DEPARTMENT OF ASTRONOMY & ASTROPHYSICS

Eberly College of Science

Undergraduate Program in Astronomy & Astrophysics

Astronomers study distant objects in the universe: planets in our solar system, stars in our galaxy, distant galaxies and quasars, and the universe as a whole. Their efforts begin with observations using large telescopes, some on the ground and others in space. Astronomers use these results to infer the physical properties and evolution of these celestial objects using the laws of physics.

The Astronomy & Astrophysics (ASTRO) major in Penn State's Eberly College of Science involves the scientific study of the universe and its constituents. Our undergraduate program includes considerable course work in physics, mathematics, and computer science, in addition to courses in astronomy. During your first two years as an ASTRO major, you will obtain a strong foundation in physics, mathematics, astronomy, and chemistry. In the later years, you receive a selection of advanced courses on topics such as theoretical astrophysics, observational methods, stars and extrasolar planets, galaxies and cosmology, high-energy astrophysics, and computational methods. At the end of your second year, you choose one of two options depending on whether you wish to emphasize physics or computer science to complement your advanced Astronomy & Astrophysics courses.

Our majors receive close personal attention in this relatively small undergraduate program. Our faculty are involved in world-class research in many areas of Astronomy & Astrophysics, and undergraduates, even as freshman, have the opportunity to join in their research efforts.

This handbook outlines the program requirements for the two options in the ASTRO major as well as the ASTRO minor. This handbook supplements, but does not supersede, the University's *Baccalaureate Degree Programs Bulletin, Policies and Rules,* and booklets on General Education and cultural diversity in the curriculum.

Additional information about the Department of Astronomy & Astrophysics, including courses, research activity, and personnel can be found at: http://www.astro.psu.edu

Contact Persons in Astronomy & Astrophysics

Students are welcome to speak with department members about their educational goals, academic questions or problems, quality of instruction, or any other issue regarding their undergraduate educational experience. The primary contacts are:

- The student's faculty advisor
- Undergraduate Staff Assistant:
  Nina Bumgarner
  525 Davey Lab
  814-865-0419
  ndb2@astro.psu.edu
- Assistant Department Head for Undergraduate Education:
  Chris Palma
  419B Davey Lab
  814-865-2255
  cpalma@astro.psu.edu
- Schreyer Honors College Advisors:
  Niel Brandt nbrandt@astro.psu.edu
  Jane Charlton charlton@astro.psu.edu
  Chris Palma cpalma@astro.psu.edu
  Steinn Sigurdsson ssigurdsson@astro.psu.edu
  Alex Wolszczan awolszczan@astro.psu.edu
- Advisor to Minors:
  Robin Ciardullo
  519 Davey Lab
  814-865-6601
  rciardullo@astro.psu.edu
- Department Head:
  Donald Schneider
  525 Davey Lab
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  dps@astro.psu.edu

Additional information can be found on bulletin boards on the fifth floor of Davey Laboratory. The display next to 541A displays undergraduate information; the board next to 531 posts research and employment opportunities.

Contents

The Astronomy & Astrophysics Major

The *Bachelor of Science* degree in Astronomy & Astrophysics consists of two options:

- Graduate Study (with increased work in math and physics)
- Computer Science (with emphasis on computer studies)

During the first two years, Astronomy & Astrophysics (ASTRO) majors begin to take core courses in astronomy, physics, mathematics, chemistry, and computer science. They also begin to fulfill the University's general education requirements, which cover courses in communication, arts, humanities, social and behavioral sciences, health and physical activity, basic mathematics, and natural sciences. At the end of the sophomore year, Astronomy & Astrophysics majors choose one of the two options for the major. The core courses for both options are in astronomy, physics, mathematics, and computer science. A minimum of 124 credits is required for this degree.

MILESTONES FOR THE ASTRONOMY & ASTROPHYSICS MAJOR

Admission and the First Year

The University Admissions Office assigns students into their baccalaureate degree programs. Applicants who plan to become an ASTRO major should indicate their intention on the application form. High school records and SAT scores must be above the basic criteria set by the admissions office in order for a student to be admitted to the Eberly College of Science. Students who enter the College of Science are designated as SCIEN majors. If you expressed an interest in the ASTRO major then you will be considered as an ASTRO premajor and you will be assigned an advisor in the Astronomy & Astrophysics department.

Students are encouraged to contact or visit their advisors during the first week of the Fall semester of their Freshman year to discuss their academic program. They should meet with their advisors at least once per semester to discuss their academic program.

The first year's academic program is generally devoted to basic, but very challenging, courses in calculus, chemistry and physics. Prospective majors (premajors) are also required to take a First Year Seminar. The program is usually rounded out with a selection from General Education courses.

Move to University Park Campus

Many Penn State students take their first-year courses at one of the locations throughout the Commonwealth. It is crucial that students intending to major in ASTRO request an early change of assignment (COA) at the end of the first year so that they can attend University Park campus for the second year of study, since most commonwealth campuses do not offer ASTRO 291 or 292. First year seminars taken at other campuses or departments are transferable, though some students may choose to take a second seminar, since they will find the astronomy and career information contained in ASTRO 020S quite useful.

The Second Year and Entry into the Major

Second-year students receive a thorough exposure to astronomy with the ASTRO 291 and 292 sequence. Other courses include more advanced mathematics and physics, plus an introduction to computer programming using the language C. In a typical program, the student requests entry into the ASTRO major, from his/her initial SCIEN major, in the spring semester of the second year.
Entry into the major requires:

- A GPA of at least 2.00 in all courses.
- Earned a grade C or better in each of the following courses: ASTRO 291, CHEM 110, MATH 140, MATH 141, PHYS 211, and PHYS 212.

The GPA for department requirements is based on the best, not average, of repeated courses. Your official GPA as computed by the University Registrar includes all grades, including repeated courses. Entry for students with non-standard programs (e.g., transfers from other departments or colleges) will be decided by the Assistant Department Head for Undergraduate Studies.

On eLion, each student may identify up to three major preferences in priority order. Students will receive an e-mail from the Registrar's office instructing them to confirm their major and campus preferences by the fourth semester deadline. Students are notified by e-mail that they've been accepted, accepted conditionally, or denied entrance to the desired major.

The Third and Fourth Years

The student now proceeds into advanced courses, concentrating in ASTRO and one of the allied fields (MATH & PHYS for the Graduate Study option or CMPSC & CMPEN for the Computer Science option). In the first semester of the third year, students should take the ASTRO 320 lab. Each student must take at least four, 400-level ASTRO courses from among the six to eight offered during the third and fourth years. Each student must fulfill the University's General Education Writing Across the Curriculum requirement. We recommend either ASTRO 420W or ASTRO 475W courses to fulfill that requirement; however another "W" course in the college (e.g., 3 credits for Phys 457W) will be accepted. A degree audit report indicating the student's progress toward graduation is available through eLion.

Substitutions of Science 495 (Co-op work experience) for any required courses should be discussed in advance with your advisor and the Assistant Department Head for Undergraduate Education.

Graduation

Graduation usually occurs after eight semesters, although some Penn State students require nine to ten semesters to complete their chosen programs. Two semesters before intended graduation, the student and advisor should carefully review the major checklist to make sure that all requirements will be fulfilled. Deviations from requirements for the major are possible; the student and advisor should submit a petition to the Assistant Department Head for Undergraduate Education and the Dean of the college before the course is taken. Requests to **waive** a requirement are rarely accepted, though reasonable requests for **substitution** are possible. For example, an advanced course in engineering or earth sciences, or industry Co-op credits, might be substituted for an unspecified PHYS 400-level course. Substitutions for specified courses (such as PHYS 400) or any ASTRO course are rarely accepted. Note that ASTRO 497 offerings (courses offered by the Department of Astronomy & Astrophysics, but not yet catalogued in the *Bulletin*) fulfill the ASTRO 400-level requirement without petition, while ASTRO 496 credits (independent study) cannot fulfill the ASTRO 400-level requirement. ASTRO 496 will be accepted as a supporting course.

Grade requirements for graduation are:

- A cumulative GPA of at least 2.00
- A grade of C or better in each the following courses: CHEM 110, MATH 140, MATH 141, PHYS 211, PHYS 212, ASTRO 291, ASTRO 292, and 12 credits of 400-level ASTRO courses.

At the beginning of their final semester, students must indicate their intent to graduate on eLion.

***Minor in Physics*:**

ASTRO majors who complete the Graduate Study Option automatically qualify for a minor in Physics if they have a grade of C or better in all courses in that minor. The prescribed courses for the Physics minor are: PHYS 211, PHYS 212, PHYS 213, PHYS 214, PHYS 237, PHYS 400, PHYS 410, and PHYS 419. Students must go to the Physics Department, 104 Davey Lab to complete the application form since minors are not conferred automatically.

***Instructional 1 Certificate for Teaching*:**

The ASTRO major also satisfies the majority of requirements for the Instructional 1 certificate for teaching physics and mathematics and/or earth and space sciences in Pennsylvania if additional credits are earned in science education courses offered by the College of Education.

The Astronomy & Astrophysics Minor

To complete the Astronomy & Astrophysics minor, students are required to have a total of 18-19 credits from courses taken in Astronomy & Astrophysics, Physics, Aerospace Engineering, Electrical Engineering, and/or Meteorology.

Minor requirements:

- ASTRO 291 and ASTRO 292
- 6 credits from 400-level ASTRO courses, except ASTRO 496
- 6-7 credits from additional ASTRO 400-level courses, AERSP 308, AERSP 312, E E 492, GEOSC 474, METEO 466, or PHYS 458
- A grade of C or better is required for all courses in the minor.

The Astrobiology Minor

The Astrobiology minor requires a total of 18 credits, with at least 6 credits at the 400 level. Several of the required courses have prerequisites, so students should work with advisers when planning to complete the Astrobiology Minor.

- BIOL/GEOSC 474 (Prereq: BIOL 110, CHEM 110)
- 9-10 credits from EARTH 002 or GEOSC 021, ASTRO 140 (Prereq: ASTRO 001, 005 & 006, or 010) or ASTRO 291 (Prereq: PHYS 211), GEOSC 204 (Prereq: BIOL 110, GEOSC 001 or 020), or BIOL 427 (Prereq: BIOL 220W & 230W)
- 5-6 credits from ASTRO 420W (Prereq: ASTRO 292), ASTRO 475W (Prereq: ASTRO 292), BIOL 405 (Prereq: BIOL 222 or 230W), BMB 401 (Prereq: CHEM 212, BMB 251 or BIOL 230), BMB 402 (Prereq: BMB 401 or CHEM 476), GEOSC 416 (Prereq: CHEM 110, 112, 111, & 113, GEOSC 001 or 020), GEOSC 419 (Prereq: CHEM 110 & 112), METEO 466 (Prereq: MATH 141, PHYS 211), or MICRB 201 (Prereq: CHEM 110)
- A grade of C or better is required for all courses in the minor

Undergraduate Courses in Astronomy & Astrophysics

For the complete course listings and official descriptions, consult the current Penn State *Baccalaureate Programs Bulletin*. General education courses that satisfy the natural sciences requirement are marked with "GN" designations.

ASTRO 120, 130 and 140 are courses on various aspects of astronomy intended for the non-major who has taken ASTRO 001, 005, 006, or 010. Majors are welcome to take any of these courses as electives, even in the first year.

ASTRO 001 (GN) ASTRONOMICAL UNIVERSE - 3 credits
The development of modern understanding of the astronomical universe from planets and stars to galaxies and cosmology. *Students who have passed ASTRO 005, ASTRO 006, or ASTRO 010 may not take this course.*

ASTRO 005 (GN) The Sky and Planets - 3 credits
The development of our modern understanding of the visible sky and planetary systems. Students who have passed ASTRO 001 or ASTRO 010 may not take this course.

ASTRO 006 (GN) Stars, Galaxies, and the Universe - 3 credits
The development of our modern understanding of stars, galaxies, and the astronomical universe. Students who have passed ASTRO 001 or ASTRO 010 may not take this course.

ASTRO 010 (GN) ELEMENTARY ASTRONOMY - 2 credits
Introductory survey of modern astronomy from planets and stars to galaxies and the universe. Students who have passed ASTRO 001 may not take this course. Students may not receive General Education credit for ASTRO 010 unless they also take ASTRO 011.

ASTRO 011 (GN) ELEMENTARY ASTRONOMY LABORATORY - 1 credit
Selected experiments and explorations to illustrate major astronomical principles and techniques. Telescopes observations of planets, stars and nebulae. Prerequisite or concurrent: ASTRO 001 or
ASTRO 010

ASTRO 020S FIRST-YEAR ASTRONOMY SEMINAR - 2 credits
Introduction to the study of modern astronomy through discussions, problem solving, activities, and writing.

ASTRO 097 SPECIAL TOPICS (1 - 9 credits)**ASTRO 120** (GN) THE BIG BANG UNIVERSE - 3 credits
Exploration of cosmology, birth, and ultimate fate of the universe; origin of galaxies, quasars, and dark matter. For non-science majors. Prerequisite: ASTRO 001, ASTRO 006, or ASTRO 010

ASTRO 130 (GN) BLACK HOLES IN THE UNIVERSE - 3 credits
The predicted properties of black holes and the astronomical evidence for their existence are investigated in the context of modern ideas about space, time, and gravity. Prerequisite: ASTRO 001, ASTRO 006, or ASTRO 010

ASTRO 140 (GN) LIFE IN THE UNIVERSE - 3 credits
The problem of the existence of life beyond Earth is investigated, drawing from recent research in astronomy and other fields. For non-science majors. Prerequisite: ASTRO 001, ASTRO 005, or ASTRO 010

ASTRO 199 (IL) FOREIGN STUDIES (1 -12 credits)

ASTRO 291 (GN) ASTRONOMICAL METHODS AND THE SOLAR SYSTEM - 3 credits
Physical processes and observational techniques in astronomical systems, characteristics of the sun, planets, and moons. Prerequisite: PHYS 211 *We recommend that all ASTRO pre-majors take this class at University Park.*

ASTRO 292 (GN) ASTRONOMY OF THE DISTANT UNIVERSE - 3 credits
Observed properties and astrophysical understanding of stars, stellar evolution, galaxies, the large-scale universe, and cosmology. Prerequisite: ASTRO 291

ASTRO 296 INDEPENDENT STUDIES (1 -18 credits)

ASTRO 297 SPECIAL TOPICS (1 - 9 credits)

ASTRO 320 (GN) OBSERVATIONAL ASTRONOMY LABORATORY - 2 credits
Basic observational astronomy techniques introduced through observational exercises, lab experiments, and lectures on relevant statistical techniques. Prerequisite: ASTRO 292

ASTRO 399 (IL) FOREIGN STUDIES (1 -12 credits)

ASTRO 410 COMPUTATIONAL ASTROPHYSICS - 3 credits
Applications of numerical methods and computer programming to astrophysics, including stellar physics and cosmology. Prerequisite: CMPSC 121 or CMPSC 201 or CMPSC 202; PHYS 212, PHYS 213, and PHYS 214

ASTRO 414 STELLAR STRUCTURE AND EVOLUTION - 3 credits
Theory of stellar structure and evolution including energy generation and transport and an examination of stellar models. Prerequisite: ASTRO 292, MATH 230, PHYS 212, PHYS 213, PHYS 214, PHYS 237

ASTRO 420W PLANETS AND PLANETARY SYSTEM FORMATION - 3 credits
Solar system properties, star formation, protoplanetary disks and planet formation, solar system model, extrasolar planets, and astrobiology. Prerequisite: ASTRO 292

ASTRO 440 INTRODUCTION TO ASTROPHYSICS - 3 credits
Theoretical investigation of physical processes in astronomical objects and systems; modern physical interpretation of astronomical phenomena. Prerequisite: MATH 230, PHYS 237

ASTRO 451 ASTRONOMICAL TECHNIQUES - 3 credits
Practical methods of modern observational astronomy, detectors, filters, instrumentation for both ground-based and space observations, and data analysis. Prerequisite: PHYS 212, PHYS 213,
PHYS 214

ASTRO 475W STARS AND GALAXIES - 3 credits
Astronomical studies concerning the distribution and evolution of stars and gas in our and other galaxies. Prerequisite: ASTRO 292

ASTRO 480 NEBULAE, GALAXIES, AND COSMOLOGY - 3 credits
Emission-line spectroscopy, structure and evolution of galaxies, physics of galactic nuclei and quasars, observational cosmology. Prerequisite: ASTRO 292, PHYS 212, PHYS 213, PHYS 214

ASTRO 485 INTRODUCTION TO HIGH-ENERGY ASTRONOMY - 3 credits
The study of black holes, neutron stars, white dwarfs, supernova remnants, and extragalactic objects through x-ray and gamma ray observations. Prerequisite: PHYS 237

ASTRO 496 INDEPENDENT STUDIES (1 -18 credits)
Creative projects, including research and design, which are supervised on an individual basis and which fall outside the scope of formal courses.

ASTRO 497 SPECIAL TOPICS (1 - 9 credits)
Formal courses given infrequently to explore, in depth, a comparatively narrow subject which may be topical or of special interest.

ASTRO 499 (IL) FOREIGN STUDIES (1 -12 credits)
Courses offered in foreign countries by individual or group instruction.

Independent Study: 3 credit hours maximum per semester. For each credit of independent study taken during the regular Fall and Spring semesters, the student is expected to contribute at least 3 hours of in-lab work per week. For a student to register for ASTRO 296 or ASTRO 496 for more than 3 credits, an explicit plan needs to be created and approved by your adviser and the Undergraduate Program Head.

Other Undergraduate Courses for the Major

CHEM 110 (GN) CHEMICAL PRINCIPLES I (3) Prerequisite: satisfactory performance on the Chemistry and Math FTCAP tests, i.e., placement beyond the level of CHEM 101 and MATH 022; or CHEM 101, and MATH 022 or MATH 041

CHEM 111 (GN) EXPERIMENTAL CHEMISTRY I (1) Prerequisite: or concurrent: CHEM 110 or CHEM 106

CHEM 112 (GN) CHEMICAL PRINCIPLES II (3) Prerequisite: CHEM 110 or CHEM 106. Prerequisite or concurrent: CHEM 111

CMPEN 271 INTRODUCTION TO DIGITAL SYSTEMS (3) Concurrent: PHYS 202 or PHYS 212

CMPEN 331 COMPUTER ORGANIZATION AND DESIGN (3) Prerequisite: CMPEN 271; CMPSC 121 or CMPSC 201

CMPEN 431 INTRODUCTION TO COMPUTER ARCHITECTURE (3) Prerequisite: CMPEN 331 or CMPEN 371

CMPEN 454 FUNDAMENTALS OF COMPUTER VISION (3) Prerequisite: MATH 230 or MATH 231; CMPSC 121 or CMPSC 201

CMPEN 471 LOGICAL DESIGN OF DIGITAL SYSTEMS (3) Prerequisite: CMPEN 331

CMPEN 473 OPERATING SYSTEMS DESIGN & CONSTRUCTION (3) Prerequisite: CMPEN 472

CMPSC 121 (GQ) INTRODUCTION TO PROGRAMMING TECHNIQUES (3) Prerequisite: MATH 110 or prerequisite or concurrent MATH 140

CMPSC 122 INTERMEDIATE PROGRAMMING (3) Prerequisite: CMPSC 121

CMPSC 201 (GQ) PROGRAMMING FOR ENGINEERS WITH C++ (3) Prerequisite: MATH 140 Concurrent: MATH 141

CMPSC 202 (GQ) PROGRAMMING FOR ENGINEERS WITH FORTRAN (3) Prerequisite: MATH 140 Concurrent: MATH 141

CMPSC 221 OBJECT ORIENTED PROGRAMMING WITH WEB-BASED APPLICATIONS (3) Prerequisite: CMPSC 122

CMPSC 360 DISCRETE MATHEMATICS FOR COMPUTER SCIENCE (3) Concurrent: CMPSC 122

CMPSC 431W DATABASE MANAGEMENT SYSTEMS (3) Prerequisite: CMPSC 221; ENGL 202C

CMPSC 442 ARTIFICIAL INTELLIGENCE I (3) Prerequisite: CMPSC 122; Concurrent: CMPSC 465

CMPSC 451/MATH 451 NUMERICAL COMPUTATIONS (3) Prerequisite: MATH 230 or MATH 231; and 3 credits of programming

CMPSC 455/MATH 455 INTRODUCTION TO NUMERICAL ANALYSIS I (3) Prerequisite: MATH 220; MATH 230 or MATH 231; and 3 credits of programming

CMPSC 458 FUNDAMENTALS OF COMPUTER GRAPHICS (3) Prerequisite: CMPSC 311; MATH 220; MATH 230 or MATH 231

CMPSC 461 PROGRAMMING LANGUAGE CONCEPTS (3) Prerequisite: CMPSC 221; CMPSC 360

CMPSC 465 DATA STRUCTURES & ALGORITHMS (3) Prerequisite: CMPSC 360 or MATH 311W

CMPSC 466 COMBINATORICS AND GRAPH THEORY (3) Prerequisite: CMPSC 465

CMPSC 467 FACTORIZATION & PRIMALITY TESTING (3) Prerequisite: CMPSC 360 or MATH 311W

CMPSC 468 THEORY OF AUTOMATA, LANGUAGES, & COMPUTABILITY (3) Prerequisite: CMPSC 122; MATH 315, MATH 311W or CMPSC 360

CMPSC 471 INTRODUCTION TO COMPILER CONSTRUCTION (3) Prerequisite: CMPSC 461

CMPSC 483W SOFTWARE DESIGN METHODS (3) Prerequisite: CMPSC 221; CMPSC 465; ENGL 202C

EE 490/AERSP 490/NUC E 490 INTRODUCTION TO PLASMAS (3) Prerequisite: E E 330 or PHYS 467

MATH 140 (GQ) CALCULUS WITH ANALYTIC GEOMETRY I (4) Prerequisite: MATH 022, MATH 026; or MATH 040 or MATH 041 or satisfactory performance on the mathematics proficiency examination

MATH 141 (GQ) CALCULUS WITH ANALYTIC GEOMETRY II (4) Prerequisite: MATH 140, MATH 140A, MATH 140B, or MATH 140H

MATH 230 CALCULUS AND VECTOR ANALYSIS (4) Prerequisite: MATH 141 or MATH 141H

MATH 251 ORDINARY AND PARTIAL DIFFERENTIAL EQUATIONS (4) Prerequisite: MATH 141 or MATH 141H

MATH 318/STAT 318 ELEMENTARY PROBABILITY (3) Prerequisite: MATH 141

MATH 405 ADVANCED CALCULUS FOR ENGINEERS AND SCIENTISTS I (3) Prerequisite: MATH 231; MATH 250 or MATH 251

MATH 406 ADVANCED CALCULUS FOR ENGINEERS AND SCIENTISTS II (3) Prerequisite: MATH 405

MATH 411 ORDINARY DIFFERENTIAL EQUATIONS (3) Prerequisite: MATH 230 or 231; MATH 250 or 251

MATH 412 FOURIER SERIES AND PARTIAL DIFFERENTIAL EQUATIONS (3) Prerequisite: MATH 230 or 231; MATH 250 or 251

MATH 417 QUALITATIVE THEORY OF DIFFERENTIAL EQUATIONS (3) Prerequisite: MATH 220, MATH 250

MATH 418/STAT 418 PROBABILITY (3) Students may take only one course from MATH(STAT) 414 and 418 for credit. Prerequisite: MATH 230 or 231

MATH 461/PHYS 461 THEORETICAL MECHANICS (3) Prerequisite: MATH 419

PHYS 211 (GN) GENERAL PHYSICS: MECHANICS (4) Concurrent: MATH 140

PHYS 212 (GN) GENERAL PHYSICS: ELECTRICITY AND MAGNETISM (4) Prerequisite: MATH 140, PHYS 211; Concurrent: MATH 141

PHYS 213 (GN) GENERAL PHYSICS: FLUIDS AND THERMAL PHYSICS (2) Prerequisite: MATH 140, PHYS 211; Concurrent: MATH 141

PHYS 214 (GN) GENERAL PHYSICS: WAVE MOTION AND QUANTUM PHYSICS (2) Prerequisite: MATH 141, PHYS 211, and PHYS 212

PHYS 237 MODERN PHYSICS (3) Prerequisite: PHYS 212; Concurrent:PHYS 214

PHYS 400 INTERMEDIATE ELECTRICITY AND MAGNETISM I (3) Prerequisite: MATH 230 or 231; MATH 250 or 251; PHYS 212, PHYS 213, and PHYS 214; Concurrent: MATH 230 or 231

PHYS 401 INTERMEDIATE ELECTRICITY AND MAGNETISM II (3) Prerequisite: PHYS 400

PHYS 402 ELECTRONICS FOR SCIENTISTS (4) Prerequisite: MATH 250 or 251; PHYS 212, PHYS 213, and PHYS 214

PHYS 406 SUBATOMIC PHYSICS (3) Prerequisite: PHYS 410

PHYS 410 INTRODUCTION TO QUANTUM MECHANICS I (3-4) Prerequisite: MATH 230 or 231; MATH 250 or 251; PHYS 237

PHYS 411 INTRODUCTION TO QUANTUM MECHANICS II (3) Prerequisite: PHYS 410

PHYS 419/MATH 419 THEORETICAL MECHANICS (3) Prerequisite: MATH 230 or 231; MATH 250 or 251; PHYS 212, PHYS 213, and PHYS 214

PHYS 420 THERMAL PHYSICS (3) Prerequisite: MATH 231, PHYS 237

PHYS 457 EXPERIMENTAL PHYSICS (1-3) Prerequisite: PHYS 212, PHYS 213, PHYS 214, and PHYS 237

PHYS 458 INTERMEDIATE OPTICS (4) Prerequisite: PHYS 212, PHYS 213, PHYS 214; MATH 230 or 231; MATH 250 or 251

PHYS 461/MATH 461 THEORETICAL MECHANICS (3) Prerequisite: MATH 419

PHYS 479/MATH 479 Special and General Relativity (3) Prerequisite: PHYS 237, PHYS 400, PHYS 419; MATH 230 or 231; MATH 250 or 251

STAT 301 (GQ) STATISTICAL ANALYSIS I (3) Prerequisite: 3 credits of calculus

STAT 318/MATH 318 ELEMENTARY PROBABILITY (3) Prerequisite: MATH 141

STAT 319/MATH 319 APPLIED STATISTICS IN SCIENCE (3) Prerequisite: STAT 318 or knowledge of basic probability

STAT 401 EXPERIMENTAL METHODS (3) Prerequisite: MATH 111 or MATH 141

STAT 414/MATH 414 INTRODUCTION TO PROBABILITY THEORY (3). Prerequisite: MATH 230 or 231

STAT 418/MATH 418 PROBABILITY (3). Prerequisite: MATH 230 or 231

Students may take only one course from STAT/MATH 414 and 418 for credit.

ASTRO MAJOR - COMPUTER SCIENCE OPTION

All CS-option students have to take: **CMPSC 121** *Introduction to Programming Techniques*
CMPSC 122 *Intermediate Programming*
CMPSC 221 *Object-Oriented Programming with Web Applications*
CMPSC 451 *Numerical Computations*

The CS-option has two sequences: (a) *software emphasis* and (b) *hardware emphasis*.

Software courses	**Hardware courses**
Required	*Required*
CMPSC 360 *Discrete Mathematics for Computer Science*	CMPEN 271 *Introduction to Digital Systems*
CMPSC 465 *Data Structures and Algorithms*	CMPEN 331 *Computer Organization and Design*
Choose 3 credits from	Choose 3 credits from
CMPSC 431W *Introduction to Database Management Systems*	CMPEN 417 *Digital Design Using Field Programmable Devices*
CMPSC 442 *Artificial Intelligence*	CMPEN 431 *Introduction to Computer Architecture*
CMPSC 450 *Concurrent Scientific Computing*	CMPEN 454 *Fundamentals of Computer Vision*
CMPEN 454 *Fundamentals of Computer Vision*	CMPEN 471 *Logical Design of Digital Systems*
CMPSC 458* *Computer Graphics*	CMPEN 472 *Microprocessors and Embedded Systems*
CMPSC 467 *Factorization and Primality Testing*	
CMPSC 468 *Theory of Automata, Language & Computability*	
CMPSC 483W* *Software Design Methods*	* - high enrollments

Planned Schedule of Offerings: 2013 – 2017

ASTRO course number	Topic	13-14		14-15		15-16		16-17	
		Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
ASTRO 001 (GN)	Astronomical Universe	X	X	X	X	X	X	X	X
ASTRO 005 (GN)	The Sky and Planets	X	X	X	X	X	X	X	X
ASTRO 006 (GN)	Stars, Galaxies, and the Universe	X	X	X	X	X	X	X	X
ASTRO 010 (GN)	Elementary Astronomy	X	X	X	X	X	X	X	X
ASTRO 011 (GN)	Elementary Astronomy Lab	X	X	X	X	X	X	X	X
ASTRO 020S	Freshman seminar	X		X		X		X	
ASTRO 120 (GN)	The Big Bang Universe		X		X		X		X
ASTRO 130 (GN)	Black Holes in the Universe				X		X		X
ASTRO 140 (GN)	Life in the Universe	X	X	X	X	X	X	X	X
ASTRO 291 (GN)	Astronomical Methods & Solar System	X		X		X		X	
ASTRO 292 (GN)	Astronomy of the Distant Universe		X		X		X		X
ASTRO 320 (GN)	Observational Astronomy Lab	X		X		X		X	
ASTRO 401	Fundamentals of Planetary Science and Astronomy	X		X		X		X	
ASTRO 402	Astronomical Telescopes, Techniques, and Data Analysis		X		X		X		X
ASTRO 410	Computational Astrophysics				X				X
ASTRO 414	Stellar Structure and Evolution		X				X		
ASTRO 420W	Planets & Planetary System Formation			X				X	
ASTRO 440	Introduction to Astrophysics				X				X
ASTRO 451	Astronomical Techniques			X				X	
ASTRO 475W	Stars & Galaxies	X				X			
ASTRO 480	Nebulae, Galaxies & Cosmology		X				X		
ASTRO 485	Intro to High Energy Astrophysics	X				X			

SUPPORTING COURSES

Several unspecified elective or supporting courses make up 10 to 12 credits in the requirements for the major. Some students fill their electives with physics or computer science courses to obtain a minor or double major in these allied departments. Some take a sequence of courses in a distant field; recent graduates have taken a minor in history or violin lessons plus orchestra performance credits. Other students take a wide range of courses, giving themselves the cultural breadth they desire for later in life. The one rule that students should follow is that choice of electives (as with their entire academic program) should be discussed regularly with their advisors.

Courses not accepted by the university:

CAS 126, ENGL 004, ENGL 005, ESL 004, LL ED 005, LL ED 010

Other courses that will not count:

CHEM	001, 003, 108, 101
CMPSC	001, 100
MATH	courses lower than MATH 140
PH SC	007
PHYS	001, 150, 151, 250, 251

Suggestions for Supporting Courses

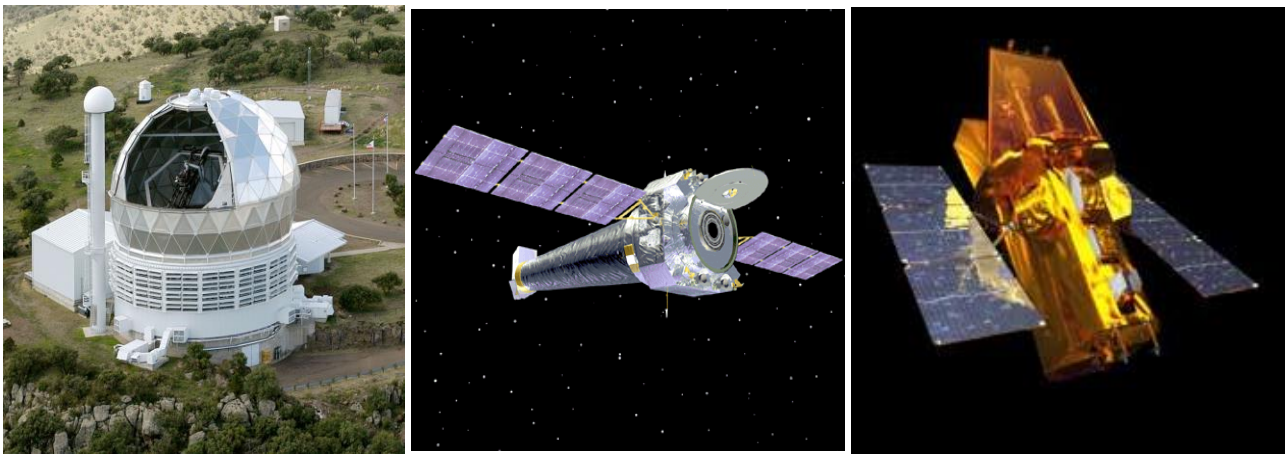
The accompanying table provides a list of courses that the department suggests for consideration when selecting electives. (Relevant courses in physics and computer science and engineering are listed on the major checklist rather than here.) Some courses may require a prerequisite beyond those provided by the ASTRO program. These are courses that complement the ASTRO program in some way. Note that up to 12 credits of electives may be earned with satisfactory/unsatisfactory (SA/US) grades, which are not included in GPA calculations.

AERSP 055 (GN) Space Science and Technology
AERSP 310 Astronautics
AERSP 490 Introduction to Plasmas
ASTRO 120 (GN) The Big Bang Universe
ASTRO 130 (GN) Black Holes in the Universe
ASTRO 140 (GN) Life in the Universe
BIOL 474 (GEOSC) Astrobiology
CHEM 451 Physical Chemistry
COMM 463 Science Journalism
CI 295 Introductory Field Experience for Teacher Preparation
EARTH 002 (GN) Gaia-The Earth System
EE 203 Principles of Electrical Engineering
GEOG 110 (GN) Climates of the World
HIST 122/123 (GH) History of Science
HIST 151 (GS) Technology and Society in American History
HIST 428 The Darwinian Revolution
HIST 457 (US;IL) The History of Women in Science
MATSE 201 Introduction to Materials Science
METEO 466 Planetary Atmospheres
METEO 473 Applications of Computers to Meteorology
METEO 474 Applications of Statistics to Meteorology
PHIL 010 (GH) Critical Thinking and Argument
PHIL 107 (GH) Introduction to Philosophy of Technology
PHIL 110 (GH) Intro to Philosophy of Science
PHIL 221 (GH) Philosophy of Science
PHIL 433 Ethics in Science and Engineering
PHIL 435 Interrelation of Science, Philosophy, & Religion
PL SC 460 Science, Technology and the Public Policy
SC 400 Consequences of Science
SCIED 411/414 Teaching Secondary Science
SCIED 454 Sciences in Early Childhood Education
STAT 319 Applied Statistics in Science
STS 100 (GH) The Ascent of Humanity
STS 101 (GH) Modern Science, Technology, & Human Values
STS 200 (GH) Critical Issues Science, Technology, & Society

UNDERGRADUATE RESEARCH

ASTRO majors have an unusually wide range of opportunities to engage in research as undergraduates. In research, the student can acquire skills not available in the classroom, participate in the excitement of pushing the frontiers of knowledge and technology, and earn important credentials for future jobs or education. Students typically begin research in the summer after their sophomore year, but some begin earlier. Research opportunities are many and varied in the department. Examples include:

- development of equipment for and analysis of data from the 9 meter Hobby-Eberly Telescope.
- analysis of images and spectra from Kitt Peak, Palomar, and Keck ground-based observatories and the Hubble Space Telescope. Topics have included search for extremely distant quasars, formation and evolution of galaxies, and study of dwarf galaxies and cataclysmic variable stars.
- analysis of data from the NAIC Arecibo radio telescope, searching for planets and other temporal phenomena in millisecond pulsars
- analysis of data from the Chandra and XMM X-ray telescopes. Penn State scientists have made extensive observations using these satellite-borne X-ray telescopes concerning quasars, young stars, supernova remnants, pulsars, and other topics.
- theoretical astrophysics on many topics including: interpretation of the enigmatic gamma-ray bursts; calculations of colliding black holes in Einstein's General Relativity; dynamics of star clusters, formation of planetary systems, and the formation of the first stars in the early universe.
- Participating in planning, data analysis, follow-up observations and interpretations for the Swift Gamma Ray Burst Explorer.



The premiere observational facilities for the Department of Astronomy and Astrophysics at Penn State are the 9 meter Hobby-Eberly Telescope, located in Fort Davis, Texas (left), the Chandra X-ray observatory located in space (middle), and the Swift Gamma Ray Burst Explorer, also located in space (right). The Swift telescope carries three instruments to enable the most detailed observations of gamma ray bursts to date. Penn State built two of the instruments and has controlled the Missions Operations Center for Swift since its launch in December 2004.

Undergraduate research in the department can be conducted either for academic credit (usually ASTRO 496 Independent Study) or for pay (full-time during the summer or part-time during the academic year).

Individual student initiative is crucial for involvement in research. Students are encouraged to knock on doors, chat with various faculty, or ask their academic advisor or the Head of the Undergraduate Program for advice about research projects.

ASTRO majors with particularly strong academic records can apply to more than a dozen nationally competitive summer research programs. Some are organized by national observatories (NRAO, NOAO), NASA, and DOE research centers. Other summer programs are hosted by other university departments nationwide under the auspices of the NSF Research Experience for Undergraduates Program. Applications are typically due between December and February prior to the summer. Lists and application forms are available from the undergraduate staff assistant and are posted on bulletin boards in the department.

Publications by ASTRO Undergraduates:

Undergraduate research projects often result in published papers. Our students are usually listed as coauthors on these publications. The student names are underlined in the following list of publications.

2013 Publications:

"Exoplanet Orbit Database (Wright+, 2011)", Wright, J. T.; Kakhouri, O.; Marcy, G. W.; Han, E.; Feng, Y.; Johnson, J. A.; Howard, A. W.; Fischer, D. A.; Valenti, J. A.; Anderson, J.; Piskunov, N.

New Features of the Exoplanet Orbit Database at Exoplanets.org", Feng, Ying; Han, E.; Wright, J.; Fakhouri, O.; Ford, E. B.; Planet Survey, California

Updates to the Exoplanet Orbit Database and Transit&Secondary Eclipse Ephemerides", Han, Eunkyu; Feng, Y.; Wright, J.; Zhao, M.; Wang, X.; Fakhouri, O.; Kane, S. R.; Dragomir, D.

2012 Publications:

"Ultraviolet Properties of Nearby Galaxies from Swift UV/Optical Telescope Imaging", Hoversten, Erik A.; Berrier, Joshua; Conroy, C.; Gronwall, C.

"A near-infrared frequency comb for Y+J band astronomical spectroscopy", Osterman, Steve; Ycas, Gabriel G.; Diddams, Scott A.; Quinlan, Franklyn; Mahadevan, Suvrath; Ramsey, Lawrence; Bender, Chad F.; Terrien, Ryan; Botzer, Brandon; Sigurdsson, Steinn; Redman, Stephen L.

"Demonstration of on-sky calibration of astronomical spectra using a 25 GHz near-IR laser frequency comb", ; Yeas, Gabriel G.; Quinlan, Franklyn; Diddams, Scott A.; Osterman, Steve; Mahadevan, Suvrath; Redman, Stephen; Terrien, Ryan; Ramsey, Lawrence; Bender, Chad F.; Botzer, Brandon; Sigurdsson, Steinn

"On the sensitivity of the HAWC observatory to gamma-ray bursts", Abeysekara, A. U.; et al, including Condreay, Phillip

"A Swift X-ray Survey Of The Localization For An Icecube 22-string Candidate Source Of High-energy Neutrinos", Conlon, Kyle; Fox, D.

"Pipeline for Making Images of Gas Flows in Binary Stars", Richards, Mercedes T.; Slobounov, Elena; Conover, Marshall; Fisher, John; Cocking, Alexander

"Cosmic Variance in the Physical Properties of Ly-alpha Emitting Galaxies at 2 < z < 3", Gronwall, Caryl; Matkovic, A.; Ciardullo, R.; Feldmeier, J. J.; Hay, J.; MUSYC Collaboration

"Evidence for a Compact Wolf-Rayet Progenitor for the Type Ic Supernova PTF 10vgv', Corsi, A.; Ofek, E. O.; Gal-Yam, A.; Frail, D. A.; Poznanski, D.; Mazzali, P. A.; Kulkarni, S. R.; Kasliwal, M. M.; Arcavi, I.; Ben-Ami, S.; Cenko, S. B.; Filippenko, A. V.; Fox, D. B.; Horesh, A.; Howell, J. L.; Kleiser, I. K. W.; Nakar, E.; Rabinak, I.; Sari, R.; Silverman, J. M.; Xu, D.; Bloom, J. S.; Law, N. M.; Nugent, P. E.; Quimby, R. M.

"Search for Relativistic Magnetic Monopoles with IceCube", IceCube Collaboration, including Larson, Michael J.

"An improved method for measuring muon energy using the truncated mean of dE/dx", IceCube Collaboration, including Larson, Michael J.

"The HD 192263 System: Planetary Orbital Period and Stellar Variability Disentangled," Dragomir, Diana; Kane, Stephen R.; Henry, Gregory W.; Ciardi, David R.; Fischer, Debra A.; Howard, Andrew W.; Jensen, Eric L. N.; Laughlin, Gregory; Mahadevan, Suvrath; Matthews, Jaymie M.; Pilyavsky, Genady; von Braun, Kaspar; Wang, Sharon X.; Wright, Jason T.

"The TERMS Project: Improved Orbital Parameters and Photometry of HD168443 and the Photometry Pipeline," Pilyavsky, Genady; Mahadevan, S.; Kane, S. R.; Howard, A. W.; Ciardi, D. R.; de Pree, C.; Dragomir, D.; Fischer, D.; Henry, G. W.; Jensen, E. L. N.; Laughlin, G.; Marlowe, H.; Rabus, M.; von Braun, K.; Wright, J. T.; Wang, X.

2011 Publications:

"Precision Rvs In The Nir: First On-sky Velocities With A U/ne Lamp And A Laser Frequency Comb", Mahadevan, Suvrath; Ramsey, L.; Redman, S.; Bender, C.; Terrien, R.; Botzer, B.; Osterman, S.; Diddams, S.; Ycas, G.; Quinlan, F.

"Laser Frequency Comb Supported Stellar Radial Velocity Determination in the NIR: Initial Results", Osterman, Steve; Diddams, S.; Quinlan, F.; Ycas, G.; Mahadevan, S.; Ramsey, L.; Bender, C.; Terrien, R.; Botzer, B.; Redman, S.

"First Stellar Radial Velocities with a Laser Frequency Comb: Observations in the NIR H Band", Osterman, Steve; Diddams, S.; Quinlan, F.; Ycas, G.; Mahadevan, S.; Ramsey, L.; Bender, C.; Redman, S.; Terrien, R.; Botzer, B.

"Precision Radial Velocities in the near-infrared Y and H bands with the Penn State Pathfinder Instrument", Terrien, Ryan; Mahadevan, S.; Ramsey, L.; Bender, C.; Redman, S.; Osterman, S.; Diddams, S.; Ycas, G.; Quinlan, F.; Botzer, B.

"A Precision Radial Velocity Pathfinder Instrument in the H Band with a Laser Frequency Comb", Mahadevan, Suvrath; Ramsey, L.; Redman, S.; Bender, C.; Botzer, B.; Osterman, S.; Diddams, S.; Ycas, G.; Quinlan, F.

The Exoplanet Orbit Database", Wright, J. T.; Fakhouri, O.; Marcy, G. W.; Han, E.; Feng, Y.; Johnson, John Asher; Howard, A. W.; Fischer, D. A.; Valenti, J. A.; Anderson, J.; Piskunov, N.

"IceCube sensitivity for low-energy neutrinos from nearby supernovae", IceCube Collaboration, including Larson, Michael J.

"Search for a diffuse flux of astrophysical muon neutrinos with the IceCube 40-string detector", Abbasi, R.; Abdou, Y.; Abu-Zayyad, T.; et al, including Larson, Michael J.

"The MgII Absorption View Through z<1 Galaxies", Mathes, Nigel; Rodriguez-Hidalgo, P.; Charlton, J.; Rao, S.; Nestor, D.

"Visible and Near-Infrared Properties of Optical Fibers Coupled to the Pathfinder High-Resolution NIR Spectrograph", McCoy, Keegan; Ramsey, Lawrence

"A Search for the Transit of HD 168443b: Improved Orbital Parameters and Photometry", Pilyavsky, Genady; Mahadevan, Suvrath; Kane, Stephen R.; Howard, Andrew W.; Ciardi, David R.; de Pree, Chris.; Dragomir, Diana; Fischer, Debra; Henry, Gregory W.; Jensen, Eric L. N.; Laughlin, Gregory; Marlowe, Hannah; Rabus, M.; von Braun, Kaspar.; Wright, Jason T.; Wang, Xuesong X.

"TERMS Photometry of Known Transiting Exoplanets",
Dragomir, Diana; Kane, Stephen R.; Pilyavsky, Genady; Mahadevan, Suvrath; Ciardi, David R.; Gazak, J. Zachary; Gelino, Dawn M.; Payne, Alan; Rabus, Markus; Ramirez, Solange V.; von Braun, Kaspar; Wright, Jason T.; Wyatt, Pamela

"The TERMS Project: Systematic Transit Exclusion", Kane, Stephen R.; Ciardi, D.; Dragomir, D.; Fischer, D.; Henry, G.; Howard, A.; Jensen, E.; Laughlin, G.; Mahadevan, S.; Pilyavsky, G.; von Braun, K.; Wang, X.; Wright, J.

"Stellar Variability of the Exoplanet Hosting Star HD 63454",
Kane, Stephen R.; Dragomir, Diana; Ciardi, David R.; Lee, Jae-Woo; Lo Curto, Gaspare; Lovis, Christophe; Naef, Dominique; Mahadevan, Suvrath; Pilyavsky, Genady; Udry, Stephane; Wang, Xuesong; Wright, Jason

"Improved Orbital Parameters and Transit Monitoring for HD 156846b", Kane, Stephen R.; Howard, Andrew W.; Pilyavsky, Genady; Mahadevan, Suvrath; Henry, Gregory W.; von Braun, Kaspar; Ciardi, David R.; Dragomir, Diana; Fischer, Debra A.; Jensen, Eric; Laughlin, Gregory; Ramirez, Solange V.; Wright, Jason T.

"Improving Transit Predictions of Known Exoplanets with TERMS", Kane, Stephen R.; Ciardi, D.; Dragomir, D.; Fischer, D.; Henry, G.; Howard, A.; Jensen, E.; Laughlin, G.; Mahadevan, S.; Pilyavsky, G.; von Braun, K.; Wright, J.

"Transit Monitoring of Known Exoplanets with TERMS", Kane, Stephen R.; Ciardi, D.; Fischer, D.; Gelino, D.; Henry, G.; Howard, A.; Jensen, E.; Laughlin, G.; Mahadevan, S.; Pilyavsky, G.; von Braun, K.; Wright, J.

2010 Publications:

"GRB 090417B and its Host Galaxy: A Step Toward an Understanding of Optically Dark Gamma-ray Bursts," Holland, Stephen T.; Sbarufatti, Boris; Shen, Rongfeng; Schady, Patricia; Cummings, Jay R.; Fonseca, Emmanuel; Fynbo, Johan P. U.; Jakobsson, Páll; Leitet, Elisabet; Linné, Staffan; Roming, Peter W. A.; Still, Martin; Zhang, Bing, *Astrophysical Journal*, 717, 1 (2010)

"The Gamma-Ray Burst GRB 090417b and its Host Galaxy: A Step Towards an Understanding of Optically-Dark Gamma-Ray Bursts," Holland, Stephen; Sbarufatti, B.; Shen, R.; Schady, P.; Cummings, J.; Fonseca, E.; Fynbo, J.; Jakobsson, P.; Leitet, E.; Linne, S.; Roming, P.; Still, M.; Zhang,B., *Bulletin American Astronomical Society*, No. 2.07 (2010)

"Spectral Energy Distributions of Weak Active Galactic Nuclei Associated with Low-Ionization Nuclear Emission Regions," Eracleous, M.; Hwang, J. A.; Flohic, H. M. L. G. *Astrophysical Journal Supplement Series*.187.135E (2010)

"An Assessment of the Energy Budgets of Low-Ionization Nuclear Emission Regions," Eracleous, Michael; Hwang, Jason A.; Flohic, Hélène M. L. G. *The Astrophysical Journal*, 711, 2, (2010)

"Choosing the Initial LISA Orbital Configuration", Jani, Karan; Finn, Lee Samuel; Benacquista, Mathew

"A Bare Molecular Cloud at z ~ 0.45," Jones, Therese M.; Misawa, Toru; Charlton, Jane C.; Mshar, Andrew C.; Ferland, Gary J., *Astrophysical Journal*, 715, 2 (2010)

"Connections of MgII Absorption Kinematics and Galaxy Properties for a Sample of DLAs and Sub-DLAs," Mathes, Nigel; Rodriguez Hidalgo, P.; Charlton, J.; Jones, T.; Rao, S., *Bulletin American Astronomical Society*, No. 215.460.09 (2010)

"Alpha-enhancement and Evolution of Very Strong MgII Absorbers," Rodriguez, Paola; Wessels, K.; Charlton, J. C.; Jones, T. M.; Cucchiara, A.; Mshar, A.; Narayanan, A., *Bulletin American Astronomical Society*, No. 215.460.02 (2010)

"The Observational Limits Of Ground Based Gravitational Wave Detectors: Core-collapse Supernovae," Lang, Meagan; Bondarescu, R.; Finn, L.; Fisher, R.; Kopparapu, R., *Bulletin American Astronomical Society*, No. 215.406.08 (2010)

"Gravitational-wave astronomy with Stokes Parameters," Bondarescu, Ruxandra; Kopparapu, R.; Finn, L.; Lang, M.; Summerscales, T., *Bulletin American Astronomical Society*, No. 215.406.07 (2010)

"Tidal Tails in Interacting Galaxies: Formation of Compact Stellar Structures," Mullan, B.; Charlton, J. C.; Konstantopoulos, I. S.; Bastian, N.; Chandar, R.; Durrell, P. R.; Elmegreen, D.; English, J.; Gallagher, S. C.; Gronwall, C.; Lee, K. H.; Astronomical Society of the Pacific, 2010., p.129 (2010)

"Star Formation In Hickson Compact Group 7: U-band Studies Of A Future Dry Merger," Lee, Kising; Konstantopoulos, I.; Charlton, J.; Gallagher, S.; Fedotov, K.; HCG Team; *Bulletin American Astronomical Society*, No. 215.478.09 (2010)

"A Limit on the Number of Isolated Neutron Stars Detected in the ROSAT All-Sky-Survey Bright Source Catalog," Turner, Monica L.; Rutledge, Robert E.; Letcavage, Ryan; Shevchuk, Andrew S. H.; Fox, Derek B., *The Astrophysical Journal*, 714, 2 (2010)

"Connections of MgII Absorption Kinematics and Galaxy Properties for a Sample of DLAs and Sub-DLAs", Mathes, Nigel; Rodriguez Hidalgo, P.; Charlton, J.; Jones, T.; Rao, S.

"The K-Band Quasar Luminosity Function from an SDSS and UKIDSS Matched Catalog," Peth, Michael; Ross, N. P.; Schneider, D. P.; *Bulletin American Astronomical Society*, No. 215.433.20 (2010)

"Measurement of sound speed vs. depth in South Pole ice for neutrino astronomy," Icecube Collaboration; Abbasi, R.; Abdou, Y.; Abu-Zayyad, T.; Adams, J.; Aguilar, J. A.; Ahlers, M.; Andeen, K.; Auffenberg, J.; Bai, X.; Baker, M.; and 250 coauthors (including Stephens, Grant), Astroparticle Physics, Volume 33, Issue 5-6, p. 277-286. (2010)

"Limits on a muon flux from Kaluza-Klein dark matter annihilations in the Sun from the IceCube 22-string detector," Icecube Collaboration; Abbasi, R.; Abdou, Y.; Abu-Zayyad, T.; Adams, J.; Aguilar, J. A.; Ahlers, M.; Andeen, K.; Auffenberg, J.; Bai, X.; Baker, M.; and 249 coauthors (including Stephens, Grant), *Physical Review D*, 81, 5 (2010)

"Search for Muon Neutrinos from Gamma-ray Bursts with the IceCube Neutrino Telescope," Icecube Collaboration; Abbasi, R.; Abdou, Y.; Abu-Zayyad, T.; Adams, J.; Aguilar, J. A.; Ahlers, M.; Andeen, K.; Auffenberg, J.; Bai, X.; Baker, M.; and 249 coauthors (including Stephens, Grant), *The Astrophysical Journal*, 710, 1 (2010)

"Luminosity Functions and Photometric Properties of Lyman-alpha Emitters at $2 < z < 3$," Wolf, Christopher; Sinawa, S.; Ciardullo, R.; Gronwall, C.; Guaita, L.; Gawiser, E.; Bond, N.; Feldmeier, J.; Padilla, N.; MUSYC Collaboration, *Bulletin American Astronomical Society*, No. 215.410.10 (2010)

2009 Publications:

"Enhanced Constraints on a Photoionization Model of a Multiple Cloud Weak MgII Absorber at $z = 2$," Green, Rebecca; Narayanan, A.; Charlton, J., *Bulletin American Astronomical Society*, No. 213.482.05 (2009)

"Testing the Possible Intrinsic Origin of the Excess Very Strong Mg II Absorbers Along Gamma-Ray Burst Lines-of-Sight," Cucchiara, A.; Jones, T.; Charlton, J. C.; Fox, D. B.; Einsig, D.; Narayanan, A. *Astrophysical Journal*, 697, 1 (2009)

"Supernova 2009jf in NGC 7479", Kasliwal, M. M.; Howell, J. L.; Fox, D. B.; Quimby, R.; Gal-Yam, A.

"SN2009jf in NGC7479 is a Type Ib supernova", Kasliwal, M. M.; Howell, J. L.; Fox, D. B.; Quimby, R.; Gal-Yam, A.

"The Enigma of the Strong MgII Absorbers Along GRB Sightlines," Cucchiara, A.; Jones, T.; Charlton, J. C.; Fox, D. B.; Einsig, D.; Naranayan, A., PROBING STELLAR POPULATIONS OUT TO THE DISTANT UNIVERSE: CEFALU 2008, Proceedings of the International Conference. AIP Conference Proceedings, Volume 1111 (2009)

"A Kinematic Comparison of Strong Mg II Absorbers Along Quasar and GRB Sightlines," Jones, Therese; Cucchiara, A.; Charlton, J.; Fox, D.; Einsig, D., *Bulletin American Astronomical Society*, No. 213.476.08 (2009)

"Chandra Observations of 1RXS J141256.0+792204 (Calvera)," Shevchuk, A. S. H.; Fox, D. B.; Rutledge, R. E., *The Astrophysical Journal*, 705, 1 (2009)

"The Swift ROSAT Bright Source Catalog - 2MASS XID Survey," Letcavage, Ryan; Rutledge, R. E.; Fox, D. B.; Shevchuk, A. H., *Bulletin American Astronomical Society*, No. 213.470.03 (2009)

"Extending the Search for Neutrino Point Sources with IceCube above the Horizon," Abbasi, R.; Abdou, Y.; Abu-Zayyad, T.; Adams, J.; Aguilar, J. A.; Ahlers, M.; Andeen, K.; Auffenberg, J.; Bai, X.; Baker, M.; and 246 coauthors (including Stephens, Grant), *Physical Review Letters*, 103, 22 (2009)

"First Neutrino Point-Source Results from the 22 String Icecube Detector," Abbasi, R.; Abdou, Y.; Ackermann, M.; Adams, J.; Aguilar, J.; Ahlers, M.; Andeen, K.; Auffenberg, J.; Bai, X.; Baker, M.; and 240 coauthors (including Stephens, Grant), *The Astrophysical Journal Letters*, 701, 1 (2009)

"Detection of X-Ray Emission from the Very Old Pulsar J0108-1431," Pavlov, G. G.; Kargaltsev, O.; Wong, J. A.; Garmire, G. P., *Astrophysical Journal*, 691, 1 (2009)

"Young Energetic PSR J1617-5055, Its Nebula, and TeV Source HESS J1616-508," Kargaltsev, O.; Pavlov, G. G.; Wong, J. A., *Astrophysical Journal*, 690, 1 (2009)

CAREER OPPORTUNITIES

Penn State students with a B. S. in astronomy & astrophysics have been successful in establishing careers in a wide variety of technical fields. Students should be aware that a degree in astronomy is less well known by employers than degrees in computer science or physics. We encourage majors intending to end their education with a B.S. to obtain a minor or double major in one of these two allied fields. Students interested in job placement after a B. S. degree are strongly encouraged to participate in departmental research or the Eberly College of Science Co-op program during their time at Penn State. For more information see: http://www.astro.psu.edu/deptinfo/CareerResources.html.

Recent graduates who chose to find employment after receiving their bachelor of science degrees in ASTRO found work in a wide range of capacities, including:

- Industry (including computer software, high-technology, telecommunications, and aerospace companies)
- High schools and universities
- Armed services
- Astronomical research enterprises like the Allegheny Observatory, Space Telescope Science Institute, and NASA

Some recent graduates include uniformed officers in the Army and Navy, a planetarium outreach astronomer, a software engineer with Orbital Sciences, a C programmer at AT&T in New Jersey, a physics high school teacher in Maryland, a programmer at the Space Telescope Science Institute, two geospatial analysts at GeoEye, a physicist at Lockheed Martin, and a researcher working on Unmanned Aerial Vehicles (UAVs) for California-based AeroVironment.

Many of our majors pursue graduate education in astronomy. Recent graduates have gone to some of the finest graduate Astronomy programs including the University of Arizona, Arizona State University, California Institute of Technology, University of Chicago, University of Colorado, Cornell University, Harvard, University of Hawaii, Johns Hopkins University, Georgia State University, Louisiana State University, University of Maryland, University of Massachusetts, Princeton University, University of Wisconsin, and Cambridge University (UK).

Some students chose graduate departments in allied fields like Physics or Earth Sciences: University of Arizona (Astrobiology, Optics), University of Chicago (Physics), University of California (Geophysics), Ohio State University (Electrical Engineering), Brandeis University (Physics), and University of California, Berkeley (Ecology), Arizona State (Geosciences), and Johns Hopkins (Geosciences).

Some alumni are now professors of astronomy or physics at major research universities, e.g., California Institute of Technology, University of Hawaii, and University of North Carolina at Chapel Hill. Other alumni are astronomers at NASA, Space Telescope Science Institute, Goddard Space Flight Center, and at various universities.

ADDITIONAL INFORMATION

HONORS PROGRAM

Some ASTRO majors are in the Schreyer Honors College. This is a University-wide honors program for academically advanced students designed to challenge, enrich, and broaden their general education, and to deepen their preparation for graduate study or a profession. Entry into the program is by invitation only, either from high school, or during the first two years at Penn State.

Schreyer Scholars may choose from a wide variety of special honors courses and sections offered to satisfy Penn State's General Education component. Students' progress in their fields of specialization is enhanced by special courses, independent study and research, graduate courses, and honors-option work in regular courses. Honors study in the freshman and sophomore years concentrates mainly on General Education (e.g., honors sections in physics and math courses). In the junior and senior years, the emphasis changes to astronomy & astrophysics, with independent research (ASTRO 496H) leading to an honors thesis and an honors degree. Scholars work closely with their honors advisor to design an academic program that best suits their needs. Honors advisors are permitted considerable flexibility in approving unusual programs, which do not require petitions to the Assistant Department Head for Undergraduate Education or the dean of the college. To remain in the Schreyer Honors College, students must take at least 9 honors credits per year, file annual plans of study, and maintain a specified grade-point average. More information can be obtained form the Schreyer Honors College office in 10 Schreyer Honors College, or visit their website at http://www.scholars.psu.edu/

The department currently has four honors advisors: Professors Niel Brandt, Jane Charlton, Steinn Sigurdsson, and Alex Wolszczan.

FINANCIAL AID AND SCHOLARSHIPS

Penn State provides four types of student aid programs: grants, scholarships, loans, and employment. First-year students are automatically considered for all available University scholarships. Many ASTRO majors find summer or academic year employment in the department, assisting the faculty and staff with research. To receive an informational booklet about financial aid, contact the Office of Student Aid, 314 Shields Building or visit http://www.psu.edu/dept/studentaid/

The department also nominates students with particularly strong academic records for a variety of scholarships and awards, some from within the University (e.g. Braddock Scholars) and some nationally competitive awards. Recent majors have won several coveted NSF Graduate Fellowships, Astronaut Fellowships, Goldwater Scholarships, NASA Scholarships, and Fulbright Fellowships. Information and applications for scholarships can be obtained from the Undergraduate Fellowships Office,11-A Grange Building or by visiting http://www.ufo.psu.edu/

ASTRONOMY CLUB

The Undergraduate Student Government sponsors an Astronomy Club that is associated with the department. The club owns several telescopes and uses department telescopes on the roof of Davey Laboratory. In addition to star parties, road trips and other activities, the club organizes Astronomy Open Houses for the Penn State/State College community. Majors interested in amateur observing, learning the sky, or just having fun with astronomy are encouraged to join the club.
http://php.scripts.psu.edu/clubs/up/astro/index.php

COMPUTING FACILITIES

In addition to the University's widely distributed laboratories with personal computers, the department has a number of modern Mac OS X workstations and PC's for undergraduate research purposes. Students engaged in research need to contact their faculty research supervisor to make a formal request for access to these machines. Additional workstations specifically devoted to undergraduate education in astronomy and related fields are located in the Undergrad Research Labs in Davey Lab rooms 531 and 535A and in the Physical Sciences Computing Laboratory in 216 Osmond Lab.

CAREER-RELATED EXPERIENCE AND STUDY ABROAD OPPORTUNITIES

Science Job Shadowing/Externship Program (First-Year, Sophomore Year)
Get a first-hand perspective on possible careers by registering for a job shadowing/externship during your freshman and/or sophomore years. The shadowing lasts one to four days; most students choose something close to your home since the shadowing happens after you've left school for the summer. You choose your top three favorites from the list of Penn State alumni extern hosts/sites, and you'll be matched with one of them. To apply, visit http://cie.science.psu.edu.

Science Cooperative Education (Junior/Senior Years)
Co-op gives you extended work experience related to your major, while earning academic credit and getting paid. It's a win-win-win! You do three co-op "rotations" before graduation, and at least one has to be completed during the fall or spring semester. Most students do a summer/fall or spring/summer assignment and then another summer. You don't have to complete all three co-ops with the same organization, so it's a great chance to get experience in a few different environments. You can use your co-op credits to meet course requirements, so plan ahead and talk with your advisor about how you can fit co-op into your degree. For more information, visit http://cie.science.psu.edu.

Science Internship
You can use the Science Career & International Education web-based database to search for opportunities and get leads on possible summer programs. Office staff will review your resume and cover letters, and answer your questions about applications. Then, you simply apply on-line to the organization web sites. Remember – summer is competitive, because you're in the same applicant pool as everyone in the country, so you need to plan ahead and search for opportunities early. If want to earn academic credit for your internship, complete and return the Request for Academic Credit form at http://cie.science.psu.edu. If not, please let the Science Career & International Education staff know about your position, so they can track the data for their annual report.

International Opportunities
You have a lot of chances to get international experience during your time at Penn State. If you want to take upper-level courses abroad, there are places where you can do that. If you're interested in studying a

language, taking gen eds, or visiting some particular country or culture, Penn State's Education Abroad Office offers almost 200 different study abroad options for Penn State students. We particularly recommend the University of Sussex in southern England, which has an excellent astronomy & astrophysics center. Tuition fees are the same as for Penn State, but the student is responsible for room and board, travel, and miscellaneous expenses. If you have financial aid, you can use it for studying abroad on a Penn State program. Study abroad credits can be indicated by ASTRO 499 or by other course numbers, but their allocation to fulfill specific graduation requirements should be approved in advance by your advisor and Assistant Department Head for Undergraduate Education. A semester abroad also satisfies the University's International Cultures (IL) requirement. If you'd like to get research experience abroad, there are several international REU (Research Experience for Undergraduates) programs available. If you're not sure about studying abroad for a full semester, then you may want to look at the summer program options, or check out the embedded courses, which are courses that are offered here on campus during the regular semester, but that include some international travel component. A complete list of all study abroad programs and embedded courses can be found at www.global.psu.edu, and more science-specific information about international opportunities can be found at http://cie.science.psu.edu. You can visit either office at any point to get more information and to explore your options, but plan early, because most programs require early applications, and you should talk with your advisor about how you want to fit an international experience into your major.

Resources

Don't have a resume or cover letter? Click "Student Handbook" on the Science Career & International Education web site at http://cie.science.psu.edu for samples and advice on getting an internship, co-op or full-time job. Please visit the Science Career & International Education Office in 108 Whitmore Lab or call 814.865.5000 for more information about gaining career-related or international experience.

GRE EXAMS

Students who plan to apply to graduate school to study Astronomy or Physics should take the Graduate Record Examination (GRE) before or during the fall semester of their senior year. You need to take both the General and Physics GRE exams. The Physics subject test is offered in October and November (with early September & October registration deadlines), while the General test is offered year-round.

The main GRE web site is at www.gre.org and has links to both the General and Subject test dates and centers. The General exam is offered at many Pennsylvania locations (test centers) often throughout the year, but the closest test center to State College is in Harrisburg. There are no General GRE test centers in State College.

The subject (Physics) exam is offered far less frequently, but typically is available at PSU/University Park. The test held in late October/early November usually sends scores to graduate schools by mid to late December. This is considered to be the best time to take the test since it ensures that scores will get to graduate programs in a timely manner. The test held in mid-December should send results to graduate schools by mid-January. The Society of Physics Students (SPS) chapter at Penn State – University Park often organizes "self-study" groups of seniors who are studying for the Physics exam. These groups are sometimes assisted by several faculty members from the Physics department. Contact Prof. Rick Robinett in Physics if you have any questions. The Astronomy department has recently initiated GRE preparation sessions. Contact the Undergraduate Program Head for further information.

ASTRO Program Checklists

Recommended Academic Plan for Astronomy & Astrophysics - Graduate Studies Option (ASTRO - GRDST at UP)

Effective Fall 2007

Semester 1	Credits	Semester 2	Credits
MATH 140 (GQ) Calculus with Analytic Geometry I	4	**MATH 141** (GQ) Calculus with Analytic Geometry II	4
PHYS 211 (GN) General Physics: Mechanics	4	**PHYS 212** (GN) General Physics: Electricity & Magnetism	4
CHEM 110 (GN) Chemical Principles I	3	CHEM 111 (GN) Experimental Chemistry I	1
General Education course (GA/GH/GS)	3	CHEM 112 (GN) Chemical Principles II	3
First-Year Seminar (ASTRO 020S)	2	*ENGL 015 or 030* (GWS) Composition/Honors Comp.	3
		Health/Kinesiology course (GHA)	1.5
Total Credits:	16	Total Credits:	16.5
Semester 3	**Credits**	**Semester 4**	**Credits**
ASTRO 291 (GN) Astronomical Methods & the Solar System	3	**ASTRO 292** (GN) Astronomy of the Distant Universe	3
MATH 230 Calculus and Vector Analysis	4	MATH 251 Ordinary and Partial Differential Equations	4
PHYS 213 (GN) General Physics: Fluids & Thermal Physics	2	PHYS 237 Introduction to Modern Physics	3
PHYS 214 (GN) Gen. Physics: Wave Motion & Quantum Phys.	2	CMPSC 121 (GQ) Intro to Programming Techniques	3
CAS 100 (GWS) Effective Speech	3	General Education course (IL/US: GA/GH/GS)	3
Total Credits:	14	Total Credits:	16
Semester 5	**Credits**	**Semester 6**	**Credits**
ASTRO 320 (GN) Observational Astronomy Laboratory	2	**ASTRO 4xx** (Select a 3-credit 400-level ASTRO course)	3
ASTRO 4xx (Select a 3-credit 400-level ASTRO course)	3	*ENGL 202C* (GWS) Effective Writing: Technical	3
MATH 405 Advanced Calculus for Engineers & Scientists or MATH 411 Ordinary Differential Equations or MATH 417	3	CMPSC/MATH/STAT (*see Notes 3*) *Select 3 credits of a 300-level or 400-level course*	3
PHYS 419 Theoretical Mechanics	3	PHYS 400 Intermediate Electricity and Magnetism I	3
General Education course (IL/US: GA/GH/GS)	3	General Education course (GA/GH/GS)	3
Health/Kinesiology course (GHA)	1.5		
Total Credits:	15.5	Total Credits:	15
Semester 7	**Credits**	**Semester 8**	**Credits**
ASTRO 4xxW (Select a 3-credit 400-level ASTRO W course)	3	**ASTRO 4xx** (Select a 3-credit 400-level ASTRO course)	3
PHYS 410 Introduction to Quantum Mechanics I	4	PHYS 4xx (Select a 400-level PHYS course - *see Notes 4*)	3
PHYS 4xx (Select a 400-level PHYS course - *see Notes 4)*	3	Supporting Course (Select 3 credits - *see Notes 5*)	3
General Education course (GA/GH/GS)	3	Supporting Course (Select 3 credits)	3
General Education course (GA/GH/GS)	3	Supporting Course (Select 4 credits)	4
Total Credits:	16	Total Credits:	16

Bold type indicates courses requiring a quality grade of C or better.

· Italics indicate courses that satisfy both major and General Education requirements.

· Bold Italics indicate courses requiring a quality grade of C or better and that satisfy both major and General Education requirements.

· GWS, GHA, GQ, GN, GA, GH, and GS are codes used to identify General Education requirements.

· US, IL are codes used to designate courses that satisfy University United States (US) and International (IL) Cultures requirements. These credits can be acquired concurrently with GA, GH, and/or GS courses.

· W is the code used to designate courses that satisfy University Writing Across the Curriculum requirement.

Program Notes:

1. ASTRO 4xx: Choose from ASTRO 400H, 410, 414, 420W, 440, 451, 475W, 480, 485 and 497 courses (except ASTRO 496).
2. For the required writing-intensive coursework we recommend taking ASTRO xxxW courses (e.g., ASTRO 420W, ASTRO 475W).
3. Suggested CSE/MATH/STAT courses: CMPSC 451/MATH 451, CMPSC 455/MATH 455, MATH 318/STAT 318, MATH 406, MATH 411, MATH 412, MATH 461, STAT 301, STAT 401. (MATH 419 cannot be used because it is identical to PHYS 419.)
4. Choose 6-7 credits from PHYS 401, 402, 406, 411, 420, 457 (2-3 credit options), 458, 461, 479, and EE 490.
5. See the Undergraduate Handbook and your advisor for recommended supporting courses.

Recommended Academic Plan for Astronomy & Astrophysics - Computer Science Option (ASTRO - CMPSC at UP)

Effective Fall 2007

Semester 1	Credits	Semester 2	Credits
MATH 140 (GQ) Calculus with Analytic Geometry I	4	**MATH 141** (GQ) Calculus with Analytic Geometry II	4
PHYS 211 (GN) General Physics: Mechanics	4	**PHYS 212** (GN) General Physics: Electricity & Magnetism	4
CHEM 110 (GN) Chemical Principles I	3	CHEM 111 (GN) Experimental Chemistry I	1
General Education course (GA/GH/GS)	3	CHEM 112 (GN) Chemical Principles II	3
First-Year Seminar (ASTRO 020S)	2	*ENGL 015 or 030* (GWS) Composition/Honors Composition	3
		Health/Kinesiology course (GHA)	1.5
Total Credits:	16	Total Credits:	16.5
Semester 3	**Credits**	**Semester 4**	**Credits**
ASTRO 291 (GN) Astronomical Methods & the Solar System	3	**ASTRO 292** (GN) Astronomy of the Distant Universe	3
MATH 230 Calculus and Vector Analysis	4	MATH 251 Ordinary and Partial Differential Equations	4
PHYS 213 (GN) General Physics: Fluids & Thermal Physics	2	PHYS 237 Introduction to Modern Physics	3
PHYS 214 (GN) Gen. Physics: Wave Motion & Quantum Phys.	2	CMPSC 121 (GQ) Introduction to Programming Techniques	3
CAS 100 (GWS) Effective Speech	3	General Education course (IL/US: GA/GH/GS)	3
Total Credits:	14	Total Credits:	16
Semester 5	**Credits**	**Semester 6**	**Credits**
ASTRO 320 (GN) Observational Astronomy Laboratory	2	**ASTRO 4xx** (Select a 3-credit 400-level ASTRO course)	3
ASTRO 4xx (Select a 3-credit 400-level ASTRO course)	3	*ENGL 202C* (GWS) Effective Writing: Technical	3
CMPSC 122 Intermediate Programming (*prereq.* CMPSC 121)	3	CMPSC 221 Object-Oriented Programming w/ Applications	3
Select 3 credits from STAT 318, 319, 401, 414 or 418	3	*Hardware*: CMPEN 271 Introduction to Digital Systems or *Software:* CMPSC 360 Discrete Math for Computer Science	3
General Education course (IL/US: GA/GH/GS)	3	General Education course (GA/GH/GS)	3
Health/Kinesiology course (GHA)	1.5		
Total Credits:	15.5	Total Credits:	15
Semester 7	**Credits**	**Semester 8**	**Credits**
ASTRO 4xxW (Select a 3-credit 400-level ASTRO W course)	3	**ASTRO 4xx** (Select a 3-credit 400-level ASTRO course)	3
CMPSC 451 Numerical Computations	3	CMPSC 4xx (Select a 400-level CSE course - *see Notes 4*)	3
Hardware: CMPEN 331 Computer Organization & Design or *Software*: CMPSC 465 Data Structures and Algorithms	3	Supporting Course (Select 3 credits)	3
General Education course (GA/GH/GS)	3	Supporting Course (Select 3 credits)	3
General Education course (GA/GH/GS)	3	Supporting Course (Select 3 credits)	3
Supporting Course (Select 2 credits)	2		
Total Credits:	17	Total Credits:	15

· Bold type indicates courses requiring a quality grade of C or better.
· Italics indicate courses that satisfy both major and General Education requirements.
· Bold Italics indicate courses requiring a quality grade of C or better and that satisfy both major and General Education requirements.
· GWS, GHA, GQ, GN, GA, GH, and GS are codes used to identify General Education requirements.
· US, IL are codes used to designate courses that satisfy University United States (US) and International (IL) Cultures requirements. These credits can be acquired concurrently with GA, GH, and/or GS courses.
· W is the code used to designate courses that satisfy University Writing Across the Curriculum requirement.

Program Notes:

1. ASTRO 4xx: Choose from ASTRO 400H, 410, 414, 420W, 440, 451, 475W, 480, 485 and 497 courses (except ASTRO 496).
2. For the required writing-intensive coursework we recommend taking ASTRO xxxW courses (e.g., ASTRO 420W, ASTRO 475W).
3. Students taking the Computer Science option should follow one of the following sequences in their junior year:
   (1) Software Emphasis: CMPSC 360 and 465 or (2) Hardware Emphasis: CMPEN 271 and 331.
4. CMPSC 4xx courses: For Software Emphasis, choose from CMPSC 431W, 442, 450, 458, 467, 468, 483W, CMPEN 454 or
   For Hardware Emphasis, choose from CMPEN 417, 431, 454, 471, 472.
5. See the Undergraduate Handbook and your advisor for recommended supporting courses.

ASTRONOMY AND ASTROPHYSICS MAJOR Program Years: **2007**

B.S. Degree, Graduate Study Option

General Education Years: 2005
Eberly College of Science
The Pennsylvania State University Student Name_____

For the B.S. degree in Astronomy and Astrophysics, a minimum of 124 credits is required. The following four requirements are to be integrated into the course requirements for the major which are listed below.

( ) First-Year Seminar (required of all students admitted to the University as freshmen since SU99)
Note: ASTRO 020S is recommended and may be used as a supporting course.
( ) International Cultures (IL)
Note: Many students will select a course which is also approved to satisfy a General Education requirement in the arts, humanities, or social and behavioral sciences (e.g., RL ST 001 GH/IL).
( ) United States Cultures (US)
Note: Many students will select a course which is also approved to satisfy a General Education requirement in the arts, humanities, or social and behavioral sciences (e.g., A ED 225 GH/US).
( ) Writing Across the Curriculum (W)
Note: ASTRO 420W or ASTRO 475W are recommended and may be used to satisfy a 400-level ASTRO course requirement.

In order to graduate, students must:

( ) complete all of the course requirements.
( ) have a 2.00 or better cumulative grade point average.
( ) earn a C or better in each of the C-required courses in the major (i.e., CHEM 110; MATH 140, 141; PHYS 211, 212; ASTRO 291, 292; and 12 credits of 400-level ASTRO courses).*
( ) earn 36 of the last 60 credits required for the degree in courses offered by the University.
( ) earn the last 60 credits within a total elapsed time of five calendar years.

Course Requirements (Record the grade earned in the space provided to the right of the credit value of the course.)

Writing and Speaking (GWS) **(9 cr)**
ENGL 15 or 30 (3) _____
CAS (SPCOM) 100 (3) _____
ENGL 202C (3) _____

Health and Physical Activity (GHA) **(3 cr)**
_____ ( ) _____
_____ ( ) _____
_____ ( ) _____

Arts (GA) **(6 cr)**
_____ ( ) _____
_____ ( ) _____
_____ ( ) _____

Humanities (GH) **(6 cr)**
_____ ( ) _____
_____ ( ) _____
_____ ( ) _____

Social and Behavioral Sciences (GS) **(6 cr)**
_____ ( ) _____
_____ ( ) _____
_____ ( ) _____

Note: Students may choose to distribute their GA/GH/GS credits as 9-6-3 (e.g.,. 9 GA, 6 GH, 3 GS). A petition is required to put this change into effect

CHEM 110 (GN) **(3 cr)*** _____
CHEM 111 (GN) **(1 cr)** _____
CHEM 112 (GN) **(3 cr)** _____

MATH 140 (GQ) **(4 cr)*** _____
MATH 141 (GQ) **(4 cr)*** _____
MATH 230 **(4 cr)** _____
MATH 251 **(4 cr)** _____

PHYS 211 (GN) **(4 cr)*** _____
PHYS 212 (GN) **(4 cr)*** _____
PHYS 213 (GN) **(2 cr)** _____
PHYS 214 (GN) **(2 cr)** _____
PHYS 237 **(3 cr)** _____
PHYS 400 **(3 cr)** _____
PHYS 410 **(4 cr)** _____
PHYS 419 **(3 cr)** _____

ASTRO 291 (GN) **(3 cr)*** _____
ASTRO 292 (GN) **(3 cr)*** _____
ASTRO 320 **(2 cr)** _____

400-level ASTRO courses (except ASTRO 496) **(12 cr)***
_____ ( ) _____ _____ ( ) _____
_____ ( ) _____ _____ ( ) _____

Select from CMPSC 121, CMPSC 201, or CMPSC 202 **(3 cr)** _____ ( ) _____

Select from MATH 405, 411, or 417 (**3 cr**)** _____ ( ) _____

Select from PHYS 401, 402, 406, 411, 420, 457, 458, 461, 479, and E E 471 **(6-7 cr)****
_____ ( ) _____ _____ ( ) _____

Select from advanced courses in CMPSC, MATH, or STAT (i.e., 300-level or 400-level courses) **(3 cr)****
_____ ( ) _____

Supporting courses (ASTRO 020S recommended for first-year students) **(10-11 cr)****
Note: Although the supporting courses are intended to be electives, there are a few types of courses which may <u>not</u> be used in this category. See department list for additional information.
_____ ( ) _____ _____ ( ) _____
_____ ( ) _____ _____ ( ) _____
_____ ( ) _____ _____ ( ) _____
_____ ( ) _____ _____ ( ) _____

CREDITS EARNED THAT DO <u>NOT</u> APPLY TOWARD GRADUATION
_____ ( ) _____ _____ ( ) _____
_____ ( ) _____ _____ ( ) _____

***A grade of C or better is required for these courses.**
****Students must complete a minimum of 20 credits of course work in the combined three categories marked.**

ASTRONOMY AND ASTROPHYSICS MAJOR Program Years: **2007**

B.S. Degree, Computer Science Option

General Education Years: 2005
Eberly College of Science
The Pennsylvania State University Student Name_____

For the B.S. degree in Astronomy and Astrophysics, a minimum of 124 credits is required. The following four requirements are to be integrated into the course requirements for the major which are listed below.

( ) First-Year Seminar (required of all students admitted to the University as freshmen since SU99)
Note: ASTRO 020S is recommended and may be used as a supporting course.
( ) International Cultures (IL)
Note: Many students will select a course which is also approved to satisfy a General Education requirement in the arts, humanities, or social and behavioral sciences (e.g., RL ST 001 GH/IL).
( ) United States Cultures (US)
Note: Many students will select a course which is also approved to satisfy a General Education requirement in the arts, humanities, or social and behavioral sciences (e.g., A ED 225 GH/US).
( ) Writing Across the Curriculum (W)
Note: ASTRO 420w or ASTRO 475W are recommended and may be used to satisfy a 400-level ASTRO course requirement.

In order to graduate, students must:

( ) complete all of the course requirements.
( ) have a 2.00 or better cumulative grade point average.
( ) earn a C or better in each of the C-required courses in the major (i.e., CHEM 012; MATH 140, 141; PHYS 211, 212; ASTRO 291, 292; and 12 credits of 400-level ASTRO courses).*
( ) earn 36 of the last 60 credits required for the degree in courses offered by the University.
( ) earn the last 60 credits within a total elapsed time of five calendar years.

Course Requirements (Record the grade earned in the space provided to the right of the credit value of the course.)

Writing and Speaking (GWS) **(9 cr)**
ENGL 15 or 30 (3) _____
CAS (SPCOM) 100 (3) _____
ENGL 202C (3) _____

Health and Physical Activity (GHA) **(3 cr)**
_____ ( ) _____
_____ ( ) _____
_____ ( ) _____

Arts (GA) **(6 cr)**
_____ ( ) _____
_____ ( ) _____
_____ ( ) _____

Humanities (GH) **(6 cr)**
_____ ( ) _____
_____ ( ) _____
_____ ( ) _____

Social and Behavioral Sciences (GS) **(6 cr)**
_____ ( ) _____
_____ ( ) _____
_____ ( ) _____

Note: Students may choose to distribute their GA/GH/GS credits as 9-6-3 (e.g.,. 9 GA, 6 GH, 3 GS. A petition is required to put this change into effect

CHEM 110 (GN) **(3 cr)*** _____
CHEM 111 (GN) **(1 cr)** _____
CHEM 112 (GN) **(3 cr)** _____

MATH 140 (GQ) **(4 cr)*** _____
MATH 141 (GQ) **(4 cr)*** _____
MATH 230 **(4 cr)** _____
MATH 251 **(4 cr)** _____

PHYS 211 (GN) **(4 cr)*** _____
PHYS 212 (GN) **(4 cr)*** _____
PHYS 213 (GN) **(2 cr)** _____
PHYS 214 (GN) **(2 cr)** _____
PHYS 237 **(3 cr)** _____

CMPSC 121 **(3 cr)** _____
CMPSC 122 **(3 cr)** _____
CMPSC 221 **(3 cr)** _____
CMPSC 451 **(3 cr)** _____

ASTRO 291 (GN) **(3 cr)*** _____
ASTRO 292 (GN) **(3 cr)*** _____
ASTRO 320 **(2 cr)** _____

400-level ASTRO courses (except ASTRO 496) **(12 cr)***

_____ ( ) _____ _____ ( ) _____
_____ ( ) _____ _____ ( ) _____

Select from STAT 318, 319, 401, 414, or 418 **(3 cr)**

_____ ( ) _____

Select from CMPEN 271, CMPEN 331, CMPSC 360, or CMPSC 465 **(6 cr)**

_____ ( ) _____

Select from 400-level courses in CMPEN or CMPSC **(3 cr)**

_____ ( ) _____

Supporting courses (ASTRO 020S recommended for first-year students) **(12 cr)**

Note: Although the supporting courses are intended to be electives, there are a few types of courses which may not be used in this category. See department list for additional information.

_____ ( ) _____ _____ ( ) _____
_____ ( ) _____ _____ ( ) _____
_____ ( ) _____ _____ ( ) _____
_____ ( ) _____ _____ ( ) _____

CREDITS EARNED THAT DO NOT APPLY TOWARD GRADUATION

_____ ( ) _____ _____ ( ) _____
_____ ( ) _____ _____ ( ) _____

***A grade of C or better is required for these courses.**

DEPARTMENT OF ASTRONOMY & ASTROPHYSICS

Astronomy & Astrophysics Minor Checklist

Student Name _____ Current Major _____

Major Advisor _____ Minor Advisor _____

Requirements for the Minor in Astronomy & Astrophysics:

_____ ASTRO 291 (3) Astronomical Methods and the Solar System

_____ ASTRO 292 (3) Astronomy of the Distant Universe

6 Credits of 400-Level ASTRO Courses: (except ASTRO 496)

_____ ASTRO 4_____(3) _____ ASTRO 4_____(1)

_____ ASTRO 4_____(3) _____ ASTRO 4_____(3)

Choose from the following 400-level Astro courses:

_____ 400H (1) Honors Seminar

_____ 410 (3) Computational Astrophysics

_____ 414 (3) Stellar Structure and Evolution

_____ 420W (3) Planets and Planetary System Formation

_____ 440 (3) Introduction to Astrophysics

_____ 451 (3) Astronomical Techniques

_____ 475W (3) Stars and Galaxies

_____ 480 (3) Nebulae, Galaxies and Cosmology

_____ 485 (4) Introduction to High-Energy Astrophysics

6-7 Credits from the following:

_____ Other ASTRO 4_____(3) _____ ASTRO 4_____(1)

_____ Other ASTRO 4_____(3) _____ ASTRO 4_____(3)

_____ AERSP 308 (3) Mechanics of Fluid

_____ AERSP 312 (3) Aerodynamics II (Fluid Mechanics)

_____ AERSP 492 (3) = EE 492 (3) Space Astronomy & Introduction to Space Science

_____ GEOSC 474 (3) = BIOL 474 (3) Astrobiology

_____ GEOSC 481 (3) Solid Earth Planetary Geophysics

_____ METEO 466 (3) Planetary Atmosphere

_____ PHYS 458 (4) Intermediate Optics

DEPARTMENT OF ASTRONOMY & ASTROPHYSICS

Astrobiology Minor Checklist

Student Name _____ Current Major _____

Major Advisor _____ Minor Advisor _____

Requirements for the Astrobiology Minor:

_____	BIOL/GEOSC 474 (3)	ASTROBIOLOGY	Prereqs: BIOL 110; CHEM 110

3 Credits from:

_____	EARTH 002 (3)	GAIA-THE EARTH SYSTEM
_____	GEOSC 021 (3)	EARTH AND LIFE: ORIGIN AND EVOLUTION

3 Credits from:

_____	ASTRO 140 (3)	LIFE IN THE UNIVERSE	Prereq: ASTRO 001 or ASTRO 010
_____	ASTRO 291 (3)	ASTRONOMICAL METHODS AND THE SOLAR SYSTEM	Prereq: PHYS 211

3 Credits from:

_____	GEOSC 204* (4)	GEOBIOLOGY	Prereqs: BIOL 110; GEOSC 001 or 020
_____	BIOL 427 (3)	EVOLUTION	Prereqs: BIOL 220W; BIOL 230W

6 Credits from:

_____	ASTRO 420W* (3)	PLANETS & PLANETARY SYSTEM FORMATION	Prereq: ASTRO 292
_____	ASTRO 475W* (3)	STARS AND GALAXIES	Prereq: ASTRO 292
_____	BIOL 405 (3)	MOLECULAR EVOLUTION	Prereq: BIOL 222 or BIOL 230W
_____	BMB 401 (2)	GENERAL BIOCHEMISTRY	Prereqs: CHEM 212; BMB 251 or BIOL 230
_____	BMB 402 (3)	GENERAL BIOCHEMISTRY	Prereq: B M B 401
_____	GEOSC 419 (3)	THE ORGANIC GEOCHEMISTRY OF NATURAL WATERS AND SEDIMENTS	Prereqs: CHEM 110; CHEM 112
_____	GEOSC 416 (3)	STABLE AND RADIOACTIVE ISOTOPES IN GEOSCIENCES: INTRODUCTION	Prereqs: CHEM 110, 111, 112, 113; GEOSC 001/020
_____	METEO 466* (3)	PLANETARY ATMOSPHERES	Prereqs: MATH 141; PHYS 211
_____	MICRB 201* (3)	INTRODUCTORY MICROBIOLOGY	

Recommendations:

- Make sure you take ASTRO 420W or 475W as one of your ASTRO 4xx courses
- Take BIOL 110 and GEOSC 001 or GEOSC 020 early on to satisfy prerequisites
- Take the minor courses

*Courses recommended for ASTRO majors

Map

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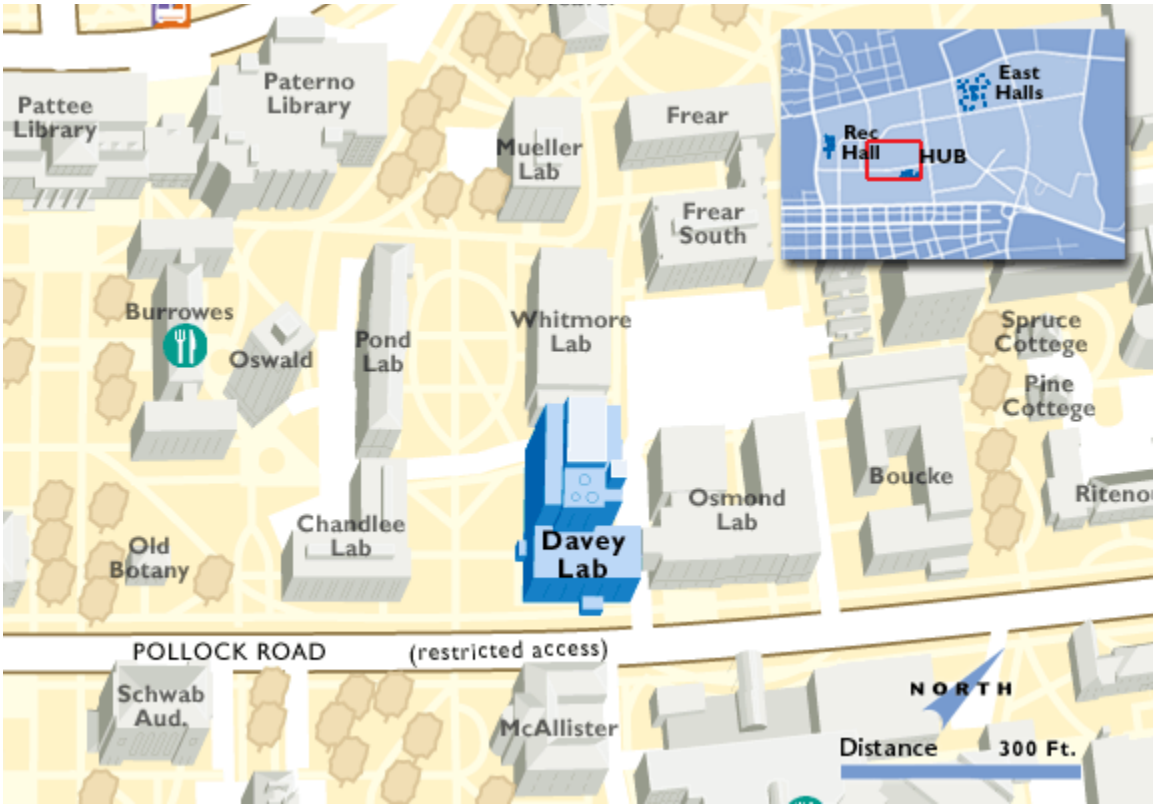
525 Davey Lab
University Park, PA 16802
Phone: (814) 865-0418
Web: http://www.astro.psu.edu



Produced by the Penn State Department of University Publications U. Ed. SCI 02-127.