What is there to do in physics and astronomy?

SWAP Research Overview

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There's lots to do "outside" astro/physics

- environmental science, planetary science, chemistry, biology, neuroscience, engineering
- software development/programming
- education (teaching, research, policy, textbook development)
- science writing
- medicine
- law
- government (elective office, policy)
- writing poetry and story lines for video games

Why do research as an undergrad?

- Research can be a valuable part of learning about science for *anyone* (not just prospective scientists)
- Very different experience (and skills!) from classes
- Some people who don’t like classes like research; some people who like classes don’t like research

Physics research subfields

- Astrophysics
- Atomic, molecular, and optical physics
- Biological physics
- Condensed matter physics
- Elementary particles and fields
- Nonlinear dynamics (fluids)
- Nuclear physics
- Plasma physics
- Other

Atomic physics

Atomic: controlling atoms with light

- Studying novel quantum states and symmetries
- Bose-Einstein condensation, slow light, quantum computation, antihydrogen

Techniques: trapping atoms, spectroscopy, theory

- High-precision measurements

Frank Moscatelli

Optical physics

Physics of and with light

Spectroscopy and imaging: nonlinear optics

Lasers: shorter and shorter pulses, pulse shaping, new types of lasers

Techniques: optical measurements and apparatus, simulations/theory

Carl Grossman

Biological physics

Single-molecule physics: forces and energetics involved in cell and molecular biology

New techniques, esp. spectroscopy and imaging

Membranes and surfactants

Neuroscience, sensory transduction

Computational genomics

Techniques: mostly experimental techniques, some modeling and computation

Condensed matter physics

How does the underlying structure of a material give rise to its properties?

What new physics do we uncover in materials?

What devices can make use of these properties?

Can we design new materials with desired properties?

Condensed matter physics

Traditional: quantum effects in electronic transport and optical properties, superconductors, nanoscale and molecular materials and devices, quantum computation

“Soft” (“squishy physics”): colloids, gels, liquid crystals, surfactants, biological materials

Applied and basic; experimental, computational, and theoretical

Amy Bug, Peter Collings, Catherine Crouch

High energy (“particle”) physics

What are the fundamental constituents of matter and energy, and how do they interact with each other? Why do particles have mass?

Very simple systems under extreme conditions; symmetries, unification schemes

Theorists (mathematics), “phenomenologists” (computer simulations), and experimentalists (data analysis and detector design

Paul Bloom

Fluid dynamics and nonlinear systems

Pattern formation, chaos, microfluidics and MEMs, chemical engineering (manufacturing)

Computer simulation/applied mathematics

Theory and experiment have a closer relationship than in most subfields (experiments are not very hard, lots of open theoretical ground).

Leo Pantelidis

Nuclear physics

How are nucleons and nuclei put together? How do the fundamental forces at work between quarks produce the properties of nuclei?

Experimental and theoretical; lots in common with high energy physics, but in a different regime

Chris Cothran

Plasma physics

Plasmas (hot ionized gases) are found in stars (such as our own sun) and have many applications (radiation sources, etching, displays).

“Fourth state of matter;” electrically conductive fluid

Fusion research: how can plasmas be confined and heated so as to eventually harness fusion as an energy source?

Michael Brown, David Cohen, Chris Cothran

Other areas

General relativity and cosmology (Chris Burns)

(How did the universe come into existence?)

Foundations of quantum mechanics (John Boccio), quantum information theory

(Do measurements really collapse quantum states? Is quantum mechanics fundamentally nonlocal?)

Novel states of matter at high pressure (metallic hydrogen) and low temperature (superfluid helium)

Lots more that I haven't mentioned!

Don’t specialize yet; explore

Now is the time to learn about lots of different areas, and figure out what you like doing day-to-day

You have plenty of time to pick a sub-field once (if) you go to grad school, and you can change fields somewhat after the Ph.D.

Build up a set of skills: experimental, mathematical, data analysis, computer programming, communications, teamwork, independent learning