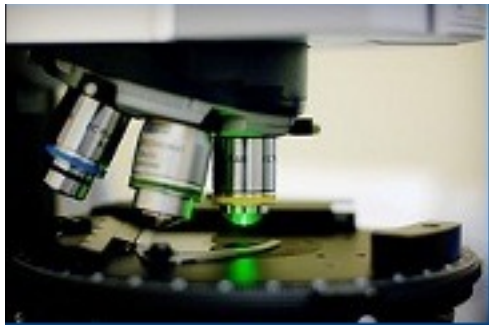
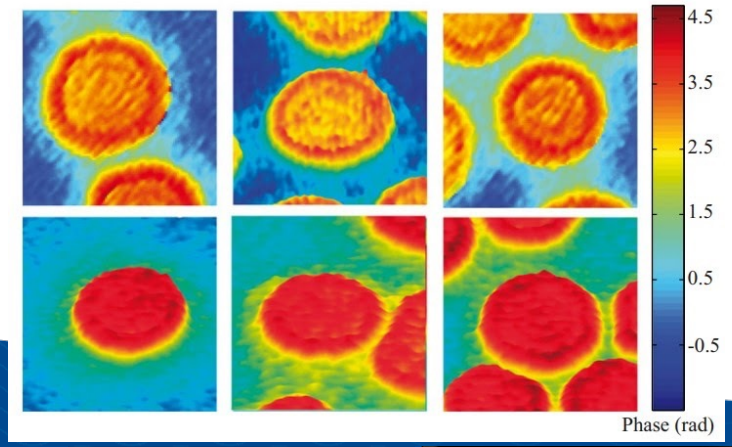
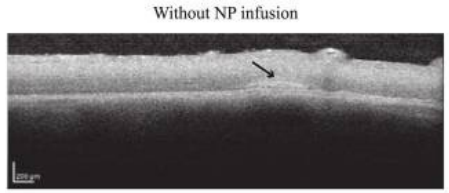
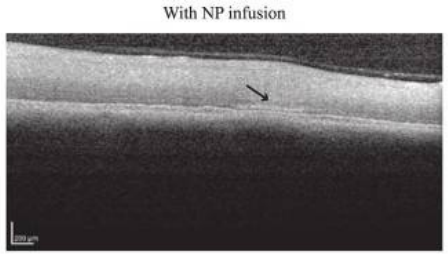
Herff Research Town Hall Series



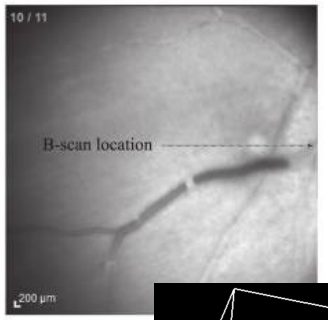


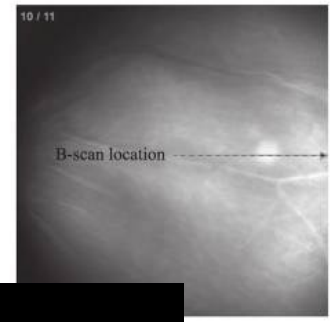


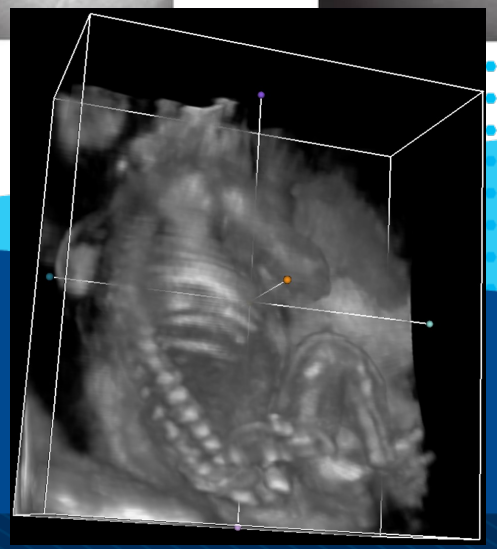


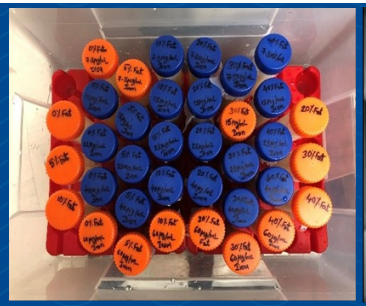
BIOIMAGING

March 24

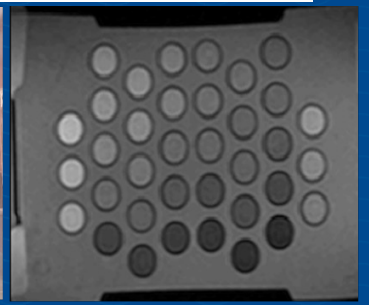




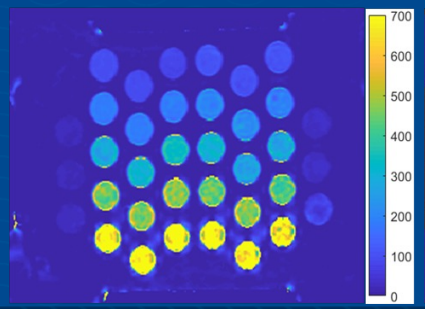




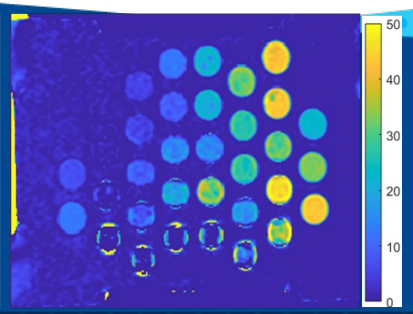
Iron-Fat Phantoms



MRI Images



R2*



Fat Fraction

Bioimaging Presenters

Chrysanthe Preza
Computational Imaging Research Laboratory (CIRL)

Ana Doblas
Optical Imaging Research Laboratory (OIRL)

Madhusudhanan Balasubramanian
Computational Ocularscience Laboratory

EECE

Aaryani Sajja
Magnetic Resonance Imaging and Spectroscopy Lab (MRISL)

Carl Herickhoff
Medical Ultrasound Imaging & Instrumentation Innovation (MU[I]^3) Lab

BME

Engineering microscopes using computational imaging

Chrysanthe Preza

Kanuri Professor and Chair

PI, Computational Imaging Research Laboratory

Dept. Electrical & Computer Engineering

The University of Memphis

CIRL

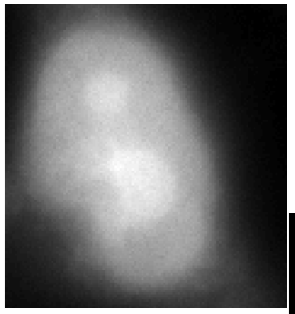
Computatuonal Imaging Research Laboratory

Driven by doing.

THE UNIVERSITY OF MEMPHIS.

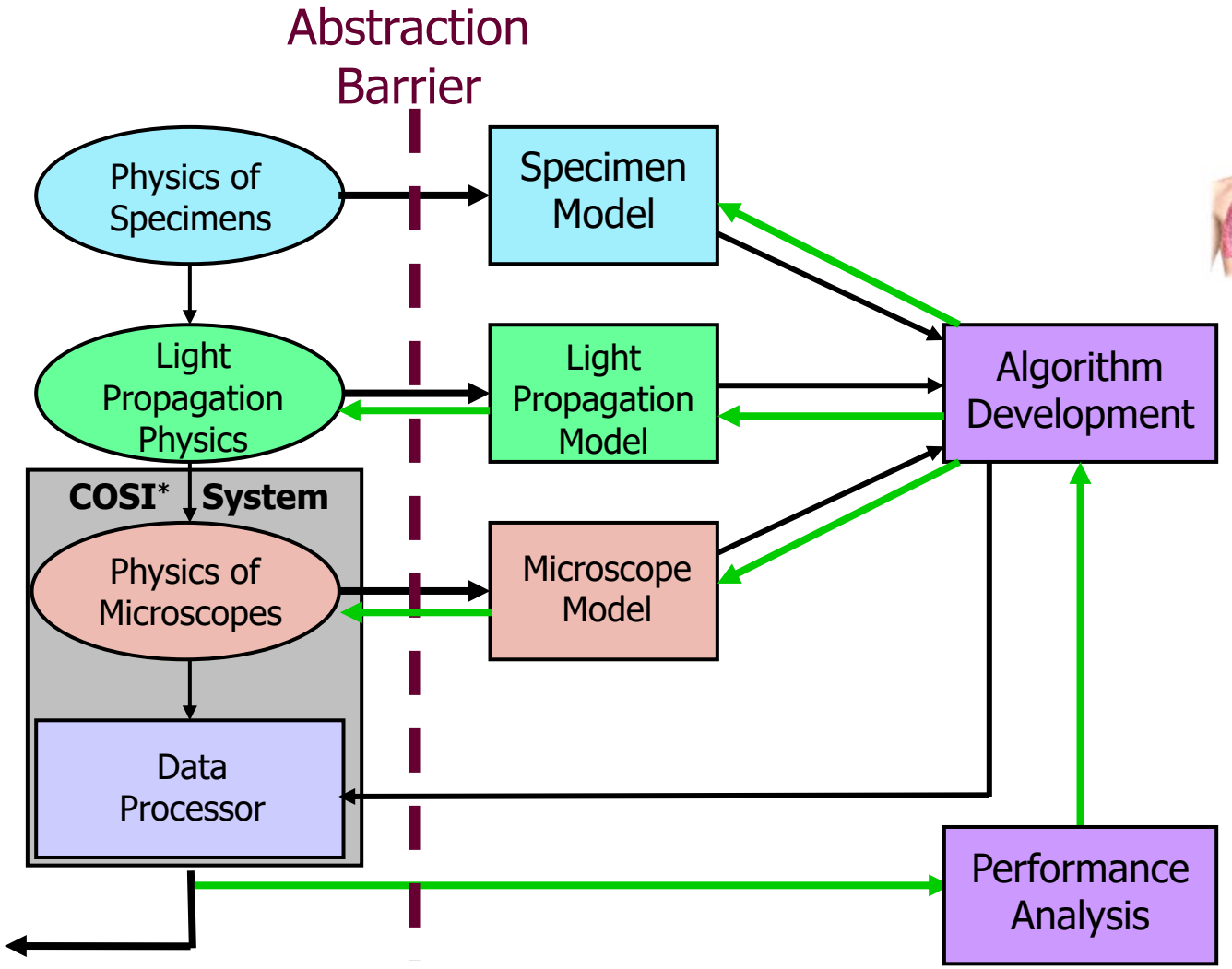
NSF

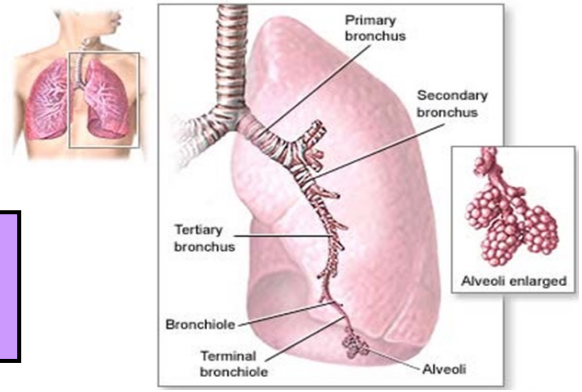
Computational Imaging for 3D Microscopy



Raw data

Processed





http://www.healthline.com/

- Address challenges in imaging thick samples
- Enable biological /biomedical investigations

*COSI – computational optical sensing and imaging

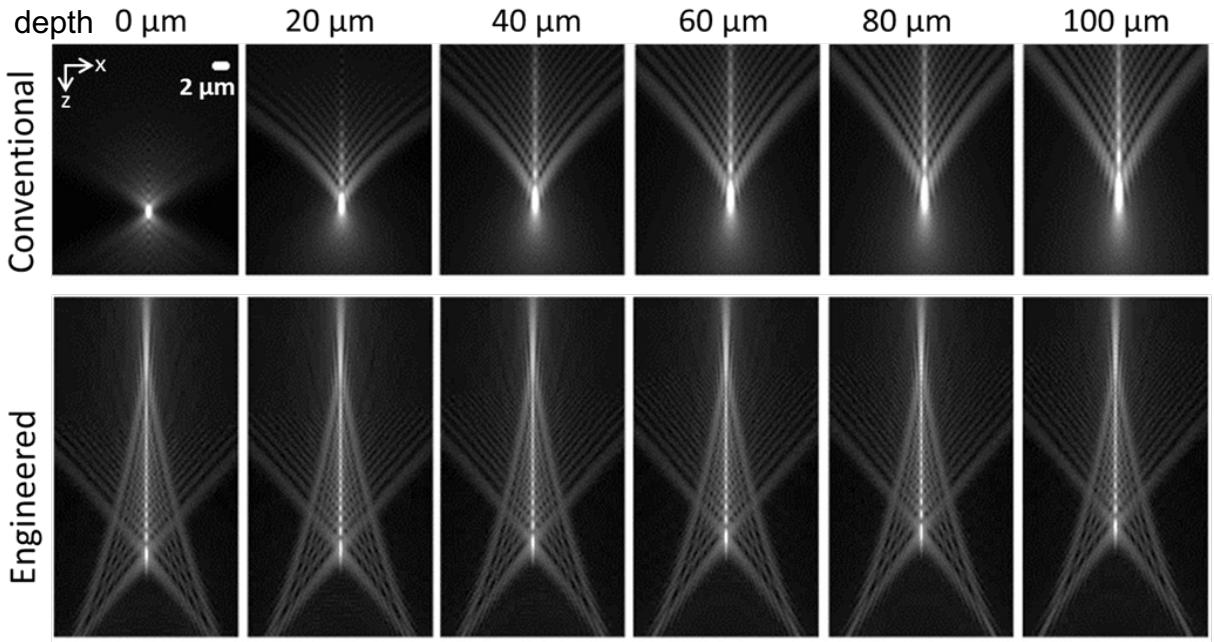
CIRL Computational Imaging Research Laboratory

Computational imaging in 3D fluorescence microscopy

Goal: Reduce depth-induced artifacts

Point spread function (PSF) engineering

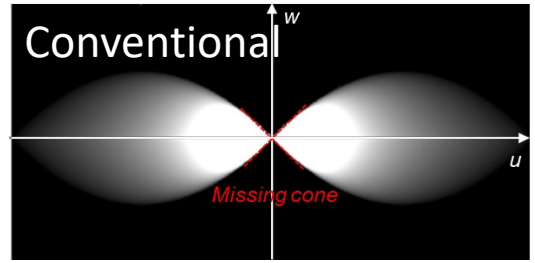
- Wavefront encoding (WFE) renders PSF insensitive to imaging depth

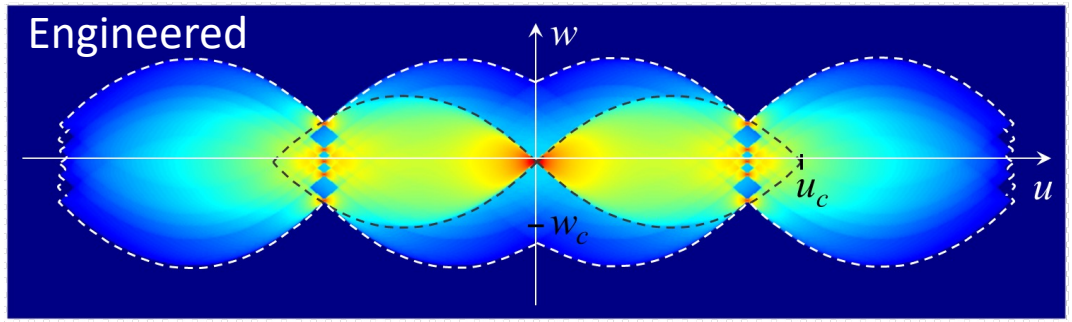


Goal: Achieve 3D super resolution

Optical transfer function (OTF) engineering

- Extend OTF compact support with structured illumination

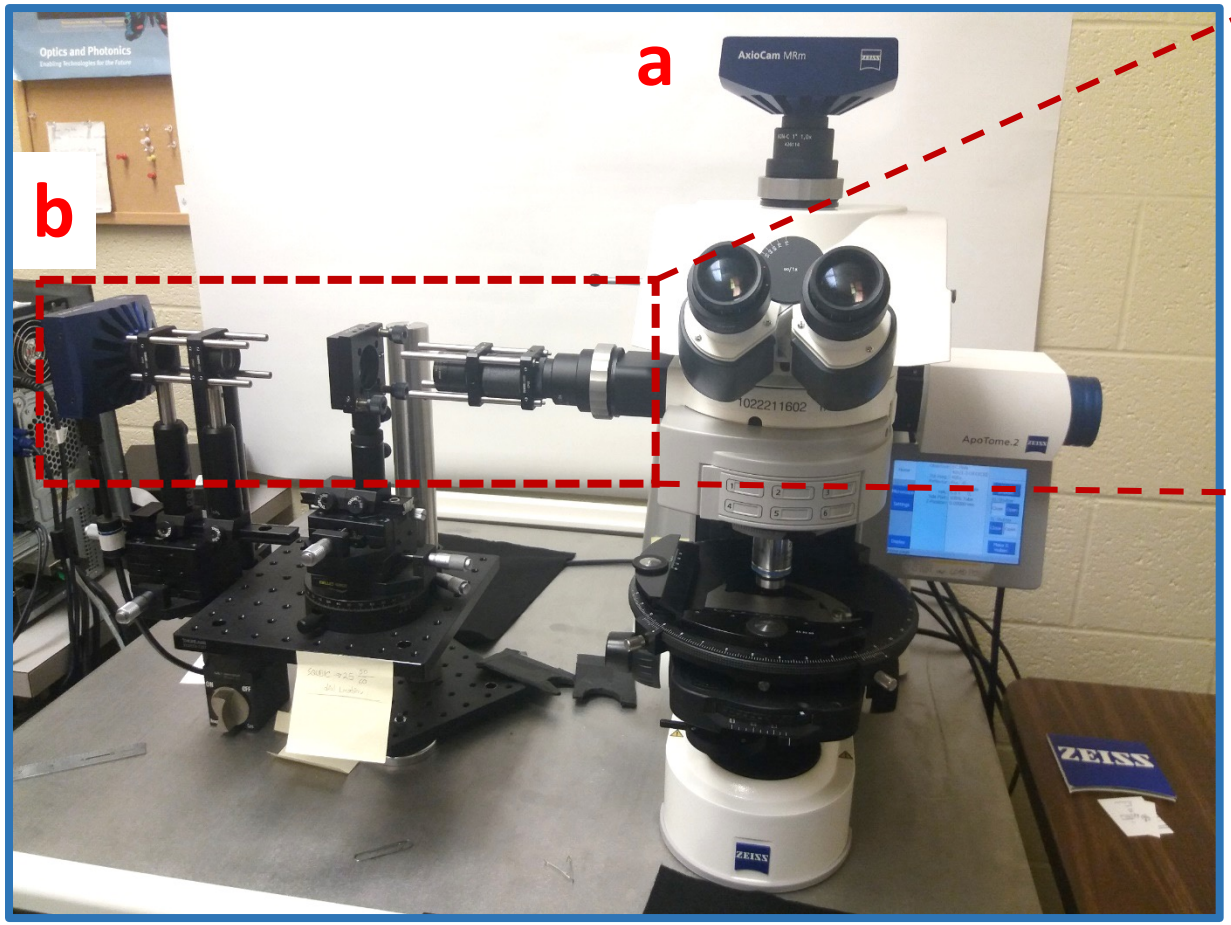




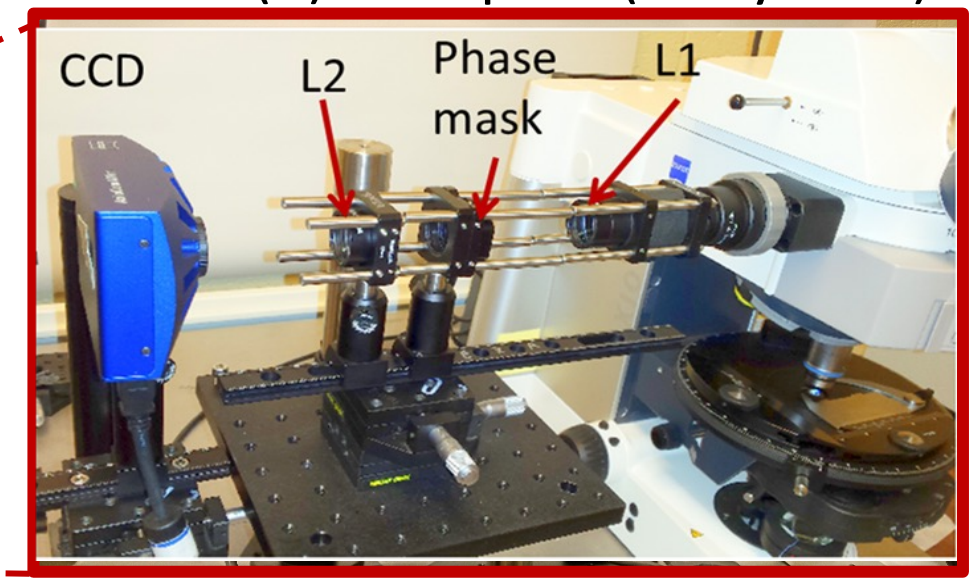
CIRL Computational Imaging Research Laboratory

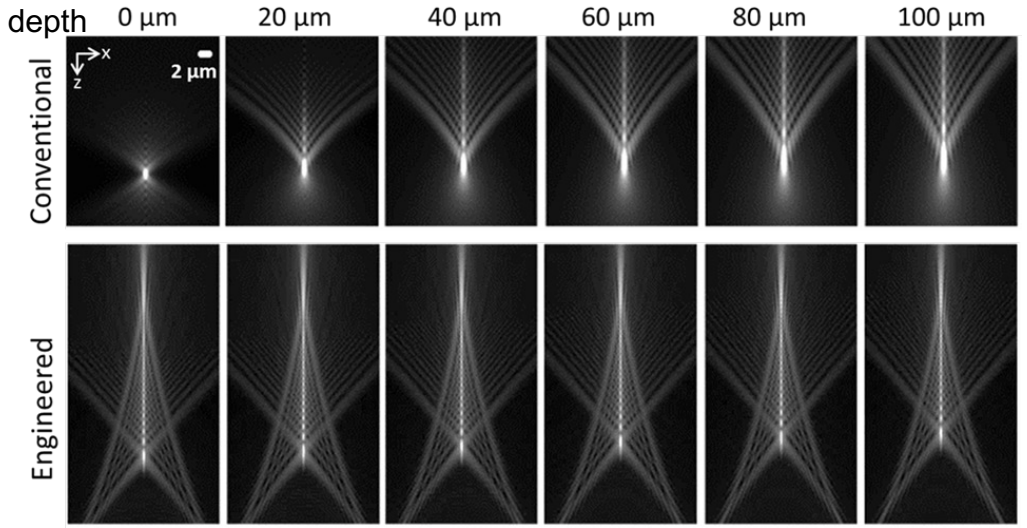
WFE implementation with fabricated mask

Dual imaging: conventional (a) and WFE (b) paths



(b) WFE path (4F System)



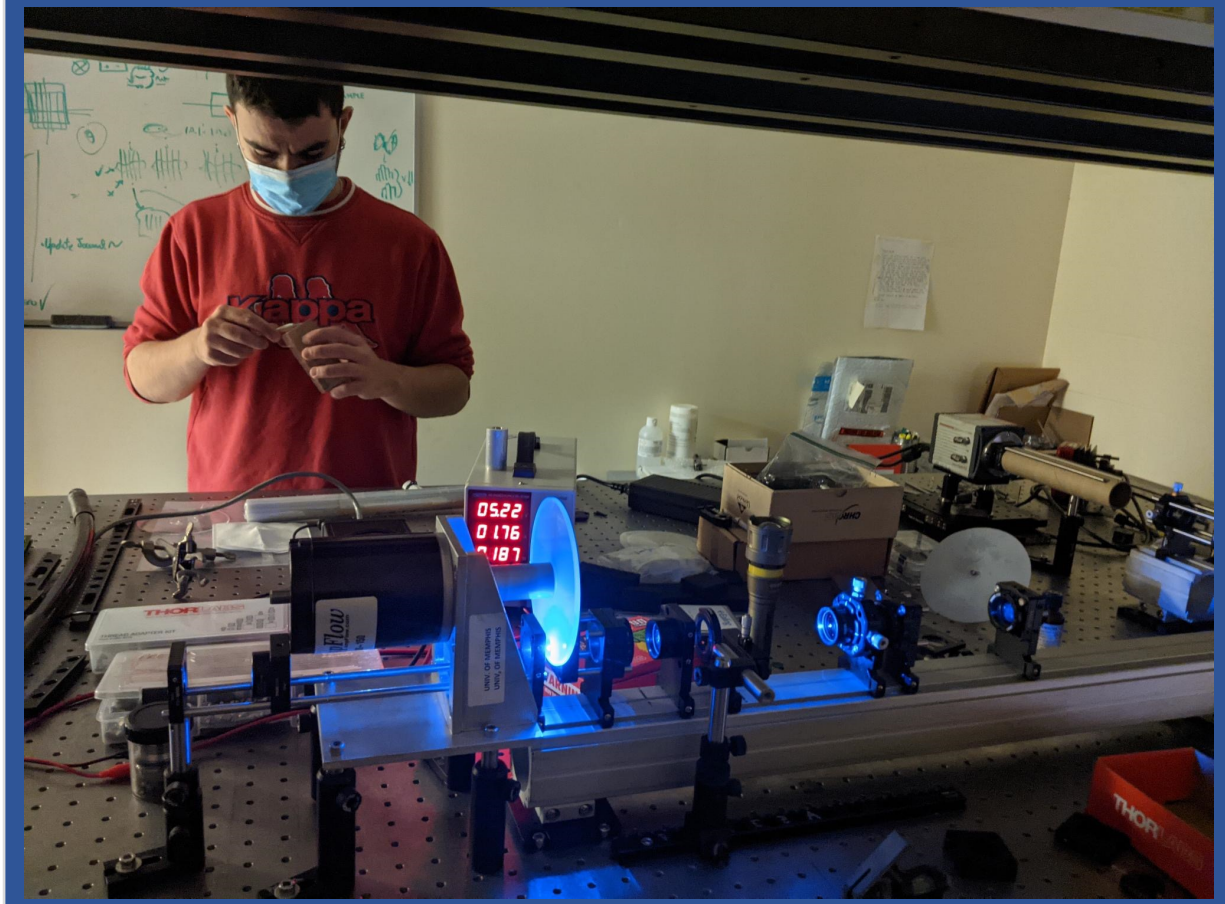


N. Patwary, H. Shabani, A. Doblas, G. Saavedra, and C. Preza, Applied Optics 56(9) D14-D23(2017)

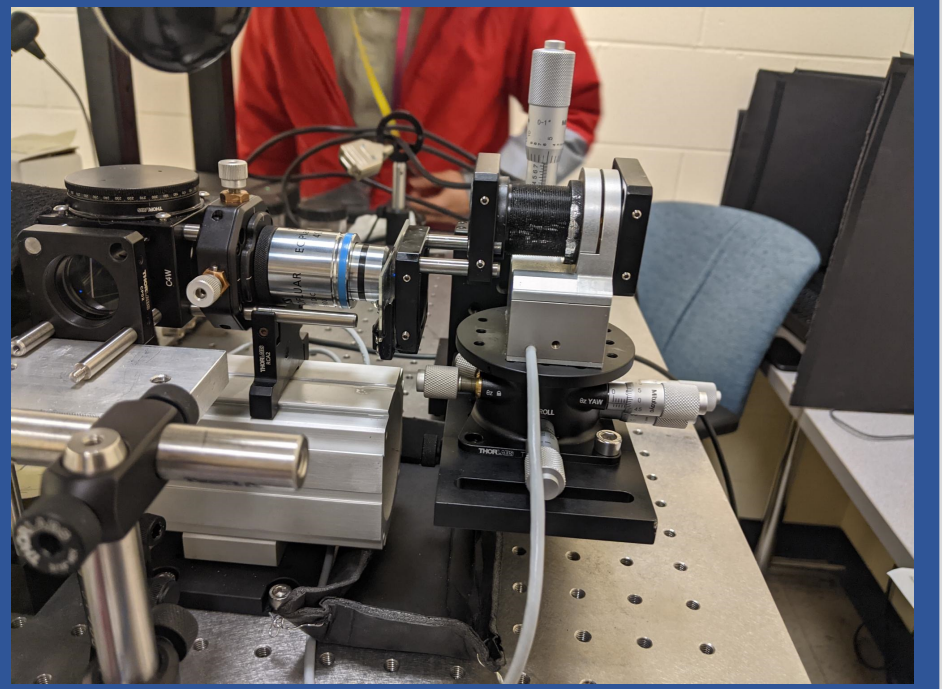
CIRL Computational Imaging Research Laboratory

Novel Structured Illumination Microscope

Ongoing Collaborative Project with Univ. of Valencia



Open set-up microscope in the CIRL at the UoM



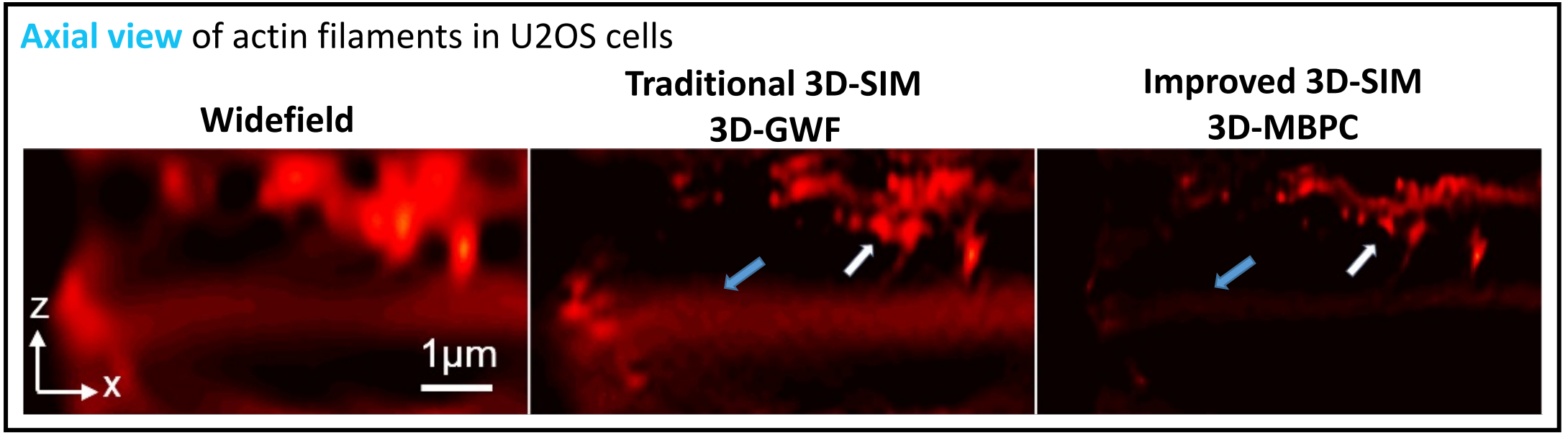
CIRL Computational Imaging Research Laboratory

Gimeno-Gomez, A., Van, C. T. S., Dajkhosh, S. P., Preza, C., Barreiro-Hervas, J. C. and. Saavedra, G., "Structured illumination microscopy by use of a spatially incoherent source with arbitrary shape," *Focus on Microscopy*, 2022.

Motivation: Improve performance of 3D Structured illumination microscopy (3D-SIM)

Computational methods have a direct impact on performance.

Goal: Develop robust **3D model-based with positivity constraint (3D-MBPC) restoration** method to improve resolution with reduced data.

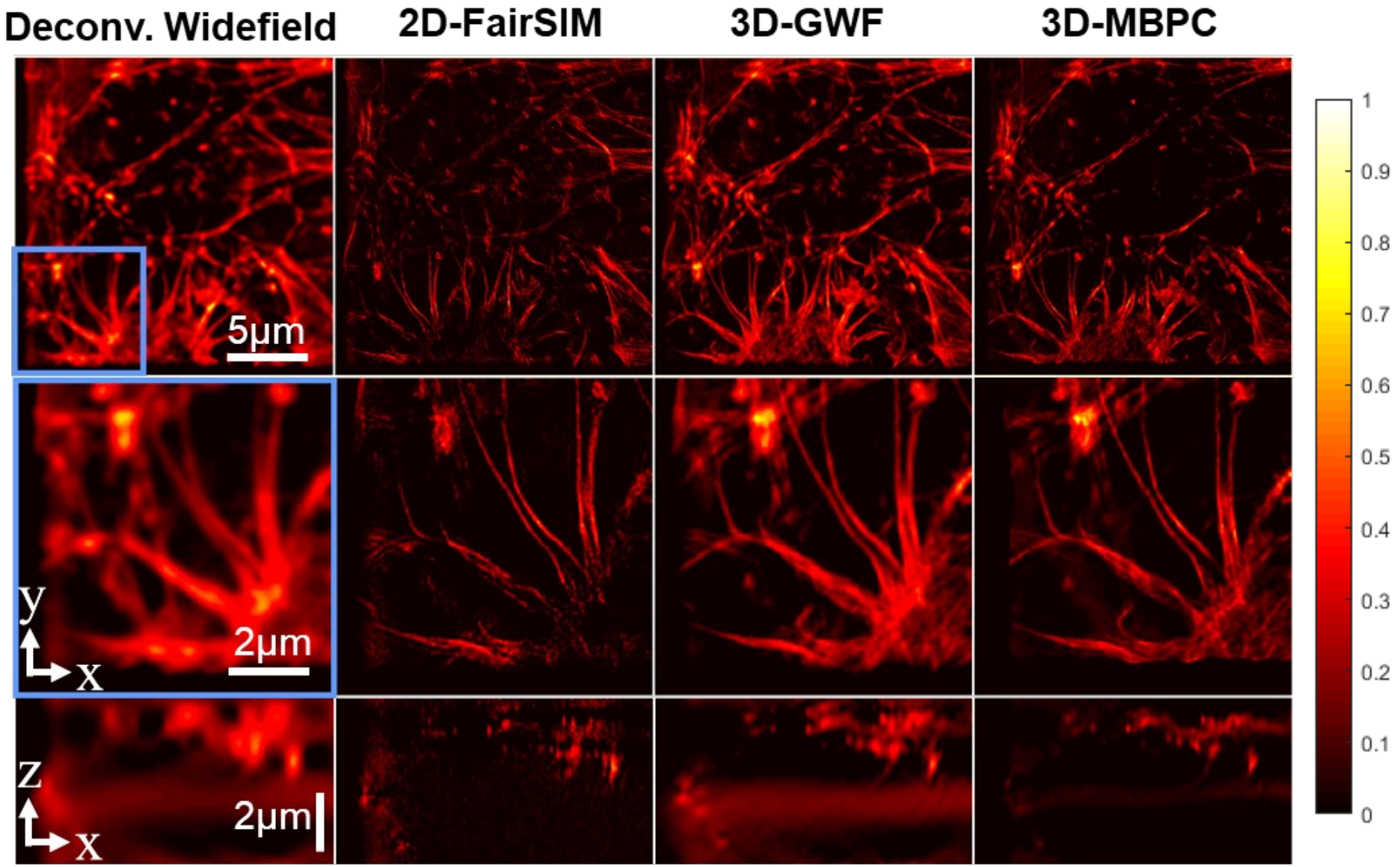


Sample: Actin filaments in U2OS cells labelled with Phalloidin-Atto488; Lens: 60x/1.42 NA oil

C. T. S Van and C. Preza, Biomedical Optics Express 12(1) (2021)

CIRL Computational Imaging Research Laboratory

Improved 3D-SIM restoration with 3D-MBPC method



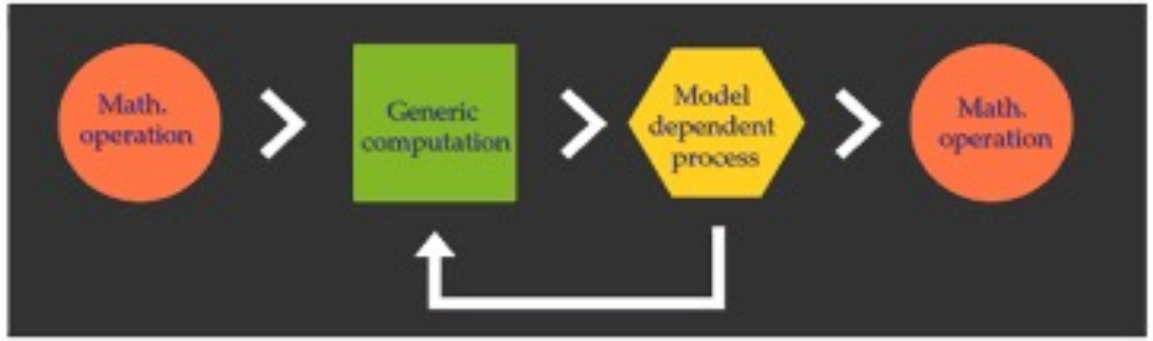
Sample: Actin filaments in U2OS cells labelled with Phalloidin-Atto488; Lens: 60x/1.42 NA oil;

C. T. S Van and C. Preza, Biomedical Optics Express 12(1) (2021)

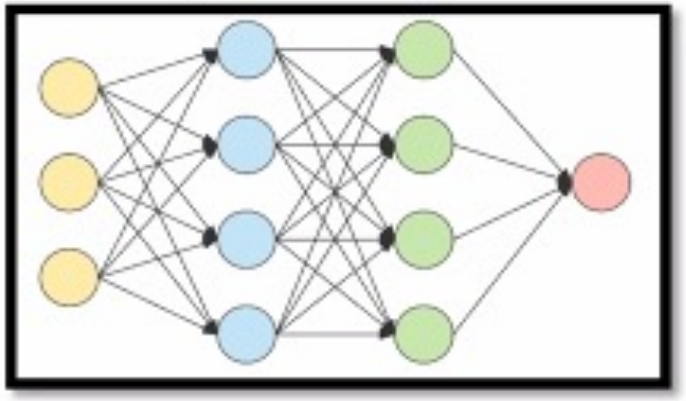
CIRL Computational Imaging Research Laboratory

Model-Based Deep Learning

› Model-based signal processing:



› Deep learning:



› How to combine?

1. Integrate model-based algorithms into deep networks

Deep unfolding / unrolling

2. Integrate deep networks into model-based algorithms

Data-driven hybrid algorithms

Slide courtesy of Dr. Yonina Eldar, Weizmann Institute of Science, Israel

NSF Funding Mechanisms and proposal idea

- NSF BIO
  - Programs: Division of Biological Infrastructure (DBI)
    - Infrastructure Innovation for Biological Research (Innovation)
- National Science Foundation Research Traineeship (NRT) Program
  - seeks proposals that explore ways for graduate students in research-based master's and doctoral degree programs to develop the skills, knowledge, and competencies needed to pursue a range of STEM careers.

NRT Proposal in Imaging Science?

Imaging Science is an interdisciplinary academic discipline that broadly addresses the design and optimization of imaging systems and the extraction of information from images. It builds on contributions from traditional fields including biomedical engineering, electrical engineering, and computer science, as well as from physics, applied mathematics, biology, and chemistry.

CIRL Computational Imaging Research Laboratory

Imaging/Sensing Instrumentation Opportunities

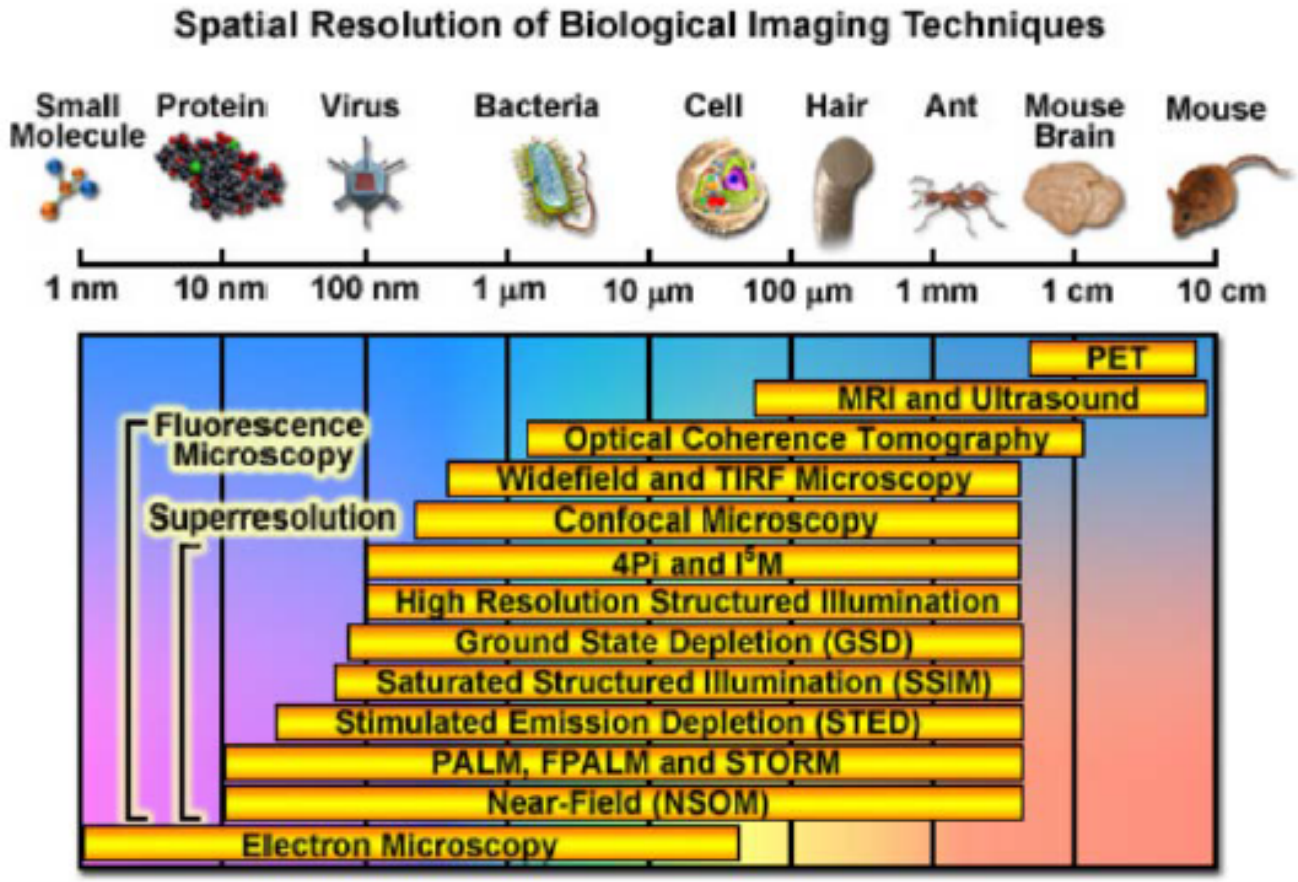
Agenda

1. Innovations in instrumentation

2. Research-based Opportunities

Innovations in instrumentation

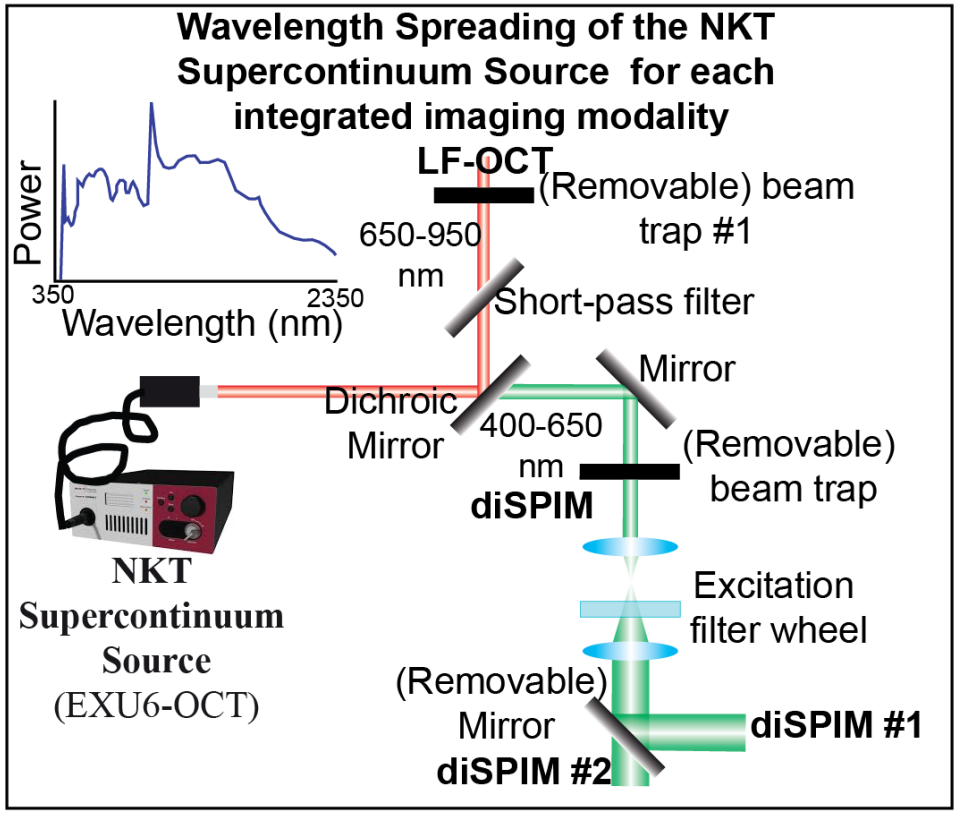
Overcome the tradeoff between different imaging modalities

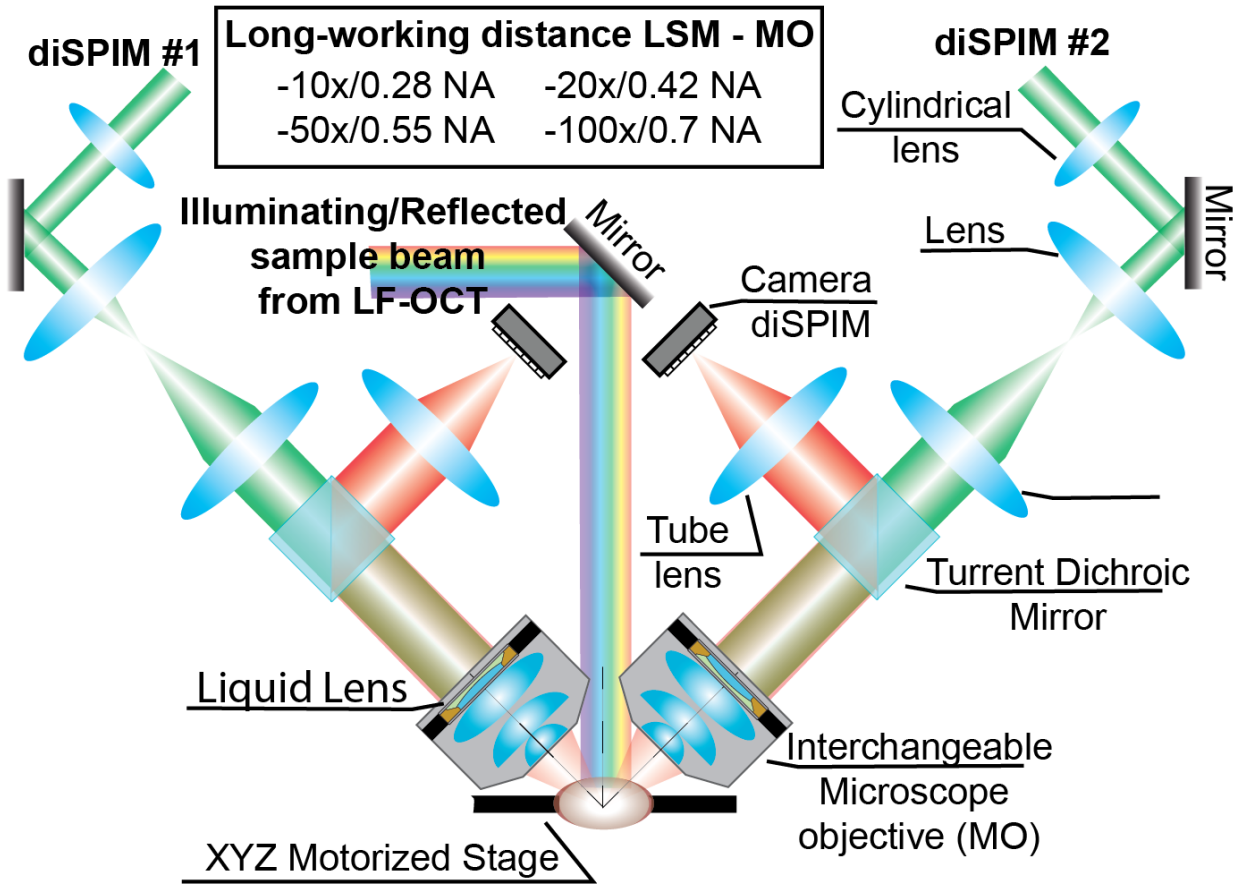


Graphic from http://zeiss-campus.magnet.fsu.edu/

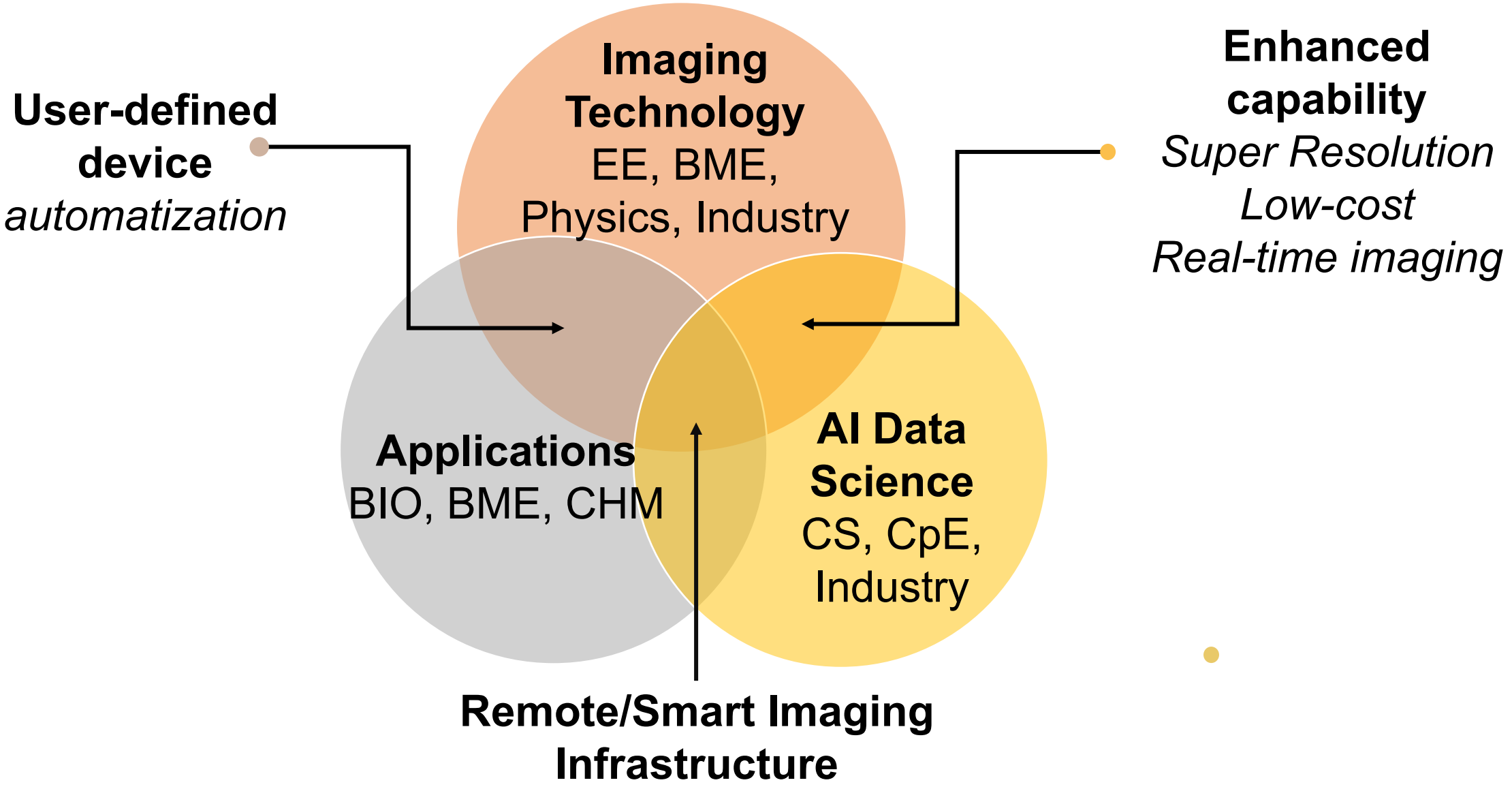
Innovations in instrumentation

Multimodal imaging platforms enables the observation of the same biological sample using different imaging capabilities – *new discoveries*



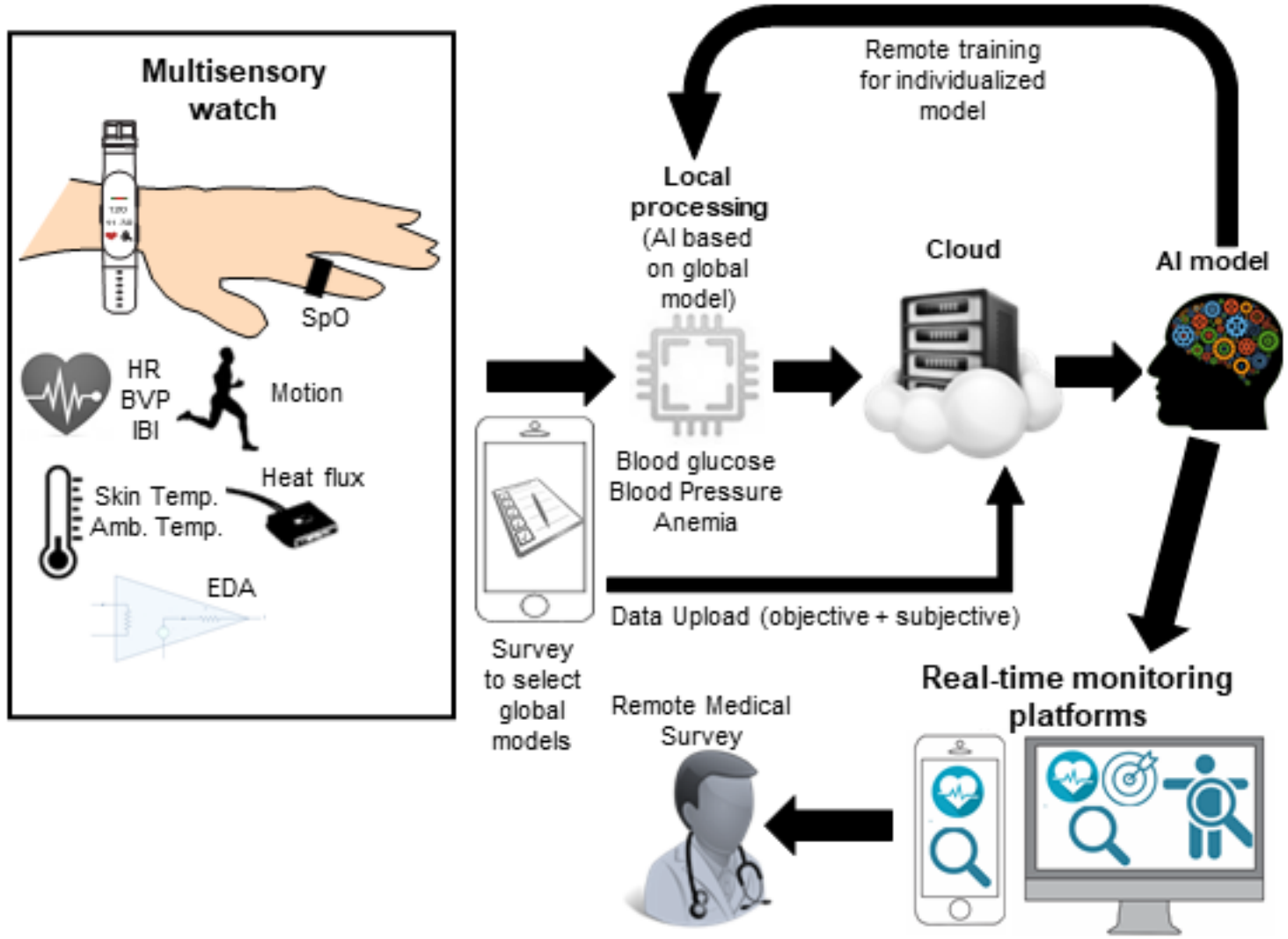


Integration with AI models

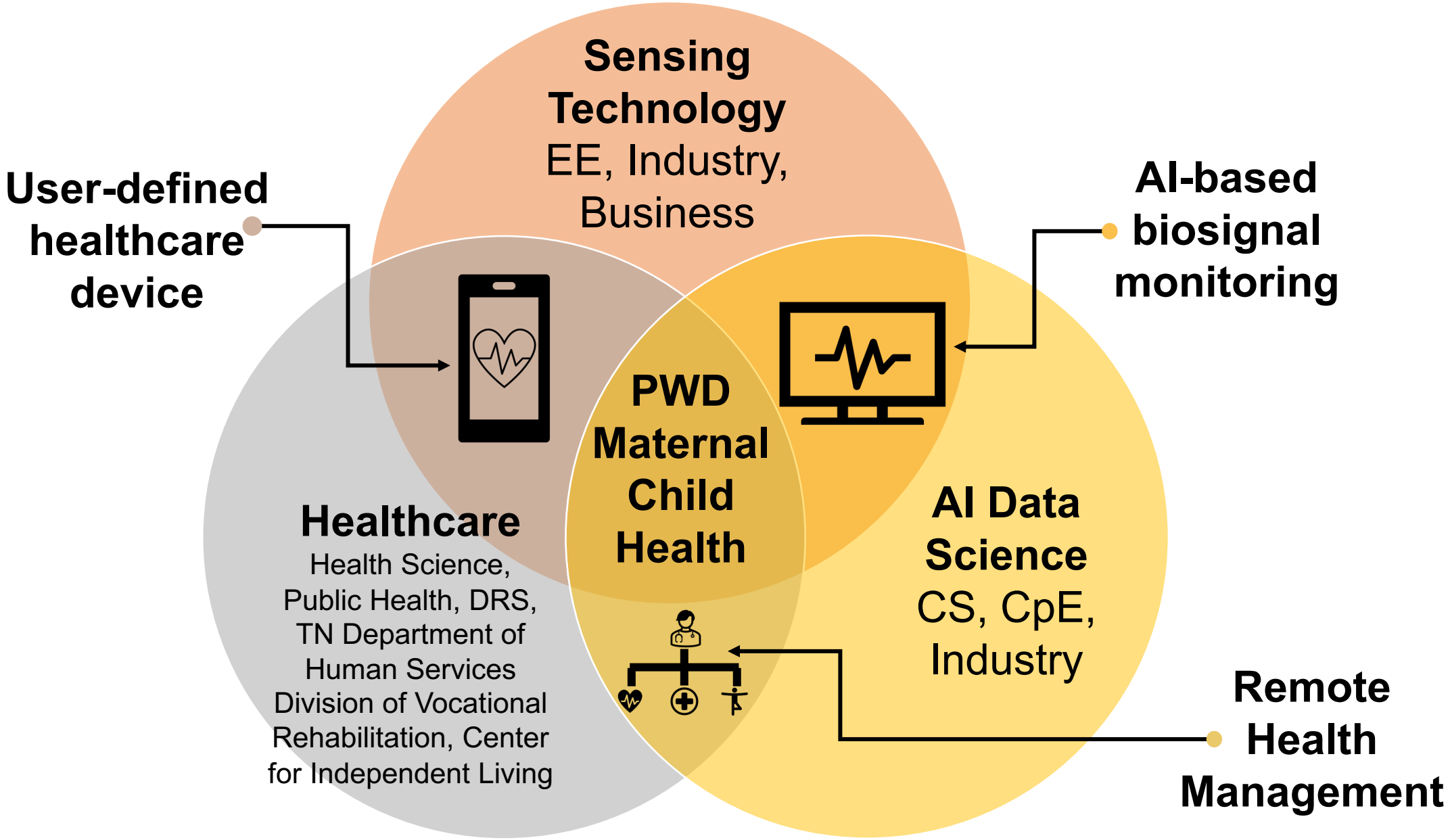


Innovations in instrumentation

Multimodal wearable devices enables the real-time tracking and monitoring of an individual's health metrics



Integration with AI models



Research-based Opportunities

NSF MRI

NSF CDS&E

NSF – NIST B

NSF ECCS

NSF SCH

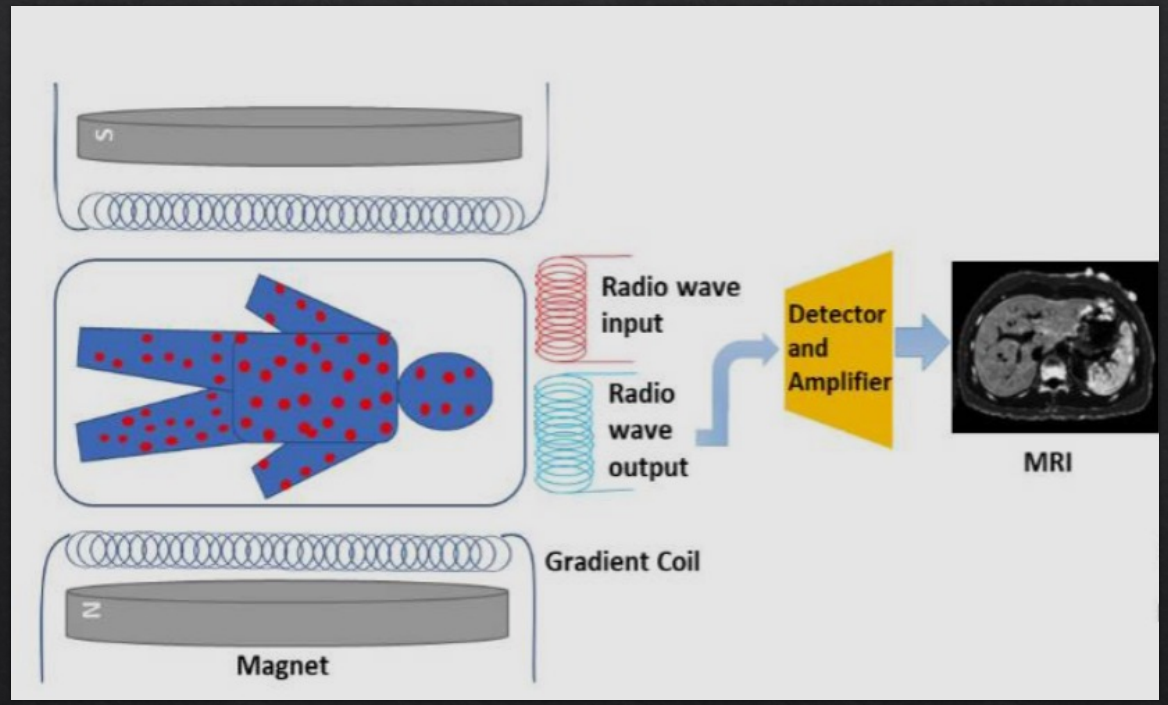
Warfighter-related funding opportunities

UofM infrastructure – Biological/Biomedical Imaging Center?

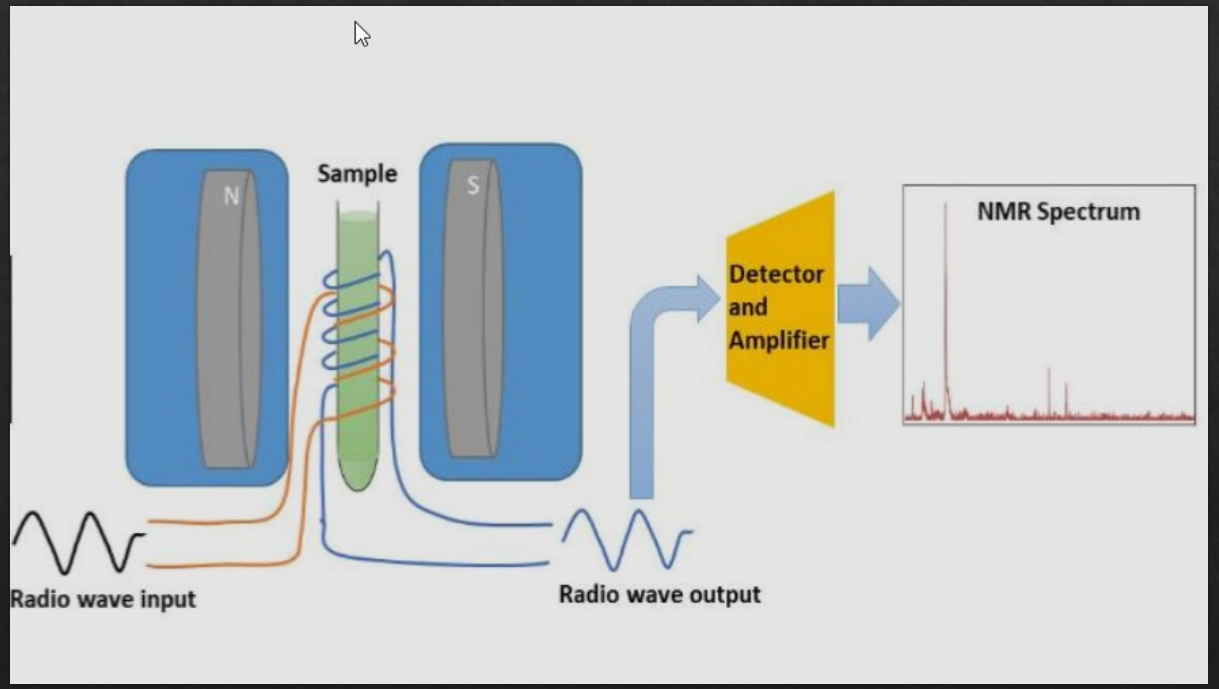
NSF Mid-scale Research Infrastructure-1

NSF Mid-scale Research Infrastructure-2

Magnetic Resonance Imaging & Spectroscopy Lab (MRISL)



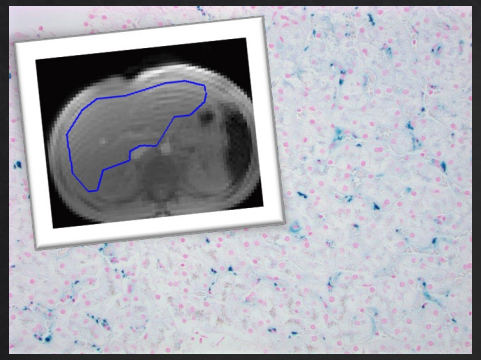
MRI



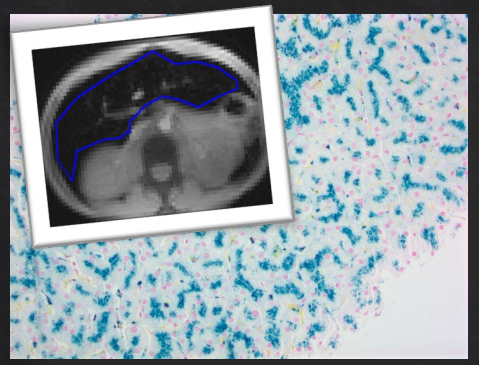
NMR

Assessment of Liver Iron Overload with MRI

- Measure iron in the body
  - Blood disorders, cancer
  - Biopsy is gold standard
  - MRI provides non-invasive measure



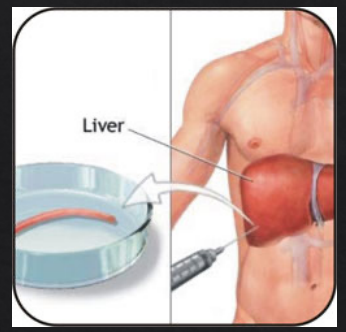
HIC: 4.2 mg Fe/g



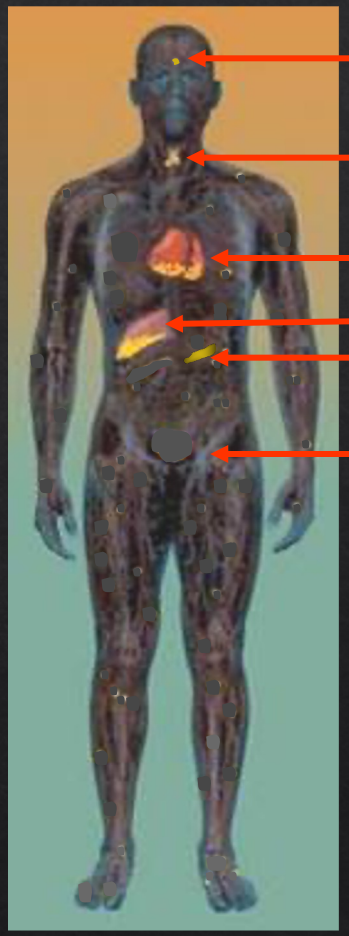
HIC: 21.3 mg Fe/g

Sickle cell anemia
Thalassemia
Cancer

1 unit of blood = 250 mg of exogenous iron!

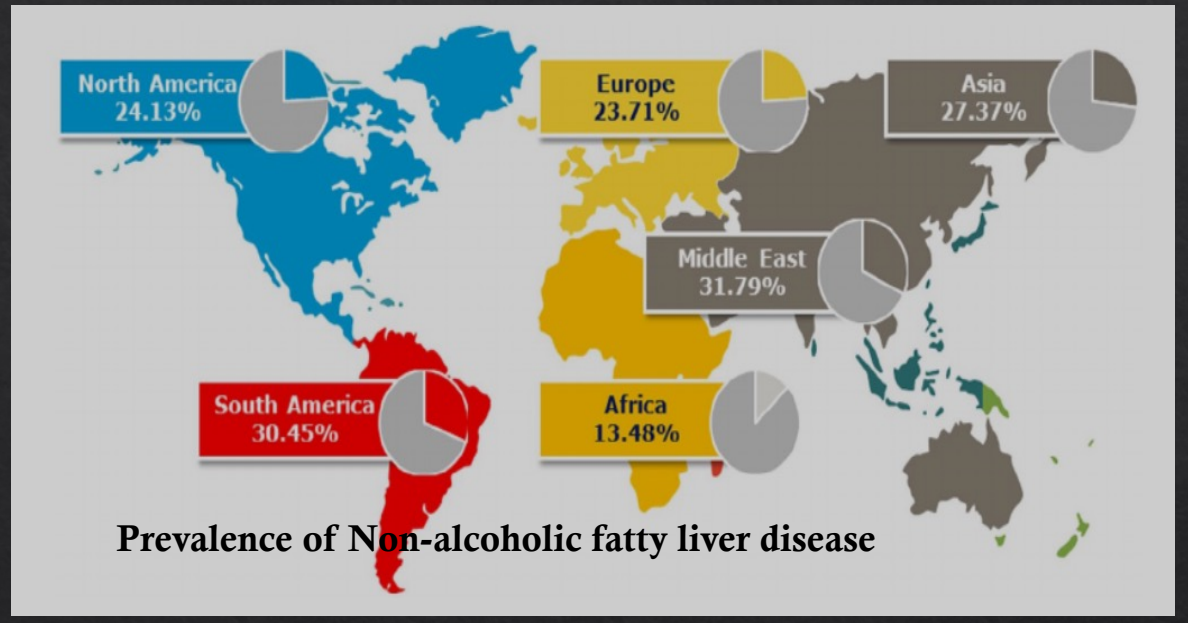


Uncontrolled iron loading of organs

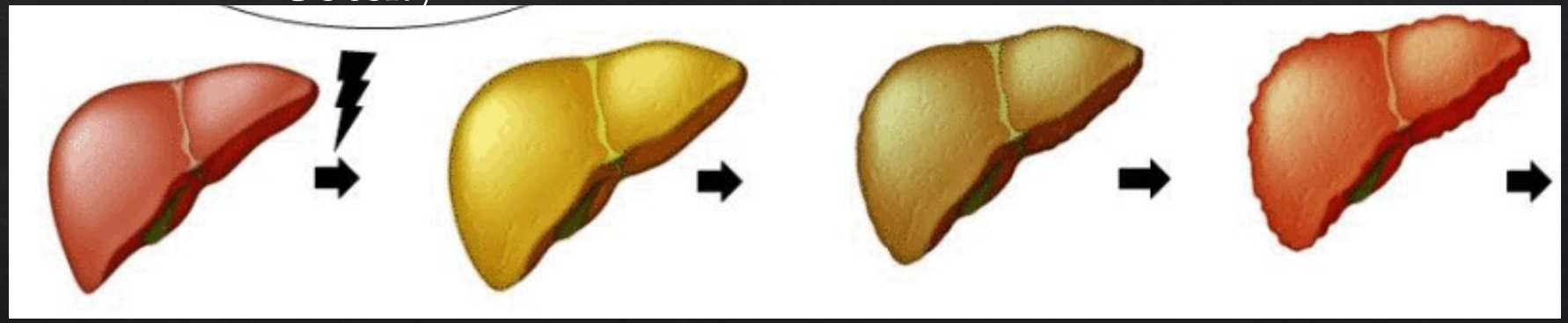


Assessment of Steatosis

- Measure **fat** in the liver
- Biopsy is gold standard
- MRI provides non-invasive measure
  - Sedentary lifestyle
  - High fat diet
  - Insulin resistance
  - Obesity



Prevalence of Non-alcoholic fatty liver disease



Normal Liver

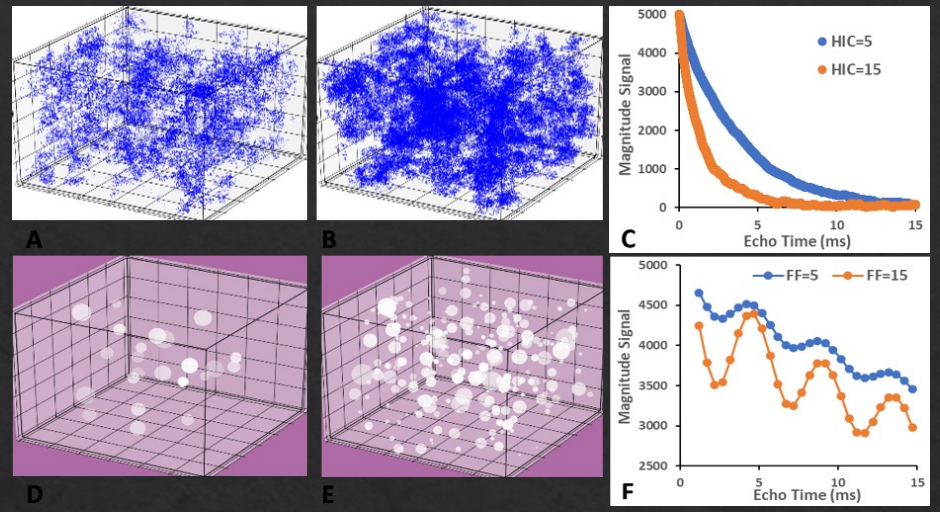
NAFL
"Simple Steatosis"

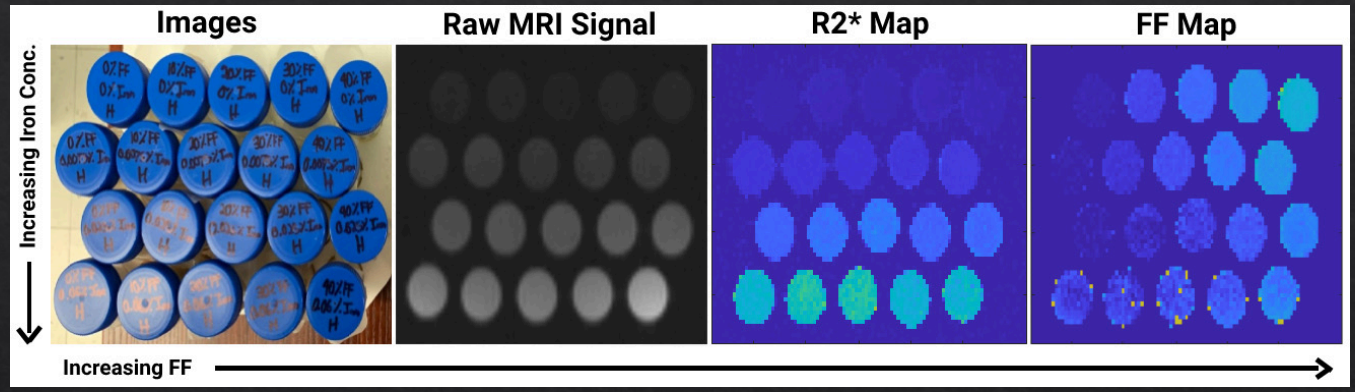
NASH

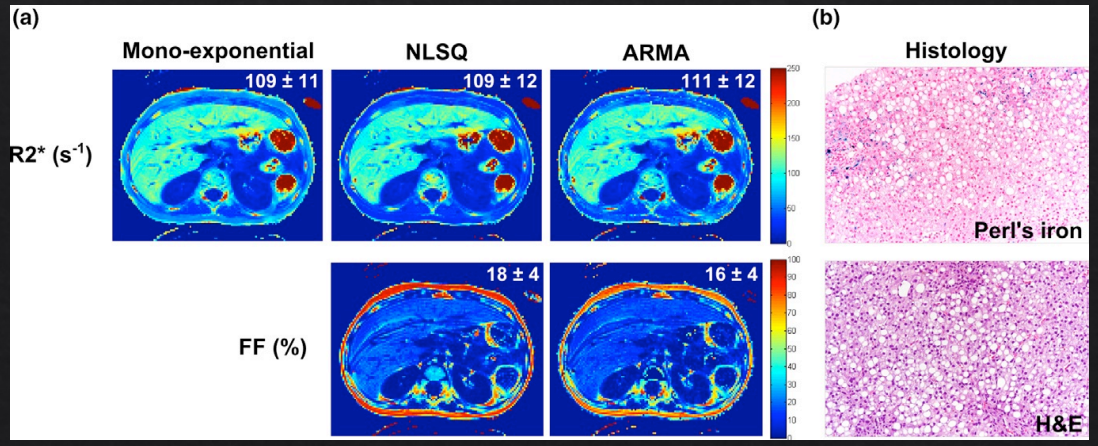
Cirrhosis

Current Projects

- **Develop MRI techniques**
  - Iron and Fat quantification
    - Simulations
    - Build Phantoms
    - Patients







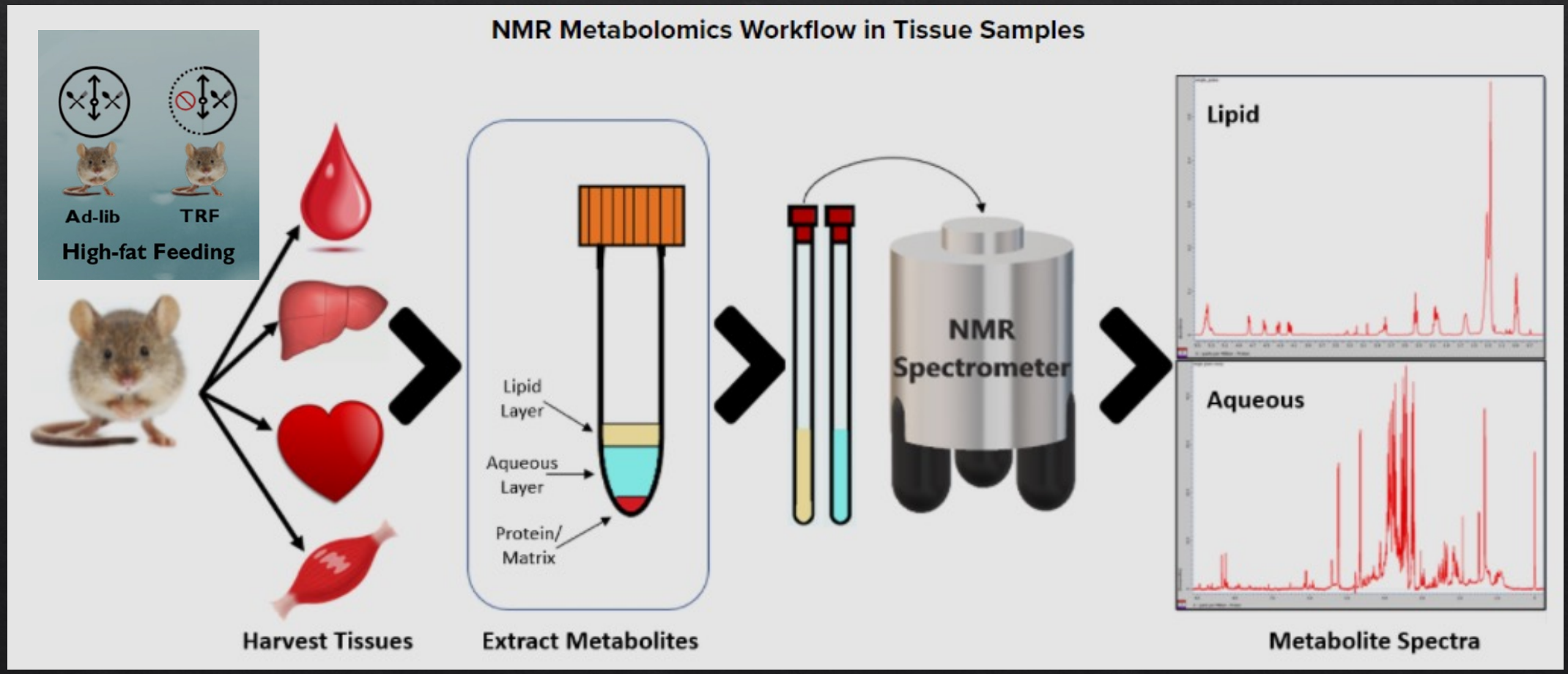
Funding: NIBIB, NIH Trailblazer (# 1R21EB031298-01)

St. Jude Children's Research Hospital
ALSAC • Danny Thomas, Founder

Northwell Health®

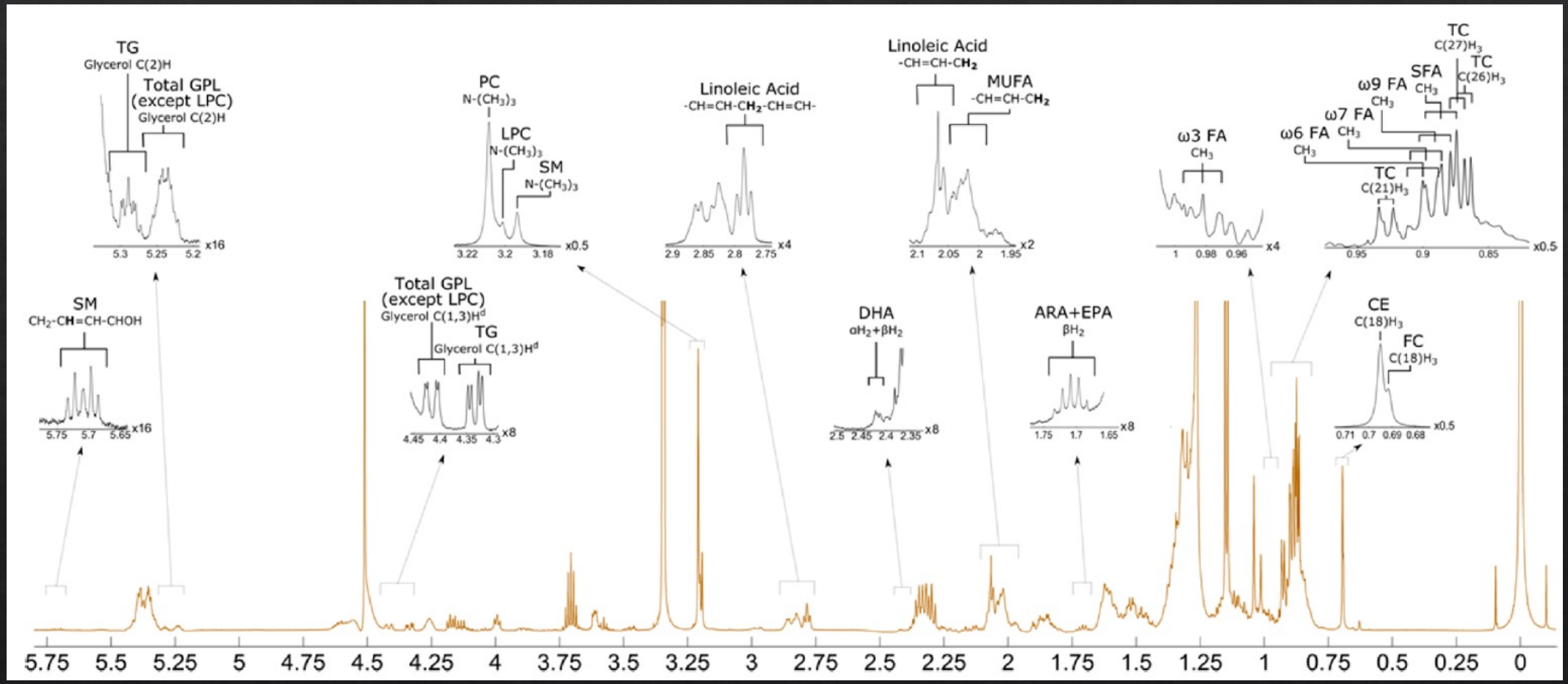
Quantitative NMR Metabolomics

- To determine early metabolic biomarkers for combatting obesity and metabolic syndrome through nutritional metabolomics



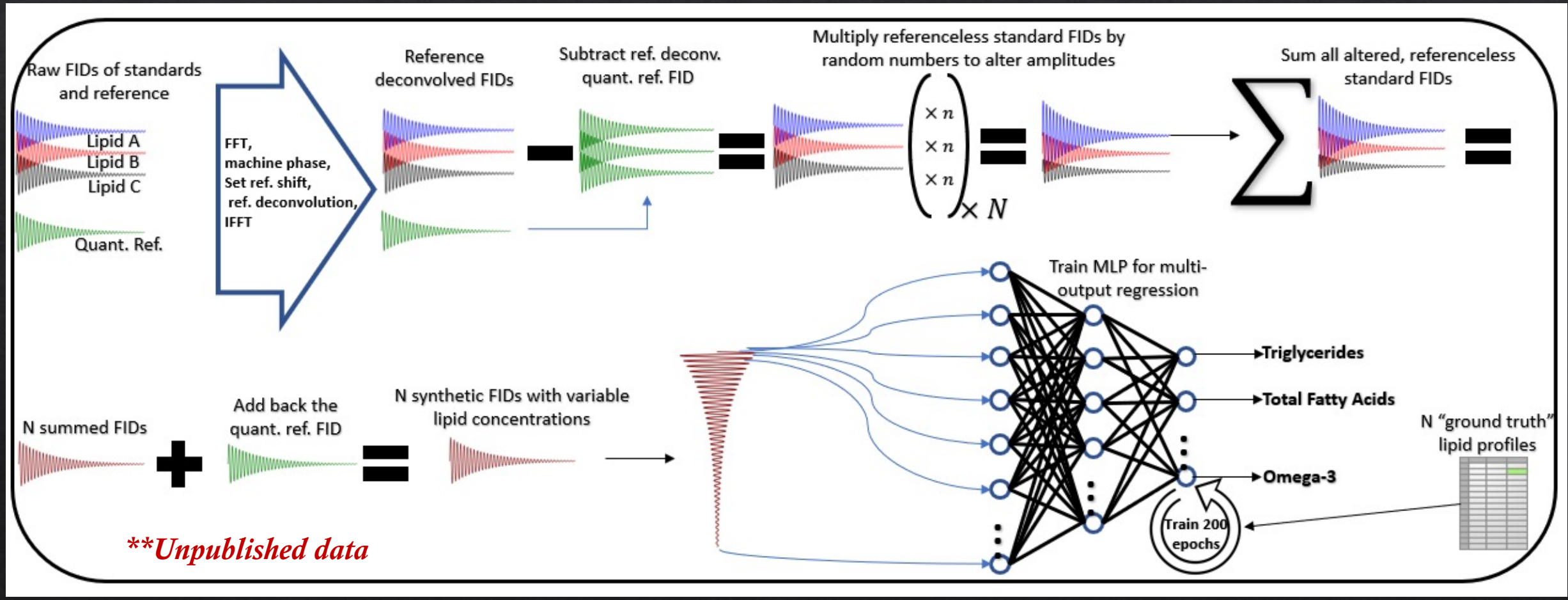
Quantitative NMR Metabolomics

- Quantify lipids & aqueous metabolites



https://www.memphis.edu/mrisl/

Neural Network for Lipid Profile Determination from NMR Data



NSF CAREER Award - Open-Access, Real-Time High-Throughput Metabolomics for High-Field and Benchtop NMR for Biological Inquiry

Acknowledgements

- UofM Collaborators


Eddie Jacobs, PhD


Marie van der Merwe, PhD


Melissa Puppa, PhD


Brandt Pence, PhD

- Department of Chemistry
  - JEOL NMR spectrometer

- Outside Collaborators


Sanjaya Satapathy, MD


Cara Morin, MD, PhD


Zachary Abramson, MD

Funding Sources:

- NIBIB, NIH Trailblazer (# 1R21EB031298-01)
- NSF 2023 CAREER Award
  DBI, Innovation - Bioinformatics

Ultrasound Devices & Systems Research

Imaging & Instrumentation Innovation

Carl Herickhoff, Ph.D.

Biomedical Engineering, University of Memphis

carl.herickhoff@memphis.edu memphis.edu/ultrasound

Current Research Thrusts

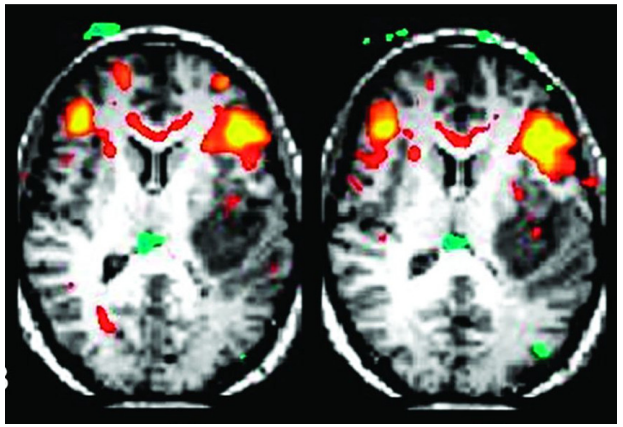
Brain Ultrasound (Transcranial)

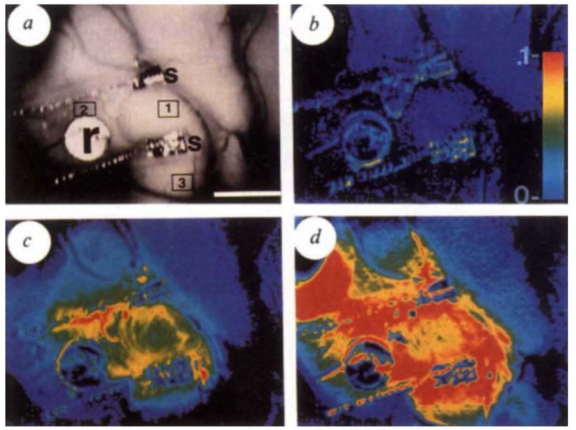
- Super-Resolution 3D Functional Imaging
- Rapid Stroke Assessment

Operator-Independent Ultrasound

- Autonomous 3D Breast Cancer Screening
- Quantitative Body Scanner

Brain Ultrasound





(Mace, et al. ‘11)

(Problem)

Want hi-res 3D brain mapping

Skull ↓ image quality

(Solution)

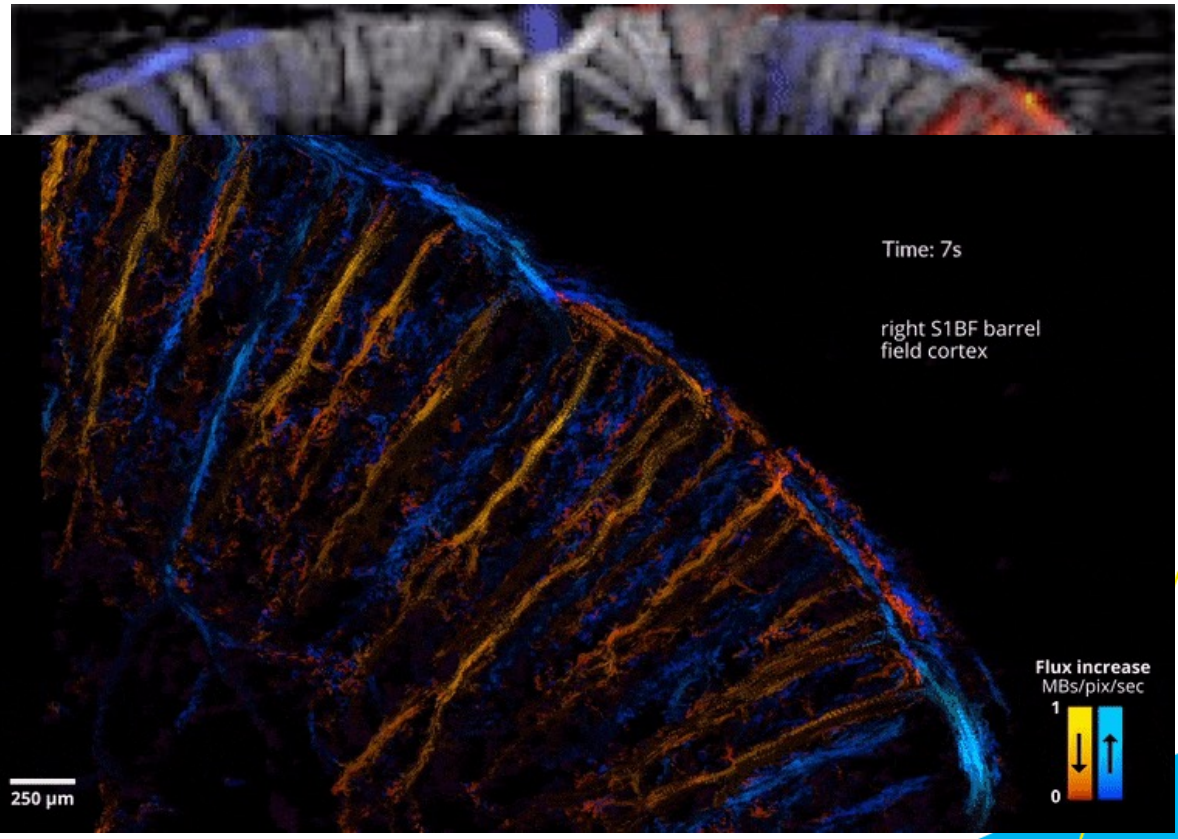
Ultrafast acquisition

Dual-freq. 2D array

µBubble superharmonics

New tracking, aberr. corr.

→ neuroscience research tool



(Renaudin, et al. ‘22)

Brain Ultrasound

(Problem)

Stroke: clot or bleed?? -ASAP!

Skull: distorts/scatters/atten.'s

…where's "window" for TCD?

(Solution)

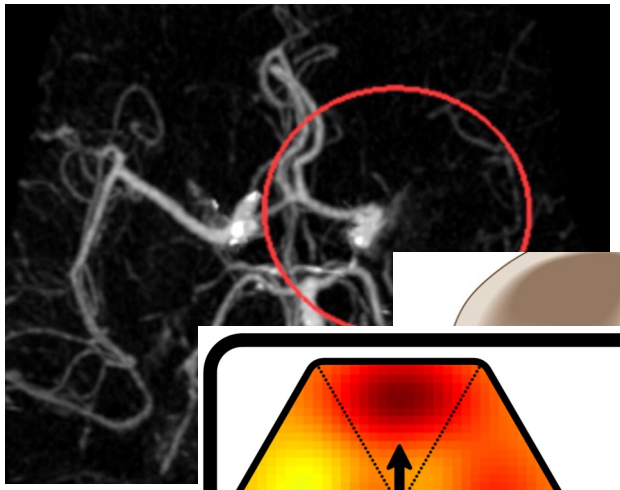
Acoustically characterize skull

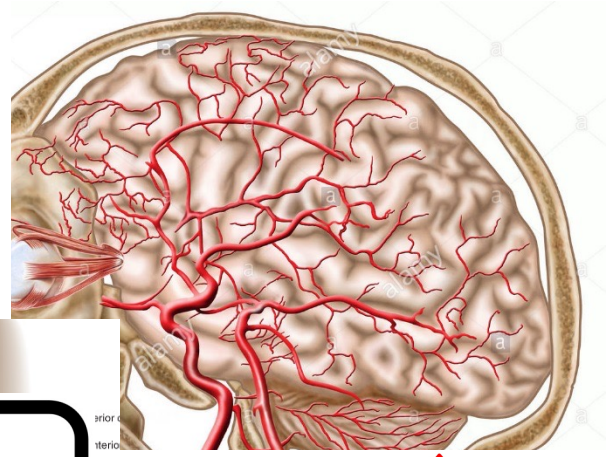
(incl. internal layers) → model

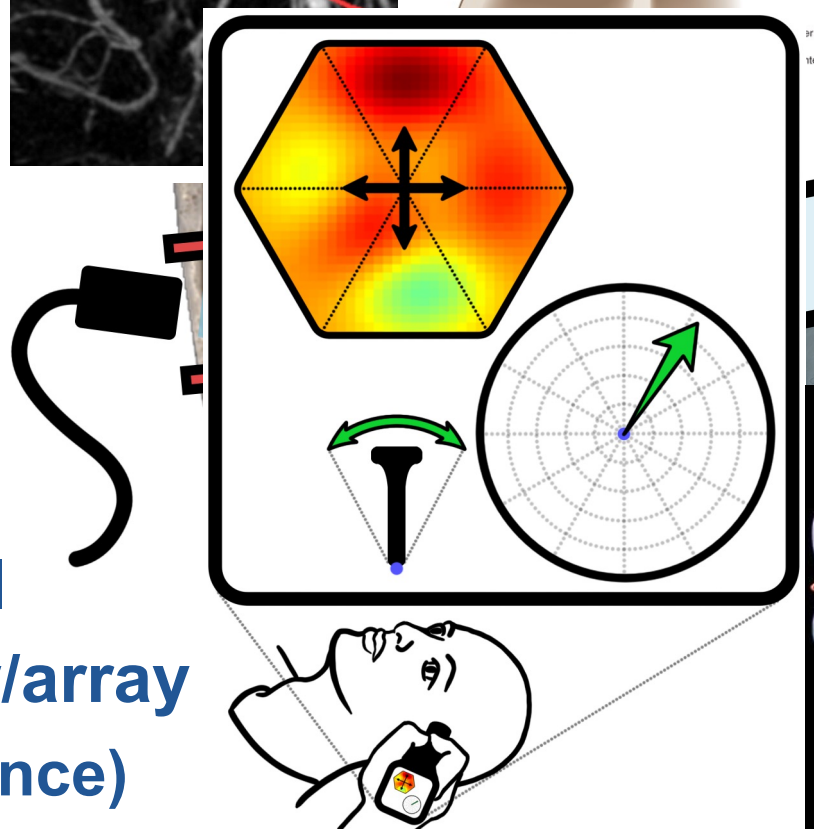
Analyze shallow echo trends w/array

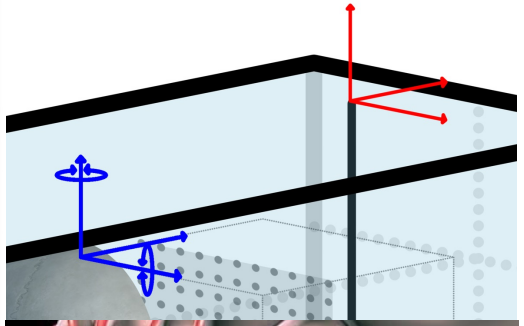
→ window-finder (user guidance)

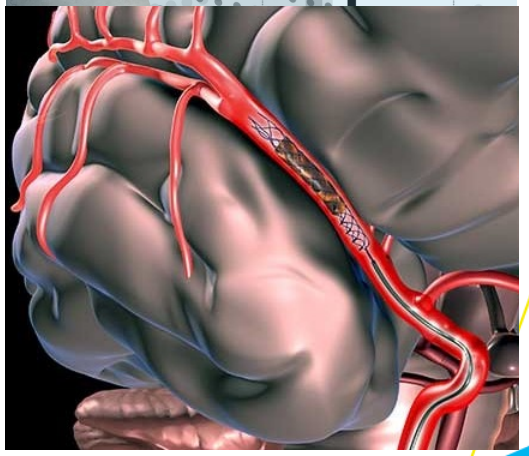
Optimize simple array design → easy rapid triage by paramedics





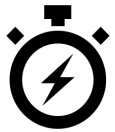






High-level Pros/Cons of Ultrasound

Pros: **Safe** (no X-rays or high mag. field), **Fast** ('live' 30 frames/sec), **Cheap** ($200k…$3k), **Portable** (handhelds → phone/tablet)

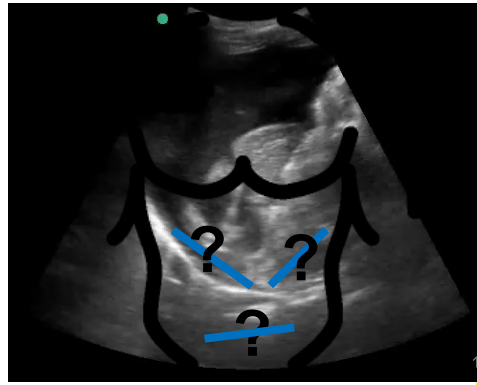



Cons:

(1) ***The Humans!*** (operator variability, reproducibility …cost)

handheld probe → no std/fixed reference frame (orient'n=?)

2D planar images → sparse sampling of 3D vol. of interest



(2) ***Not Quantitative!*** (echo 'brightness' from many effects)

assumes uniform sound prop. speed (all soft tissue = 1540 m/s)

attenuation: can't tell where, how much (vary gain w/depth)

Autonomous Robotic Multi-modal 3D US to Reduce Breast Cancer Disparity

(Problem)

Breast Cancer Mortality: *41% higher* in Black women

Mammograms: poor sensitivity in dense breasts (>50

Key: Efficacy, Affordability, & ACCESS to Screening

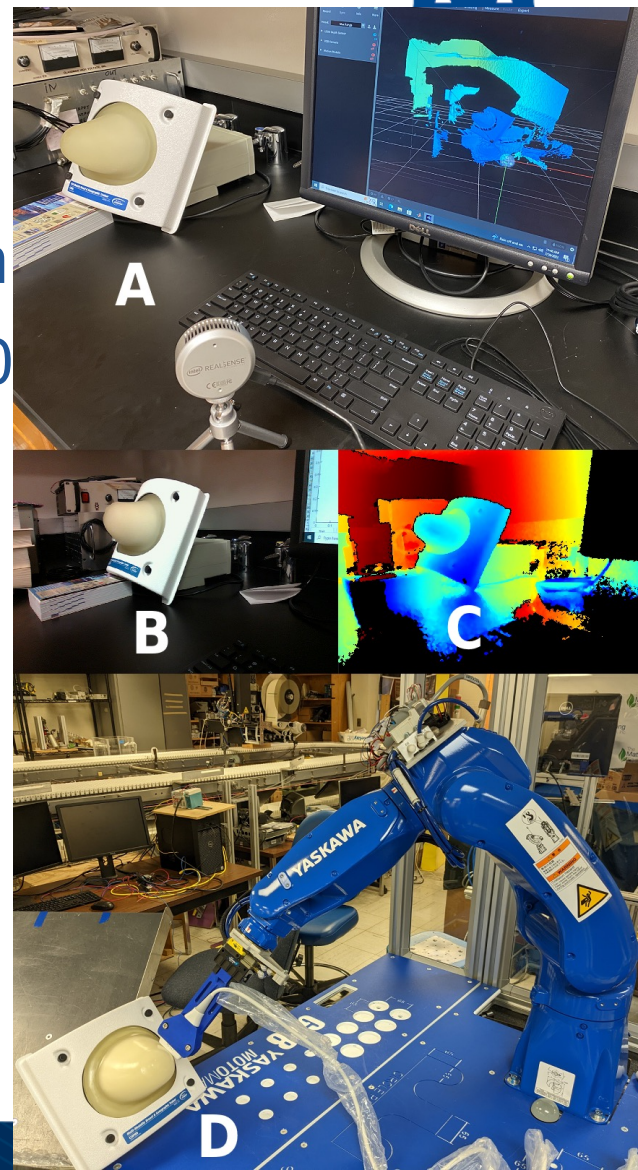
(Solution)

Computer Vision (ranging cameras)

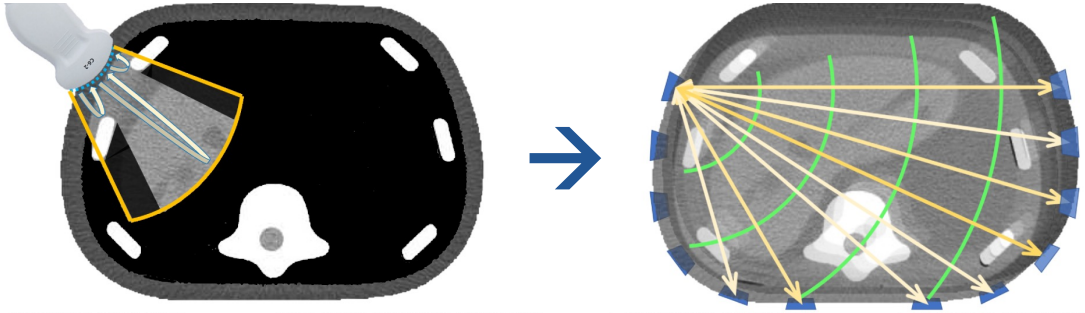
A.I.-trained Robots → safe, adaptable 3D acq's

3-in-1: structure/stiffness/flow (+ A.I. analysis)

→ sensitive, accurate, accessible screening



US Body Scanner



(Problem)

Want quantitative x-section images

…new algorithms, scalable HW/sys

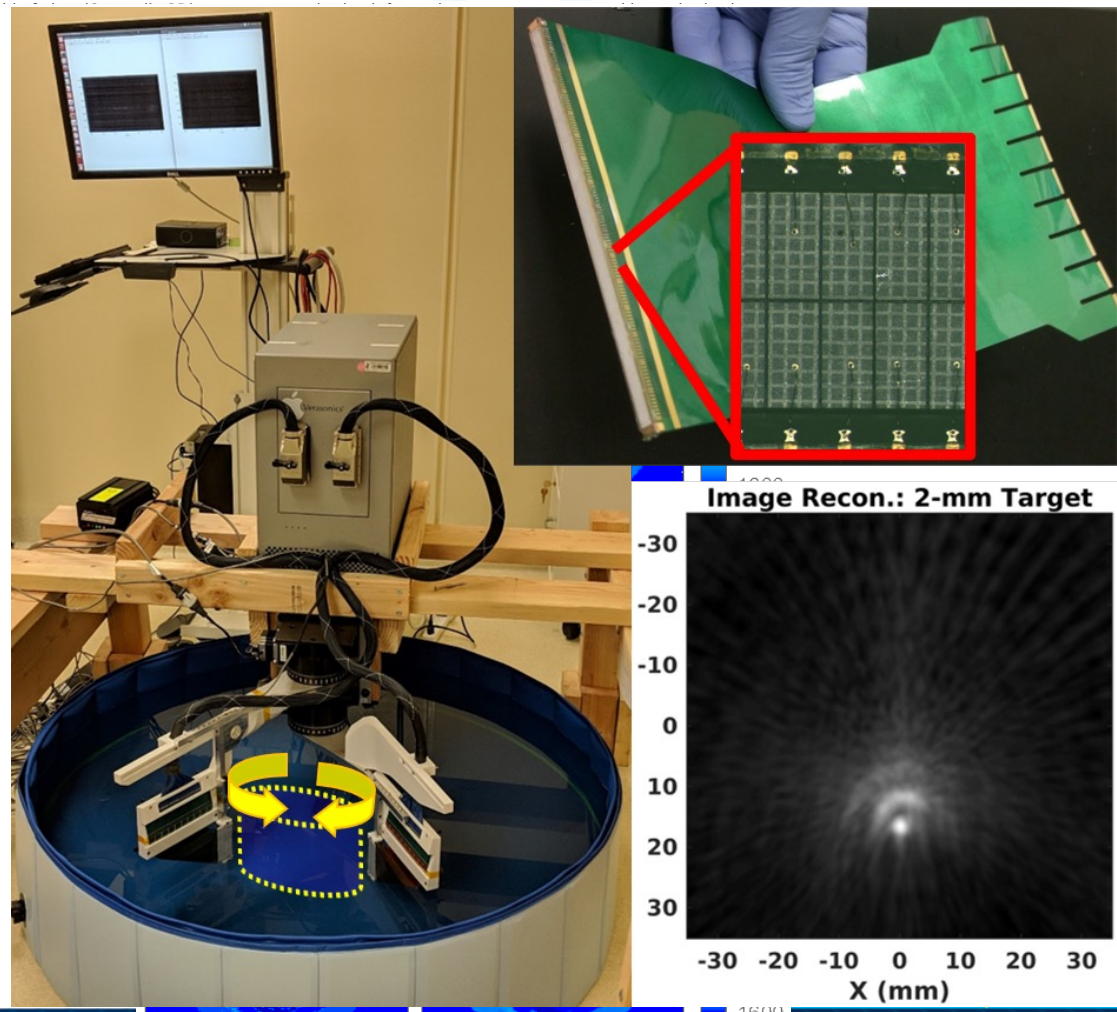
(Solution)

A.I. → sound speed, atten. (FWI)

Hardware → add. mnfct, modular

Sys/Data → integ/distrb'd architecture

→ high-res, tomo US (>CT 4 ped's)



Future Dir's, Funding & Collab. Opp's

Transcranial Doppler & Neuroimaging

Low-cost Autonomous 3D US Systems

for screenings (cancer, NAFLD, aneurysm) & emergency/military settings

US Body Scanner

acq & recon algorithms, scalable arrays & system electronics

Custom US Transducer Array Design & Fabrication

(incl. catheters) for elasticity, flow; also therapy (ablation, drug deliv.)

Research Funding - Federal

NIH: Nat'l Inst. of Biomedical Imaging & Bioengineering (NIBIB)

R01 (4-5 yrs, ~$500k/yr), R21 Trailblazer (New/ESI; 3 yrs, $400k/yr), R15 AREA (3 yrs, $100k/yr), R03 (2 yrs, $50k/yr) …add'l RFAs (e.g., BRAIN)

NSF: Dir. for Biol. Sciences (BIO), Div. of Biol. Infrastructure (DBI)

Infrastructure Innovation for Biological Research

Instrument Development for " " " " " " (IDBR)

Dept of Defense

(BCRP) Breakthrough Award: BTA1 ($450k/3yrs), BTA2 ($1M/3yrs), BTA3 ($4M/4yrs), BTA4 ($15M/4yrs)

Research Funding - Foundations

American Heart Association (AHA)*

- Career Development Award ($230k/3yrs)
- Institutional Research Enhancement Award ($150k/2yrs)
- Transformational Project Award ($300k/3yrs)

West Cancer Foundation Initiative

- $10k Seed Grants (Equity, ↓Disparity)
- $250k/2yr Causes of Breast Cancer

Bright Focus Foundation

Glaucoma Foundation

Fight for Sight


Thank You

(Madhu’s Slides)