Virtual Graduate Open House
March 13-14, 2020
Agenda
Friday March 13

4:00-5:30pm Faculty Overview/Question & Answer Session

Saturday March 14

8:30-11:30am Virtual Lab and Office Visits with Individual Groups
   (separate list of meeting IDs will be sent via email)

12:00-1:15pm Grad Student Panel Discussion
   (same meeting ID as this one)

1:15-1:30pm Grad OPS
   (same meeting ID as this one)

1:30-2:30pm Faculty Panel Discussion
   (same meeting ID as this one)
Main Physics Building

Cosmology

Theory

High Energy Expt

Condensed Matter Expt

Administration, Classrooms, Complexity

CME and HE Laboratories
Center for Quantum Mathematics and Physics
Roessler Hall – Lectures, Teaching Laboratories
Crocker Nuclear Laboratory
Friday evening agenda

• Chair’s Welcome
  Zieve
• Grad Program Overview
  Singh
  5 short talks on research opportunities:
• Condensed Matter
  Taufour
• Cosmology
  Valenti
• Complexity Science
  Singh
• High Energy
  Pantic
• High Energy/Cosmology Theory
  Luty
$8.5M renovation project for 5000 square feet of laboratory space

Helium Recycling Center – One of several labs recently renovated ($8.5M, 5000 square feet)
Synthesis Laboratories on Second Floor
ARPES and Ultrafast Laboratories in Basement
Graduate Program in Physics at UC Davis
Physics Research at UC Davis
Masters 1956
PhD 1961

National Ranking:
1990  66
2018  29

160 Grad Students
20 Ph.D./Year
15 Masters/Year

Time-line of Physics Department, UC Davis

Faculty Head Count

Year


Cosmology

Dark Matter

Neutrinos

QMAP

Quantum Matter

Condensed

Matter

Particle

Physics

Cyclotron Services
Recently Hired Faculty

IUPAP Young Scientist Prize in Particle Physics
Fellow International Society on Gen. Rel. and Gravitation
Chancellor’s Fellow

Sloan Fellowship
NSF Career Award
DOE Career Award
New Members of the **Graduate Group**

Raissa Dsouza, Network/ Computer Science  
Thilo Gross, Network/ Computer Science  
Mark Goldman, Neuroscience  
Marina Radulaski, Electrical and Computer Engineering
## Some Data on the Graduate Program

<table>
<thead>
<tr>
<th>Year</th>
<th>Applications</th>
<th>Admits</th>
<th>Enrollment</th>
<th>Degrees Conferred</th>
<th>% Applicants Admitted</th>
<th>% Admits Enrolled</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>New</td>
<td>Continuing</td>
<td>Total</td>
<td>Master’s</td>
</tr>
<tr>
<td>2007-2008</td>
<td>314</td>
<td>94</td>
<td>34</td>
<td>97</td>
<td>131</td>
<td>7</td>
</tr>
<tr>
<td>2008-2009</td>
<td>273</td>
<td>58</td>
<td>15</td>
<td>111</td>
<td>126</td>
<td>15</td>
</tr>
<tr>
<td>2009-2010</td>
<td>273</td>
<td>79</td>
<td>29</td>
<td>116</td>
<td>145</td>
<td>14</td>
</tr>
<tr>
<td>2010-2011</td>
<td>252</td>
<td>66</td>
<td>17</td>
<td>122</td>
<td>139</td>
<td>23</td>
</tr>
<tr>
<td>2011-2012</td>
<td>332</td>
<td>69</td>
<td>23</td>
<td>107</td>
<td>130</td>
<td>14</td>
</tr>
<tr>
<td>2012-2013</td>
<td>334</td>
<td>94</td>
<td>20</td>
<td>113</td>
<td>133</td>
<td>19</td>
</tr>
<tr>
<td>2013-2014</td>
<td>366</td>
<td>106</td>
<td>38</td>
<td>106</td>
<td>144</td>
<td>12</td>
</tr>
<tr>
<td>2014-2015</td>
<td>440</td>
<td>101</td>
<td>26</td>
<td>125</td>
<td>151</td>
<td>10</td>
</tr>
<tr>
<td>2015-2016</td>
<td>363</td>
<td>73</td>
<td>30</td>
<td>127</td>
<td>157</td>
<td>16</td>
</tr>
<tr>
<td>2016-2017</td>
<td>428</td>
<td>79</td>
<td>26</td>
<td>135</td>
<td>161</td>
<td>18.5%</td>
</tr>
</tbody>
</table>

### Doctoral 6- & 8-Year Completion Rates

<table>
<thead>
<tr>
<th>Cohort Entry Year</th>
<th>Cohort Size</th>
<th>6 Year Completion Rate</th>
<th>8 Year Completion Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>22</td>
<td>45.5%</td>
<td>55%</td>
</tr>
<tr>
<td>2002</td>
<td>19</td>
<td>47.4%</td>
<td>47%</td>
</tr>
<tr>
<td>2003</td>
<td>26</td>
<td>30.8%</td>
<td>50%</td>
</tr>
<tr>
<td>2004</td>
<td>38</td>
<td>18.4%</td>
<td>55%</td>
</tr>
<tr>
<td>2005</td>
<td>31</td>
<td>35.5%</td>
<td>77%</td>
</tr>
<tr>
<td>2006</td>
<td>13</td>
<td>46.2%</td>
<td>62%</td>
</tr>
<tr>
<td>2007</td>
<td>34</td>
<td>55.9%</td>
<td>82%</td>
</tr>
<tr>
<td>2008</td>
<td>15</td>
<td>20.0%</td>
<td>73%</td>
</tr>
<tr>
<td>2009</td>
<td>29</td>
<td>37.9%</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>17</td>
<td>35.3%</td>
<td></td>
</tr>
</tbody>
</table>
UCD Numbers: 6 18 32 23 14 7 18%
Student Support

<table>
<thead>
<tr>
<th>quarters</th>
<th>Teaching</th>
<th>GSR</th>
<th>Dept fellowship</th>
<th>Other fellowship</th>
<th>Self-support</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>268.5</td>
<td>142.5</td>
<td>32</td>
<td>18</td>
<td>10</td>
</tr>
<tr>
<td>percentage</td>
<td>57</td>
<td>30</td>
<td>7</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

**Departmental Endowed Fellowships:**
Paul Brady-Charles Soderquist Fellowship
John Jungerman-Charles Soderquist Fellowship
John Jungerman Fellowship
Ling-Lie Chau Fellowship
Paul Brady Fellowship
Ching Fong Fellowship
**James David Cone Fellowship**

Ryan Couch Travel Fellowship
Katherine Fadley-Pusateri Travel Fellowship

Also: NSF, DOE, Livermore, UC MEXUS, UC Davis Dissertation Fellowships
## Employment after graduation

**UC Davis (Physics)**

<table>
<thead>
<tr>
<th>employer type</th>
<th>position type</th>
<th>number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Universities</td>
<td>faculty</td>
<td>26</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>(permanent) research</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>postdoc</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>student</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>other</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Industry</td>
<td>technology</td>
<td>16</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>programming or data science</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td></td>
<td>finance</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>other</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>National labs</td>
<td>staff</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>postdoc</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Other government</td>
<td></td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

### National Numbers (American Institute of Physics):
- Private Sector: 438 (38%)
- Government Labs: 190 (16%)
- Academia: 533 (46%)

### Stanford University (Natural Sciences):
- Academia: 131 (55%)
- BGN: 109 (45%)

(Business/Government/Non-Profit)
Condensed Matter Physics at UC Davis

... Complex Quantum Physics in Matter

Cox          Pickett          Savrasov       Scalettar       Singh          Zimanyi

Chiang      Curro          Yu       Zhu          Zieve
Condensed Matter Physics impacts our quality of life, politics & future.

semi-conductors
everyday technology
superconducting magnets
hard-drive

SQUID for magnetoencephalography
Wind turbine
solid-state battery
solar-cells
Condensed Matter Physics impacts our understanding of nature

- black-body radiation
- quantization of vibrations
- Pauli exclusion principle for electrons
- spontaneous symmetry breaking
- scaling laws, renormalization, quantum criticality
- topological phases
A Quantum Revolution is Coming
An exciting time to be doing Condensed Matter Physics

Can we harness the properties of quantum materials?

Which materials? Which properties?
What will be the ‘silicon’ of quantum computers?

National Quantum Initiative Act
From Wikipedia, the free encyclopedia

The National Quantum Initiative Act is an Act of Congress passed on December 13, 2018 and signed into law on December 21, 2018. The law gives the United States a plan for advancing quantum technology, particularly quantum computing. It passed unanimously by United States Senate and was signed by President Donald Trump.[1][2][3][4][5]

National Quantum Initiative Act

Long title
An Act to provide for a coordinated Federal program to accelerate quantum research and development for the economic and national security of the United States.

Enacted by
the 115th United States Congress

Effective
December 21, 2018
Topological Materials

Energy efficient electrical transport, computers and electronics...
Beyond the qubit approach to quantum computation...

Topological Materials

- Weyl and Dirac Semimetals
- Topological Insulators
- Topological Superconductors
- Majorana quasiparticles...

New quantum properties that are protected by topology
Controlling topological electrons with photons.
Other topics at the frontier of knowledge...

- High-temperature superconductivity
- Exotic Magnetism
- Heavy Fermion Physics
- Quantum Phase Transitions
- Superfluid Helium
Energy and the Environment

- Yu
- Zimanyi

How to meet our energy needs sustainably?
How to meet our water needs sustainably?

Surfaces and Interfaces

- Visual and other probes monitor surfaces.
- New physics at interfaces!

- Chiang
- Zhu
- Vishik

March 13, 2020
UC Davis Physics Open House
Recent Investment in Experimental Condensed Matter Physics

New state-of-the art equipment... Multi million $ investment.

- Synthesis Lab
- Physical Property Measurements Lab
- Condensed Matter low temperature helium lab (basement)
- Vishik (basement) ARPES Lab

Taufour (2\textsuperscript{nd} Floor)
- Synthesis Lab
- Physical Property Measurements Lab
Bright PhD students

Yuxi Zhang  Wei-ting Chiu

Electron Phonon Interactions and Dirac Fermions


March 13, 2020  UC Davis Physics Open House
Bright PhD students

Yu group

Topological exciton condensates: can excitons be a superfluid and make quantum computers?
Halide perovskites: can we make a better solar cell by manipulating phase?
Bobby Prater

Rotational glitches in superfluid neutron in neutron stars... or in superfluid helium in the lab
Bright PhD students

Join us in the new quantum revolution!!!
Cosmology & Astrophysics Group
studying the Universe across 13.8 billion years

Galaxy Cluster Abell 2218
NASA, A. Fruchter and the ERO Team (STScI, ST-ECF) • STScI-PRC00-08
we study the light side and the dark side
the early Universe, inflation, dark energy
mapping dark matter across the Universe

Marusa Bradac
Tony Tyson
David Wittman
Chris Fassnacht
galaxy formation: from the first galaxies to the Milky Way

Marusa Bradac
Tucker Jones
Lori Lubin
Andrew Wetzel
stars, their birth and death (supernovae), black holes, gravitational waves

Pat Boeshaar
Matt Richter
Stefano Valenti
what our graduate students (you?) do

Keck observatory (Hawaii)

Large Synoptic Survey Telescope (Chile)

SOFIA (on a 747!)

Hubble & James Webb Space Telescopes
what our graduate students (you?) do

pleiades supercomputer
Complexity @ UC Davis
Int’l Institute of Complex Adaptive Matter
Daniel Cox, Director

Biological Physics

Complexity Sciences Center
Jim Crutchfield, Director

Physics of Information
Biological Physics

What distinguishes biological matter?

Features:
- Multiple length scales
- Multiple time scales
- Emergent properties

Approaches:
- Models and phenomenology
- “Systems” level approaches
- Multiple disciplines
Biological Physics
Molecular Legos:
Stick proteins together to make useful things!

Modify existing β-solenoid proteins, like this antifreeze protein

Grow modified proteins into 2D filaments arrays

Grow nanoparticles on arrays to produce photovoltaic
Biological Physics

• Biology respects physics, but ...
  • Dynamical processes
  • Far out of equilibrium
• What distinguishes biological matter?
  • Structure, control, & function
• Information Processing (Machine Learning and Neuroscience)
Information versus Energy?

- Landauer’s Principle:
  \[ \Delta S_{\text{erase}} \geq k_B T \ln 2 \]

- A Maxwellian Demon:
  Szilard’s Engine is Chaotic ...

• Direct Measurement of Energetics in Computation

• First *direct* experimental test of Landauer’s Principle

• Flux Qubit:

Information Engines
informationengines.org

Michael Roukes
Caltech

Jim Crutchfield
UC Davis
Toward a Physics of Intelligence

Seeking intelligence...and no biology allowed

Human beings are proof that intelligence is possible, but we don’t have a monopoly. Computers, although not on par with people for some tasks, compute. Even try chemical reactions perform computations.

Perhaps that’s where we should be looking for intelligence: embodied in the world around us, says SFI External Professor Jim Crutchfield.

“The paradigm we’ve come to associate with digital computing is very limited,” Jim says, “and there might very well be other kinds of biological, chemical, and physical intelligence that transcend the digital, discrete computation paradigm.”

So he and SFI External Professor Arthur Hübler have set out to find it. They’ve just received a grant from DARPA to define, identify, and measure intelligence in physical systems.

But they have a strict ground rule: “No biology is allowed,” says Jim. “No neurons, no cells, no human being, no subjective criteria like the Turing test.”

Instead, they’re looking at structures like self-repairing dendritic trees, self-replicating RNA, and metal-organic frameworks.

Furthermore, the intelligence they find must be rigorously measurable, Jim says. “The artificial intelligence model is: We know it when we see it.” Our physical intelligence model is: “We know it when we measure it.”

Between order and chaos

James P. Crutchfield

What is a pattern? How do we come to recognize patterns never seen before? Quantifying the notice of pattern and formalizing the process of pattern discovery go right to the heart of physical science. Over the past few decades physics’ view of nature’s lack of structure—its unpredictability—underwent a major renovation with the discovery of deterministic chaos, overthrowing two centuries of Laplace’s strict determinism in classical physics. Behind the veil of apparent randomness, though, many processes are highly ordered, following simple rules. Tools adapted from the theories of information and computation have brought physical science to the brink of automatically discovering hidden patterns and quantifying their structural complexity.

One designs clocks to be as regular as physically possible. So much so that they are the very instruments of determinism. Yet ubiquitous clocks play a role in the utterly unpredictable. Randomness is a necessary evil to physics as determinism—think of the essential role that ‘random seeds’ play in establishing the existence of thermodynamic chaos. The clock and the coin flip, as such, are mathematical artifacts to which reality is often added. The extreme difficulty of engineering the author’s clock—and inescapable nature of randomness—suggests

Perception is made all the more problematic when the phenomena of interest arise in systems that spontaneously organize. Spontaneous organization, as a common phenomenon, renders use of a more basic, rugged piece. It, as Prussian blue, chaos is evident in dynamics, why is it the world not a mass of randomness? The world is, in fact, quite structured, and we now know several of the mechanisms that shape microscopic fluctuations as they are amplified to macroscopic patterns. Critical phenomena in statistical mechanics and phase transitions in dynamics are

Fossil Fuels From Tight Places

Physics of Information

Network Science

Super Fracking

Statistical Physics & Complex Systems
Contact Jim Crutchfield for more information

<crutchfield@physics.ucdavis.edu>
Experimental Particle Physics

CMS (Colliders)
Neutrino Physics
Rare Muon Processes
Cosmic Dark Matter Searches
Cutting edge of High Energy Particle Physics

CMS group working on analysis of a 4-year run and various upgrades.
CMS students spend a lot of time @CERN
CMS Forward Pixel Detector
CMS UCD:10 graduate students and 4 postdocs

Development of high-luminosity tracker module
Development of Gas electron multiplier detectors for endcap muon upgrade
Rich phenomenology of Neutrino physics
Neutrino group working on variety of new experiments:
(proto)DUNE, ANNIE, Theia, SNO+, ARTIE
Nu UCD: 6 graduate students and 3.5 postdocs

Prototype of the giant neutrino liquid-argon base detector DUNE

How far neutrons travel in liquid argon? (ARTIE)

Search for neutrinoless double beta decay (SNO+)

(THEIA) Nano-filtration for Water-based Liquid Scintillator
Nu UCD: 6 graduate students and 4 postdocs

Development, fabrication and analysis of Accelerator Neutrino Neutron Interaction Experiment (ANNIE)

Pickard
Wooley
Calibration source

Julie He
Gd doping

Pershing

Fisher
Assaying
Charged lepton flavor violation in Muon Physics

Mu2e UCD group: developing and construction Mu2e@FNAL

2 graduate students and one postdoc

\[ \sim 105 \text{ MeV e}^- \]
Radiation effects and cancer therapy at the UCD Cyclotron

Instrumentation studies of interest to the High Energy Physics community and much wider.

UCD Physics UG student being trained
Direct search for Dark Matter with noble liquids

DM UCD: development & construction of LZ and Darkside-20k, 6 students and 1.5 postdocs

LZ - 7 ton LXe detector to start taking data later this year @SURF.

Darkside-20k -50 ton LAr detector under construction @ LNGS.
THANK YOU!
Center for Quantum Mathematics and Physics (QMAP)

A research center aimed at fostering a vibrant research environment for addressing foundational questions in modern theoretical and mathematical physics.
Fields, Strings & Gravity

- What is quantum gravity? What is string theory?
- Are spacetime and gravity emergent phenomena?
- Are black holes the most efficient quantum computers?
- Why is gravity holographic?
- What new mathematical structures lie behind quantum field theory?
Elementary Particle Theory

Hsin-Chia Cheng  Markus Luty  John Terning

• What is quantum field theory beyond perturbation theory?

• What is the origin of the exponentially large hierarchies of scales in the fundamental laws of nature?

• What new physics lies beyond the Standard Model of particle physics?

• What is the microscopic nature of dark matter?

• How can we search for new physics in experiments?
Theoretical Cosmology

- How did our universe begin?
- Why is our universe so large and long-lived?
- How do we use quantum mechanics to describe the whole universe?
- What model of cosmic inflation describes our universe?
- What can we hope to learn experimentally about “dark” physics?
- What can we learn from precision cosmological data?
QMAP Office/Interaction Space

Coming Fall 2020...
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