Universidad de Puerto Rico
Recinto Universitario de Mayagüez
Senado Académico

CERTIFICACION NUMERO 18-10

La que suscribe, Secretaria Interina del Senado Académico del Recinto Universitario de Mayagüez de la Universidad de Puerto Rico, **CERTIFICA** que en la reunión ordinaria celebrada en la sesión del martes, 23 de enero de 2018, este organismo **APROBÓ** la **PROPUESTA PARA UNA CREACIÓN DE UNA SECUENCIA CURRICULAR EN ASTRONOMÍA Y ASTROFÍSICA.**

La propuesta cumple en formato y contenido con los elementos de una secuencia curricular de Categoría IV según la Certificación 15-07 del Senado Académico del Recinto Universitario de Mayagüez.

La propuesta consiste de 15 créditos, de los cuales doce (cuatro cursos) corresponden a cursos medulares y tres (1 curso) son electivos. Aunque estudiantes de otros programas pueden participar, la Secuencia está orientada principalmente a estudiantes de Física y Ciencias Físicas. El Departamento de Física posee el personal docente y los recursos de infraestructura necesarios para enseñar los cursos y para proveer mentoría a los estudiantes. Todos los cursos se ofrecen actualmente en el Recinto. Para ser admitido al programa el estudiante deberá completar el formulario de solicitud de admisión, tener un promedio académico de 2.50 o más, haber aprobado FISI 3161 y FISI 3162 (o equivalentes) con C o más, y haber aprobado MATE 3131 y MATE 3032 (o equivalentes) con C o más.

La creación de la secuencia curricular forma parte de la certificación.

Y para que así conste expido y remito la presente certificación a las autoridades universitarias correspondientes, bajo el Sello de la Universidad de Puerto Rico a los veinticinco días del mes de enero del año dos mil dieciocho, en Mayagüez, Puerto Rico.

Nilda E. Pérez Collazo
Secretaria Interina

LPM

Anejo

290496

Universidad de Puerto Rico
Recinto Universitario de Mayagüez
Senado Académico

Aprobada 1/23/18

4 enero 2018

Certificación número 18-10

APROBADO

Miembros del Senado Académico
Recinto Universitario de Mayagüez

David Sotomayor Ramírez
Presidente, Comité Asuntos Curriculares

Propuesta para la creación de una Secuencia Curricular en Astronomía y Astrofísica

El Comité de Asuntos Curriculares recibió la propuesta del Departamento de Física para la creación de una Secuencia Curricular en Astronomía y Astrofísica. La propuesta cumple en formato y contenido con los elementos de una secuencia curricular de categoría IV según la Certificación 15-07 del Senado Académico del Recinto Universitario de Mayagüez.

La propuesta consiste de 15 créditos, de los cuales doce (cuatro cursos) corresponden a cursos medulares y tres (1 curso) son electivos. Aunque estudiantes de otros programas pueden participar, la Secuencia está orientada principalmente a estudiantes de Física y Ciencias Físicas. El Departamento de Física posee el personal docente y los recursos de infraestructura necesarios para enseñar los cursos y para proveer mentoría a los estudiantes. Todos los cursos se ofrecen actualmente en el Recinto. Para ser admitido al programa el estudiante deberá completar el formulario de solicitud de admisión, tener un promedio académico de 2.50 o más, haber aprobado FISI 3161 y FIS 3162 (o equivalentes) con C o más, y haber aprobado MATE 3131 y MATE 3032 (o equivalentes) con C o más.

El Comité de Asuntos Curriculares entiende que la propuesta será de beneficio para los estudiantes y para la Institución y recomienda al Senado Académico la aprobación de la propuesta.

Anejo
Propuesta Secuencia Curricular en Astronomía y Astrofísica

University of Puerto Rico, Mayagüez Campus

Department of Physics

Proposal for the creation of a Curricular Sequence in Astronomy & Astrophysics (*CSAA*)

1. Introduction

The proposed Curricular Sequence in Astronomy & Astrophysics (henceforth *CSAA*) will emphasize a mixture of theory, phenomenology and practice (via research projects). The *CSAA* curricular sequence will start with a general overview of astronomy and astrophysics, introduce more advanced topics in courses on stellar evolution and radio astronomy, and finally have elective courses in specialized topics. Demonstration and research opportunities using optical telescopes and radio telescopes at UPRM Physics Planetarium and Observatory and Arecibo Observatory can be offered. The *CSAA* could potentially benefit a large student population from programs such as: physics, physical science, geology or engineering students. Furthermore, the CSAA will help fill an academic gap, offer a complete learning experience, strengthen the Physics curriculum, and fulfill a social need by producing informed citizens.

The proposed 15-credit *CSAA* formalizes a curricular offer of the Physics Department at no additional costs, with all frequently offered courses in place and available faculty.

2. Vision of the CSAA

The proposed *CSAA* will connect fundamentally with the vision of the University of Puerto Rico Mayagüez in *"[...] transforming society through the pursuit of knowledge [...]"*. The pursuit of understanding the heavens has systematically begun at least 5,000 years ago with recording positions, cataloging events and developing calendars.

As much as astronomy is an ancient science, it also evolves into the future. One of many examples are the space missions that visited all planets in our solar system and are culminating with the flyby of the most distant of them all, the dwarf planet Pluto in 2015. Space agencies are investing billions of dollars into missions to Mars or hitchhiking asteroids. Other observational projects are searching for exoplanets that would maintain liquid water and could potentially harbor life. These examples demonstrate that astronomy has always been and always will be fueling our imagination, challenging our scientists and engineers, and asking the profound question: *How did the universe begin and evolve?*

Another important mission of the University of Puerto Rico Mayagüez is to ensure that *"[...] both the academic and research components [...] share a common*

perspective [...]". The proposed *CSAA* is a complete learning experience, comprising a theoretical and a demonstration component and also offering an optional research component. In the theoretical component a general introduction to astronomy will be followed by a course on astrophysics, emphasizing the physical and mathematical perspective. Additionally, modern observational techniques are introduced. The two more advanced core courses will discuss stellar evolution in detail and provide a comprehensive introduction to radio astronomy. Radio astronomy is an important part of the *CSAA* and will include a discussion of the fundamentals of radio signal emission by celestial objects as well as detection by telescopes and signal processing.

The demonstration component includes the use of optical telescopes and radio telescopes. These demonstration components will be seamlessly included into the first two Astronomy courses (Astronomy I and II). For the optical demonstration, students will have supervised access to the in-house 16-inch optical telescope located at the UPRM Physics Department Observatory. The students will be taken to the Physics Department observatory during class hours and will learn about the operation of an optical telescope. Additionally, weather permitting, an observation night with the optical telescope can be included. For the radio astronomical demonstrations, data from a 20-meter diameter radio telescope of the National Radio Astronomy Observatory in Green Bank, West Virginia, can be used. The educational radio telescope in Green Bank can be accessed on-line during class hours, which will permit demonstrations about radio telescope set-up and data taking.

The optional research component could offer undergraduate research possibilities with the Arecibo Radio Telescope, which is part of the National Astronomy and Ionosphere Center or more commonly known as the "Arecibo Observatory". There are professors in the Department of Physics that have maintained formal and informal research collaborations with the Arecibo Observatory for several decades, including research projects with undergraduate and graduate students. These collaborations can provide observatory staff co-advisors for students doing research. The students can also choose to work on theoretical or computational aspects of astrophysics with the advice of participating faculty.

The previous discussion leads directly to yet another University mission, which is to *"Assist government agencies [...]"* and concurrent to this the Physics Department states that one of its objectives is to *"Promote interactions [...] with national laboratories [...]"*. The *CSAA* can provide on-site interaction with the Arecibo telescope and its staff through the optional undergraduate research course. Research projects may be provided for students, which may be jointly supervised by departmental faculty and observatory staff and may include observing time with the telescope. Additionally, we will organize one student tour of the Arecibo Observatory each semester including access to the control room and the edge-of-the-dish. With each passing semester we will continue to develop research collaboration between physics faculty and observatory scientists.

The interaction with the Arecibo Observatory highlights another important aspect in

that it is a local effort. The Observatory is a state-of-the-art national research facility with local staff and support and actively promotes STEM research in Puerto Rico as part of their educational and public engagement efforts. This could motivate our students to engage in a lifelong exchange with the local scientific community. Lastly, the acquired experimental skills and techniques, together with the theoretical knowledge will be an important asset to students seeking employment with NASA and other research agencies and institutions. It can be expected that the *CSAA* will provide a constant flow of undergraduate students into internships or graduate programs.

In summary, the vision of the proposed *CSAA* is:

- ***Pursuing scientific knowledge*** in Astronomy.
- ***Providing a complete learning experience*** by offering an academic program including theoretical knowledge, observational techniques, and experimental research.
- ***Promoting strong interactions with national observatories,*** including the Arecibo Observatory.

3. Specific Objectives

At the end of the proposed *CSAA*, the successful student will be able to:

Locate and identify celestial objects. Looking through a telescope one can see planets, stars, star clusters, nebulae and galaxies, each with different size, characteristics and distance. The student will be able to appreciate and describe those differences and will be able to locate celestial objects, identify its main characteristics and to track the daily apparent motion of visible stellar objects.

Explain and compare the properties of stars. There is a substantial range of sizes, masses and temperatures among stars. The classification of stars in the so-called Hertzsprung-Russell diagram has provided an understanding of their birth, life and death. The student will be able to explain basic concepts in the complete life cycle of stars in the context of nuclear reactions, particles and forces, as well as quantum mechanics and thermal physics.

Describe and discuss the structure of the universe. Our solar system is part of the Milky Way galaxy, which is part of the local cluster of galaxies, that belongs to a local supercluster, within the universe. Each of these sub-structures has its own particular dynamics and evolution. Through the discussion of this hierarchy, the student will be able to understand the universe from its beginnings in the Big Bang through the present day.

Evaluate and interpret information across the electromagnetic spectrum. Visible light represents only a tiny fraction of the entire electromagnetic spectrum, ranging from very long radio waves to gamma-rays. Celestial objects can emit across the entire spectrum through different generating physical processes and its study permits constructing a

complete picture of the respective object. The student will realize that we need a variety of observational techniques and that each provides a look through a different "window" into the universe.

Assess and differentiate astronomical telescopes. There are only two spectral ranges that can fully penetrate the Earth's atmosphere, the optical (visible) range and the radio range, which represent the two "windows" that ground-based telescopes can utilize. The student will be able to assess these two observational techniques, the main characteristics of the respective telescopes and the recording and processing of information.

Review and reference astronomical research literature (optional). The optional research component of the program will have students work with astronomical and astrophysical scientific literature. All of the required journals are available on-line. The student will be able to locate and search journals, extract relevant information and reference scientific publications.

4. Student Preparation

The proposed *CSAA* is primarily aimed at physics and physical sciences students, however, it is open to all qualified students. The program could potentially be of interest to geology and chemistry students from Arts & Sciences and to electrical, computer, and aerospace students from Engineering. After successful completion of the program, students will be prepared for a variety of future studies and work experiences.

One aim is to prepare students to pursue a graduate degree in astronomy and astrophysics. The courses in the curriculum will provide a solid knowledge base and help in deciding which specific field to enter. The number of program credit hours and selection of courses is on par with Minor programs at Universities in the U.S. mainland and internationally. BSc programs in Astronomy are not widely available and graduate programs often admit students with different BSc degrees, particularly Physics degrees. The students will have obtained the necessary knowledge to compete for Research Experience for Undergraduates (REU) programs offered at many universities and observatories across the U.S. mainland, Hawaii and Puerto Rico (Arecibo Observatory) and which are very competitive due to the limited number of places and slots. A very rewarding and important educational job is high-school teacher and for which there is currently a shortage of qualified science teachers in Puerto Rico. The *CSAA* could be a much valuable addition to the standard physics courses for aspiring school teachers and provide them with a broad knowledge in history, phenomenology, and observational techniques in astronomy.

There is a widely held belief that an undergraduate degree in physics necessarily implies entering graduate school in order to find work. While this is the traditional path of many physicists-to-be, there are professions that can be taken up with a BSc degree. With the additional *CSAA* the student can work as science writer/editor, public outreach official, astrophotographer, or planetarium/observatory assistant, just to name a few.

5. Justifications

Filling an academic gap. While the University of Puerto Rico system has a broad academic offer, yet there is no degree or program in Astronomy & Astrophysics. There are individual courses, many of which are in the Physics Department in Mayagüez, however, student approval of these do not lead to a degree or even to a certificate in this field. The proposed *CSAA* will be the first of its kind at this level, filling an academic gap as well as having a strong impact on education and research in Mayagüez. Furthermore, the *CSAA* shares many objectives stated by the Physics Department and the UPRM and is acknowledged as an academic option of interest for many students, as the letter from the SPS (Society of Physics Students) signifies.

Complementing the Physics Department planetarium and observatory. The Physics Department features an observatory with a 16-inch optical telescope and a 64-seat planetarium, both of which were installed in 1973. Both facilities provide educational experiences yearly to thousands of high-school students and the general public. Open House events are held monthly. Additionally, the telescope is also used for undergraduate investigation and for demonstrations during astronomy courses. Clearly, the observatory and planetarium will complement the proposed *CSAA* and contribute toward a complete learning experience.

Strengthening the physics curriculum. The proposed *CSAA* could potentially connect with the existing curricular sequence in Atmospheric Sciences & Meteorology, since both are space sciences. Furthermore, astrophysics uses concepts of particle physics and will potentially be able to connect with the high-energy physics group. Interestingly, the high-energy physics group may work on the so-called dark matter problem; dark matter is believed to be present in the Milky Way galaxy, but has so far eluded direct experimental observation. Hence, the *CSAA* could be able to connect with several branches in the Physics Department and significantly strengthen its academic and research missions.

Fulfilling a "social need". An essential mission of all universities is to produce informed citizens. In astronomy and astrophysics there is a flood of misinformation or simply nonsense, while on the other hand, there is huge genuine public interest in many recent space missions, *e.g.*, the water-searching missions to Mars and to one of the comets. The proposed *CSAA* will provide fact-based teaching and help clarify many doubts and so prepare well-informed citizens. At the same time, it will cater to the physical sciences students, who are preparing to enter our schools as science teachers and who need to receive the best possible and most accurate education.

Serving the global community. Space exploration is an endeavor of interest across all continents and organizations and is conducted mostly in pursuit of knowledge or for strategic reasons. Space missions satisfy a human need in exploring, and overcoming our

limitations, while also collecting a wealth of experimental observations that provide input for astronomical research. On the other hand, the preparation and administration of space missions crucially depend upon a deeper understanding of the processes in the solar system and Milky Way galaxy. The proposed *CSAA* will provide the basic knowledge to potentially be part of the global space community and therefore could attract students across all STEM disciplines.

6. Courses and Curricular Sequence

The proposed *CSAA* requires a minimum of 15 credit hours for completion distributed in 4 core courses and a minimum of one recommended optional course. We have 5 full-time faculty members from the Department of Physics that can contribute to the *CSAA*. The student can take more than one of the recommended optional courses. The core courses, codifications and lists of topics discussed are as follows:

Course	Title	Pre-requisites
ASTR 4005	Astronomy I	FISI 3151 o FISI3161 o FISI 3171
ASTR 4006	Astronomy II	ASTR 4005 y (FISI 3152 0 FISI3162 o FISI3172)
ASTR 4015	Radio Astronomy	ASTR 4006 y FISI 4020
ASTR 4017	Stellar Evolution	ASTR 4006 y FISI 4105

A brief list of the topics to be discussed in the core courses follows:

ASTR 4005 (Astronomy I): motion of celestial objects, historical perspective, Kepler's and Newton's laws, matter and radiation, types of telescopes, the Earth-Moon system, overview of the solar system, the Sun, properties of stars.

ASTR 4006 (Astronomy II): blackbody radiation and line spectra, optical and radio telescopes, binary stars, the Sun and main sequence stars, stars at the end of their life cycle, interstellar medium and star formation, the Milky Way and other galaxies.

ASTR 4015 (Radio Astronomy): radio astronomy fundamentals and wave propagation, telescope antennas and receivers, single-dish and interferometry basics, galactic and extragalactic radio sources, data acquisition and processing.

ASTR 4017 (Stellar Evolution): basic concepts in astrophysics, properties of matter and radiation, stellar interiors and atmospheres, heat transfer in stars, thermonuclear fusion in stars, beyond hydrogen burning, stellar structure calculations, endpoints of stellar evolution.

Recommended electives (other courses may be considered upon approval):

Course	Title	Pre-requisites
ASTR 4025	Radio Pulsars	ASTR 4006 y FISI4071
ASTR 4999	Undergraduate Research	DIR
ASTR 5005	Formation and Evolution of Galaxies	N/A
ASTR 5007	Planetary Astronomy	ASTR 4005 0 DIR
FISI 4997	Special Problems in Physics	DIR

The pre-requisite courses to the core and optional courses along with their pre-requisites (not including Introductory Physics courses) are:

Course	Title	Pre-requisites	Co-requisites
FISI 4020	Physics of Waves	FISI3162 o FISI 3172	MATE 4009
FISI 4105	Modern Physics	FISI3162 o FISI 3172	N/A
FISI 4071	Electricity and Magnetism	(MATE 3063 o MATE 3185) y (FISI 3162 o FISI3172)	N/A

Since both programs, for the Physics B.S. and the Physical Sciences B.S., allow for 18 or more credits in electives (including free and recommended) in their programs, the proposed *CSAA* can be taken without the necessity of additional coursework.

The *CSAA* is following a 4-semester cycle. An example of the required coursework is as follows:

1st Semester		2nd Semester	
ASTR 4005	Astronomy I	ASTR 4006	Astronomy II
FISI 4105*	Modern Physics	FISI 4020*	Physics of Waves
3rd Semester		4th Semester	
ASTR 4017	Stellar Evolution	ASTR 4015	Radio Astronomy
		****	Recommended Elective

*These curses are not part of the sequence but they are pre-requisites to subsequent core courses.

7. Admission Requirements and Classifications

To enter the *CSAA*, all of the following requirements have to be met. This curricular sequence is mainly considered for students who are enrolled in a STEM undergraduate program as a primary program, although students from other programs who satisfy the requirements may be considered. The student must:

1. have a minimum general GPA of 2.50 on a scale from 0 to 4.00.
2. have approved FISI 3161 and FISI 3162 (or equivalent) with a minimum grade of C.
3. have approved MATE 3031 and MATE 3032 (or equivalent) with a minimum grade of C.
4. students that have a STEM bachelor's degree can be considered for admission to the *CSAA* if they comply with points 2 – 3 above.
5. apply for admission to the *CSAA*.

If a student is enrolled in a College or University other than the University of Puerto Rico, then the final decision for admission is made by the chairman of the Physics Department after consultation with the Astronomy & Astrophysics committee.

8. Successful Program Completion and Residence Requirement

To successfully complete the *CSAA* and obtain a certificate, the student must approve satisfactorily the four core courses and at least one of the recommended optional courses for a total of 15 credit hours. Additionally, for a course to count toward the *CSAA*, it must be approved with a minimum grade of C, and the required minimum *CSAA* GPA across all coursework must be 2.50. All courses which appear in the list of possible courses for the *CSAA* taken by a student, will count towards the *CSAA* minimum requirement, regardless of the final grade obtained by the student.

The student must finish all the requirements of his/her primary program before or simultaneously with the successful completion of the *CSAA*.

If a student has taken the course *Astronomy I* in any of the other UPR campuses and approved with a minimum grade of C, then a validation can be considered. The student has to submit a written request for the validation, enclose the official syllabus, and present an official transcript showing a minimum grade of C. The final decision for validation is made by the chairman of the Physics Department after consultation with the Astronomy & Astrophysics committee.

The residence requirement is that all *CSAA* courses except *Astronomy I* must be taken and approved in the Physics Department at UPRM.

The student that successfully completes all *CSAA* requirements will obtain a certificate and an annotation in his/her academic records. The registrar's annotation in the student's transcript will be:

"Successfully completed all requirements for the Curricular Sequence in Astronomy and Astrophysics."

9. Resources and Assessment Plan

The proposed *CSAA* has 5 full-time faculty members from the Physics Department participating: Drs. L. Nowakowski, H. Radovan, E. Roura, S. Santana and P. Marrero. All faculty members are available for teaching the courses and supervising undergraduate research projects. The *CSAA* currently offers 8 courses with the ASTR codification, 4 of which were newly created, which is sufficient to support the 15-credit sequence. It is anticipated that more courses will be prepared in the near future, e.g., a course on General Relativity/Cosmology. Furthermore, the Physics Department houses an observatory with a 16-inch optical telescope as well as a 64-seat planetarium, both of which can be used to supplement the academic and research components. Students registering for the

Undergraduate Research course may opt to perform research projects in collaboration with Physics Department faculty and Arecibo Observatory scientific staff. No other resources are necessary and no other costs are anticipated to start and maintain the *CSAA*.

To maintain a high quality *CSAA*, an assessment plan will be implemented. The following items will be assessed:

- ***admission requirements:*** particularly important at the beginning is to evaluate how well the admitted students perform and use these observations to adjust, if necessary, the admission requirements. The goal is to establish admission criteria that would be realistic indicators for the success of the *CSAA*.
- ***students' choice of electives:*** depending on which electives are chosen and on the respective enrollment numbers, popular electives can be offered more frequently, while new electives could be created if demand arises.
- ***overall satisfaction level:*** an important mechanism in improving the *CSAA* is feedback provided by students as well as by faculty. The feedback could be about any aspect of the program, such as course content, research project topics or course prerequisites.
- ***completion-to-entry ratio:*** it is desirable that the majority of the entering students successfully complete the sequence. This "completion-to-entry ratio" can provide a valuable marker about the technical level, organization and administration of the program.
- ***tendency in student numbers:*** this is an indicator that provides feedback for the long run and could be evaluated, e.g., over a 5-year period. We will try to correlate these numbers with the freshman enrollment in Physics.
- ***contact with alumni:*** yearly surveys of alumni having taken the *CSAA* could provide general input such as effectiveness, attractiveness and usefulness of the program, now evaluated with a more mature and professional eye of the alumni.

The assessment plan will be presented by the Director of the Physics Department, Associate Director of the Physics Department or Program Coordinator to the Physics Department Faculty every two years, where revisions to the CSAA will be considered.

Objectives	**Instrument**	**Success criteria**	**People responsible for implementation**	**Evaluation Period**
Generate a stable demand for the CSAA	Registry of the students that have been admitted to the CSAA	10 students admitted to the CSAA during the first three years with an increasing tendency in	Director, Associate Director of the Physics Department, Academic Counselor, Program Coordinator	Annual

Objectives	Instrument	Success criteria	People responsible for implementation	Evaluation Period
		subsequent years.		
High retention rate	Number of students that complete the CSAA within three years	At least 65% of the students who enroll I in the CSAA will complete it when graduating from their bachelor's degree	Director, Associate Director of the Physics Department, Academic Counselor, Program Coordinator	Annual
Impact on Alumni	Satisfaction survey for students who complete the CSAA	Increase tendency of CSAA alumni that recommend other students to complete the CSAA	Academic Counselor, Program Coordinator	Annual
	Registry of alumni that continue graduate studies in fields related to Astronomy or Astrophysics	At least 50% of the CSAA alumni continue graduate studies in fields related to the CSAA	Academic Counselor, Program Coordinator	Biennial
	Effectiveness survey	At least 65% of the CSAA alumni consider the CSAA was effective for their professional development	Academic Counselor, Program Coordinator	Biennial