Caltech Astronomy Program

- Ay Option Representative
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All the Information:

http://www.astro.caltech.edu/~lah/option/

Caltech Astrophysics Option

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While most universities and colleges consider the major area of concentration the "Major," at Caltech we call that the undergraduate "Option".
We also have a first-rate graduate program.

The Option Rep is the professorial faculty member who serves as:

- a point of general consultation for undergraduate students, who also have individual academic advisors as per the registrar.
- the official academic advisor for graduate students in the first and second years, until they sign up with a thesis advisor.
- a resource as needed for more senior graduate students, who also have a research/thesis advisor/s.

As a Caltech Ay student, you are welcome at any time to come and talk to me, especially if you have a problem.
These days, send me an email and we can arrange to either meet in person on campus somewhere, or ZOOM.

If you are looking for information regarding **admissions**, try:

- Ay grad admissions and Caltech application
- Caltech undergrad admissions. Also note that we have a summer research program for local high school students.

Information on **courses**:

- Ay course descriptions
- Ph course descriptions
- All Caltech courses
- Caltech Academic Calendars

Information for **everyone**:

- The official Caltech Catalog (all the rules are contained herein)
- The Honor Code -- undergrad honor system and graduate student honor system
- The Astronomy/Astrophysics Library (link is now a more general PMA page)
- Lynne's definitely outdated (but maybe some useful nuggets survive) links and advice for Ay students

Information for **undergraduate students**:

- The Ay option is fairly similar to the Ph option, with the basic difference being four required Ay courses: Ay20, 21, 101, 102, and consequently fewer required lab courses. For a more complete desription of the Ay undergrad program, see the relevant chapter in the Catalog.
- There are ample opportunities for undergraduate research in all of: theory, experimental, and observational astronomy. Ask professors about how to get involved, for example in working with our many research facilities. Research can be conducted for course credit (Ay 142 generally, Ay 78 for senior thesis) or as part of work-study, or as a summer SURF project.
- For those students interested in pursuing graduate study, please feel free to consult with the Option Representative in addition your formal Academic Advisor. Important components to a graduate school application include: your CIT transcript; GRE test scores (the General and often also a Subject test, usually in Physics); a personal statement; and letters of recommendation (typically three). Graduate schools like to see research experience, so you should aim to participate in the SURF program; this also gives you something to write about in the personal statement, and access to potential letter writers. One letter should come from your Academic Advisor who can speak broadly about your Caltech experience and academic preparation. Please note that we *never* accept our own undergraduates into our graduate program -- not because you are not well-qualified, but because you really should go out into the world and thrive at another institution. So save your application fee money. However, for general familiarity with the process, it may be useful to look at the CIT graduate admissions office FAQ for prospective applicants.
- Upperclass students are also a good resource for advice on courses or applying to graduate schools. Your compatriots are listed in the compilation of current undergraduate students in Ay

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Information for **graduate students**:

- Overview of Ay graduate program and student life
- Catalog description of the Ay grad program
- Caltech Graduate Studies Office
- Official information for current students (including financial support, degree tracking, health insurance, vacation policy, etc.)
- List of current graduate students in Ay
- Progress through our program entails:
  - The **first year**:
    - Graduate Studies Office information for incoming students
    - Ay student guide to arrival
    - Ay faculty perspective and requirements of the first year program
  - The **second year**:
    - A major milestone at the very beginning of second year is the qualifying exam.
    - The second year program
    - Ay student TA advice.
  - The **third year**:
    - The third year program
    - A major milestone in third year is the candidacy exam.
  - Years **beyond**:
    - The thesis
    - Information on filing the thesis and forms
    - The typical time to Ph.D. in the Caltech Ay graduate program is 5.45 years.
    - Alumni !

Elements of a Graduate Education

- course work = foundations
- research = exploration → new knowledge
- teaching experience & mentoring opportunities
- thesis definition and planning
- oral and written presentation
- skills development, e.g.
  - analysis methods and techniques
  - programming / instrumentation / observing
  - project proposing / organization / management
- thesis completion

Curriculum

Ay Degree of Doctor of Philosophy

The student's proposed overall program of study must be approved by the option representative during the first year.

Astrophysics Core Program

The following are required of all students for candidacy: Ay 121, Ay 123, Ay 124, Ay 125, Ay 126, and Ay 127. The student should take these courses in the first year. Students must also take at least one term of Ay 122 unless exempted. Also required are research and reading projects. Credit for this work will be given under Ay 142 and Ay 143. The above courses must be passed with a grade of B– or better.

Electives Program

The first two years of graduate study should include at least four courses (36 units) of additional electives relevant to astrophysics, with six courses (54 units) required of theory students. The electives requirement may be reduced for students who need to take Ph 106, Ph 125 or Ph 129 in order to make up for gaps in preparation at the undergraduate level.

Astrophysics Core Program

- **Ay 121. Radiative Processes.** *9 units (3-0-6); first term. Prerequisite: Ph106bc, Ph 125 or equivalent (undergraduates).* The interaction of radiation with matter: radiative transfer, emission, and absorption. Compton processes, coherent emission processes, synchrotron radiation, collisional excitation, spectroscopy of atoms and molecules

- **Ay 122 abc. Astronomical Measurements and Instrumentation.** *9 units (3-0-6); first term (a), second term (b). Prerequisites: Ph 106bc or equivalent.* Measurement and signal analysis techniques througout the electromagnetic spectrum. Courses may include lab work and field trips to Caltech observatories. Ay 122a concentrates on infrared, optical, and ultraviolet techniques: telescopes, optics, detectors, photometry, spectroscopy, active/adaptive optics, coronography. Imaging devices and image processing. Ay 122b concentrates on radio through submillimeter techniques: antennae, receivers, mixers, and amplifiers. Interferometers and aperture synthesis arrays. Signal analysis techniques and probability and statistics, as relevant to astronomical measurement. Ay 122c (not offered) concentrates on X-ray through gamma-ray techniques.

- **Ay 123. Structure and Evolution of Stars.** *9 units (3-0-6); second term. Prerequisites: Ay 101; Ph 125 or equivalent (undergraduates).* Thermodynamics, equation of state, convection, opacity, radiative transfer, stellar atmospheres, nuclear reactions, and stellar models. Evolution of low- and high-mass stars, supernovae, and binary stars.

- **Ay 124. Structure and Dynamics of Galaxies.** *9 units (3-0-6); second term. Prerequisites: Ay 21; Ph 106 or equivalent (undergraduates).* Stellar dynamics and properties of galaxies; kinematics and dynamics of our galaxy; spiral structure; stellar composition, masses, and rotation of external galaxies; star clusters; galactic evolution; binaries, groups, and clusters of galaxies.

- **Ay 125. High-Energy Astrophysics.** *9 units (3-0-6); third term. Prerequisites: Ph 106 and Ph 125 or equivalent (undergraduates).* High-energy astrophysics, the final stages of stellar evolution; supernovae, binary stars, accretion disks, pulsars; extragalactic radio sources; active galactic nuclei; black holes.

- **Ay 126. Interstellar and Intergalactic Medium.** *9 units (3-0-6); third term. Prerequisite: Ay 102 (undergraduates).* Physical processes in the interstellar medium. Ionization, thermal and dynamic balance of interstellar medium, molecular clouds, hydrodynamics, magnetic fields, H II regions, supernova remnants, star formation, global structure of interstellar medium.

- **Ay 127. Cosmology and Galaxy Formation.** *9 units (3-0-6); first term. Prerequisites: Ay 21; Ph 106 or equivalent (undergraduates).* Cosmology; extragalactic distance determinations; relativistic cosmological models; galaxy formation and clustering; thermal history of the universe, microwave background; nucleosynthesis; cosmological tests.

Curriculum

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Astrophysics Core Program

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Electives Program

The first two years of graduate study should include at least four courses (36 units) of additional electives relevant to astrophysics, with six courses (54 units) required of theory students. The electives requirement may be reduced for students who need to take Ph 106, Ph 125 or Ph 129 in order to make up for gaps in preparation at the undergraduate level.

Electives Program

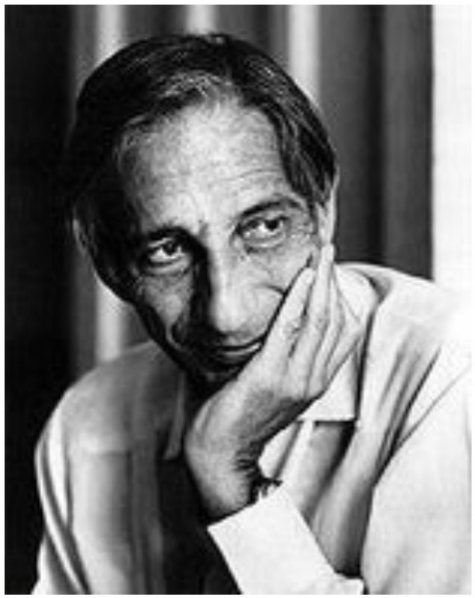
Suggested elective courses include, but are not limited to: Ph 101, Ph 105, Ph/Aph 118 a, Ph 127 b, Ph 135, Ph 136 ab, Ph 236 a, Ph 237. For theory students, Ph 136 a and Ph 136 b are required with Ph 136 c and Ph 101 highly recommended, and in addition to Ph, electives in applied mathematics should be considered. For students in observation and experiment, Ph 136 a and Ph 136 b are strongly recommended, and in any case at least one of the four advanced course electives must be in Ph, while the complement may be from other options such as electrical engineering, applied mechanics, computer science, planetary science (geophysics or geochemistry). Seminar courses and research practicum courses do not count as satisfying the requirement for pedagogical elective coursework; however, students are encouraged to take these types of courses during second year. No more than 18 of the elective units may be taken P/F; all others must be passed with a grade of C or better. In the third year and above, students are welcome to enroll in additional advanced astronomy and physics courses.

Reading / Speaking / Researching

- **Ay 141 abc. Research Conference in Astronomy.** ***2*** *units (1-0-1); first, second, third terms.* Oral reports on current research in astronomy, providing students an opportunity for practice in the organization and presentation of technical material. A minimum of two presentations will be expected from each student each year. In addition, students are encouraged to participate in a public-level representation of the same material for posting to an outreach website. This course fulfills the option communication requirement and is required of all astronomy graduate students who have passed their preliminary exams. It is also recommended for astronomy seniors. Graded pass/fail.

- **Ay 142. Research in Astronomy and Astrophysics.** *Units in accordance with work accomplished.* The student should consult a member of the department and have a definite program of research outlined. Approval by the student's adviser must be obtained before registering. 36 units of Ay 142 or Ay 143 required for candidacy for graduate students. Graded pass/fail.

- **Ay 143. Reading and Independent Study.** *Units in accordance with work accomplished.* The student should consult a member of the department and have a definite program of reading and independent study outlined. Approval by the student's adviser must be obtained before registering. 36 units of Ay 142 or Ay 143 required for candidacy for graduate students. Graded pass/fail.



“Most learning is not the result of instruction. It is rather the result of unhampered participation in a meaningful setting. Most people learn best by being "with it," yet school makes them identify their personal, cognitive growth with elaborate planning and manipulation.”

— **Ivan Illich, Deschooling Society**

tags: education, experience, learning, teaching

Ay 111 ab. Introduction to Current Astrophysics Research. *3 units; first and second terms.* This course is intended primarily for first-year Ay graduate students, although participation is open and encouraged. Students are required to attend seminar-style lectures given by astrophysics faculty members, describing their research, to attend the weekly astronomy colloquia, and to follow these with additional readings on the subject. At the end of each term, students are required to summarize in oral or written form (at the discretion of the instructor), one of the covered subjects that is of most interest to them.

Checkpoint #1: Qualifying Exam

In fall of their second year, all students are required to take a general oral qualifying examination. Students will be examined on the substance and status of, as well as their performance on, a research project, which should be started not later than the summer following the first year. They will further be examined on their broad understanding of current topics in, and fundamentals of, astrophysics. Both of these aspects of the examination are intended to evaluate the candidate's aptitude for a research career in astrophysics. In addition, at the discretion of the executive officer, students who have not done well in one, or at most two, areas covered in the Ay 120 course series during their first year will be retested in these areas during the examination. Students must pass all of the aspects of this examination, as judged by the faculty committee conducting it, in order to continue in the Ph.D. program.

Checkpoint #2: Candidacy Exam

Advising and Thesis Supervision. By the summer of their first year, students should be spending most of their time on research. During their first two years, students are free to work with any faculty they wish, on one or more projects. However, by the summer of their second year at the latest, they should have defined a thesis project and been accepted by a faculty research adviser for that project (in cases where the thesis involves multiple projects, a second faculty adviser may supervise part of the research, but one must be selected as primary adviser). An oral candidacy exam dealing with the student's proposed thesis research should be taken before the end of the third year. The date and time of the exam are the responsibility of the student to arrange. The examining committee is chosen by the executive officer in consultation with the student's adviser. It will stand until the final examination, and be charged with ensuring that satisfactory progress toward the Ph.D. is being made.

If the candidate does not pass the oral candidacy exam, then the examining committee may at its discretion offer the candidate a second oral examination. This examination must be successfully completed by the end of the third term of the third year.

Checkpoint #3: Thesis Defense

Final Examination. A final draft of the thesis must be submitted at least six weeks before the commencement at which the degree is to be conferred. At least two weeks after submission of the thesis, the student will be examined orally on the scope of his or her thesis and its relation to current research in astrophysics. The examination will be conducted by a committee selected in the same way as the oral candidacy committee. The examination should occur before the end of the fifth year.

Teaching

Other Requirements. An ability to explain concepts and to verbally present one's work is vital to a successful career in research and/or teaching. To this end, all graduate students in astrophysics are required to serve as teaching assistants during their second year, and to make oral presentations as part of the course Ay 141, 3 terms of which must be taken every year by all students beginning in their second year.

Undergrad Courses you may TA

Ay 1. The Evolving Universe. *9 units (3-3-3); third term; This course is intended primarily for freshmen not expecting to take more advanced astronomy courses and will satisfy the menu requirement of the Caltech core curriculum.* Introduction to modern astronomy that will illustrate the accomplishments, techniques, and scientific methodology of contemporary astronomy. The course will be organized around a set of basic questions, showing how our answers have changed in response to fresh observational discoveries. Topics to be discussed will include telescopes, stars, planets, the search for life elsewhere in the universe, supernovae, pulsars, black holes, galaxies and their active nuclei, and Big Bang cosmology. This class will be offered in a "flipped classroom" mode: the students will be required to watch the video lectures first, and then discuss them and work out problems in the classroom. A field trip to Palomar Observatory will be organized. Not offered on a pass/fail basis. Instructor:

Ay 20. Basic Astronomy and the Galaxy. *10 units (3-1-6); first term. Prerequisites: Ma 1 abc, Ph 1 abc or instructor's permission.* The electromagnetic spectrum and basic radiative transfer; ground and space observing techniques; "pictorial Fourier description" of astrophysical optics; Kepler's laws; exoplanets; stellar masses, distances, and motions; the birth, structure, evolution, and death of stars; the structure and dynamics of the Galaxy. Lessons will emphasize the use of order-of-magnitude calculations and scaling arguments in order to elucidate the physics of astrophysical phenomena. Short labs will introduce astronomical measurement techniques. Instructor:

Ay 21. Galaxies and Cosmology. *9 units (3-0-6); second term. Prerequisites: Ma 1 abc, Ph 1 abc or instructor's permission.* Cosmological models and parameters, extragalactic distance scale, cosmological tests; constituents of the universe, dark matter, and dark energy; thermal history of the universe, cosmic nucleosynthesis, recombination, and cosmic microwave background; formation and evolution of structure in the universe; galaxy clusters, large-scale structure and its evolution; galaxies, their properties and fundamental correlations; formation and evolution of galaxies, deep surveys; star formation history of the universe; quasars and other active galactic nuclei, and their evolution; structure and evolution of the intergalactic medium; diffuse extragalactic backgrounds; the first stars, galaxies, and the reionization era. Instructor:

Ay 101. Physics of Stars. *11 units (3-2-6); second term. Prerequisite: Ay 20 is recommended.* Physics of stellar interiors and atmospheres. Properties of stars, stellar spectra, radiative transfer, line formation. Stellar structure, stellar evolution. Nucleosynthesis in stars. Stellar oscillations. Instructor

Ay 102. Physics of the Interstellar Medium. *9 units (3-0-6); third term. Prerequisite: Ay 20 is recommended.* An introduction to observations of the inter-stellar medium and relevant physical processes. The structure and hydrodynamic evolution of ionized hydrogen regions associated with massive stars and supernovae, thermal balance in neutral and ionized phases, star formation and global models for the interstellar medium. Instructor:

Ay/Ph 104. Relativistic Astrophysics. *9 units (3-0-6); second term. Prerequisites: Ph 1, Ph 2 ab.* This course is designed primarily for junior and senior undergraduates in astrophysics and physics. It covers the physics of black holes and neutron stars, including accretion, particle acceleration and gravitational waves, as well as their observable consequences: (neutron stars) pulsars, magnetars, X-ray binaries, gamma-ray bursts; (black holes) X-ray transients, tidal disruption and quasars/active galaxies and sources of gravitational waves. I

Ay 105. Optical Astronomy Instrumentation Lab. *10 units (0-6-4); second term. Prerequisite: Ay 20.* An opportunity for astronomy and physics undergraduates (juniors and seniors) to gain firsthand experience with the basic instrumentation tools of modern optical and infrared astronomy. The 10 weekly lab experiments are expected to include radiometry measurements, geometrical optics, optical aberrations and ray tracing, spectroscopy, fiber optics, CCD electronics, CCD characterization, photon counting detectors, vacuum and cryogenic technology, and stepper motors and encoders. Instructors:

Typical Timeline

Year 1: Ay 121, Ay 123–127; at least two advanced physics courses; reading and independent study. Begin research.

Year 2: Early fall—general oral qualifying examination. Fulfill teaching requirement. Complete 36 units of physics (54 for theorists); a term of Ay 122 if applicable; optional advanced astronomy courses. Ay 141. Research projects; select thesis and adviser.

Year 3: Complete oral candidacy exam on proposed thesis before end of second term. Annual report from student and adviser. Ay 141. Optional Advanced CoursesYear 4: Annual report from student and adviser. Thesis Advisory Committee (TAC) check-in. Ay 141.

Year 5: Annual report from student and adviser. Thesis Advisory Committee (TAC) check-in. Ay 141. Complete Ph.D. thesis before the end of year 5. Final oral thesis defense.

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