., Schneider, F., Enderlein, J. & Chen, T. "Leaflet-Specific Structure and Dynamics of Solid and Polymer Supported Lipid Bilayers." *Angew. Chem. Int. Ed.* 64(21), e202423784 (2025).
- Chen, T., Karedla, N. & Enderlein, J., "Observation of E-cadherin adherens junction dynamics with metal-induced energy transfer imaging and spectroscopy." *Commun. Biol.* 7, 1596

(2024).

Fluorophore dipole orientation characterization

Montse López

Affiliation: TU Wien (Austria)

Time: Friday, June 20, 14:40 – 15:05

Abstract:

Fluorophores are dipole emitters. When their rotation is constrained, they emit non isotropically, producing distorted, tilted PSFs. We will show how we can determine the dipole orientation of individual fluorophores by using biplane imaging, and how this method compares to others.

Algebraic circle fitting algorithms for 2-dimensional noise correlated case with application to size oligomeric biomolecules on cryo single molecule localization microscopy

Yakun Dong & Zheyi Yang

Affiliation: University of Vienna (Austria)

Time: Friday, June 20, 15:10 – 15:35

Abstract:

In this work, we proposed a second-order bias-free estimator for the algebraic circle (plane) fitting algorithm under noise correlations across different orthogonal directions. We explored a general and realistic case of a tilted sample plane in cryogenic single-molecule localization microscopy (cryo-SMLM). Applications of the proposed algebraic fitting algorithm to sizing simulated oligomeric structures under cryo-SMLM are presented.

Notes