

Graduate Student Reunion 2018

Washington University, St. Louis



Washington University Physics



- ▶ 23 tenured or tenure-track faculty; 6 unfilled slots.
- ▶ 2-3 full-time Lecturers
- ▶ 4 teaching staff
- ▶ 8 Research Faculty
- ▶ ~ 90 graduate students
- ▶ ~ 65 undergraduate majors

Undergraduate Experience

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$
$$\oint (\nabla \times \vec{E}) \cdot d\vec{A} = \int -\frac{\partial \vec{B}}{\partial t} \cdot d\vec{A} = -\frac{\partial}{\partial t} \int \vec{B} \cdot d\vec{A}$$
$$\oint \vec{E} \cdot d\vec{l} = -\frac{\partial \Phi_B}{\partial t}$$
$$\frac{d\Phi_B}{dt} = N \frac{d}{dt} \int \vec{B} \cdot d\vec{A}$$

5/11/10 DEAS
FARADAY'S LAW

If you're lucky,
nobody gets hurt.

BERNATOWICZ & TROUSIL

PHYSICS 197/198 · LIVE AT CROW · FALL 2006

“Advanced Lab”, 1980s–2018



Undergraduate Experience

Freshman physics:

about 800 students: premeds, engineers, architects, etc.

Sophomore – Senior:

about 20 majors per year.

All have the opportunity for research experience at Wash U.

2018 Freshman physics overhaul:

- ▶ A combination of textbook, online tutorials, and instructor materials, called *FlipItPhysics!*, developed by the Physics Education Group at the University of Illinois at Urbana Champaign. Extensively tested at U.C. Boulder
- ▶ One credit honors section for students wanting more of a challenge
- ▶ Peer Led Teaching and Learning: 50 groups to help students

Graduate Experience



- ▶ Diverse population: students from U.S., China, India, Iran, . . .
- ▶ Two years of coursework: Tuition waived and stipend provided
- ▶ Qualification for Ph.D. program:
 - ▶ Good grades in core graduate courses
 - ▶ Oral qualifier exam
- ▶ 3–4 years of research, supported by research group grants
- ▶ Oral theses defense

Wash. U. Physics Research

- ▶ **Biophysics**

Computational Networks in Brains, Actin Polymerization, Neural Networks

- ▶ **Condensed Matter and Materials**

Metallic Glasses, Exotic Materials, Graphene, Quantum Circuits

- ▶ **Particle and Nuclear Physics**

Strong Interactions, Nuclear Matter, Exotic Nuclei, Quark Matter, Neutron Stars, PT-symmetric Quantum Theory

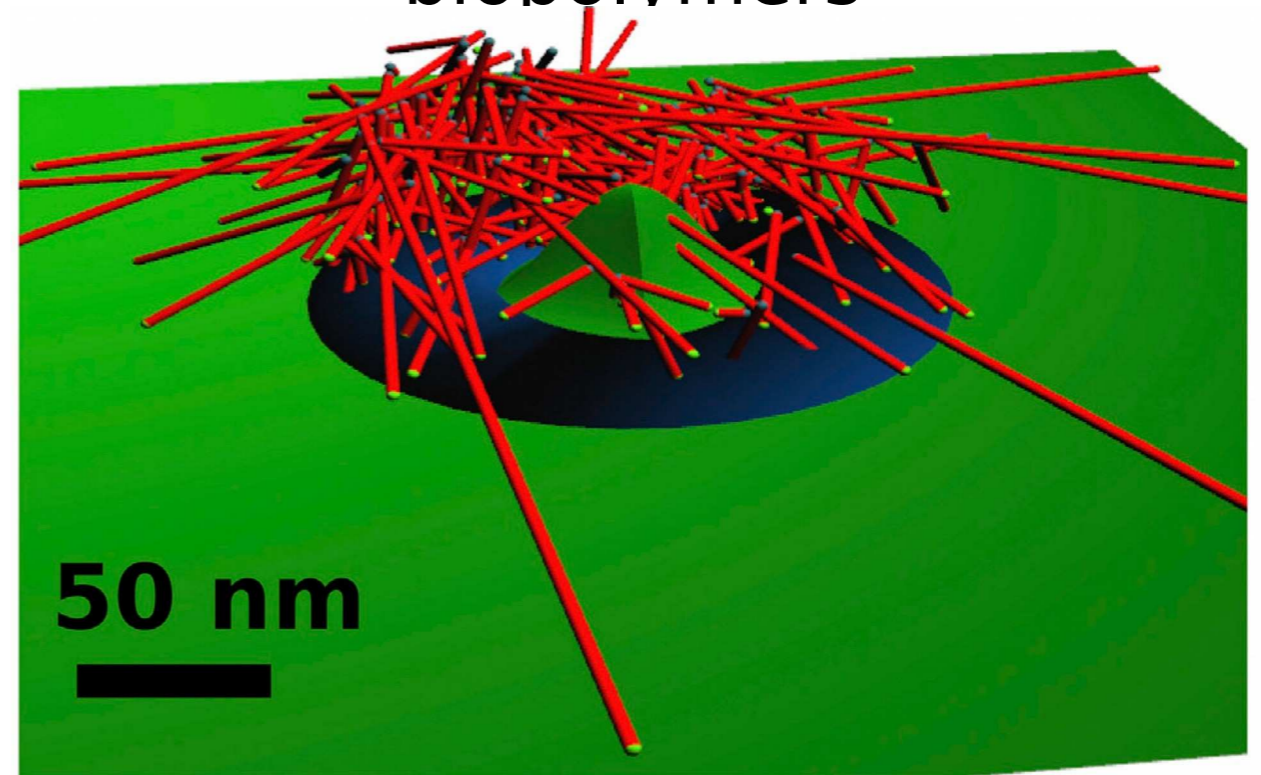
- ▶ **Astrophysics**

Cosmic Rays, X-ray and Gamma-ray astronomy, Extraterrestrial Materials, Dark Matter detection, Precision tests of Gravity

Anders Carlsson (shifted to biophysics ~1998)

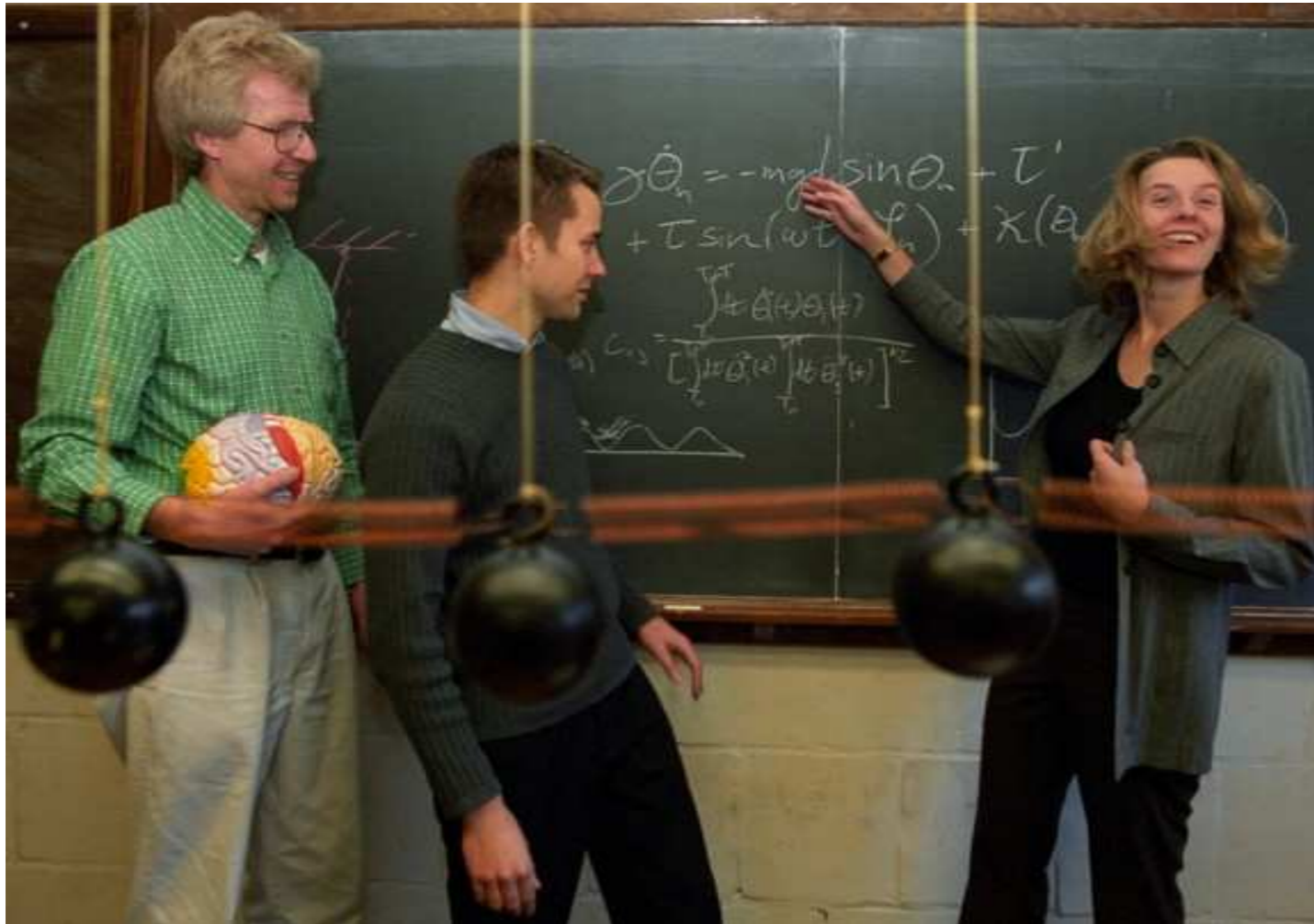
Force Generation in Cells

An endocytic dimple being pulled into a cell by growing biopolymers

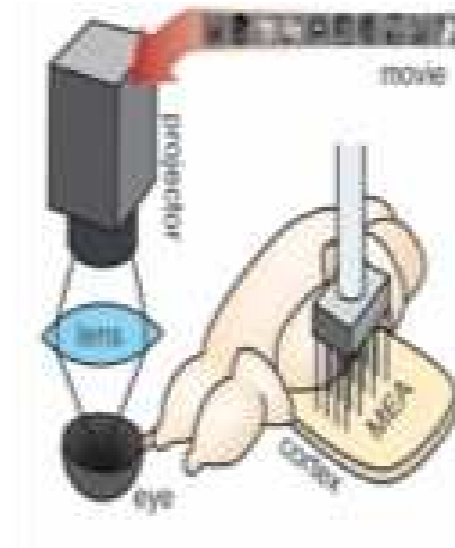


How is the energy of growing biopolymers focused to generate a force distribution that bends the membrane when needed?

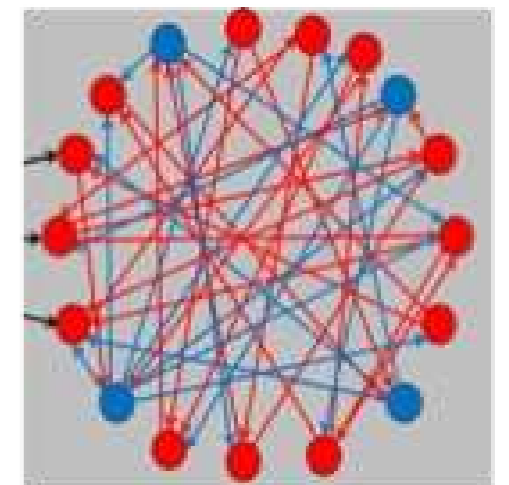
Ralf Wessel (2001) - Physics of the Brain



Advanced
Neurotechnology



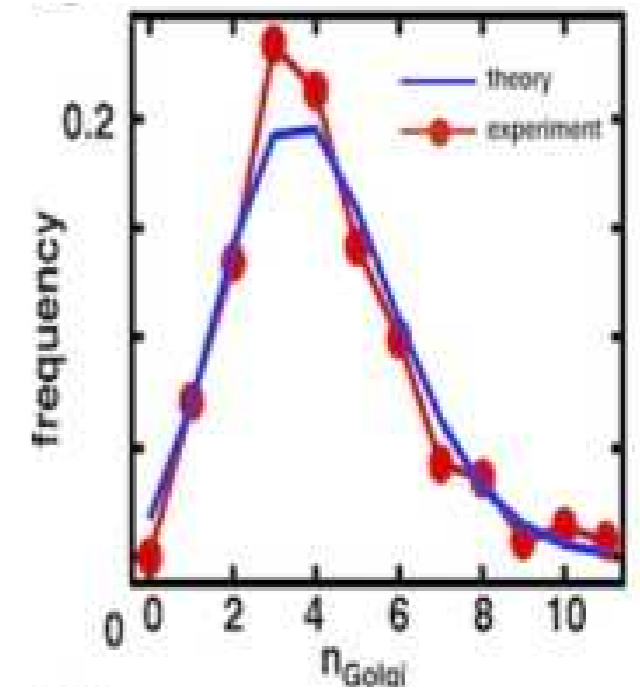
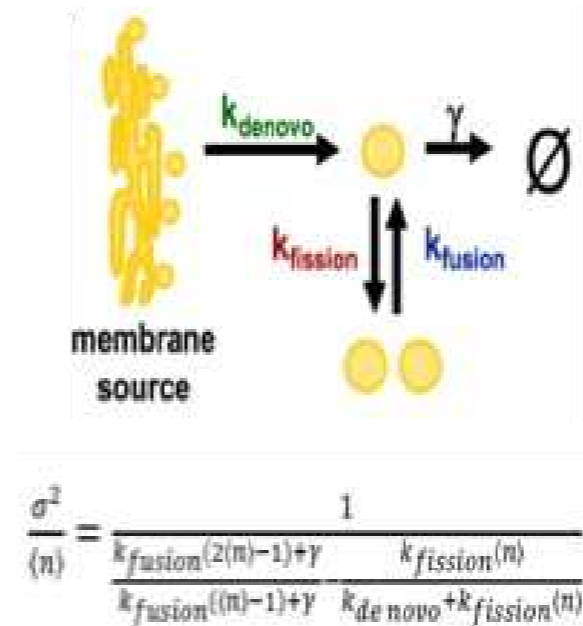
Physics-Inspired
Theory



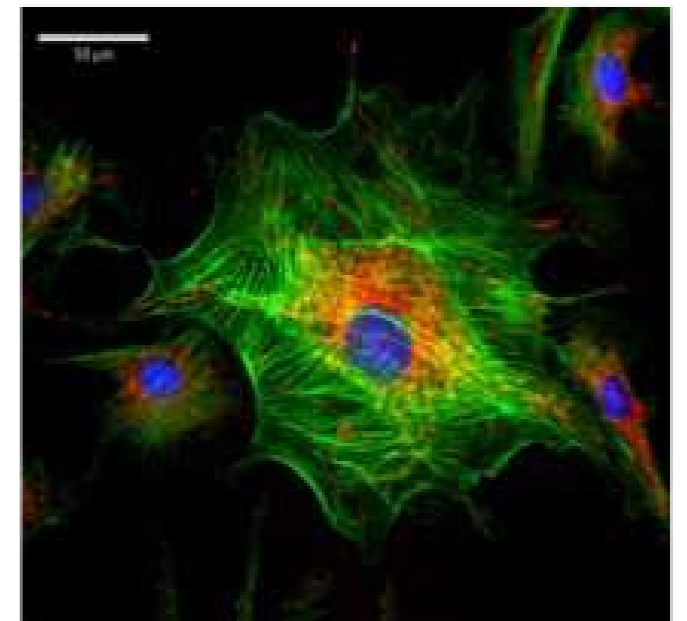
How does visual perception emerge from the nonlinear interaction between visual inputs and the internal dynamic state of brain circuits?

Shankar Mukherji (2017) - Systems Cell Biology

Deciphering the physical principles of cell organization



The Mukherji lab uses statistical physics to derive the rules governing how the eukaryotic cell organizes flows of matter and energy at the femtoliter scale to regulate growth and homeostasis.

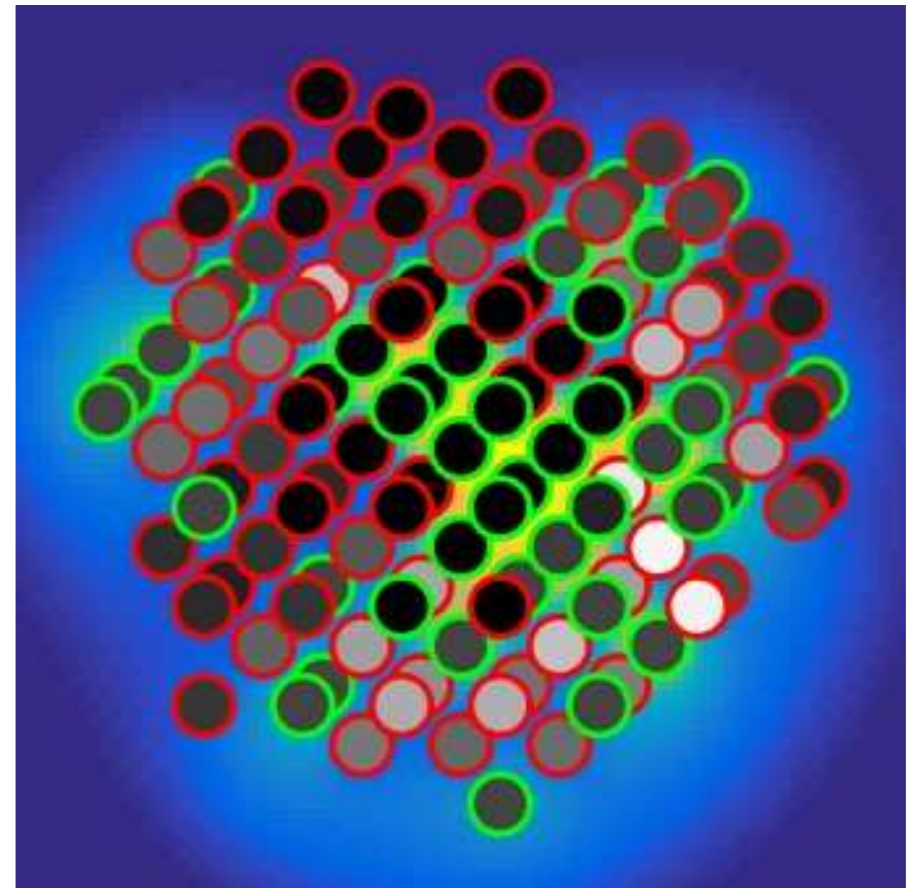


Mikhail Tikhonov (Fall 2018)

Organization of multicellular systems and statistical physics of the genome



Prof. Tikhonov's research lies at the intersection of statistical physics, bioinformatics and microbial ecology.



Secreting (red) and consuming (green) cells organized in a colony fed by a metabolite (blue)

Biomedical Physics

Biomedical physics, with a focus on magnetic resonance imaging and ultrasonic imaging, emerged in the 1970s from the condensed matter experimental groups of Richard E. Norberg and Dan I. Bolef.



Norberg



Bolef

Biomedical Physics



Jim Miller's research team focused primarily on the physics underpinning echocardiography and its clinical applications.



Mark Conradi's research team focused primarily on the physics underlying magnetic resonance imaging of the lung and on pulmonary pathologies.

Condensed Matter & Materials



Richard Norberg
(1954 - 1993)
NMR - amorphous Si,
hydrogen in metals
Department Chair



Kazimierz Luszczynski
(1959 - 2002)
Superconductivity



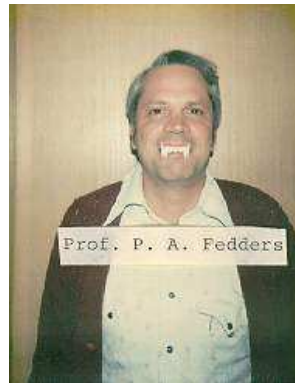
Dan Bolef
(1962 - 1987)
Nuclear acoustic
resonance



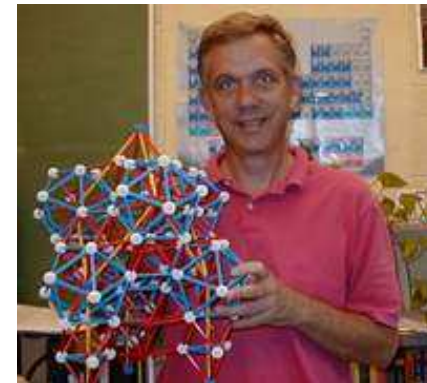
Jim Burgess
Electron Spin
Resonance



Ron Sundfors
(1963 - 1997)
Superconductivity,
nuclear acoustic
resonance



Peter Fedders
(1968 - 2002)
Theory - Amorphous
Si, hydrogen in metals



Pat Gibbons
(1976 - 2013)
EELS, quasicrystals,
semiconductor
nanocrystals



Mark Conradi
(1986 - 2018)
NMR & MRI, hydrogen
in metals MRI of hyper-
polarized He(3) in lungs



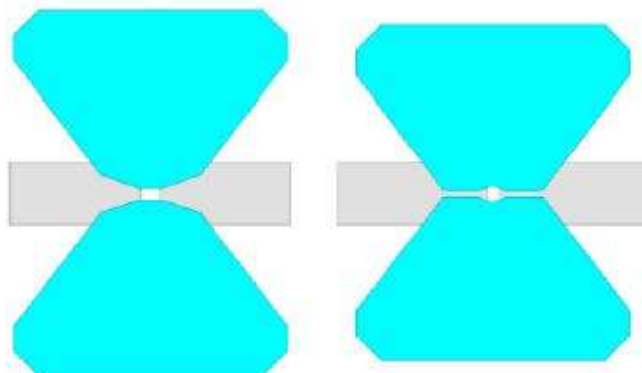
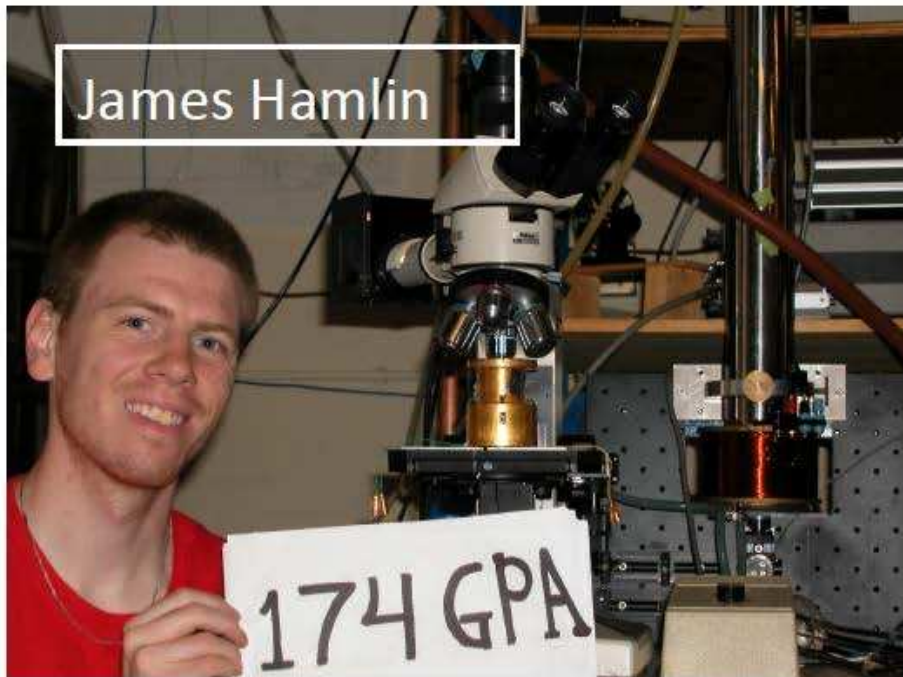
Yaotian Fu
(1987 - 1997)
Condensed Matter and
statistical physics and
Physical acoustics



Stuart Solin
2002 – 2017
Fundamental physical
phenomena in ordered
and disordered solids,
Magnetoresistance

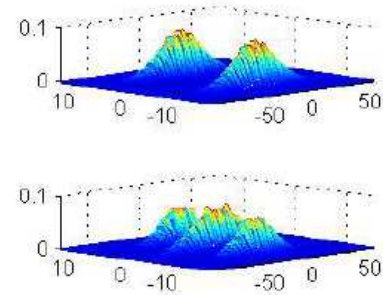
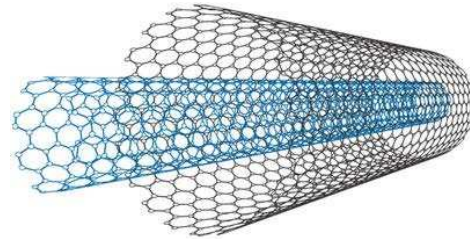
Fierce Competition in Schilling's Group!

The Winner!

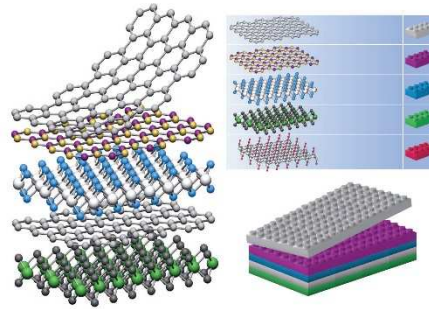
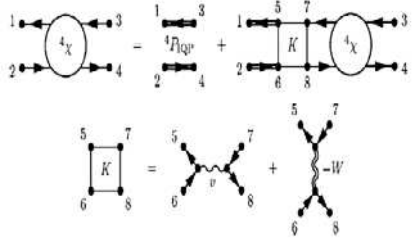


Quantum Mechanics in Materials (Li Yang)

$$i\hbar \frac{\partial}{\partial t} \Psi = \hat{H} \Psi$$



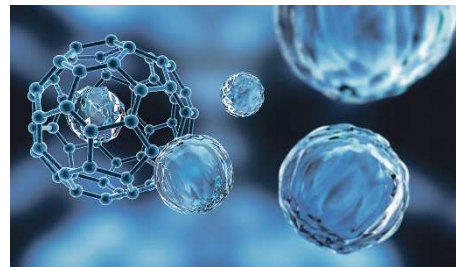
Quantum Excitations



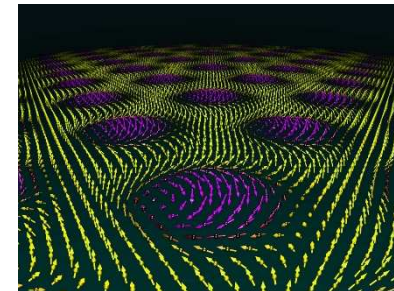
Energy Materials



Simulation of Quantum Mechanics



Novel Materials



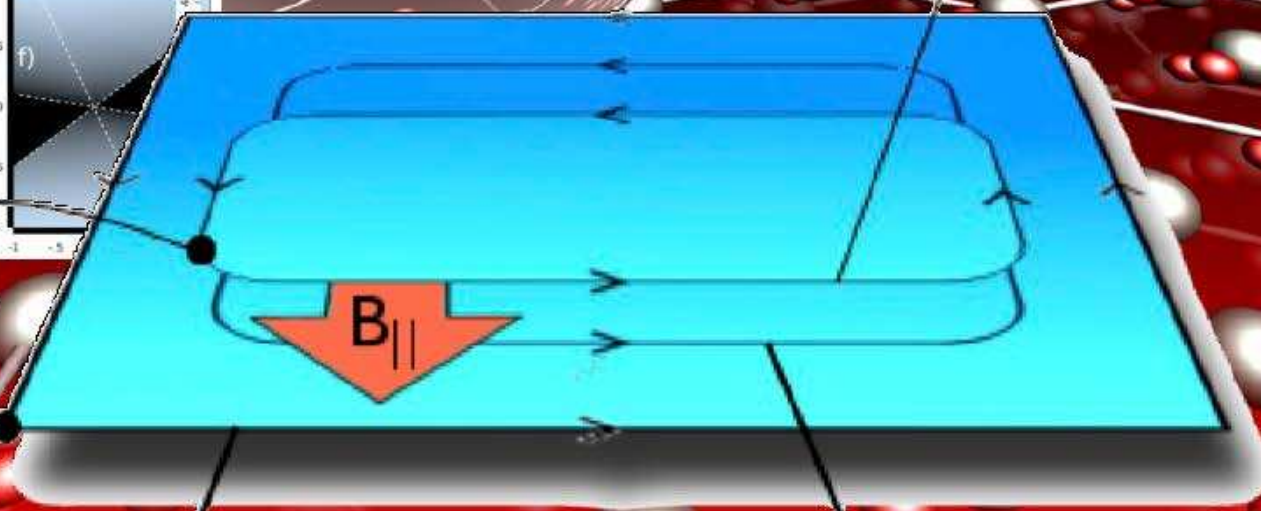
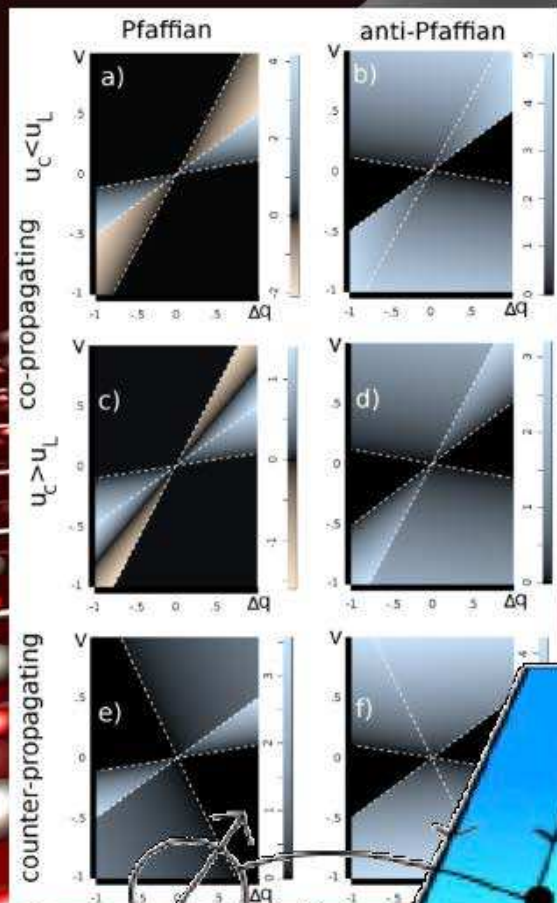
Quantum Topological Property

New Quantum Properties, Materials, and Applications

Alex Seidel

theoretical condensed matter physics
topological phases
fractional quantum Hall effect
quantum magnetism
exactly solvable models
entanglement properties of correlated matter

below and to the left:
probing the quantum Hall edge via
momentum resolved tunneling



$\nu=2$ edge

$\nu=1/2$ edge

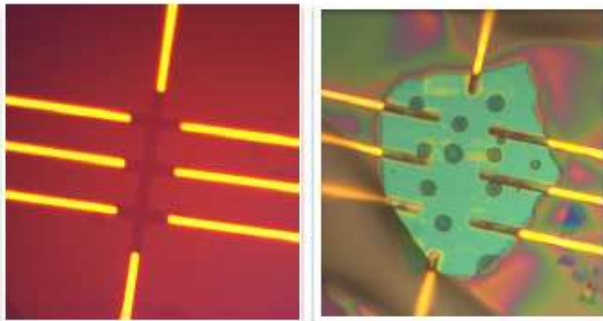
Erik Henriksen – condensed matter physics



Assistant Professor
Department of Physics
henriksen@wustl.edu

- *low temperature and high magnetic field* electronic transport and infrared magnetospectroscopy
- atomically thin crystals (*graphene*)
- *topological materials*
- *quantum spin liquids* in magnetic insulators

graphene-based device (left) for proximity probe of quantum spin liquid in RuCl_3 (right)

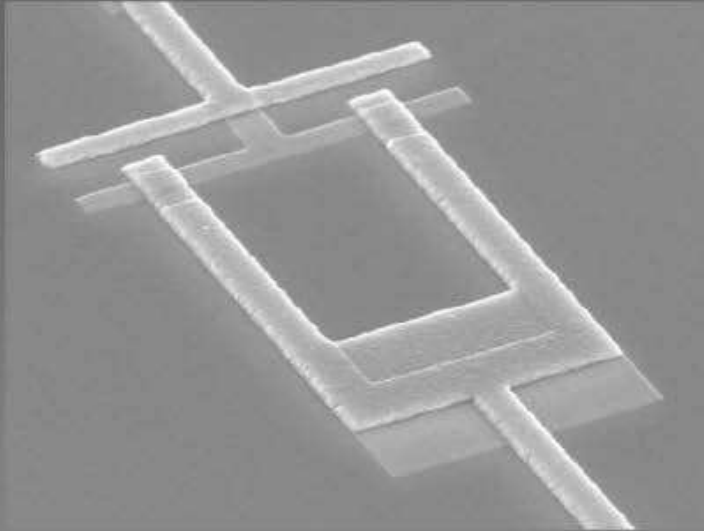


Cryostat for low temperature infrared magnetospectroscopy of atomically thin materials

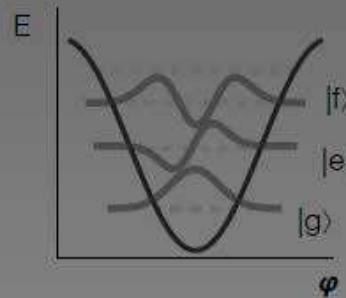


Murch Group

Superconducting quantum electronics



~nm scale aluminum circuits cooled to mK temperatures.



Lowest energy states of the circuit can be used as a qubit for quantum information processing.

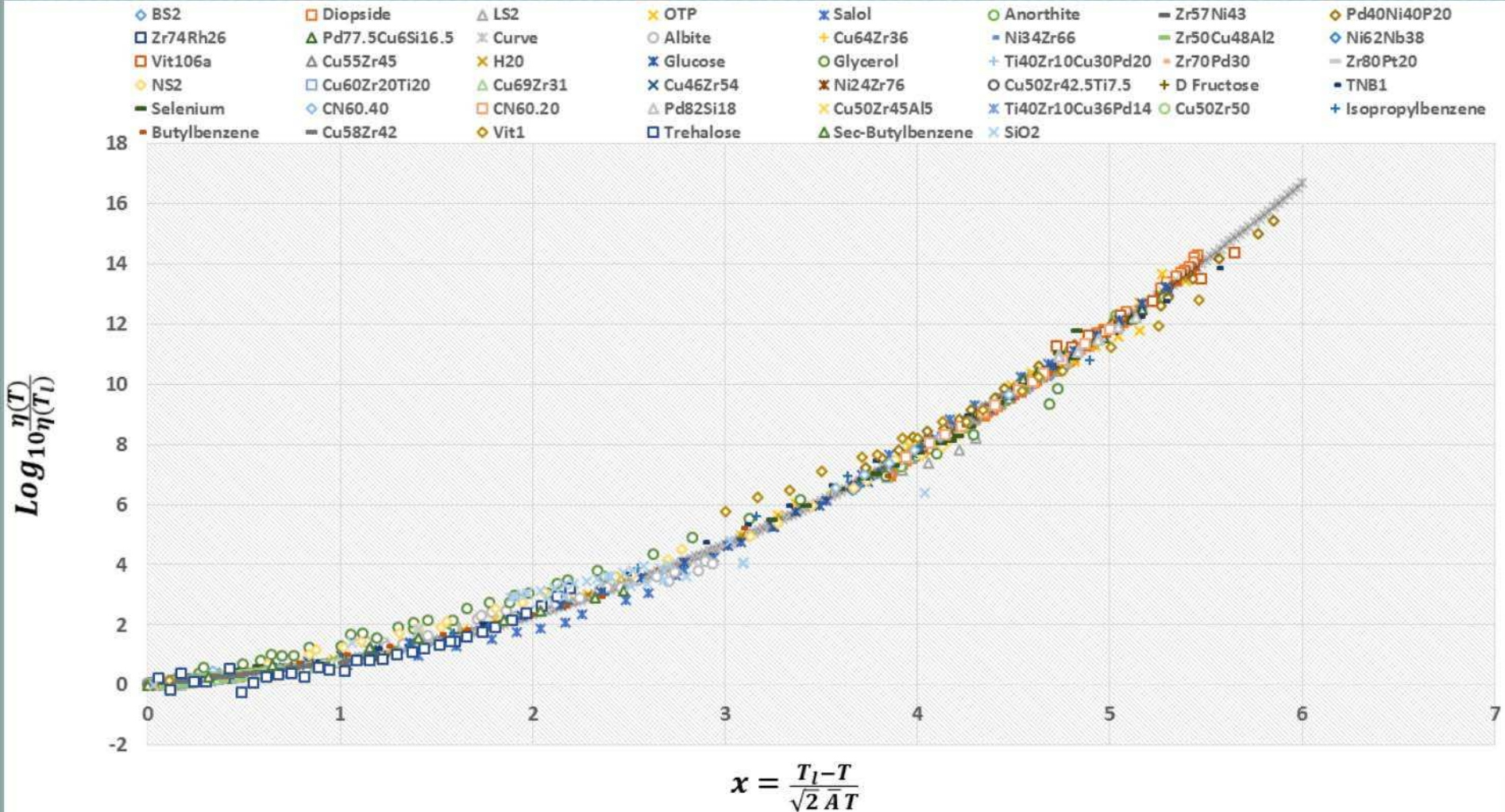
Quantum measurement: dissecting the dynamics of wave function collapse.

S. Weber et al, Nature 511 570 (2014)
In collaboration with A. Jordan, Rochester Univ. and I. Siddiqi, UC Berkeley.

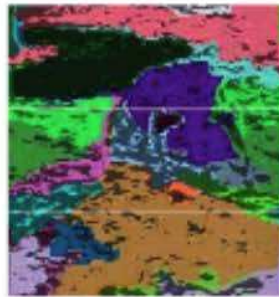
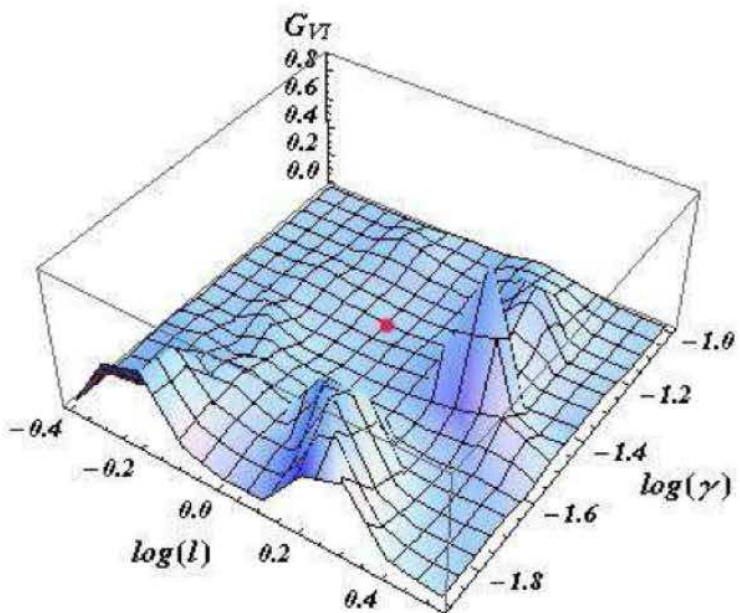
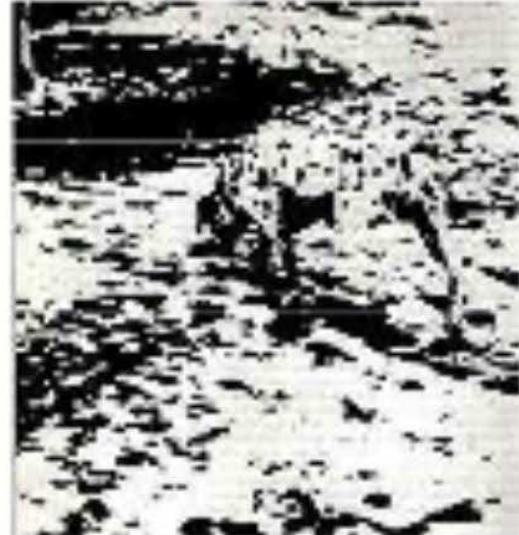


Nussinov Group: condensed matter physics and statistical mechanics

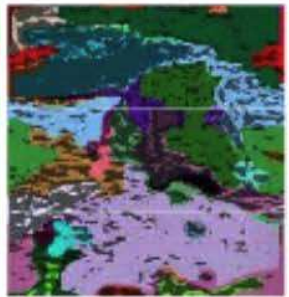
Theoretical Prediction of the viscosity of supercooled fluids



Statistical mechanics based machine learning



$l=1$



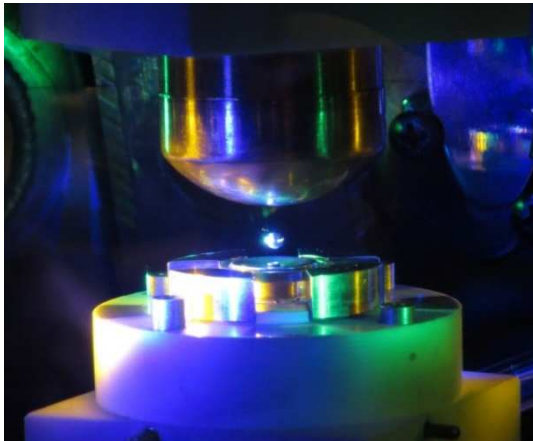
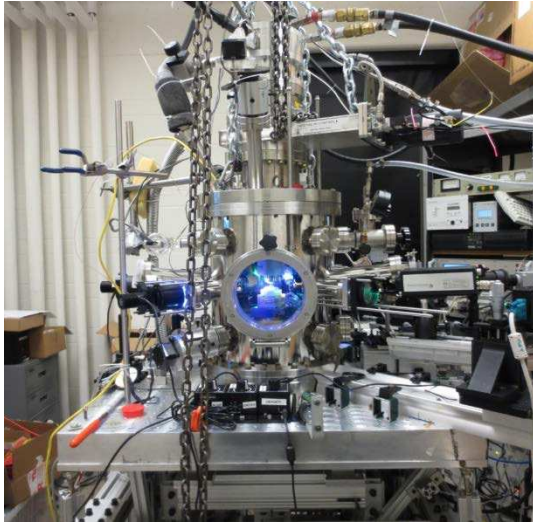
$l=1.29$



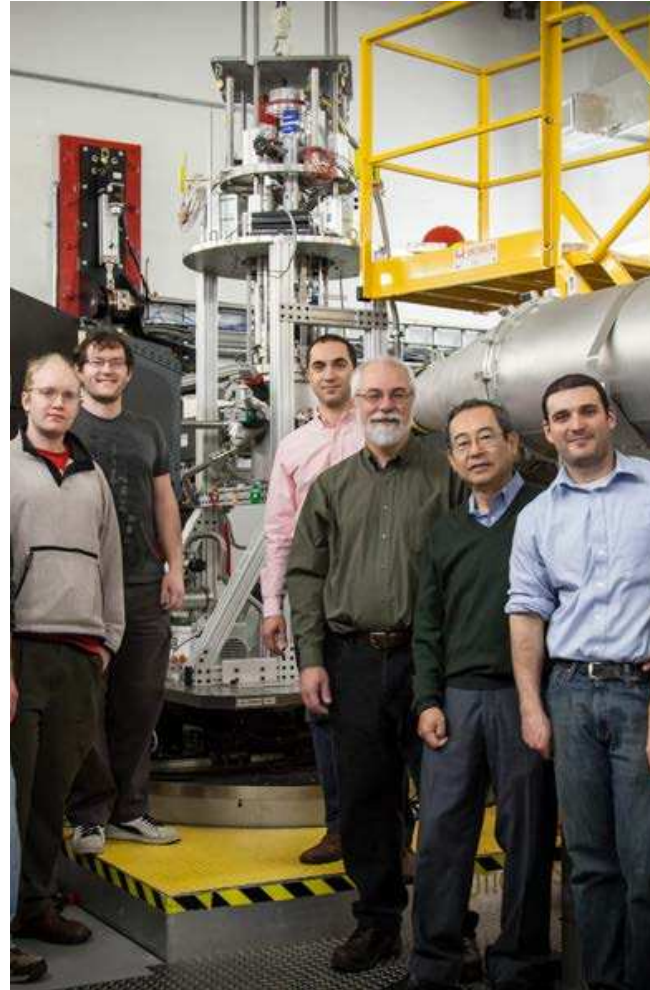
$l=0.63$

Studies of liquid and glass structure, dynamics and phase transitions (Ken Kelton)

Electrostatic levitation of metallic liquids for X-ray and properties studies



Elastic and inelastic neutron scattering studies of levitated metallic liquids



Studies of crystal nucleation in liquids and glasses



Silicate Glass



Metallic Glass

Murch selected as 2018 Cottrell Scholar

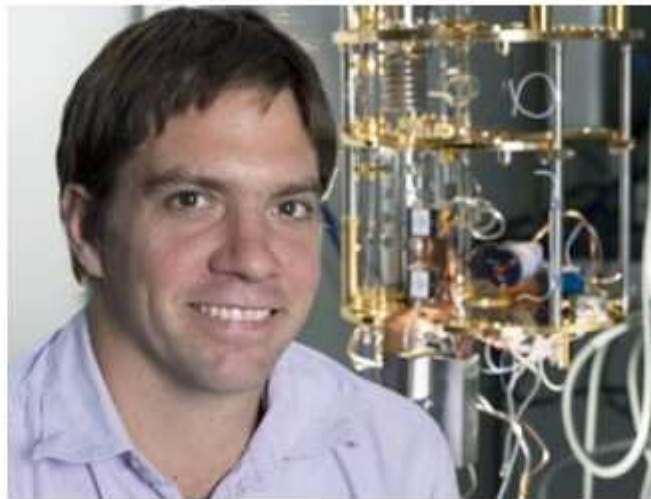
The award recognizes 'outstanding teacher-scholars'

February 13, 2018



[Kater Murch](#), assistant professor of physics in Arts & Sciences at Washington University in St. Louis, has been named a [2018 Cottrell Scholar](#) by the Research Corporation for Science Advancement. The \$100,000 award is for teacher-scholars early in their careers in chemistry, physics or astronomy, and recognizes innovation in both research and teaching.

In his teaching, Murch has utilized “flipped classrooms,” an approach that uses video to supplement lectures. He plans to work with other physics faculty to help them incorporate this approach. He also is broadening his use of flipped classrooms to include it in advanced-level classes and in the lab.



Murch

POPUL



Center for Quantum Information, Quantum Sensors, and Fundamental Physics

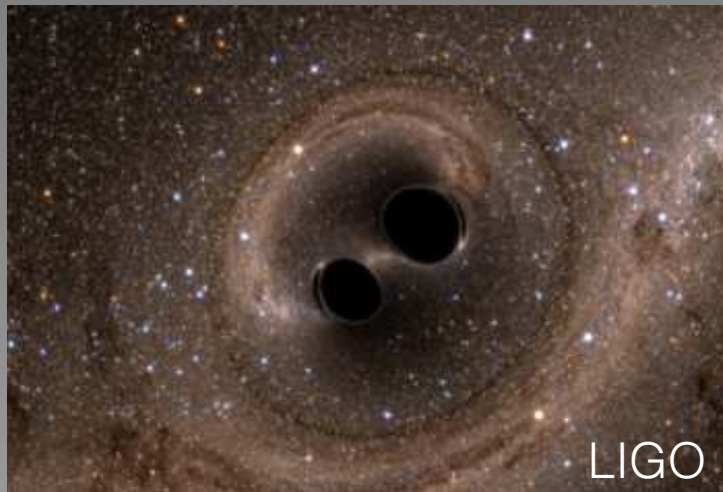
The 20th century was the century of silicon with massive technological transformations enabled by transistor technology. The 21st century will be the century of quantum technologies, with experimental control over quantum systems enabling new paradigms in computation and measurement technologies allowing a new era of fundamental discoveries.

The age of the quantum: transforming science from computing to black holes



Quantum computers
Annealers..

Quantum Supremacy



Quantum enhanced metrology

Quantum gravity



Nuclear Physics at Washington University

- **Experiment**

- Cyclotron 1940: The first isolated plutonium in the world, which would barely fit on the head of a pin, was produced with it.
- Nowadays in Radiochemistry
 - Demetrios Sarantites and Lee Sobotka active with a constant stream of Ph.D. students (many in physics)

- **Theory** with many Ph.D. students ~40

- Henry Primakoff (1946-1960)
- Eugene Feenberg (1946-1977)
- John Clark (1963-)
- Wim Dickhoff (1986-)
- Mark Alford (2003-)
- Saori Pastore (2018-)
- Maria Piarulli (2018-)



Henry Primakoff



Eugene Feenberg



- Past: Primakoff

REVIEWS OF MODERN PHYSICS

VOLUME 31, NUMBER 3

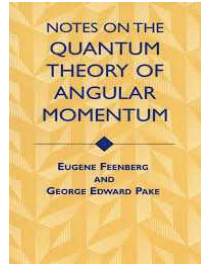
JULY, 1959

Theory of Muon Capture*

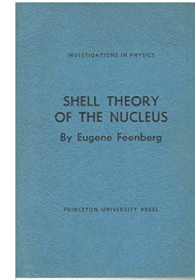
H. PRIMAKOFF

Department of Physics, Washington University, St. Louis 5, Missouri

- Feenberg:



almost Nobel ->



many-body prize



- More recent: Clark -> method of correlated basis functions CBF

PHYSICAL REVIEW

VOLUME 113, NUMBER 2

JANUARY 15, 1959

Simplified Treatment for Strong Short-Range Repulsions in N-Particle Systems. I. General Theory*

JOHN W. CLARK AND EUGENE FEENBERG

UPDATE ON THE CRISIS IN NUCLEAR-MATTER THEORY: A SUMMARY OF THE TRIESTE CONFERENCE

J. W. CLARK

Nuclear Physics A 328 (1979) 587-595

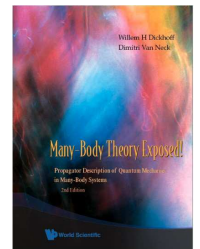
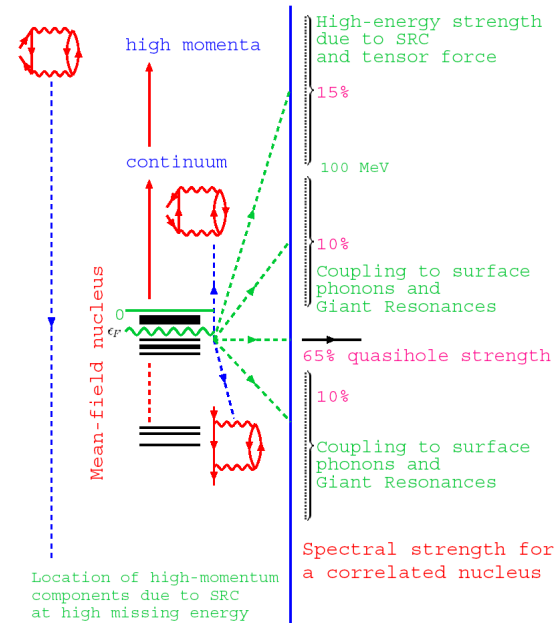
- Much more recent: Dickhoff

W. H. Dickhoff and C. Barbieri

Self-consistent Green's function method for nuclei and nuclear matter.

Prog. Part. Nucl. Phys. 52 (2004) 377-496.

How does a nucleon spend its time in the nucleus:



2008

Present-Future includes Monte Carlo

- Alford

[QCD at finite baryon density: nucleon droplets and color superconductivity](#)

By: Alford, M; Rajagopal, K; Wilczek, F

famous papers:

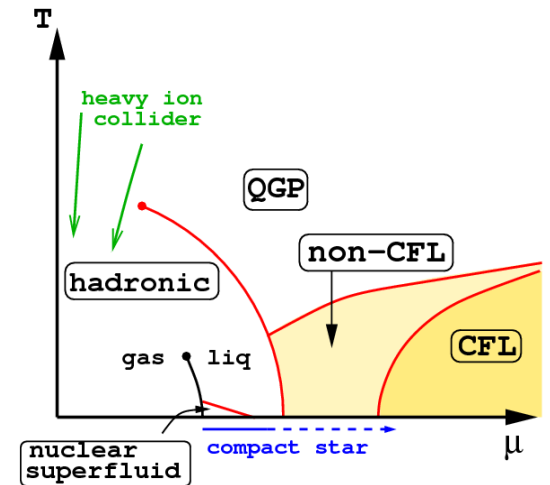
[PHYSICS LETTERS B](#) Volume: 422 Issue: 1-4 Pages: 247-256 Published: MAR 12 1998

[Color-flavor locking and chiral symmetry breaking in high density QCD](#)

By: Alford, M; Rajagopal, K; Wilczek, F

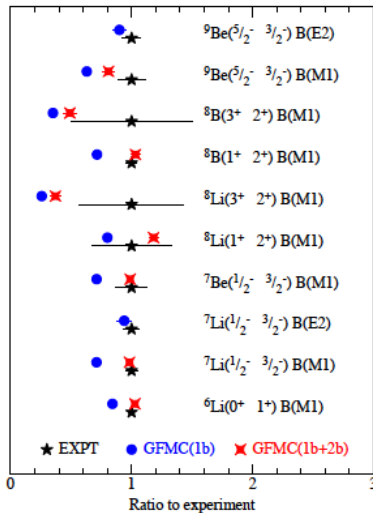
[NUCLEAR PHYSICS B](#) Volume: 537 Issue: 1-3 Pages: 443-458 Published: JAN 4 1999

[Astrophysics - Quark matter in compact stars?](#) and many more

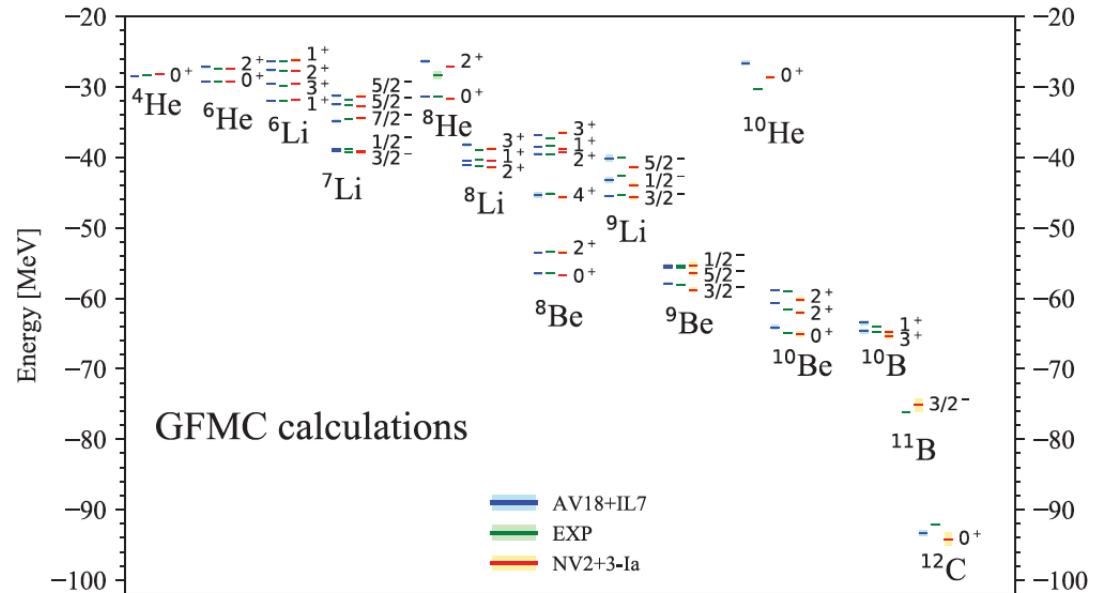


- Pastore: electroweak currents & nuclei & neutron stars

Electromagnetic Decays in Light Nuclei



Pastore et al. PRC87(2013)035503 & PRC90(2014)024321, Datar et al. PRL111(2013)062502

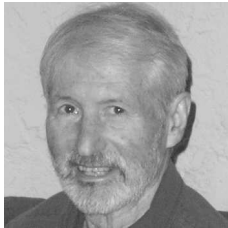


PHYSICAL REVIEW LETTERS **120**, 052503 (2018)

- Piarulli: chiral NN interactions for

light nuclei & nuclear matter

Particle Physics, past



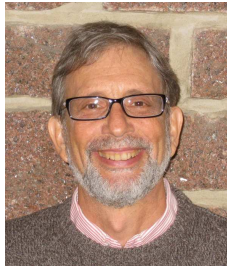
James Ely Shrauner
(1965-2001)

chirality, pions,
quark scattering



Jeffrey Mandula
(1979-1987)

lattice field theory,
mathematical
physics



Claude Bernard
(1991-2015)

lattice gauge theory,
effective field
theories



Maarten Golterman
(1992-2001)

lattice field theory,
chiral symmetry

Particle physics, present



Carl Bender
(1977–2018)

PT-symmetric
quantum mechanics



Michael Ogilvie
(1986–)

quantum
chromodynamics,
lattice gauge theory



Francesc Ferrer
(2012–)

cosmology and
particle physics



Bhupal Dev
(2015–)

beyond the
standard model

PUBLIC RELEASE: 13-OCT-2016

Quantum physicist Carl M. Bender wins 2017 Dannie Heineman Prize for Mathematical Physics

AIP and APS award prestigious prize to professor at Washington University in St. Louis for helping scientists understand and describe the complexities of quantum interactions

AMERICAN INSTITUTE OF PHYSICS



 PRINT  E-MAIL

WASHINGTON, D.C., October 13, 2016 -- The American Institute of Physics (AIP) and the American Physical Society (APS) announced today, on behalf of the Heineman Foundation for Research, Educational, Charitable, and Scientific Purposes, that Carl M. Bender of Washington University in St. Louis is the recipient of the 2017 Dannie Heineman Prize for Mathematical Physics, which is awarded annually to honor significant contributions to the field.

In recognizing Bender, the two organizations cited him: "For developing the theory of PT symmetry in quantum systems and sustained seminal contributions that have generated profound and creative new mathematics, impacted broad areas of experimental physics, and inspired generations of mathematical physicists."



IMAGE: THIS IS CARL M. BENDER, WINNER OF THE 2017 DANNIE HEINEMAN PRIZE FOR MATHEMATICAL PHYSICS. [view more >](#)

CREDIT: JOE ANGELES/WASHINGTON UNIVERSITY



MCDONNELL CENTER FOR THE SPACE SCIENCES

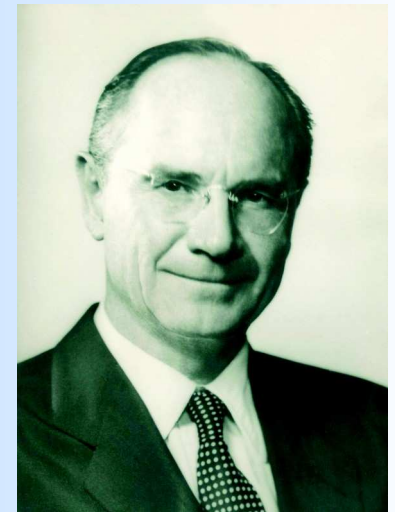
Founded in 1975 with a generous grant from James S. McDonnell and with later contributions from the Danforth Foundation.

Physics
Earth & Planetary Sciences
Affiliations: Engineering & Biology

Mission:

*Investigate the Interconnections
between the Microcosm
and the Macrocosm*

- ◇ **MCSS Professorships:** 4 in Physics and 4 in Earth & Planetary Sciences
- ◇ **Graduate and Postdoctoral Fellowships**
- ◇ **Support:** Travel, Visiting Scientists, Symposia/Workshops
- ◇ **Major Equipment:** the first NanoSIMS 50, SuperTIGER, X-ray Polarimetry, Tescan SEM, Neptune M-ICP-MS
- ◇ **Innovative Research Initiatives:** Astroparticle-Physics, Astrophysics, Black Holes, Cosmic Rays, Cosmology, Dark Matter, Neutron Stars, Origins of the Solar System, X-Ray and Gamma Ray Astronomy, Einstein's Equivalence Principle Test
- ◇ **Outreach:** 2 Distinguished Lecture Series per year, summer undergraduate research, middle school, high school & adult education



James S. McDonnell

Cosmic Ray Group



Mike Friedlander
(1956–1998)



Joe Klarmann
(1961–1996)



Marty Israel
(1969–)



Bob Binns
(1980–)

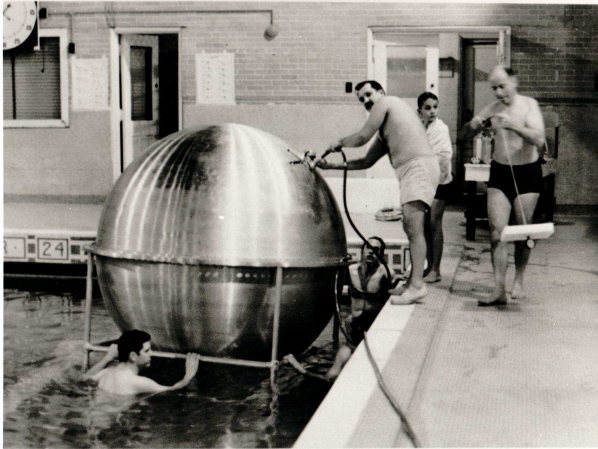
Mike Friedlander received his PhD from the University of Bristol, under Cecil Powell (1950 Nobelist). Mike had discovered the beta decay of the kaon in cosmic ray collisions.

At WU, Friedlander switched to cosmic ray research.

In 1961, Mike was joined by Joe Klarmann from Rochester, and they worked on the composition and energy spectra of cosmic rays.

In 2012, Nature planned to celebrate the 100th anniversary of the discovery of the cosmic rays, and Mike was invited to provide an historical note.

Cosray pool science



Pressure test of gondola prior to first high-altitude balloon flight
In pool: Profs. Bob Binns, Martin Israel, Dick Mewaldt(?)
Right side: Prof. Joseph Klarmann

Early balloon flight



Mike Friedlander:

In 1962, we had balloon flights in the region of the southern geomagnetic anomaly. Our balloons were filled with hydrogen: helium was not used in those days. Hydrogen was supplied by African Oxygen Co, which featured our balloon on the cover of its magazine.

Cosmic Ray Isotope Spectrometer (CRIS) on the NASA Advanced Composition Explorer (ACE), launched in 1997 and still returning excellent data.

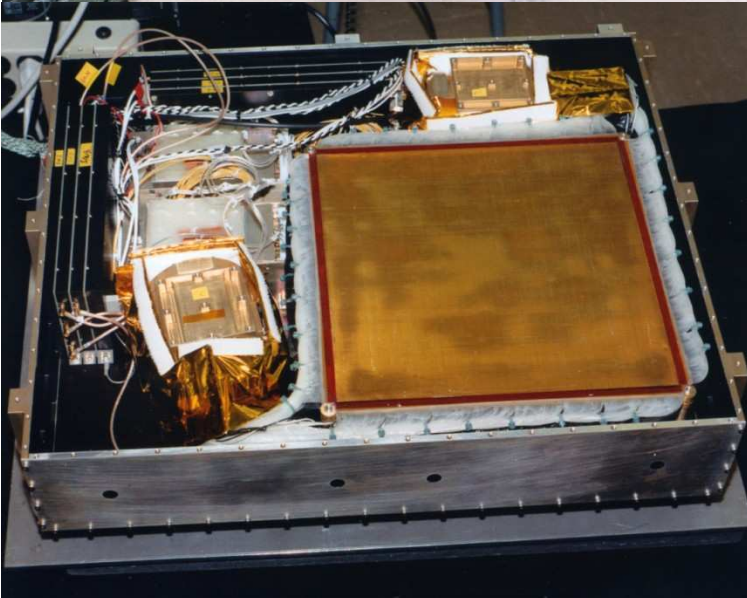
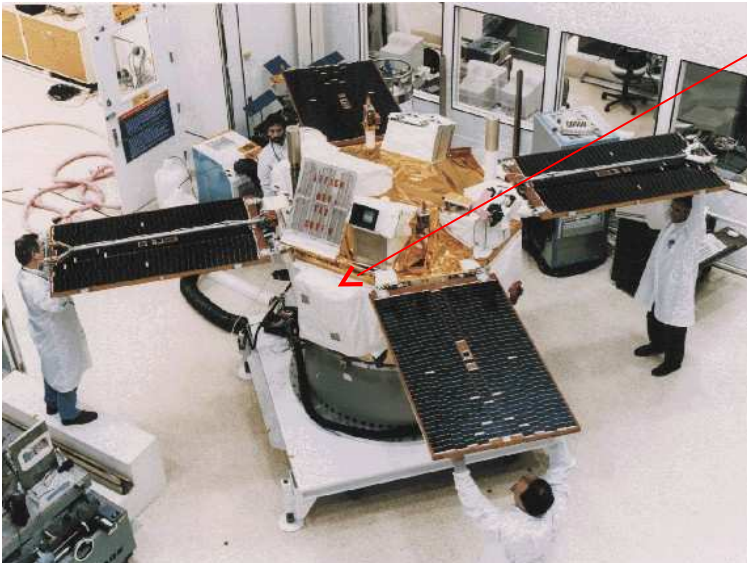
CRIS

The SuperTIGER experiment, designed to measure the elemental composition of cosmic-ray nuclei with $Z > 30$

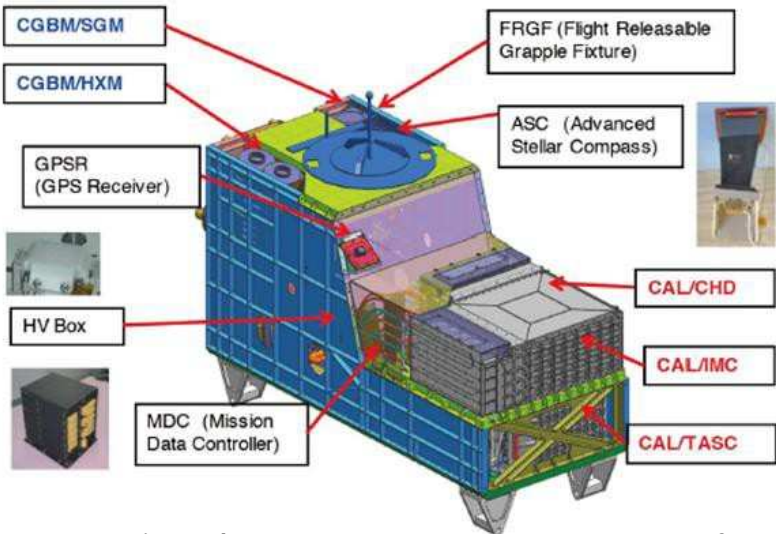


- Flew on high-altitude balloon from Antarctica in 2012-2013
- 55 day long flight
- Preparing for second Antarctic flight in December, 2018

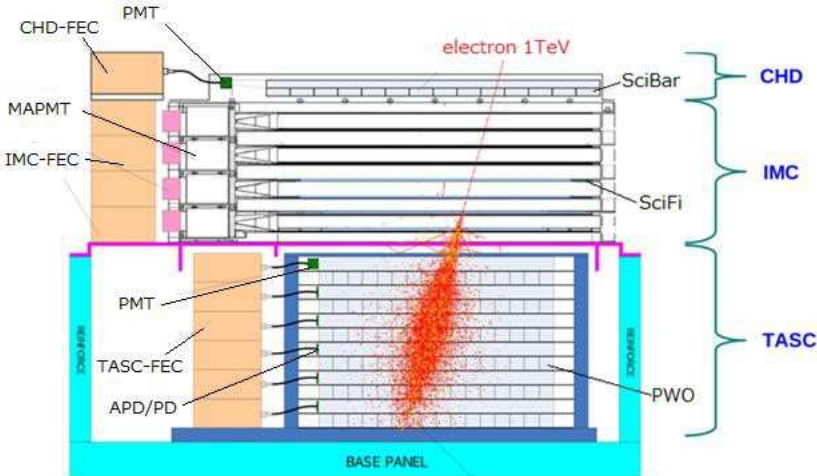
- View of scintillating fiber hodoscope built by WU for the CRIS instrument
- First SciFi detector in space



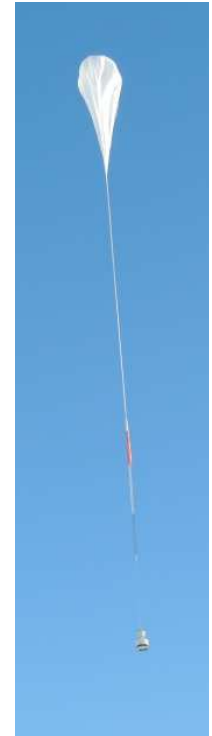
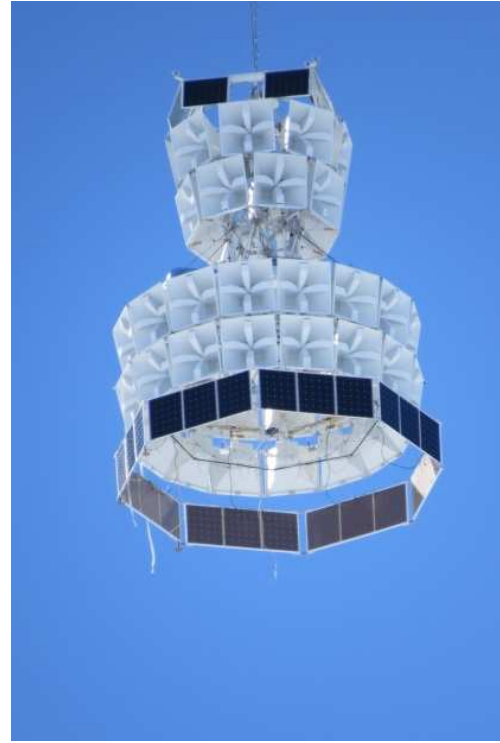
- CALET instrument on International Space Station—Japanese, Italian, & American collaboration. Launched ~3 years ago



- Designed to measure energy spectrum of electrons. Also does gamma-rays and element abundances for $Z=1-40$
- Simulated shower in detector stack below



- Antarctic Impulsive Transient Antenna (ANITA)
- Designed to detect very high energy neutrinos that interact in the Antarctic ice cap, producing a radio frequency pulse that can be detected by instrument on high-altitude balloon.
- Four flights completed and planning a 5th flight in 2020



ANITA launch, 2014

Extraterrestrial Materials

also known as
Space Sciences



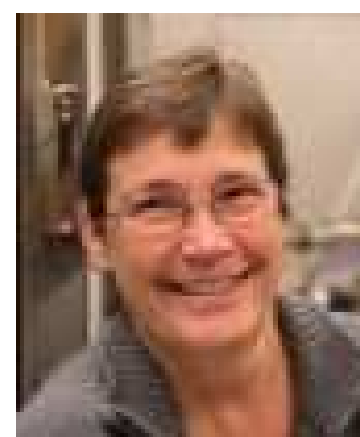
Tom Bernatowicz
1980- 2016



Joyce Brannon
1978- 2009



Ghislaine Crozaz
1973 - 2003



Christine Floss
1996 - 2018



Charles Hohenberg
1969 - 2015



Frank Podosek
1973 - 2011



Frank Stadermann
1996 - 2010



Robert Walker
1966 - 2004



Ernst Zinner
1965 - 2015



Sachiko Amari
1990 - present



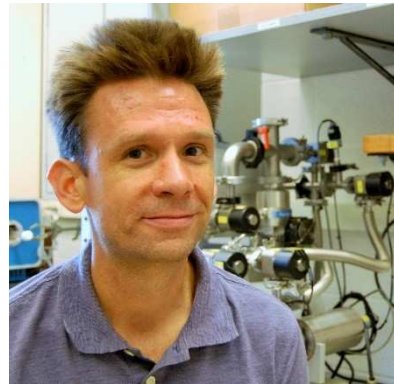
Ram Cowsik
2002 - present



Nan Liu
January 2018 -
present



Alex Meshik
1996 - present

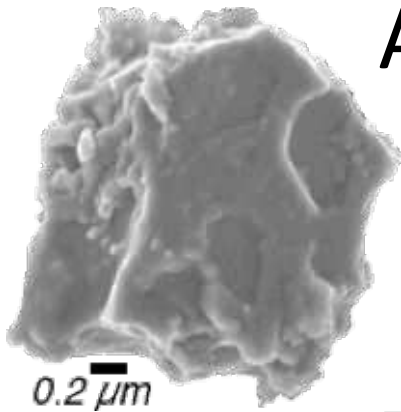


Ryan Ogliore
2015 - present

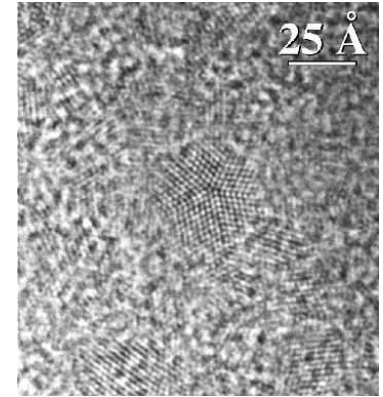


Olga Pravdivtseva
1996 - present

Analysis of Presolar Grains



stellar evolution
nucleosynthesis of the elements
history of the early solar system



silicon carbide

THE ASTROPHYSICAL JOURNAL LETTERS, 768:L17 (5pp), 2013 May 1
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doi:10.1088/2041-8205/768/1/L17

FIRST LABORATORY OBSERVATION OF SILICA GRAINS FROM CORE COLLAPSE SUPERNOVAE

PIERRE HAENECOUR^{1,2,4}, XUCHAO ZHAO³, CHRISTINE FLOSS¹, YANGTING LIN³, AND ERNST ZINNER^{1,2}

nanodiamonds

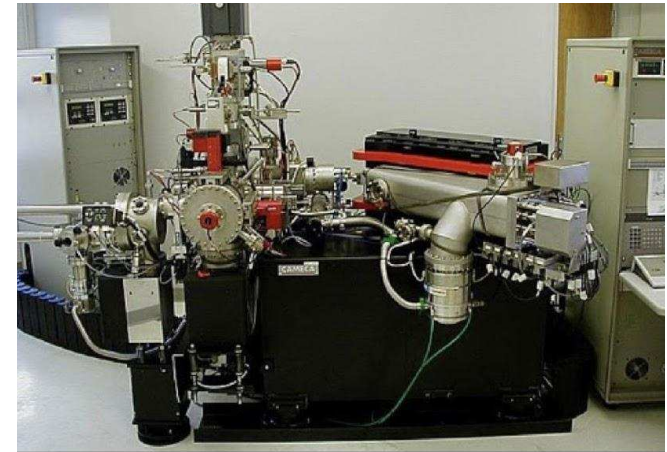
“The discovery of these two silica grains provides definitive evidence of the condensation of silica dust in supernova ejecta.”



Auger Electron Spectrometer



Focused Ion Beam SEM



NanoSIMS

Sample Return Missions

Genesis Mission to Sample the Sun (2001–2004)

Stardust Mission to Comet Wild 2 (1999–2006)

OSIRIS-REx Mission to Asteroid Bennu (2016–2023)



Genesis solar wind collector

THE ASTROPHYSICAL JOURNAL, 763:140 (11pp), 2013 February 1
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doi:10.1088/0004-637X/763/2/140

THE ABUNDANCE OF PRESOLAR GRAINS IN COMET 81P/WILD 2

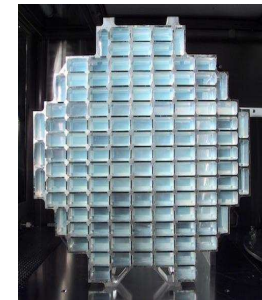
CHRISTINE FLOSS¹, FRANK J. STADERMANN¹, ANTON T. KEARSLEY², MARK J. BURCHELL³, AND W. J. ONG¹

¹Laboratory for Space Sciences, Physics Department, Washington University, 1 Brookings Drive, St. Louis, MO 63130, USA; floss@wustl.edu

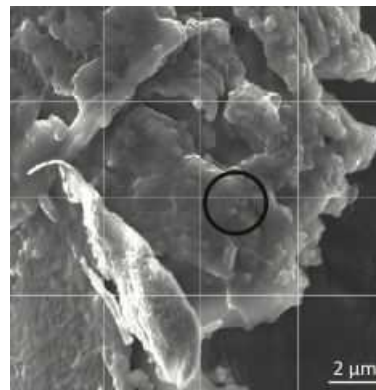
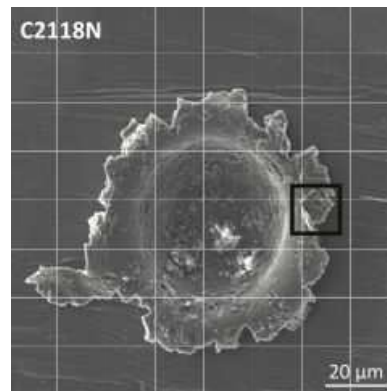
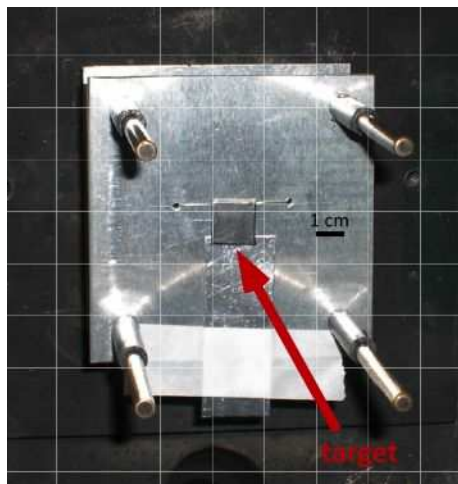
²Impacts and Astromaterials Research Centre, Science Facilities, Natural History Museum, London SW7 5BD, UK

³Centre for Astrophysics and Planetary Sciences, School of Physical Sciences, University of Kent, Canterbury, Kent CT2 7NH, UK

Received 2012 October 5; accepted 2012 December 6; published 2013 January 17



Stardust comet Wild 2 collector



Future Directions



New and upgraded instrumentation:

- Hyperion ion source for NanoSIMS: Chronology of small grains from comets, asteroids, and the Moon
- Tescan Mira3 FEG-SEM: High resolution imaging and X-Ray analyses, fully automated to search for circumstellar grains in sea sediments, or foreign material in meteorites

Spaceflight Hardware:

- Development of sample-return instruments for planetary science missions

New Returned Space Samples:

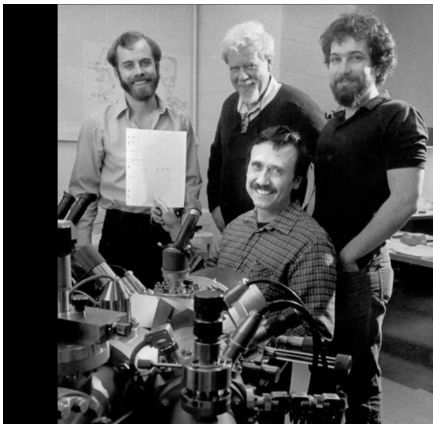
- Hayabusa2 and OSIRIS-REx samples returned from asteroids in the next five years; analog analyses of meteorites, space-weathering processes, ...



“4th floor” group in 1969.

Seated: Marty Seitz, Bob Walker, Ghislaine Crozaz, Michel Maurette

Standing: Howard Hoyt, Mitsuhiro Miyajima, Michael Hair, John
Kardos, Mark Wittels, Dorothy Woolum



Ernst Zinner proudly displays the graph showing the first data obtained with the Washington University IMS-3f ion probe to the obvious joy of onlookers (from left) Scott Sanford, Bob Walker, and Kevin McKeegan (1983).



Ernst Zinner and Bob Walker doing serious science

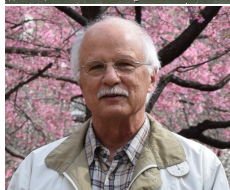
Retiring this year



Carl Bender
(1977-2018)



James Miller
(1970-2018)



James Schilling
(1990-2018)

Arriving this fall



Michael Tikhonov
(2018–)
Biophysics



Saori Pastore
(2018–)
Nuclear theory



Maria Piarulli
(2018–)
Nuclear theory

Labs/Offices Available for Tours

Professor	Room Number	Area
Shankar Mukherji	Crow 120	Biophysics
Ralf Wessel	Crow 117	Biophysics
Erik Henriksen	Crow 1 - Sub-basement	Condensed Matter
James Schilling	Crow 5 - Sub-basement	Condensed Matter
Ken Kelton	Compton 153	Condensed Matter
Martin Israel	Compton 258	Astrophysics
Brian Rauch	Compton 258	Astrophysics
Henric Krawczynski (10:30am-noon)	Compton 266	Astrophysics
John Clark	Compton 351	Nuclear Theory
Patrick Gibbons	Compton 366	Condensed Matter
Claude Bernard	Compton 367	Particle Theory
Alex Meshik (Request assistance for access)	Compton 464 - Noble Gas Lab	Space Science
Shop/Student Shop (10:00-10:30am)	Compton 143	
Student Labs	3rd Floor Crow	