PROPOSAL FOR A

BACHELOR OF SCIENCE DEGREE IN ASTROPHYSICS

AND

BACHELOR OF ARTS DEGREE IN ASTRONOMY

IN THE

DEPARTMENT OF PHYSICS AND ASTRONOMY
COLLEGE OF NATURAL SCIENCES
UNIVERSITY OF HAWAI'I AT MANOA

Locus (Unit School/College):	College of Natural Sciences
Chair/Conveners of Planning Committee:	Günther Hasinger, Pui Lam
Program Category:	New
Department Unit/Program:	Physics and Astronomy
Level of Program:	Undergraduate
Degree and Certificates Proposed:	Bachelor of Science in Astrophysics Bachelor of Arts in Astronomy
Proposed Date of Implementation:	Academic Year 2014 - 2015

Final Version: 03 April, 2014

Table of Contents

1. Program Objectives and Learning Outcomes

A. Program Objectives

We propose to create two new degree programs. Both will prepare UH-Manoa (UHM) students for careers in astronomy or related fields, and both will enable students to participate in astronomical research at the Institute for Astronomy (IfA).

The *B.S. Astrophysics Major* is a rigorous option for students preparing for graduate studies in astronomy, astrophysics or physics with the long-term goal of a research career. The selection of courses and emphasis on research for this degree are modeled on the undergraduate preparation of most UHM astronomy graduate students. This option draws heavily on existing physics undergraduate courses in the Physics program at UHM.

The *B.A. Astronomy Major* is intended for students planning careers in planetarium work, night assistant work, teaching, science writing, or other STEM-related fields. This option integrates a number of existing Astronomy courses into a coherent program.

B. Learning Outcomes

The astrophysics and astronomy degrees both cover the nature and content of the astronomical universe and the techniques used to make astronomical observations; in addition, the astrophysics degree emphasizes in-depth knowledge of physics and mathematical applications of physics to astronomy.

i. Astrophysics BS Learning Objectives

Astrophysics students will be able to:

1. Explain the physical laws and concepts of classical mechanics, thermodynamics and statistical mechanics, electromagnetism, optics, relativity, and quantum mechanics.
2. Describe the nature, structure, distribution, and formation of astronomical objects, including planets, stars, and galaxies, and the history of the universe.
3. Demonstrate an appreciation of the universality of physical laws and apply these laws to explain phenomena in astronomical systems and the universe.
4. Formulate astrophysical problems in mathematical terms and use analytic and numerical methods to obtain solutions.
5. Use the scientific method to ask meaningful questions, to design experiments to address these questions, to acquire and critically analyze the data, and to draw appropriate conclusions.
6. Communicate research design and results effectively in both written and oral formats.
7. Define and interpret the observational properties of astronomical objects.
8. Reduce astronomical images and spectra using standard analysis software, and measure observational properties from reduced data.

9. Propose, plan, and conduct astronomical observations with professional telescopes.
10. Use sources from astronomical literature, databases, and on-line catalogs to obtain relevant information about astronomical objects and theories.

ii. Astronomy BA Learning Objectives

Astronomy students will be able to:

1. Describe physical laws, emphasizing the elements of mechanics, electromagnetism, thermodynamics, and modern physics.
2. Describe the nature, structure, distribution, and formation of astronomical objects, including planets, stars, and galaxies, and the history of the universe.
3. Demonstrate an appreciation of the universality of physical laws and apply these laws to explain phenomena in astronomical systems and the universe.
4. Use the scientific method to ask meaningful questions, to design experiments to address these questions, to acquire and critically analyze the data, and to draw appropriate conclusions.
5. Communicate research design and results effectively in both written and oral formats.
6. Define and interpret the observational properties of astronomical objects.
7. Reduce astronomical images and spectra using standard analysis software, and measure observational properties from reduced data.
8. Propose, plan, and conduct astronomical observations with professional telescopes.
9. Use sources from astronomical literature, databases, and on-line catalogs to obtain relevant information about astronomical objects and theories.

2. Appropriateness of the Program for the College, University, and State

A. Relationship to State, University and Campus mission and development plans

The State of Hawai‘i has placed considerable recent emphasis on developing an infrastructure that can support high technology industries. In 2007, then Governor Lingle began the Hawai‘i Innovation Initiative, which has a stated goal of "…providing Hawai‘i students with world-class analytical and problem-solving skills developed through science, technology, engineering and math (STEM) education." The Abercrombie administration has reiterated the importance of "… a conscious effort by government … to establish digital media, information technology, nanotechnology, ocean sciences, biotechnology, aerospace, astronomy, and other innovation fields. These industries bring dollars into Hawai‘i, often have minimal impacts on our environment, enhance the quality of education, lead our drive toward self-sufficiency, and create high paying jobs for our local families." The establishment of undergraduate Astrophysics and Astronomy Programs will help to support these goals by providing a young, motivated, and highly educated workforce for the growing STEM-based economy.

The University of Hawaiʻi at Manoa is the flagship campus of the University of Hawaiʻi system and is ranked by the Carnegie Foundation as the only top-tier research university in the State of Hawaiʻi. One of the stated goals of the previous UHM Chancellor is to establish Manoa as "a leading, global research university that meets society's needs around the world." The 2010 Manoa strategic plan defines as strategic goals that we should "expand and create transdisciplinary opportunities and programs" and "increase student appreciation for research and all types of scholarly activities, and emphasize that they are an integral part of teaching and learning." The proposed Astrophysics and Astronomy Programs will be hosted within the Department of Physics & Astronomy (P&A) at UHM, but will provide a "transdisciplinary" education through both required and elective upper-level courses that will include educational contributions from both P&A and IfA faculty. Students pursuing both the BS Astrophysics and BA Astronomy degrees will be encouraged to integrate research and education through required Astronomy Laboratory (ASTR 300L) and Observational Projects courses (ASTR 301) that will teach modern techniques used in astronomical research, and will also be encouraged to participate in faculty-directed investigations through enrollment in Senior Research Projects (ASTR 495).

B. Uniqueness of the new BS and BA Programs within the UH System

Undergraduate BS Astrophysics and BA Astronomy degrees have never be offered within the UH system. The only current undergraduate degree program in astronomy is the BS Astronomy Major at UH-Hilo (UHH). The BS Astronomy major at UHH has a unique focus and emphasis that differs significantly from both the proposed BS Astrophysics and BA Astronomy majors at UHM. Also, the BS Astronomy major at UHH does not offer the depth of Physics course requirements that are part of the proposed BS Astrophysics major at UHM. The large and diverse faculties in P&A and the IfA at UHM offer a unique opportunity to teach the courses required for a rigorous Astrophysics and Astronomy degree program that is on a par with our national peers. Both P&A and IfA faculty voted on and strongly support this initiative. The new B.S. Astrophysics and B.A. Astronomy undergraduate programs at UHM will be coordinated with the existing B.S. Astronomy undergraduate program in Hilo in a way that all three programs are complementary to each other, with different specializations, but utilizing common infrastructure, cross-listing courses, and exploring opportunities for distance learning.

Currently, undergraduates at UH Hilo also have the option of taking a BA in Natural Science (NS) with a minor in Astronomy. This option may be attractive to students with a broad interest in natural science. However, it is somewhat less focused than the BA Astronomy degree proposed here: the UHH minor requires 15 credits of Astronomy (including 6 upper-division credits), while the BA degree will require 27 credits of Astronomy (including 21 upper-division credits). It therefore appears that the BA Natural Sciences with an Astronomy minor and the proposed BA Astronomy major will serve significantly different student populations as well as different geographical locations. We note that UH Hilo may, in the future, develop a BA Astronomy program to complement their existing BS Astronomy degree; this seems entirely appropriate and we would fully support the development of a BA Astronomy degree at UHH with requirements broadly comparable to those of the degree we are proposing for UHM.

We had two meetings with the IfA-Hilo astronomy faculty and the UHH Department of Physics and Astronomy faculty, together with the IfA director and Dean Hirokawa to discuss the roster of courses offered and the respective specializations of the different programs. The attached "tripartite" memo of May 2, 2012 summarizes an agreement between Guenther Hasinger (IfA Director), William Ditto (Dean, CNS, UHM) and Randy Hirokawa (Dean, VAS, UHH) to establish a cooperative arrangement between the new astronomy degree programs at UHM and the existing B.S. Astronomy major at UHH. The coordination between the UH Hilo and UH Manoa programs was also discussed in several meetings with the Hilo Chancellor, Philippe Binder (UHH P&A Chair), and UHM VCAA.

The UH Maui College's Bachelor of Applied Science (BAS) in Engineering Technology program includes courses in optics, detectors, and instruments for remote sensing applications which are congruent to courses offered in the existing BS Astronomy program at UHH and the proposed BS Astrophysics and BA Astronomy programs at UHM. Since the Maui program appears to be strongly focused on the mission of the Air Force telescopes located on Haleakala, there's relatively little duplication of effort; our programs are adjacent to Maui's but offer a wider perspective on Astronomy and Astrophysics as fields of scientific research. It seems unlikely that students could easily transfer between programs since the requirements for a BAS Engineering degree are necessarily quite different from those for a BA Astronomy or BS Astrophysics degree. However, it should be possible to allow students to cross-register and take courses remotely; for example, BAS students on Maui with an interest in observational astronomy could take courses in our programs at UHM or UHH. Over the longer term, it may be worth exploring a partnership with Maui and the UHM College of Engineering to develop an Astro-engineering degree with a focus on instrumentation. The graduates of such a degree would be well-positioned to find technical jobs with astronomical observatories.

C. Survey of Programs at Peer and Benchmark Institutions

All 33 of our peer and benchmark institutions (as defined by the National Research Council list of Astronomy Graduate Programs in its "decadal surveys" of the strength and quality of research doctorate programs in the United States), offer undergraduate major degree programs. The University of Hawaii at Manoa is **unique** in not offering an undergraduate degree program in astronomy or astrophysics, despite its continued ranking in the upper tier of graduate degree programs nationally, as well as throughout the world. This is a distinction that we do not want to continue to maintain: it puts students in Hawaii at a distinct disadvantage when they wish to consider astronomy as a career path, and denies them the excitement of being able to participate in the discoveries being made and the research being carried out at the world-class astronomical facilities in their own State.

All of our peer and benchmark astronomy graduate programs at US institutions administer their undergraduate degree programs in Astronomy and/or Astrophysics either through a separate Department of Astronomy (23), a combined Department of Physics & Astronomy (7), or in 3 cases through a combined program that merges the role of a Department with that of an Observatory or Space Laboratory (e.g. the Lick Board of

Studies in Astronomy & Astrophysics at UC Santa Cruz, the School of Astronomy and Space Sciences at U. Minnesota, and the Division of Astrophysics and Space Sciences at the Massachusetts Institute of Technology). The majority of our peer institutions offer both a BS and BA degree in Astrophysics/Astronomy, and many also offer Minor degree options in Astronomy/Astrophysics.

D. Justification for Administering through the Department of Physics & Astronomy

Astronomy and Astrophysics are a natural part of the Department of Physics & Astronomy at UHM, and it is obvious to us that the administration of the undergraduate majors in both Astrophysics and Astronomy at UHM should be through the Department of Physics & Astronomy, as is already the case for the graduate programs in Astronomy and Physics, respectively. Teaching duties for the physics (PHYS) courses in the BA Astronomy and BS Astrophysics Programs will be covered by the tenured/tenured-track/non-tenure-track P&A faculty members (see list below).

List of P&A faculty who will teach PHYS courses in the BA and BS Programs.

1	Bindi	Veronica	Tenure-Track	I3
2	Browder	Thomas	Tenure	I5
3	Elias	Luis	Tenure	I5
4	Gorham	Peter	Tenure	I5
5	Harris	Fredrick	Tenure	I5
6	Kumar	Jason	Tenure	I4
7	Lam	Pui	Tenure	I5
8	Learned	John	Tenure	I5
9	Madey	John	Tenure	I5
10	Marfatia	Danny	Tenure	I4
11	Maricic	Jelena	Tenure-Track	I3
12	Mathews	Geoffrey	Non Tenure-Track	I2
13	Milincic		Non Tenure-Track	I2
14	Nassir	Michael	Non Tenure-Track	I2
15	Sattler	Klaus	Tenure	I5
16	Szarmes	Eric	Tenure	I4
17	Tata	Xerxes	Tenure	I5
18	Vahsen	Sven	Tenure-Track	I3
19	Varner	Gary	Tenure	I4
20	Vause	Chester	Tenure	I5
21	Von Doetinchem	Philip	Tenure-Track	I3

Currently there are formally 4 I-positions allocated to IfA to teach astronomy (ASTR) courses. These 4 I-positions are divided into fractional (0.25I) positions, and are occupied by the 32 IfA faculty (see list below) by rotation (16 each semester), corresponding to who is teaching each semester. A member of the IfA faculty will serve as the Chair of the undergraduate astronomy program and will be responsible for staffing ASTR courses.

List of IfA faculty who will teach ASTR Courses in the BA/BS Program

1	Baranac	Christoph	Tenure-Track	0.25I,0.75R3
2	Barnes	Joshua	Tenure	0.25I,0.75R5
3	Bresolin	Fabio	Tenure	0.25I,0.75R5
4	Chambers	Kenneth	Tenure	0.25I,0.75R5
5	Chun	Mark	Tenure	0.25I,0.75S5
6	Coleman	Paul	Tenure	0.25I,0.75S5
7	Cowie	Antoinette	Tenure	0.25I,0.75R5
8	Cowie	Len	Tenure	0.25I,0.75R5
9	Habbal	Shadia	Tenure	0.25I,0.75R5
10	Hasinger	Guenther	Tenure	0.25I,0.75R5
11	Hodapp	Klaus	Tenure	0.25I,0.75R5
12	Howard	Andrew	Tenure-Track	0.25I,0.75R3
13	Hu	Esther	Tenure	0.25I,0.75R5
14	Jedicke	Robert	Tenure	0.25I,0.75S5
15	Joseph	Robert	Tenure	0.25I,0.75R5
16	Kaiser	Nick	Tenure	0.25I,0.75R5
17	Kudritzki	Rolf	Tenure	0.25I,0.75R5
18	Kuhn	Jeff	Tenure	0.25I,0.75R5
19	Lin	Haosheng	Tenure	0.25I,0.75R5
20	Liu	Mike	Tenure	0.25I,0.75R5
21	Lu	Jessica	Tenure-Track	0.25I,0.75R3
22	Meech	Karen	Tenure	0.25I,0.75R5
23	Mendez	Roberto	Tenure	0.25I,0.75R5
24	Reipurth	Bo	Tenure	0.25I,0.75R5
25	Sanders	David	Tenure	0.25I,0.75R5
26	Szapudi	Istvan	Tenure	0.25I,0.75R5
27	Tholen	David	Tenure	0.25I,0.75R5
28	Tokunaga	Alan	Tenure	0.25I,0.75R5
29	Tonry	John	Tenure	0.25I,0.75R5
30	Tully	Brent	Tenure	0.25I,0.75R5
31	Wainscoat	Richard	Tenure	0.25I,0.75S5
32	Williams	Jonathan	Tenure	0.25I,0.75R5

E. Student Interest

To gauge student interest in the new Astrophysics and Astronomy degree programs, we have used three different methods, each designed to represent distinct groups of potential undergraduate astronomy majors at UHM – (1) those undergraduate students who are currently enrolled at UHM and who are taking one of our ASTR Introductory courses (e.g. ASTR 110) or one of the PHYS Introductory courses (e.g. PHYS 151 or 170), (2) secondary school students here in Hawaii who show interest in Astronomy through participation in our HI STAR summer astronomy research, and (3) high school students outside Hawaii who contact us asking for information about undergraduate degree programs in Astronomy at UHM.

1. Students who already enroll in ASTR and/or PHYS Introductory courses:

Astronomy (ASTR) undergraduate Introductory courses have historically been an extremely popular science elective at UHM, with ~700-800 students annually, over the last two decades, enrolling in ASTR 100-level courses. With the growing visibility of astronomy as a career path, and with the increasing interdisciplinary nature of astronomy programs, we are fielding more and more questions from students in these classes as to the availability of a formal curriculum path for UHM undergraduate students who wish to further their studies in astronomy. Just this year, we conducted a one-day, in-class poll of all students attending our ASTR110 lectures – asking them to indicate their level of interest in both a BA Astronomy and a BS Astrophysics major. The choices were – A) no interest, B) not very interested, C) mildly interested and D) very interested. Of the 180 students surveyed, 7 indicated "very interested" in the BA Astronomy Major and 5 indicated "very interested" in the BS Astrophysics major. The numbers choosing "mildly interested" were 15 for the BA and 8 for the BS. We have also surveyed students who have already declared that they are interested in obtaining a Physics undergraduate degree, by asking them which sub-discipline of Physics (including astrophysics) they would be most interested in, and one quarter (5/20) indicated "astrophysics". *From these surveys of current UHM undergraduates who enroll in ASTR and PHYS Introductory courses, we estimate that ~30 students annually would choose a BA Astronomy major, and ~15 students would choose a BS Astronomy major.*

2. Hawaii high school students interested in an Astronomy undergraduate degree at UHM:

The IfA has a history of conducting year-round K-12 outreach programs in Astronomy, including one of the forefront programs in the country (HI STAR) that allows motivated Hawaii secondary school students (and some of their teachers !) to be involved with hands on astronomical research. Several of these students have gone on to participate in, and win awards at our state science fair, and a few have continued on to the national stage where they have represented their state with great pride and ability. Although some of the most gifted of these students have the luxury of scholarship offers to pursue an astronomy degree at top Universities, until now they have sadly not been able to follow their dream at UHM. *We estimate that ~8 Hawaii senior high school students each year would choose to enroll at UHM (rather than enrolling at an out-of-state school) to pursue either the BS Astrophysics or BA Astronomy degree.*

3. Out-of-state students who might enroll at UHM for an Astronomy Undergraduate Degree

The IfA continually receives inquiries from both foreign and mainland high school students about the possibility of attending UHM to obtain an undergraduate degree in Astrophysics or Astronomy. Many of these inquiries appear to be motivated by the desire to be at a University with access to the best astronomical research site on the planet, and several of these students have actually chosen to visit the observatories in Hawaii prior to making their inquiry. *Based of the annual number of email and phone inquireies to the IfA, it seems* *reasonable to us to assume that ~12 students per year from outside Hawaii would choose to enroll at UHM in order to pursue an undergraduate degree in either Astrophysics or Astronomy.*

From all of the above sources of information, and assuming that only 50% of those who say they are "very interested" in pursuing an undergraduate Astronomy or Astrophysics degree at UHM, we *__conservatively__* *estimate that ~20 students per year will choose the BA Astronomy major, and ~12 students per year will choose the BS Astrophysics major for their undergraduate degree at UHM.*

F. Astronomy Employment Opportunities in Hawaii

The Mauna Kea Observatories (MKO) on Hawaii Island and the Haleakala Science City on Maui Island are home to what are arguably the most powerful collection of ground based telescopes on Earth. Both Haleakala and MKO will continue to be the pre-eminent ground-based astronomical sites for at least the next several decades with the expected arrival of the world's most powerful solar telescope - The Advanced Technology Solar Telescope (ATST) on Haleakala, and the Thirty Meter Telescope (TMT) on Mauna Kea. The size of the astronomy workforce in Hawaii is currently estimated to be ~1400 people, including technology (57%) , science (18%), administration (23%) and maintenance (4%) positions, and will be expected to grow by ~20% over the next decade with hiring for ATST and TMT.

The most recent comprehensive report of astronomy-related job opportunities in Hawaii is the 2010 report prepared by the Hawaii County Workforce Investment Board (WIB) and Mauna Kea Observatories titled, *"Hawaii Island Astronomy Workforce Opportunities, 2010-2023"*. The WIB-MKO report estimates that ~330 jobs in technology and ~104 science positions will become available on Hawaii Island through 2023, for an average of ~31 jobs per year over the 14-year period, and ***ALL*** *of these technology/science jobs will require at least a BA/BS degree, preferably in astronomy or a closely related field.* Currently, Hawaii Island astronomy represents ~60% of the total astronomy-related workforce in the state, with the remaining jobs on Maui (15%) and Oahu (25%); thus the total number of technology/ science job openings in the State could be as high as *~52 jobs per year, all of which will require at least a BS/BA degree in an astronomy related field of study.*

At present, the majority of the technical and science jobs in astronomy are filled by with out-of-state recruitments, due largely to the lack of Hawaii residents with the prerequisite degrees and skills required for the technical and science positions. Furthermore, studies show that turnover is nearly 3 times larger for those out-of-state personnel, compared to those who were either born in Hawaii or who have been living in Hawaii prior to their recruitment. Thus, there is a very strong desire by all of the astronomy employers in Hawaii, to increase the number of Hawaii residents with undergraduate (and graduate) degrees in astronomy who can then successfully compete for the large number of technical and science positions in astronomy that will continue to be available for the foreseeable future.

3. Organization of the Program

A. Program Course Requirements

Students must fulfill all UHM General Education requirements and all College of Arts & Sciences requirements. Specific requirements for the B.A. and B.S. degrees include foundational basic science requirements, Astronomy and Astrophysics core requirements, and Astronomy and Astrophysics elective requirements. Proposed 4 year graduation plans are included in Appendix B. In developing the B.S. Astrophysics curriculum, we started with the existing Physics curriculum, and added Astronomy and Astrophysics courses while scaling back the upper-level Physics courses to a sequence culminating in Quantum Mechanics. The B.A. Astronomy curriculum basically combines a number of existing Astronomy courses with a subset of the new courses developed for the B.S. degree.

i. Required for BA in Astronomy

Foundational requirements:			credits
1.	CHEM 161/161L	General Chemistry I	4
2.	CHEM 162/162L	General Chemistry II	4
3.	MATH 215 or 241 or 251A	Calculus I	4
4.	MATH 242 or 252A	Calculus II	4
	subtotal		16

Astronomy & physics core course requirements:			credits
1.	ASTR 240	Foundations of Astronomy	3
2.	ASTR 300/300L	Observational Astronomy	5
3.	ASTR 301 (*new*)	Observational Projects	4
4.	ASTR 320 (*new*)	Astronomical Spectroscopy	3
5.	ASTR 495 (*new*)	Senior Research Project	3
6.	PHYS 151/151L	College Physics I	4
7.	PHYS 152/152L	College Physics II	4
8.	PHYS 485	Professional Ethics	1
	subtotal		27

PHYS 170/170L, 272/272L and 274/274L may be substituted for PHYS 151/151L and 152/152L; the subtotal of the core courses is then 32 credits. In this case, PHYS 274 also satisfies one of the related elective requirements below.

Astronomy elective requirements.
At least 21 credits.

Astronomy (Three courses from the following, including at least six upper-divison credits and three 400-level credits; if 495 counts as an elective, it must be taken both senior semesters for a total of six credits. 110-150 only count if taken before 240)

ASTR 110 Survey of Astronomy

ASTR 120	Astronomical Origins
ASTR 130	Introduction to Archaeoastronomy
ASTR 140	History of Astronomy
ASTR 150	Voyage through the Solar System
ASTR 280	Evolution of the Universe
ASTR 281	Astrobiology
ASTR 380	The Cosmos in Western Culture
ASTR 399	Directed Reading and Research (max 3 credits)
ASTR 426 (*new*)	Galaxies & Cosmology
ASTR 430 (*new*)	The Solar System
ASTR 495 (*new*)	Senior Research Project

Related subjects (Four courses from the following, including at least three upper-division credits.)

CHEM 272	Organic Chemistry
ECON 321	Introduction to Statistics
EE 160	Programming for Engineers
GG 101 (or 170)	Dynamic Earth (or Physical Geology)
GG 200-level or above	(any NI Geo course worth 3 or more credits)
ICS 111	Introduction to Computer Science I
ICS 211	Introduction to Computer Science II
MATH 243	Calculus III
MATH 244	Calculus IV
MATH 300-level or above	(any UD Math course worth 3 or more credits)
PHYS 274	General Physics III
PHYS 300-level or above	(any UD Physics course worth 3 or more credits)

Total Credits of Required Non-Foundational Courses: 48

ii. Required for BS in Astrophysics

Foundational requirements:			credits
1.	CHEM 161/161L	General Chemistry I	4
2.	CHEM 162/162L	General Chemistry II	4
3.	MATH 241 or 251A	Calculus I	4
4.	MATH 242 or 252A	Calculus II	4
5.	MATH 243	Calculus IIII	3
6.	MATH 244	Calculus IV	3
7.	MATH 311 or 307	Linear Algebra	3
	subtotal		25

Astrophysics core course requirements:			credits
1.	ASTR 241	Foundations of Astrophys. I	3
2.	ASTR 242	Foundations of Astrophys. II	3
3.	ASTR 300/300L	Observational Astronomy	5

4.	ASTR 301 (*new*)	Observational Projects	4
5.	ASTR 423 (*new*)	Stellar Astrophysics	3
6.	ASTR 495 (*new*)	Senior Research Project	6
7.	PHYS 170/170L	General Physics I	5
8.	PHYS 272/272L	General Physics II	4
9.	PHYS 274/274L	General Physics III	4
10.	PHYS 310	Theoretical Mechanics I	3
11.	PHYS 311	Theoretical Mechanics II	3
12.	PHYS 350	Electricity and Magnetism	3
13.	PHYS 450	Electromagnetic Waves	3
14.	PHYS 480	Quantum Mechanics I	3
15.	PHYS 485	Professional Ethics	1
	subtotal		53

<u>Astrophysics elective requirements.</u>
At least 9 credits.

Astronomy (one from the following)

ASTR 320 (*new*)	Astronomical Spectroscopy
ASTR 426 (*new*)	Galaxies & Cosmology
ASTR 430 (*new*)	The Solar System

Physics (two from the following)

PHYS 400	Mathematical Methods
PHYS 460	Physical Optics
PHYS 481	Quantum Mechanics II
PHYS 490	Modern Physics

Total Credits of Required Non-Foundational Courses: 62

B. Program Admission

Students will be admitted into the Astrophysics Program if they have successfully completed CHEM 162/162L, MATH 242 or 252A, and PHYS 170/170L with a C (not C–) or better grade in each course, or have received equivalent transfer or AP credit. Students will be admitted into the Astronomy Program who have successfully completed CHEM 162/162L, MATH 241 or 251A, and PHYS 151/151L with a C (not C–) or better grade in each course, or that have received equivalent transfer or AP credit. MATH 215 or 216 may be substituted for MATH 241 provided the student has passed with a B (not B–) or better grade. In general, these course requirements can only be met by students that have at least sophomore standing (25 or more credits).

C. Advising and Counseling

Advising for all declared majors will be handled by faculty within the IfA. Upon declaring as an Astronomy or Astrophysics major, students will be assigned to a faculty member who will serve as their advisor through graduation. Academic advising shall be mandatory every semester. Additional faculty will be recruited and trained for advising as needed.

D. Focus Requirements

Several courses required for the BA and BS degrees can plausibly carry WI (writing intensive) or OC (oral communication) focus designations. The catalog description for ASTR 301 mentions presentation of "results in written and verbal form". Students in this course are required to draft observing proposals, keep logs of observations and data analysis procedures, and prepare written final reports, so obtaining a WI designation should be fairly straightforward. Moreover, since this course is worth four credits and its design includes significant discussion among participants as well as verbal presentation of results, we believe it should also be possible to give this course an OC designation. Another potentially WI course is ASTR 495, which explicitly requires "significant written products" including initial proposals, research logs, progress reports, and capstone research papers. Individual faculty associated with ASTR 301 and ASTR 405 will apply for WI and OC designations; once a suitable track record has been established, the Department will apply for permanent designation.

The BA and BS programs both include PHYS 485, a one-credit course in professional research ethics, designed to satisfy the E (ethics) focus requirement. This course already includes examples from "physics and astronomy", so it's suitable without modification for BS Astrophysics and BA Astronomy majors. To handle the increased demand for this course, IfA faculty will offer Fall sections of PHYS 485, complementing the Spring sections currently offered by P&A faculty.

We anticipate that Astronomy and Astrophysics majors will satisfy the HAP (Hawaiian, Asian, and Pacific) focus requirement by taking HWST 107.

E. Transfer from Community Colleges

The BA Astronomy program can easily accommodate students who want to continue at UHM after receiving a UH Community College degree. All of the Chemistry, Mathematics, and Physics courses (or equivalents) required for the BA degree are offered at most UH Community Colleges, as is ASTR 110, which counts as an elective for the BA degree. Students entering UHM after earning Associate of Science (AS) degrees with concentrations in the physical sciences or engineering could complete the BA Astronomy degree in two years by taking ASTR 240 and ASTR 300/300L simultaneously. This would be challenging but manageable for a motivated student who has already taken ASTR 110. (If there is a significant demand for this option, the formal prerequisites for ASTR 300 and 300L could be revised to facilitate this.)

The BS program has a much more specific and extensive set of required courses. Only some of the Community Colleges offer the full set of Mathematics and Physics courses required in years one and two of the BS degree, and the ASTR 241/242 sequence is given only at UHM. An AS degree with a physical science or engineering concentration would offer the best fit to the BS Astrophysics program, but some juggling of courses would be necessary to satisfy the requirements. The best strategy might be for a student to take the

AS degree with electives which cover most of UHM Core and Graduation requirements, and then focus on the upper-level physics and astronomy courses after enrolling at UHM.

Since the courses required for program admission (Section 3B) are all offered at the UH Community Colleges, students transferring to UHM after one year could merge seamlessly into the proposed BA Astronomy and BS Astrophysics 4-year plans (see Appendix B).

F. Changing Tracks between BA and BS

We anticipate that some students will enroll in one of our programs but ultimately decide that the other program would better serve their long-term goals. While switching tracks at a late stage is inherently difficult, there are several "junction points" where students could move from one program to the other. To simplify the following discussion, prospective transfer students are assumed to be following the nominal 4-year plans listed in Appendix B; variants taliored to specific cases can easily be devised.

BA ➔ BS: Switching from the BA Astronomy to the BS Astrophysics program is constrained by the number of Physics courses required for the latter. However, it seems reasonable to assume that most individuals contemplating this switch have fairly strong interests in Physics and are taking the Calculus-based Physics sequence (PHYS 170/170L, 272/272L, 274/274L). BA students who have taken ASTR 240 and are following the Calculus-based physics sequence would be allowed to transfer into the BS program by taking *either* ASTR 241 or 242. Such students would have obtained a good overview of the astronomical universe from ASTR 240, and would have also been exposed to one semester of Calculus-based astrophysics; this should be sufficient for a motivated individual to succeed in the BS Astrophysics program.

BS ➔ BA: Switching from the BS Astrophysics to the BA Astronomy program is relatively straightforward. BS students who have completed *both* ASTR 241 and 242 would be allowed to switch at any point thereafter without taking ASTR 240; this is appropriate because 241+242 together cover the astronomical universe as comprehensively as 240 does. On the other hand, BS students who want to switch immediately after taking ASTR 241 would be required to take 240, since 241 only covers the Solar System (at the discretion of the Undergraduate Astronomy Program Chair, these students may be allowed to count ASTR 241 as an Astronomy elective).

Implementing these "junction points" will not be difficult. The blanket statement "*Credit not given for both 240 and 241*" would be changed to "*Students who have passed both 241 and 242 with a grade of C (not C-) or better may not receive credit for 240*". The prerequisites for ASTR 242 could be modified to allow students who have taken 240 to register, although this could also be handled via instructor consent.

G. Scheduling Considerations

Students who do not follow typical 4-year plans are sometimes delayed in their studies because important prerequisite courses are not given every semester. This problem can be partly addressed by offering key courses both semesters. In particular, offering ASTR 240 in the Spring semester as well as the (currently scheduled) Fall semester would give students a second chance each year to begin the BA Astronomy program; this would also help students who need ASTR 240 to switch from the BS to the BA. Offering a Spring session of ASTR 240 is a high priority once the BA program is launched. If sufficient demand exists, ASTR 300/300L and 301 could also be offered both semesters.

ASTR 426 and 430, which are advanced electives for both the BA and BS programs, are scheduled to be given in alternate Spring semesters. However, the prerequisites for these courses do not limit enrollment to Seniors; Junior-year students who have passed ASTR 300 can also take these courses. This insures that students are not forced to take the one offered during their Senior year; they can take either (or both) depending on their interests.

4. Enrollment in the Program

All undergraduate students at UHM will be eligible for enrollment in the program, provided that they meet prerequisite requirements. We anticipate that enrollment will include students broadly interested in scientific research, technical careers or teaching careers. The UHM College of Natural Sciences currently has nearly 1800 students in various declared majors (Fall 2010 data), and we can reasonably anticipate that a small portion of these students will choose to join the BA Astronomy and BS Astrophysics Programs.

As described in Section 2E, we have used a variety of methods to estimate the level of student interest. Surveys of UHM undergraduates in introductory Physics & Astronomy courses and inquiries from students in Hawaii and elsewhere, indicate that we can reasonably expect an annual enrollment of 12 and 20 students, respectively, in our Astrophysics and Astronomy Major Programs.

The estimated numbers of 12 for BS in Astrophysics and 20 for BA in Astronomy are numbers of students **per year**. Since students typically declare their majors in their second year, they would stay in the program for at least 3 years before graduation. By the third year (FY16/17), the total enrollment will reach a steady level of 36 for BS Astrophysics and 60 for BA Astronomy (see the table in Section 6 "Efficiency"). Hence the total number of students in both programs is 96, which is quite sizable in comparison with other programs in CNS.

We have also examined enrollment in Astrophysics and Astronomy Programs administered through Astronomy Departments at other universities. Based upon data available through the American Physical Society for the 33 Astronomy Programs in the US that were ranked by the National Academy in its recent "Survey of Astronomy Graduate Programs in the United States", Astronomy Departments graduated 5-14 undergraduate Astrophysics majors each year, and 10-50 Astronomy majors each year. Major factors in the total number of majors appear to be the size of the University and the requirements for math-based courses including Calculus and Quantum Mechanics. Those departments with stringent requirements have relatively few students, while those with lenient requirements have more students. UHM is intermediate in the size of its undergraduate student body, while our curriculum is on the stringent side for the Astrophysics Major and on the intermediate side in terms of requirements for the Astronomy Major.

5. Resources

A. Faculty

The Cost and Revenue Template and associated notes (Appendix G) provide a detailed breakdown of the Instructional faculty required to implement the BS Astrophysics and BA Astronomy Majors.

Existing FTE – Approximately half of the courses required for the new programs are already being taught by current Physics faculty and current IfA Faculty (roughly half of the 4.0 I-positions allocated to IfA and distributed on a rotating basis as sixteen 0.25 I appointments each semester, the other half teaching the graduate program).

New FTE – The new courses required to implement the new majors will require additional instructional resources. Three to four new Astronomy courses will be introduced per year, and enrollment in Physics courses is expected to increase. We propose to fulfill this instructional need with one new instructor (I-2, 1.0 FTE) already hired, and one new tenure-track faculty (1.0 FTE) to be funded by the College of Natural Sciences (CNS) once the program is in full swing. The instructor's duties include teaching two sections of ASTR 110 per semester (thereby making IfA faculty currently teaching these classes available to teach the new courses required for the majors), developing instructional materials for and teaching ASTR 300L, and maintaining the lab equipment and remote observing facilities. We anticipate that the two new programs will increase the class size in current physics courses, and that new sections may be needed. Contingent upon the success of the program, we will therefore propose a new tenure-track faculty position starting in FY 2016-17. If early demand for the new programs exceeds our expectations, the CNS will provide funding for lecturers as needed to ensure that the prevailing average teaching load of the P&A faculty will remain the same. The current P&A teaching load is at a level that allows both teaching and research activities flourish. The department has received a high National Research Council ranking (among top 12 in the nation). Internal or external investments in these new degree programs will enhance the choices and experiences of our students while also enhancing and strengthening the research and educational collaborations between P&A and IfA by bridging the research interests of both groups. We envision that this will make the two strong groups even stronger.

B. Space resources

All new courses will be accommodated within existing facilities. The BS Astrophysics and BA Astronomy Majors will require a "remote observing room" and astronomy computer laboratory. The former will be used by third and fourth year students to carry out real-time observing projects using telescopes on Mauna Kea and Haleakala, while the latter will be used to reduce the data obtained from the telescopes. The observing room and computer lab (approx. 800 to 1000 sq.ft.) will be housed in existing space in the Physical Sciences Building (PSB) on the UHM Campus. A separate room in PSB has been identified for an astronomy optics lab.

C. Equipment and supply resources

We will need to purchase a modest size, state-of-the-art, robotic telescope for the exclusive use of astronomy undergraduate students as part of their astronomy laboratory courses and research projects. This telescope will also serve as the UHH educational telescope; it will be placed in an existing dome on Mauna Kea and no new construction is needed. The Physics & Astronomy Department and the Chancellor at UH-Hilo, the UHM Dean of the CNS, and the UH Foundation, along with the IfA Director, are implementing a plan to share in the cost and to jointly raise funds to purchase the telescope. We will also need to purchase lab computers, software licenses, and experimental equipment for the optics lab. All these expenses are included in the Cost and Revenue Template as Unique Program Costs (Line E).

D. Other resources

A new program secretary (0.5 FTE) will be needed to administer the new undergraduate programs and to provide assistance to students and faculty in connection with these programs.

E. Sources of funds (See Cost Revenue Template in Appendix G)

Most of the faculty required to teach the courses are already employed by the CNS and by the IfA, and consequently the Instructional Costs (line C) given in the Cost and Revenue Template overestimate the new personnel costs actually needed to implement these programs. In the first few years, the new personnel costs are limited to one Instructor (I-2) and one part-time secretary; new equipment and supplies include laboratory equipment/computers and a share of a robotic telescope for use by the undergraduate students. The funds needed to cover these expenses and support the first ~100 students will be provided by the CNS. From year three on, we will also propose to collect a program fee of $500 per semester. As shown on the Cost and Revenue Template (line J), we project a substantial Net Revenue from AY 2016-17 onward.

6. Efficiency

To estimate the annual costs and revenues for the Astrophysics/Astronomy Programs, we have assumed an intake of 12 students per year in the BS program and 20 students per year in the BA degree program (see Section 2E). We also assumed that students formally enter the program at the start of their 2nd year, and proceed according to the 4-year plans given in Appendix B. We have not factored attrition into these estimates; attrition is briefly discussed below. For the revenues estimate, we counted only required ASTR and PHYS courses (including required electives) in tabulating numbers of courses, credits, and SSH. A full accounting of the annual costs and revenues attributable to the program is given in the Cost and Revenue Template (Appendix G).

To place the net size of the proposed programs in perspective, the Table below gives total numbers of majors and graduates per year for undergraduate degree programs in the College of Natural Science, averaged over a five year period (2009-2013). These figures were provided by the CNS. We note that CNS undergraduate programs are growing and that current enrollments and graduation rates in many programs exceed long-term averages.

The table below also estimates the total number of majors and projected graduation rate for P&A once the BA Astronomy and BS Astrophysics programs reach a “steady state”. We note that these estimates ignore attrition and assume that students complete the nominal 4-year plans (Appendix B) three years after declaring an Astronomy or Astrophysics major. However, even with an attrition rate as high as 50% over three years, the total number of majors and number of graduates per year for the proposed programs would be comparable to those of many other CNS programs. (This 50% rate is used for illustration only; in our view, such a high rate of attrition would indicate serious problems which we would promptly address through changes to recruitment, advising, and possibly program requirements.) Conversely, if students remain in the programs but take more than three

Department	Degrees	Headcount	Graduation Rate
Biology	BIOL + MBIO + ZOOL	1172	136
Botany	BOT + EBOT	43	8
Chemistry	CHEM + BIOC	141	17
ICS	ICS + CSCI	321	36
Mathematics	MATH	55	14
Microbiology	MICR + MCB	97	21
Physics & Astronomy	PHYS	53	6
Physics & Astronomy	**PHYS + ASTR + ASPH**	**149**	**38**

Sizes and graduation rates of undergraduate CNS departments

Headcounts are averaged over Fall 2009 through Fall 2013. Graduates per year are averaged over AY 2008-09 through 2012-13. BA and BS programs are combined.

years, the total number of majors will increase in proportion, but the number of graduates per year is unchanged in the steady state. We note that reducing mean time to graduation is a priority at UH, and our advising to students will emphasize the value of making progress in a timely fashion.

As shown in the table above, the projected size of the Physics and Astronomy Programs, combined, is above the median size when compared to other department-based degree programs in the College of Natural Sciences. Program costs have been minimized by resizing the introductory Astronomy classes (specifically ASTR110), and reassigning astronomy faculty who have previously been teaching the Introductory Astronomy classes to the new ASTR classes which make up the BS Astrophysics and BA Astronomy Programs. Instructional costs are then reduced to initially hiring an Instructor to teach two large sections of ASTR110 each semester, and to help manage the observing labs. The remaining costs are for a one-time purchase of a dedicated "professional grade" teaching telescope, and the outfitting of an observing room and data reduction lab on the UHM campus, and recurring costs for observing materials and laboratory supplies. Once the necessary equipment is purchased, the total costs are well below the estimated revenues based on total SSH and per-credit-hour tuition (see line J of the Cost and Revenue Template).

Further efficiency is realized due to the combination of the Astrophysics and Astronomy Programs within the existing P&A Department, which already offers undergraduate degrees in Physics. Since many of the courses for the new Astrophysics program use existing Physics courses taught by existing faculty, salaries for upper-division Physics instruction have already been budgeted. The Astrophysics Program is projected to more than double the total number of majors served by the P&A Department, and thus the total faculty salary cost per SSH should decrease significantly. Given the expected enrollment in the BA Astronomy program the demand for lower-division Physics courses may increase; if so, temporary lecturers will be used for these courses.

7. Demonstration of Effectiveness

The Astronomy and Astrophysics programs are designed to serve two distinct groups of students. Students planning to continue on to graduate-level studies in Astronomy, Astrophysics, or Physics are expected to take the BS Astrophysics degree. For this program, the percentage of graduates gaining admission to a suitable graduate school is a straightforward measure of success. Students interested in becoming telescope technicians, planetarium operators, educators, science writers, or other STEM careers are expected to take the BA Astronomy degree. For this program, the percentage of graduates obtaining suitable employment measures success.

To evaluate the effectiveness of the programs, we will focus on two key questions: First, *are students accompishing the learning objectives listed in Section 1B?* We will use a variety of assessment tools to track student progress at each stage of the BS and BA programs. Second, *are graduates of the programs finding employment and gaining admission to graduate programs?* We will track students from the moment they enter the program through graduation and beyond, and maintain contact through an accurate address database, obtaining data to conduct a longitudinal study for up to 6 years.

The outcome of these studies will inform the ongoing development of the BA and BS programs. First, we will adjust the content and delivery of the individual courses to insure that learning objectives are achieved. Second, we will examine the longer-term success of our students and use the results to revise our learning objectives.

A. Student outcomes

Assessment of student learning outcomes (SLOs) in the BA Astronomy and BS Astrophysics programs is outlined in the Curriculum Maps in Appendix C. Individual courses will track the introduction (I), reinforcement (R), and mastery (M) of specific outcomes, challenging students to demonstrate increasing levels of proffciency. Instruments used to assess student progress will include problem sets, quizzes, midterms and final exams, laboratory reports, and oral presentations. The design of these instruments will be based on a set of rubrics describing levels of ability and understanding expected as students progress through introduction, reinforcement, and mastery of each concept. An example rubric for a subset of Physical Laws in Astronomy is given in Appendix C.

Senior-year (400-level) courses will include general assessment (A) tools. These tools will go beyond the specific SLOs of the individual courses and examine overall integration of knowledge. At this level, students will be expected to make connections between material taught in different courses spanning a range of subjects. Astronomy includes a number of topics which demand integrative, multi-scale thinking; Appendix C includes a sample rubric for general assessment across multiple areas.

All students in the BA Astronomy and BS Astrophysics programs will be required to complete a senior research project (ASTR 495) and present their work in writing and orally. The scope and content of these projects will vary somewhat between the two programs, but only projects which support significant assessment of a core set of SLOs will be approved. Capstone projects provide a direct assessment of the overall success of the programs by providing students with an opportunity to demonstrate their knowledge of Astronomy and apply that knowledge to produce a tangible and unique product.

However, not all projects will provide an opportunity to demonstrate mastery of all the SLOs. For example, a BS student interested in astrophysical theory may do a project with no observational component, and a BA student interested in astronomy education may do a project with little direct application of physical law. To insure that all SLOs are assessed, other advanced courses (ASTR 423, 426, 430) will include assessment in key areas, including physical law and its application to astronomy, as well as observational properties of astronomical objects. In addition, mastery of data reduction and observational methods will be covered by signature assessments at the conclusion of ASTR 301.

B. Student placement

Recent graduates of the programs will be surveyed annually in order to measure their success in obtaining Astronomy or technology-related jobs or in gaining admission to graduate programs in Astronomy or Physics. In this questionnaire students will be asked to provide the following types of information:

- Are they in school, working, or unemployed?
- What type of position do they have? Is this position on track towards their ultimate career goals?
- How many applications or interviews did they complete to get the position, and was the position they took one of their top choices?
- Do they feel that their training at UH was an important factor in obtaining this position?

C. Course and instructor evaluation

The Astronomy and Astrophysics Programs will use written course evaluations to solicit student feedback in all courses. Numeric evaluation scores will be used to guide course improvements, particularly with respect to textbook selection, homework and exam design, and lecture presentation. Anonymous student suggestions for course improvements will also be solicited and reviewed. These evaluations and comments will be continuously compiled to provide a longitudinal analysis of course development.

We will also track student satisfaction with the programs. All students in the programs will fill out anonymous questionnaires on an annual basis and will be asked to assess their training in the key areas described within the Astronomy and Astrophysics Program SLOs. Detailed feedback will be obtained where areas of deficiency are noted, and this will be used to improve course design.

8. Appendices

A. Suggested UHM Catalog Listings

B. Sample 4-year Graduation Plans

C. Curriculum Maps

D. New Proposed Courses for Astrophysics/Astronomy Majors
   1. ASTR 241: Foundations of Astrophysics I. (effective – F’12)
   2. ASTR 242: Foundations of Astrophysics II. (effective – S’13)
   3. ASTR 300: Observational Astronomy (effective – F’14)
   4. ASTR 300L: Observational Astronomy Laboratory (effective – F’14)
   5. ASTR 301: Observational Astronomy Projects (effective – S’15
   6. ASTR 320: Spectra of Stars and Interstellar Material (effective – S’15)
   7. ASTR 423: Stellar Astrophysics (effective – F’15)
   8. ASTR 426: Galaxies and Cosmology (effective – F’15)
   9. ASTR 495: Senior Research Project (effective – F’15)

E. Revised Course Listings for Astrophysics/Astronomy Majors
   1. ASTR 240: Foundations of Astronomy (effective – F’13)
   2. ASTR 427: Cosmology (effective – S’15)
   3. ASTR 430: The Solar System (effective – S’15)

F. Letters of Support
   1. Tripartite Memo (UHM-CNS, UH-IfA, UHH-CAA)

Appendix A.
Suggested UHM Catalog Listings

BA Astronomy Degree

Requirements (C [not C-] grade minimum)

Students must complete 48 credit hours in ASTR, PHYS, and related courses, including:

- ASTR 240, 300/300L, 301, 320, 495 (3 credits)
- PHYS 151/151L, 152/152L, 485 (170/170L, 272/272L, 274/274L may be substituted for 151/151L, 152/152L; if so 274 also satisfies one of the non ASTR electives below.)
- Four courses, including at least 6 upper-division credits, from ASTR 110, 120, 130, 140, 150, 280, 281, 380, 399, 426, 430, 495 (110-150 only count if taken before 240; 399 may be taken for a maximum of 3 credits; if 495 counts as an elective as well as a core requirement, it must be taken both semesters for 6 credits total)
- Four courses, including at least 3 upper-division credits, from CHEM 272, ECON 321, EE 160, GG 101 (or 170), any GG course at 200-level or higher worth at least 3 credits, ICS 111, ICS 211, MATH 243, 244, PHYS 274, any MATH or PHYS course at 300-level or higher worth at least 3 credits
- CHEM 161/161L and 162/162L or 171/171L or 181A/181L
- MATH 241, 242 (251A, 252A may be substituted for 241, 242. 215, 216 may be substituted for 241, 242 with consent from advisor.)
- Recommended languages: German, French, or Japanese.

Upon approval of an Astronomy Program Advisor and Chair, the elective requirements may be modified to accommodate a special emphasis or interdisciplinary program that is appropriate for a major in Astronomy.

BS Astrophysics Degree

Requirements (C [not C-] grade minimum)

Students must complete 62 credit hours in ASTR and PHYS courses, including:

- ASTR 241, 242, 300/300L, 301, 423, 495 (6 credits)
- PHYS 170/170L, 272/272L, 274/274L, 310, 311, 350, 450, 480, 485
- One course from ASTR 320, 426, 430
- Two courses from PHYS 400, 460, 481, 490
- CHEM 161/161L and 162/162L or 171/171L or 181/181L
- MATH 241, 242, 243, 244, 311 or 307 (251A, 252A, 253A may be substituted for 241, 242, 243, 244. 215, 216 may be substituted for 241, 242 with consent from advisor.)
- Recommended languages: German, French, or Japanese.

Upon approval of an Astrophysics Program Advisor, the elective requirements may be modified to accommodate a special emphasis or interdisciplinary program that is appropriate for a major in Astrophysics.

Appendix B.
Sample 4-year Graduation Plans

Proposed BS Astrophysics Undergraduate Major
4 year plan

Fall 1		CR	UD	***Spring 1***		CR	UD
CHEM 161/161L	General Chemistry I	4		CHEM 162/162L	General Chemistry II	4	
MATH 241	Calculus I	4		MATH 242	Calculus II	4	
FG		3		PHYS 170/170L	General Physics I	5	
FW		3		FG		3	
		14	0			16	0
Fall 2				***Spring 2***			
ASTR 241	Astrophysics I	3		ASTR 242	Astrophysics II	3	
MATH 243	Calculus III	3		MATH 244	Calculus IV	3	
PHYS 272/272L	General Physics II	4		PHYS 274/274L	General Physics III	4	
LANG 101		3		LANG 102		3	
				HAP		3	
		13	0			16	0
Fall 3				***Spring 3***			
ASTR 300/300L	Observational Astron.	5	5	ASTR 301	Observational Projects	4	4
PHYS 310	Theoretical Mech. I	3	3	PHYS 311	Theoretical Mech. II	3	3
PHYS 350	Electricity & Magnetism	3	3	PHYS 450	Electromag. Waves	3	3
MATH 311	Linear Algebra	3	3	LANG 202		3	
LANG 201		3		DIV		3	
		17	14			16	10
Fall 4				***Spring 4***			
ASTR 423	Stellar Astrophysics	3	3	ASTR 495	Sr. Research Project	3	3
ASTR 495	Sr. Research Project	3	3	Astron. elective		3	3
PHYS 480	Quantum Mech. I	3	3	Physics elective		3	3
PHYS 485	Professional Ethics	1	1	DIV		3	
Physics elective		3	3	DIV		3	
DIV		3					
		16	13			15	9
					Total credits:	123	
					UD credits:	46	

Astronomy Electives (1 course required)

ASTR 320	Astronomical Spectroscopy
ASTR 426	Galaxies & Cosmology
ASTR 430	The Solar System

Physics Electives (2 courses required)

PHYS 400	Mathematical Methods
PHYS 460	Physical Optics
PHYS 481	Quantum Mechanics II
PHYS 490	Modern Physics

Proposed BA Astronomy Undergraduate Major
4 year plan

Fall 1		CR	UD
CHEM 161/161L	General Chemistry I	4	
FW		3	
FG		3	
elective		3	
elective		3	
		16	0

Spring 1		CR	UD
CHEM 162/162L	General Chemistry II	4	
MATH 241	Calculus I	4	
PHYS 151/151L	College Physics I	4	
FG		3	
		15	0

Fall 2			
ASTR 240	Found. of Astronomy	3	
MATH 242	Calculus II	4	
PHYS 152/152L	College Physics II	4	
LANG 101		3	
		14	0

Spring 2			
Astron. elective		3	
Related elective		3	
LANG 102		3	
HAP		3	
elective		3	
		15	0

Fall 3			
ASTR 300/300L	Observational Astron.	5	5
Related elective		3	
LANG 201		3	
DIV		3	
		14	5

Spring 3			
ASTR 301	Observational Projects	4	4
ASTR 320	Astron. Spectroscopy	3	3
Related elective		3	
LANG 202		3	
DIV		3	
		16	7

Fall 4			
PHYS 485	Professional Ethics	1	1
Astron. elective		3	3
Related elective		3	3
DIV		3	
DIV		3	
elective		3	
		16	7

Spring 4			
ASTR 495	Sr. Research Project	3	3
Astron. elective		3	3
DIV		3	
elective		3	
elective		3	
		15	6

Total credits: 121
UD credits: 25

Astronomy Electives (3 courses, 6 UD credits required, including 3 at 400-level. 100-level courses only count if taken before 240.)

ASTR 100-level	(any 100-level lecture)
ASTR 280	Evolution of the Universe
ASTR 281	Astrobiology
ASTR 380	Cosmos in Western Culture
ASTR 399	Direct. Reading & Research
ASTR 426	Galaxies & Cosmology
ASTR 430	The Solar System
ASTR 495	Senior Research Project

Related Electives (4 courses, 3 UD credits required)

CHEM 272	Organic Chemistry
ECON 321	Introduction to Statistics
EE 160	Programming for Engineers
GG 101 (or 170)	Dynamic Earth (Phys. Geo.)
GG 200+	(any 3+ credit course at 200+level)
ICS 111	Intro. to Computer Science I
ICS 211	Intro. to Computer Science II
MATH 243	Calculus III
MATH 244	Calculus IV
MATH 300+	(any 3+ credit course at 300+level)
PHYS 274	General Physics III
PHYS 300+	(any 3+ credit course at 300+level)

Appendix C.
Curriculum Maps

BS Astrophysics – curriculum map

OUTCOME	P170/ 171L	A241	P272/ 272L	A242	P274/ 274L	A300	A300L	P310	P350	A301	P311	P450	A423	P480	P485	A495
1. Laws of Physics	I	R	I	R	I	R	R	R	R	R	R	M	M	M		**M,A**
2. Astronomical Objects		I		I		R	R			R			M			**M,A**
3. Physical Law in Astronomy		I		R						R			M			**M,A**
4. Astrophysical Problems		I		R									M			**M,A**
5. Scientific Method	I	I	I	I	I	R	R	R	R	R	R	R	M	M	R	**M,A**
6. Scientific Communications						I				R					R	**M,A**
7. Observational Properties						I	R			R			**M,A**			
8. Astronomical Data Reduction						I	R			**M,A**						
9. Observing Methods						I	R			**M,A**						
10. Astronomical Literature						I				R					R	**M,A**

BA Astronomy – curriculum map

OBJECTIVE	P151/ 151L	A240	P152/ 152L	A300	A300L	A301	A320	A4XX elec.	P485	A495
1. Laws of Physics	I		I	R	R	R	R	**M,A**		
2. Astronomical Objects		I		R	R	R	R	M		**M,A**
3. Physical Law in Astronomy		I				R	R	**M,A**		
4. Scientific Method	I	I	I	R	R	R	R	M	R	**M,A**
5. Scientific Communication				I		R			R	**M,A**
6. Observational Properties		I		I	R	R		**M,A**		
7. Astronomical Data Reduction				I	R	**M,A**				
8. Observing Methods				I	R	**M,A**				
9. Astronomical Literature				I		R		R	R	**M,A**

Sample Rubrics for Physical Laws in Astronomy			
Subject	**Introduce**	**Reinforce**	**Master**
Orbital motion	Kepler's Laws. General 2-body problem.	Perturbations; secular evolution.	Non-Keplerian potentials; orbital invariants.
Continuum mechanics	Hydrostatic equilibrium: atmospheres.	Hydrostatic equilibrium: planetary & stellar interiors.	Solar & stellar winds; time-dependent problems; shocks.
Matter & Radiation	Steffan-Boltzmann & Wien laws.	Planck function; hydrogen levels; line formation in LTE.	Non-LTE systems; astrophysical masers.
Nuclear Reactions	alpha and beta decay.	Hydrogen and helium burning.	Reaction networks; R and S process.

Sample Rubrics for General Assessment of Astronomical Knowledge			
Subject	**Planetary Astronomy**	**Stellar Astronomy**	**Extragalactic Astronomy**
Distance Measurements	Determination of astronomical unit	Parallax; photometric methods; eclipsing binary stars	Redshifts; T.F. & fundamental-plane; SN Ia; calibration
Astronomical Ages	Radioactive decay methods	Stellar evolution; helioseismology	Hubble timescale; cosmological models
Origin of Elements	Abundances in solar system; radio-heating of meteorites	Nuclear burning; supernovae; Pop. I and II abundances	Galactic chemical evolution; Big Bang nucleosynthesis
Life in the Universe	Origin on Earth; pre-biotic conditions on planets & moons.	Detection of extrasolar planets	

Appendix D.

New Proposed Courses for Astrophysics/Astronomy Majors

(UHM-1 Cover Form + Justification for each new course)

ASTR 241	Foundations of Astrophysics I.	(effective – F’12)
ASTR 242	Foundations of Astrophysics II.	(effective – S’13)
ASTR 300	Observational Astronomy	(effective – F’13)
ASTR 300L	Observational Astronomy Laboratory	(effective – F’13)
ASTR 301	Observational Astronomy Projects	(effective – S’14)
ASTR 320	Spectra of Stars and Interstellar Material	(effective – S’14)
ASTR 423	Stellar Astrophysics	(effective – S’15)
ASTR 426	Galaxies and Cosmology	(effective – S’15)
ASTR 495	Senior Research Project	(effective – S’15)

UNIVERSITY OF HAWAIʻI AT MĀNOA
UHM-1 FORM (ADD A COURSE)

See *Guidelines* for instructions and deadlines. For undergraduate courses, submit an original and 4 copies; graduate courses, submit an original and 6 copies. If cross-listed, include extra copies for cross-listed department(s) & college(s). List one course per form. Attach additional sheets as needed.

1. Course Subject	2. Course Number	3. Effective Term *(semester & year)*	4. Frequency *(check all that apply)*
ASTR	241	Fall 2012	[x] Fall semester; [ ] Spring semester; [ ] Summer semester; [ ] Alternate years; [ ] Other: ______

5. Offering Status *(check one)*: [x] Regular; [ ] Experimental; [ ] Single-term

6a. Full Course Title *(Alpha courses: attach separate sheet & specify title for each alpha)*
Foundations of Astrophysics I: The Solar System

6b. BANNER Course Title *(30 characters max, including spaces/punctuation. Alpha courses: attach separate sheet & specify title for each alpha)*
Foundations of Astrophysics I

7. Grade Option *(check all that apply)*
- [x] Letter Grade
- [ ] Credit/No Credit
- [ ] Audit
- [ ] Satisfactory/Unsatisfactory (500, 700, 700F, 800, 800C only)
- [ ] Honors (Medicine only)

8. Gen Ed Core or Hawaiian/Second Language Requirement Designation *(check one)*
- [ ] Do not consider for Core or Hawaiian/Second Language designation.
- [x] Request approval of DP Diversification (DA, DH, DL, DB, DP, DY, DS), Foundations (FW, FS, FG), or Hawaiian/Second Language (HSL) designation (For Foundations, also submit a proposal to General Education Office.)

GEC Use: [ ] Approve [ ] Deny ______ GEC Initials

9. Contact Hours *(meeting hours per week – if variable, specify range)*	10. # of credits *(if variable, give range)*	11. Repeat Limit	12. Credit Limit
3	3	0	3

13. Schedule Type *(check all that apply)*
- [x] Lecture (LEC)
- [ ] Laboratory (LAB)
- [ ] Discussion (DIS)
- [ ] Seminar (SEM)
- [ ] Lecture/Discussion combined (LED)
- [ ] Lecture/Laboratory combined (LEL)
- [ ] Thesis/Dissertation (THE)
- [ ] Hybrid Technology Intensive (HTI)
- [ ] Directed Reading or Research (DRR)
- [ ] Field Experience/ Internship/Practicum (PRA)

14. Co-requisite Course(s)	15a. Major Restriction *(as it should appear in Catalog)*	15b. Banner codes of acceptable majors	16. Class Standing Restriction
PHYS 272	N/A	N/A	N/A

17a. Prerequisite Course(s) *(Use "ands", "ors" and punctuation to indicate relationships between prerequisites. "Or consent" is implied for ALL prerequisites. "Consent" requirements can be implemented through your class schedules each semester.)*
PHYS 170, and MATH 242 or 252A

17b. Minimum required grade for prerequisites	17c. Blanket requirements listed in Catalog *(if none, write "none")*	17d. Non-introductory (NI) Course? *(Numbered between 300 & 499, or 200-level with college-level course as a prerequisite)*
C	none	[x] Yes [ ] No

18. Catalog Description *(Limit 35 words; 85 words for alpha courses)*
Solar-system astrophysics. Dynamics of planets, satellite systems, asteroids and comets; internal and atmospheric structure of terrestrial and giant planets; thermal balance; the Sun as a star. Credit not given for both ASTR 240 and 241.

19. Justification *Attach separate sheets and indicate the rationale for the request, expected course enrollment, and a course syllabus.*

20. Cross-listed or Honors Course(s)

Course Subject & Number	Chair/Director	Signature	Date

21. Requested By

Department/Unit	Chair/Director	Signature	Date
Phys. & Astr.	Pui Lam		

Approved By

1st College or School	Dean	Signature	Date
2nd College or School	Dean	Signature	Date

General Education *(Undergraduate courses)*
Director — Signature — Date

Graduate Division *(600 level and above)*
Dean — Signature — Date

Mānoa Chancellor's Office
Vice Chancellor for Academic Affairs — Signature — Date

Rev. 06/10

Course Justification for ASTRONOMY 241
Foundations of Astrophysics I: The Solar System

1 Description & Objectives

ASTR 241 is a rigorous, calculus-based introduction to Solar System astrophysics. In this course, basic concepts of classical mechanics and thermodynamics are used to understand the structure and evolution of the Solar System. Historically, the Solar System was the original proving ground for much of Newtonian dynamics, and it provides many opportunities to apply mechanics and thermodynamics on a grand scale. In addition to introducing students to the study of the Solar System, ASTR 241 will deepen their understanding and ability to use basic physical concepts.

The key prerequisite for this course is PHYS 170, which covers basic concepts of classical mechanics, waves, and thermodynamics, and it is assumed that students taking ASTR 241 have a good understanding of these subjects. Students are also expected to have studied basic calculus including an introduction to ordinary differential equations. PHYS 272 is listed as a co-requisite since some elements of electricity and magnetism will be used in the last weeks of this course. More advanced aspects of physics and mathematics will be introduced when necessary; for example, thermal radiation is needed to discuss heat balance in planets, and some basic nuclear physics is needed to discuss energy generation in the Sun. These advanced concepts will be presented phenomenologically.

2 Organization & Syllabus

ASTR 241 is a lecture course, meeting for three contact hours per week. The syllabus contains twelve sections, each spanning approximately one week; one week is allotted for final review, and two weeks are allotted for midterm exams and review.

1. **Solar System Overview.** Constituents: Sun, planets, asteroids, dwarf planets, comets, zodiacal dust, solar wind. Overall structure and motions: rotation and revolution.

2. **Orbital Motion.** Kepler's laws; universal gravitation; review of Newton's laws. Derivation of Kepler's laws, including non-circular orbits.

3. **Tides.** Differential acceleration. The Earth-Moon system. Response of idealized and real oceans. Tidal friction. Synchronous rotation. Evolution of the Moon's orbit. Tidal disruption.

4. **Resonances.** Resonances in the Solar System. Periodic perturbations. Introduction to stability and instability. Gaps in the asteroid belt and in Saturn's rings. Origin of near-Earth objects.

5. **Planetary Atmospheres.** Hydrostatic equilibrium. Thermal balance. Atmospheric chemistry. Escape of atmospheric constituents. Circulation patterns.

6. **Terrestrial Planets.** Internal structure of differentiated planets. Heat production and transport. Convection. Geological activity.

7. **Giant Planets.** Internal structure of gas giants and ice giants. Equilibrium of rotating bodies. Escape of internal heat.

8. **Asteroids & Comets.** Monoliths vs. rubble piles. Orbital families. Collisional disruption. Sublimation of comets. Meteor showers.
9. **Space Weather.** The solar wind. Planetary magnetic fields. Planetary magnetospheres.
10. **The Solar Atmosphere.** The quiet sun. Solar magnetic fields. The solar cycle. Sunspots, prominences, flares & coronal mass ejections.
11. **The Solar Interior.** Pressure balance. Thermal equilibrium. Energy transport via radiation and convection. Helioseismology. Hydrogen burning.
12. **Solar System Formation.** Cloud collapse. Rotation of proto-solar nebula. Condensation of solids. Terrestrial planet formation. The frost line. Giant planet formation. Impacts.

The text for this course will be B.W. Carroll & D.A. Ostlie's "An Introduction to Modern Astrophysics" (2^{nd} ed., 2006) or an equivalent. Carroll & Ostlie can also serve as a text for the subsequent course, ASTR 242 (see below).

2.1 Student learning outcomes

After taking this course, students will be able to apply basic Newtonian dynamics to various problems in celestial motion. They will grasp the connection between periodic motion and resonance, and qualitatively distinguish between stable and unstable systems. They will be able to apply the ideal gas law to planetary atmospheres and interiors, and discuss the loss of atoms in the tail of the velocity distribution. They will be able to apply equilibrium thermodynamics to solar system objects, and describe heat escape from planetary interiors. They will be able to show the solar wind is inherently dynamic and describe its interaction with planetary magnetic fields. They will be able to describe how solar magnetic fields control activity in the Sun's atmosphere. They will be able to apply ideal gas laws to the interior of the Sun and understand radiative and convective energy transport. They will be able to explain how the Sun regulates the process of hydrogen burning to maintain a steady energy output. They will be able to apply conservation laws to the collapse of the proto-solar nebula. They will be able to discuss models for planet formation.

3 Expected Enrollment

ASTR 241 is targeted to students with a significant interest in astronomy as well as physics. The listed co-requisite, PHYS 272, enrolls ~ 140 students per semester. Other NI astronomy courses currently enroll ~ 25 to 35 students per semester, and often reach maximum enrollment. We expect an enrollment of ~ 25 to 40 students in ASTR 241.

4 Relation to Curriculum

ASTR 241 is intended as the first part of a year-long introduction to astrophysics; it will be followed by ASTR 242, which will cover stars, galaxies, and cosmology. Ultimately, these courses will comprise a key element of an astrophysics major now under development. However, ASTR 241 can also serve as a stand-alone course for anyone with the necessary physics and mathematics background who is interested in learning about the solar system as a physical entity.

5 Overlap with Other Courses

ASTR 241 has limited overlap with other courses at UH Manoa. The Solar System is discussed in ASTR 110 and ASTR 240, but these courses do not use calculus-based physics and therefore cannot examine the rich physical basis for Solar System phenomena. ASTR 630 (also listed as ASTR 430) covers this material and more but also presumes a much deeper familiarity with observational astronomy. GG 105 presents a descriptive survey of the Solar System at an introductory level, while GG 304 applies physics to the internal structure of planets but does not explore orbital dynamics or solar structure.

6 Number of Credits

ASTR 241 is a substantial lecture course with three contact hours per week; it is appropriate for students to receive three credits for this course.

7 Student Evaluation

Students will be graded on the basis of (a) weekly problem sets, (b) two mid-term exams, and (c) a cumulative final exam.

8 Instructors

Although ASTR 241 focuses on Solar System astrophysics, it will not require instructors with a particularly deep knowledge of Solar System astronomy. Much of the astronomical material will be presented at a level not much higher than in ASTR 110. However, while ASTR 110 offers phenomenological descriptions, ASTR 241 will emphasize *physical* explanations. Physical reasoning is the core of astrophysics, and most of the Astronomy faculty could teach this course.

9 Impact on Workload

The IfA Graduate Chair, Dr. David Sanders, confirms that this course will not limit the ability of Physics & Astronomy to give other courses already listed in the catalog. No other course will be sacrificed to offer this course.

UNIVERSITY OF HAWAI'I AT MĀNOA

UHM-1 FORM (ADD A COURSE)

See *Guidelines* for instructions and deadlines. For undergraduate courses, submit an original and 4 copies; graduate courses, submit an original and 6 copies. If cross-listed, include extra copies for cross-listed department(s) & college(s). List one course per form. Attach additional sheets as needed.

1. Course Subject	2. Course Number	3. Effective Term *(semester & year)*	4. Frequency *(check all that apply)*
ASTR	242	Spring 2013	☐ Fall semester ☒ Spring semester ☐ Summer semester ☐ Alternate years

5. Offering Status *(check one)*: ☒ Regular ☐ Experimental ☐ Single-term

6a. Full Course Title *(Alpha courses: attach separate sheet & specify title for each alpha)*: Foundations of Astrophysics II: Galaxies and Stars

6b. BANNER Course Title *(30 characters max, including spaces/punctuation. Alpha courses: attach separate sheet & specify title for each alpha)*: Foundations of Astrophysics II

7. Grade Option *(check all that apply)*: ☒ Letter Grade ☐ Credit/No Credit ☐ Audit ☐ Satisfactory/Unsatisfactory (500, 700, 700F, 800, 800C only) ☐ Honors (Medicine only)

8. Gen Ed Core or Hawaiian/Second Language Requirement Designation *(check one)*:
☐ Do not consider for Core or Hawaiian/Second Language designation.
☒ Request approval of DP Diversification (DA, DH, DL, DB, DP, DY, DS), Foundations (FW, FS, FG), or Hawaiian/Second Language (HSL) designation. (For Foundations, also submit a proposal to General Education Office.)

GEC Use: ☐ Approve ☐ Deny GEC Initials

9. Contact Hours *(meeting hours per week – if variable, specify range)*	10. # of credits *(if variable, give range)*	11. Repeat Limit	12. Credit Limit
3	3	0	3

13. Schedule Type *(check all that apply)*: ☒ Lecture (LEC) ☐ Laboratory (LAB) ☐ Discussion (DIS) ☐ Seminar (SEM) ☐ Lecture/Discussion combined (LED) ☐ Lecture/Laboratory combined (LEL) ☐ Thesis/Dissertation (THE) ☐ Hybrid Technology Intensive (HTI) ☐ Directed Reading or Research (DRR) ☐ Field Experience/Internship/Practicum (FRA)

14. Co-requisite Course(s)	15a. Major Restriction *(as it should appear in Catalog)*	15b. Banner codes of acceptable majors	16. Class Standing Restriction
N/A	N/A	N/A	N/A

17a. Prerequisite Course(s) *(Use "ands", "ors" and punctuation to indicate relationships between prerequisites. "Or consent" is implied for ALL prerequisites. "Consent" requirements can be implemented through your class schedules each semester.)*

ASTR 241, PHYS 274 (or concurrent), and MATH 243 or 253A (or concurrent)

17b. Minimum required grade for prerequisites: C

17c. Blanket requirements listed in Catalog *(if none, write "none")*: Credit not given for both 240 and 241/242.

18. Catalog Description *(Limit 35 words; 85 words for alpha courses)*

Astrophysics of galaxies and stars. Galactic structure and dynamics; active nuclei; large-scale structure. Elements of Newtonian and relatavistic cosmology. Stellar atmospheres and spectral lines. Stellar interiors; nuclear energy generation; main-sequence and evolved stars.

19. Justification *Attach separate sheets and indicate the rationale for the request, expected course enrollment, and a course syllabus specifying student learning objectives for the course.*

20. Cross-listed or Honors Course(s)

Course Subject & Number Chair/Director Signature Date

Course Subject & Number Chair/Director Signature Date

21. Requested By

I certify that the student learning objectives for the course are consistent with the learning objectives of each program under which the course is listed.

Department/Unit	Chair/Director	Signature	Date
Phys. & Astr.	Pui Lam		

Approved By

1st College or School Dean Signature Date

2nd College or School Dean Signature Date

General Education *(Undergraduate courses numbered 100-499)*

Director Signature Date

Graduate Division *(600 level and above)*

Dean Signature Date

Mānoa Chancellor's Office

Vice Chancellor for Academic Affairs Signature Date

Rev. 1/2012

Course Justification for ASTRONOMY 242
Foundations of Astrophysics II: Galaxies and Stars

1 Description & Objectives

ASTR 242 is a rigorous, calculus-based introduction to the physics of galaxies and stars. In this course, basic concepts of modern physics are used to understand the nature of stars, the structure of galaxies, and the overall scale and age of the universe. These topics are central to modern astrophysics, and they provide a natural context to apply aspects of statistical mechanics, relativity, quantum mechanics, and nuclear physics. ASTR 242 will introduce students to key ideas in astrophysics and demonstrate applications of modern physics.

This course is designed to be taken with or after PHYS 274 as part of an astrophysics major. PHYS 274 introduces physical optics, relativity, quantum mechanics, and nuclear physics; these topics are critical for ASTR 242. To insure that students have the necessary physics background at each stage, this course first introduces galaxies and develops aspects of large-scale structure and cosmology; subsequently, it treats the physics of stellar atmospheres, and finally introduces elements of nuclear astrophysics. It is assumed that students will have had physics prerequisites to PHYS 274; they are also expected to have studied ordinary differential equations, vector calculus and multiple integrals. More advanced aspects of physics and mathematics will be introduced when necessary; for example, some elements of statistical mechanics are used to describe stellar atmospheres. Some advanced concepts will be presented phenomenologically.

2 Organization & Syllabus

ASTR 242 is a lecture course, meeting for three contact hours per week. The syllabus contains twelve sections, each spanning approximately one week; one week is allotted for final review, and two weeks are allotted for midterm exams and review.

1. **Light.** Nature of light, blackbody radiation, quanta. Stellar parallax, apparent and absolute magnitudes, colors.
2. **Constituents of Galaxies.** Phenomenology of stars: HR diagram, main sequence, giants and dwarfs, variable stars. Interstellar material: neutral gas, molecular clouds, emission nebulae. Star clusters.
3. **The Milky Way.** Overview of galactic structure. Distances in the galaxy. Structure and kinematics of the disk. The galactic bulge and halo.
4. **Other Galaxies.** The Hubble sequence. Stellar orbits and 2-body relaxation. Dark matter in galaxies. Galactic interactions and mergers.
5. **Active Galaxies.** Phenomenology of active galactic nuclei. Supermassive black holes. Accretion disks. Radio galaxies. Jets and superluminal motion.
6. **Clusters & Large-Scale Structure.** Groups and clusters of galaxies. Evidence for hot gas and dark matter in clusters. Gravitational collapse. Statistics of galaxy clustering. Evolution of large-scale structure.
7. **Cosmology.** Kinematics of the expanding universe. Newtonian cosmology. Homogeneous relativistic models. Cosmological constant.

8. **Spectral Lines.** Energy levels. Excitation and ionization equilibria. Line formation. Elemental abundances.

9. **Stellar Atmospheres.** Radiation fields. Local thermodynamic equilibrium. Sources of opacity. Optical depth. Radiative transfer equation.

10. **Stellar Interiors.** Hydrostatic equilibrium. Equation of state. Hydrogen burning. Radiative and convective energy transport. Polytropic models.

11. **Stellar Evolution.** The main sequence. Red giants. Helium burning. Degeneracy pressure. White dwarfs.

12. **Origin of Elements.** Advanced nuclear burning. Core-collapse and white-dwarf supernovae. S-process and r-process nucleosynthesis.

One possible text for this course is B.W. Carroll & D.A. Ostlie's "An Introduction to Modern Astrophysics" (2^{nd} ed., 2006), which is also the text for the previous course, ASTR 241. Other possibilities include D. Maoz's "Astrophysics in a Nutshell" (2007) and B. Ryden & B.M. Peterson's "Foundations of Astrophysics" (2009).

2.1 Student learning outcomes

After taking this course, students will understand key aspects of modern astrophysics, including (a) the history and large-scale structure of the universe, (b) the nature and physics of galaxies, and (c) the structure and evolution of stars. They will be able to apply Newtonian dynamics on galactic and extragalactic scales, and discuss evidence for unseen matter. They will understand the role of conservation laws in accretion physics, and be able to apply relativistic kinematics to jets from active galaxies. They will be able to summarize the key parameters of modern cosmological models and calculate their properties. They will grasp the basic principles of radiative transfer, apply them to stellar atmospheres, and discuss the interpretation of stellar spectra. They will understand the key ideas of stellar structure: hydrostatic equilibrium, energy transport via radiation and convection, and nuclear energy generation. Finally, they will be able to apply basic nuclear physics to advanced stellar evolution and the synthesis of the elements in stars.

3 Expected Enrollment

ASTR 242 is intended for students with a significant interest in astronomy as well as physics. The listed co-requisite, PHYS 274, enrolls ~ 50 students per semester. Other NI astronomy courses currently enroll ~ 25 to 35 students per semester, and often reach maximum enrollment. We expect an enrollment of ~ 20 to 30 students in ASTR 242.

4 Relation to Curriculum

ASTR 242 is intended as the second part of a year-long introduction to astrophysics. Together with ASTR 241, this course comprises a key element of an astrophysics major. However, ASTR 242 can also serve as a stand-alone course for anyone with the necessary physics and mathematics background and an interest in modern astrophysics.

5 Overlap with Other Courses

ASTR 242 has limited overlap with other courses at UH Manoa. Stars, galaxies and cosmology are discussed in ASTR 110 and ASTR 120 but these courses assume no prior knowledge of physics and therefore limited to fairly superficial descriptions. ASTR 240 discusses these topics but cannot go into the underlying physics as deeply as ASTR 242 will.

6 Number of Credits

ASTR 242 is a substantial lecture course with three contact hours per week; it is appropriate for students to receive three credits for this course.

7 Student Evaluation

Students will be graded on the basis of (a) weekly problem sets, (b) two mid-term exams, and (c) a cumulative final exam.

8 Instructors

Although ASTR 242 focuses on stellar and galactic astrophysics, it will not require instructors with a particularly deep knowledge of these topics. Much of the astronomical material will be presented at a level only moderately higher than in ASTR 110. However, while ASTR 110 offers simple phenomenological descriptions, ASTR 242 will emphasize *physical* explanations. Physical reasoning is the core of astrophysics, and most of the Astronomy faculty could teach this course.

9 Impact on Workload

The IfA Graduate Chair, Dr. David Sanders, confirms that this course will not limit the ability of Physics & Astronomy to give other courses already listed in the catalog. ASTR 242 is envisioned as a critical component of a new astrophysics major for which a proposal is in the process of being finalized. We envisage that this course will be ultimately staffed by new faculty for this program or by the current-year hire of a new Astronomy faculty member.

UNIVERSITY OF HAWAIʻI AT MĀNOA
UHM-1 FORM (ADD A COURSE)

See *Guidelines* for instructions and deadlines. For undergraduate courses, submit an original and 4 copies; graduate courses, submit an original and 6 copies. If cross-listed, include extra copies for cross-listed department(s) & college(s). List one course per form. Attach additional sheets as needed.

1. Course Subject	**2. Course Number**	**3. Effective Term** *(semester & year)*	**4. Frequency** *(check all that apply)*
ASTR	300	Fall 2013	☒ Fall semester ☐ Alternate years ☐ Spring semester ☐ Summer semester

5. Offering Status *(check one)*
☒ Regular
☐ Experimental
☐ Single-term

6a. Full Course Title *(Alpha courses: attach separate sheet & specify title for each alpha*
Observational Astronomy

6b. BANNER Course Title *(30 characters max, including spaces/punctuation. Alpha courses: attach separate sheet & specify title for each alpha)*
Observational Astronomy

7. Grade Option *(check all that apply)*
☒ Letter Grade
☐ Credit/No Credit
☐ Audit
☐ Satisfactory/Unsatisfactory (500, 700, 700F, 800, 800C only)
☐ Honors (Medicine only)

8. Gen Ed Core or Hawaiian/Second Language Requirement Designation *(check one)*
☐ Do not consider for Core or Hawaiian/Second Language designation.
☒ Request approval of DP Diversification (DA, DH, DL, DB, DP, DY, DS), Foundations (FW, FS, FG), or Hawaiian/Second Language (HSL) designation. (For Foundations, also submit a proposal to General Education Office.)

GEC Use:
☐ Approve
☐ Deny
GEC Initials

9. Contact Hours *(meeting hours per week – if variable, specify range)*	**10. # of credits** *(if variable, give range)*	**11. Repeat Limit**	**12. Credit Limit**
3	3	0	3

13. Schedule Type *(check all that apply)*
☒ Lecture (LEC)
☐ Laboratory (LAB)
☐ Discussion (DIS)
☐ Seminar (SEM)
☐ Lecture/Discussion combined (LED)
☐ Lecture/Laboratory combined (LEL)
☐ Thesis/Dissertation (THE)
☐ Hybrid Technology Intensive (HTI)
☐ Directed Reading or Research (DRR)
☐ Field Experience/Internship/Practicum (PRA)

14. Co-requisite Course(s)	**15a. Major Restriction** *(as it should appear in Catalog)*	**15b. Banner codes of acceptable majors**	**16. Class Standing Restriction**
ASTR 300L	N/A	N/A	N/A

17a. Prerequisite Course(s) *(Use "ands", "ors" and punctuation to indicate relationships between prerequisites. "Or consent" is implied for ALL prerequisites. "Consent" requirements can be implemented through your class schedules each semester.)*

ASTR 240 or 242; PHYS 152 or 274; MATH 215, 241, or 251A

17b. Minimum required grade for prerequisites	**17c. Blanket requirements listed in Catalog** *(if none, write "none")*
C	none

18. Catalog Description *(Limit 35 words; 85 words for alpha courses)*
Principles and techniques of optical and near-infrared astronomical observation. Astronomical coordinate systems. Telescopes, cameras, spectrographs, and detectors. Astrometry, photometry and spectroscopy of astronomical objects.

19. Justification *Attach separate sheets and indicate the rationale for the request, expected course enrollment, and a course syllabus specifying student learning objectives for the course.*

20. Cross-listed or Honors Course(s)

Course Subject & Number | Chair/Director | Signature | Date

Course Subject & Number | Chair/Director | Signature | Date

21. Requested By
I certify that the student learning objectives for the course are consistent with the learning objectives of each program under which the course is listed.

Phys. & Astr. | Pui Lam
Department/Unit | Chair/Director | Signature | Date

Approved By

1st College or School | Dean | Signature | Date

2nd College or School | Dean | Signature | Date

General Education *(Undergraduate courses numbered 100-499)*

Director | Signature | Date

Graduate Division *(600 level and above)*

Dean | Signature | Date

Mānoa Chancellor's Office

Vice Chancellor for Academic Affairs | Signature | Date

Rev. 1/2012

Course Justification for ASTRONOMY 300
Observational Astronomy

1 Description & Objectives

ASTR 300 is an introduction to the techniques of observational astronomy. In this course, students will learn how the observational properties of astronomical objects are measured and characterized. They will also acquire a working knowledge of astronomical telescopes, cameras, spectrographs, and detectors. Mastery of these topics will prepare students to plan, conduct, and analyze professional astronomical observations. The co-requisite lab course, ASTR 300L, will provide students with hands-on experience in reduction and analysis of astronomical data.

This course is designed to be taken after ASTR 240 or 242. It follows ASTR 240 in the pending Astronomy BA degree, and ASTR 242 in the pending Astrophysics BS degree. ASTR 300 assumes students have some knowledge of modern physics – in particular, the wave/particle nature of light, atomic structure, and atomic energy levels and transitions – at the level covered in PHYS 152 or 274; either of these courses can serve as a prerequisite. It also assumes students have a basic knowledge of calculus, including single-variable differentiation and integration; these topics are covered in MATH 215, 241, and 251a, and any one of these courses suffices as a prerequisite. More advanced aspects of physics and mathematics will be introduced when necessary; some advanced concepts will be presented phenomenologically.

2 Organization & Syllabus

ASTR 300 is a lecture course, meeting for three contact hours per week. The syllabus contains twelve sections, each spanning approximately one week; one week is allotted for final review, and two weeks are allotted for midterm exams and review.

1. **Astronomical Coordinates. I.** Equatorial coordinates. Coordinate transformation. Solar system and galactic coordinates.
2. **Astronomical Coordinates. II.** Elements of astrometry. Precession. Time systems.
3. **Light & Atoms.** Review of electromagnetic radiation, blackbody radiation, photons. Atomic structure, energy levels, transitions.
4. **Telescopes & Optics. I.** Geometric optics. Lenses & mirrors. Telescope design. Image formation & aberrations.
5. **Telescopes & Optics. II.** Wave optics. Interference & diffraction. Angular resolution. Gratings. Interferometers.
6. **Atmosphere & Seeing.** Atmospheric transparency. Sky glow. Atmospheric turbulence. Wavefront distortion. Introduction to adaptive optics.
7. **Photon Detectors. I.** Basic principles. Photoelectric effect. Semiconductors. Bolometers.
8. **Photon Detectors. II.** Detector arrays. Charge-coupled devices. Infrared arrays. Detector artifacts & their removal.
9. **Photometry. I.** Luminosity, intensity & flux. Apparent & absolute magnitude. Photometric systems. Calibration.

10. **Photometry. II.** Photometric transformations. Measurement of color. Imaging of extended objects. Aperture photometry.

11. **Spectroscopy. I.** Basic spectrograph design. Spectral lines & continuum. Line profiles. Equivalent widths.

12. **Spectroscopy. II.** Wavelength & flux calibration. Interpretation of spectra. Multiobject & integral-field spectroscopy.

There are several possible texts describing the practice and techniques of observational astronomy at the undergraduate level. One suitable text for a course at this level is F.R. Chromey's "To Measure the Sky" (2010), which can also serve as a text for the associated lab course, ASTR 300L.

2.1 Student learning outcomes

After taking this course, students will possess the conceptual background needed to plan, execute, and analyze basic astronomical observations. They will know how the observational properties of astronomical objects are described and measured. They will understand the strengths and limitations of astronomical instruments, and appreciate the constraints imposed by observing through the Earth's atmosphere. They will have some familiarity with the physics and electronics of modern detectors for optical and near-infrared astronomy. They will understand how the positions of astronomical objects are specified and determined observationally. They will know how the brightness and color of unresolved and resolved objects are described and measured. Finally, they will acquire a basic knowledge of astronomical spectroscopy, and understand how the spectra of stars and nebulae are observed and characterized.

3 Expected Enrollment

ASTR 300 is required of all students in the Astronomy BA and Astrophysics BS degree programs. These programs have not yet been approved and introduced, but based on queries from prospective students and enrollment in comparable programs elsewhere, we anticipate an enrollment of ~ 30 students per year.

4 Relation to Curriculum

ASTR 300 provides a practical introduction to observational astronomy. It is a key element of both the Astronomy BA and Astrophysics BS programs, and (along with ASTR 300L) a necessary gateway to hands-on astronomical observation with professional telescopes.

5 Overlap with Other Courses

ASTR 300 has very limited overlap with other undergraduate courses at UH Manoa. ASTR 240 discusses some aspects of magnitude and coordinate systems, but not at level of detail presented here. ASTR 633, which is required in the Astronomy MS and PhD programs, covers a superset of the material in ASTR 300 at the higher level appropriate for a graduate course.

The closest analog to ASTR 300 is offered at UH Hilo as ASTR 250; both courses cover key aspects of observational astronomy. However, ASTR 300 is intended for third-year students and assumes a higher level of preparation in physics and math.

6 Number of Credits

ASTR 300 is a substantial lecture course with three contact hours per week; it is appropriate for students to receive three credits for this course.

7 Student Evaluation

Students will be graded on the basis of (a) weekly problem sets, (b) two mid-term exams, and (c) a cumulative final exam.

8 Instructors

ASTR 300 focuses on the practice of observational astronomy. The majority of teaching faculty at the Institute for Astronomy (IfA) are working observational astronomers. Thus a large pool of potential instructors is available.

9 Impact on Workload

The IfA Graduate Chair, Dr. David Sanders, confirms that this course will not limit the ability of Physics & Astronomy to offer other courses already listed in the catalog. ASTR 300 is envisioned as a critical component of the new astronomy and astrophysics majors for which a proposal is in the process of being finalized. We expect that this course will be primarily staffed by faculty from the IfA.

UNIVERSITY OF HAWAIʻI AT MĀNOA
UHM-1 FORM (ADD A COURSE)

See *Guidelines* for instructions and deadlines. For undergraduate courses, submit an original and 4 copies; graduate courses, submit an original and 6 copies. If cross-listed, include extra copies for cross-listed department(s) & college(s). List one course per form. Attach additional sheets as needed.

1. Course Subject	2. Course Number	3. Effective Term *(semester & year)*	4. Frequency *(check all that apply)*
ASTR	300L	Fall 2013	☒ Fall semester ☐ Alternate years ☐ Spring semester ☐ Summer semester

5. Offering Status *(check one)*: ☒ Regular ☐ Experimental ☐ Single-term

6a. Full Course Title *(Alpha courses: attach separate sheet & specify title for each alpha*: Observational Astronomy Laboratory

6b. BANNER Course Title *(30 characters max, including spaces/punctuation. Alpha courses: attach separate sheet & specify title for each alpha)*: Observational Astronomy Lab

7. Grade Option *(check all that apply)*: ☒ Letter Grade ☐ Credit/No Credit ☐ Audit ☐ Satisfactory/Unsatisfactory (500, 700, 700F, 800, 800C only) ☐ Honors (Medicine only)

8. Gen Ed Core or Hawaiian/Second Language Requirement Designation *(check one)*
☐ Do not consider for Core or Hawaiian/Second Language designation.
☒ Request approval of DY Diversification (DA, DH, DL, DB, DP, DY, DS), Foundations (FW, FS, FG), or Hawaiian/Second Language (HSL) designation. (For Foundations, also submit a proposal to General Education Office.)

GEC Use: ☐ Approve ☐ Deny
GEC Initials

9. Contact Hours *(meeting hours per week – if variable, specify range)*	10. # of credits *(if variable, give range)*	11. Repeat Limit	12. Credit Limit
3	2	0	2

13. Schedule Type *(check all that apply)*: ☐ Lecture (LEC) ☐ Laboratory (LAB) ☐ Discussion (DIS) ☐ Seminar (SEM) ☐ Lecture/Discussion combined (LED) ☒ Lecture/Laboratory combined (LEL) ☐ Thesis/Dissertation (THE) ☐ Hybrid Technology Intensive (HTI) ☐ Directed Reading or Research (DRR) ☐ Field Experience/Internship/Practicum (PRA)

14. Co-requisite Course(s)	15a. Major Restriction *(as it should appear in Catalog)*	15b. Banner codes of acceptable majors	16. Class Standing Restriction
N/A	N/A	N/A	N/A

17a. Prerequisite Course(s) *(Use "ands", "ors" and punctuation to indicate relationships between prerequisites. "Or consent" is implied for ALL prerequisites. "Consent" requirements can be implemented through your class schedules each semester.)*

ASTR 300 (or concurrent); PHYS 152 or 274; PHYS 152L or 274L; MATH 215, 241, or 251A

17b. Minimum required grade for prerequisites	17c. Blanket requirements listed in Catalog *(if none, write "none")*
C	none

18. Catalog Description *(Limit 35 words; 85 words for alpha courses)*
Optical and near-infrared astronomy laboratory. Error analysis, properties of light, data and image processing. Astrometric, photometric, and spectroscopic measurement.

19. Justification *Attach separate sheets and indicate the rationale for the request, expected course enrollment, and a course syllabus specifying student learning objectives for the course.*

20. Cross-listed or Honors Course(s)

Course Subject & Number | Chair/Director | Signature | Date

Course Subject & Number | Chair/Director | Signature | Date

21. Requested By
I certify that the student learning objectives for the course are consistent with the learning objectives of each program under which the course is listed.

Phys. & Astr. | Pui Lam

Department/Unit | Chair/Director | Signature | Date

Approved By

1st College or School | Dean | Signature | Date

2nd College or School | Dean | Signature | Date

General Education *(Undergraduate courses numbered 100-499)*

Director | Signature | Date

Graduate Division *(600 level and above)*

Dean | Signature | Date

Mānoa Chancellor's Office

Vice Chancellor for Academic Affairs | Signature | Date

Rev. 1/2012

Course Justification for ASTRONOMY 300L
Observational Astronomy Laboratory

1 Description & Objectives

ASTR 300L is a practical introduction to the methods of observational astronomy. In this course, students will perform computer-based and hands-on exercises exploring key concepts which underlie observational astronomy. In addition, they will learn how to extract scientific information from astronomical data, using existing observations from telescopes on Mauna Kea and other professional facilities. In conjunction with ASTR 300 (Observational Astronomy), this course will prepare students for hands-on work with professional astronomical instruments.

This course is designed to be taken after ASTR 240 or 242. It follows ASTR 240 in the pending Astronomy BA degree, and ASTR 242 in the pending Astrophysics BS degree. ASTR 300L assumes students have some knowledge of modern physics – in particular, the wave/particle nature of light, atomic structure, and atomic energy levels and transitions – at the level covered in PHYS 152 or 274; either of these courses, along with the corresponding lab, can serve as prerequisites. ASTR 300L also assumes students have a basic knowledge of calculus, including single-variable differentiation and integration; these topics are covered in MATH 215, 241, and 251A, and any one of these courses suffices as a prerequisite. More advanced aspects of physics and mathematics will be introduced when necessary; some advanced concepts will be presented phenomenologically.

2 Organization & Syllabus

ASTR 300L is a laboratory course, meeting for three contact hours per week. We plan to schedule two meetings per week; each meeting will include a brief lecture and a longer laboratory activity. The syllabus contains seven sections, each spanning approximately two week; one week will be allotted for review.

1. **Measurement & Statistics.** Uncertainty & error. Gaussian statistics. Poisson statistics. Significance tests. Non-parametric tests.
2. **Experiments with Light. I.** Inverse-square law. Optical elements. Photoelectric effect.
3. **Experiments with Light. II.** Diffraction & interference. Wavelength measurement. Laboratory spectroscopy.
4. **Introduction to IDL.** Introduction to programming. Data types. Flow of control. Functions & procedures. Graphics.
5. **Image Processing.** CCD image data. Bias, dark, flat, fringe correction. Image manipulation.
6. **Photometry & Astrometry.** Photometry of unresolved and extended sources. Photometric calibration. World coordinate systems. Position measurements.
7. **Quantitative Spectroscopy.** Wavelength and flux calibration. Measurement of spectral lines. Equivalent width. Line profiles & broadening mechanisms.

The laboratory activities in ASTR 300L are coordinated with the topics covered in ASTR 300. For example, sections 2 and 3 above coincide with sections on light and optics in ASTR 300; section 5 is matched to a section on astronomical detectors, and sections 6 and 7 closely correspond to sections on photometry and spectroscopy. By taking these courses together (as recommended in the proposed BS and BA curricula), students will benefit by seeing lecture material promptly reinforced in the laboratory. However, it is also possible to take ASTR 300L after taking ASTR 300.

Students who have taken PHYS 274L may find some of the exercises in sections 2 and 3 redundant. Instead of requiring these students to repeat these exercises, we will offer them more advanced alternatives (e.g., compound optical systems, characteristics of optical aberrations, measurement of angular resolution, solar spectroscopy).

There are several possible texts describing the practice and techniques of observational astronomy at the undergraduate level. One suitable text for a course at this level is F.R. Chromey's "To Measure the Sky" (2010), which can also serve as a text for the associated lecture course, ASTR 300.

2.1 Student learning outcomes

After taking this course, students will possess the basic skills needed to analyze astronomical observations. They will understand the role of statistical inference in analysis of scientific data. They will be familiar with properties of light relevant to observational astronomy through laboratory experiments. They will have sufficient knowledge of scientific programming and image processing to perform basic exercises with real observational data. They will have direct experience in measuring the brightness, position, and spectral properties of astronomical objects from existing data sets.

3 Expected Enrollment

ASTR 300L will be required of all students in the Astronomy BA and Astrophysics BS degree programs. These programs have not yet been approved and introduced, but based on queries from prospective students and enrollment in comparable programs elsewhere, we anticipate net enrollment may reach ~ 30 students per year. Individual sections of ASTR 300L will be limited to 15 students to provide individual attention and insure efficient use of laboratory resources.

4 Relation to Curriculum

ASTR 300L provides a practical introduction to observational astronomy. It is a key element of the Astronomy BA and Astrophysics BS programs currently under development, and (along with ASTR 300) a necessary gateway to hands-on astronomical observation with professional telescopes.

5 Overlap with Other Courses

ASTR 300L has very limited overlap with other undergraduate courses at UH Manoa. The closest analog to ASTR 300L is offered at UH Hilo as ASTR 250L; both courses cover key aspects of observational astronomy. However, ASTR 300L assumes a higher level of preparation in physics and math.

6 Number of Credits

ASTR 300L is a substantial lab course with three contact hours per week. Outside of class, students will spend a considerable amount of time reading background material and writing lab reports. It is appropriate for students to receive two credits for this course.

7 Student Evaluation

Students will be graded on the basis of brief in-class quizzes and weekly lab reports. We will require lab reports to be written in a standardized format, including a title, abstract, methods, results, discussion, and references.

8 Instructors

ASTR 300L focuses on the practice of observational astronomy. The majority of teaching faculty at the Institute for Astronomy (IfA) are working observational astronomers. Thus a large pool of potential instructors is available.

9 Impact on Workload

The IfA Graduate Chair, Dr. David Sanders, confirms that this course will not limit the ability of Physics & Astronomy to give other courses already listed in the catalog. ASTR 300L is envisioned as a critical component of the new astronomy and astrophysics majors for which a proposal is in the process of being finalized. We expect that this course will be staffed by IfA faculty, with substantial help from graduate astronomy teaching assistants.

UNIVERSITY OF HAWAIʻI AT MĀNOA

UHM-1 FORM (ADD A COURSE)

See *Guidelines* for instructions and deadlines. For undergraduate courses, submit an original and 4 copies; graduate courses, submit an original and 6 copies. If cross-listed, include extra copies for cross-listed department(s) & college(s). List one course per form. Attach additional sheets as needed.

1. Course Subject: ASTR

2. Course Number: 301

3. Effective Term *(semester & year)*: Spring 2014

4. Frequency *(check all that apply)*: ☐ Fall semester ☑ Spring semester ☐ Summer semester ☐ Alternate years

5. Offering Status *(check one)*: ◉ Regular ☐ Experimental ☐ Single-term

6a. Full Course Title *(Alpha courses: attach separate sheet & specify title for each alpha)*: Observational Astronomy Projects

6b. BANNER Course Title *(30 characters max, including spaces/punctuation. Alpha courses: attach separate sheet & specify title for each alpha)*: Observational Projects

7. Grade Option *(check all that apply)*: ☑ Letter Grade ☐ Credit/No Credit ☐ Audit ☐ Satisfactory/Unsatisfactory (500, 700, 700F, 800, 800C only) ☐ Honors (Medicine only)

8. Gen Ed Core or Hawaiian/Second Language Requirement Designation *(check one)*:
☐ Do not consider for Core or Hawaiian/Second Language designation.
◉ Request approval of DY Diversification (DA, DH, DL, DB, DP, DY, DS), Foundations (FW, FS, FG), or Hawaiian/Second Language (HSL) designation.
(For Foundations, also submit a proposal to General Education Office.)

GEC Use: ☐ Approve ☐ Deny — GEC Initials

9. Contact Hours *(meeting hours per week – if variable, specify range)*: 3 - 6

10. # of credits *(if variable, give range)*: 4

11. Repeat Limit: 0

12. Credit Limit: 4

13. Schedule Type *(check all that apply)*: ☐ Lecture (LEC) ☐ Laboratory (LAB) ☐ Discussion (DIS) ☐ Seminar (SEM) ☐ Lecture/Discussion combined (LED) ☑ Lecture/Laboratory combined (LEL) ☐ Thesis/Dissertation (THE) ☐ Hybrid Technology Intensive (HTI) ☐ Directed Reading or Research (DRR) ☑ Field Experience/Internship/Practicum (PRA)

14. Co-requisite Course(s): N/A

15a. Major Restriction *(as it should appear in Catalog)*: N/A

15b. Banner codes of acceptable majors: N/A

16. Class Standing Restriction: N/A

17a. Prerequisite Course(s) *(Use "ands", "ors" and punctuation to indicate relationships between prerequisites. "Or consent" is implied for ALL prerequisites. "Consent" requirements can be implemented through your class schedules each semester.)*: ASTR 300 and 300L

17b. Minimum required grade for prerequisites: C

17c. Blanket requirements listed in Catalog *(if none, write "none")*: A grade of C (not C-) or better is required for all prerequisites.

18. Catalog Description *(Limit 35 words; 85 words for alpha courses)*:
Practical astronomical observing. Students select objects to study, plan and conduct remote observations using research-grade telescopes, reduce data, present results in written and verbal form. Introduces LaTeX, literature search, time allocation.

19. Justification *Attach separate sheets and indicate the rationale for the request, expected course enrollment, and a course syllabus specifying student learning objectives for the course. Syllabi are not required for "~99" courses.*

20. Cross-listed or Honors Course(s)

Course Subject & Number — Chair/Director — Signature — Date

Course Subject & Number — Chair/Director — Signature — Date

21. Requested By

I certify that the student learning objectives for the course are consistent with the learning objectives of each program under which the course is listed.

Department/Unit: Phys. & Astr. — Chair/Director: Pui Lam — Signature — Date

Approved By

1st College or School: Natural Sciences — Dean: Michael W. Peters — Signature — Date

2nd College or School — Dean — Signature — Date

General Education *(Undergraduate courses numbered 100-499)*

Director — Signature — Date

Graduate Division *(600 level and above)*

Dean — Signature — Date

Mānoa Chancellor's Office

Vice Chancellor for Academic Affairs — Signature — Date

Rev. 7/2012

Course Justification for ASTRONOMY 301
Observational Astronomy Projects

1 Description & Objectives

ASTR 301 is a hands-on introduction to the practice of observational astronomy. In this course, students will plan and conduct astronomical observations, using remote observing technology to access research-grade telescopes (e.g., the Faulkes Observatory on Haleakala). They will reduce their observations to obtain publication-quality scientific data, and present their results verbally and in written form. Students completing ASTR 301 will be prepared to undertake independent observational research under the supervision of Astronomy faculty.

This course is designed to be taken after ASTR 300 and 300L; these courses are listed as prerequisites. Thus, ASTR 301 assumes students are familiar with the characterization of astronomical objects, basic telescope and detector technology, and the techniques of image processing and analysis. In addition, students are expected to be familiar with concepts in astronomy at the level of ASTR 240 or 241+242, in modern physics at the level covered in PHYS 152 or 274, and single-variable calculus at the level covered in MATH 215, 241, and 251A. More advanced aspects of physics and mathematics will be introduced when necessary; some advanced concepts will be presented phenomenologically.

2 Organization & Syllabus

ASTR 301 combines a wide variety of activities. Planning and preparing for astronomical observation will be carried out during regularly-scheduled daytime meetings. Astronomical observations will typically occur at night, on a schedule dictated by the visibility of observational targets. Reduction and analysis of observational data can be performed during daytime hours in a computer lab, although students with access to suitable personal computers will be able to process data on their own. The course will meet for a minimum of three daytime contact hours per week.

Brief descriptions of some possible observing projects are given below. The actual projects to be undertaken will depend in part on student interest as well as visibility of relevant astronomical objects. At a minimum, each student will undertake 3 different projects, typically working in teams. Students will be required to form different teams for different projects.

1. **Asteroid orbit determination.** A small number of newly-discovered asteroids will be imaged periodically during the semester. Positions measured from these images will be used to construct and refine asteroid orbits.

2. **Asteroid rotation periods.** As a consequence of their irregular shapes, asteroids exhibit periodic variations in brightness as they rotate. Repeated observations of selected asteroids will be analyzed to measure brightness variations and deduce rotation periods.

3. **Star-cluster photometry.** Stars in clusters share a common distance, age, and chemical composition. By measuring the apparent brightnesses of cluster members in different colors, a synoptic portrait of a star cluster is assembled. The results can be used to deduce the cluster's age and distance, and infer the amount of light-absorbing dust along the line of sight.

4. **Variable-star light curves.** The intrinsic luminosities of some stars are periodically variable. A small number of variable stars will be monitored throughout the semester; images

taken in multiple colors will be analyzed and reduced to chart each star's variation in luminosity and color.

5. **Distances to nearby galaxies.** The distance to a galaxy can be measured directly if individual stars of known intrinsic brightness are observed within it. Cepheid variable stars are useful for such measurements, since there's a well-studied relationship between a Cepheid's period and its luminosity. Images of nearby galaxies, taken throughout the semester, will be reduced to find Cepheid variables and determine their periods; these in turn will allow galaxy distances to be determined.

6. **Galaxy photometry.** Multi-color images of galaxies encode information on galactic structure and stellar populations. Galaxies spanning a range of morphologies will be observed; the resulting images will be quantitatively analyzed to measure luminosity profiles and color gradients.

In the initial weeks of the course, students will select projects to undertake and draft brief observing proposals describing the objectives and observational resources necessary for each project. Meeting as a group, students will review these proposals and prioritize allocation of telescope time. Observations will commence shortly thereafter; the necessary data for some projects can be acquired in a few nights, while others will require observations spread over a month or more. Reduction and analysis of the data will begin as soon as possible. The final weeks of the course will focus on the interpretation of the data and presentation of scientific results in written and verbal form.

Students will be expected to consult primary sources as well as detailed instructions for individual observing projects. A suitable reference textbook for background concepts and techniques is F.R. Chromey's "To Measure the Sky" (2010), previously used as a text for ASTR 300.

2.1 Student learning outcomes

After taking this course, students will be familiar with the procedures and practices of modern observational astronomy. They will have acquired an understanding of the time-allocation process via direct participation in collective decision-making. They will have learned to operate a research-grade telescope using a remote observing system. They will have developed the skills needed to extract scientifically relevant information from real astronomical data, including an appreciation for random and systematic error. Finally, they will have learned to interpret their results and present them in written and verbal form.

3 Expected Enrollment

ASTR 301 will be required of all students in the Astronomy BA and Astrophysics BS degree programs. These programs have not yet been approved, but based on queries from prospective students and demand for comparable programs elsewhere, we anticipate demand may reach ~ 30 students per year. However, sections will be limited to 15 students to insure adequate interaction with faculty.

4 Relation to Curriculum

ASTR 301 provides a hands-on introduction to observational astronomy with research-grade telescopes. It is a key element of both the Astronomy BA and Astrophysics BS programs, and a necessary gateway to independent astronomical research.

5 Overlap with Other Courses

ASTR 301 has no significant overlap with other undergraduate courses at UH Manoa.

6 Number of Credits

ASTR 301 is a very substantial course with at least three contact hours per week; in addition, students will be required to participate in night-time observing sessions and reduce their data. At a minimum, the level of effort and commitment required for this course will be comparable to a combined lecture+laboratory course. It is therefore appropriate for students to receive four credits for this course.

7 Student Evaluation

Astr 301 is designed to be a writing-intensive course. We expect students to describe and document their work in written form throughout the semester. Informal written work, to be periodically reviewed by the instructors, will include comprehensive observational plans, observing logs, and detailed data analysis logs. Formal written work, to be reviewed and discussed by the entire class, will include observing proposals and final reports; the latter will be prepared using LaTeX to facilitate the seamless inclusion of mathematical equations and figures as needed. Informal written work must be complete and clear, while formal work, in addition, must display some degree of style and polish, follow a specified outline, and include complete references. In addition to written final reports, students will also make verbal presentations summarizing their findings to the entire class.

8 Instructors

ASTR 301 focuses on the practice of observational astronomy. The majority of teaching faculty at the Institute for Astronomy (IfA) are working observational astronomers. Thus a large pool of potential instructors is available.

9 Impact on Workload

The IfA Graduate Chair, Dr. David Sanders, confirms that this course will not limit the ability of Physics & Astronomy to offer other courses already listed in the catalog. ASTR 301 is envisioned as a critical component of the new astronomy and astrophysics majors for which a proposal is in the process of being finalized. We expect that this course will be staffed by faculty and teaching assistants from the IfA.

UNIVERSITY OF HAWAIʻI AT MĀNOA
UHM-1 FORM (ADD A COURSE)

See *Guidelines* for instructions and deadlines. For undergraduate courses, submit an original and 5 copies; graduate courses, submit an original and 6 copies. If cross-listed, include extra copies for cross-listed department(s) & college(s). List one course per form. Attach additional sheets as needed.

1. Course Subject	2. Course Number	3. Effective Term *(semester & year)*	4. Frequency *(check all that apply)*
ASTR	320	Spring 2015	☐ Fall semester ☑ Spring semester ☐ Summer semester ☐ Alternate years

5. Offering Status *(check one)*: ◉ Regular ☐ Experimental ☐ Single-term

6a. Full Course Title *(Alpha courses: attach separate sheet & specify title for each alpha*
Astronomical Spectroscopy

6b. BANNER Course Title *(30 characters max, including spaces/punctuation. Alpha courses: attach separate sheet & specify title for each alpha)*
Astronomical Spectroscopy

7. Grade Option *(check all that apply)*
☑ Letter Grade ☐ Credit/No Credit ☐ Audit ☐ Satisfactory/Unsatisfactory (500, 700, 700F, 800, 800C only) ☐ Honors (Medicine only)

8. Gen Ed Core or Hawaiian/Second Language Requirement Designation *(check one)*
☐ Do not consider for Core or Hawaiian/Second Language designation.
◉ Request approval of DP Diversification (DA, DH, DL, DB, DP, DY, DS), Foundations (FW, FS, FG), or Hawaiian/Second Language (HSL) designation. (For Foundations, also submit a proposal to General Education Office.)

GEC Use: ☐ Approve ☐ Deny
GEC Initials

9. Contact Hours *(meeting hours per week – if variable, specify range)*	10. # of credits *(if variable, give range)*	11. Repeat Limit *(Do NOT write "None")*	12. Credit Limit *(Do NOT write "None")*
3	3	0	3

13. Schedule Type *(check all that apply)*
☑ Lecture (LEC) ☐ Laboratory (LAB) ☐ Discussion (DIS) ☐ Seminar (SEM) ☐ Lecture/Discussion combined (LED) ☐ Lecture/Laboratory combined (LEL) ☐ Thesis/Dissertation (THE) ☐ Hybrid Technology Intensive (HTI) ☐ Directed Reading or Research (DRR) ☐ Field Experience/ Internship/Practicum (PRA)

14. Co-requisite Course(s)	15a. Major Restriction *(as it should appear in Catalog)*	15b. Banner codes of acceptable majors	16. Class Standing Restriction
N/A	N/A	N/A	N/A

17a. Prerequisite Course(s) *(Use "ands", "ors" and punctuation to indicate relationships between prerequisites. "Or consent" is implied for ALL prerequisites. "Consent" requirements can be implemented through your class schedules each semester.)*
ASTR 240 or 242; PHYS 152 or 274; MATH 216 or 242 or 252A

17b. Minimum required grade for prerequisites	17c. Blanket requirements listed in Catalog *(if none, write "none")*
C	A grade of C (not C-) or better is required for all prerequisites.

18. Catalog Description *(Limit 35 words; 85 words for alpha courses)*

Introduction to astronomical spectroscopy. Stellar atmospheres, line formation, elements of radiative transfer. Phases of interstellar material. Emission line diagnostics. Doppler shift and kinematics.

19. Justification *Attach separate sheets and indicate the rationale for the request, expected course enrollment, program learning objectives and institutional learning objectives that the new course will cover, and a course syllabus specifying student learning objectives for the course. Syllabi are not required for "~99" courses.*

20. Cross-listed or Honors Course(s)

Course Subject & Number   Chair/Director   Signature   Date

Course Subject & Number   Chair/Director   Signature   Date

21. Requested By
I certify that the student learning objectives for the course are consistent with the learning objectives of each program under which the course is listed.

Physics & Astronomy   Pui Lam
Department/Unit   Chair/Director   Signature   Date

Approved By

1st College or School   Dean   Signature   Date

2nd College or School   Dean   Signature   Date

General Education *(Undergraduate courses numbered 100-499)*

Director   Signature   Date

Graduate Division *(600 level and above)*

Dean   Signature   Date

Mānoa Chancellor's Office

Vice Chancellor for Academic Affairs   Signature   Date

Rev. 7/2013

Course Justification for ASTRONOMY 320
Astronomical Spectroscopy

1 Description & Objectives

ASTR 320 is an introduction to astronomical spectroscopy. In this course, students will learn the different characteristics of spectra produced by a variety of astronomical sources (stars, nebulae, galaxies), and what kind of information can be extracted from them. They will be exposed to the complexity of atomic and molecular energy levels, and will understand the formation of absorption and emission lines in widely different physical conditions. A good understanding of these topics will allow the student to fully appreciate the array of observational techniques regularly used in collecting the empirical knowledge that allows to build and test astrophysical theories.

This course is designed to be taken after ASTR 240 or 242. It is complementary to ASTR 300, 300L. PHYS 152 or 274 are prerequisites. MATH 216 or 242 or 252A are prerequisites.

2 Organization & Syllabus

ASTR 320 is a lecture course with extensive integrated discussion, meeting for three contact hours per week. The syllabus contains 10 sections. One week is allotted for final review. One week is allotted for midterm exams and review.

At least one discussion session will be included in each of the 10 sections of this course. At the beginning of each section, students will be given a short list of challenge questions. Several classes will typically be given as lectures, interspersed with brief active-learning exercises to focus student thinking and foreshadow subsequent discussion. The final class of each section will be devoted to discussion, problem-solving exercises, and student presentations. One or more of the challenge questions distributed at the start of the section will form the basis for a student-led discussion, guided as necessary by the instructor toward a clear resolution; other questions will be discussed informally as time permits. Some discussion sections will also include student presentations; these will be scheduled to insure that every student has at least one occasion to co-present a brief ($\sim$ 15 minute) review on a subject relevant to the course material. These presentations will also give students an opportunity to consult primary sources in the scientific literature.

2.1 Sections

1. **Theory of radiation.** Stellar radiation flux. Thermodynamic equilibrium and black-body radiation. Atomic energy levels.

2. **Spectra of stars.** Absorption and emission features. Doppler effect and radial velocities. Spectral classification. Thermal excitation and ionization: Boltzmann and Saha. Explanation of the OBAFGKMLTY sequence of spectral types.

3. **Theory of line broadening.** Rotational broadening and turbulence. Spectral luminosity classes. Curve of growth and abundance determinations. Model atmospheres and modern quantitative analysis of stellar spectra. Element abundances in the Sun and other stars. The concept of metallicity.

4. **Stellar winds and mass loss.** P Cygni profiles and their interpretation.
5. **The interstellar medium:** basic phases and properties.
6. **Thermal emission nebulae:** H II regions and planetary nebulae. Photoionization and recombination. Collisional excitation and metastable levels. Forbidden lines. Electron temperature and electron density diagnostics. Abundance determinations in gaseous nebulae. Non-thermal emission nebulae: SN remnants.
7. **Gas kinematics:** expansion distances, bubble formation.
8. **Neutral gas.** Absorption lines and bands from cold gas. H I 21-cm line observations, column densities, kinematic information. Lyα forest and the intergalactic medium.
9. **Molecular gas.** Molecular energy levels. CO lines and other important molecular lines.
10. **Integrated spectra of galaxies.** Line broadening by line-of-sight velocity dispersion in the stellar population: calibration and interpretation.

Because of the broad range of topics, no single textbook will cover all the material. The best solution is probably a set of lecture notes prepared by the instructor.

2.2 Student learning outcomes

After taking this course, students will know what kind of information can be extracted from the spectra of astronomical sources, how it is done in practice, and what are the limitations to each technique. They will acquire elementary knowledge of stellar and interstellar medium properties, and will be prepared to embark in the more detailed descriptions that characterize more advanced courses like ASTR 423, 426 or 430.

3 Expected Enrollment

ASTR 320 is required of all students in the Astronomy BA degree program, and is an elective for the Astrophysics BS degree program. These programs have not yet been approved and introduced, but based on queries from prospective students, and enrollment in comparable programs elsewhere, we anticipate an enrollment of ~ 20 students per year.

4 Relation to Curriculum

ASTR 320 provides a practical introduction to astronomical spectroscopy. It is a key element of the Astronomy BA program, one of several ASTR electives for the Astrophysics BS programs, and an important complement to ASTR 300 and 300L. Spectroscopic techniques are the foundation of most of our quantitative knowledge of the Universe.

5 Overlap with Other Courses

ASTR 320 initial topics overlap with ASTR 423, where some key concepts like spectral line formation and stellar abundance determinations are explored in more detail.

6 Number of Credits

ASTR 320 is a substantial lecture course with three contact hours per week; it is appropriate for students to receive three credits for this course.

7 Student Evaluation

Students will be graded on the basis of (a) in-class participation in discussion sessions and presentations, (b) weekly problem sets, (c) two mid-term exams, and (d) a cumulative final exam.

8 Instructors

ASTR 320 focuses on the foundations and practice of observational astronomy. The majority of teaching faculty at the Institute for Astronomy (IfA) are working observational astronomers. Therefore, several potential instructors are available.

9 Impact on Workload

The IfA Graduate Chair, Dr. David Sanders, confirms that this course will not limit the ability of Physics & Astronomy to offer other courses already listed in the catalog. ASTR 320 is envisioned as a critical component of the new astronomy and astrophysics majors for which a proposal is in the process of being finalized. We expect that this course will be primarily staffed by faculty from the IfA.

UNIVERSITY OF HAWAIʻI AT MĀNOA
UHM-1 FORM (ADD A COURSE)

See *Guidelines* for instructions and deadlines. For undergraduate courses, submit an original and 5 copies; graduate courses, submit an original and 6 copies. If cross-listed, include extra copies for cross-listed department(s) & college(s). List one course per form. Attach additional sheets as needed.

1. Course Subject	**2. Course Number**	**3. Effective Term** *(semester & year)*	**4. Frequency** *(check all that apply)*
ASTR	423	Spring 2015	☑ Fall semester ☐ Spring semester ☐ Summer semester ☐ Alternate years

5. Offering Status *(check one)*
- ☒ Regular
- ☐ Experimental
- ☐ Single-term

6a. Full Course Title *(Alpha courses: attach separate sheet & specify title for each alpha*
Stellar Astrophysics

6b. BANNER Course Title *(30 characters max, including spaces/punctuation. Alpha courses: attach separate sheet & specify title for each alpha)*
Stellar Astrophysics

7. Grade Option *(check all that apply)*
- ☑ Letter Grade
- ☐ Credit/No Credit
- ☐ Audit
- ☐ Satisfactory/Unsatisfactory (500, 700, 700F, 800, 800C only)
- ☐ Honors (Medicine only)

8. Gen Ed Core or Hawaiian/Second Language Requirement Designation *(check one)*
- ☐ Do not consider for Core or Hawaiian/Second Language designation.
- ☒ Request approval of DP Diversification (DA, DH, DL, DB, DP, DY, DS), Foundations (FW, FS, FG), or Hawaiian/Second Language (HSL) designation. (For Foundations, also submit a proposal to General Education Office.)

GEC Use: ☐ Approve ☐ Deny

GEC Initials

9. Contact Hours *(meeting hours per week – if variable, specify range)*	**10. # of credits** *(if variable, give range)*	**11. Repeat Limit** *(Do NOT write "None")*	**12. Credit Limit** *(Do NOT write "None")*
3	3	0	3

13. Schedule Type *(check all that apply)*
- ☑ Lecture (LEC)
- ☐ Laboratory (LAB)
- ☐ Discussion (DIS)
- ☐ Seminar (SEM)
- ☐ Lecture/Discussion combined (LED)
- ☐ Lecture/Laboratory combined (LEL)
- ☐ Thesis/Dissertation (THE)
- ☐ Hybrid Technology Intensive (HTI)
- ☐ Directed Reading or Research (DRR)
- ☐ Field Experience/ Internship/Practicum (PRA)

14. Co-requisite Course(s)	**15a. Major Restriction** *(as it should appear in Catalog)*	**15b. Banner codes of acceptable majors**	**16. Class Standing Restriction**
N/A	N/A	N/A	N/A

17a. Prerequisite Course(s) *(Use "ands", "ors" and punctuation to indicate relationships between prerequisites. "Or consent" is implied for ALL prerequisites. "Consent" requirements can be implemented through your class schedules each semester.)*
ASTR 242 and 300, and PHYS 480 (or concurrent)

17b. Minimum required grade for prerequisites	**17c. Blanket requirements listed in Catalog** *(if none, write "none")*
C	A grade of C (not C-) or better is required for all prerequisites.

18. Catalog Description *(Limit 35 words; 85 words for alpha courses)*

Stars: atmospheres, structure, and evolution. Radiative transfer, equations of state, nuclear reaction rates. Main-sequence and red-giant stars, supernovae, degenerate objects. Origin of elements.

19. Justification *Attach separate sheets and indicate the rationale for the request, expected course enrollment, program learning objectives and institutional learning objectives that the new course will cover, and a course syllabus specifying student learning objectives for the course. Syllabi are not required for "~99" courses.*

20. Cross-listed or Honors Course(s)

Course Subject & Number | Chair/Director | Signature | Date

Course Subject & Number | Chair/Director | Signature | Date

21. Requested By
I certify that the student learning objectives for the course are consistent with the learning objectives of each program under which the course is listed.

Physics & Astronomy | Pui Lam

Department/Unit | Chair/Director | Signature | Date

Approved By

1st College or School | Dean | Signature | Date

2nd College or School | Dean | Signature | Date

General Education *(Undergraduate courses numbered 100-499)*

Director | Signature | Date

Graduate Division *(600 level and above)*

Dean | Signature | Date

Mānoa Chancellor's Office

Vice Chancellor for Academic Affairs | Signature | Date

Rev. 7/2013

Course Justification for ASTRONOMY 423
Stellar Astrophysics

1 Description & Objectives

ASTR 423 is a calculus-based introduction to all the most important aspects of stellar astrophysics. In this course, students will be exposed to the basic properties of stars, and to a comprehensive array of techniques and procedures used to gain our knowledge of those properties. A thorough understanding of the information provided in this course is an essential prerequisite for any further work in astronomy.

This course is designed to be taken after ASTR 242, 300 and 320. PHYS 480 is a prerequisite, or can be taken concurrently.

2 Organization & Syllabus

ASTR 423 is a lecture course, meeting for three contact hours per week. The syllabus contains 9 sections. One week is allotted for final review. One week is allotted for midterm exams and review.

1. **Basic stellar parameters.** Size, mass, luminosity. Effective temperature. Observed quantities: angular size, apparent brightness, magnitudes, colors. Narrow-band photometry, monochromatic fluxes. Positions, proper motions, trigonometric parallax measurements from the ground and space. Distances and absolute magnitudes. The HR diagram. Bolometric magnitudes and bolometric corrections. Direct measurement of stellar angular sizes: interferometry and lunar occultation techniques. The Barnes-Evans relation.

2. **Stellar spectra.** Stellar absorption and emission features and spectral classification. Doppler shifts, radial velocity measurements, rotational broadening.

3. **Binary systems.** Methods for period determination: single and multiple periodicities. Double-lined spectroscopic binaries: radial velocity curves and derivation of orbital parameters. Double-lined eclipsing binaries: analysis of light curves and derivation of physical sizes and masses. Application of the Barnes-Evans relation for binary distance determinations.

4. **Luminosity classes.** The role of surface gravity. The $\log g$ – $\log T_{\rm eff}$ diagram. Theory of line broadening. Curve of growth and abundance determinations. Model atmospheres and modern quantitative analysis of stellar spectra. Element abundances in the Sun and other stars. Stellar winds and mass loss: P-Cygni profiles and their interpretation.

5. **Evolution of single stars.** Cepheids, RR Lyrae stars, and other pulsating variables. Baade-Wesselink method.

6. **The distance ladder.** Cluster main sequence fitting, cepheids in open clusters, cepheids in the LMC, calibration of the cepheid period–luminosity relation.

7. **End states of single stars:** brown dwarfs, planetary nebulae and white dwarfs, core-collapse supernovae. Neutron stars, pulsars and black holes. Gamma-ray bursters (long).

8. **Evolution in close binary systems.** Roche lobes, mass transfer and the Algol paradox. Common-envelope phase and planetary nebulae. Cataclysmic binaries and SNe of type Ia. Calibration of SN Ia light curves for cosmological distance determinations. Binary pulsars: testing general relativity. Gamma ray bursters (short).

9. **Origin of most natural elements:** nucleosynthesis in different phases of stellar evolution.

Because of the broad range of topics, no single textbook will cover all the material. The best solution is probably a set of lecture notes prepared by the instructor.

2.1 Student learning outcomes

After taking this course, students will be familiar with the basic properties of stars of all kinds, and will have working knowledge of the different methods used to investigate them. They will understand the step-by-step process of astronomical distance determinations, and will be prepared to undertake graduate studies and research activity in stellar astrophysics.

3 Expected Enrollment

ASTR 423 is required of all students in the BS Astrophysics program. This program has not yet been approved and introduced, but based on queries from prospective students, and enrollment in comparable programs elsewhere, we anticipate an enrollment of ~ 20 students per year.

4 Relation to Curriculum

ASTR 423 provides a thorough introduction to observational stellar astrophysics. It is a key element of the Astrophysics BS program.

5 Overlap with Other Courses

ASTR 320 initial topics overlap with ASTR 423, where some key concepts like spectral line formation and stellar abundance determinations are explored in more detail.

6 Number of Credits

ASTR 423 is a substantial lecture course with three contact hours per week; it is appropriate for students to receive three credits for this course.

7 Student Evaluation

Students will be graded on the basis of (a) weekly problem sets, (b) a mid-term exam, and (c) a cumulative final exam.

ASTR 423 is the most advanced and rigorous lecture course in the Astrophysics sequence. It discusses the astrophysics of stars at a high level, making extensive use of Quantum Mechanics and the methods of Mathematical Physics. As such, ASTR 423 provides an opportunity to assess the overall success of the BS Astrophysics program, and the exams and assignments for this course will be designed and graded with program assessment in mind.

8 Instructors

ASTR 423 focuses on the foundations and practice of observational stellar astrophysics. The majority of teaching faculty at the Institute for Astronomy (IfA) are working observational astronomers. Therefore, several potential instructors are available.

9 Impact on Workload

The IfA Graduate Chair, Dr. David Sanders, confirms that this course will not limit the ability of Physics & Astronomy to offer other courses already listed in the catalog. ASTR 423 is envisioned as a critical component of the new astronomy and astrophysics majors for which a proposal is in the process of being finalized. We expect that this course will be primarily staffed by faculty from the IfA.

UNIVERSITY OF HAWAIʻI AT MĀNOA
UHM-1 FORM (ADD A COURSE)

See *Guidelines* for instructions and deadlines. For undergraduate courses, submit an original and 5 copies; graduate courses, submit an original and 6 copies. If cross-listed, include extra copies for cross-listed department(s) & college(s). List one course per form. Attach additional sheets as needed.

1. Course Subject	**2. Course Number**	**3. Effective Term** *(semester & year)*	**4. Frequency** *(check all that apply)*
ASTR	426	Spring 2015	☐ Fall semester ☑ Spring semester ☐ Summer semester ☑ Alternate years

5. Offering Status *(check one)*
- ◉ Regular
- ○ Experimental
- ○ Single-term

6a. Full Course Title *(Alpha courses: attach separate sheet & specify title for each alpha*
Galaxies & Cosmology

6b. BANNER Course Title *(30 characters max, including spaces/punctuation. Alpha courses: attach separate sheet & specify title for each alpha)*
Galaxies & Cosmology

7. Grade Option *(check all that apply)*
- ☑ Letter Grade
- ☐ Credit/No Credit
- ☐ Audit
- ☐ Satisfactory/Unsatisfactory (500, 700, 700F, 800, 800C only)
- ☐ Honors (Medicine only)

8. Gen Ed Core or Hawaiian/Second Language Requirement Designation *(check one)*
- ○ Do not consider for Core or Hawaiian/Second Language designation.
- ◉ Request approval of DP Diversification (DA, DH, DL, DB, DP, DY, DS), Foundations (FW, FS, FG), or Hawaiian/Second Language (HSL) designation. (For Foundations, also submit a proposal to General Education Office.)

GEC Use: ☐ Approve ☐ Deny
GEC Initials

9. Contact Hours *(meeting hours per week – if variable, specify range)*	**10. # of credits** *(if variable, give range)*	**11. Repeat Limit** *(Do NOT write "None")*	**12. Credit Limit** *(Do NOT write "None")*
3	3	0	3

13. Schedule Type *(check all that apply)*
- ☑ Lecture (LEC)
- ☐ Laboratory (LAB)
- ☐ Discussion (DIS)
- ☐ Seminar (SEM)
- ☐ Lecture/Discussion combined (LED)
- ☐ Lecture/Laboratory combined (LEL)
- ☐ Thesis/Dissertation (THE)
- ☐ Hybrid Technology Intensive (HTI)
- ☐ Directed Reading or Research (DRR)
- ☐ Field Experience/Internship/Practicum (PRA)

14. Co-requisite Course(s)	**15a. Major Restriction** *(as it should appear in Catalog)*	**15b. Banner codes of acceptable majors**	**16. Class Standing Restriction**
N/A	N/A	N/A	N/A

17a. Prerequisite Course(s) *(Use "ands", "ors" and punctuation to indicate relationships between prerequisites. "Or consent" is implied for ALL prerequisites. "Consent" requirements can be implemented through your class schedules each semester.)*
ASTR 300; PHYS 152 or 274; MATH 216 or 242 or 252A

17b. Minimum required grade for prerequisites	**17c. Blanket requirements listed in Catalog** *(if none, write "none")*
C	A grade of C (not C-) or better is required for all prerequisites.

18. Catalog Description *(Limit 35 words; 85 words for alpha courses)*

Extragalactic astronomy. Galaxy morphology & kinematics. Luminosity functions. Dark matter. Groups & clusters. Lensing. Redshifts. Homogeneous cosmological models. The Big Bang. Thermal history of the Universe. Structure formation.

19. Justification *Attach separate sheets and indicate the rationale for the request, expected course enrollment, program learning objectives and institutional learning objectives that the new course will cover, and a course syllabus specifying student learning objectives for the course. Syllabi are not required for "~99" courses.*

20. Cross-listed or Honors Course(s)

Course Subject & Number	Chair/Director	Signature	Date

21. Requested By
I certify that the student learning objectives for the course are consistent with the learning objectives of each program under which the course is listed.

Department/Unit	Chair/Director	Signature	Date
Physics & Astronomy	Pui Lam		

Approved By

		Signature	Date
1st College or School	Dean		
2nd College or School	Dean		

General Education *(Undergraduate courses numbered 100-499)*
Director — Signature — Date

Graduate Division *(600 level and above)*
Dean — Signature — Date

Mānoa Chancellor's Office
Vice Chancellor for Academic Affairs — Signature — Date

Rev. 7/2013

Course Justification for ASTRONOMY 426
Galaxies & Cosmology

1 Description & Objectives

ASTR 426 is an advanced survey of extragalactic astronomy. In this course, students will learn about galaxies, galaxy clusters, and the largest structures in the astronomical universe. These objects and their formation will be placed in context based on the standard cosmological model, ΛCDM. ASTR 426 presents an accurate, although necessarily brief, summary of our current understanding of galaxies and cosmology. For students continuing to graduate school in astronomy, this course provides an introduction to a rich and active area of astronomical research.

This course will be offered in alternate years as an elective for both the Astronomy BA and Astrophysics BS degrees. It will typically be taken in the Spring of the junior or senior year. Students are assumed to be familiar with observational astronomy at the ASTR 300 level, and to have previously encountered basic aspects of galaxies & cosmology in ASTR 240 or 242. They should have completed PHYS 152 or 274, which provide necessary background in mechanics, electromagnetism, and some aspects of modern physics. Mathematics through Calculus II (MATH 216, 242, or 252A), covering integration, differentiation, and ordinary differential equations will be used routinely. More advanced concepts in physics and mathematics will be introduced as needed.

2 Organization & Syllabus

ASTR 426 is a lecture course with extensive integrated discussion, meeting for three contact hours per week. The syllabus contains three sections: (I) Phenomenology of Galaxies, (II) The Standard Cosmological Model, and (III) Galaxy Formation. The first two sections introduce the key subjects of the course, and the third section integrates this material to provide a comprehensive picture. Each section will span four weeks; reviews and midterms will be given after sections I and II.

By design, ASTR 426 will meet on a MWF schedule and cover a specific topic each week. At the beginning of each week, students will be given a short list of challenge questions associted with that week's topic. The Monday and Wednesday classes will typically be given as lectures, interspersed with brief active-learning exercises to focus student thinking and foreshadow subsequent discussion. The final class of each week will be devoted to discussion, problem-solving exercises, and student presentations. One or more of the challenge questions distributed at the start of the week will form the basis for a student-led discussion, guided as necessary by the instructor toward a clear resolution; other questions will be discussed informally as time permits. Some weeks will also include student presentations; these will be scheduled to insure that every student has at least one occasion to co-present a brief ($\sim$ 15 minute) review on a subject relevant to the course material. These presentations will also give students an opportunity to consult primary sources in the scientific literature.

2.1 Topics

A week-by-week outline might run as follows:

1. **Introduction.** Discovery of galaxies. Structure of the Milky Way. Hubble's law. Dark matter and dark energy.
2. **Galaxy Mechanics.** Gravitational fields. Orbital motion. Two-body relaxation. Violent relaxation. Dynamical equilibrium.
3. **Spiral and Elliptical Galaxies.** The Hubble diagram. Properties of spiral, elliptical, and dwarf galaxies. The luminosity function.
4. **Groups, Clusters, and Large-Scale Structure.** The Local Group. The Local Supercluster. Loose and compact groups. Structure and contents of rich galaxy clusters. Redshift surveys. Correlation functions. Walls and voids.
5. **The Expanding Universe.** Cosmological distance scales. The redshift-distance relation. Homogeneity and isotropy. Kinematics of the expanding universe.
6. **Homogeneous Cosmological Models.** Newtonian cosmology. Relativistic models. Equations of state. Open, closed, and critical models.
7. **The Microwave Background.** The Big Bang. Detection of the Cosmic Microwave Background. Recombination and decoupling. Temperature fluctuations.
8. **Cosmic Nucleosynthesis.** Thermal history of the Early Universe. Neutrons and protons. Nuclear reactions in the Early Universe. Synthesis of deuterium, helium, and lithium.
9. **Gravitational Structure Formation.** The Jeans instability. Effects of expansion. The fluctuation spectrum. Hot and cold dark matter.
10. **Galaxy Formation Scenarios.** Collapse models. Hierarchical models. Core collapse in heavy halos. Infall and mergers.
11. **Photometric, Chemical, and Dynamical Evolution.** Overview of stellar evolution. Stellar populations. Chemical enrichment by super-novae. Inflows and outflows. Dynamical instabilities.
12. **The Universe at High Redshift.** The high-redshift galaxy zoo. Quasars and active galaxies. The Lyman-α forest.

2.2 Textbooks

The two key subjects of this course are typically covered in separate textbooks. Fortunately, a number of good options are available. For example, "Galaxies in the Universe" by L.S. Sparke & J.S. Gallagher, III could be paired with "Introduction to Cosmology" by B. Ryden; both books are written for juniors and seniors majoring in astronomy and physics.

2.3 Student learning outcomes

After taking ASTR 426, students will have a broad but reasonably precise knowledge of galaxies, cosmology, and the interface between these subjects. They will be able to describe galaxies as physical objects, characterize their contents, and apply physical concepts such as dynamical equilibrium. They will know how to describe the kinematics of simple cosmological models, calculate their evolution using Newtonian mechanics, and generalize to include relativistic effects. They will understand the significance of cosmological relics such as microwave background photons and light elements, and be able to discuss the connection between them. They will have a basic understanding of gravitational instability, the physics of cosmic structure formation, and specific models for galaxy formation. Finally, they will be able to quantitatively describe the evolution of galaxies due to stellar and dynamical processes, and trace this evolution from high-redshift until the present.

3 Expected Enrollment

ASTR 426 will be targeted at juniors and seniors who have already taken a substantial number of Astronomy courses. We expect enrollment of approximately 15–25 students in ASTR 426.

4 Relation to Curriculum

ASTR 426 is a capstone course, designed to provide students in the third and fourth years of the BA Astronomy and BS Astrophysics programs with an integrated picture of a major area of astronomical research.

5 Overlap with Other Courses

ASTR 426 has limited overlap with other undergraduate courses at UHM. ASTR 280 treats a number of the same topics, but does so with fairly simple physics and math; it may be a good preparation for ASTR 426, but in no way replaces it. ASTR 242 discusses galaxies as physical systems but does not have time to present observational galactic astronomy in detail and does not touch on cosmology or galaxy formation.

6 Number of Credits

ASTR 426 is a substantial lecture/discussion course with three contact hours per week; it is appropriate for students to receive three credits for this course.

7 Student Evaluation

Students will be graded on the basis of (a) in-class participation in discussion sessions and presentations, (b) weekly problem sets, (c) two mid-term exams, and (d) a cumulative final exam.

ASTR 426 is one of the most advanced and rigorous courses in the BA Astronomy and BS Astrophysics programs. It presents observations and theory of galaxies and cosmology at a high level, drawing extensively on basic observational astronomy and elements of classical and modern physics. Consequently, ASTR 426 provides an opportunity to assess several key components of the BA Astronomy and BS Astrophysics programs, including physical laws and their application to astronomy, as well as the observational properties of astronomical objects. The exams and assignments for this course will be designed and graded with program assessment in mind.

8 Instructors

ASTR 426 covers key topics in extragalactic astronomy. A large number of teaching faculty at the Institute for Astronomy conduct research on galaxies or cosmology. Therefore, several potential instructors are available.

9 Impact on Workload

The IfA Graduate Chair, Dr. David Sanders, confirms that this course will not limit the ability of Physics & Astronomy to offer other courses already listed in the catalog. ASTR 426 is envisioned as a critical component of the new astronomy and astrophysics majors for which a proposal is in the process of being finalized. We expect that this course will be primarily staffed by faculty from the IfA.

UNIVERSITY OF HAWAIʻI AT MĀNOA
UHM-1 FORM (ADD A COURSE)

See *Guidelines* for instructions and deadlines. For undergraduate courses, submit an original and 5 copies; graduate courses, submit an original and 6 copies. If cross-listed, include extra copies for cross-listed department(s) & college(s). List one course per form. Attach additional sheets as needed.

1. Course Subject: ASTR

2. Course Number: 495

3. Effective Term *(semester & year)*: Spring 2015

4. Frequency *(check all that apply)*
- ☑ Fall semester
- ☑ Spring semester
- ☐ Summer semester
- ☐ Alternate years

5. Offering Status *(check one)*
- ◉ Regular
- ○ Experimental
- ○ Single-term

6a. Full Course Title *(Alpha courses: attach separate sheet & specify title for each alpha*
Senior Research Project

6b. BANNER Course Title *(30 characters max, including spaces/punctuation. Alpha courses: attach separate sheet & specify title for each alpha)*
Senior Project

7. Grade Option *(check all that apply)*
- ☑ Letter Grade
- ☐ Credit/No Credit
- ☐ Audit
- ☐ Satisfactory/Unsatisfactory (500, 700, 700F, 800, 800C only)
- ☐ Honors (Medicine only)

8. Gen Ed Core or Hawaiian/Second Language Requirement Designation *(check one)*
- ○ Do not consider for Core or Hawaiian/Second Language designation.
- ○ Request approval of ________ Diversification (DA, DH, DL, DB, DP, DY, DS), Foundations (FW, FS, FG), or Hawaiian/Second Language (HSL) designation. (For Foundations, also submit a proposal to General Education Office.)

GEC Use: ☐ Approve ☐ Deny
__________ GEC Initials

9. Contact Hours *(meeting hours per week – if variable, specify range)*	10. # of credits *(if variable, give range)*	11. Repeat Limit *(Do NOT write "None")*	12. Credit Limit *(Do NOT write "None")*
2 - 5	2 - 4	1	8

13. Schedule Type *(check all that apply)*
- ☐ Lecture (LEC)
- ☐ Laboratory (LAB)
- ☑ Discussion (DIS)
- ☐ Seminar (SEM)
- ☐ Lecture/Discussion combined (LED)
- ☐ Lecture/Laboratory combined (LEL)
- ☐ Thesis/Dissertation (THE)
- ☐ Hybrid Technology Intensive (HTI)
- ☐ Directed Reading or Research (DRR)
- ☑ Field Experience/Internship/Practicum (PRA)

14. Co-requisite Course(s)	15a. Major Restriction *(as it should appear in Catalog)*	15b. Banner codes of acceptable majors	16. Class Standing Restriction
N/A	N/A	N/A	N/A

17a. Prerequisite Course(s) *(Use "ands", "ors" and punctuation to indicate relationships between prerequisites. "Or consent" is implied for ALL prerequisites. "Consent" requirements can be implemented through your class schedules each semester.)*
ASTR 301

17b. Minimum required grade for prerequisites	17c. Blanket requirements listed in Catalog *(if none, write "none")*
C	A grade of C (not C-) or better is required for all prerequisites.

18. Catalog Description *(Limit 35 words; 85 words for alpha courses)*

Research in observational, theoretical, or numerical astronomy or astronomical instrumentation development, supervised by Institute for Astronomy faculty. Significant written products required.

19. Justification *Attach separate sheets and indicate the rationale for the request, expected course enrollment, program learning objectives and institutional learning objectives that the new course will cover, and a course syllabus specifying student learning objectives for the course. Syllabi are not required for "~99" courses.*

20. Cross-listed or Honors Course(s)

Course Subject & Number	Chair/Director	Signature	Date

21. Requested By
I certify that the student learning objectives for the course are consistent with the learning objectives of each program under which the course is listed.

Department/Unit	Chair/Director	Signature	Date
Physics & Astronomy	Pui Lam		

Approved By

		Signature	Date
1st College or School	Dean		
2nd College or School	Dean		

General Education *(Undergraduate courses numbered 100-499)*

Director ____ Signature ____ Date ____

Graduate Division *(600 level and above)*

Dean ____ Signature ____ Date ____

Mānoa Chancellor's Office

Vice Chancellor for Academic Affairs ____ Signature ____ Date ____

Rev. 7/2013

Course Justification for ASTRONOMY 495
Senior Research Project

1 Description & Objectives

ASTR 495 is designed to provide a structured research experience for students in the final year of the Astrophysics BS and Astronomy BA programs. In this course, students will conduct individual research projects under the supervision of astronomy faculty. Astrophysics BS students will be required to take six credits of ASTR 495 and describe the results of their work in a detailed research paper – in effect, a senior thesis. Astronomy BA students must take at least three credits of ASTR 495 and produce a significant written report. Both BA and BS students will also be required to present their work verbally.

This course provides a mechanism whereby UH Manoa undergraduates can participate in cutting-edge astronomical research. It harnesses the outstanding research prowess of the Institute for Astronomy (IfA), an internationally-recognized center of excellence in optical and infrared astronomy and instrumentation. Students will be able to pursue projects in observational, theoretical, and numerical astronomy and instrument development. Significant undergraduate research experience is strongly correlated with success in graduate education; this course will allow UH Manoa students to compete effectively for admission to elete graduate programs.

This course is designed to be taken in the senior year, after students have taken ASTR 301 and acquired hands-on experience in observational astronomy with professional telescopes and analysis techniques. While ASTR 301 is the only prerequisite for this course, the structure of the Astrophysics BS and Astronomy BA programs insures that students enrolling in ASTR 495 are ready to begin independent research.

2 Organization & Syllabus

ASTR 495 projects will span a wide range of subjects; it is not possible to outline a syllabus in advance. However, the organization of the course can be made explicit; this is in fact a necessity for the students and the faculty who mentor them. The highly successful Research Experience for Undergraduates (REU) program at the IfA provides a plausible model for the design of ASTR 495.

IfA faculty interested in mentoring undergraduates will form a working group, chaired by the Undergraduate Chair. This group will generate and discuss a set of brief research proposals, which will be distributed to BA Astronomy and BS Astrophysics students during the spring semster of their junior year. This will provide time for students to explore possibilities and have informal discussions with potential mentors. In their senior year, students will formally select their projects and, in collaboration with their mentors, develop detailed plans for conducting their research.

Our experience with REU students shows that motivated undergraduates are capable of advanced research if they receive close supervision and support. We will therefore require that ASTR 495 students meet with mentoring faculty for a minimum of two hours per week. These meetings should be scheduled at regular times and must be made up if missed. In addition, the working group of IfA faculty mentoring undergraduates will continue to meet at regular intervals to monitor progress and discuss problems as they arise. These meetings will help insure that students are held to a uniform standard.

While ASTR 495 is a variable-credit course, all participating students will be expected to write up and present their research at the end of each semester. Detailed progress reports or interm research papers will be required of continuing students. All students will give brief research talks to an audience including their peers as well as IfA faculty, postdocs, and graduate students.

2.1 Student learning outcomes

After completing this course, Astrophysics BS students will be prepared for independent research at the graduate level, and Astronomy BA students will have a good grasp of the nature and conduct of scientific research. By direct participation, students will have learned how research projects are developed, conducted, and presented. They will have first-hand experience with the scientific literature. Depending on the details of individual projects, they may have participated in (a) drafting observing proposals, (b) conducting astronomical observations, developing instruments, running numerical simulations, or mining observational databases and (c) writing and submitting papers to refereed journals. Students will also have learned how to present brief, focused talks summarizing their research, and field questions posed by the audience.

3 Expected Enrollment

Students in the BS Astrophysics program must take two semesters of ASTR 495, while students in the BA Astronomy program must take at least one semester. These programs have not yet been approved and introduced, but based on queries from prospective students and enrollment in comparable programs elsewhere, we anticipate an enrollment of ~ 15 to 25 students per year.

4 Relation to Curriculum

ASTR 495 provides a capstone research experience for the Astrophysics BS and Astronomy BA programs. The BS program is designed to prepare students for graduate school in Astronomy or Physics; we consider the solid research experience provided by 6 credits of ASTR 495 to be a critical element of this program. The BA program has a wider scope, appropriate for careers in science writing, telescope or planetarium operation, or other STEM areas; students in the BA program will take between 3 and 6 credits of ASTR 495 to gain research experience.

5 Overlap with Other Courses

ASTR 495 has some overlap with ASTR 399, which also offers supervised research with Astronomy faculty. However, the objectives of the two courses are different. ASTR 399 can accommodate a wide variety of directed reading and research activities for undergraduates at different levels. ASTR 495 is specifically designed to provide a capstone research experience for students in the last year of the Astrophysics BS and Astronomy BA programs.

6 Number of Credits

ASTR 495 is a variable-credit course. Astrophysics BS students are required to take a total of 6 credits of ASTR 495 spread over two semesters. Astronomy BA students may register for either one or two semesters, taking between 3 and 6 credits in total. The number of credits taken in a given semester will be determined by the student and the mentor, and must be approved by the Undergraduate Chair to insure that uniform standards are maintained.

7 Student Evaluation

Evaluation of research is inherently difficult, since the outcome of a research project can't be predicted in advance, and the eventual impact of a finding may not become apparent for some time. Individual mentors typically have detailed knowledge of student effort and performance, but do not always have the objectivity needed to view student work in context.

To provide a concrete record, each ASTR 495 student will be required to keep a detailed log of their research activities. This log will be reviewed by the mentor and Undergraduate Chair before a final course grade is assigned. Students will receive separate grades and detailed feedback on their progress reports, research papers, and research talks. At the end of each semester, mentors will provide brief written statements assessing student performance, with attention to effort, initative, and creativity; these will be reviewed and forwarded to the students.

8 Instructors

The Undergraduate Chair will serve as the instructor of record for ASTR 495. This will simplify the paperwork involved and insure that grades are submitted in a uniform and timely manner. Mentors for ASTR 495 projects will be recruited from the research faculty at the IfA. We have a large pool of researchers covering virtually every aspect of observational astronomy and instrumentation, as well as significant theoretical and numerical expertise.

9 Impact on Workload

The IfA Graduate Chair, Dr. David Sanders, confirms that this course will not limit the ability of Physics & Astronomy to offer other courses already listed in the catalog. ASTR 495 is envisioned as a critical component of the new astronomy and astrophysics majors for which a proposal is in the process of being finalized. We expect that this course will be staffed by faculty from the IfA.

Appendix E.

Revised Course Listings in support of Astrophysics/Astronomy Majors

(UHM-2 Cover Form + New Justification if needed)

ASTR 240	Foundations of Astronomy	(effective – F’13)
ASTR 427	Cosmology	(effective – S’15)
ASTR 430	The Solar System	(effective – S’15)

UNIVERSITY OF HAWAI'I AT MĀNOA

UHM-2 FORM (MODIFY/DELETE A COURSE)

See *Guidelines* for instructions and deadlines. For undergraduate courses, submit an original and 4 copies; graduate courses, submit an original and 6 copies. If cross-listed, include extra copies for cross-listed department(s) & college(s). List one course per form. Attach additional sheets as needed.

1. Transaction Type	2. Course Subject and Number	3. Existing Full Course Title	4. Effective Term of Change
☒ Modify ☐ Delete	Astr 240	Foundations of Astronomy	Spring 2013

5. Honors Counterpart Exists? ☒ No *(To add honors counterpart course also check Box 8n)* ☐ Yes – *Honors Program must sign box 11. Specify course:*

6. Existing Cross-Listed Course(s) *Signature of cross-listed department(s) required in Box 11 and Dean(s) in "Approved By" section. To remove cross-listed status also check Box 8n.*

7. Existing Diversification, Foundations, Hawaiian/ Second Language Designation *If requesting change to designation also fill out Box 8f* DP

GEC Use: ☐ Continue ☐ Remove

GEC Initials

8. Type of Change *Check all that apply. For each change, fill in CHANGE DETAILS below. Read instructions carefully before completing this section. Use additional sheets if needed.*

- ☐ a. Course Subject &/or Number
- ☐ b. Frequency
- ☐ c. Offering Status
- ☐ d. Full Course Title/Banner Title *(Banner title 30 char. max incl. spaces/punctuation)*
- ☐ e. Grade Option
- ☐ f. Diversification, Foundations, Hawaiian/Second Language Designation
- ☐ g. Contact Hours/Number of Credits/Repeat Limit/Credit Limit
- ☐ h. Schedule Type
- ☐ i. Co-requisite Course(s)
- ☐ j. Major Restrictions
- ☐ k. Class Standing Restrictions
- ☒ l. (i) Prerequisite Course(s) (ii) Prerequisite Grade Requirement (iii) Blanket Requirements (iv) NI Status
- ☒ m. Catalog Description
- ☐ n. Cross-listed/Honors Course(s) – *Signatures required in Box 11 (& "Approved By" section for cross-listings). Submit syllabus for honors courses.*

CHANGE DETAILS

Change Type *(Specify letter noted above)*	Existing Data *(Check Banner to confirm)*	Proposed Data *(Enter data as it should appear AFTER change. Use Box 9 to describe change.)*
M.	Introduction to the astronomical universe for science or engineering students. Satisfies requirements for non-introductory level credit. Pre: PHYS 151 or PHYS 170, or consent. Credit not given for both 110 and 240. NI DP	A rigorous overview of modern astronomy: solar system, stellar, galactic and extragalactic astronomy and cosmology. For science and engineering students. Pre: PHYS 151 or PHYS 170, or consent. NI DP
L. (ii)	C-	C

9. Description of Change(s) & Justification *Describe the change and why it is being requested, including its relationship to your overall curriculum. Attach additional sheets if needed. Attach a course syllabus for the modified course specifying student learning objectives for the course.*

Change description and minimum prerequisite grade. The new description reflects the content of 240 more accurately. 240 is more advanced than 110; students who take 110 should not be discouraged from taking 240. The existing statement about non-introductory credit is not necessary since the course is designated NI. The new minimum grade of C for prerequisites is consistent with the minimum for 241; it will not significantly limit enrollment and is appropriate once 240 is reintroduced as a gateway course for an Astronomy BA.

10. Consultation: If other UHM departments and/or UH-system campuses will be affected, have they been consulted? (e.g., course is a prerequisite, required for another major, offered at another UH campus, etc.) ☐ Yes – *Indicate offices/campuses:* ☒ Not applicable

11. Cross-listed Department(s)/Honors Program

Dept/Unit	Chair/Director	Signature	Date

12. Requested By

I certify that the student learning objectives for this modified course are consistent with the learning objectives of each program under which the course is listed.

Dept/Unit	Chair/Director	Signature	Date
Phys. & Astr.	Pui Lam		

Approved By

1st College/School	Dean	Signature	Date
2nd College/School	Dean	Signature	Date

General Education *(Undergraduate courses numbered 100-499)*

Director — Signature — Date

Graduate Division *(600 level and above)*

Dean — Signature — Date

Mānoa Chancellor's Office

Vice Chancellor for Academic Affairs — Signature — Date

Rev. 1/2012

UNIVERSITY OF HAWAI'I AT MĀNOA

UHM-2 FORM (MODIFY/DELETE A COURSE)

See *Guidelines* for instructions and deadlines. For undergraduate courses, submit an original and 4 copies; graduate courses, submit an original and 6 copies. If cross-listed, include extra copies for cross-listed department(s) & college(s). List one course per form. Attach additional sheets as needed.

1. Transaction Type	2. Course Subject and Number	3. Existing Full Course Title	4. Effective Term of Change
☐ Modify ☒ Delete	ASTR 427	Cosmology	Spring 2014

5. Honors Counterpart Exists? ☒ No *(To add honors counterpart course also check Box 8n)* ☐ Yes – *Honors Program must sign box 11. Specify course:*

6. Existing Cross-Listed Course(s) *Signature of cross-listed department(s) required in Box 11 and Dean(s) in "Approved By" section. To remove cross-listed status also check Box 8n.*

7. Existing Diversification, Foundations, Hawaiian/ Second Language Designation *If requesting change to designation also fill out Box 8f*

GEC Use: ☐ Continue ☐ Remove

GEC Initials

8. Type of Change *Check all that apply. For each change, fill in CHANGE DETAILS below. Read instructions carefully before completing this section. Use additional sheets if needed.*

- ☐ a. Course Subject &/or Number
- ☐ b. Frequency
- ☐ c. Offering Status
- ☐ d. Full Course Title/Banner Title *(Banner title 30 char. max incl. spaces/punctuation)*
- ☐ e. Grade Option
- ☐ f. Diversification, Foundations, Hawaiian/Second Language Designation
- ☐ g. Contact Hours/Number of Credits/Repeat Limit/Credit Limit
- ☐ h. Schedule Type
- ☐ i. Co-requisite Course(s)
- ☐ j. Major Restrictions
- ☐ k. Class Standing Restrictions
- ☐ l. (i) Prerequisite Course(s) (ii) Prerequisite Grade Requirement (iii) Blanket Requirements
- ☐ m. Catalog Description
- ☐ n. Cross-listed/Honors Course(s) – *Signatures required in Box 11 (& "Approved By" section for cross-listings). Submit syllabus for honors courses.*

CHANGE DETAILS

Change Type *(Specify letter noted above)*	Existing Data *(Check Banner to confirm)*	Proposed Data *(Enter data as it should appear AFTER change. Use Box 9 to describe change.)*

9. Description of Change(s) & Justification *Describe the change and why it is being requested, including its relationship to your overall curriculum. Attach additional sheets if needed. Attach a course syllabus for the modified course specifying student learning objectives for the course. Syllabi are not required for "-99" courses.*

ASTR 427 was offered concurrently with a graduate-level course, ASTR 627. However, the latter is now being taught at a very high level and it is unrealistic to expect undergraduates will be able to follow the presentation. The subject will be covered at a level appropriate for advanced undergraduates in a new course, ASTR 426.

10. Consultation: If other UHM departments and/or UH-system campuses will be affected, have they been consulted? (e.g., course is a prerequisite, required for another major, offered at another UH campus, etc.) ☐ Yes – *Indicate offices/campuses:* ☐ Not applicable

11. Cross-listed Department(s)/Honors Program

Dept/Unit	Chair/Director	Signature	Date

12. Requested By

I certify that the student learning objectives for this modified course are consistent with the learning objectives of each program under which the course is listed.

Dept/Unit	Chair/Director	Signature	Date
Physics & Astronomy	Pui Lam		

Approved By

		Signature	Date
1st College/School: Natural Sciences	Dean: Michael W. Peters		
2nd College/School	Dean		

General Education *(Undergraduate courses numbered 100-499)*

Director — Signature — Date

Graduate Division *(600 level and above)*

Dean — Signature — Date

Mānoa Chancellor's Office

Vice Chancellor for Academic Affairs — Signature — Date

Rev. 7/2012

UNIVERSITY OF HAWAIʻI AT MĀNOA
UHM-2 FORM (MODIFY/DELETE A COURSE)

See *Guidelines* for instructions and deadlines. For undergraduate courses, submit an original and 4 copies; graduate courses, submit an original and 6 copies. If cross-listed, include extra copies for cross-listed department(s) & college(s). List one course per form. Attach additional sheets as needed.

1. Transaction Type
- ☒ Modify
- ☐ Delete

2. Course Subject and Number: ASTR 430

3. Existing Full Course Title: The Solar System

4. Effective Term of Change: Spring 2015

5. Honors Counterpart Exists?
- ☒ No (*To add honors counterpart course also check Box 8n*)
- ☐ Yes – *Honors Program must sign box 11. Specify course:*

6. Existing Cross-Listed Course(s) *Signature of cross-listed department(s) required in Box 11 and Dean(s) in "Approved By" section. To remove cross-listed status also check Box 8n.*

7. Existing Diversification, Foundations, Hawaiian/ Second Language Designation *If requesting change to designation also fill out Box 8f*

GEC Use:
- ☐ Continue
- ☐ Remove

GEC Initials

8. Type of Change *Check all that apply. For each change, fill in CHANGE DETAILS below. Read instructions carefully before completing this section. Use additional sheets if needed.*

- ☐ a. Course Subject &/or Number
- ☐ b. Frequency
- ☐ c. Offering Status
- ☐ d. Full Course Title/Banner Title *(Banner title 30 char. max incl. spaces/punctuation)*
- ☐ e. Grade Option
- ☐ f. Diversification, Foundations, Hawaiian/Second Language Designation
- ☐ g. Contact Hours/Number of Credits/Repeat Limit/Credit Limit
- ☐ h. Schedule Type
- ☐ i. Co-requisite Course(s)
- ☐ j. Major Restrictions
- ☐ k. Class Standing Restrictions
- ☒ l. (i) Prerequisite Course(s) (ii) Prerequisite Grade Requirement (iii) Blanket Requirements
- ☒ m. Catalog Description
- ☐ n. Cross-listed/Honors Course(s) – *Signatures required in Box 11 (& "Approved By" section for cross-listings). Submit syllabus for honors courses.*

CHANGE DETAILS

Change Type *(Specify letter noted above)*	Existing Data *(Check Banner to confirm)*	Proposed Data *(Enter data as it should appear AFTER change. Use Box 9 to describe change.)*
l.(i)	PHYS 170	ASTR 300; PHYS 152 or 274; MATH 216, 242, or 252A
m.	Observations and physical nature of planets and moons, asteroids, comets, and other small bodies; formation of the Solar System; discovery of other planetary systems; solar activity. Given concurrently with 630.	Observations and physical nature of planets and moons, asteroids, comets, and other small bodies; formation of the Solar System; discovery of other planetary systems; solar activity.

9. Description of Change(s) & Justification *Describe the change and why it is being requested, including its relationship to your overall curriculum. Attach additional sheets if needed. Attach a course syllabus for the modified course specifying student learning objectives for the course. Syllabi are not required for "~99" courses.*

New prerequisites are necessary to integrate ASTR 430 into Astronomy BA and Astrophysics BS programs. Course description should be changed since this course will no longer be given concurrently with ASTR 630. See attached syllabus.

10. Consultation: If other UHM departments and/or UH-system campuses will be affected, have they been consulted? (e.g., course is a prerequisite, required for another major, offered at another UH campus, etc.)
- ☐ Yes -- *Indicate offices/campuses:*
- ☒ Not applicable

11. Cross-listed Department(s)/Honors Program

Dept/Unit	Chair/Director	Signature	Date

12. Requested By

I certify that the student learning objectives for this modified course are consistent with the learning objectives of each program under which the course is listed.

Dept/Unit	Chair/Director	Signature	Date
Physics & Astronomy	Pui Lam		

Approved By

		Signature	Date
1st College/School	Dean		
2nd College/School	Dean		

General Education *(Undergraduate courses numbered 100-499)*

Director — Signature — Date

Graduate Division *(600 level and above)*

Dean — Signature — Date

Mānoa Chancellor's Office

Vice Chancellor for Academic Affairs — Signature — Date

Rev. 7/2013

Course Justification for ASTRONOMY 430
The Solar System

1 Description & Objectives

ASTR 430 is a rigorous course covering the major topics of planetary astrophysics. It is designed to be taken by advanced undergraduates who have already had several courses in astronomy and who are comfortable with mathematics including calculus and differential equations. ASTR 430 has been previously offered concurrently with ASTR 630, a course on similar topics for graduate students. We now envision ASTR 430 as an undergraduate course that will emphasize physical understandings of the phenomena and objects that dominate the Solar System and extrasolar planetary systems.

2 Organization & Syllabus

ASTR 430 is a lecture course with extensive integrated discussion, meeting for three contact hours per week. The syllabus contains ten sections enumerated below, each spanning 1–1.5 weeks. One week is allotted for final review and two weeks are allotted for midterm exams and review.

At least one discussion session will be included in each of the ten sections of this course. At the beginning of each section, students will be given a short list of challenge questions. Several classes will typically be given as lectures, interspersed with brief active-learning exercises to focus student thinking and foreshadow subsequent discussion. The final class of each section will be devoted to discussion, problem-solving exercises, and student presentations. One or more of the challenge questions distributed at the start of the section will form the basis for a student-led discussion, guided as necessary by the instructor toward a clear resolution; other questions will be discussed informally as time permits. Some discussion sections will also include student presentations; these will be scheduled to insure that every student has at least one occasion to co-present a brief ($\sim$ 15 minute) review on a subject relevant to the course material. These presentations will also give students an opportunity to consult primary sources in the scientific literature.

1. **Solar System Overview** – inventory of the Solar System – giant planets, terrestrial planets, small bodies, satellites and ring systems; planetary properties.

2. **Dynamics** – keplerian motion; the three body problem; perturbations and resonances; stability; tides.

3. **The Sun and Solar Wind** – solar magnetism; interaction of solar wind with planetary magnetospheres, ionospheres, and minor bodies.

4. **Planetary Atmospheres** – thermal structure; composition; winds; photochemistry; atmospheric escape; properties of giant planet atmospheres; properties of terrestrial planet atmospheres.

5. **Planetary Surfaces** – mineralogy, surface morphology, volcanism, impact cratering, dating techniques, surface geology of individual bodies – Moon, Mercury, Venus, Mars, giant planet satellites.

6. **Planetary Interiors** – modeling of interiors, seismology, internal structure of individual bodies – Earth, other terrestrial planets, giant planets, giant planet satellites.
7. **Planetary Rings** – Tidal forces and Roche's limit, flattening and spreading of rings, resonances, shepherding, observations of ring systems – Jupiter, Saturn, Uranus, Neptune.
8. **Small Bodies** – Comets – orbits, coma/tail formation, composition, formation; asteroids; meteorites; trans-Neptunian objects; near-Earth objects and potentially hazardous objects; observational surveys.
9. **Extrasolar Planets** – detection using radial velocity, transits, direct imaging and other techniques; statistical properties of planet populations; orbital characterization; atmospheric characterization; SETI.
10. **Planet Formation** – star formation; evolution of protoplanetary disks; observations of disks; growth of small bodies; formation of terrestrial planets; formation of giant planets; planetary migration; the Nice model; in-situ formation.

2.1 Student learning outcomes

After taking this course, students will be fluent in all of the major topics related to Solar System astronomy. They will be able to calculate the dynamics of two and three-body motion, including responses to perturbations, resonances, and tides. They will understand the sources of solar magnetism, the characteristics of the solar wind, and it's impact on planets and minor bodies in the Solar System. They will be able to model the atmospheres, surfaces, and interiors of the planets in the Solar System and will be able to use those models to make predictions about the composition, photochemistry, surfaces features, and internal structure of the terrestrial and gas giant planets. They will understand how the detailed structures of planetary rings are generated, shaped, and maintained. They will know the origins, compositions, taxonomies, and orbits of comets, asteroids, and other small bodies in the Solar System. They will be able to model the detection and characterization of extrasolar planets using modern techniques. They will be able to discuss the formation of our Solar System and place it in the context of planet formation generally.

3 Expected Enrollment

ASTR 430 will be targeted at juniors and seniors who have already taken a substantial number of Astronomy courses. We expect enrollment of approximately 15–25 students in ASTR 430.

4 Relation to Curriculum

ASTR 430 is a capstone course primarily targeting students majoring in astrophysics (BS) or astronomy (BA). However, ASTR 430 can also serve as a stand-alone course for anyone with the necessary physics and mathematics background who is interested in understanding the important physical processes of solar system science.

5 Overlap with Other Courses

ASTR 430 has some overlap in topics covered with ASTR 241 and ASTR 630. ASTR 241 is an introduction to astrophysics that uses problems in the Solar System as a vehicle for teaching astrophysical thinking. It covers some of the same topics with less depth and mathematical rigor. ASTR 630 is a graduate course that covers many of the same topics as AST 430, but it presumes much deeper familiarity with observational astronomy. ASTR 150 = GG 105 presents a descriptive survey of the Solar System at the introductory level. GG 304 applies physics to the internal structure of planets, overlapping with two of the ten units in ASTR 430 (Planetary Surfaces and Planetary Interiors).

6 Number of Credits

ASTR 430 is a substantial lecture course with three contact hours per week; it is appropriate for students to receive three credits for this course.

7 Student Evaluation

Students will be graded on the basis of (a) in-class participation in discussion sessions and presentations, (b) weekly problem sets, (c) two mid-term exams, and (d) a cumulative final exam.

ASTR 430 is one of the most advanced and rigorous courses in the BA Astronomy and BS Astrophysics programs. It describes the structure and history of the Solar System at a high level, drawing extensively on basic observational astronomy and elements of classical and modern physics. Consequently, ASTR 430 provides an opportunity to assess several key components of the BA Astronomy program of the BA Astronomy and BS Astrophysics programs, including physical laws and their application to astronomy, as well as the observational properties of astronomical objects. The exams and assignments for this course will be designed and graded with program assessment in mind.

8 Instructors

ASTR 430 focuses on physical processes in the Solar System and extrasolar systems and could be easily taught by the (currently) eight Astronomy faculty members whose research focuses on solar system astronomy and/or extrasolar planets.

9 Impact on Workload

The IfA Graduate Chair, Dr. David Sanders, confirms that this course will not limit the ability of Physics & Astronomy to offer other courses already listed in the catalog. ASTR 430 is envisioned as a critical component of the new astronomy and astrophysics majors for which a proposal is in the process of being finalized. We expect that this course will be primarily staffed by faculty from the IfA.

Appendix F.

Letters of Support

1. Memo: Tripartite Agreement - Astronomy / Astrophysics Undergraduate Programs

   To: Dr. Reed Dasenbrock, Vice Chancellor for Academic Affairs, UH Manoa

   From: Dr. Guenther Hasinger – Director, Institute for Astronomy, UH
   Dr. William Ditto – Dean, College of Natural Sciences, UH Manoa
   Dr. Randy Hirokawa – Dean, College of Arts and Sciences, UH Hilo

Institute for Astronomy
Office of the Director

UNIVERSITY of HAWAI'I
MĀNOA

MEMORANDUM

May 2, 2012

TO: Reed Dasenbrock
Vice Chancellor for Academic Affairs

FROM: Günther Hasinger, Director, UH Institute for Astronomy
William Ditto, Dean, College of Natural Sciences, UH Manoa
Randy Hirokawa, Dean, College of Arts and Sciences, UH Hilo

SUBJECT: Astronomy/Astrophysics Undergraduate Programs

Hosting some of the premier astronomical observatories on the summits of Mauna Kea and Haleakala, astronomy is one of the big and very visible research enterprises of the University of Hawaii and therefore one of the large attractions for students. Consequently, there are astronomy teaching programs both in Manoa and in Hilo and the Institute of Astronomy (IfA) is located on all three islands, Oahu, Maui and Hawaii Island. The IfA astronomy graduate program in Manoa is one of the largest and most respected in the US and the Astronomy B.S. undergraduate program in Hilo is attractive because of the vicinity to the World's premier astronomical observatory. The astronomy undergraduate classes for non-science majors in Manoa are extremely popular and regularly draw ~800-900 students per year into the ASTR100-level courses, but so far do not provide a formal curriculum path for undergraduate students who wish to further their studies in astronomy. With the increasing visibility of astronomy as a career path, and with the increasing interdisciplinary nature of astronomy programs, there is a significant potential for growth.

The proposal to establish new Astronomy B.A. and Astro-Physics B.S. undergraduate programs in Manoa in cooperation with the Astronomy B.S. program in Hilo aims to leverage the UH attractions and integrate them to a more coherent UH astronomy education system. The three degrees (1) Astronomy B.A. (Manoa), (2) Astronomy B.S. (Hilo) and (3) Astro-Physics B.S. (Manoa) will represent different flavors and specializations of UH astronomy undergraduate education tailored to different student clienteles.

Variant (1) will be a degree aimed at students who may later go into science writing, public communication, planetarium work, or science politics. Experience from other schools in the US shows that the B.A. option has the potential to draw large numbers of students. Variants (2) and (3) are aimed to bring their best students into competitive astronomy graduate programs, including our own. The existing program (2) in Hilo is attractive because of the vicinity to the observatories on the Big Island and the corresponding instrumentation/engineering programs. Apart from graduate programs it also has the potential to strengthen the workforce development for the observatories on the Big Island. IfA is committed to support the instrumentation specialization in this program at UH Hilo. The new Astro-Physics specialization (3) is a rigorous physics degree with a specialization in astronomy in cooperation with the Physics & Astronomy Department in Manoa. Compared to (2) it requires a higher degree of specialization in physics, leading up to a full year of senior level quantum mechanics and a senior supervised research project with an IfA faculty member.

While the three different degree programs are independent of each other and given by their responsible host campuses (Hilo or Manoa), there is a great potential for synergies and coordination among the programs. The contents of the lower-level courses can be harmonized and cross-listed, so that students can transfer credit points between the two campuses. This allows a larger variety of career paths in the course of the undergraduate studies. The selection of higher-level courses could be specialized and coordinated, so that students from the two campuses can select from a larger number of possibilities, assuming the necessary remote learning capabilities. Finally, important and expensive infrastructure should be used jointly. Particularly attractive is the utilization of the new UHH 24" educational telescope Hoku Ke'a. Equipped with remote observing capabilities, this telescope can be used for lab classes both in Hilo and in Manoa.

The establishment of an astronomy undergraduate program integrated between UH Manoa, UH Hilo and the IfA is therefore a unique win-win opportunity and wholeheartedly supported by the three units involved.

Appendix G.

Academic Cost and Revenue Template

Notes on Line items:

- Headcount Enrollment (Fall)
- Annual SSH
- Instructional costs without Fringe
- Other Personnel Costs
- Unique Program Costs
- Total Direct and Incremental Costs
- Tuition rate per credit
- Other
- Total Revenue
- New Cost (Revenue)
- Instructional Cost with Fringe/SSH
- Support Cost/SSH
- Total Program Cost/SSH
- Total Campus Expenditure/SSH
- Comparable Cost/SSH

Academic Cost and Revenue Template – New Program

A. Headcount Enrollment (Fall)

The projected total enrollment, broken down by academic year in Table G.1, is based on an intake of 12 students/year for the Astrophysics BS, and 20 students/year for the Astronomy BA. It is assumed that the programs formally begin in AY 2014-15, that students declare a major at the beginning of their second year and take three years to complete their degrees, and that after AY 2016-17 the programs reach a steady state.

B. Annual SSH

Annual SSH for the Astrophysics BS and Astronomy BA are calculated in Table G.1. Only P&A courses taken by declared majors are counted in the courses and credits; it is assumed

		AY 2014-15				AY 2015-16				AY 2016-17			
		Sop.	Jun.	Sen.	Total	Sop.	Jun.	Sen.	Total	Sop.	Jun.	Sen.	Total
BS Astrophys	Enrollment	12			**12**	12	12		**24**	12	12	12	**36**
	Courses	4			**4**	4	6		**10**	4	6	8	**18**
	Credits	14			**14**	14	21		**35**	14	21	22	**57**
	SSH	168			**168**	168	252		**420**	168	252	264	**684**
BA Astronomy	Enrollment	20			**20**	20	20		**40**	20	20	20	**60**
	Courses	3			**3**	3	3		**6**	3	3	4	**10**
	Credits	10			**10**	10	12		**22**	10	12	10	**32**
	SSH	200			**200**	200	240		**440**	200	240	200	**640**
Total Enrollment		**32**				**64**				**96**			
Total SSH		**368**				**860**				**1324**			

Table G.1: Projected Enrollment and Student Semester Hours

that students follow the 4-year Graduation plans shown in Appendix B.

C. Instructional Cost without Fringe

C1. Number (FTE) of FT Faculty/Lecturers

Table G.2 shows how courses will be introduced as the programs are launched, and the number of Instructional FTEs required to offer these courses. All of the 200-level ASTR courses are already in rotation, as is ASTR 380. The remaining 300-level courses will be added in AY 2014-15, and the 400-level courses the following year. In AY 2016-17, additional sections of ASTR 240, 300, 300L, 301 and PHYS 485 are included to handle projected demand.

The FTE computation is based on number of credits taught. BOR policy for teaching loads at 4-year campuses is 24 credits/year; the "Raw" FTE = (total credits)/24 reflects this. A load of 24 credits/year is appropriate for the 4.0 Instructional FTEs currently associated with the IfA, which are divided among a much larger number of Research faculty teaching a graduate program as well as undergraduate courses. However, Physics faculty and lecturers, especially those who teach upper-division courses, also have significant research and non-instructional workloads. The "Adjusted" FTE = (Astr credits)/24 + (LD Phys credits)/15 + (UD Phys credits)/12 better reflects the FTEs actually required for these courses.

An Instructor (I-2), hired using funding provided by CNS, will spend 0.5 FTE developing material for ASTR 300L, teaching this course, and maintaining the lab equipment and remote observing room. Thus the "Total" FTE, which is used in the Template, includes an extra 0.5 FTE, but deducts the credits for ASTR 300L from the

	AY 2014-15				AY 2015-16				AY 2016-17			
	Fall		Spring		Fall		Spring		Fall		Spring	
ASTR Courses	240, 241, 280, 300, 300L		242, 281, 301, 320, 380		240, 241, 280, 300, 300L, 423, 495		242, 281, 301, 320, 380, 426/430, 495		240, 241, 280, 300 (x2), 300L (x2), 423, 495		240, 242, 281, 301 (x2), 320, 380, 426/430, 495	
Astr Credits	14		16		20		22		25		29	
PHYS Courses	152, 152L, 272, 272L		274, 274L		152, 152L, 272, 272L, 310, 350		274, 274L,311, 450		152, 152L, 272, 272L, 310, 350, 480, 485		274, 274L,311, 450, Phys. Elec.	
Phys Credits	8	0	4	0	8	6	4	6	8	10	4	9
Raw FTE	1.75				2.75				3.54			
Adjust. FTE	2.05				3.55				4.63			
Total FTE	**2.47**				**3.97**				**4.97**			

Table G.2: Courses, Credits, and Instructional FTEs

total (Astr Credits).

C2. Number (FTE) of PT Lecturers

No part-time instructional staff are required to implement these programs during the initial phase unless enrollment is much greater than projected.

D. Other Personnel Costs

The figure shown represents 0.5 FTE for secretarial support for the Astrophysics BS and Astronomy BA programs. A 1.0 FTE Secretary II is assumed to cost $33,720.

E. Unique Program Costs

This includes initial purchase, support, and upgrades for computer hardware and software, and purchase and support of optics laboratory equipment. Costs for AY 2015-16 and 2016-17 include the purchase of a robotic telescope, to be shared and jointly operated by UHM and UHH. The net cost of this telescope is estimated at $600K. One-quarter of this cost will be covered by UHM, one-quarter by UHH, and one-half raised by the UH Foundation. Operating costs for this facility are included from AY 2015-16 on.

F. Total Direct and Incremental Costs

Calculated by the Template (sum of C, D, and E).

G. Tuition rate per credit

The tuition rates shown are per the published UHM tuition schedule (Resident). Since no tuition information for subsequent years is available, the AY 2018-19 rate is used for all subsequent years of the program as shown (despite the likelihood of future tuition increases). Tuition of non-resident students is not accounted for in the template format and therefore all students are indicated as residents. The Astrophysics BS and Astronomy BA programs are expected to attract a significant number of non-resident students.

H. Other

Effective AY 2016-17, the program will charge a fee of $500 per semester (entered as $1000 × headcount enrollment).

I. Total Revenue

Calculated by the Template.

J. Net Cost (Revenue)

Calculated by the Template (a negative number indicates net revenue or revenue in excess of cost).

K. Instructional Cost with Fringe/SSH

K1. Total Salary FT Faculty/Lecturers

Since specific faculty have not been assigned to the program, and will vary over the life of the program, the salary rate base is assumed to be an average of current full time faculty salaries.

K2. Cost Including Fringe of K1

Calculated by the Template.

K3. Total Salary of PT Lecturers

No part-time instructional staff are required to implement these programs during the initial phase unless enrollment is much greater than projected.

K4. Cost Including Fringe of K3

Calculated by the Template.

L. Support Cost/SSH

Non-Instructional Exp/SSH

Amount entered is as reported by UH (2011-12 data).

System-wide Support/SSH

Amount entered is as reported by UH (2011-12 data).

Organized Research/SSH

Amount entered is as reported by UH (2011-12 data).

M. Total Program Cost/SSH

Calculated by the Template (sum of K and L).

N. Total Campus Expenditure/SSH

Amount entered is as reported by UH (2011-12 data).

O. Comparable Cost/SSH

Amount entered is as reported by UH for the UHM Bachelor's in Engineering degree program. This program is a reasonable match to the proposed Astrophysics BS and Astronomy BA programs in terms of content and professional orientation, although the number of Engineering students exceeds the projected enrollment in our programs.

Academic Cost and RevenueTemplate - New Program (adjust template for appropriate number of years) (Updated 10/31/12)

ENTER VALUES IN YELLOW CELLS ONLY

CAMPUS/Program: MANOA/BA/BS Astronomy/Astrophy

	Provisional Years (2 yrs for Certificate, 3 yrs for Associate Degree, 6 yrs for Bachelor's Degree, 3 yrs for Masters Degree, 5 yrs for Doctoral Degree)					
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
ENTER ACADEMIC YEAR (i.e., 2011-2012)	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Students & SSH						
A. Headcount enrollment (Fall)	32	64	96	96	96	96
B. Annual SSH	368	860	1,324	1,324	1,324	1,324
Direct and Incremental Program Costs Without Fringe						
C. Instructional Cost **without** Fringe	$ 222,300	$ 357,300	$ 447,300	$ 447,300	$ 465,192	$ 483,800
C1. Number (FTE) of FT Faculty/Lecturers	2.47	3.97	4.97	4.97	4.97	4.97
C2. Number (FTE) of PT Lecturers	-	-	-	-	-	-
D. Other Personnel Costs	$ 16,860	$ 16,860	$ 16,860	$ 16,860	$ 16,860	$ 16,860
E. Unique Program Costs	$ 25,000	$ 125,000	$ 125,000	$ 50,000	$ 50,000	$ 50,000
F. Total Direct and Incremental Costs	$ 264,160	$ 499,160	$ 589,160	$ 514,160	$ 532,052	$ 550,660
Revenue						
G. Tuition	$ 140,208	$ 352,600	$ 583,884	$ 627,576	$ 675,240	$ 675,240
Tuition rate per credit	$ 381	$ 410	$ 441	$ 474	$ 510	$ 510
H. Other	$ -	$ -	$ 96,000	$ 96,000	$ 96,000	$ 96,000
I. Total Revenue	$ 140,208	$ 352,600	$ 679,884	$ 723,576	$ 771,240	$ 771,240
J. Net Cost (Revenue)	123,952	146,560	-90,724	-209,416	-239,188	-220,580
Program Cost per SSH With Fringe						
K. Instructional Cost **with** Fringe/SSH	$ 816	$ 561	$ 456	$ 456	$ 474	$ 493
K1. Total Salary FT Faculty/Lecturers	$ 222,300	$ 357,300	$ 447,300	$ 447,300	$ 465,192	$ 483,800
K2. Cost Including Fringe of K1	$ 300,105	$ 482,355	$ 603,855	$ 603,855	$ 628,009	$ 653,130
K3. Total Salary PT Lecturers	$ -	$ -	$ -	$ -	$ -	$ -
K4. Cost Including fringe of K3	$ -	$ -	$ -	$ -	$ -	$ -
L. Support Cost/SSH	$ 467	$ 467	$ 467	$ 467	$ 467	$ 467
Non-Instructional Exp/SSH	$ 534	$ 534	$ 534	$ 534	$ 534	$ 534
System-wide Support/SSH	$ 68	$ 68	$ 68	$ 68	$ 68	$ 68
Organized Research/SSH	$ 135	$ 135	$ 135	$ 135	$ 135	$ 135
M. Total Program Cost/SSH	$ 1,283	$ 1,028	$ 923	$ 923	$ 941	$ 960
N. Total Campus Expenditure/SSH	$ 971	$ 971	$ 971	$ 971	$ 971	$ 971
Instruction Cost with Fringe per SSH						
K. Instructional Cost/SSH	$ 816	$ 561	$ 456	$ 456	$ 474	$ 493
O. Comparable Cost/SSH	$ 519	$ 519	$ 519	$ 519	$ 519	$ 519
Program used for comparison.	Bachelor's in Engineering					

Reviewed by campus VC for Administrative Affairs: **(signature and date)**