Physics Graduate Program

Rensselaer

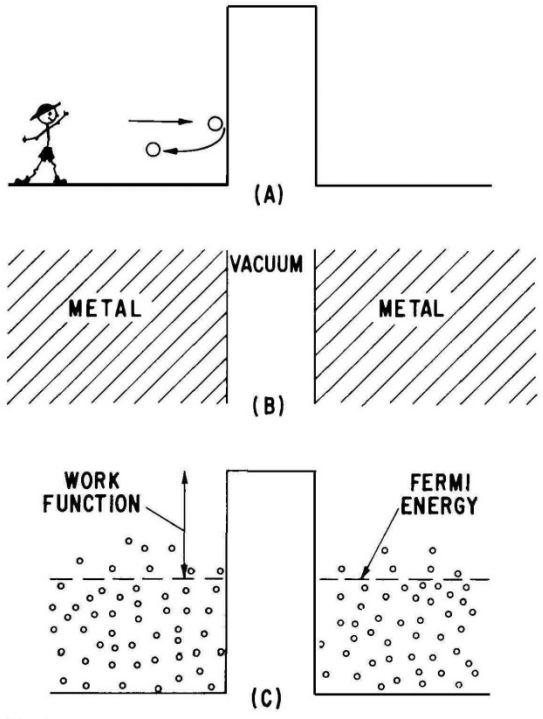
Gyorgy Korniss, Graduate Program Director, korniss@rpi.edu

History, Recognitions, Achievements

Oldest technological university in the US (1824)

Ivar Giaever
GE Research,
Ph.D. at RPI, 1964
Noble Prize, 1973
Professor at RPI (1988-2005)
Alumni Hall of Fame, 1998

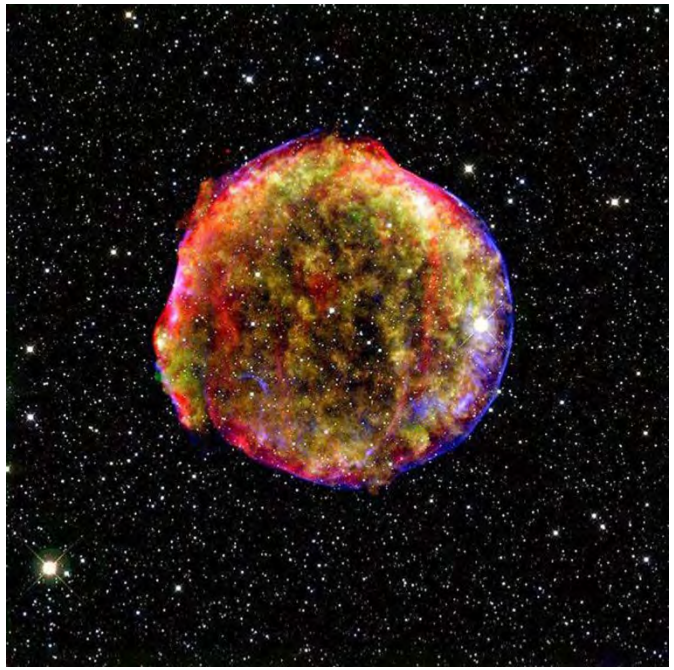
Tunneling phenomena in superconductors
(research performed at GE in 1960)



Heidi Newberg
B.S. at RPI, 1987
Professor at RPI (1988-)
Gruber Prize in Cosmology, 2007, shared
Breakthrough Prize in Fundamental Physics, 2015, shared

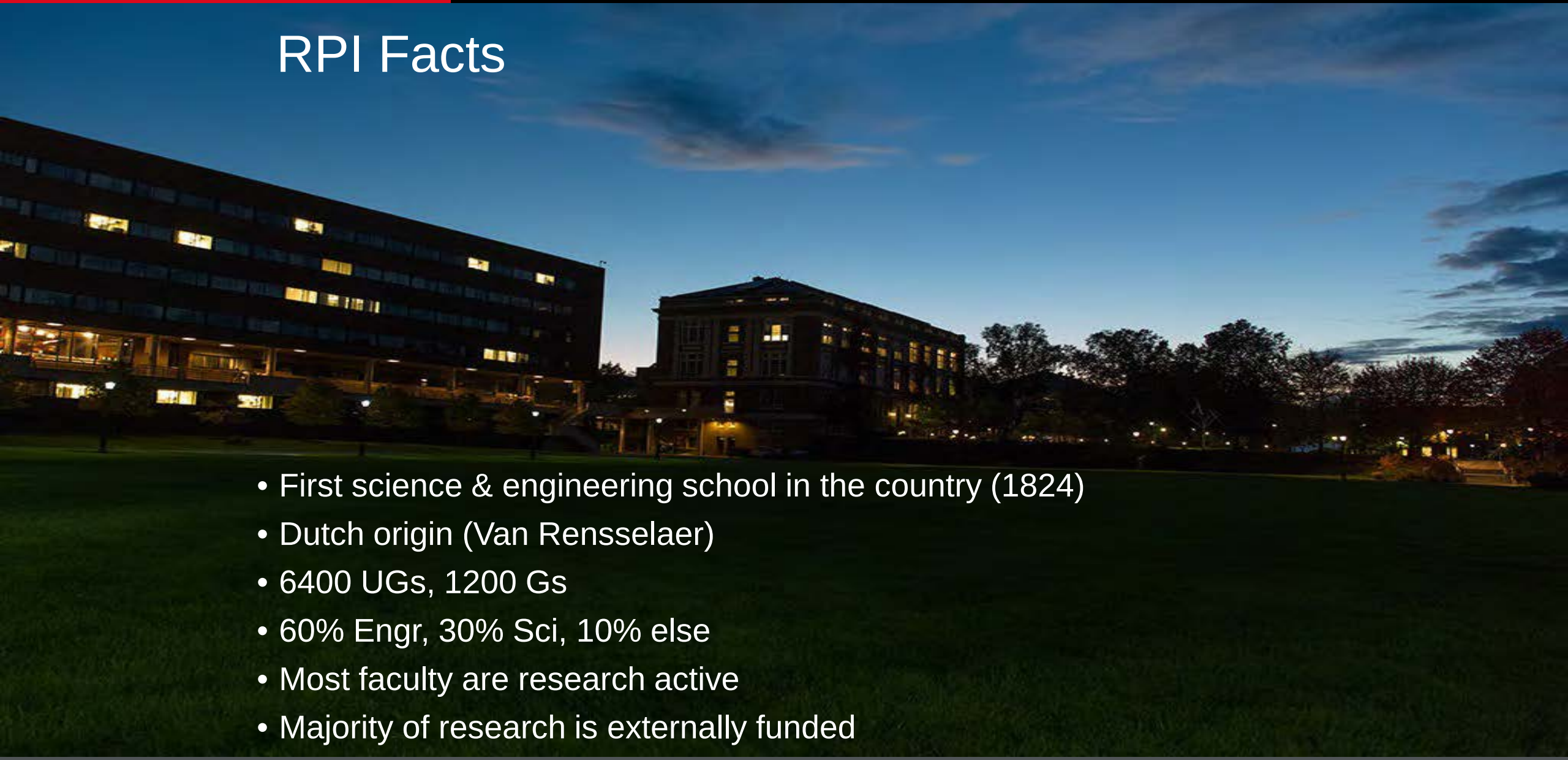
Supernova Cosmology Project:
provided strong evidence that the
expansion of our universe is accelerating;

S. Perlmutter *et al.*, *The Astrophysical Journal* **517**, 565 (1999).
Noble Prize, 2011



NASA, via Agence France-Presse — Getty Images

RPI Facts



- First science & engineering school in the country (1824)
- Dutch origin (Van Rensselaer)
- 6400 UGs, 1200 Gs
- 60% Engr, 30% Sci, 10% else
- Most faculty are research active
- Majority of research is externally funded

Physics Department Facts

- 24 faculty (4 joint)
- 4 lecturers
- 8 APS Fellows, 5 AAAS Fellows, 3 MRS Fellows
- ~240 UGs
- ~38 Gs
- ~7 Postdocs

- External research funded by:

NSF, NASA, DOE, DARPA, ARL, ARO, ONR, DHS, DTRA

Admission Requirements (Holistic Approach)

- Undergraduate GPA (suggested minimum): 3.2

  Students are normally expected to have taken intermediate-level courses in mechanics, electricity and magnetism, quantum physics, statistical mechanics, and experimental physics

- GRE General Test: ***optional for Spring/Fall 2022***
- GRE Subject Test in Physics: ***optional for Spring/Fall 2022***

- TOEFL score of 250 CBT/**100 iBT/600** PBT (IELTS 7.0 or PTE 68) (also accepting Duolingo equivalent scores)

- We look beyond the numbers: we evaluate the application material holistically and give special attention to Research/teaching/work experience, elaborated in Personal Statement and Resume, possibly supported by Recommendation Letters

Teaching/Research Assistantships, and Fellowships

- TA: $23,830 (academic year); (summer RA possible)
- RA: $23,830 (academic year); $7,834 (summer)
  $31,664 (calendar year)

- Fellowship: $35,750 (calendar year) + waiver of fees

All of the above forms of support carries full tuition waiver for 9-15 credits for TAs and 12-15 credits for RAs and Fellowship recipients.

Normally, all of our incoming graduate students are supported as TAs.

Grad School

- #1 advanced coursework that builds on strong UG education/preparation
- **#2 grad school is about focusing on a research project, becoming an expert in something, making significant findings & publishing them**
- #3 skills as scientist and professional (speaking, writing, analysis, computational, experimental, theoretical, organizational, etc.)

Program Summary

- **72 credits**
- Qualifying Exam
  (***can be waived: GRE Physics subject 700+ or RPI core courses A- or better***)
- Candidacy exam
- Thesis defense/Dissertation

Two Main Components

- Coursework
- Research

Ph.D. Timeline

- Typical time to complete = 5 yrs
- **Limit of 7 yrs** (5 yrs if formally entering with a M.S.)
- Candidacy typically taken in the 3rd year, but should be passed at least 1 year prior to defense
- 3.0 or higher GPA (individual core courses with a grade lower than B are also cause for concern)
- Dissertation credits make up a lot of the total

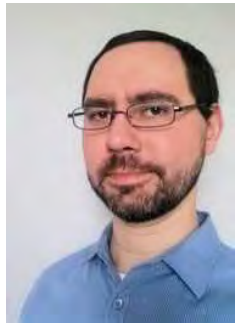
Careers

Yiping Zhao
Professor at University of Georgia
Ph.D. at RPI, 1999

Hasan Guclu
Prof. at Istanbul Medeniyet University
Prof. at University of Pittsburgh
Ph.D. at RPI, 2005

Lauren O'Malley
MITRE
Ph.D. at RPI, 2008

Casey Doyle
Sandia Natl. Lab
Ph.D. at RPI, 2018

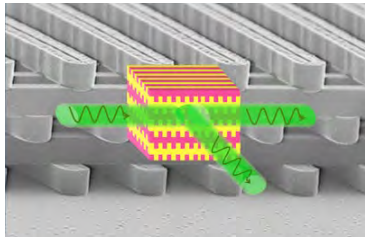


Matt Newby
Professor at Temple University
Ph.D. at RPI, 2013

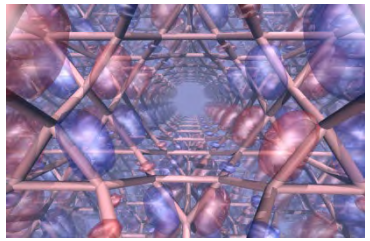
Panagiotis Karampourniotis
IBM Cambridge
Ph.D. at RPI, 2017

Major Research Areas

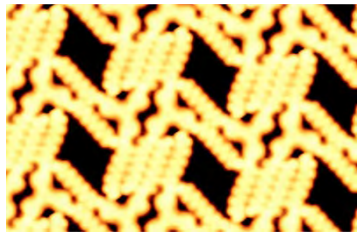
Astronomy and Astrophysics
Computational astronomy, galactic structure and evolution, large astronomical surveys, dark matter.



Optical Physics
Plasmonic structures, light-matter interaction, terahertz spectroscopy, quantum optics and photon entanglement.



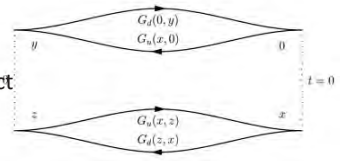
Condensed Matter
Molecular electronics, quantum molecular dynamics, semiconductor materials and devices, thin film morphologies and transport, low-dimensional systems.

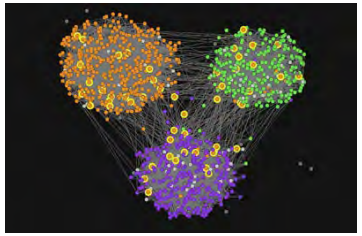


Nanoscience and Nanomaterials
Nanoelectronics, Nanophotonics, nanostructures, nano-bio interfaces.

Energy Research Energy harvesting, conversion and transfer, solid-state lighting, complex systems and networks.

Particle Physics Direct detection of dark matter, lattice field theory, neutrinoless double beta decay.





Statistical Physics
Complex systems and networks, social dynamics, transport, flow, and cascading failures in complex networks.

https://science.rpi.edu/sites/default/files/PhysicsGraduateProgramInformation.pdf

Research Centers at RPI

- **Collaborations**
- **Interdisciplinary research**

Center for Computational Innovations (CCI)

Center for Biotechnology and Interdisciplinary Studies (CBIS)

Center for Materials, Devices, and Integrated Systems (CMDIS)

Center for Future Energy Systems (CFES)

Data Science Research Center (DSRC)

Network Science and Technology Center (NeST)

Institute for Data Exploration and Applications (IDEA)

National Labs, Industry, Collaborations

- **Los Alamos National Laboratory**
- **Oak Ridge National Laboratory**
- **Army Research Laboratory**
- **LNGS (Italy): XENON 100/XENON1T (Dark Matter)**
- **Sloan Digital Sky Survey**
- **IBM**
- **GE**
- **Lockheed Martin**
- **…**

Questions?

Admission Requirements and Program Information:

https://science.rpi.edu/physics/programs/graduate

https://science.rpi.edu/sites/default/files/PhysicsGraduateProgramInformation.pdf

https://science.rpi.edu/sites/default/files/RPI_Physics_GradSchool_AIP.pdf

Gyorgy Korniss, Graduate Program Director, korniss@rpi.edu

Additional Program Details

Required/Core Courses

- Quantum Mechanics I (4 cr)
- Quantum Mechanics II (4 cr)
- Statistical Mechanics (4 cr)
- Electrodynamics (4cr)
- Colloquium (four semesters, 4x1 cr)

Elective Requirement

- 12 credits
- 6 with PHYS or ASTR prefix
- 4000 or 6000 level*
- Pre-approved list in handbook
- Other course may be approved upon review by graduate program director

* Of these 12 credits of technical electives, **at least 6 credits must have a PHYS or ASTR prefix**, and **at least 6 credits must be at the 6000 level** (a single class can be counted towards both requirements). In addition, in satisfying degree requirements, **at least two-thirds of the total credit hours, excluding thesis, must contain the suffix numbers 6000-7999**, with the further limitation that no more than 15 credit hours of 4000-4990 courses are to be allowed.

Elective Courses (PHYS/ASTR)

- PHYS 4620: Elementary Particle Physics
- PHYS 4810: Computational Physics
- PHYS 4960: Density Functional Theory
- PHYS 4960: Photonics
- PHYS 4960: Optical Properties of Materials
- PHYS 6530: Quantum Mechanics III
- PHYS 6710: Theory of Solids I

- ASTR 4120: Observational Astronomy
- ASTR 4220: Astrophysics
- ASTR 4240: Gravitation and Cosmology
- ASTR 4510: Origins of Life: A Cosmic Perspective
- ASTR 6250: Interstellar Medium
- ASTR 6900: Astrophysics Seminar

Elective Courses (examples)

- …
- CSCI 6100 Machine and Computational Learning
- CSCI 6360 Parallel Computing
- …
- MATH 4700 Foundations of Applied Mathematics
- MATH 6660 Stochastic Processes and Modeling
- …
- MTLE 4150 Kinetics in Materials Systems
- MTLE 4160 Semiconducting Materials
- …

Further Notes

- Most of the rest of the 72 credits will be dissertation credits.
- You should have at least 9 credits/semester as a TA, and at least 12 credits/semester as an RA.

Qualifying Exam*

- Classical Mechanics (including special relativity)
- Electromagnetism (including special relativity)
- Quantum Mechanics
- Thermodynamics/Statistical Mechanics

  - ➢Administered in August and January
  - ➢Must be passed by August of the beginning of the second year for fall entry (normally three attempts)
  - ➢There is an appeal process.

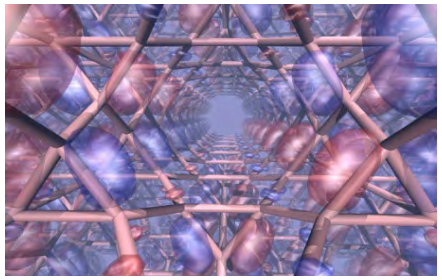
**** Waived with GRE Physics Subject 700+ or RPI core courses A- or better***

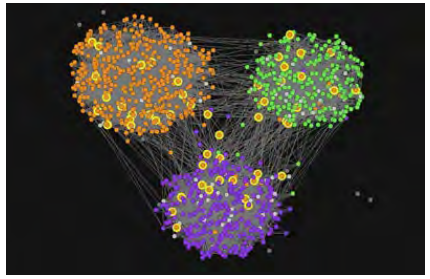
Qualifying Exam

- Classical Mechanics (CM, 5 problems, including special relativity)
- Electromagnetism (EM, 5 problems, including special relativity)
- Quantum Mechanics (QM, 6 problems)
- Thermodynamics/Statistical Mechanics (SM, 4 problems)

  - These may be passed individually
    [3/5 (CM), 3/5 (EM, 4/6 (QM, 2/4 (SM)].
  - Passing score is 6/10 pts on each problem.
  - **Physics GRE score of 700 or above waives the exam**
  - **Parts may be waived with A or A- in certain courses taken at RPI**
  - Spelled out in **Grad Program Handbook**

Faculty Research Highlights

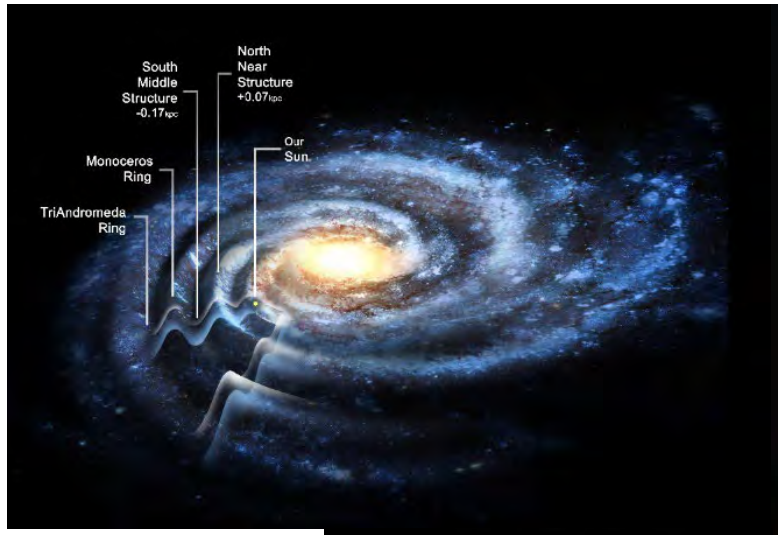


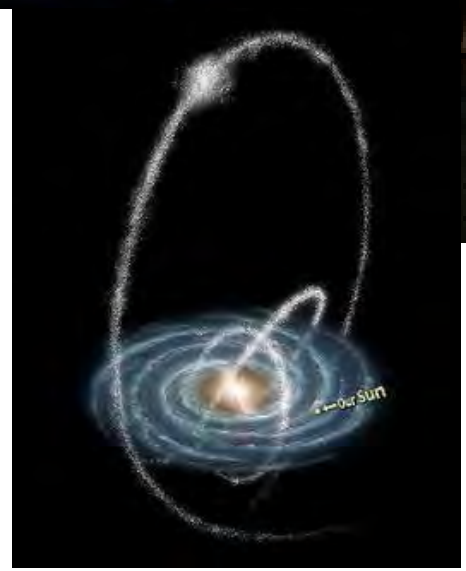


https://science.rpi.edu/sites/default/files/PhysicsGraduateProgramInformation.pdf

Newberg Group Research

- Discovery of streams of stars tidally stripped from dwarf galaxies as they fall into the Milky Way
- Discovery of ripples in the disk caused by infalling galaxies
- Data Science with large sky surveys
- Computational Science: PetaFLOPS-scale MilkyWay@home volunteer computing



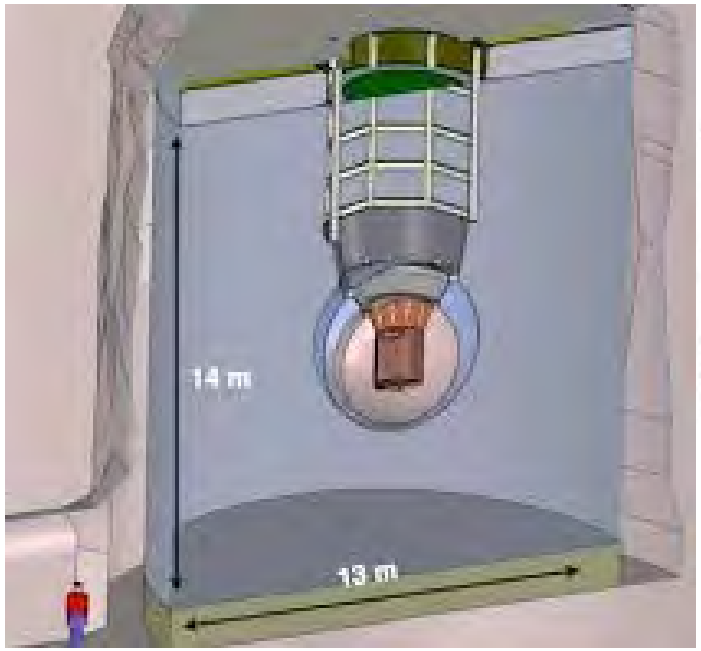


Heidi Jo Newberg

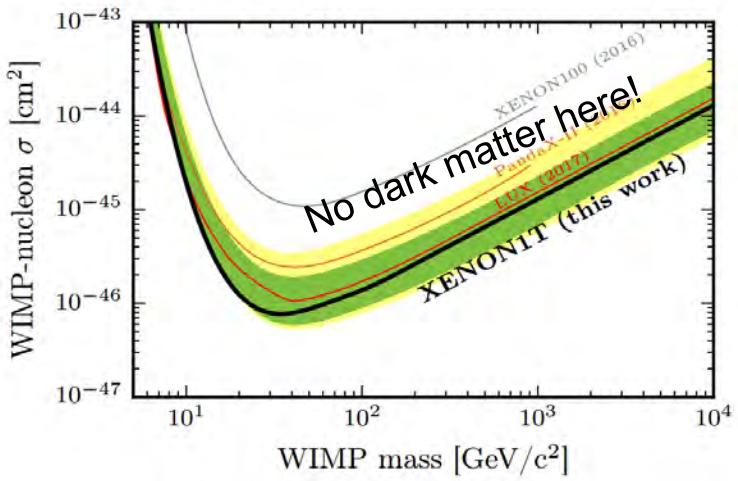
Particle Astrophysics, Dark Matter and Neutrino Experiments

Prof. Ethan Brown

XENON1T – Largest dark matter experiment in the world!



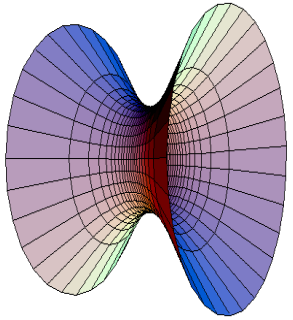
- nEXO Experiment
- Search for rare neutrino properties

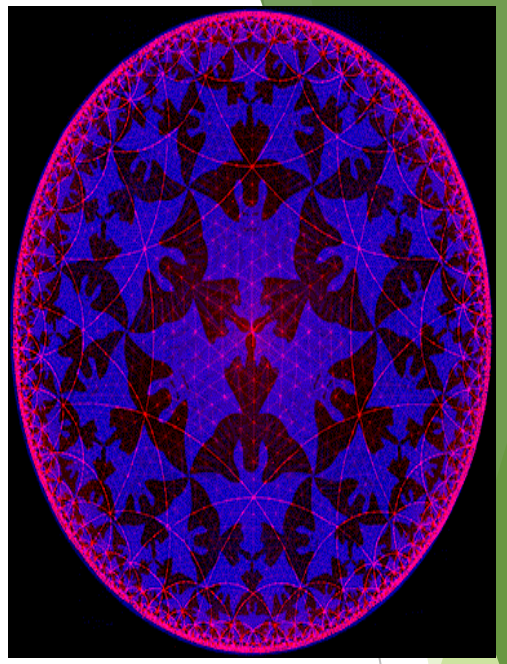


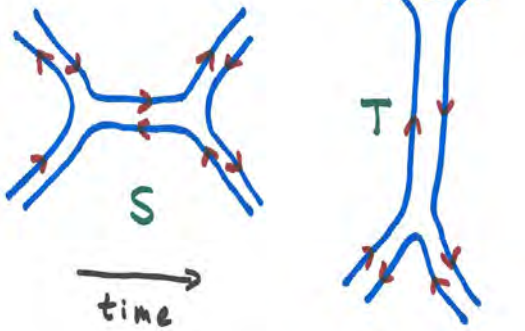
Most competitive search worlwide

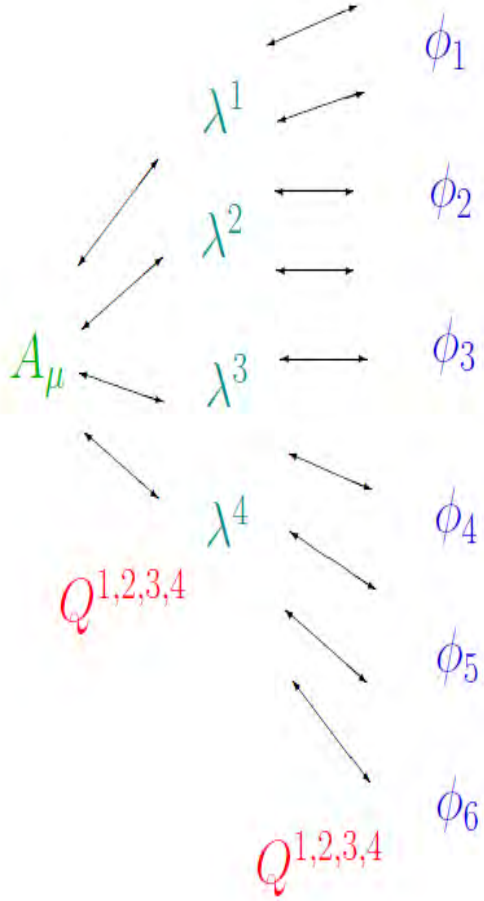
- Use particle physics to answer questions about astronomy
- Probe fundamental physics by experiment

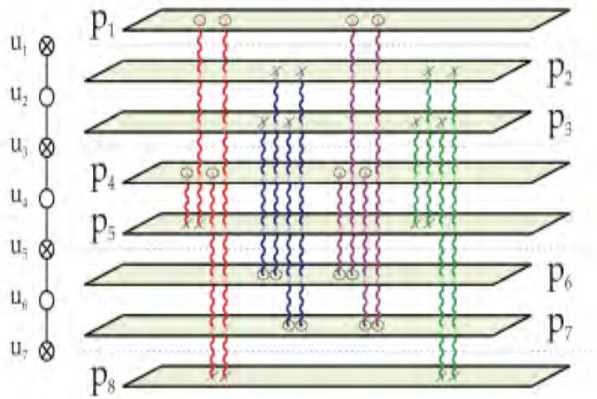
N=4 super-Yang-Mills on the lattice (Joel Giedt)







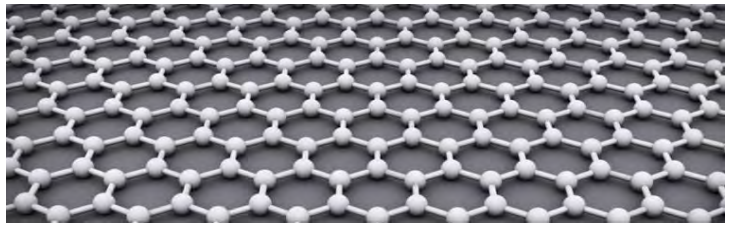




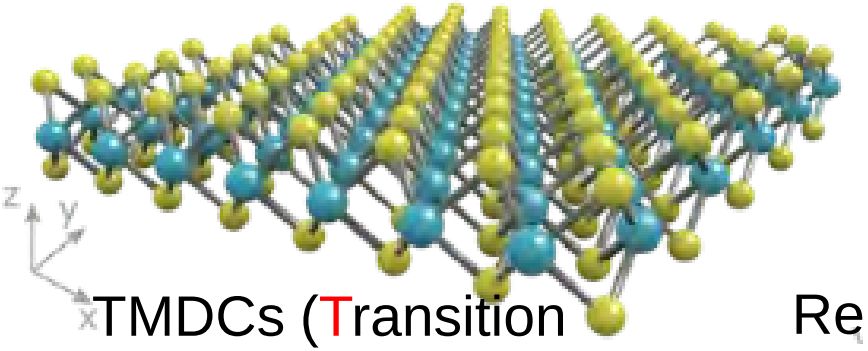
Experimental Condensed Matter Physics

- Study of physical and chemical structures of two-dimensional (2D) materials, ultrathin films and nanostructures using wave interference (electron diffraction and X-ray diffraction) and atomic force microscopy

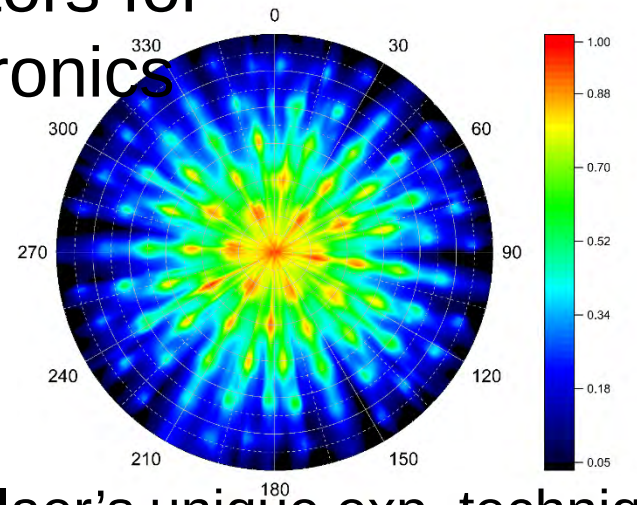
- Materials include metals, semiconductors, and insulators for applications in solar cells, microelectronics, optoelectronics and spintronics.



Graphene



TMDCs (Transition metal Dichalcogenides)



Rensselaer's unique exp. technique: 2D reciprocal space map (of MoS_2)

Shengbai Zhang, Senior Kodosky constellation chair professor; first-principles theory & calculations

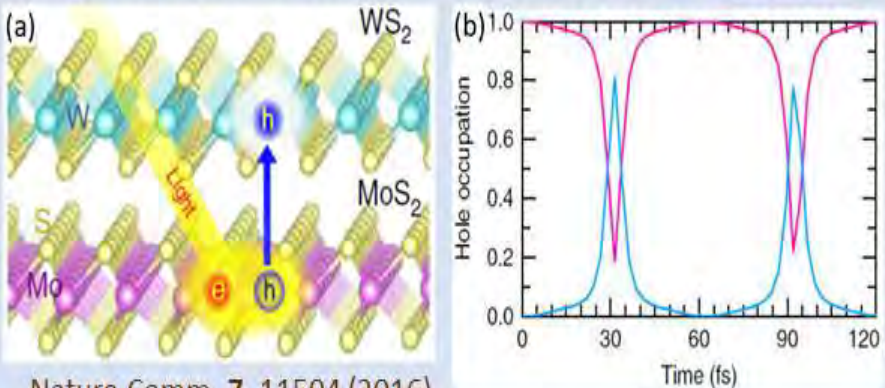
Peek the Physics of Infinity

- Bloch theorem forces us to work with infinitely large crystals, where divergence or conditional convergence problems due to a long Coulomb tail is often encountered
- These long-lasting problems are solved recently by applying simultaneously deeper physical insights & mathematical skills.

PRL **114**,196801 (2015); PRB **96**, 155424 (2017); PRL (under review)

Exciplasmon in the wildness of a 2D Junction

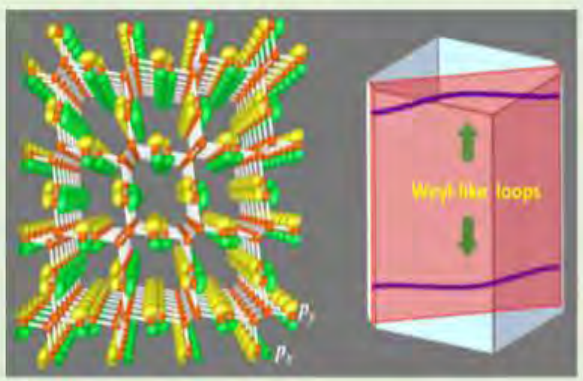
- In a vertical junction, coherent excitons may sustain plasmon excitations to exhibit exotic non-linear physics.



Nature Comm. **7**, 11504 (2016)

The Unthinkable: Making Carbon a Topological Matter

- Graphene is not a topological insulator due to its vanishing spin-orbit coupling. As a 3D network, however, carbon can be rich of topological physics, including being a Weyl semimetal.

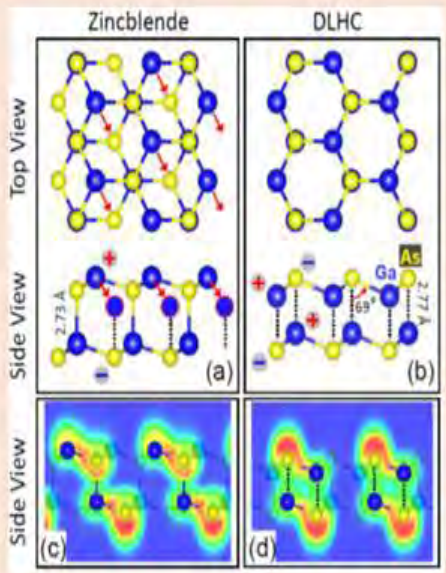


Nano Lett. **15**, 6974 (2015); Nature Comm. **8**, 15641 (2017)

Traditional Semiconductors in the 2D Limit

(they are not what we think!)

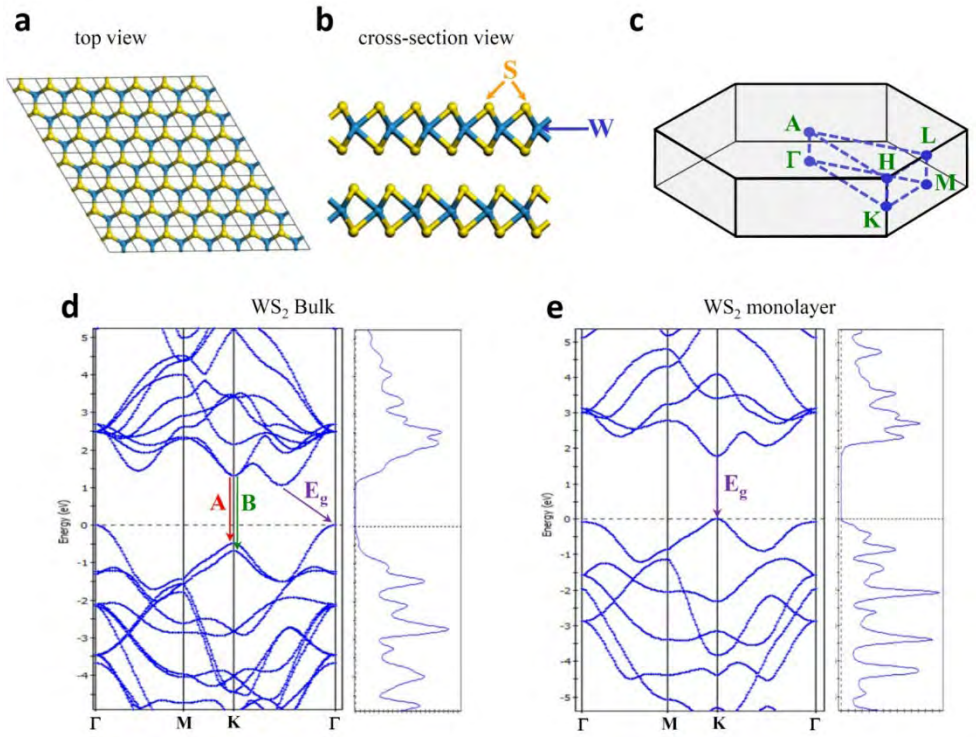
- An ultrathin semiconductor may become a topological insulator
- The 3D bulk structure is also replaced by a van der Waals layered structure.



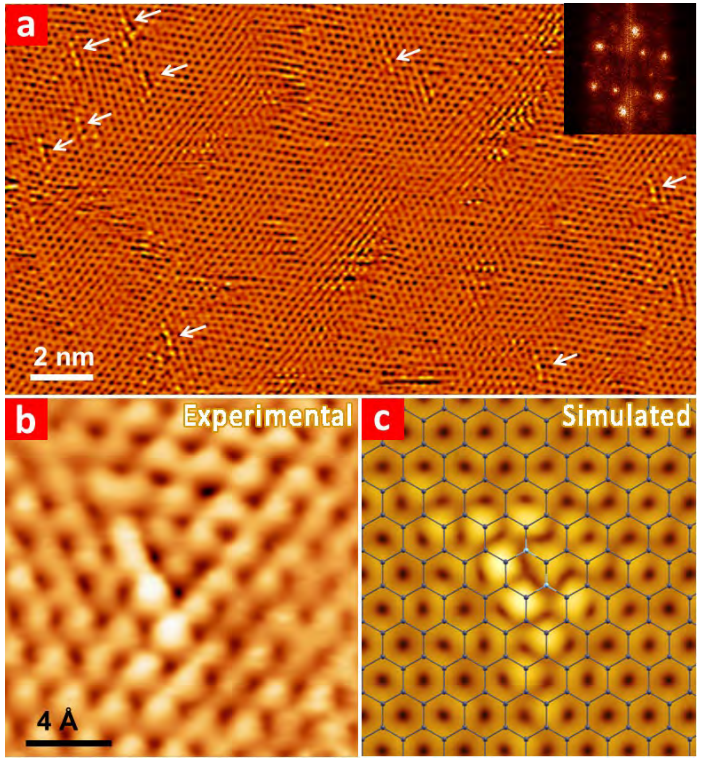
PRL **120**, 086101 (2018)

Condensed Matter Physics: Nanostructures and 2-D Materials.
Prof. Humberto Terrones

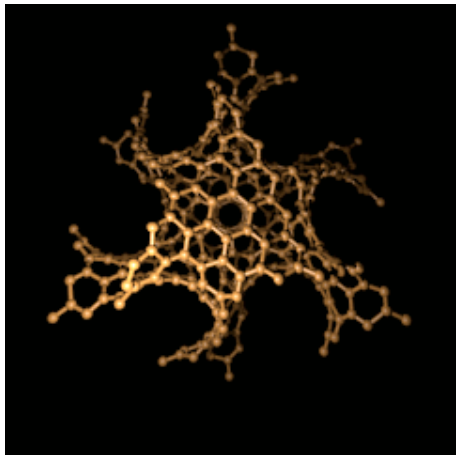
- First Principles Calculations: Electronic, mechanical and optical properties.
- Theoretical and experimental spectroscopy



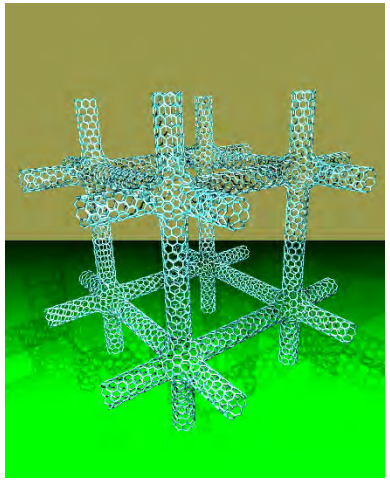
Electronic properties of 2-D nanostructures



Doped Graphene



Curved graphene



Nanotube fabric

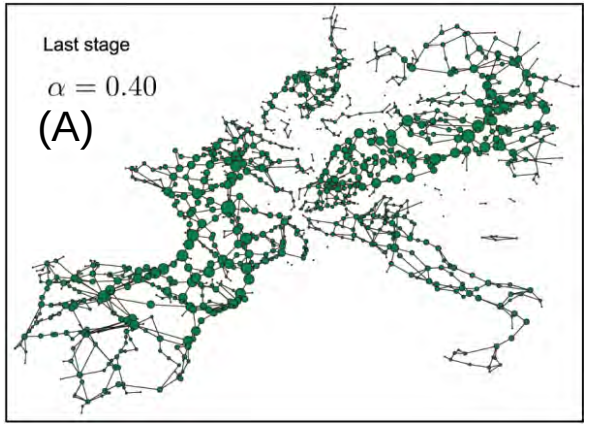
Cascading Overload Failures in Spatial Networks

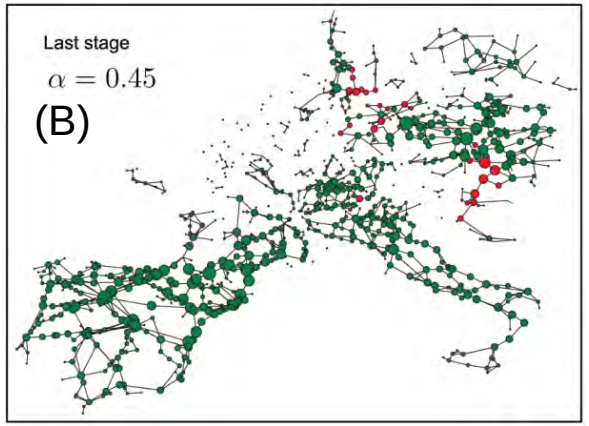
G. Korniss (Phys.), B.K. Szymanski (Comp. Sci./Phys.)

- ***Commonly used epidemic or percolation-based spreading models do not capture essential-features of cascading load-based failures***. We have developed load/flow-based models to analyze relevant network vulnerabilities

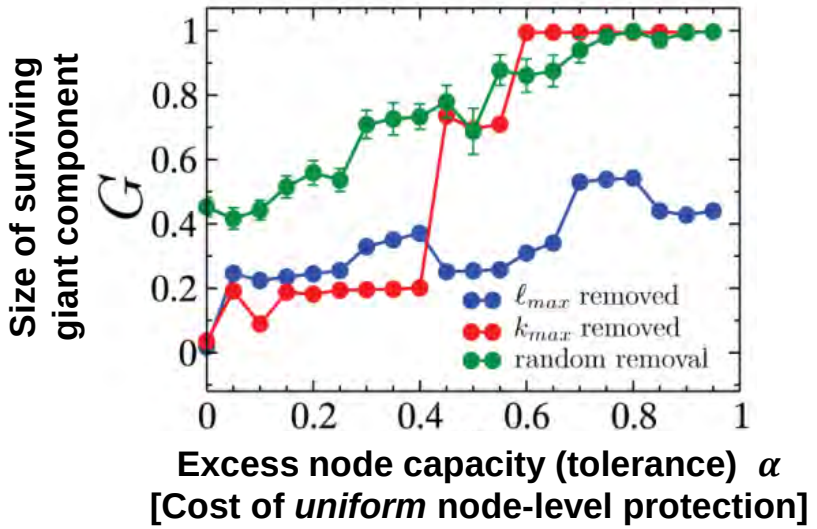
- We modeled cascading failures in the ***UCTE (European) power grid***.

- We have found that ***indiscriminately investing in the protection*** or hardening of nodes or links (e.g., by uniformly by increasing local node or edge tolerance) can actually ***make the network more vulnerable against cascading failures***.
- Cascade progression is ***non-local***, difficult to predict.



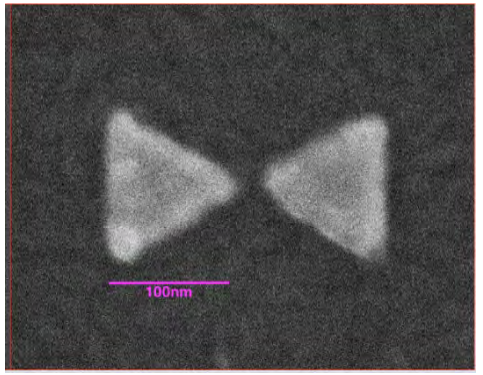


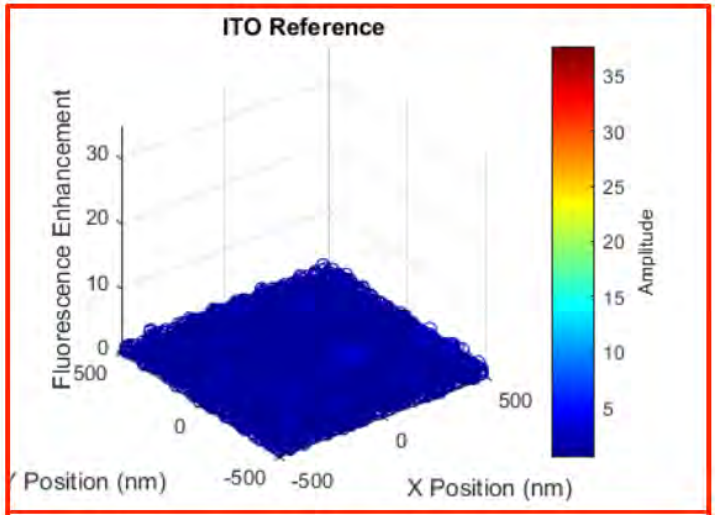
UCTE power grid network snapshots after cascades.

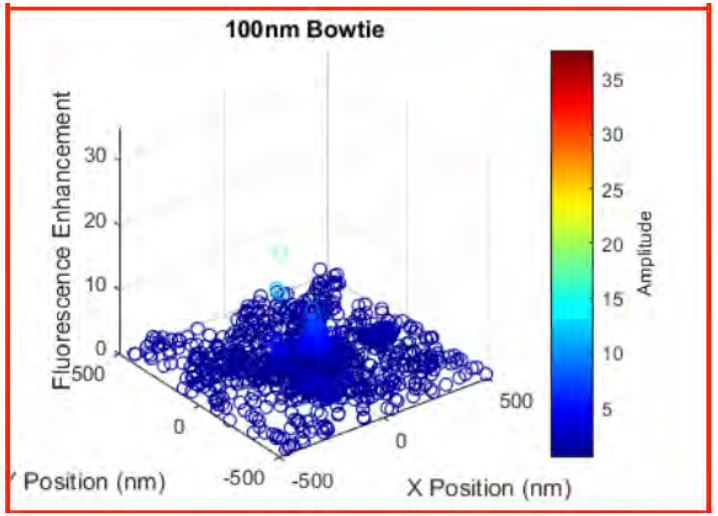


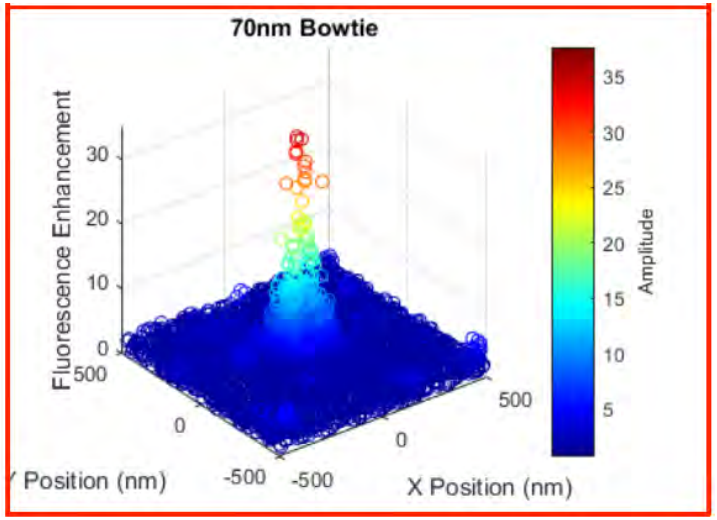
Nanoscale light-matter interactions – Wertz Lab

- Use super-resolution imaging and optical trapping to study light-matter interactions at the nanometer scale
- Explore the coupling between quantum emitters and plasmonic cavities.



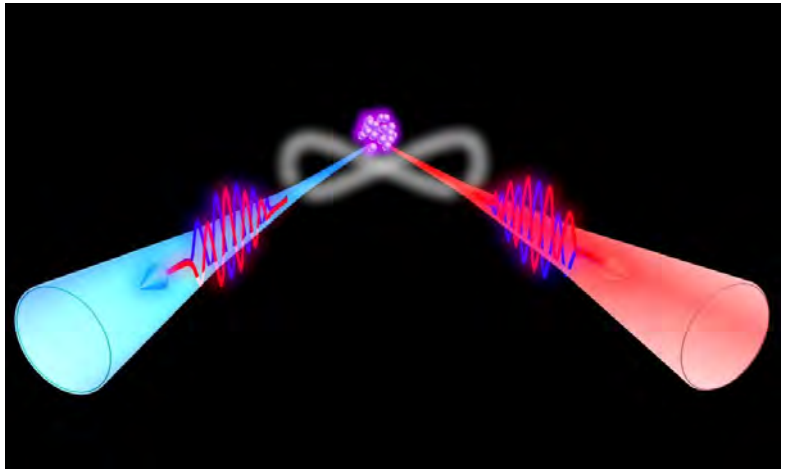


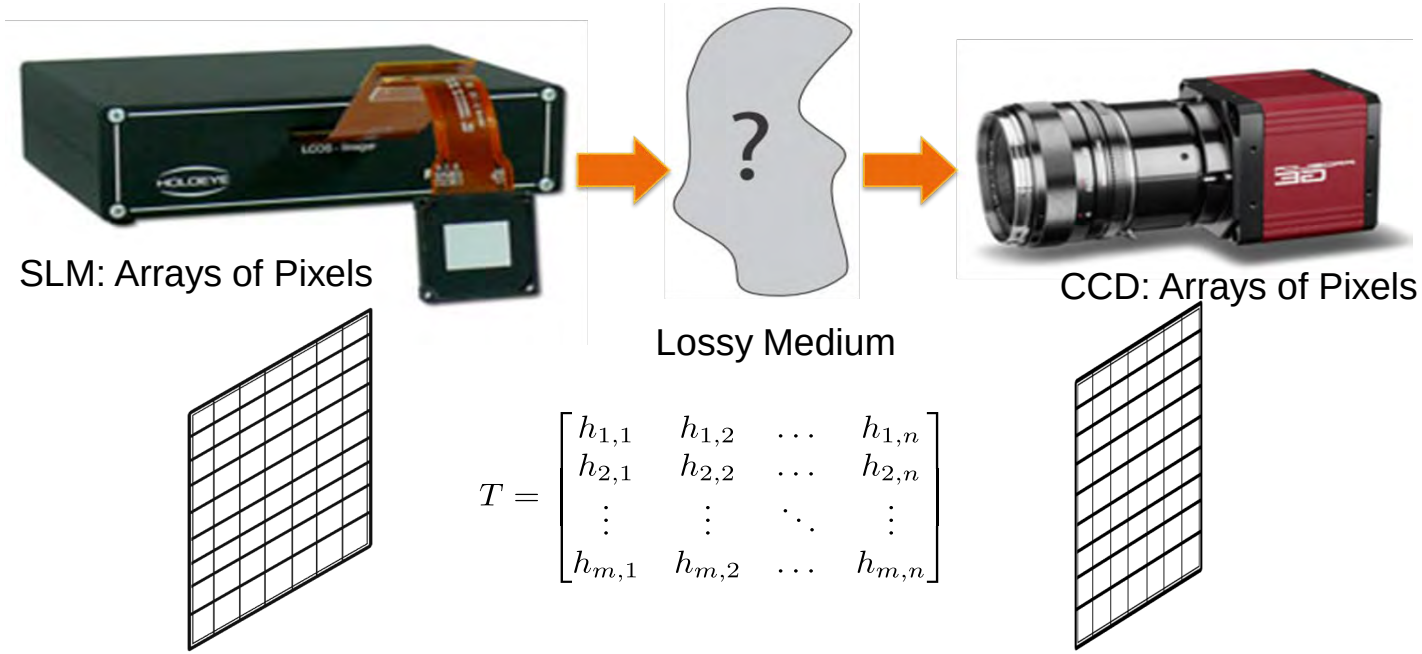




N'Gom's Labs: Wavefront Shaping: a New Tool in Optics

- Light manipulation at a Microscopic level for fundamental understanding in:
  - Quantum Secure Communication
  - Biomedical Imaging

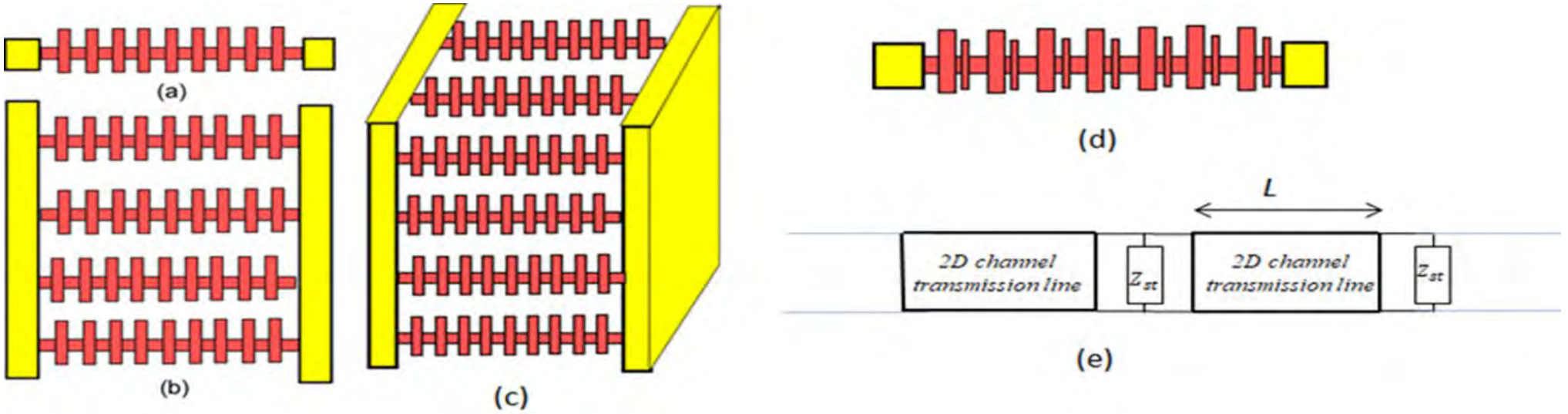




$$T = \begin{bmatrix} h_{1,1} & h_{1,2} & \dots & h_{1,n} \\ h_{2,1} & h_{2,2} & \dots & h_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ h_{m,1} & h_{m,2} & \dots & h_{m,n} \end{bmatrix}$$

Plasmonic Crystals with Stubs for THz Generation and Detection, Prof. M. Shur

- The plasmonic stubs solve the key bottleneck in implementing THz emission, which is the effect of the nonideal contacts between the crystal sections and the section boundaries. The stubs provide matching impedances at THz frequencies and could be optimized for achieving the largest instability increment and coherent emission from the plasmonic crystal cells.



From R. Aizin, J. Mikalopas, and M. Shur, Current driven Dyakonov-Shur instability in ballistic nanostructures with a stub, Phys. Rev. Applied, 10, 064018 (2018), DOI: 10.1103/PhysRevApplied.10.064018

Dr. Ingrid Wilke , Associate Professor of Physics, Terahertz & Ultrafast Spectroscopy Laboratory

- **Teaching:**

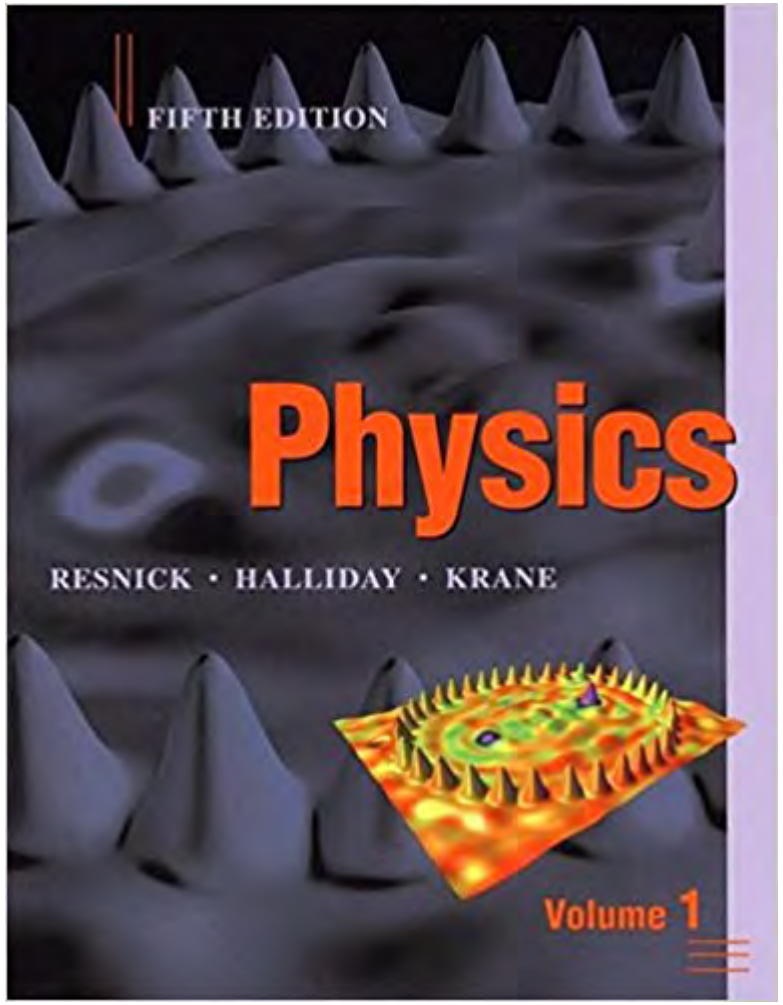
  Introductory Physics for Physics, Science and Engineering Majors, Classical Mechanics and Electromagnetic Theory for Physics Majors, Experimental Physics.

- **Advising:**

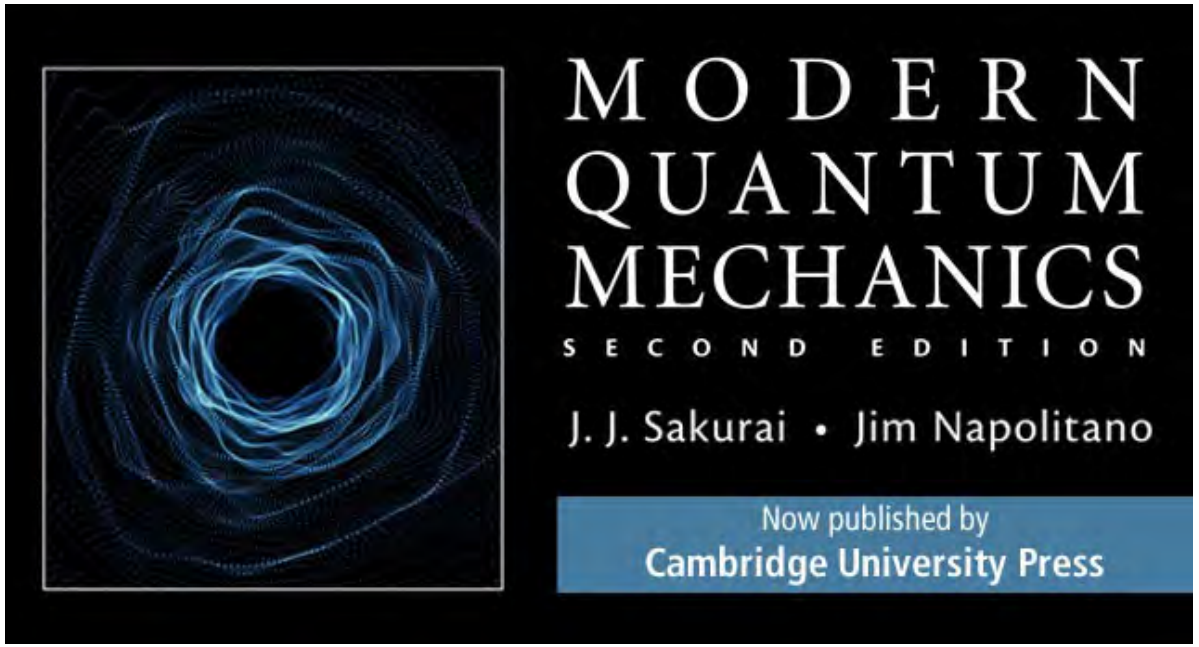
  Academic advisor to physics majors in the classes of 2007, 2014, 2018, 2021, 2022.

- **Research:**

  My research is focused on the generation, detection and application of terahertz (THz) radiation. THz waves are invisible to the human eye. In our solar system, the Sun is a natural source of THz waves. Broadly, THz waves are employed for spectroscopy, imaging and sensing.



Robert Resnick (1923 – 2014)
Professor at RPI (1956-1993)



Jim Napolitano
M.S. at RPI, 1977
Professor at RPI (1992-2015)