UNIVERSITY OF CALGARY
FACULTY OF SCIENCE

Department of Physics & Astronomy
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REVISED COURSE OUTLINE FOR REMOTE LEARNING

To account for the necessary transition to remote learning from March 13 onward, adjustments have been made to assessment deadlines and requirements so that all coursework tasks are in line with the necessary and evolving health precautions for all involved (students and staff). If you are unable to meet the deadlines or requirements specified, please connect with your course instructor to work out alternative dates/assessments.

1. **Course:** ASPH 403, Stellar Structure and Evolution - Winter 2020

   Lecture 01: MWF 11:00 - 11:50 - Remote Learning (check with your instructor or coordinator for details)

Instructor	Email	Phone	Office	Hours
Dr. Jeroen Stil	jstil@ucalgary.ca	403 220-8015	SB 519	Fridays, 2 pm - 3 pm

   ASPH 403 deals with the internal structure of stars, and the evolution of that structure. Key concepts for this course are physical principles that establish equilibrium in a sphere of gas with mass of order 2000 billion billion billion kg, and how fast conditions change if equilibrium is disturbed. We apply physics of a plasma with a density 20 times that of solid steel and a temperature of 15 million K. As a result, this course is more theoretical than preceding ASPH courses, and it introduces a multitude of concepts that are required to understand how stars work. Some of the challenges of this course are associated with these concepts and applications of thermodynamics, hydrodynamics, quantum mechanics and nuclear physics that will be introduced in this course.

   Course Site:

   D2L: ASPH 403 L01-(Winter 2020)-Stellar Structure and Evolution

   Note: Students must use their U of C account for all course correspondence.

2. **Requisites:**

   See section 3.5.C in the Faculty of Science section of the online Calendar.

   Prerequisite(s):
   Astrophysics 213 or 305; Physics 325 and Mathematics 375.

3. **Grading:**

   The University policy on grading and related matters is described in F.1 and F.2 of the online University Calendar. In determining the overall grade in the course the following weights will be used:

Component(s)	Weighting %
Assignments/term work	25
Observing lab	15
Midterm 1, Wednesday, February 12, in class	12.5
Midterm 2, Take-home exam, due March 28, 2020 at 23:59	12.5
Final Exam, Take-home exam, due on date scheduled by registrar	35

   Take-home exams will be made available by the instructor in D2L 24 hours before the due date of the exam.

   Each piece of work (reports, assignments, quizzes, midterm exam(s) or final examination) submitted by the student will be assigned a grade. The student's grade for each component listed above will be combined with the indicated weights to produce an overall percentage for the course, which will be used to determine the course letter grade.

   The conversion between a percentage grade and letter grade is as follows.

	A+	A	A-	B+	B	B-	C+	C	C-	D+	D
Minimum % Required	93 %	90 %	85 %	80%	75%	70 %	65 %	60%	55%	50 %	45 %

   The posted boundaries are **strict minimum thresholds** for the assignment of a letter grade, with no rounding

applied. For example, a 84.99% average for the course will result in a B+ grade.

The over-all assignment grade will be calculated as the average grade of all assignments, with equal weight assigned to each assignment.

Bear in mind that a grade of D+ or below will result if a student does not receive a passing grade for the final exam. If a passing grade for the final exam is not obtained, the maximum possible letter grade for the course is D+ irrespective of the weighted mean percentage grade for the course.

4. **Missed Components Of Term Work:**

The University has suspended requirements for students to provide evidence for reasons for absences so please do not attend medical clinics for medical notes or Commissioners for Oaths for statutory declarations. Please let your instructor know immediately if you are ill and cannot meet the deadlines specified.

Missed components of course work receive a zero grade. If you miss any component of the course, contact the instructor at the earliest possible opportunity. It is best to do this by email, with supporting documentation. Students are reminded that doctor's notes are acceptable, but not required. A statutory declaration made to a commissioner of oath is also acceptable. In case of a documented, valid reason, accommodation will be made at the discretion of the instructor.

5. **Scheduled Out-of-Class Activities:**

There are no scheduled out of class activities for this course.

6. **Course Materials:**

Required Textbook(s):

> Dina Prialnik, *An Introduction to the Theory of Stellar Structure and Evolution, 2nd Edition*, Cambridge University Press.

Lecture notes made in class on the document camera will be posted on D2L. These notes are made available as a study aid, and as a supplement to the text book. They are not a replacement for the text book. It is highly recommended to read the set chapters of the text book carefully, with emphasis on understanding key physics. In the lectures, we will emphasize important parts of the theory and discuss key steps in detail, with the expectation that the essential intermediate steps can be learnt from the text book.

7. **Examination Policy:**

Exams may draw from all components of the course, including assignments, course notes, TopHat questions, and set sections of the text book.

The second midterm exam and the final exam will be administered as "take-home exams". There may be different versions of the exam at the discretion of the instructor. Students will receive the exam in 24 hours in advance and they must return their answers through their dropbox in D2L by the due date. Take home exams are open book exams. A formula sheet will not be provided. Students may be asked to discuss a topic related to the course in a few paragraphs as part of the exam. In that case, the marking will be based on the level of insight in the topic displayed in the text provided.

Students should understand that discussing a take home exam with other students is a form of academic misconduct.

This course contains a great amount of detail from different disciplines in physics. The emphasis in on understanding how physical processes define the constitution of the stellar interior as a function of stellar mass, composition and evolutionary state. For this purpose, an understanding of the physics of these processes is required. The exams may assess this understanding, and your ability to do calculations on specific physical processes.

All exams are cumulative.

Students should also read the Calendar, Section G, on Examinations.

8. **Approved Mandatory And Optional Course Supplemental Fees:**

   There are no mandatory or optional course supplemental fees for this course

9. **Writing Across The Curriculum Statement:**

   For all components of the course, in any written work, the quality of the student's writing (language, spelling, grammar, presentation etc.) can be a factor in the evaluation of the work. See also Section E.2 of the University Calendar.

   Grading depends in part on clarity and conciseness of the answers provided. This includes the structure and logic progression of solutions. No points are awarded for unclear or illegible answers. No points will be subtracted for minor grammatical, style, or spelling errors.

10. **Human Studies Statement:**

    Students will not participate as subjects or researchers in human studies.

    See also Section E.5 of the University Calendar.

11. **Reappraisal Of Grades:**

    A student wishing a reappraisal, should first attempt to review the graded work with the Course coordinator/instructor or department offering the course. Students with sufficient academic grounds may request a reappraisal. Non-academic grounds are not relevant for grade reappraisals. Students should be aware that the grade being reappraised may be raised, lowered or remain the same. See Section I.3 of the University Calendar.

    a. **Term Work:** The student should present their rationale as effectively and as fully as possible to the Course coordinator/instructor within **ten business days** of either being notified about the mark, or of the item's return to the class. If the student is not satisfied with the outcome, the student shall submit the Reappraisal of Graded Term work form to the department in which the course is offered within 2 business days of receiving the decision from the instructor. The Department will arrange for a reappraisal of the work within the next ten business days. The reappraisal will only be considered if the student provides a detailed rationale that outlines where and for what reason an error is suspected. See sections I.1 and I.2 of the University Calendar

    b. **Final Exam:**The student shall submit the request to Enrolment Services. See Section I.3 of the University Calendar.

12. **Other Important Information For Students:**

    a. **Mental Health** The University of Calgary recognizes the pivotal role that student mental health plays in physical health, social connectedness and academic success, and aspires to create a caring and supportive campus community where individuals can freely talk about mental health and receive supports when needed. We encourage you to explore the mental health resources available throughout the university community, such as counselling, self-help resources, peer support or skills-building available through the SU Wellness Centre (Room 370, MacEwan Student Centre, Mental Health Services Website) and the Campus Mental Health Strategy website (Mental Health).

    b. **SU Wellness Center:** The Students Union Wellness Centre provides health and wellness support for students including information and counselling on physical health, mental health and nutrition. For more information, see www.ucalgary.ca/wellnesscentre or call 403-210-9355.

    c. **Sexual Violence:** The University of Calgary is committed to fostering a safe, productive learning environment. The Sexual Violence Policy (https://www.ucalgary.ca/policies/files/policies/sexual-violence-policy.pdf) is a fundamental element in creating and sustaining a safer campus environment for all community members. We understand that sexual violence can undermine students' academic success and we encourage students who have experienced some form of sexual misconduct to talk to someone about their experience, so they can get the support they need. The Sexual Violence Support Advocate, Carla Bertsch, can provide confidential support and information regarding sexual violence to all members of the university community. Carla can be reached by email (svsa@ucalgary.ca) or phone at 403-220-2208 .

    d. **Misconduct:** Academic misconduct (cheating, plagiarism, or any other form) is a very serious offence that will be dealt with rigorously in all cases. A single offence may lead to disciplinary probation or suspension or expulsion. The Faculty of Science follows a zero tolerance policy regarding dishonesty. Please read the sections of the University Calendar under Section K. Student Misconduct to inform yourself of definitions, processes and penalties. Examples of academic misconduct may include: submitting or presenting work as if it were the student's own work when it is not; submitting or presenting work in one course which has also been submitted in another course without the instructor's permission; collaborating in whole or in part without prior agreement of the instructor; borrowing experimental values from others without the instructor's

approval; falsification/ fabrication of experimental values in a report. **These are only examples**.

e. **Assembly Points:** In case of emergency during class time, be sure to FAMILIARIZE YOURSELF with the information on assembly points.

f. **Academic Accommodation Policy:** Students needing an accommodation because of a disability or medical condition should contact Student Accessibility Services in accordance with the procedure for accommodations for students with disabilities available at procedure-for-accommodations-for-students-with-disabilities.pdf.

Students needing an accommodation in relation to their coursework or to fulfill requirements for a graduate degree, based on a protected ground other than disability, should communicate this need, preferably in writing, to the Associate Head of the Department of Physics & Astronomy, Dr. David Feder by email phas.ahugrd@ucalgary.ca or phone 403-220-8127. Religious accommodation requests relating to class, test or exam scheduling or absences must be submitted no later than **14 days** prior to the date in question. See Section E.4 of the University Calendar.

g. **Safewalk:** Campus Security will escort individuals day or night (See the Campus Safewalk website). Call 403-220-5333 for assistance. Use any campus phone, emergency phone or the yellow phones located at most parking lot pay booths.

h. **Freedom of Information and Privacy:** This course is conducted in accordance with the Freedom of Information and Protection of Privacy Act (FOIPP). Students should identify themselves on all written work by placing their name on the front page and their ID number on each subsequent page. For more information, see Legal Services website.

i. **Student Union Information:** VP Academic, Phone: 403-220-3911 Email: suvpaca@ucalgary.ca. SU Faculty Rep., Phone: 403-220-3913 Email: sciencerep@su.ucalgary.ca. Student Ombudsman, Email: ombuds@ucalgary.ca.

j. **Internet and Electronic Device Information:** Unless instructed otherwise, cell phones should be turned off during class. All communication with other individuals via laptop, tablet, smart phone or other device is prohibited during class unless specifically permitted by the instructor. Students that violate this policy may be asked to leave the classroom. Repeated violations may result in a charge of misconduct.

k. **Surveys:** At the University of Calgary, feedback through the Universal Student Ratings of Instruction (USRI) survey and the Faculty of Science Teaching Feedback form provides valuable information to help with evaluating instruction, enhancing learning and teaching, and selecting courses. Your responses make a difference - please participate in these surveys.

l. **Copyright of Course Materials:** All course materials (including those posted on the course D2L site, a course website, or used in any teaching activity such as (but not limited to) examinations, quizzes, assignments, laboratory manuals, lecture slides or lecture materials and other course notes) are protected by law. These materials are for the sole use of students registered in this course and must not be redistributed. Sharing these materials with anyone else would be a breach of the terms and conditions governing student access to D2L, as well as a violation of the copyright in these materials, and may be pursued as a case of student academic or non-academic misconduct, in addition to any other remedies available at law.

1. If you need help.

Detailed course information will be posted on D2L. Check D2L for important dates like due dates for assignments, midterm information, etc.

Email to the instructor is strictly for issues related to the organization of the course, or to book an appointment. Questions about course material cannot be effectively answered by email. Do not send scanned notes by email.

Questions about course material can be asked immediately after class, during office hours, or by appointment. The instructor will make an effort to stay after lectures until all questions have been answered.

In the on-line course delivery because of the COVID-19 virus, office hours will be held as a town-hall style meeting in zoom. Details to be announced by email. Office hours will not be recorded.

Zoom lectures may be recorded to be made available only for the purpose of studying for ASPH 403.

2. Assignments.

Assignments are intended to provide hands-on experience with course material and to explore specific parts of the theory by self-study. To achieve these goals, we will do a mix of on-line and written assignments. The on-line assignments will be administered through TopHat. These allow a wider range of practice problems and a faster turnaround time.

The TopHat course identification is **ASPH403W2020**. The join code is **760060**. You must make sure your name and student ID are entered in the correct area, to ensure you receive grades for TopHat assignments.

Written assignments allow for more in-depth considerations and calculations. **Written assignments must be submitted on paper by the due date.** Latex/Word typesetting or hand-written solutions are accepted on an equal basis. Pages must be securely stapled together.

Assignments will receive equal weight for the purpose of calculating the over-all assignment grade.

All assignments will be announced by email.

3. Observing Lab.

ASPH 403 includes an observing lab in which groups of 3-4 students observe the spectrum of a star with the new Echelle Spectrometer on the Clarke-Milone telescope of the Rothney Astrophysical Observatory. The observations are done after hours (when the sky is dark and clear) from Campus, using a web interface to work with the telescope.

Lab groups of 3 to 4 students must be formed by **Monday, January 20, 2020**. Each team sends an email to the instructor with the team members. Changes in the team after January 20 must be approved by the instructor.

Each group is assigned a star. Each star has its own interesting spectrum in the context of stellar evolution. The task is to observe and analyze the spectrum and BVR photometry for its specific significant features and to report on this in the context of the evolutionary state of the star. Some details of the observations will be different for each group, depending on the brightness of the star and the spectroscopic analysis.

It is possible for a group to propose a star for observations. The brightness of the star must be between visual magnitude 2 and 6, and the star's spectrum must be of interest in the context of stellar evolution. **Any star must be pre-approved by the instructor.** The telescope cannot observe all of the visible sky. Students must follow instructions to avoid damage to the equipment.

The report must describe the observations, present the calibrated spectrum, and interpretation. There must be at least one page of text that discusses the spectrum in the context of the star's evolutionary state. Each group submits one report, with a title page that contains the names of all group members, and the contributions of each group member.

The spectrograph is a new instrument at the Rothney Astrophysical Observatory. Students will learn to operate the spectrograph remotely. The starlight is captured by an optical fiber. For this purpose, the star must be kept in a specific point of the field of view of the telescope. Regular adjustments of the telescope pointing are required. The team should distribute tasks such that some take care of the observations, while others make an initial assessment of the quality of the spectrum. This prevents disappointments during data processing and the need to redo the observations.

Considering the risk posed by the COVID-19 virus, processing the spectra in groups is not allowed. A best effort will be made to provide students with their processed spectra by the RAO teaching assistant. The marking of the report will also shift more toward analysis of the data and discussion of the observed spectrum in relation to the star's evolutionary state.

If data processing is interrupted by external circumstances, individual students are offered the choice to either

- **submit a detailed report on their star based on at least 3 research papers,**
- **or to have their course grade evaluated based solely on their performance on the other course components.**

In any case, students are expected to research their star specifically, the class of stars to which it belongs (e.g. eclipsing binaries, pulsating stars, Be stars), and the astrophysical context of the star and its class in terms of stellar structure and evolution.

Observations should be complete by March 15, 2020. Students are required to contact the instructor if they have not finished observations by this date.

The lab report is due on or before April 11, 2020. Use Latex or Word for typesetting your report. The report must be submitted electronically as a PDF. If the file is too large to attach to an email, contact the instructor.

4. Course Syllabus

The following topics are presented approximately in order of subsequent chapters in the text book:

The HR diagram, main regions in the HR diagram, colour-magnitude diagram, mass-luminosity relation

Equations of stellar structure, thermal equilibrium, hydrostatic equilibrium, virial theorem, equation for changing chemical composition, dynamical time scale, hydrostatic timescale, thermal time scale, nuclear time scale

Equation of state (ideal gas, degenerate gas), gas law for mixture of ions and electrons, radiation pressure, adiabatic exponent, radiative transfer,

Nuclear binding energy, Nuclear reactions, H, He, C, O, Si burning, Creation of heavy elements (s and r process),

Stellar equilibrium configurations, polytropic stellar models, Chandrasekhar mass, Eddington luminosity,

Secular thermal and dynamical instability of stars, convection, mixing length method

Evolution of stars, The log(T)-log(density) plane, evolution of the centre of a star, theory of the main sequence, late evolutionary phases,

Stellar mass loss (basic physical description only)

Detailed picture of the evolution of stars, Hayashi zone and pre-main sequence evolution, Main sequence structure and evolution, late stages of stellar evolution by mass (low, intermediate and high mass stars).

Expected prior knowledge for students: Astrophysics: basic nature of stars, galaxies and the interstellar medium. Concepts of flex, flux density, intensity, luminosity and how these are related, apparent and visual magnitude. Physics: properties of radiation, black body spectrum, Stefan-Boltzmann law, Wien displacement law, radiation transfer equation, atoms, and spectral lines, basics of nuclear physics and atomic physics. Mathematics: multivariate calculus and differential equations.

Course Outcomes:

- Understand the equations that relate pressure, density and temperature in a star in hydrostatic and local thermodynamic equilibrium for chemically homogeneous and inhomogeneous stars.
- Relate the physical state of the gas in the interior of a star to evolutionary time scales and the observed distribution of stars in the Hertzsprung-Russell diagram.
- Quantitatively evaluate the equation of state and physical processes such as nuclear fusion, convection, and radiation transport for plasma in equilibrium ionization under non-degenerate and degenerate conditions.
- Discuss the late stages of stellar evolution as a function of mass, and how these relate to the creation of heavy elements and the dissemination of products of stellar nucleosynthesis into the interstellar medium.
- Describe the main features of the spectra of stars in the spectral sequence OBAFGKM and understand the physical origin of spectral lines.

Electronically Approved - Mar 18 2020 18:47

Department Approval

Electronically Approved - Mar 18 2020 18:51

Associate Dean's Approval for alternate final examination arrangements or remote learning