The UCR Physics Department

Graduate School Preview Day Nov 23 '09
Welcome to UC Riverside!
Schedule

- Lunch
- Why Grad school? Why UCR? (Harry)
- The UCR the physics program (Ken)
- Condensed mater physics at UCR (Roland)
- Astrophysics at UCR (Bahram)
- Particle/heavy ion physics at UCR (Bob)
- Application/financial support information (Ken)
- Graduate program requirements (Umar)
- Lab tour
- Group meetings with faculty in your field of interest
Is a Ph.D. in Physics right for you?

Harry W. K. Tom
Chair, Physics and Astronomy Dept.
UC Riverside
What do Physicists do?

- Explore new phenomena and seek new fundamental understanding (physics-academia-research)
- Apply physics in new ways to other science and engineering disciplines (applied physics, biophysics, chemical physics, material science, academia-research)
- Apply physics to solve real world problems (nuclear physics, biomedical physics, materials physics, device physics, environmental physics—research--industry)
What do Physicists do?

- Use disciplinary skills in abstraction, model building, mathematics and computing to solve technical problems (production and manufacturing, stock market modeling)
- Use physics knowledge for business, technical sales, patent law, science administration, and policy (science, education, defense, environmental)
- Teaching at K-12 and higher levels
What Do Physics BS graduates do?

- 40% get immediate employment
- 36% in Physics/Astronomy Graduate School
- 20% in “other” Graduate Study
  - Medical/Dental/Health Professional
  - Law (especially business or patent)
  - Business (especially tech sector)
  - Engineering (Electrical, Material Science, Mechanical, Chemical, Aeronautical)
- Chemistry & Physical Chemistry
- Biochemistry/Biology/Biophysics/Bioengineering
BS Initial Employment

- 40% get jobs immediately

**Initial Employment Sectors of Physics Bachelor’s, Classes of 2005 & 2006**

- High School: 13%
- College & Universities: 11%
- Civilian government, FFR&DC*: 8%
- Active Military: 5%
- Other: 6%

* FFR&DC: Federally Funded Research & Development Center

**What’s a Bachelor’s Degree Worth?**

Typical Salaries Offered by Campus Recruiters, 2002-2003

- Bachelor’s Field
  - Chemical Engineering
  - Electrical Engineering
  - Computer Science
  - Mechanical Engineering
  - Physics
  - Mathematics
  - Chemistry
  - Civil Engineering
  - Accounting
  - Finance and Economics
  - Bus. Admin. / Management
  - Marketing
  - Environmental Science
  - Biology / Life Sciences
  - Psychology
  - Secondary Education

**Starting Salary in Thousands**

Typical salaries are the middle 50%, i.e. between the 25th and 75th percentiles.

Reprinted from the Fall 2003 Salary Survey, with permission of the National Association of Colleges and Employers, copyright holder.
BS Private Sector and Salary

Field of Employment for Physics Bachelors in the Private Sector, Classes of 2005 and 2006

- Engineering: 31%
- Computer or Information Systems: 17%
- Other Technology: 7%
- Other Natural Sciences: 7%
- Physics or Astronomy: 5%
- Math: 2%
- Education: 1%
- Non-STEM: 32%

STEM: Science, Technology, Engineering and Math

AIP Statistical Research Center, Initial Employment Survey

Typical Starting Salaries for Physics Bachelor's Classes of 2005 & 2006

- Private Sector STEM
- Private Sector non-STEM
- Active Military
- High School Teachers
- College or University

Note: Typical salaries are the middle 50%, i.e. between the 25th and 75th percentiles. STEM refers to positions in Science, Technology, Engineering, and Math.

AIP Statistical Research Center, Initial Employment Survey
What do PhD’s vs BS’s do?

› Academia
  › Ph.D.’s teach at community colleges, state universities (CSU) and research universities (UC)
  › B.S. teach K-12

› Government
  › Ph.D.’s do scientific research at national laboratories (LANL), administer science programs as science specialists (NSF), serve as scientific experts in government agencies (DOE)
  › B.S. work as lab assistants in government labs, or serve in administrative roles in scientific agencies, or assist scientific experts in government labs.
What do PhD’s vs BS’s do?

Industry

- Ph.D.’s do scientific or engineering research (IBM, HP), provide intellectual property for companies, serve as technical managers
- B.S. work as physicist/engineer on current projects, assist Ph.D.’s on research projects as lab assistants or technicians, work in technical sales or production and production management.
Physicist work in Academia, Government, Private Industry and High Schools

Figure 11. Long-term career goals for physics bachelor's by immediate outcome, classes of 2003 & 2004.

Hoped for Future Sector of Employment

<table>
<thead>
<tr>
<th>Sector</th>
<th>Graduate School, Physics</th>
<th>Graduate School, Other Fields</th>
<th>Employed or Seeking</th>
</tr>
</thead>
<tbody>
<tr>
<td>College or University</td>
<td>59</td>
<td>16</td>
<td>25</td>
</tr>
<tr>
<td>Government</td>
<td>45</td>
<td>15</td>
<td>40</td>
</tr>
<tr>
<td>Private Sector</td>
<td>22</td>
<td>26</td>
<td>52</td>
</tr>
<tr>
<td>High School</td>
<td>8</td>
<td>28</td>
<td>64</td>
</tr>
</tbody>
</table>

## Skills used by Physics PhD’s

### Table 4. Skills used by physics PhDs, classes of 2005-2006

*“To what extent does this position involve the following?”*

<table>
<thead>
<tr>
<th>Skill</th>
<th>Potentially Permanent</th>
<th>Postdoc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific problem solving</td>
<td>80%</td>
<td>98%</td>
</tr>
<tr>
<td>Basic physics principles</td>
<td>79%</td>
<td>90%</td>
</tr>
<tr>
<td>Software development or modeling</td>
<td>59%</td>
<td>69%</td>
</tr>
<tr>
<td>Sophisticated or specialized equipment</td>
<td>57%</td>
<td>69%</td>
</tr>
<tr>
<td>Advanced physics principles</td>
<td>53%</td>
<td>79%</td>
</tr>
<tr>
<td>Advanced Mathematics</td>
<td>42%</td>
<td>55%</td>
</tr>
</tbody>
</table>

Note: Percentages are based on a 4-point scale: never, infrequently, often, and always.

*AIP Statistical Research Center, Initial Employment Report*
Getting a PhD/Permanent Job

- BS degree 4 years
- [MSc program: typically 2 years can be terminal degree or prep for PhD—can apply to PhD program towards end of completion]
- PhD program: typical 6.5 years, 5-8 years range (theory shorter, experiment longer)
  - MSc is typically included along way in 2 years
- Postdoctoral Research Position: 2-5 years of additional “post-PhD” training, depending on field and desired job
Initial Employment for PhD’s

Figure 1. Initial employment of physics PhDs, 1979-2006.

In 1991, the survey questionnaire was changed to measure “other temporary” employment as a separate category.

### Ph.D. Starting Salary & Sector

#### Table 3. Initial employment sectors of physics PhDs by type of position accepted, classes of 2005 & 2006.

<table>
<thead>
<tr>
<th>Type of Position</th>
<th>Potentially Permanent %</th>
<th>Postdoc %</th>
<th>Other Temporary %</th>
<th>Overall %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic*</td>
<td>29</td>
<td>75</td>
<td>68</td>
<td>61</td>
</tr>
<tr>
<td>Private Sector</td>
<td>60</td>
<td>1</td>
<td>13</td>
<td>19</td>
</tr>
<tr>
<td>Government</td>
<td>10</td>
<td>22</td>
<td>12</td>
<td>17</td>
</tr>
<tr>
<td>Nonprofit</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Other</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

*Includes University Affiliated Research Institutes

#### Figure 2. PhD starting salaries, classes of 2005 & 2006.

Table 2. Postdocs from the classes of 2005-2006
“Why were the most important reasons for taking this temporary position?”

<table>
<thead>
<tr>
<th>Reason</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Necessary step to get desired future position</td>
<td>34</td>
</tr>
<tr>
<td>To obtain research experience in my field</td>
<td>22</td>
</tr>
<tr>
<td>To work with a particular scientist or research group</td>
<td>20</td>
</tr>
<tr>
<td>Could not obtain suitable permanent position</td>
<td>10</td>
</tr>
<tr>
<td>To switch to a different field</td>
<td>6</td>
</tr>
<tr>
<td>Personal or family related reasons</td>
<td>4</td>
</tr>
<tr>
<td>Visa restrictions limited my options*</td>
<td>3</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
</tr>
</tbody>
</table>

* 5% of foreign citizens took a postdoc because of visa restrictions.

_AIP Statistical Research Center, Initial Employment Report_
Initial Employment by subfield

Figure 3. Initial employment of physics and astronomy PhD’s by subfield of dissertation, classes of 2005 & 2006

- Applied Physics
- Optics & Photonics
- Materials Science
- Atmospheric & Space
- Relativity
- Nuclear Physics
- Atomic & Molecular
- Particles & Fields
- Condensed Matter
- Surface Physics
- Biological Physics
- Plasma & Fusion
- Astronomy & Astrophysics

Postdoctoral Appointment □ Other Temporary □ Potentially Permanent

### Typical salaries and median age for major employment sectors, PhDs 2006. (a)

<table>
<thead>
<tr>
<th>Academic sector</th>
<th>Typical salaries (in thousands $)</th>
<th>Median Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>University</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9-10 month salary</td>
<td>64 to 100</td>
<td>49</td>
</tr>
<tr>
<td>11-12 month salary</td>
<td>64 to 115</td>
<td>48</td>
</tr>
<tr>
<td>4-Year college</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9-10 month salary</td>
<td>51 to 75</td>
<td>47</td>
</tr>
<tr>
<td>Non-Academic sector</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospital, medical services</td>
<td>105 to 170</td>
<td>49</td>
</tr>
<tr>
<td>Government</td>
<td>100 to 135</td>
<td>50</td>
</tr>
<tr>
<td>FFR&amp;DC (b)</td>
<td>92 to 135</td>
<td>53</td>
</tr>
<tr>
<td>Industry, self-employed</td>
<td>93 to 136</td>
<td>49</td>
</tr>
<tr>
<td>UARI (b)</td>
<td>70 to 120</td>
<td>49</td>
</tr>
<tr>
<td>Nonprofit</td>
<td>65 to 117</td>
<td>47</td>
</tr>
</tbody>
</table>

(a) Employed U.S. resident members only. Postdoctorates excluded.
(b) FFR&DC = Federally-Funded Research and Development Center
UARI = University-Affiliated Research Institute or Observatory
Paying for a PhD degree

- Almost all PhD granting programs in Physics provide financial aid
  - Teaching Assistantships (1-2 years)
  - Fellowships (1-2 years)
  - Graduate Research Assistantships (years 3-end)
- Admission to a graduate program is essentially receiving a scholarship—provided you make satisfactory progress
  - Demanding undergraduate curriculum, good grades, GRE scores, undergraduate research participation/internships increase your chances
# Job Sector Growth

## Table 2
Employment growth and job openings in STEM occupations, projected 2004-14

<table>
<thead>
<tr>
<th>Occupational group</th>
<th>Employment</th>
<th>2004-14 change</th>
<th>Job openings due to growth and net replacement, 2004-14</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2004</td>
<td>2014</td>
<td>Numeric</td>
</tr>
<tr>
<td>Science occupations, natural*</td>
<td>806,330</td>
<td>931,027</td>
<td>124,697</td>
</tr>
<tr>
<td>Life scientists</td>
<td>231,723</td>
<td>279,890</td>
<td>48,166</td>
</tr>
<tr>
<td>Physical scientists</td>
<td>250,417</td>
<td>280,913</td>
<td>30,496</td>
</tr>
<tr>
<td>Natural science technicians</td>
<td>324,190</td>
<td>370,224</td>
<td>46,034</td>
</tr>
<tr>
<td>Technology occupations (computer specialists)</td>
<td>3,045,836</td>
<td>4,002,547</td>
<td>956,711</td>
</tr>
<tr>
<td>Engineering occupations</td>
<td>2,299,778</td>
<td>2,576,906</td>
<td>277,128</td>
</tr>
<tr>
<td>Engineers</td>
<td>1,448,871</td>
<td>1,643,500</td>
<td>194,629</td>
</tr>
<tr>
<td>Drafters, engineering, and mapping technicians</td>
<td>850,906</td>
<td>933,406</td>
<td>82,500</td>
</tr>
<tr>
<td>Mathematical science occupations</td>
<td>106,965</td>
<td>117,297</td>
<td>10,332</td>
</tr>
<tr>
<td>STEM occupations, total</td>
<td>6,258,909</td>
<td>7,627,777</td>
<td>1,368,867</td>
</tr>
</tbody>
</table>

*This group may include a small number of social science technicians, who are counted among life, physical, and social science technicians, all other.*
Reasons to get a PhD at UC Riverside

Harry W. K. Tom
Chair, Physics and Astronomy Dept.
UC Riverside
Distinguished Faculty

› 29 Faculty
  › Junior Faculty Awards
    › 5 National Science Foundation Career Award
    › 1 Sloan Research Fellow
    › 2 Office of Naval Research Young Investigator Award
    › 3 Dept of Energy Outstanding Junior Investigator Award
  › 18 Full Professor Honors
    › APS Panofsky Prize (High Energy)
    › Humboldt Fellowship
    › Guggenheim Fellowship
    › 9 APS Fellows
    › 5 AAAS Fellows
Growing Graduate Program

- Graduate enrollment has grown from 66 to 109 in last 5 years
- Expected enrollment for Fall 2010 is 116 and Fall 2011 is 125.
- Entering class ~24 students, 10 foreign, 14 domestic provides critical mass for student cohort, student breadth, national and international diversity and full graduate curriculum
Full Graduate Curriculum

› 29 graduate courses offered
  › 26 each year, 3 courses in alternate years
  › 17 core courses (first year), and 12 electives

› Ph.D. in Physics with Emphasis in 7 tracks
  › Nuclear and Particle Physics
  › Condensed Matter, Surface, Optical Physics and Biophysics
  › Astrophysics
  › Cosmology and Astroparticle Physics
  › Environmental Physics
  › Materials and Nanoscale Physics
  › Astronomy.
Research Infrastructure/Activities

- ~$7M Extramural Grants/year
- Support for > 20 Postdoctoral Researchers, 3-5 Research Scientists giving students 29 faculty and 25 additional PhD’s to train with
- Weekly Dept colloquium and topical seminars bring outside physicists and astronomers to campus
  - Condensed Matter
  - Nanoscale Science and Engineering
  - Astronomy
  - High Energy
Graduate Program Highlights

- Outstanding Multidisciplinary Training and Research Opportunities
  - For Condensed Matter with UCR Center for Nanoscale Science and Engineering with faculty from Chemistry and Engineering College
  - For Biophysics with UCR’s Biochemistry/Molecular Biology and Bioengineering
  - For Environmental Physics with joint MSc program with UCR Environmental Science
Graduate Program Highlights

- High Energy and Relativistic Heavy Ion Physics programs highly leveraged with international collaborations at LHC, RHIC, SLAC, Fermi Lab
- Astronomy program well-leveraged with UC telescopes (Keck and future TMT), Southern California astronomy infrastructure, and access to SpARCS and COSMOS survey data
Schedule

- Lunch
- Why Grad school? Why UCR? (Harry)
- The UCR the physics program (Ken)
- Condensed mater physics at UCR (Roland)
- Astrophysics at UCR (Bahram)
- Particle/heavy ion physics at UCR (Bob)
- Application/financial support information (Ken)
- Graduate program requirements (Umar)
- Lab tour
- Group meetings with faculty in your field of interest
Growth of UCR Physics

Graduate Students
Incoming Grad Students
Faculty
Growth of UCR Physics

Physics & Astronomy Applicants

- TOT Applicants
- Domestic Applicants
- Out of State Domestic Applicants


Number of Applicants

- 2004-5: 50
- 2005-6: 100
- 2006-7: 200
- 2007-8: 250
- 2008-9: 300
- 2009-10: 350
Astrophysics Faculty

Astrophysics

- Experimental x-ray/Gamma ray Satellites/Balloons Land Based Observations Zych, Canalizo, Mobasher, Wilson

Cosmology / particle astrophysics Hanson, Ma, Wudka, Mobasher, Wilson

Gabriela Canalizo

Allen D. Zych

Bahram Mobasher

Gillian Wilson
Condensed Matter Faculty

Condensed Matter

- Correlated Electrons
  *Beyermann, MacLaughlin, Mills*
- Optical, Lasers
  *Mohideen, Tom, Kawakami, Jing Shi*
- Surfaces
  *Yarmoff, Tom*
- Spintronics
  *Jing Shi, Kawakami, Lau*
- Environmental
  *Tom, Yarmoff*
- Fundamental Forces
  *Mohideen*
- Biophysics
  *Beyermann, Mills, Tom, Mohideen, Zandi*
- Theory
  *Aji, Pryadko, Varma, Tsai, Shtengel, Zandi*
- Connections to Environmental Sciences, Engineering, Chemistry, Biology

Vivek Aji
Mark Bockrath
Allen P. Mills
Jory Yarmoff
Roya Zandi
Chandra Varma
Particle/Nuclear Faculty

Proton Colliders
FNAL/CERN/SLAC
Wimpenny/Ellison
Clare/Hanson

Lepton Colliders
LEP/SLAC
Clare/Hanson
Gary/Long

Relativistic Heavy Ions
BNL-RHIC
Barish/Seto

Neutrono factory
Hanson

Cosmology / particle astrophysics
Hanson, Ma, Wudka, Mobasher, Wilson

Particle/Nuclear

Ken Barish  Bob Clare  Bipin Desai  John Ellison  Bill Gary

Gail Hanson  Owen Long  Ernest Ma  Rich Seto

Steve Wimpenny  Jose Wudka
Schedule

- Lunch
- Why Grad school? Why UCR? (Harry)
- The UCR the physics program (Ken)
- Condensed mater physics at UCR (Roland)
- Astrophysics at UCR (Bahram)
- Particle/heavy ion physics at UCR (Bob)
- Application/financial support information (Ken)
- Graduate program requirements (Umar)
- Lab tour
- Group meetings with faculty in your field of interest
WHAT IS “CONDENSED MATTER”? 

HOW DO NEW PROPERTIES EMERGE WHEN BASIC CONSTITUENTS ARE BROUGHT TOGETHER?

-- DIAMOND VS. GRAPHITE (MATERIALS)
-- SUPERCONDUCTIVITY (COMPLEX SYSTEMS)
-- WHAT IS LIFE? (BIOPHYSICS)

BROADEST AND LARGEST AREA OF PHYSICS

INTERDISCIPLINARY (ENGINEERING, CHEMISTRY, BIOLOGY)
FACULTY: 10 EXPERIMENT, 6 THEORY

RESEARCH AREAS:
1. NANOSCIENCE AND MATERIALS
2. ATOMIC
3. BIOPHYSICS
4. COMPLEX SYSTEMS

NATIONALLY-RECOGNIZED PROGRAM
1. Nanoscience and Materials
Building structures and materials atom-by-atom.

How do macroscopic properties emerge from atoms?

What new properties can be created?
  -- Ultrafast electronic materials
  -- Spintronics (memory, computation)
  -- Efficient light emitters and absorbers

Effects of dimensionality: 0D (quantum dots), 1D (quantum wires), 2D (quantum wells), 3D
GRAPHENE (2D SHEET OF CARBON)

- Incredibly strong
- Electrons act like massless particles
- Fast-moving electrons
- Can control the electron concentration (good for transistors)

Single atomic sheet of graphene

Periodic Ripples

“Strain-tronics”
Spintronics – using the electron spin for electronics

Graphene is an excellent material for room temperature spintronics
Molecular Beam Epitaxy (MBE): Atom-by-Atom Material Deposition

Atomically precise superlattices (LSMO/STO)

Ion scattering from Quantum Dots
UCR Nanofabrication Facility

- Electron beam patterning
- Film deposition
- Nanoscale Ion beam milling
- Atomic Force Microscopy

Materials Science Building
2. Atomic Physics
Fundamental Physics at Low Energy ("Table-top expt"): Properties of electrons, atoms, photons, muons, etc.

Experimental tests of quantum mechanics

Nature of the vacuum and zero-point energy

Matter/Antimatter interactions

Bose-Einstein condensates – "Superatoms"
CASIMIR FORCE

Forces due to quantum fluctuations of the vacuum

\[ E = \hbar \omega (n + \frac{1}{2}) \]

Zero-point energy of the electromagnetic field

Precision measurement based on Atomic Force Microscope

\[ E = \hbar \omega (n + \frac{1}{2}) \]
MATTER/ANTIMATTER INTERACTIONS: BOSE CONDENSATION OF POSITRONIUM

Positrons

Positronium

Laser Cooling

Bose condensation

Annihilation: Coherent $\gamma$-rays
3. Biophysics
How do the living properties of biological systems emerge from atoms & forces?

Living system, by definition, are far from equilibrium.
→ Challenges for non-equilibrium statistical mechanics.

Model systems for life: Viruses.

Understanding microscopic mechanisms of important processes: Protein folding, biomolecular binding, biological self-assembly, etc.
• Probing fundamental questions of biomolecule binding and unbinding

• Access to stochastic aspects of the process
4. Complex Systems

Emergent behavior that cannot be explained in “one-electron” approximation.

Exactly solvable models.

Phase transitions without temperature.

High temperature superconductors.
HIGH TEMPERATURE SUPERCONDUCTORS

QUANTUM SPIN MODELS

TOPOLOGICAL QUANTUM COMPUTING

ULTRACOLD ATOMS IN OPTICAL LATTICES (ARTIFICIAL SOLIDS)

LASER COOLING

LASER COOLING
Schedule

- Lunch
- Why Grad school? Why UCR? (Harry)
- The UCR the physics program (Ken)
- Condensed mater physics at UCR (Roland)
- Astrophysics at UCR (Bahram)
- Particle/heavy ion physics at UCR (Bob)
- Application/financial support information (Ken)
- Graduate program requirements (Umar)
- Lab tour
- Group meetings with faculty in your field of interest
Observational Astronomy and Cosmology in Riverside

Bahram Mobasher
University of California, Riverside
The Astronomy Faculty

- Gabriela Canalizo (Black holes, Active Galactic Nuclei, Quasars)
- Bahram Mobasher (Formation and Evolution of Galaxies, high-z Galaxies, Dark Matter and Dark Energy)
- Gillian Wilson (Galaxy clusters, gravitational lensing, high-z clusters)
Fundamental Questions in Cosmology

- How do galaxies form and evolve?
- How galaxies develop the morphology and the mass they have today?
- Is the Universe open or closed?
- What are the first generation of galaxies like?
- How the Universe started?
- How about the future of the Universe?
- Does dark energy exist?
- What is the nature of Dark Energy?
- How do we find the most distant galaxies?
What data do we need?

- **A large-area, deep survey**
  - Need **much** more area than the Hubble Deep Fields
  - Need comparable **depth**

- **High-resolution and multi-wavelength data**
  - Need to follow morphology through cosmic time

- **Large wavelength coverage** (colors)
  - provide redshift constraints for very faint sources
  - Chandra, ACS, Spitzer, Radio + sub-mm probe the overall energetic output, dust obscuration
GOODS: Great Observatories
Origins Deep Survey

Multiwavelength galaxy

From the ultraviolet through to the near-infrared, different stellar populations are visible, and dust has more, or less impact.

The characteristics at each wavelength for all galaxies give a cumulative measurement.
To address these questions, we need multi-waveband galaxy surveys

Great Observatories Origins Deep Survey (GOODS)

Cosmic Evolution Survey (COSMOS)

Hubble Ultra-Deep Field (HUDF)

Coma Hubble Treasury Program
Great Observatories Origins Deep Survey (GOODS)

Medium Deep Surveys of Large Areas – designed to study formation and evolution of galaxies and to search for high redshift galaxies
Seeing back into the cosmos

- GOODS: Great Observatories
- Origins Deep Survey
- Seeing back into the cosmos
- HST GOODS / CHANDRA DEEP FIELD
- JWST
- Modern universe: 13.7 billion years
- Age of the universe (billions of years):
  - First galaxies: 0.95 billion years
  - First stars: 0.3 billion years
  - Cosmic microwave background: 0.0004 billion years (~400,000 years)
  - Big Bang: 0 billion years
The GOODS Treasury/Legacy Mission

**Aim:** to establish deep reference fields with public data sets from X-ray through radio wavelengths for the study of galaxy and AGN evolution of the broadest accessible range of redshift and cosmic time.

GOODS unites the deepest survey data from NASA’s Great Observatories (HST, Chandra, SIRTF), ESA’s XMM-Newton, and the great ground-based observatories.

**Primary science goals:**

- The star formation and mass assembly history of galaxies
- The growth distribution of dark matter structures
- Supernovae at high redshifts and the cosmic expansion
- Census of energetic output from star formation and supermassive black holes
- Measurements or limits on the discrete source component of the EBL

**Raw data public upon acquisition; reduced data released as soon as possible**
GOODS: Great Observatories Origins Deep Survey

**Aim:** Unite extremely deep, multiwavelength observations to create a public, legacy data set for exploring the distant Universe.

- Deepest X-ray observations
- HST/ACS Treasury program
- Spitzer Legacy program
- ESO/NOAO/… follow-up programs (imaging, spectroscopy)
Quasar activity is triggered by galaxy interaction and mergers which would also result in massive star formation activity in their host galaxy.

The epoch at which mergers take place was used (for the first time) to estimate the age of nuclear activity.

A sizable fraction of Quasar hosts have starbursts with ages over 1 billion years.
By looking at distant regions in the Universe, we look back in time. By looking for the most distant galaxies, we look at the beginning of the Universe.
An imaging LBG demonstration

LBGs are star forming galaxies at $z > 2$, identified by the color signature of the Lyman limit and Ly-$\alpha$ breaks.

First studied in large numbers by Steidel et al. (1995-2001).
Now $\sim 1000$ with measured redshifts.
Hubble Ultra-Deep Field
The Deepest view to the Universe ever taken by the mankind
Hubble Ultra-Deep Field

Why Ultra-deep?
Or when counting is not enough

• In any survey of high redshift galaxies one obtains more objects by widening the area rather than increasing the depth.

• However, extra depth is necessary to discover a new class of objects or determine the properties of a class of objects at the limit of our detection.
GOODS: Great Observatories
Origins Deep Survey

Modern universe 13.7
HDF 1.0
HDF Ultra Deep Field 0.7 - 0.4
Age of the universe (billions of years)

First galaxies
First stars

“Dark Ages”
Radiation Era

Big bang
Cosmic Evolution Survey (COSMOS)

LARGEST amount of Hubble Space Telescope time ever awarded to a single project (20% of the Hubble time in one cycle)

Medium deep survey of a VERY LARGE area (2 sq. deg) to study properties of galaxies as a function of environment, SFR, morphology, redshift, luminosity
Cosmic Evolution Survey (COSMOS)

- large area -- 1.4 x 1.4 deg
  => cover largest large scale structures

- high sensitivity (I > 28.6 mag AB, 5σ)
  => morphology of L* galaxies at z < 2

- sensitivity + area
  => 2x10^6 galaxies, unusual objects at higher z

- equatorial => multi-λ observations from all tel.
GOODS and COSMOS offer:

• Extensive multi-waveband surveys from radio to X-ray
• A number of independent SF diagnostics: X-ray, UV, Hα, IRAC (3.6-8.0 mm), MIPS (24 mm), radio (1.4 GHz)
• Large area coverage (2 sq. deg.) – COSMOS
• Deep ACS data and rest-frame morph - GOODS
• HST/ACS morphologies (B/D, Sersic, concentration, asymmetry, clumpiness)
• Accurate photometric/spectroscopic redshifts and spectral types (from early-type to starburst)
• Galaxy stellar masses
Observational Evidence for Dark Energy and Acceleration of the Universe
The content of the universe

Dark Energy 73%

Cold Dark Matter 23%

Atoms 4%

remember, this is it!!
Science is all about testing our understanding

- **Cosmic Geometry**
  - WMAP + $H_0$ + Ly-alpha forest provide good constraints but do not tightly constrain $\Omega_\Lambda$
  - **High-redshift supernovae** when combined with WMAP provide tight constraints, but are we being fooled by dust or evolution?

- **We need more independent tests of the basic cosmological parameters**: a robust sample of high-redshift ($z>1$) supernovae.
Finding High-z Sne

GOODS: Great Observatories
Origins Deep Survey

• We found 6 of the 7 highest redshift (z>1) supernovae currently known

Search completed:
- 43 SNe identified
- ~25 Type Ia candidates at z>1
  - 10 follow-ups by ToO program
  - 12 spectroscopic confirmations so far
  - 3 highest-z spectral confirmations (z>1.3)

Four Additional Epochs of HDFN in 2004:
- Riess et al. and Perlmutter et al.

~1 FTE with HST “as is“ will yield ~100 Sne at z>1
- Probe the nature of the dark energy
- HST+ground=SNAP-lite NOW!

High-z SN “Artemis“ from CDF-S ACS observations
Taylor Expansion of the left hand side of the Friedman Eq: $a(t) = f(t, H, q, j, \ldots)$

$H(z) = f(z, H_0, q_0, dq/dz) = f(z, H_0, q_0, j_0)$

- $q_0 = -$, $dq/dz = 0$ ($j_0 = 0$)
- $q_0 = +$, $dq/dz = +$ ($j_0 = +$)
- Freely expanding
- $q(z) = 0$
- Constant acceleration
- $q_0 = +$, $dq/dz = 0$ ($j_0 = 0$)
- Constant deceleration

Relative Brightness ($\Delta m$)

0.0 0.5 1.0 1.5 2.0

Redshift $z$

Present 0.5 1.0 1.5 2.0 Past

November 12, 2002

Treasury Workshop
GOODS: Great Observatories
Origins Deep Survey

Dark Energy pushes

Dark Matter pulls
Facts about Dark Matter

• Ordinary baryonic matter only constitutes one-sixth of the total matter in the Universe
• Dark Matter does not interact via electromagnetism—neither emits nor reflects light
• DM does interact via gravity
• DM is most effectively probed by gravitational lensing
• Dynamical mass of galaxy clusters were found to be substantially larger than the sum of the luminous mass seen in a single cluster ➔ Dark Matter
Observe light from distant galaxies, behind any structure we're interested in.

Gravitational Lensing

- Translation
- Magnification
- Shear
- Flexion/curvature

Gravitational lenses are sensitive to any mass along the line of sight and, like glass lenses, are most effective when it is half way between the source and the observer.
Schedule

- Lunch
- Why Grad school? Why UCR? (Harry)
- The UCR the physics program (Ken)
- Condensed mater physics at UCR (Roland)
- Astrophysics at UCR (Bahram)
- Particle/heavy ion physics at UCR (Bob)
- Application/financial support information (Ken)
- Graduate program requirements (Umar)
- Lab tour
- Group meetings with faculty in your field of interest
Particle Physics
and
Heavy Ion Physics
at
UCR

Cal State Preview Day
November 23, 2009
Quantum Universe


1. Undiscovered principles of nature
   Clare, Ellison, Gary, Hanson, Long, Wimpenny, Ma, Wudka, Mohideen

2. Dark Energy
   Clare, Ellison, Gary, Hanson, Wimpenny, Mohideen

3. Extra Dimensions
   Clare, Ellison, Gary, Hanson, Wimpenny, Mohideen, Wudka

4. Forces become one
   Clare, Ellison, Gary, Hanson, Wimpenny

5. So many kinds of particles
   Clare, Ellison, Gary, Hanson, Long, Wimpenny

6. Dark matter
   Clare, Ellison, Gary, Hanson, Wimpenny, Mohideen

7. What are neutrinos saying
   Ma, Hanson

8. How did universe come to be
   Clare, Ellison, Gary, Hanson, Wimpenny, Barish, Seto

9. Antimatter
   Gary, Long, Ma

QUESTIONS FOR THE UNIVERSE

1. Do all the forces become one?
2. How can we solve the mystery of dark energy?
3. Are there extra dimensions of space?
4. Are there undiscovered principles of nature: new symmetries, new physical laws?
5. Why are there so many kinds of particles?
6. What is dark matter?
7. What are neutrinos telling us?
8. How did the universe come to be?
9. What happened to the antimatter?
Theory Group

Desai
- Origins of mass. Is there a symmetry behind the mass spectrum that we observe?

Ma
- Origin of neutrino mass
  - Why is the mass so small, but not zero?
- Leptogenesis
  - Can we use neutrinos to generate the baryon asymmetry in the universe?

Wudka
- Effective theories
  - We see nothing (yet!) beyond SM. What does this imply about the underlying physics?
- Extra dimensions
  - Trying to find a model with right particle content...
Neutrino Factory - Muon Collider

Hanson

Induction linac No.1
100 m
Drift 20 m

Induction linac No.2
80 m
Drift 30 m

Induction linac No.3
80 m

Recirculating Linac
2.5 – 20 GeV

Proton driver
Target
Mini-cooling
3.5 m of LH, 10 m drift

Bunching 56 m
Cooling 108 m
Linac 2.5 GeV

ν beam
Storage ring
20 GeV

1.5 × 10^{22} protons/year

1.5 × 10^{21} muons/year

16 GeV/c Proton Accelerator
π Production Target
Pion Decay Channel

5 × No. p’s in MI
Intense K Physics
Stopped π^0

Stopped/Low Energy Muons

Neutrinos from muon storage rings
Intense High-Energy Muon & Neutrino Beams

Higgs, t, WW, ...

Department of Physics
University of California Riverside
Babar at SLAC

Gary, Long
Studying rare B meson decays
Investigating CP violation with B mesons
D0 at Fermilab

- Clare, Ellison, Heinson, Wimpenny
  - Electroweak physics
  - Top quark
  - Searches for new phenomena
D0 - Example physics

- First evidence for single top production

- Use to measure coupling of W to tb
D0 - Example physics

- Search for Higgs boson

![Graph showing the search for Higgs boson with Tevatron Run II Preliminary results. The graph includes data from LEP, DØ, CDF, Tevatron Expected, and Tevatron Observed with an integral of Ldt=0.3-1.0 fb⁻¹.](image)
CMS at CERN

Clare, Ellison, Gary
None, yet! Data taking is scheduled to start the end of this year, right as we speak!

But maybe soon:

Signal of the Higgs!
Schedule

- Lunch
- Why Grad school? Why UCR? (Harry)
- The UCR the physics program (Ken)
- Condensed matter physics at UCR (Roland)
- Astrophysics at UCR (Bahram)
- Particle/heavy ion physics at UCR (Bob)
- Application/financial support information (Ken)
- Graduate program requirements (Umar)
- Lab tour
- Group meetings with faculty in your field of interest
Heating up the Vacuum: a new spin on QCD at RHIC

Kenneth N. Barish
UC Riverside
Nov 2009
Heavy ion / spin group at UCR

Faculty: Rich Seto & Ken Barish

Postdocs: Richard Hollis, Aneta Iordanova, Raul Armendariz, Ondrej Chavala

Grad students: Astrid Morreale, Tim Hester, Sky Rolnick, David Kleinjan, Ken Sedgwick, Matt Mendoza

Mainly stationed at Brookhaven National Laboratory in Long Island, New York (60 mi from NYC)
Questions RHIC hopes to address

» What makes up the spin of the proton?
  ⇒ polarized proton collisions

» Why are quarks confined inside protons?
  ⇒ heavy-ion collisions

» What makes up most of the mass around us?
  ⇒ recreate “simple” vacuum
Relativistic Heavy Ion Collider

- Accelerator at the Brookhaven National Laboratory - 4km circumference
- 100+100 GeV² Au-Au collisions
- Spin polarized proton collisions at 500 GeV
PHENIX experiment at RHIC
UCR Grad Acceptance Requirements

- **GPA** (junior and senior years)
  - UCR has a minimum of 3.25 for fellowships

- **GRE general**
  - UCR has a minimum of 1100 for the combined verbal and quantitative scores

- **GRE subject**
  - UCR has no specific minimum requirement

- **Letters of recommendation**
  - Generally from faculty who are aware of your intellectual ability / research experience
Physics Department Requirements

- Research Experience (Lab work, published papers, conference presentations etc.)
  - Evaluated by a faculty in your field of interest.
- GRE Physics Subject Exam
- Full slate of standard physics upper division classes (Quantum, E&M, classical mechanics, thermo/stat mech)
Application Fee Waiver

- Application fee will be waived by the graduate division.

- Procedure:
  - Fill out today’s sign-in sheet with full name & birth date or SSN.
  - Complete and save on-line application (but withhold payment of the application fee).
  - E-mail Maria Franco Agular – maria.franco@ucr.edu
    - Write that under the UCR SEED program you qualify for an application fee waiver. Mentioned you attended the Nov 23 physics grad preview day.
  - Submit application.
Graduate application process

http://www.physics.ucr.edu/graduate/graduate_apply.html

- Everyone who applies for Fall 2010 before January 5th 2010 will be considered for financial support. There are no special forms needed.

To apply to the UCR Physics Department you must:

- Fully complete the UCR Electronic Graduate Application
  - Statement of Purpose, personal history statement, biographical info, etc.
  - Three (3) letters of recommendation (submitted electronically).

- Submit the following documents to the address below:
  - Official transcript for all higher education schools attended (must be in sealed envelopes).
  - Official General and Physics Subject GRE scores.

- Incomplete graduate applications cannot be forwarded to the Graduate Division for fellowship and/or admission consideration.
Fellowship/TA/GSR packages

1\textsuperscript{st} year
- Fellowship (academic year + summer)
- 50\% TA (20 h/week) (covers tuition & health)

2\textsuperscript{nd} year
- 50\% TA (20 h/week) (covers tuition & health)
- Summer research support through PI (or TA)

3\textsuperscript{rd} year +
- TA/GSR (covers tuition & health)
- Summer research support through PI (or TA)
TA Duties

**Option 1 (majority of 1st year students):**
1. Manage two 3 hr labs per week
2. Office hours (2hrs/week)
3. Grade the lab books (~20 students /lab)
4. Help with proctoring and exam grading

**Option 2:**
1. Lead 4 or 5 discussion sections (mostly for lower division intro physics)
2. Office hours
3. Help with proctoring and exam grading

Nominal 20 hours per week job.
Contact Information

Graduate Advisor:
- Prof. Kenneth Barish
  - Kenneth.Barish@ucr.edu
  - (951) 827-5023

Student Affairs:
- Derek Beving
  - gophysics@ucr.edu
  - (951) 827-5332

Department Mailing Address:
- Student Affairs
- Department of Physics
- University of California-Riverside
- Riverside, CA 92521
Schedule

- Lunch
- Why Grad school? Why UCR? (Harry)
- The UCR the physics program (Ken)
- Condensed mater physics at UCR (Roland)
- Astrophysics at UCR (Bahram)
- Particle/heavy ion physics at UCR (Bob)
- Application/financial support information (Ken)
- Graduate program requirements (Umar)
- Lab tour
- Group meetings with faculty in your field of interest
WELCOME TO UCR
RELEVANT FACTS ABOUT UCR

- 19000 Total Students
- 2400 Graduate Students
- 92 Undergraduates in Physics
- 109 Graduate Students in Physics
- 850 Total Faculty
- 29 Faculty in Physics

Most ethnically diverse UC Campus
What are the requirements for PhD in Physics?

**Core Classes** (all done in first year)
- Classical Mechanics 1 quarter
- Electricity and Magnetism 3 quarters
- Quantum Mechanics 3 quarters
- Statistical Mechanics 2 quarters

**Elective Classes** (Spring of 1st & second year)
- 3 quarters of either Condensed Matter Physics or Elementary Particle Physics or Astrophysics

**Pass all classes with B- grade or better.**
What are the requirements for PhD in Astronomy?

**Core Classes** (all done in first year)
- Classical Mechanics 1 quarter
- Electricity and Magnetism 3 quarters
- Statistical Mechanics 1 quarter
- Astrophysics of the Interstellar Medium 1 quarter
- Tech. of Observational Astronomy 1 quarter
- Fundamental of Astrophysics 1 quarter
- Cosmology & Galaxy Formation 1 quarter

**Elective Classes** (Spring of 1st & second year)
- 3 quarters of Astrophysics electives

**Pass all classes with B- grade or better.**
Tracks

Tracks & modified Elective Requirements (new courses added)

*Core classes + 3 elective course from Tracks:

Nuclear and Particle Physics
Phys 225 A,B  Elementary Part.

Condensed Matter, Surface & Optical
Phys 209A,B  Intro. Q. Electronics
Phys 240A,B,C Cond. Matter Phys
Phys 242  Phys at Surf & Interfaces
Phys 234  Phys. of Nanoscale Syst
Phys 235  Spintronics and Nano Mag
Phys 236  Adv. Imaging Techniques

Cosmology & Astroparticle
Phys 225 A,B  Elementary Part.
Phys 208  Gen. Relativity
Phys 226  Cosmology
Phys 227  Particle Astrophysics

Astrophysics
3electives reqd.
Phys 211A,B  Rad Proc & Fluid Dyn Astro.
Phys 208  Gen. Relativity
Phys 221A,B,C Quantum Mech.
Phys 216  Star Formation
Phys 217  Stellar Structure and Evolution
Phys 215  Dynamics & Evolution of Galaxies
Phys 226  Cosmology
Exams I- Physics PhD

1. Comprehensive exam at the end of the first year. Pass at the PhD level. (Written)

Subjects: (4 hrs. 2 questions each - All to be answered)
- Classical Mechanics (graduate level)
- Electricity and Magnetism (graduate level)
- Thermodynamics (graduate level)
- Quantum Mechanics (graduate level)

- Two Tries: June of 1st year and Jan of 2nd year
- Ph D Pass rate 75% after 2 tries. 
  (07-08 Students 69% PhD pass after just one try
  08-09 Student 50% PhD pass after one try).
Exams I- Ph D Astronomy

1. **Comprehensive exam** at the end of the first year. Pass at the PhD level. (Written)

**Subjects**: (Two days)
- Classical Mechanics (Graduate level)
- Electricity and Magnetism (Graduate level)
- Thermodynamics and Stat. Mech (Graduate level)
- Astrophysics (Graduate level)

- Two Tries: June of 1\textsuperscript{st} year and Jan of 2\textsuperscript{nd} year
Exams II

- Pick a research Advisor by Spring quarter of first year.
- Oral Qualifying Exam on research potential before the end of the 3rd year.
- Two attempts allowed.
Graduation

Write and Defend a Thesis

Mean Time to graduation is about 6 yrs.
General range 4-7 yrs.
National Average 6.8 years

How Long Does It Take to Get a Physics PhD?

This graph depicts the number of full time equivalent years of graduate study completed by the PhD class of 2000.

Source: Initial Employment Report
Median salary and age for major employment sectors, PhDs 2004.

<table>
<thead>
<tr>
<th>Academic sector</th>
<th>Typical salaries (in thousands)</th>
<th>Median Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>University</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9-10 month salary</td>
<td>$60 to 96</td>
<td>48</td>
</tr>
<tr>
<td>11-12 month salary</td>
<td>$59 to 110</td>
<td>48</td>
</tr>
<tr>
<td>4-Year college</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9-10 month salary</td>
<td>$49 to 68</td>
<td>46</td>
</tr>
<tr>
<td>Non-Academic sector</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospital, medical services</td>
<td>$92 to 150</td>
<td>48</td>
</tr>
<tr>
<td>FFR&amp;DC (b)</td>
<td>$96 to 130</td>
<td>49</td>
</tr>
<tr>
<td>Industry, self-employed</td>
<td>$85 to 127</td>
<td>47</td>
</tr>
<tr>
<td>Government</td>
<td>$86 to 125</td>
<td>51</td>
</tr>
<tr>
<td>Nonprofit</td>
<td>$67 to 108</td>
<td>47</td>
</tr>
<tr>
<td>UARI (b)</td>
<td>$60 to 100</td>
<td>46</td>
</tr>
</tbody>
</table>

*(a) Employed U.S. resident members only. Postdoctorates excluded. (b) FFR&DC=Federally-Funded Research and Development Center UARI=University-Affiliated Research Institute or Observatory*
Requirements for MS degree

- 36 units of classes (core + elective classes)
- Pass with grade better than B-
- Pass the Comprehensive Exam at the MS level
  
or
  Do MS research thesis

Automatic for students continuing towards PhD
Financial Assistance I

**Fellowship (1st year):**
No teaching or research duties
+ Summer
+ Tuition + Health Insurance

+ Additional
(Need to maintain GPA above 3.5 – mixture of A’s and B’s)
Financial Assistance II

Teaching Assistantship (TA):
50% TA (20 hours per week)
$16637 + Summer (Research or Teaching~$4000)
+ Tuition + Health Insurance

Need to maintain GPA above 3.0 (B average)
50% TA Duties

Nominal 20 hours per week job (7 assigned hours). Duties are:

1. Manage two 3 hr labs per week
2. Grade the lab books (about 20 students per lab)
3. Proctor and Grade (1 problem) of final/midterm exams