From:	noreply@wsu.edu
To:	curriculum.submit
Subject:	669829 New or Restore Course: ASTRONOM 530
Date:	Friday, October 1, 2021 10:25:33 AM
Attachments:	2021.10.01.10.05.59.94.FormData.html 2021.10.01.10.05.58.82.currentFileUpload_Astronomy530syllabus.pdf 2021.10.01.10.05.58.82.currentFileUpload1_Justification_for_Astronomy_530.pdf

Matthew Duez has submitted a request for a major curricular change. His/her email address is: m.duez@wsu.edu.

Course Subject: ASTRONOM

Course Number: 530

Title: Gravitation and Cosmology

Lecture Hours: 3

Total Credits: 3

Prerequisite: graduate standing

Note revised description:
Gravitation and Cosmology 3 Special relativity; 4-vectors; introduction to tensors; examples of space-time metrics; black holes; gravitational waves; gravitational lensing; the Robertson-Walker metric; Inflationary cosmology; Big bang nucleosynthesis; Cosmic microwave background radiation; Structure formation. Typically offered Fall.

Catalog Description: 4-vectors; special relativity; introduction to tensors; examples of space-time metrics; black holes; gravitational waves; gravitational lensing; the Robertson-Walker metric; Inflationary cosmology; Big bang nucleosynthesis; Cosmic microwave background radiation; Structure formation.

Grading Type: Letter graded A-F

Requested Effective Date: Fall 2022

Dean: Swindell, Samantha - Assoc Dean - CAS

Chair: Saam, Brian – Chair – Physics and Astronomy

UCORE Committee Approval Date	All-University Writing Com / Date

Catalog Subcommittee Approval Date	AAC, PHSC, or GSC Approval Date	Faculty Senate Approval Date

From: Saam, Brian
To: curriculum.submit
Cc: Swindell, Samantha; Stratton, Robin G
Subject: RE: 669829 New or Restore Course: ASTRONOM 530
Date: Friday, October 1, 2021 11:21:25 AM

I approve this proposal in its current form.

Brian T. Saam, Ph.D.
Professor and Chair
Department of Physics and Astronomy
Washington State University
509-335-1182

From: curriculum.submit@wsu.edu <curriculum.submit@wsu.edu>
Sent: Friday, October 1, 2021 10:06 AM
To: Saam, Brian <brian.saam@wsu.edu>
Cc: Swindell, Samantha <sswindell@wsu.edu>
Subject: 669829 New or Restore Course: ASTRONOM 530

Saam, Brian – Chair – Physics and Astronomy,

Swindell, Samantha - Assoc Dean - CAS,

Matthew Duez has submitted a request for a major curricular change.

Course Subject: ASTRONOM

Course Number: 530

Title: Gravitation and Cosmology

Lecture Hours: 3

Total Credits: 3

Prerequisite: graduate standing

Catalog Description: 4-vectors; special relativity; introduction to tensors; examples of space-time metrics; black holes; gravitational waves; gravitational lensing; the Robertson-Walker metric; Inflationary cosmology; Big bang nucleosynthesis; Cosmic microwave background radiation; Structure formation.

Grading Type: Letter graded A-F

Requested Effective Date: Fall 2022

From: Swindell, Samantha
To: curriculum.submit; Saam, Brian
Subject: RE: 669829 New or Restore Course: ASTRONOM 530
Date: Friday, October 1, 2021 10:28:15 AM

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1. I approve this proposal in its current form.

From: curriculum.submit@wsu.edu <curriculum.submit@wsu.edu>
Sent: Friday, October 1, 2021 10:06 AM
To: Saam, Brian <brian.saam@wsu.edu>
Cc: Swindell, Samantha <sswindell@wsu.edu>
Subject: 669829 New or Restore Course: ASTRONOM 530

Saam, Brian – Chair – Physics and Astronomy,

Swindell, Samantha - Assoc Dean - CAS,

Matthew Duez has submitted a request for a major curricular change.

Course Subject: ASTRONOM

Course Number: 530

Title: Gravitation and Cosmology

Lecture Hours: 3

Total Credits: 3

Prerequisite: graduate standing

Catalog Description: 4-vectors; special relativity; introduction to tensors; examples of space-time metrics; black holes; gravitational waves; gravitational lensing; the Robertson-Walker metric; Inflationary cosmology; Big bang nucleosynthesis; Cosmic microwave background radiation; Structure formation.

Grading Type: Letter graded A-F

Requested Effective Date: Fall 2022

Both Chair and Dean approval is required to complete the submission process. Please indicate that you have reviewed the proposal by highlighting one of the statements below and **reply all** to this email. (curriculum.submit@wsu.edu.) [Details of major change requested can be found in the attached supplemental documentation]

Justification for a graduate astronomy sequence

The Department of Physics and Astronomy has targeted astronomy/astrophysics as one of its primary research areas, with four tenure or tenure-track faculty engaged in research and graduate advising in the subject. Each year, about a third of our graduate applicants express a preference for doing research in astronomy/astrophysics, and of our annual incoming graduate class of around ten, usually a few have astronomy/astrophysics as their main interest. Students must master a significant body of existing knowledge before they can meaningfully engage in astrophysical research. Unfortunately, while the department's required graduate curriculum gives students a strong physics background, it includes no astronomy. In fact, the course catalog currently lists only one graduate-level astronomy class: Astronomy 581: Advanced Topics in Astronomy. The lack of a graduate astronomy sequence no doubt hurts our ability to recruit astronomy graduate students, who can see that we have no structure in place to guarantee that they will be properly trained.

For the past decade, Physics and Astronomy faculty engaged in astrophysical research have tried to overcome this deficiency by offering Astronomy 581 at an average rate of about once per academic year. Often, faculty would teach a subject relevant to their research area. This was an imperfect arrangement, because there was no coordination to make sure all the foundational material was covered. Indeed, some of the core, foundational topics in astrophysics, such as stellar structure and radiation transport, have *never* been taught at a graduate level. Furthermore, students could have no guarantee that any particular astrophysical subject would be taught during their time as graduate students, and many have been driven to fulfill their course requirements with classes irrelevant to their topic of interest.

There is thus a great need for a sequence of courses which 1) is designed so that a student who takes all of them will have the core knowledge that any working astronomer or astrophysicist should have, and 2) is offered regularly, so that astronomy/astrophysics students can plan their course schedules with the knowledge that they will be able to take these classes within their first two or three years.

The astronomy faculty at WSU have jointly devised a 4-course sequence of 500-level classes for astronomy-focused graduate students. The plan is to offer one class per semester, so that each is taught once every other year. In the Physics and Astronomy department, it is customary for students to spend their first two years taking classes, and subsequent years focused on research. The planned schedule would allow students to take the astronomy sequence during this time. Which two Astronomy classes a student takes in his or her first year and which in the second year would, of course, alternate. We have designed the classes to be independent. None is a prerequisite of any other, so they can be taken in any order.

The proposed schedule also guarantees a minimal increase in faculty load, since the new classes will *replace* the current disorganized Astronomy 581 offerings. It will require teaching a graduate astronomy class each semester rather than each year. Fortunately, the number of qualified faculty will soon be double what it was a few years ago. Last year, a new astronomer, Vivienne Baldassare, joined us at the Assistant Professor level. Also, next semester, Associate Professor Sukanta Bose will return to Pullman after several years in India.

None of the proposed courses overlaps with any existing course in another department. The undergraduate astronomy sequence (ASTRONOM 435 and 436) would be totally inadequate for training graduate astronomy students.

For the graduate astronomy program to grow and thrive, the need for a core astronomy graduate sequence is obvious and urgent.

Justification for Astronomy 530: Gravitation and Cosmology

This course will cover topics that are at the base of several active areas of research today. It will prepare Physics and Astronomy graduate students to process new information being gathered by multiple types of detectors and observatories around the globe and construct from it explanations for interesting cosmic objects and phenomena. It will also partially help them to make informed decisions about what area they should select their problems from for their MSc or PhD thesis.

It is timely to begin offering this course. Many interesting discoveries have been made in this area over the last several years. In fact, the Physics Nobel Prize in 2017 and 2019 was awarded for discoveries in this area. In 2017 it was awarded for the direct observation of (colliding black holes with) gravitational waves and in 2019 the award was shared by a couple of astronomers who spent their lives studying the supermassive black hole at the center of our galaxy and a cosmologist who contributed immensely to understanding big bang nucleosynthesis, the cosmic microwave background radiation, and structure formation – all topics to be covered in this course.

While the aforementioned studies and breakthroughs in gravitation and cosmology have explained many fascinating observations, they have also raised multiple interesting questions and unraveled many new problems that generations of students will tackle in their graduate research. An express objective of this course will be to discuss these questions and teach the students tools and techniques they will need to answer some of them.

Astronomy 530 Syllabus

Course Information

Fall 2023

Astronomy 530: Gravitation and cosmology

3 credits. 4-vectors, special relativity, introduction to tensors, examples of space-time metrics, black hole formation and growth, gravitational waves, gravitational lensing, the Robertson-Walker metric, Inflationary cosmology, Big bang nucleosynthesis, Cosmic microwave background radiation, Sunyaev-Zel'dovich effect, Structure formation.

Course type: Face to face.

Meeting Schedule

Tu Th 11:35am – 12:50pm

Webster B12

Persistent zoom link for attendance while sick: TBD

Instructor Information

Sukanta Bose (or Matthew Duez)

948-B Webster

sukanta@wsu.edu, 509.335.1698

Office hours Tuesdays 2-4 or by appointment, face to face or zoom.

Textbooks and Course Materials

Required textbook:

Gravitation: Foundations and Frontiers, by T. Padmanabhan, Cambridge University Press, 1st edition (28 January 2010), ISBN-13: 978-0521882231

Student Learning Outcomes

Students will gain an in-depth knowledge of general relativity and its solutions, including cosmic phenomena it helps explain.

By the end of this course, students will:

- Be able to solve Einstein's equations for certain spacetime symmetries and matter-radiation distributions.

- Develop a thorough understanding of black hole spacetimes, including trajectories of massive and massless test particles

- Understand how certain properties of the cosmos can be deduced from CMBR observations, including the existence of dark energy

- Learn how the large-scale structure of the universe, with all its clumpiness, formed from nearly uniform initial conditions

- Understand how cosmic inflation explains certain key features of the universe, such as its isotropy.

Means of assessments: Weekly homework assignments will be used to assess conceptual understanding, mathematical fluency, and written expression. Mid-term and Final Exams will assess conceptual understanding and mathematical fluency.

Expectations for Student Effort

For each hour of lecture equivalent, students should expect to have a minimum of two hours of work outside class.

Course Timeline

Week	Topic	Assignments
01	4-vectors and special relativity recap	
02	Introduction to tensors, Christoffel symbols	HW1
03	The stress-energy and curvature tensors	HW2
04	Einstein field equation & some spacetime solutions	HW3
05	Black hole spacetimes	HW4
06	Black hole formation and growth	HW5
07	Gravitational waves	
08	Gravitational lensing	exam 1
09	The Robertson-Walker metric and cosmic evolution	
10	Inflationary universe	HW6
11	Big bang nucleosynthesis	HW7
12	Cosmic microwave background radiation	
13	Sunyaev-Zel'dovich effect	HW8

14	Dark matter	
15	Structure formation	exam 2

Description of Required Assignments

There will be about eight homework assignments. Each homework assignment will have three components: conceptual, analytic, and computational. Students will write and submit them online. Each homework assignment will review course material covered earlier in the week.

There will be two exams, each covering material from half of the course.

Course Grading

Grading policy

Homework will weigh 70% as regards determining a grade, with the exams weighing the remaining 30%. The weighted average will be assigned a letter grade according to a fixed scale:

W.S.U. Letter Grade	W.S.U. Grade Point	Percentage range
A	4.0	92+
A-	3.7	89 – 91.99
B+	3.3	86 – 88.99
B	3.0	83 – 85.99
B-	2.7	80 – 82.99
C+	2.3	77 – 79.99
C	2.0	74 – 76.99
C-	1.7	71 – 73.99
D+	1.3	68 – 70.99
D	1.0	65 – 67.99
F	0.0	0-64.99

Written expression, including correct grammar, punctuation, and spelling, is assessed as part of the homework assignments and exams. Exactitude and correctness also matter, for numerical answers as well as conceptual clarity.

Attendance Policy

Full attendance is expected. If you are fall sick you should stay home and (1) email the instructor, and (2) connect via zoom if possible. Chronic absenteeism will result in a reduced grade by one letter grade per week missed. This policy may be modified at the instructor's discretion.

Late Assignments

Late assignments will be penalized 5% per day late.

Exam make up policy

Makeup exams must be arranged in advance with the professor with suitable documentation such as a note from the coach or doctor and will suffer a 10% penalty in score regardless of the nature of the excuse.

COVID-19 Statement

Students are expected to abide by all current COVID-19 related university policies and public health directives, which could include wearing a cloth face covering, physically distancing, self-attestations, and sanitizing common use spaces. All current COVID-19 related university policies and public health directives are located at https://wsu.edu/covid-19/. Students who do not comply with these directives may be required to leave the classroom; in egregious or repetitive cases, students may be referred to the Center for Community Standards for university disciplinary action.

Academic Integrity Statement

Academic integrity is the cornerstone of higher education. As such, all members of the university community share responsibility for maintaining and promoting the principles of integrity in all activities, including academic integrity and honest scholarship. Academic integrity will be strongly enforced in this course. Students who violate WSU's Academic Integrity Policy (identified in Washington Administrative Code (WAC) 504-26-010(4) will receive a zero credit for the affected assignment(s), will not have the option to withdraw from the course pending an appeal, and will be reported to the Center for Community Standards.

Cheating includes, but is not limited to, plagiarism and unauthorized collaboration as defined in the Standards of Conduct for Students, WAC 504-26-010(3). You need to read and understand all of the definitions of cheating. If you have any questions about what is and is not allowed in this course, you should ask course instructors before proceeding.

If you wish to appeal a faculty member's decision relating to academic integrity, please use the form available at communitystandards.wsu.edu. Make sure you submit your appeal within 21 calendar days of the faculty member's decision.

Reasonable Accommodation Statement

Students with Disabilities: Reasonable accommodations are available for students with documented disabilities or chronic medical or psychological conditions. If you have a disability and need accommodations to fully participate in this class, please visit your campus' Access Center/Services website to follow published procedures to request accommodations. Students may also contact their campus offices to schedule an appointment with a Disability Specialist. All disability related accommodations are to be approved through the Access Center/Services on your campus. It is a university expectation that students visit with instructors (via email, Zoom, or in person) to discuss logistics within two weeks after they have officially requested their accommodations.

For more information contact a Disability Specialist on your home campus:

- Pullman, WSU Global Campus, Everett, Bremerton, and Puyallup: 509-335-3417 Access Center (https://www.accesscenter.wsu.edu) or email at access.center@wsu.edu
- Spokane: 509-358-7816 Access Services (https://spokane.wsu.edu/studentaffairs/access-resources/) or email j.schneider@wsu.edu
- Tri-Cities: Access Services (http://www.tricity.wsu.edu/disability/) or email g.hormel@wsu.edu
- Vancouver: 360-546-9238 Access Center (https://studentaffairs.vancouver.wsu.edu/student-wellness-center/access-center) or email van.access.center@wsu.edu

Accommodation of Religious Observances

Washington State University reasonably accommodates absences allowing for students to take holidays for reasons of faith or conscience or organized activities conducted under the auspices of a religious denomination, church, or religious organization. Reasonable accommodation requires the student to coordinate with the instructor on scheduling examinations or other activities necessary for course completion. Students requesting accommodation must provide written notification within the first two weeks of the beginning of the course and include specific dates for absences. Approved accommodations for absences will not adversely impact student grades. Absence from classes or examinations for religious reasons does not relieve students from responsibility for any part of the course work required during the period of absence. Students who feel they have been treated unfairly in terms of this accommodation may refer to Academic Regulation 104 - Academic Complaint Procedures.

Severe Weather Policy

For severe weather alerts, see: http://alert.wsu.edu/ and https://oem.wsu.edu/emergency-procedures/severe-weather/. In the event of severe weather affecting university operations, guidance will be issued through the alert system.

Safety and Emergency Notification

Classroom and campus safety are of paramount importance at Washington State University and are the shared responsibility of the entire campus population. WSU urges students to follow the "Alert, Assess, Act," protocol for all types of emergencies and the "Run, Hide, Fight" response for an active shooter incident []. Remain ALERT (through direct observation or emergency notification), ASSESS your specific situation, and ACT in the most appropriate way to assure your own safety (and the safety of others if you are able).
Please sign up for emergency alerts on your account at MyWSU. For more information on this subject, campus safety, and related topics, please view the FBI's Run, Hide, Fight video and visit the WSU safety portal.
Full details can be found at https://provost.wsu.edu/classroom-safety/

Learning Management System / Course Website

[Information concerning LMS space or course website]

Final Exam Information

[Date, time, and location for final exam]

Grading Policy – Incompletes

University policy (Academic Regulation 90) states that a grade of Incomplete may be awarded only if "the student is unable to complete their work on time due to circumstances beyond their control." A student in such circumstances should contact the instructor as soon as the inability to complete the course work becomes apparent, which must be before the work's due date.

Important Dates and Deadlines

[Course-specific dates and deadlines]

Classroom Expectations

Students are expected to be attentive throughout class. Questions for the instructor are encouraged. About once a week, students will work in groups on an in-class exercise. They should bring a laptop and a pencil and paper (or functional equivalent) to class to facilitate this group work. If students must arrive late or leave early, they should try to do so quietly to minimize disruption.

Instructional Methods

The class will have a traditional lecture format, supplemented with in-class group exercises. Students are allowed and encouraged to discuss homework with each other, but each student's homework submissions are expected to be completely his or her own. Homework submission consists in "sharing " (i.e. granting online access to) the student's homework notebook with the instructor any time before the due date. (It will remain accessible by the instructor thereafter.) Unless otherwise stated, students

should not alter their notebooks after submission. Such changes will be visible to the instructor via the notebook's history; the document will be graded according to its state at the time the homework was due.

Discrimination and Harrassment Policy Statement

Discrimination, including discriminatory harassment, sexual harassment, and sexual misconduct (including stalking, intimate partner violence, and sexual violence) is prohibited at WSU (See WSU Policy Prohibiting Discrimination and Harassment (Executive Policy 15) and Standards of Conduct for Students (WAC Code 504-26)).
If you feel you have experienced or have witnessed discriminatory conduct, you can contact the WSU Office of Civil Rights Compliance & Investigation (CRCI) and/or the WSU Title IX Coordinator (see crciwsu.edu/title-ix/) at 509-335-8288 to discuss resources, including confidential resources, and reporting options. (Visit crci.wsu.edu for more information).
Most WSU employees, including faculty, who have information regarding sexual harassment or sexual misconduct are required to report the information to CRCI or a designated Title IX Coordinator or Liaison. (Visit crci.wsu.edu/reporting-requirements for more info).

Students in Crisis – Pullman Resources

If you or someone you know is in immediate danger, DIAL 911 FIRST!

Student Care Network: https://studentcare.wsu.edu/

Cougar Transit: 978 267-7233

WSU Counseling and Psychological Services (CAPS): 509 335-2159

Suicide Prevention Hotline: 800 273-8255

Crisis Text Line: Text HOME to 741741

WSU Police: 509 335-8548

Pullman Police (Non-Emergency): 509 332-2521

WSU Office of Civil Rights Compliance & Investigation: 509 335-8288

Alternatives to Violence on the Palouse: 877 334-2887

Pullman 24-Hour Crisis Line: 509 334-1133