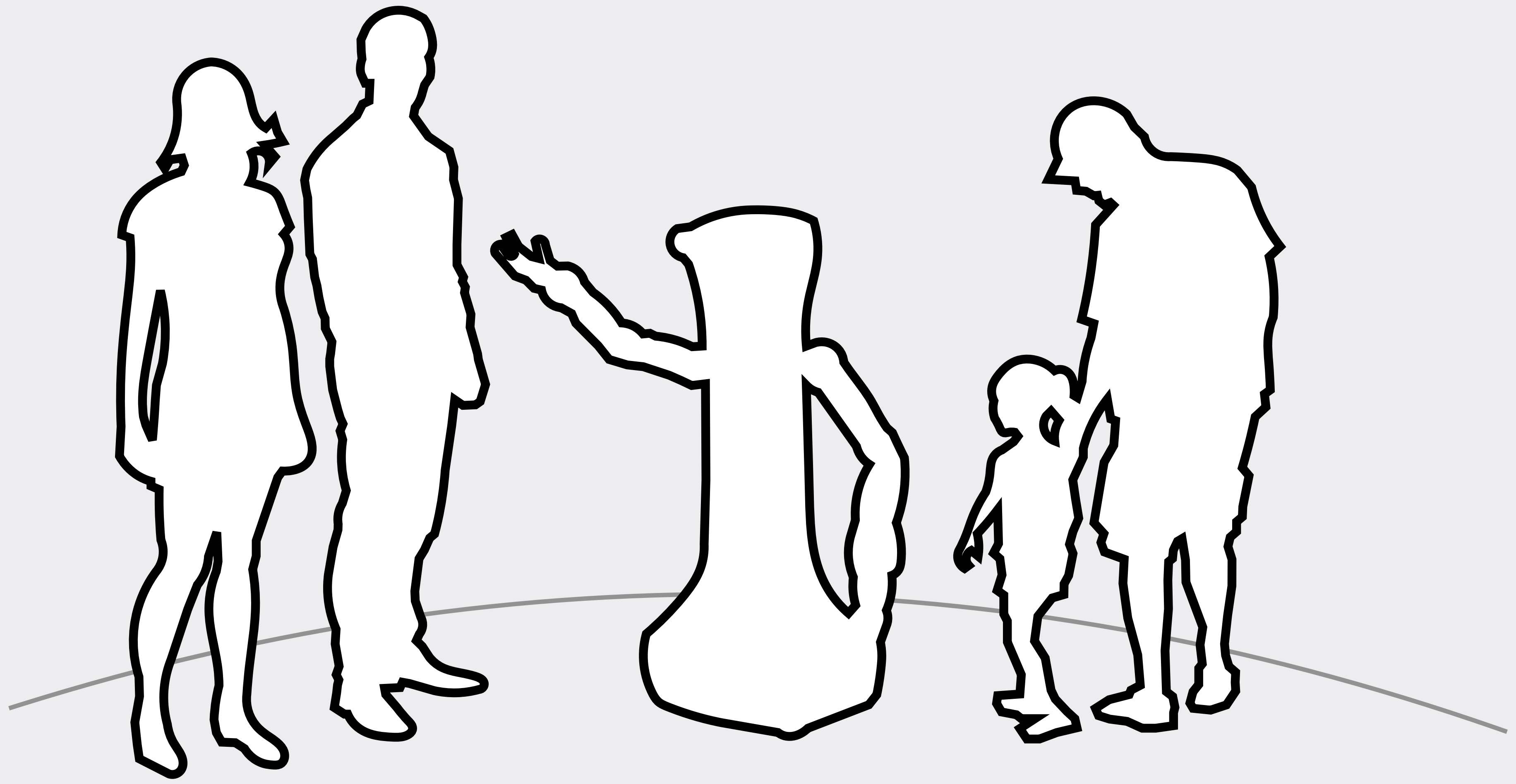
Do you want to help us advance Human-Robot Interaction?

We create social robots for complex human environments.



Marynel Vázquez

Assistant Professor, Yale Computer Science

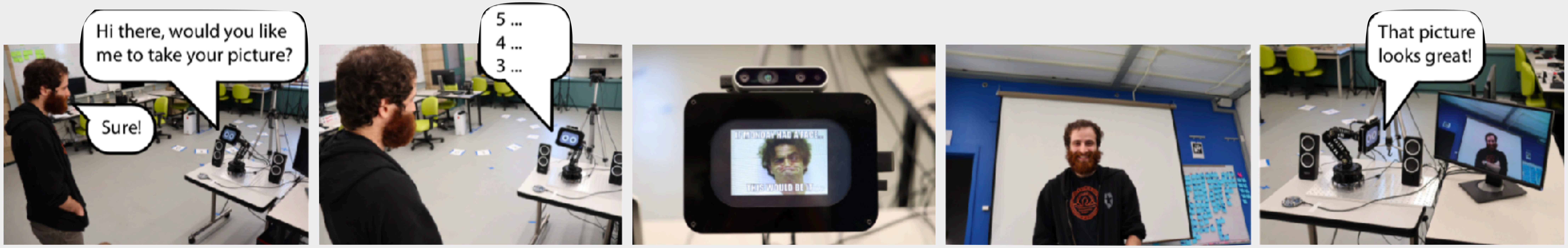
http://www.marynel.net

marynel.vazquez@yale.edu

Yale

INTERACTIVE MACHINES GROUP

Project 1. Shutter, the Robot Photographer



We are building a **social robot photographer**. The robot tells jokes to make people laugh while trying to take portrait pictures of them.

Yale

INTERACTIVE MACHINES GROUP

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Assistant Professor, Yale Computer Science
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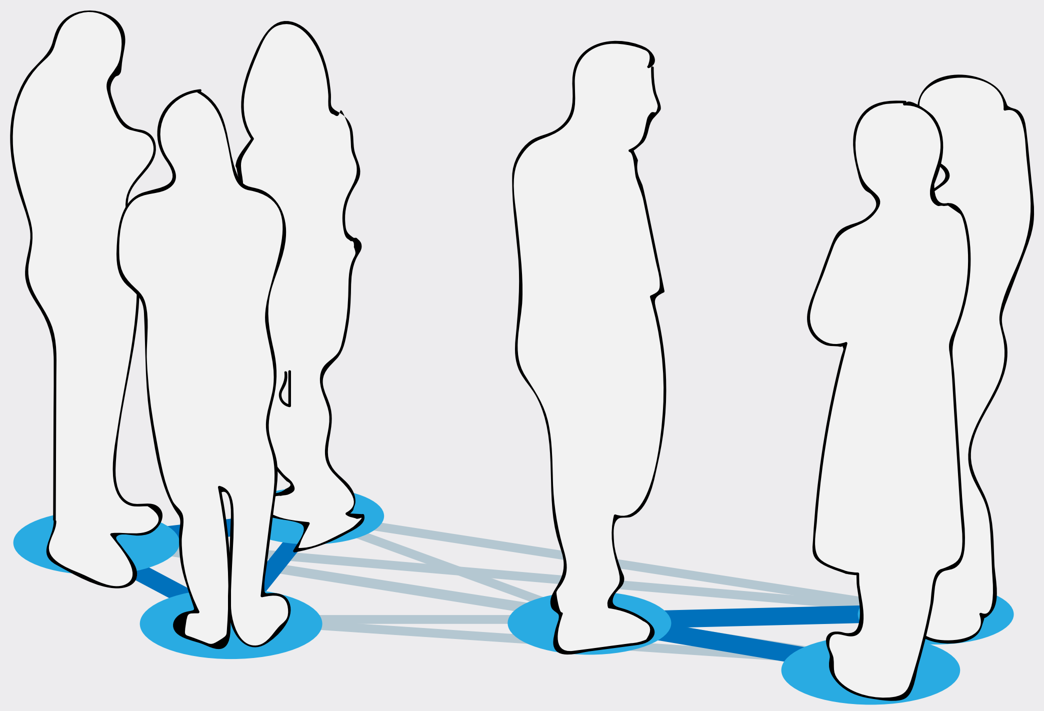
Project 2. Understanding Spatial Group Behavior

We are creating **models of spatial patterns of behavior** that are typical of social conversations. These models allow robots to predict who is conversing with whom in social settings.

Scene from the Coffee Break dataset



Node for an individual
Edge among two individuals
Edge connecting people in the same group

Yale

INTERACTIVE MACHINES GROUP

Marynel Vázquez
Assistant Professor, Yale Computer Science
http://www.marynel.net
marynel.vazquez@yale.edu

Contact us!

What can you do in the lab? Help us prototype robotic systems, conduct user experiments, and/or implement algorithms.

Mentoring: Direct supervision by Marynel and her graduate students. Weekly meetings.

Students: We are looking for 1-2 students.

Want to learn more? http://interactive-machines.com

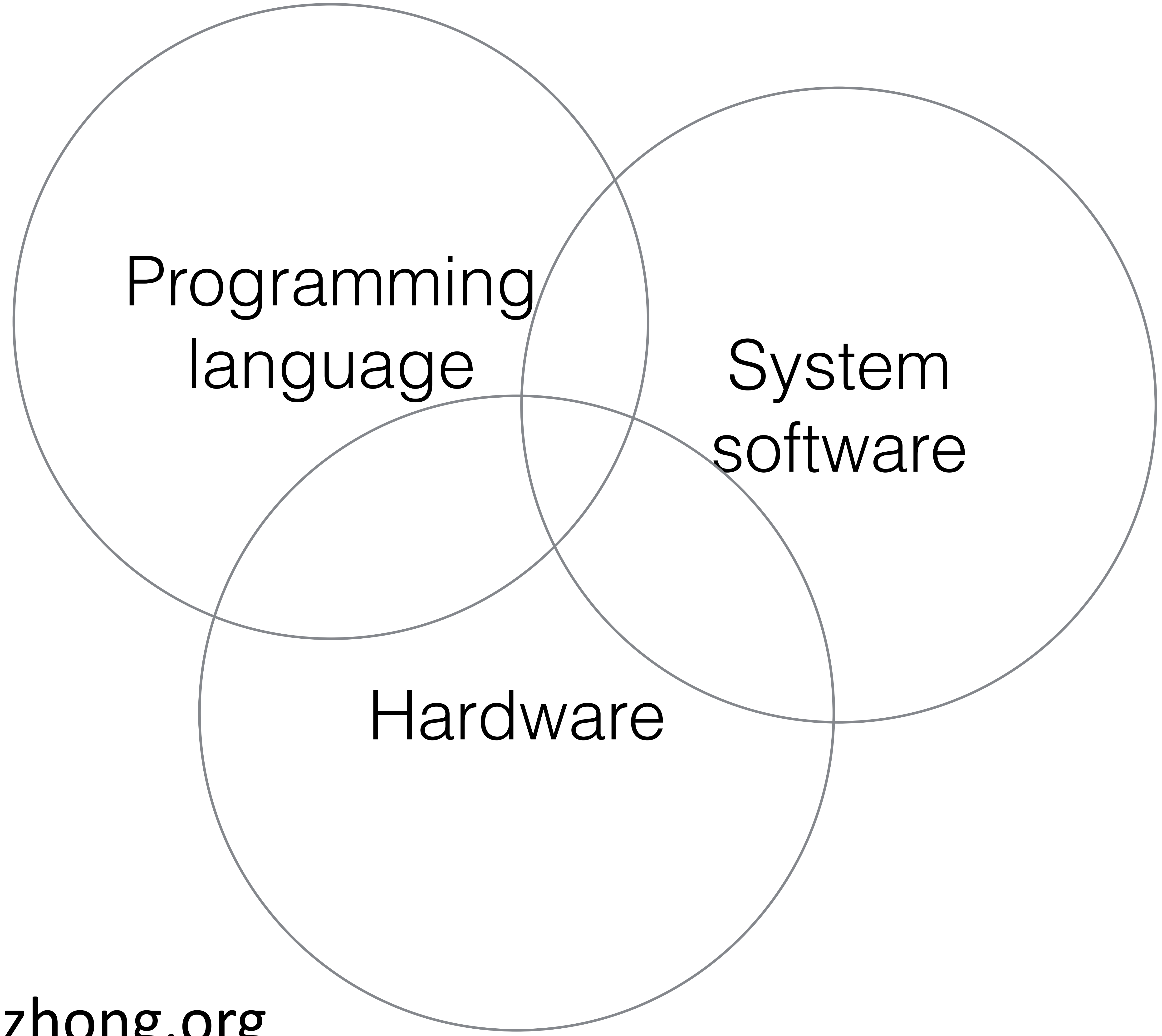
Yale

INTERACTIVE MACHINES GROUP

Marynel Vázquez
Assistant Professor, Yale Computer Science
http://www.marynel.net
marynel.vazquez@yale.edu

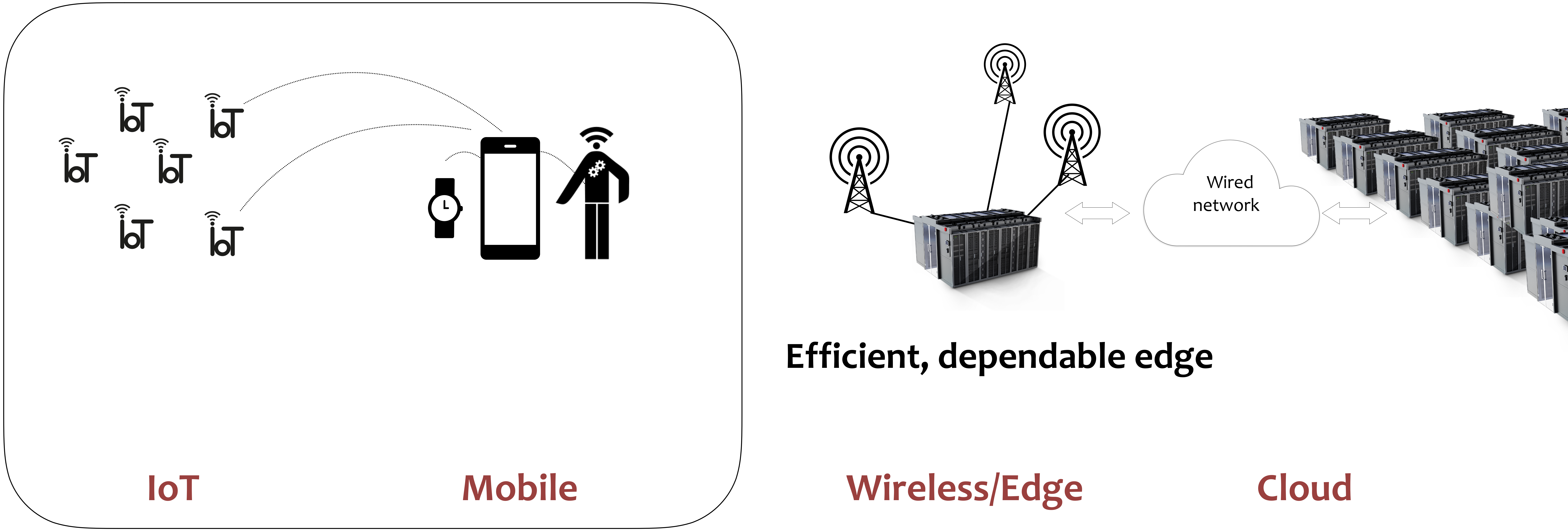
Yale Efficient Computing Lab

+



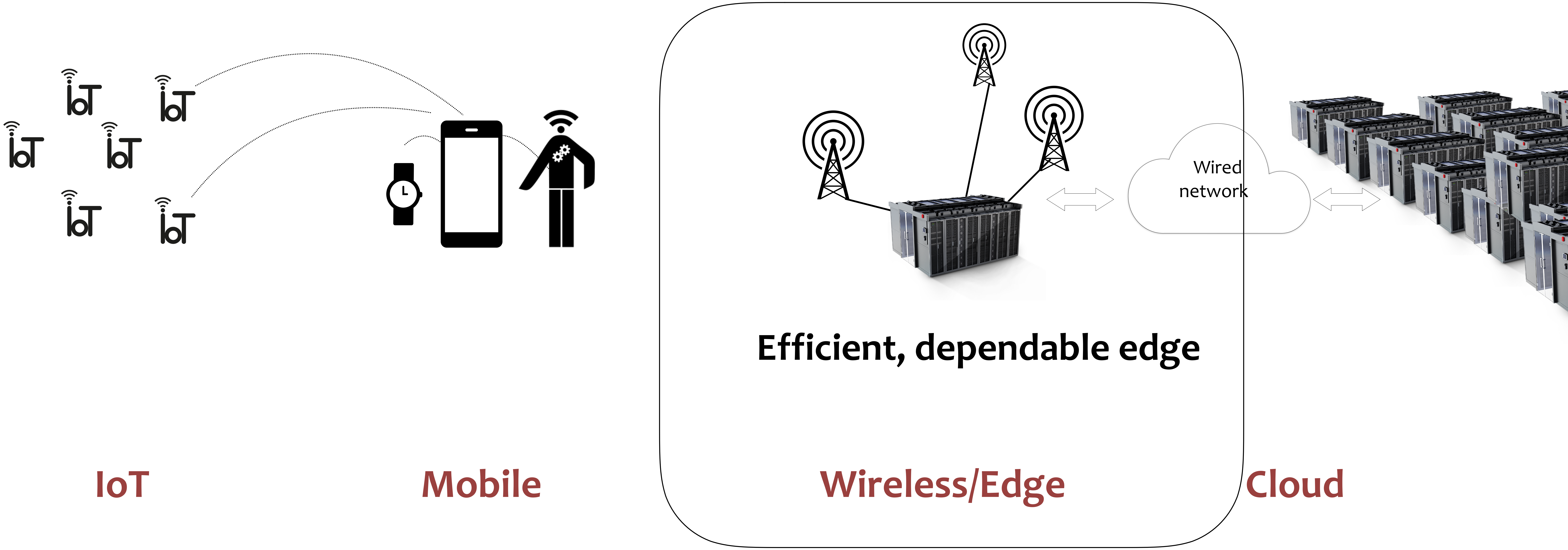
https://www.linzhong.org

Secure & privacy-respecting personal computing



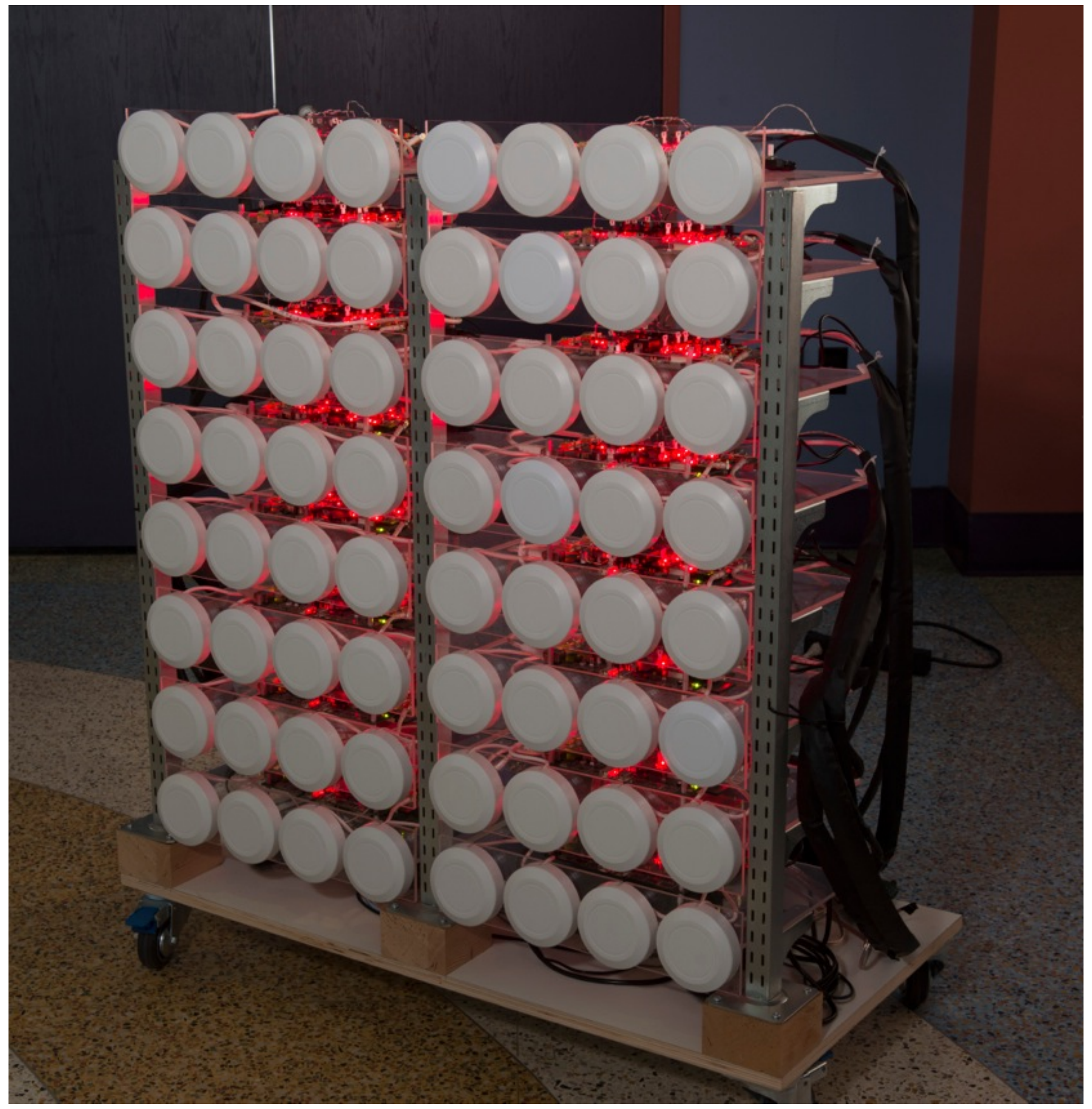
Privacy. Security

5G & Edge data centers

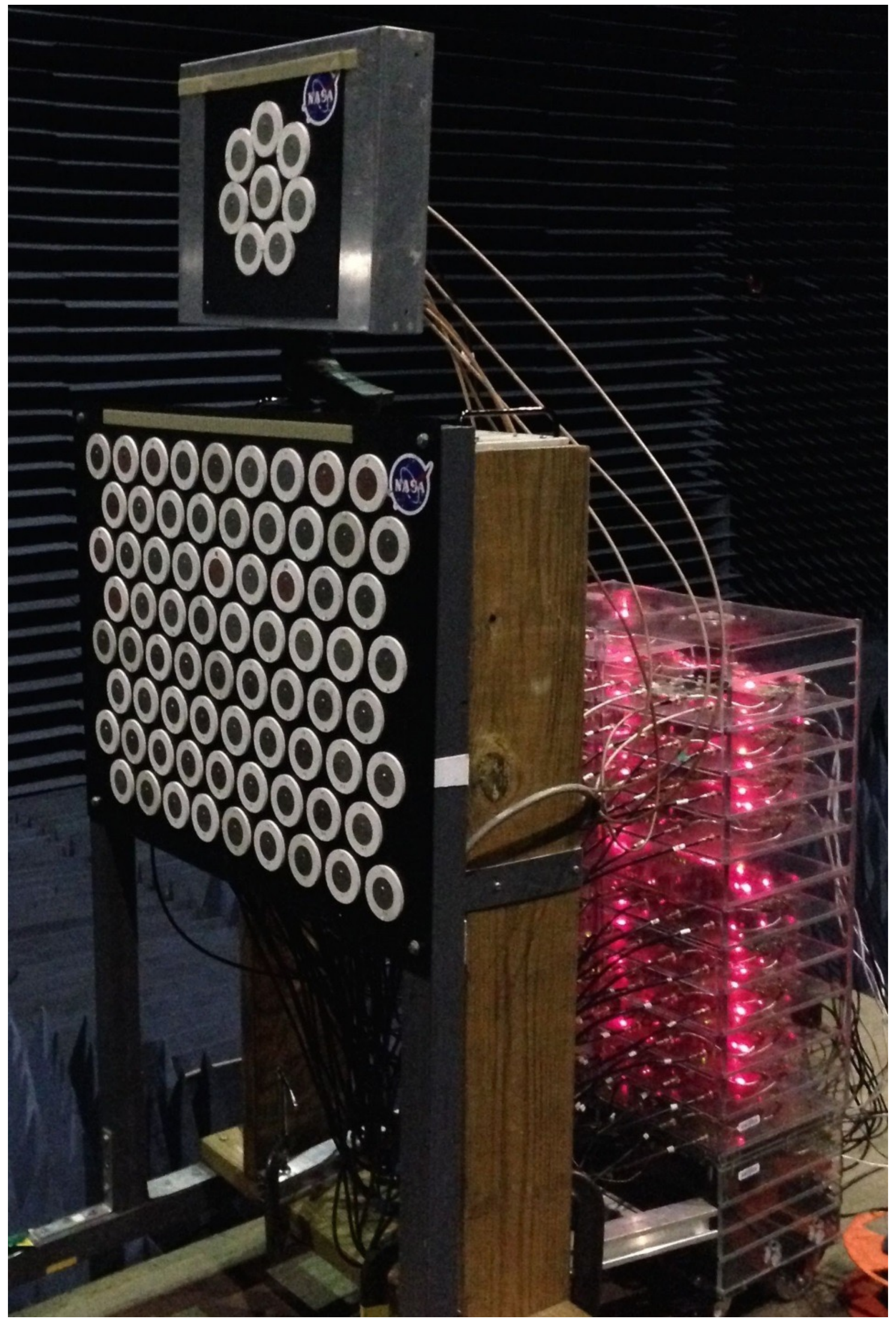


Efficiency. Reliability

Three generations of massive MIMO



Argos V1 (2011)
World's first Massive MIMO
base station



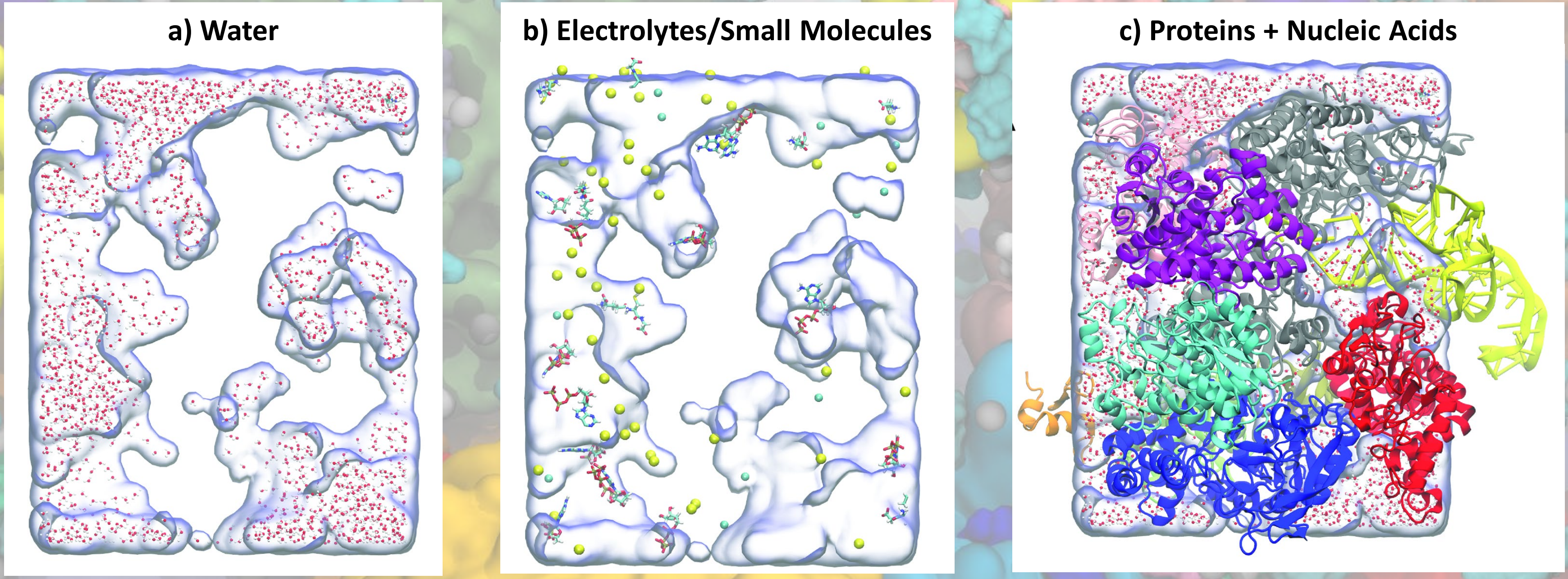
Argos V2 (2013)
World's first real-time Massive MIMO
system

Argos V3 (2017) and ArgosNet (2018)
World's first **network** testbed for massive MIMO

Caitlin Davis, Department of Chemistry contact: c.davis@yale.edu

Davis Lab Research

- Traditionally chemistry is studied in test tubes, but chemistry happens inside cells
- A test tube is mostly water, but the cell volume includes approximately:
  a) 70% water
  b) 10% electrolytes and small organic molecules
  c) 20% nucleic acids and proteins
- **How does the cellular environment affect protein and RNA interactions?**



C. M. Davis, M. Guebele, and S. Sukenik, *Curr. Opin. Struct. Biol.* **2018,** *48*, 23-29.

Background: Meredith Rickard, Gruebele Lab

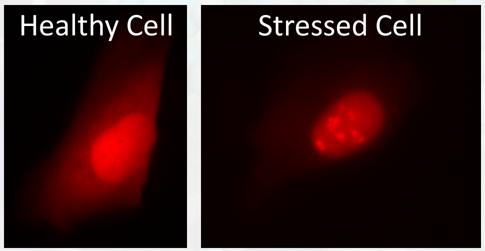
Caitlin Davis, Department of Chemistry

contact: c.davis@yale.edu

Potential Undergraduate Projects

Mapping Huntington's Disease-Associated Protein Phase Transitions

- Cells organize dysfunctional proteins into "droplets" like oil droplets in water



Proteins move from the cytoplasm and nucleus of healthy cells to droplets in the nucleus of stressed cells.

- It is difficult to study droplets inside cells because cells are hard to control, but…
- Physical properties of droplets measured in test tubes differ from inside cells
- We will test how crowding, sticking, pH, temperature, etc. impact droplets
- <u>We will create an assay that reproduces in-cell observations in a test tube</u>

Development of a Microfluidic Mixer for Cell Culture Investigations

- Because cells are difficult to control, we need new ways to trigger and monitor reactions inside ce

A laser quickly heats the sample to induce a "temperature jump," an microscopy monitors dynamics of protein or

- A complementary mixing to quickly change the local environment (pH, salt, temperature, etc)
- <u>We will design and test a microfluidic mixer for our infrared microscope</u>
- This will be the basis for future studies of how cells respond to external stimuli

Background: Meredith Rickard, Gruebele Lab

Student Mentoring and Expectations

Qualifications

Motivated and enthusiastic researchers interested in research at the interface of biology, physics, and chemistry.

Mentoring

Day-to-day supervision by a postdoc mentor. Professor in lab for additional mentoring.

Meetings

Weekly group meeting to discuss research progress. Available for additional meetings informally or on request.

Funding

Looking for two students. Expected to apply for external funding.

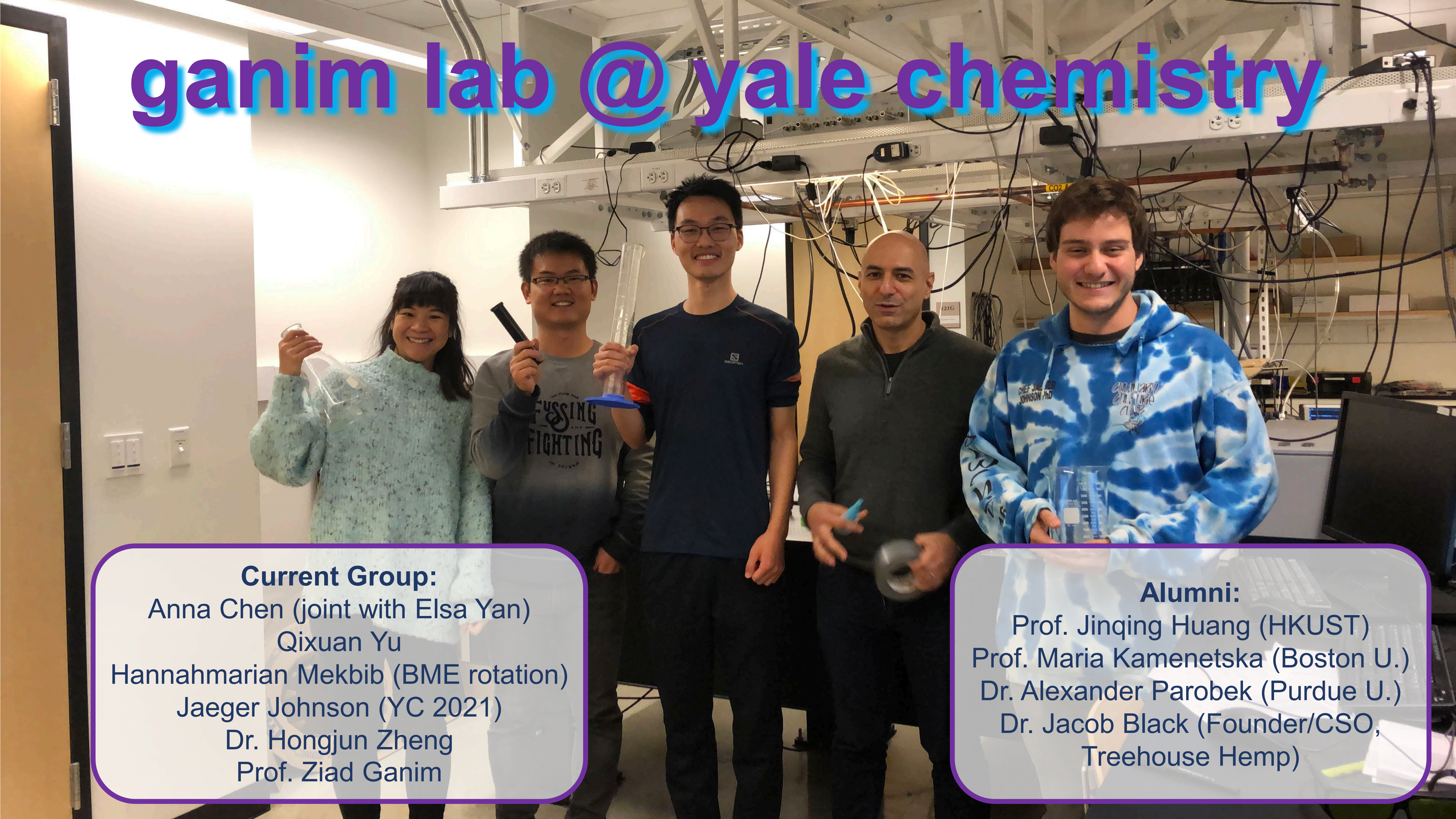
Learning Outcomes

Students will receive training in a combination of protein and RNA biophysics, live cell microscopy, spectroscopy, programming, data analysis, and physical chemistry.

Contact Information

Dr. Caitlin Davis
Assistant Professor
Department of Chemistry
Yale University
c.davis@yale.edu

@thedavislab
www.caitlindavislab.com



ganim lab @ yale chemistry

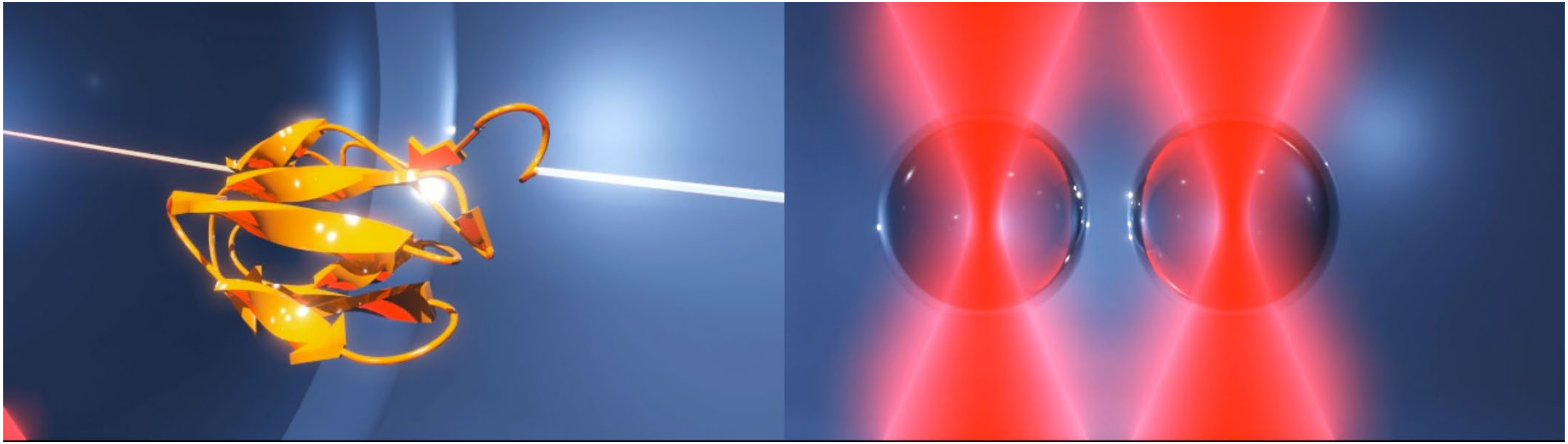
Current Group:
Anna Chen (joint with Elsa Yan)
Qixuan Yu
Hannahmarian Mekbib (BME rotation)
Jaeger Johnson (YC 2021)
Dr. Hongjun Zheng
Prof. Ziad Ganim

Alumni:
Prof. Jinqing Huang (HKUST)
Prof. Maria Kamenetska (Boston U.)
Dr. Alexander Parobek (Purdue U.)
Dr. Jacob Black (Founder/CSO, Treehouse Hemp)

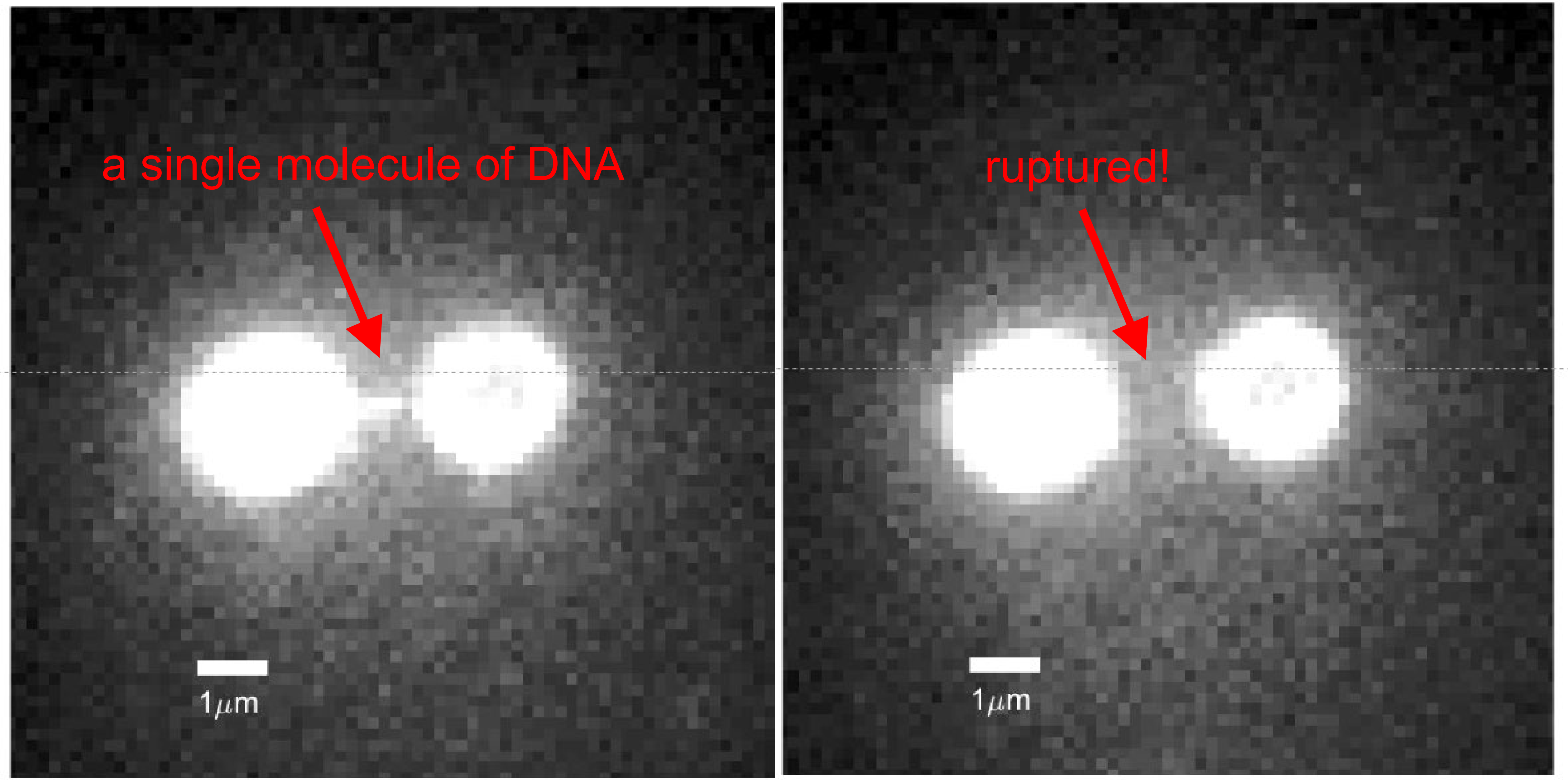
optical tweezers and spectro/microscopy

as a tool to:

- immobilize single molecules in solution
- apply and measure force
- perform advanced spectroscopies

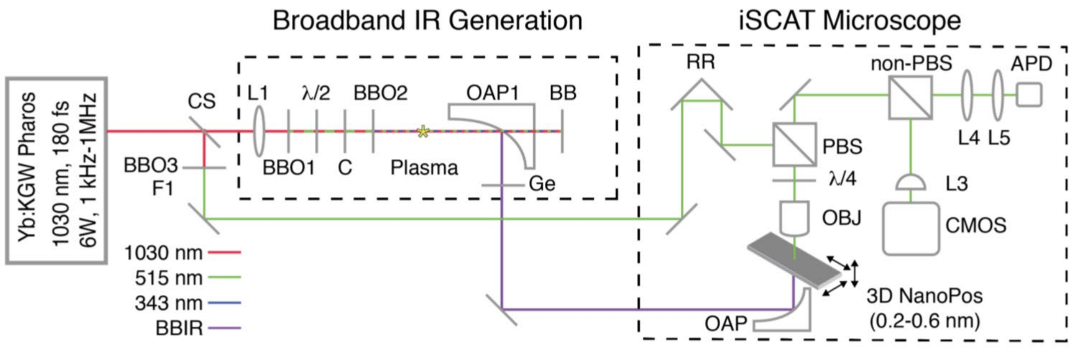


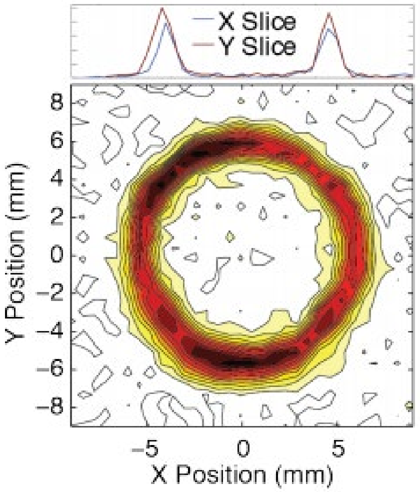
concept graphics: criss hohmann und alexander mehlich

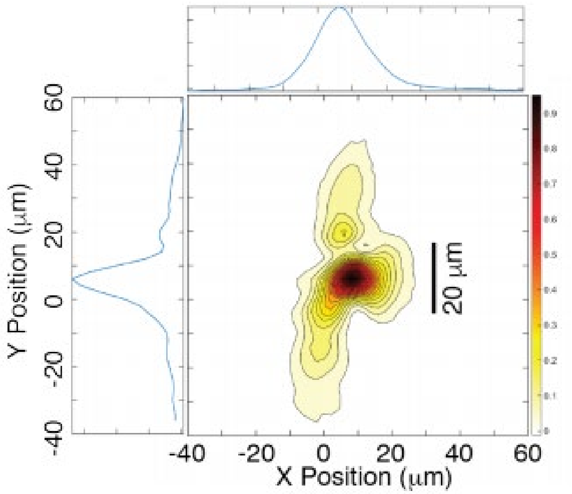

a single molecule of DNA
1 μm
ruptured!
1 μm

femtosecond broadband infrared microscopy

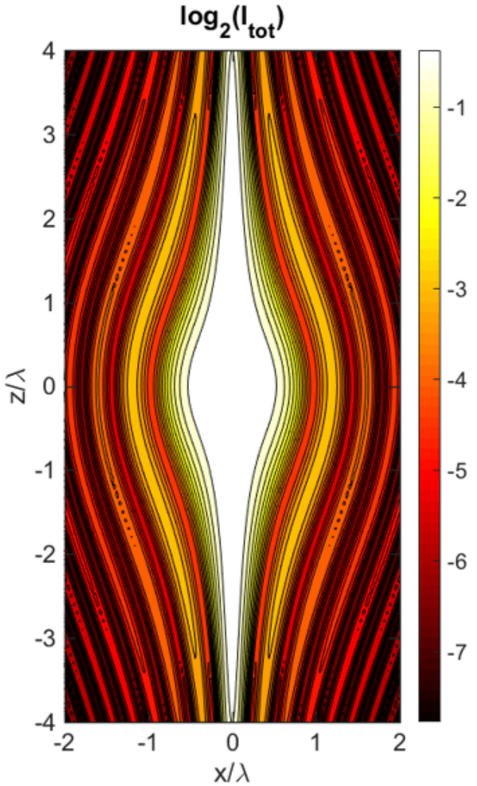
experiments

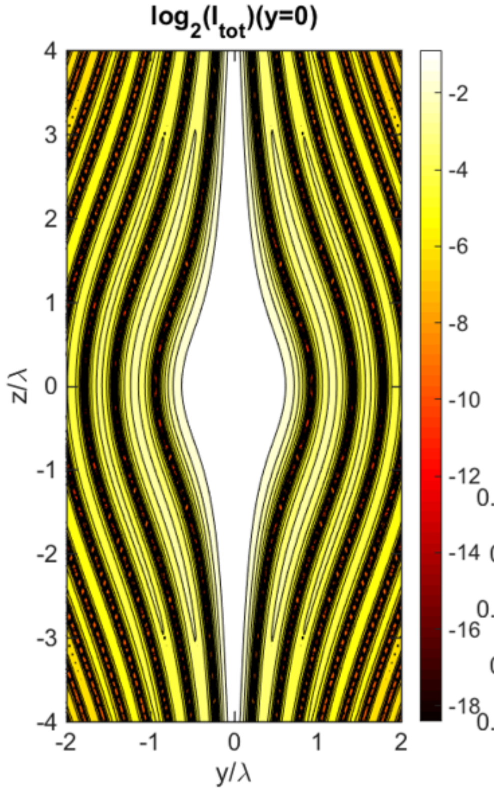


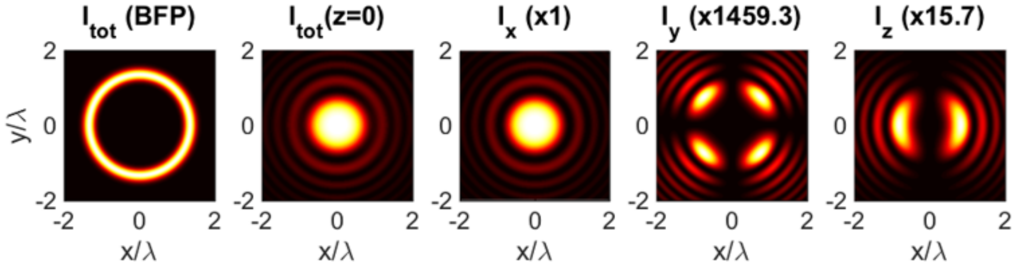


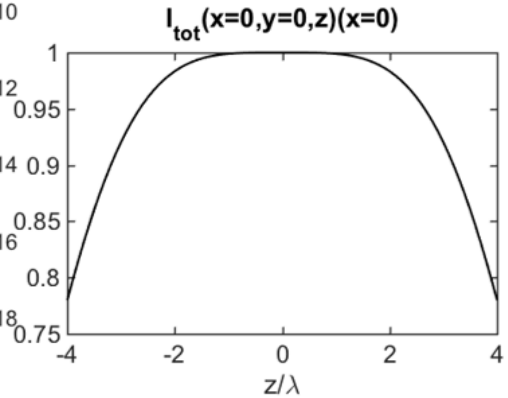


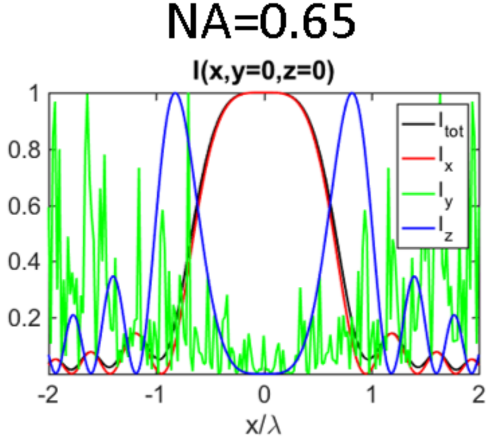
beam propagation simulations











Yale University

Undergraduate Student Research Presentation

- 25 undergraduates have worked in the group
- 10 went to graduate school in chemistry, 3 went to in medical school
- 5 received NSF Fellowships
- 8 were in the STARS program
- We would love to have more!

Hazari Group (nilay.hazari@yale.edu)

Inorganic Chemistry

Catalysts

A *catalyst* is a substance that alters the rate of a reaction without being consumed in the reaction

$$A + B \xrightarrow{\text{slow or no reaction}} C + D$$

$$A + B \xrightarrow[\textit{catalyst}]{\text{fast reaction}} C + D$$

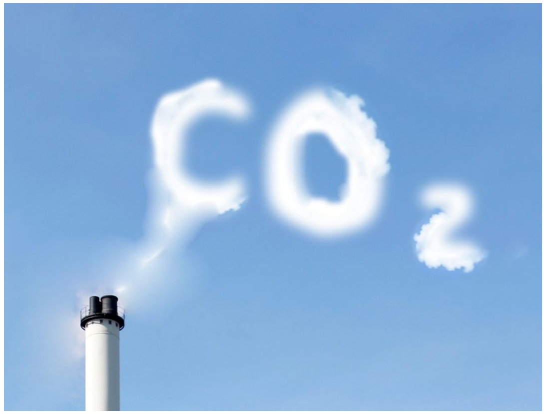
- **Almost 90% of chemicals that are produced commercially utilize a catalyst at some point in their synthesis**

We develop transition metal based catalysts for a variety of different applications

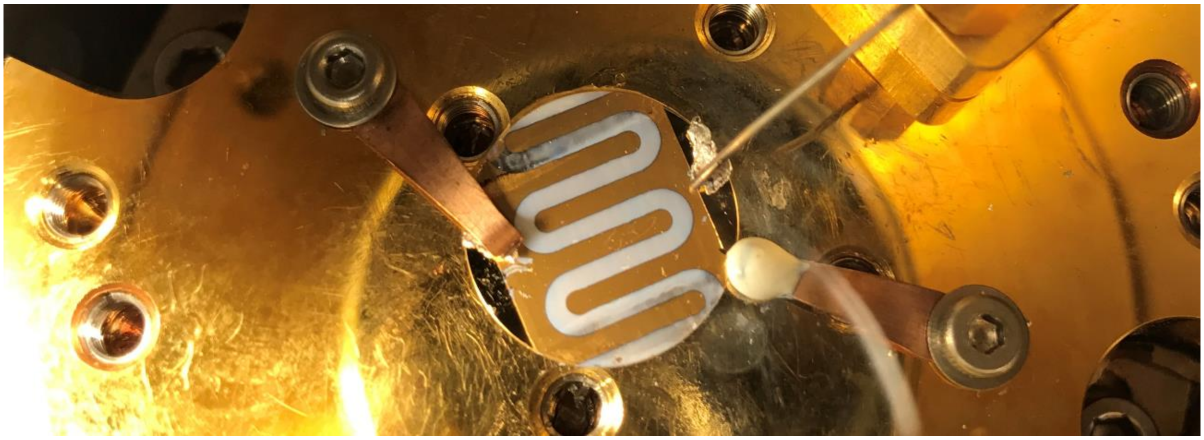
The Hazari Group

- **Applications of Hazari group research**
  - **Synthesis of active ingredients in pharmaceuticals**
  - **Synthesis of commodity chemicals**
  - **Energy related problems, such as hydrogen storage and CO_2 utilization**

- **Research areas and techniques**
  - **Inorganic synthesis**
  - **Organic synthesis**
  - **Catalysis**
  - **Materials**
  - **NMR, UV-Vis, IR spectroscopy**
  - **X-ray crystallography**
  - **Mass spectrometry**
  - **Electrochemistry**



Please feel free to contact me for more information



Konezny Lab

Contact: Steve Konezny (steven.konezny@yale.edu)

Research Area: Materials for solar energy conversion applications

Research Description: We use theoretical, experimental, and computational methods to study the mechanisms of charge transport and structure-electronic property relationships in materials that are the backbone of many renewable energy strategies such as solar cells, batteries, and fuel cells. These studies inform the design of materials and devices with optimal performance and energy conversion efficiency. By combining low-temperature high-sensitivity electrical measurements with computational modeling and theory, our work is focused on the characterization and mechanistic studies of electron transport in important materials for energy applications.

Open Projects: I have 4 research projects that are focused on fabrication, measurement, and/or theory, depending on student interest and experience:

Project 1. *Device Design and Characterization for Energy-Related Materials*

This project involves studying charge transport in materials for solar energy conversion using various device architectures and methods. The student will learn thin-film fabrication and microscopy characterization methods, how to design and deposit electrodes, and useful techniques in the west campus clean room such as photolithography and optical profilometry.

Project 2. *Theory of Charge Transport in Nanostructured Materials*

Studying charge transport is important from a fundamental physics perspective, but also can provide guidance for material design. This project involves studying the mechanisms of charge transport important to nanostructured materials used for solar energy conversion. The student will learn how to apply these models to temperature-dependent electrical data. Programming experience recommended.

Project 3. *Temperature-Dependent Charge Transport Measurements in Energy Materials*

Our lab on west campus has a cryostat capable of accessing temperatures between ~7 and 315 K. By measuring the conductivity of materials in this range, one can decipher the mechanism of charge transport and learn valuable information about improving device performance. Because important materials for energy applications are often highly porous by design for achieving high surface area, conductivities are often very low. The cryostat is therefore equipped with highly sensitive electrical equipment capable of measuring currents on the order of femtoamps. This project is a study of charge transport as a function of temperature under various light and ambient gas conditions. Prior experience in LabView and Python would be helpful, though experience can be swapped for an interest to learn.

Project 4. *Impedance Spectroscopy for Studying Materials for Energy Applications*

Studying the resistance and capacitance properties of a material upon application of an ac signal can potentially provide much more information than dc methods. These data can be fit with an equivalent circuit model, each component of which corresponding to a particular physical process in the device. This project is an application of this powerful method, which allows complicated systems such as thin-film devices or electrochemical cells to be studied systematically. Some programming experience will be useful.

Laura Newburgh

laura.newburgh@yale.edu

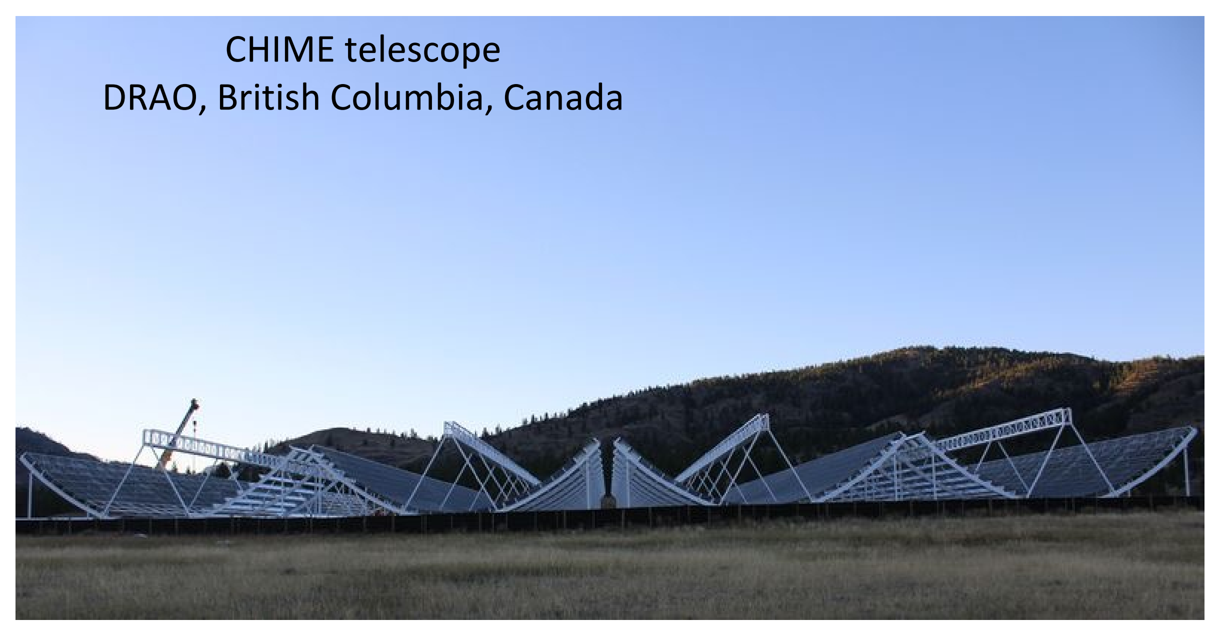
Next-generation Cosmology Instrumentation and Science with Millimeter and Radio Telescopes

Cosmic Microwave Background Measurements with the Simons Observatory (and CMB-S4)

- Simons Observatory: 4 telescopes in ~2020
- Main science goals using measurements of the power spectrum, maps, and lensing: inflation, neutrino mass sum, light relics, dark energy
- I lead the group on 'data acquisition' focusing on software development: all acquisition and control, software, timing, live monitoring

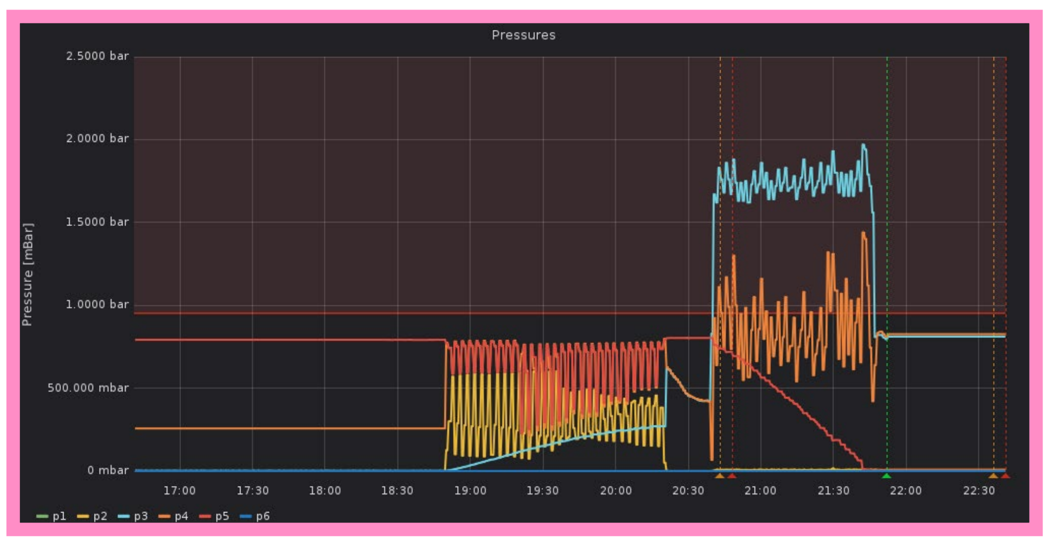
21cm Measurements of Dark Energy with CHIME and HIRAX

- CHIME is a new radio interferometer in Canada, seeking to use a new technique ('21cm intensity mapping') to expand the reach of galaxy surveys to very high redshift, critical for improving our understanding of Dark Energy
- I work on calibration: measuring the PSF of the instrument using a co-located a steerable dish and quadcopter drone measurements
- I also am a collaborator on HIRAX, a prototype instrument in South Africa which should overlap with other cosmological surveys (like SO)



Simons Observatory work

Sanah (gap year student, now grad student here) working with low temperature thermometry in the Dilution Refrigerator



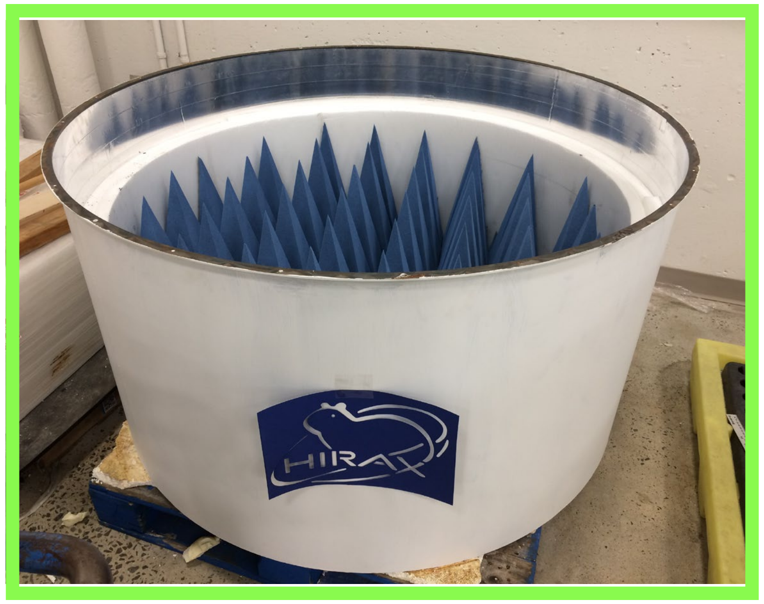
Sam, Sebastian, and Ananya contributed to software for calibrating thermometry in the Dilution Refrigerator. Shown here is our grafana-based live monitor of the state of our Fridge.

Sam (pictured) and Sebastian (not pictured) designed and built power and thermometry boxes for fielding in Chile

This was version #1 —- it got much more 'real'

Receiver noise testbed - led by graduate student Emily Kuhn

Maile constructing the fibreglass insert



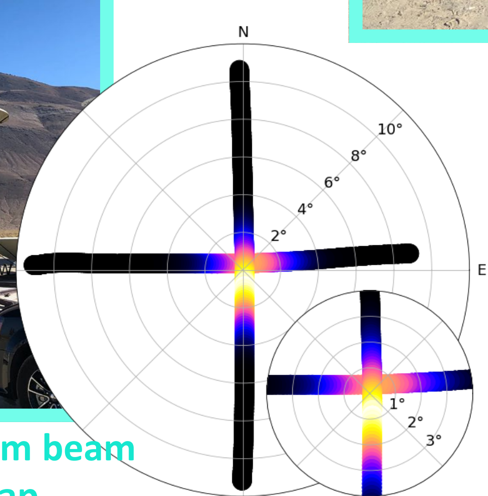
One of two receiver noise test-beds done!

Emily and Ben building the foam insert

Emily and and Maile shaving down the foam insert (power tools were very helpful!)

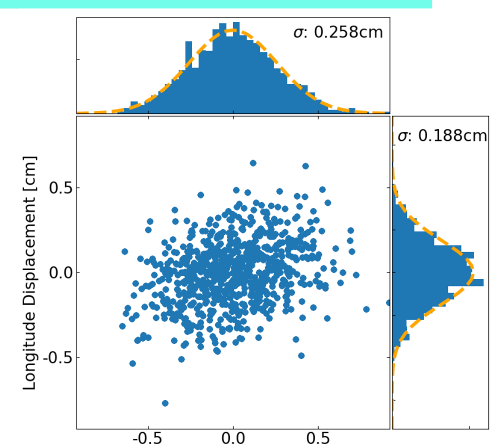
Debating

Drone beam mapping



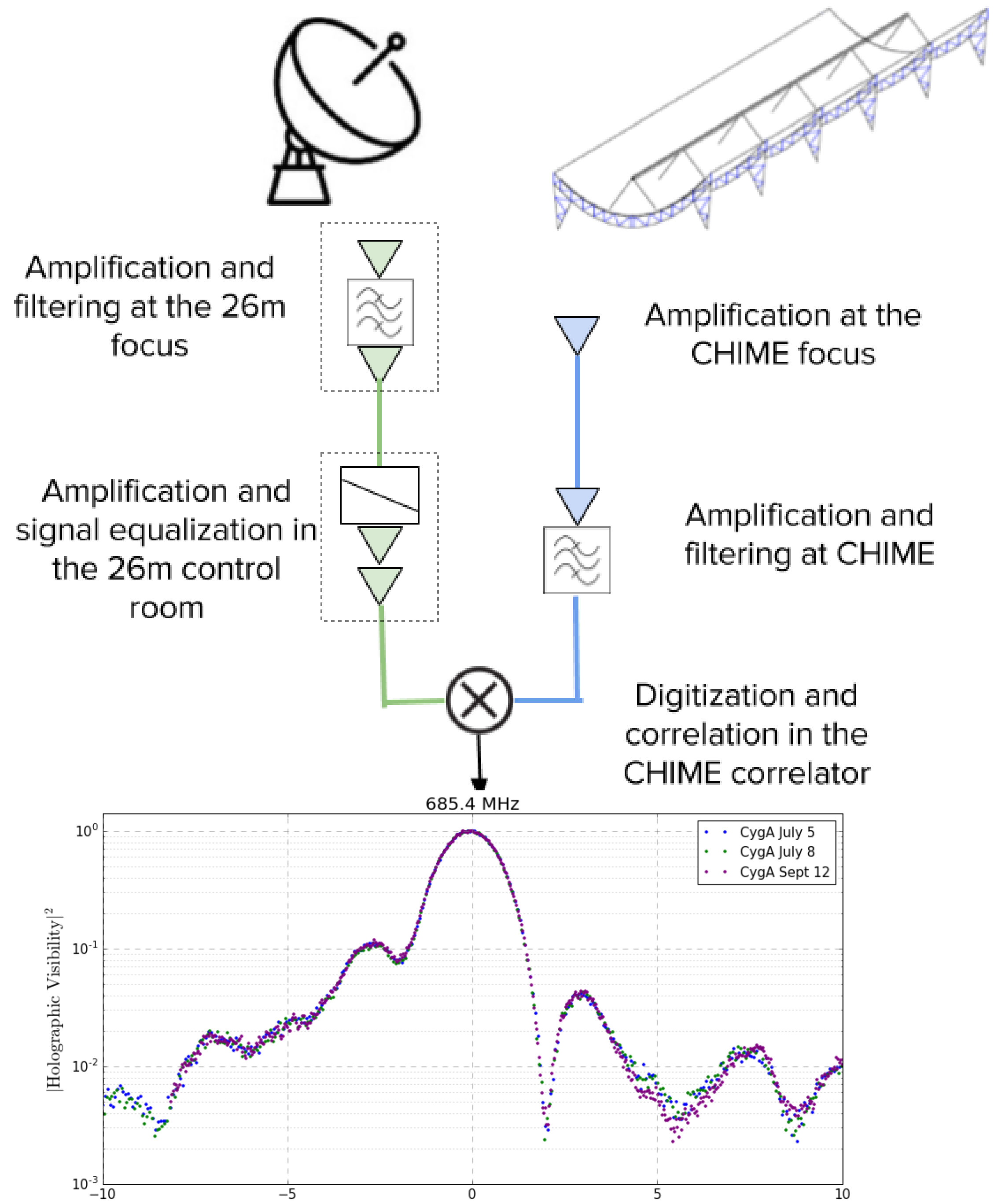
data from beam map

Annie analyzed the data — the drone has excellent relative position accuracy



Calibrate with Holography

Tracking dish



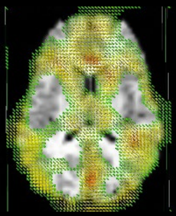
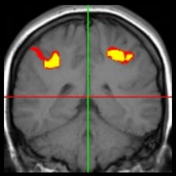
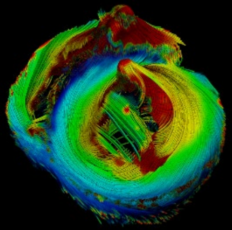
Lawrence Staib

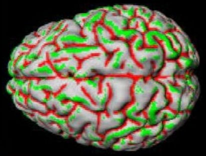
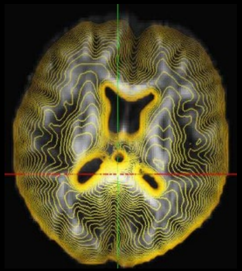
Departments of Biomedical Engineering and
Radiology & Bioimaging Sciences

lawrence.staib@yale.edu

- Focus on:

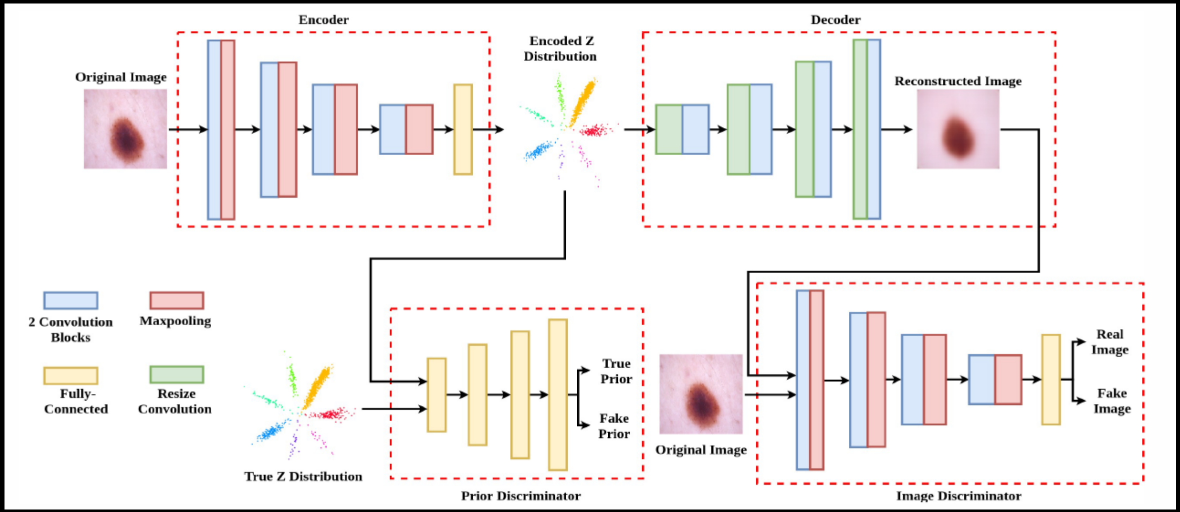
Medical Image Analysis
and Machine Learning
for quantification
diagnosis,
prognosis, and
characterization
of normal and pathological
structure and function

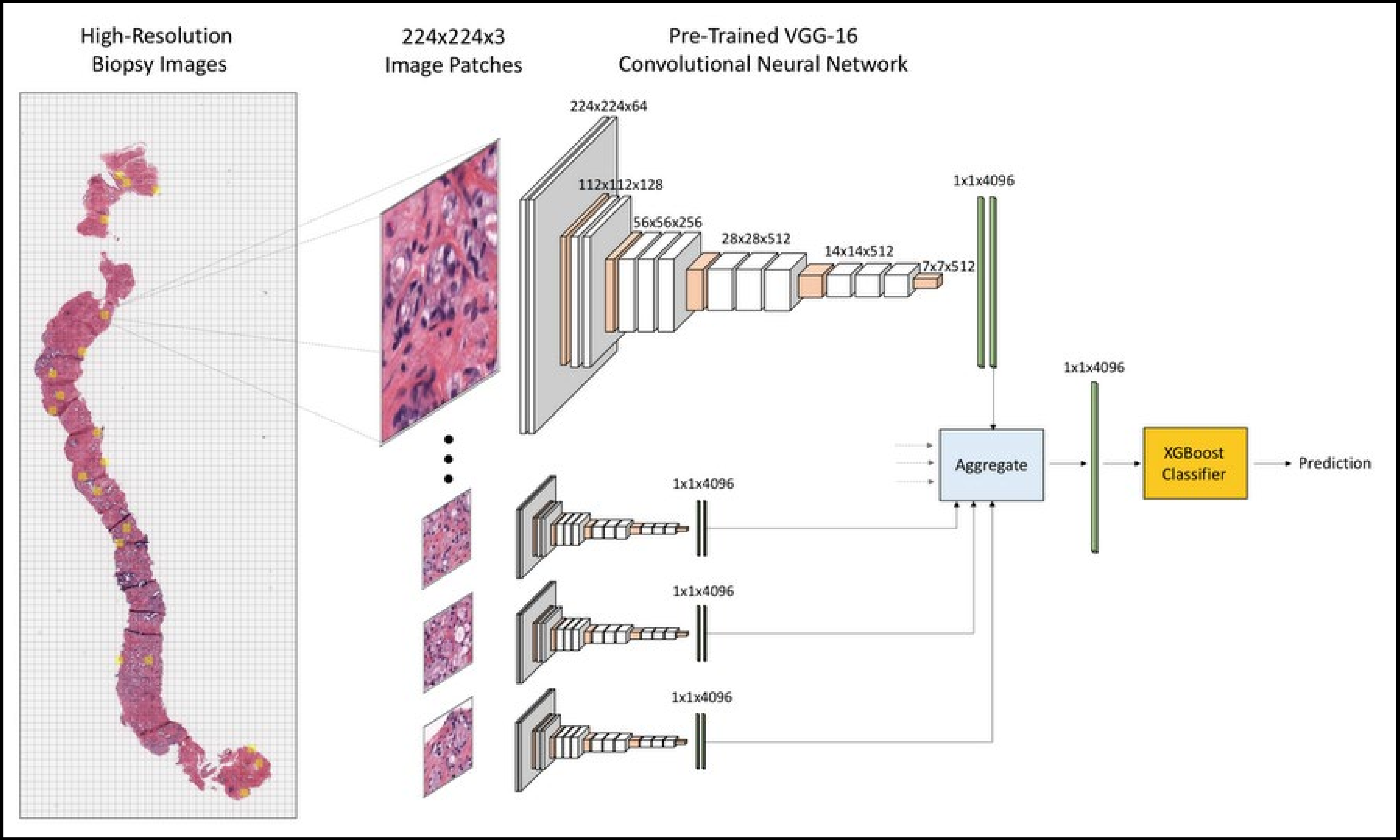
Potential Projects

- Applications in neuroimaging, cardiovascular disease, cancer, etc.

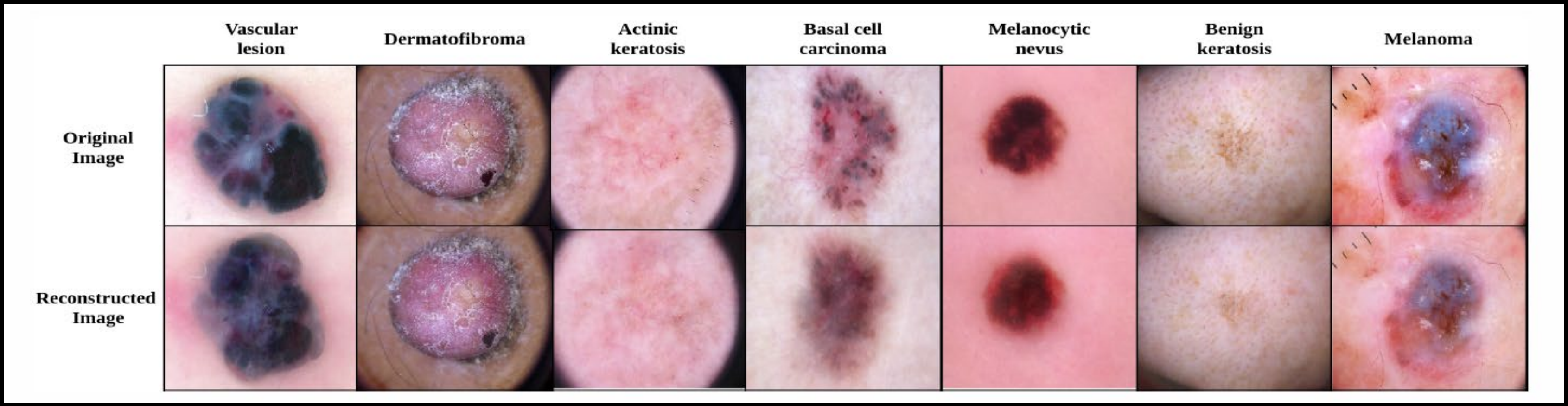


- Image segmentation
- Diagnosis from images
- Image registration
- Treatment selection
- Outcome prediction
- End-to-end quantification

Biopsy Analysis



- Mentoring: touch base with me every day with a longer meeting each week; open door policy
- Prior projects:
  - Predicting liver tumor growth from imaging features
  - Lung lesion segmentation/classification
  - Dermoscopic image generation
  - Uncertainty estimation



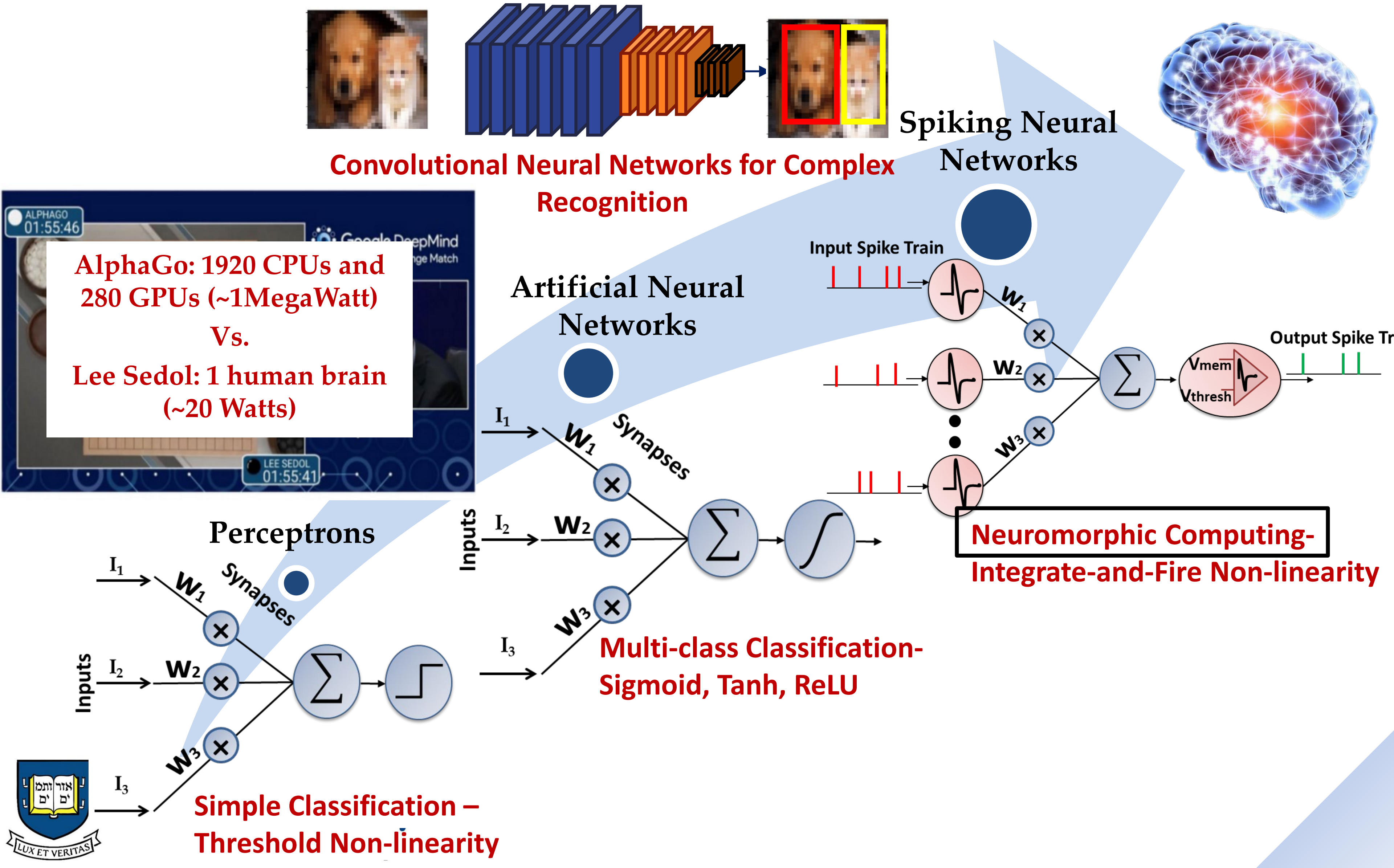
Lawrence Staib, lawrence.staib@yale.edu

Prof. Priya Panda
Assistant Professor, Electrical Engineering
priya.panda@yale.edu

INTELLIGENT COMPUTING LAB

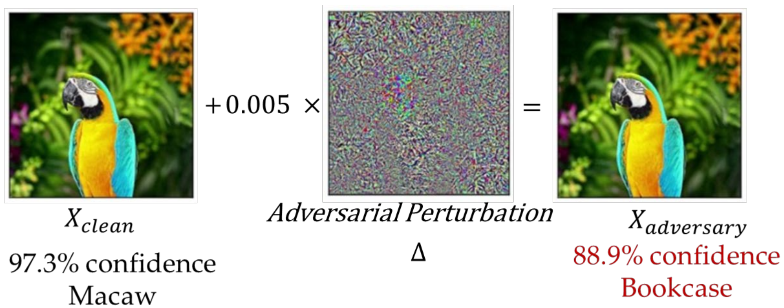
https://intelligentcomputinglab.yale.edu/

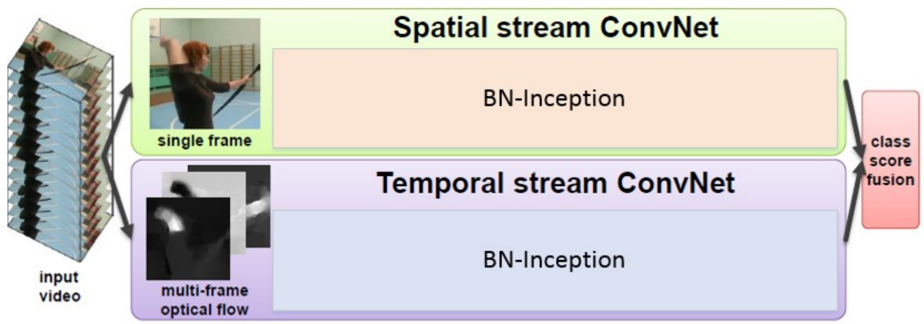
Research Focus: Towards energy-efficient and robust machine intelligence with brain inspired ‘spikes’ computing

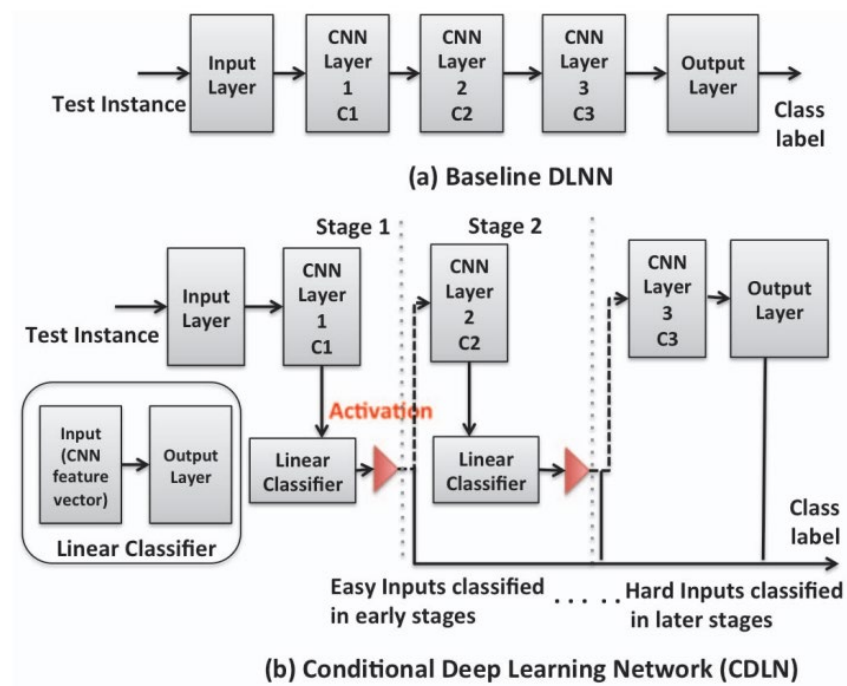


Projects

- Adversarial Susceptibility of Spiking Neural Networks
- Design neural networks to say 'I don't know'
- Conditional Spiking Neural Network for real-time fast and efficient learning
- Action Recognition with brain-inspired neural network designs







Logistics

Pre-Req: Having background in neural network and knowing basic Python skills will be good.

Mentoring: Will closely work with the students in defining the problem. Typically meet with me 1-2 times a week. Informal drop ins welcome

Funding: Looking for 2-3 students, encourage to find funding of your own!

Want to learn more? https://intelligentcomputinglab.yale.edu/

Prof. Priya Panda
Assistant Professor
Electrical Engineering
priya.panda@yale.edu

Yale University

Ultracold Quantum Matter Lab @ Yale

Sloane Physics Laboratory

- Study complex quantum phenomena with highly-controllable synthetic quantum systems: ultracold atoms (***atomic legos***)

$$\hat{H} = \sum_{i=1}^{N} \frac{\hat{\mathbf{p}}_i^2}{2m} + \sum_{i=1}^{N} V_{\mathrm{trap}}(\hat{\mathbf{r}}_i) + \sum_{i<j} V_{\mathrm{int}}(\hat{\mathbf{r}}_i, \hat{\mathbf{r}}_j)$$

Temperature

Trapping landscapes

Interactions

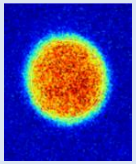
Quantum statistics

- Many 'knobs'
  - external/internal degrees of freedom
  - tunable interactions
  - easily accessible observables

Fermi lab

(SPL 20)

Lego: Fermionic ^{6}Li atoms in programmable boxes



Research themes

Pairing with strong interactions

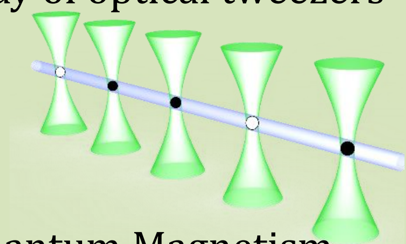
Exotic superfluid phases

Quantum vortices and rotation

Tweezer lab

(SPL 20A)

Lego: Single ^{88}Sr atoms in array of optical tweezers



Quantum Magnetism

Dynamics of entanglement

Quantum cellular automata

Bose lab

(SCL 140D)

Lego: Bose-Einstein Condensates of ^{39}K

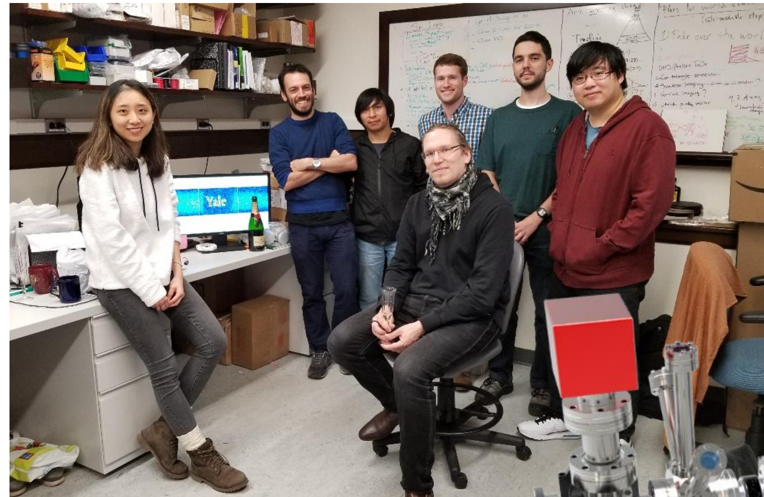
Atom interferometry

Thermodynamics

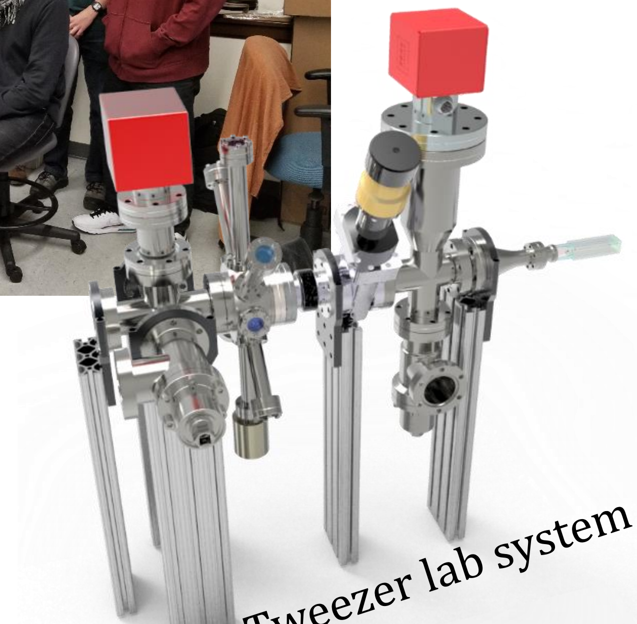
Matter-wave turbulence

Ultracold Quantum Matter Lab @ Yale

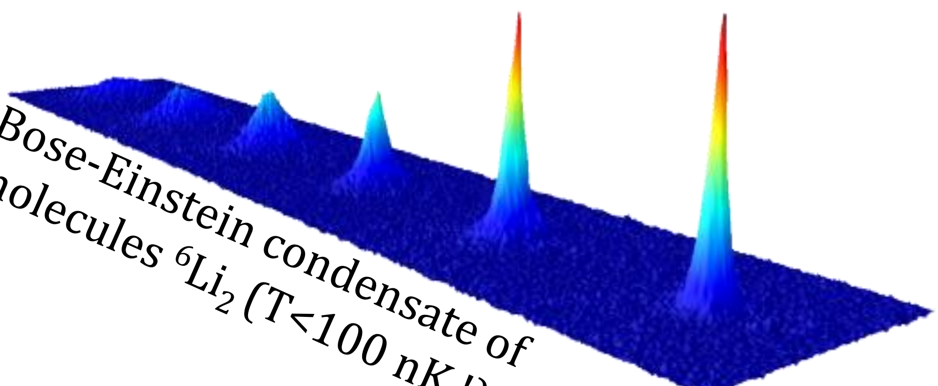
Join us!
Grad students: Yunpeng Ji, Grant Schumacher, Gabriel Assumpcao, Peter Zhou,
Postdocs: Jere Makinen, Franklin Vivanco



Undergraduate projects: ultrahigh-vacuum constructions, laser building, spectroscopy, optical setups, electromagnet design, control electronics, software design, quantum control

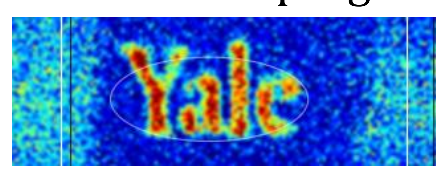


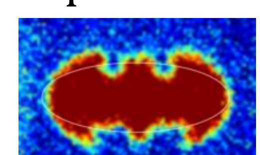
Tweezer lab system



Bose-Einstein condensate of molecules $^{6}Li_2$ (T<100 nK !)

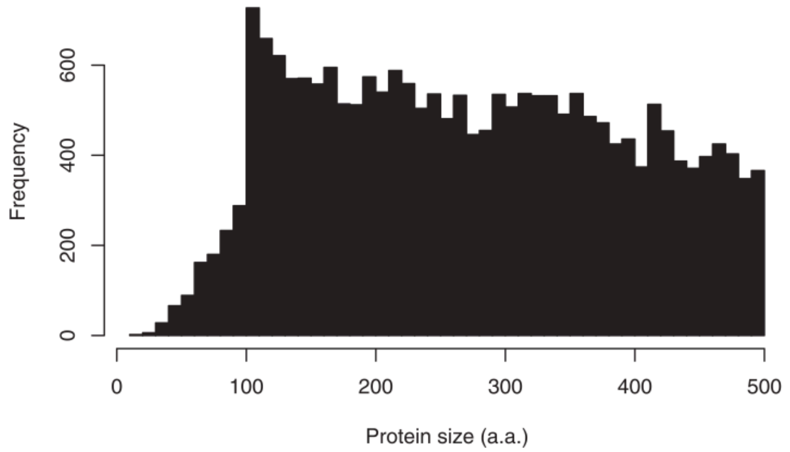
'Atomic painting': strongly-interacting fermions in programmable potentials





Slavoff Lab: Dark Matter of the Human Genome

Annotated mammalian protein size



>Ten years ago, the mean size of annotated proteins in mammalian genomes was 375 amino acids
Precipitous, artifactual drop off in annotated proteins <100 amino acids
In reality, there are thousands of small proteins, but they were invisible to geneticists – until now

Frith, M.C. et al. *PLoS Genet* **2**, e52 (2006).

Small Open Reading Frames: smORFs

The Slavoff lab develops and applies new technologies, including ribosome profiling and mass spectrometry-based proteomics, to discover small ORFs (smORFs) encoding *thousands of never-before-seen small proteins in human cells.*

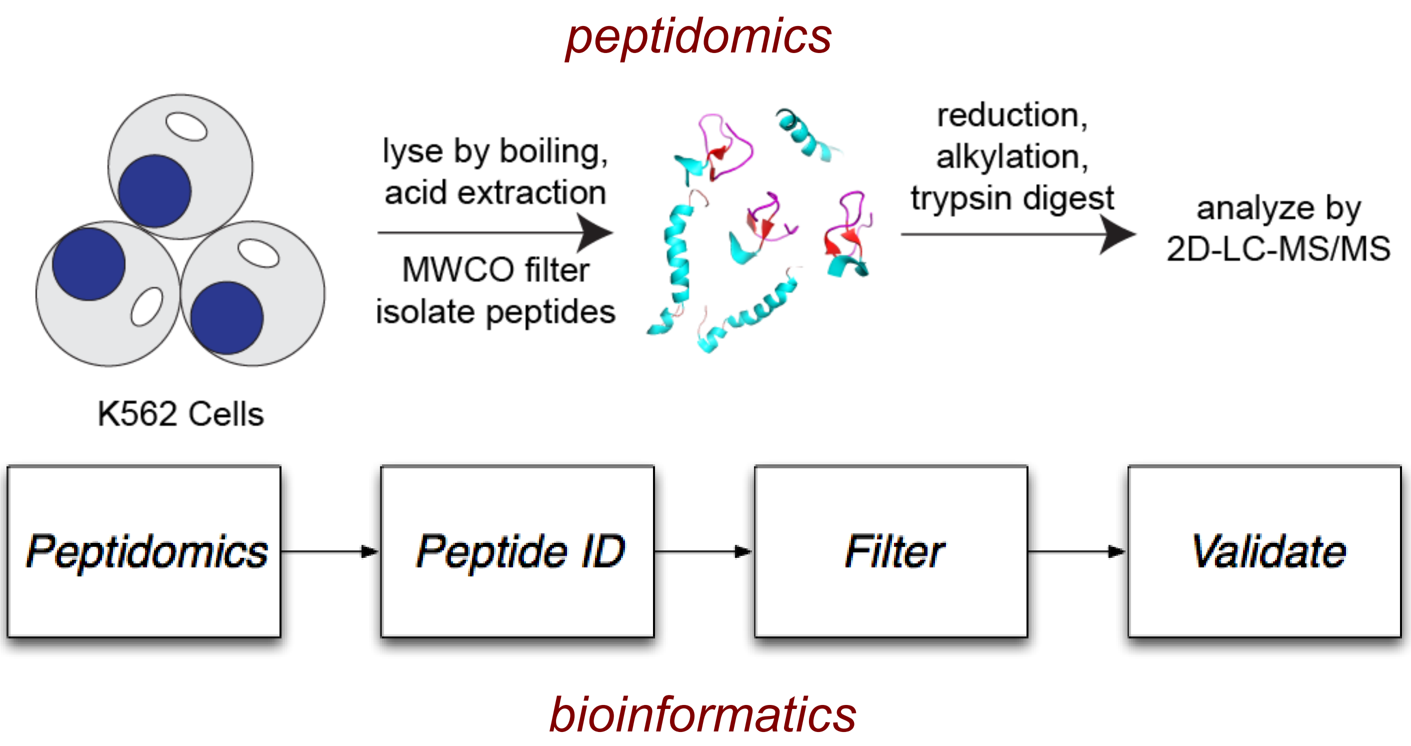
These smORFs were previously missed by genome annotation pipelines because (1) arbitrary size cutoffs for gene annotation of >100 amino acids were applied, and (2) small proteins and peptides are hard to detect with standard biochemical and proteomic approaches.

We and other labs around the world continue to discover more smORFs all the time, and to use multidisciplinary approaches from biochemistry, cell biology and structural biology to characterize their functions.

smORF discovery methods and results

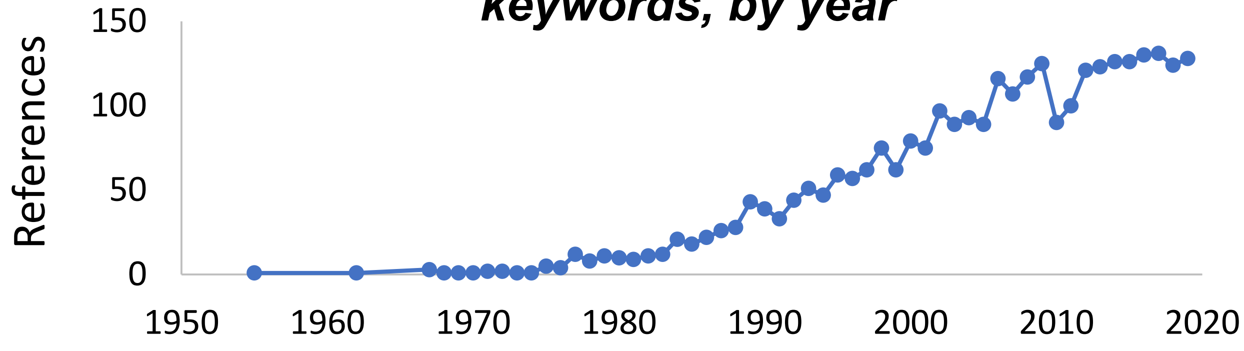
We primarily apply mass spectrometry-based proteomics, coupled with libraries of non-coding RNA sequences, to discover novel expressed smORFs in human cells.

Thousands have been identified to date, and more are being found all the time. Some also serve very important functions inside cells.

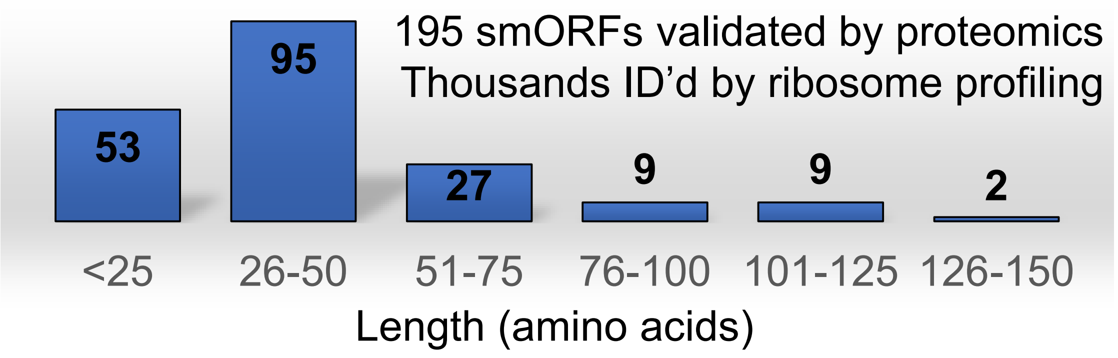


Highly stringent MS/MS criteria for a positive ID (i.e. false negatives for the price of no false positives)

PubMed references to smORFs and related keywords, by year

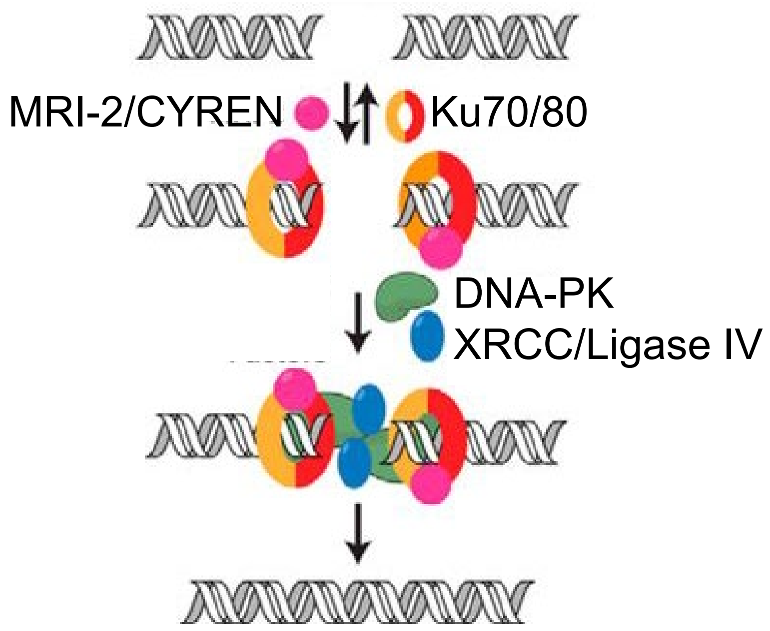


Numbers and lengths of smORFs in K562 cells



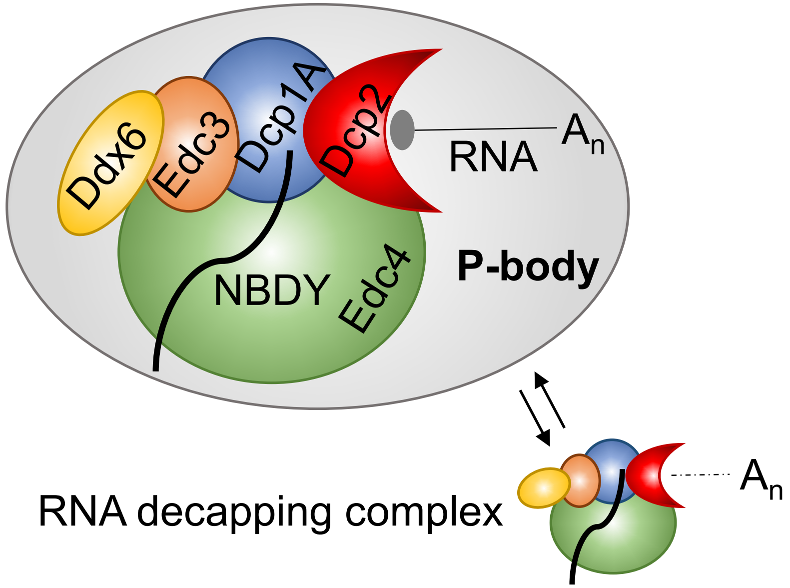
Small open reading frame (smORF) discovery: examples of functions

DNA double-strand break repair



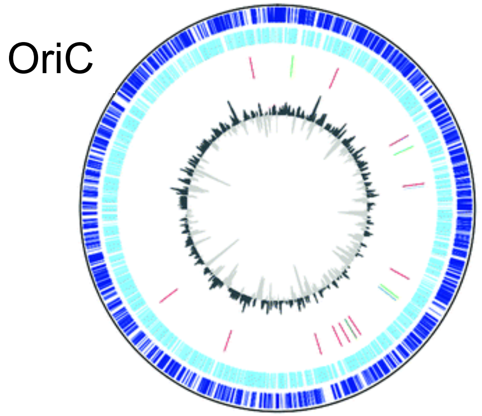
Slavoff et al., 2014

Cytoplasmic 5'-to-3' RNA decay



Slavoff lab, 2017

Cellular stress responses



Stress responsive smORFs in *E. coli* genome

Also: oxidative stress, hypoxia, nutrient starvation

Slavoff lab, 2018

Student Project Features

- Multi-disciplinary (mass spec, genetics, biochemistry, microscopy, bioinformatics)
- New discoveries (name your own gene!)
- Positive, engaged and exciting mentors
- Contribute to our understanding of the information content in the human genome

Interested? Contact Sarah Slavoff (sarah.slavoff@yale.edu) to discuss project ideas!

Protein Folding and Dynamics Revealed by Single-Molecule Force Spectroscopy

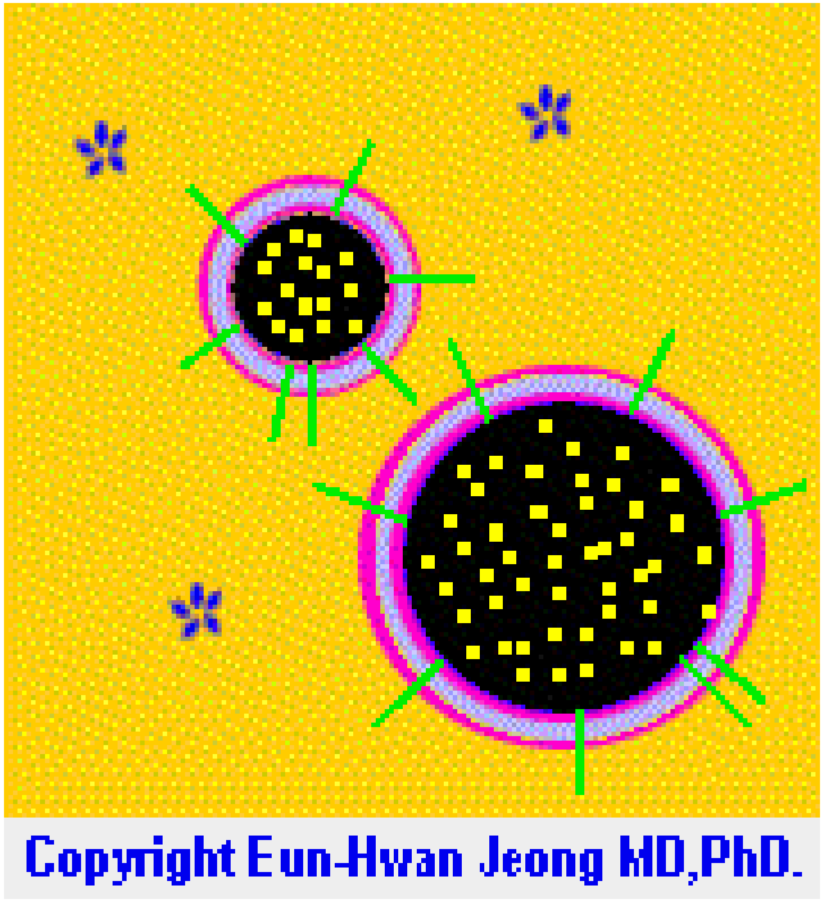
Yongli Zhang

Associate Professor
Department of Cell Biology
Yale University
Email: yongli.zhang@yale.edu

Some former Yale undergraduate students worked in the Zhang lab:

- Christina de Fontnouvelle, now medical student at Yale School of Medicine
- James Ting, now medical student at Johns Hopkins University
- Blessing Aghaulor, now medical student at North Carolina at Chapel Hill
- Gregory Gundersen, now graduate student at Princeton University

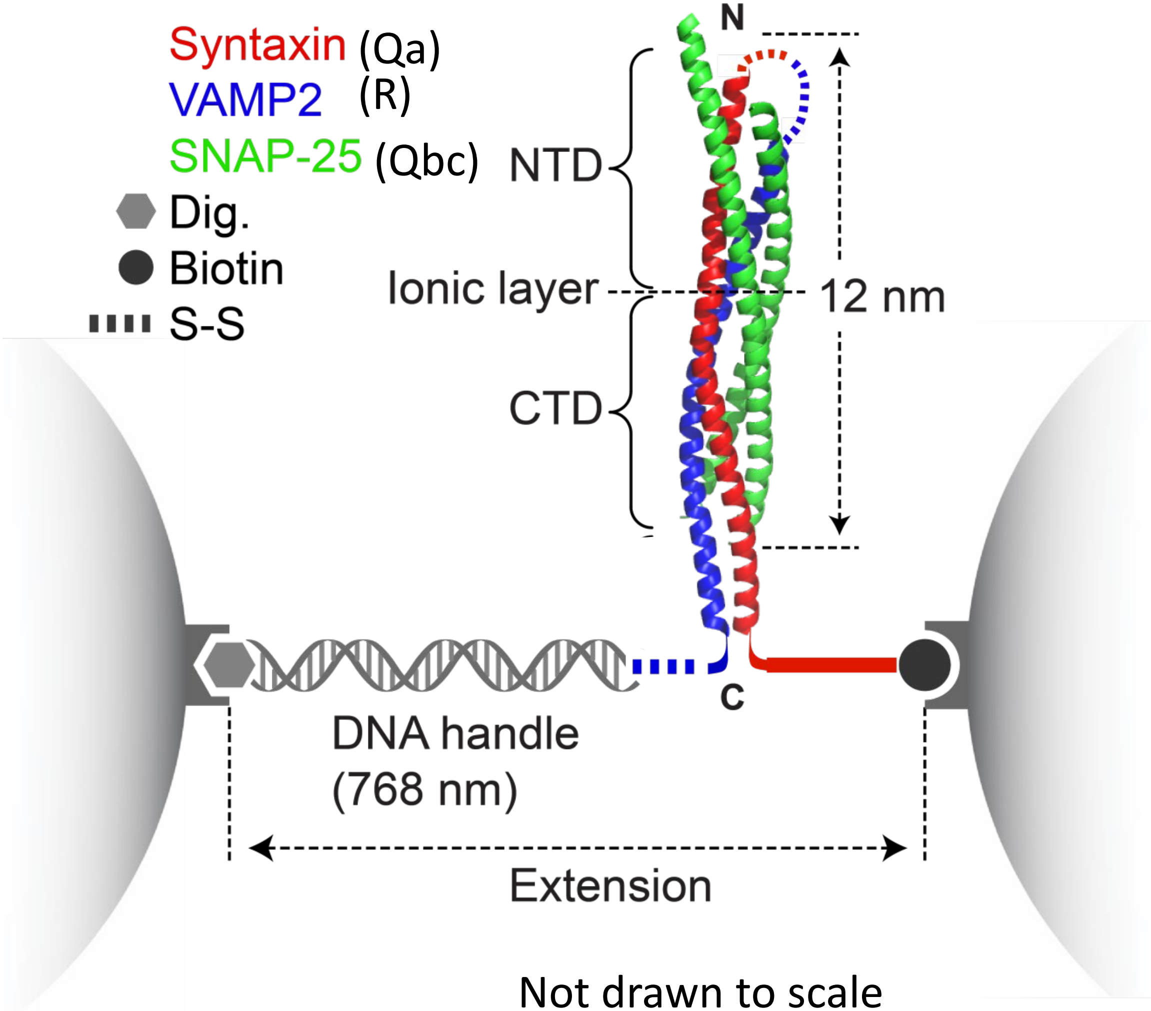
SNAREs couple their folding/assembly to membrane fusion



1. Energy barrier for fusion > 30 kT
2. Synaptic Vesicle fusion
   - Fast (<0.1 ms)
   - Frequent (>100 Hz)
   - Highly regulated
   - Related to many diseases
3. Complex kinetics of exocytosis (hemifusion, fusion pore flickering, itc.)

SNARE hypothesis: Sollner, T., …, Rothman, J.E. (1993). Nature *362*, 318-324.
SNARE zippering hypothesis: P. Hanson,,…, R. Jahn, J. Heuser, Cell, 90, 523 (1997)

Single-molecule manipulation of SNARE complexes



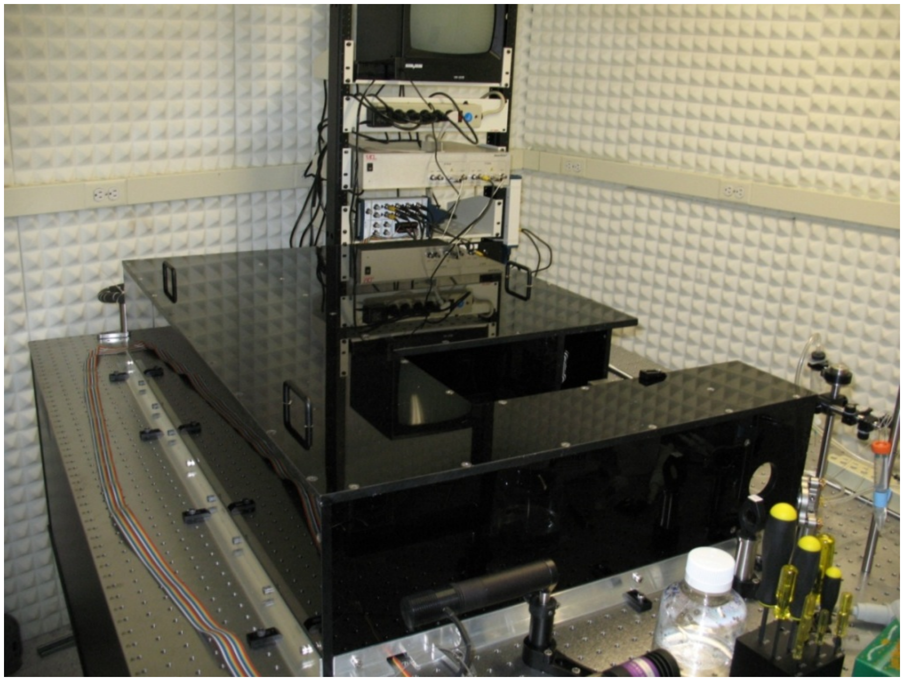
Not drawn to scale

Y. Gao, …, J. E. Rothman, Y. L. Zhang, *Science* **337**, 1340 (2012).

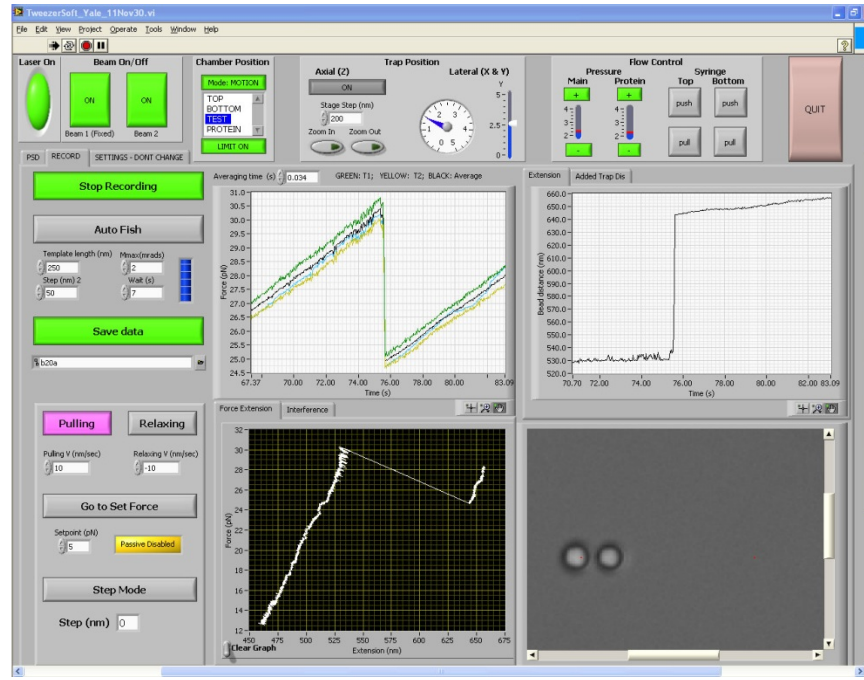
Jiao, J., He, M., …, Hughson, F. and Zhang, Y., ***Elife***, 2018

High-resolution optical tweezers

Hardware



Software



Measurement range

- Displacement: **0.2 nm** – 50 µm
- Force: **0.05 pN**– 200 pN (water); 10^{-21} N in vacuum
- Time: **20 µs** – 2 hours

Force to unfold macromolecules or generated by molecular motors: 1-40 pN

Force to break covalent bond: > 1000 pN