Astrophysics I – Radiative Processes in Astrophysics

Fall Semester 2021

Course and Contact Information

Department and Course:	Physics, PHYS 6630
Semester:	Fall 2021
Time:	Monday and Wednesday 3:45 PM - 5:00 PM
Location:	Corcoran 413
Course Web Site:	http://blackboard.gwu.edu

Instructor: Prof. Oleg Kargaltsev

Campus address: Corcoran 407 (office)

Phone: 202-994-7225 (office)

E-Mail: kargaltsev@gwu.edu

Office Hours: Wednesday, 11 am -noon

PHYS 6630 – Radiative Processes in Astrophysics

Week	Date	Homework Due or Exam	Topics
1	Monday Aug 30		Course structure and motivation. Assessment. Astrophysics as physics and astronomy. Multiwavelength Universe.
1	Wednesday Sep 1		Electromagnetic Radiation: Accelerated charge. Spectrum.
2	Monday Sep 6		Labor Day (no class)
2	Wednesday Sep 8		Radiation from moving charges.
3	Monday Sep 13	HW#1	Basic Radiation Quantities. Thermal radiation.
3	Wednesday Sep 15		Optical depth. Radiative transfer.
4	Monday Sep 20		Bremsstrahlung.
4	Wednesday Sep 22		Review and problem solving.
5	Monday Sep 27		Line emission and absorption. Absorption in ISM.
5	Wednesday Sep 29	HW#2	Saha equation. Strömgren sphere.
6	Monday Oct 4		Cherenkov radiation. Cyclotron radiation.
6	Wednesday, Oct 6		Special Relativity reminder. Application to radiation.
7	Monday Oct 11	HW#3	Review and problem solving.
7	Wednesday Oct 13		Synchrotron and Curvature Radiation.
8	Monday Oct 18		Applications of synchrotron and curvature radiation.
8	Wednesday Oct 20	HW#4	Review and problem solving.
9	Monday Oct 25		Special topic: What can we learn from variability?
9	Wednesday Oct 27		Thomson and Compton Scattering.
10	Monday Nov 1		Applications of Thomson and Compton Scattering.

10	Wednesday Nov 3	HW#5	Review and problem solving.
11	Monday Nov 8		MIDTERM EXAM
11	Wednesday Nov 10	Term project outline is due	Coherent emission. Applications.
12	Monday Nov 15		Working with spectra. Examples of actual data analysis.
12	Wednesday Nov 17		Inferring source properties from multiwavelength spectrum.
13	Monday Nov 22	Term Project Progress Report	Recognizing radiative processes in astrophysical sources.
13	Wednesday Nov 24		**Thanksgiving Break**
14	Monday Nov 29	HW#6	Term project updates. Discussion of term projects.
14	Wednesday Dec 1		Gravitational waves.
15	Monday Dec 6	Term Project due.	**Term project presentations.**
15	Wednesday Dec 8		**Term project presentations.**

Detailed Course Description

LEARNING OBJECTIVES:

In this course, you will:

1. Acquire knowledge about radiation processes relevant to cosmic sources;
2. Develop analytical, scientific, and critical thinking skills;
3. Develop the ability to identify the appropriate physics laws/principles and mathematical methods needed to tackle a specific astrophysics problem;
4. Make connections between mathematics, physics and astronomy.

COURSE DESCRIPTION: *In this astrophysics course you will learn about the physics of radiative processes and multiwavelength radiation from cosmic sources, you will also learn how to apply theoretical framework to real measurements and learn about the nature of various cosmic objects. Recent developments in multiwavelength and gravitational wave astrophysics will be covered.*

PREREQUISITE: **Electrodynamics and Classical Field Theory (PHYS 6210).** If the prerequisite requirement is not fulfilled, instructor's approval is required to enroll into Astrophysics I (PHYS 6630).

LECTURES: Lectures are primarily meant to explain difficult concepts, to expand on the reading material, and to introduce topics not covered in the textbooks such as examples from real observations and data or recently published results. If you do not understand something, you are very much encouraged to ask questions during the lectures. If something is not clear, please raise your hand and tell me right away. All previous lectures, all reading assignments, and all homework assignments will be posted in the Blackboad course page. Please check this page frequently. If the page is updated, announcements will be made through the Blackboard.

YOUR RESPONSIBILITIES:

1. Reading the textbook material assigned for every class.
2. Reading any additional materials distributed in class or via Blackboard.
3. Actively participating in discussions during class.
4. Reproducing any calculations and derivations shown in class alone by yourself (with textbook and lecture notes closed).
5. Doing the homework by yourself and turning it in time.
6. Perform an independent study of radiation from a cosmic source of your choice and submit a written report (in lieu of final exam).

TEXTBOOKS AND OTHER USEFUL BOOKS:

There is one **required** (you need to buy it or get them from the library) textbook for this course:

* Radiative Processes in Astrophysics
  G.B. Rybicki and A.P. Lightman
  Wiley Interscience, 1979

ISBN: 0-471-82759-2
This excellent but somewhat old book is the most frequently used a graduate level textbook the radiative processes course.

There are other ***optional*** but very good books which include radiative processes topics with a focus on high-energy astrophysics that can be useful for various parts of this course and also for your future research. Here are some titles:

* High-Energy Astrophysics: Third Edition
M.S. Longair
Cambridge University Press, 2011
ISBN: 978-0-521-75618-1
Extensive coverage of high-energy astrophysics including phenomenological astronomy, physical processes, Galactic and extragalactic sources.

* Plasma Astrophysics: Saas-Fee Advanced Course 24. Lecture Notes 1994.
J.G. Kirk, D.B. Melrose, E.R. Priest (Author)
Springer-Verlag Berlin Heidelberg 2010
ISBN: 978-364-208202-3
An excellent, concise introduction to plasma astrophysics and magnetohydrodynamics

* High Energy Radiation from Black Holes: Gamma Rays, Cosmic Rays, and Neutrinos
Charles D. Dermer & Govind Menon
Princeton University Press, 2009
ISBN: 9780691144085
Great modern graduate level textbook covering broad range of topics in theoretical high-energy astrophysics.

* Black Holes, White Dwarfs, and Neutron Stars: The Physics of Compact Objects
S.L. Shapiro and S.A. Teukolsky
Wiley Interscience, 1983
ISBN: 0-471-87316-0
This somewhat old but renown book covers the physics compact objects mentioned in its title. Very well written in places more advanced than undergraduate course.

GW Gelman Library should have most of these books. However, if you are planning a professional career in astronomy/astrophysics, you will need to take a look at these books at some point so you may want to buy them in Amazon (used books are cheaper).

In addition to the textbooks, *I also strongly encourage you to look through the preprints abstracts http://arxiv.org/list/astro-ph/recent for articles relevant for the topic of the upcoming class. If something catches your attention, we shall discuss it at the beginning of each class period. This will count toward your active participation part the course grade.*

GRADING: Your grade will be based on homework (30%), the midterm exam (20%), class attendance/participation (20%), term project (30%). Lectures are mandatory and active participation during the class period is expected. If you missed my lecture because of medical reasons you are required to bring a note from your doctor stating that you have been sick.

The grading scale for the course is as follows:

106.00 - 94.000	A
93.999 - 90.000	A–
89.999 - 86.000	B+
85.999 - 82.000	B
81.999 - 78.000	B–
77.999 - 74.000	C+
73.999 - 70.000	C
69.999 - 66.000	C–
65.999 - 61.000	D+
60.999 - 55.000	D
54.999 - 50.000	D–
49.999 - 0.000	F

HOMEWORK AND TEAMWORK POLICY: Homework assignments will be distributed and collected ***before*** the class starts. The due dates are specified otherwise in the course timetable (unless a different date is announced in class). The homework problems will also be available through the Homework section of the course in the Blackboard. Any homework turned in late, without a valid excuse (e.g., medical), will be assigned only half of the credit. Please start working on your homework early and do not postpone it till the last day!

In this course you are expected to think independently and creatively. You will need this skill in your future careers. You are required to work by yourself (alone!) on each problem for an hour before you discuss it with anyone else or come to the office hours for help. Feel free to consult the textbooks and lecture notes but *do not* google the solution. After you made an honest attempt to solve a problem for at least 1 hour, you may discuss it with other students. Any substantial use of online resources must be *clearly indicated* in your homework. A partial credit is given if the answer wrong or even if the wrong method is used but a reasonable hypothesis about the underlying physical processes is formulated and an effort to solve the problem is demonstrated. Should a particular problem cause troubles for majority of students in the class, it will be reviewed in class.

It is required to write the homework solution in a detailed and clear way. If the logic of the solution is unclear, no credit will be given. A detailed, well-structured solution will always result in a higher grade. Please, do not substitute the numbers into the equations until the very end, whenever possible. Clearly number the problems in your homework in the same way as they are numbered in the homework assignment. Some homework sets may include more challenging (research grade) problems for extra credit. Solving them can be used to compensate for poor performance in exams.

Each problem (homework or exams) is graded on a five-point scale. One point is awarded if you demonstrate understanding of the physical processes associated with the problem. Another point is awarded if you use the correct equations (assuming the equations are needed to solve the problem). Two points are awarded for correct solution of the equations. Final point is awarded if the numerical answer (if required) is correct or, if you got the wrong numerical answer but realized this and wrote a more reasonable answer you found elsewhere. There may deviation from this grading scheme, if the problem does not require any equation solving or numerical answers.

If you disagree with the homework grade, you must appeal by e-mail **within 1 week** from the date when graded homework was distributed. The appeal must include your name, clearly identify the issue in question, contain a detailed explanation of what you think is wrong or unfair, and your original homework must be included as a part of the appeal. The same procedure applies to the exam.

EXAMS: There will be **one (midterm) exam** and the term project (in lieu of the final exam). The midterm exam will cover all topics up to the day of the exam. You will be responsible for knowing the material presented in class as well as material from the assigned readings including the textbooks and other assigned reading material (unless the material was marked as optional). The exam will be closed book and closed notes (except for those distributed to you). You may use standard, non-programmable calculators on the exams. Cell phones, laptops, Ipads, and calculators that can store equations and text are not allowed. The violation of this policy will cost you half the exam score. A table with physical constants (in cgs) will be provided during the exam.

The midterm exam will have about 5 questions/problems. Questions may include definitions, physical explanations, brief calculations, and brief derivations. You should work efficiently to earn as many points as possible. Do not get stuck on a single question for the entire exam period. An incomplete solution can result in partial credit. To get the full or partial credit, your written answers must be easily legible and must demonstrate your reasoning clearly. Please provide your solutions in the same order in which the questions are presented.

If you missed the exam and have a medical or other valid excuse, you must contact the instructor as soon as possible regarding this matter.

TERM PROJECT: An application of what you learned about the radiative processes to the measured source properties (e.g., with JVLA, Chandra, XMM-Newton, NuStar, Swift, Hubble, Fermi LAT etc.) with the goal to infer physical properties of the source and/or determine its nature. You will need to write a detailed report about your investigation and submit by the date specified in the course schedule (see above). You will also need to present your investigation to the rest of the class and answer questions. Think of this as a short, research-grade paper. The report needs to be prepared in Latex (preferred) or other word processor. There are some important intermediate steps in this process. Please see the course schedule for details and due dates for the intermediate steps.

CLASS ATTENDANCE AND PARTICIPATION: The class attendance and participation are very important. They are part of the grade (see above). To do well in this course , you should (1) come to class and pay attention during the lecture, (2) answer questions when they are posed by the instructor, (3) ask questions in class when you don't understand something, have an idea, or just curious about something related to the lecture topic, (4) perform simple tasks at the whiteboard when requested by the instructor, (5) be courteous and friendly to your fellow students and the instructor.

OFFICE HOURS AND QUESTIONS: You are *strongly* encouraged to come to the office to get help with the course. If you cannot make it at the appointed times, please e-mail the instructor to find an alternative different time to meet.

Miscellaneous

***Blackboard* system:** The *Blackboard* courseware system will be used for this course. The address for the *Blackboard* web site is: **http://blackboard.gwu.edu**

After entering *Blackboard*, it is necessary for you to click on the PHYS 6630 course. You are *automatically* subscribed within the *Blackboard* system to the courses for which you are registered (but you also must have a GW e-mail address!). The web access provided by *Blackboard* is a valuable resource for all aspects of the class. It includes course announcements, lecture notes, homework solutions, discussion forums, and other useful features. You should visit it frequently!

University policies

Use of Electronic Course Materials and Class Recordings

Students are encouraged to use electronic course materials, including recorded class sessions, for private personal use in connection with their academic program of study. Electronic course materials and recorded class sessions should not be shared or used for non-course related purposes unless express permission has been granted by the instructor. Students who impermissibly share any electronic course materials are subject to discipline under the Student Code of Conduct. Please contact the instructor if you have questions regarding what constitutes permissible or impermissible use of electronic course materials and/or recorded class sessions. Please contact Disability Support Services at disabilitysupport.gwu.edu if you have questions or need assistance in accessing electronic course materials.

Academic Integrity Code

Academic Integrity is an integral part of the educational process, and GW takes these matters very seriously. Violations of academic integrity occur when students fail to cite research sources properly, engage in unauthorized collaboration, falsify data, and in other ways outlined in the Code of Academic Integrity. Students accused of academic integrity violations should contact the Office of Academic Integrity to learn more about their rights and options in the process. Outcomes can range from failure of assignment to expulsion from the University, including a transcript notation. The Office of Academic Integrity maintains a permanent record of the violation.

More information is available from the Office of Academic Integrity at studentconduct.gwu.edu/academic-integrity. The University's "Guide of Academic Integrity in Online Learning Environments" is available at studentconduct.gwu.edu/guide-academic-integrity-online-learning-environments. Contact information: rights@gwu.edu or 202-994-6757.

University policy on observance of religious holidays

In accordance with University policy, students should notify faculty during the first week of the semester of their intention to be absent from class on their day(s) of religious observance. For details and policy, see "Religious Holidays" at provost.gwu.edu/policies-procedures-and-guidelines.

Support for students outside the classroom

Virtual academic support

A full range of academic support is offered virtually in the fall 2020 and spring 2021 semesters. See coronavirus.gwu.edu/top-faqs for updates.

Tutoring and course review sessions are offered through Academic Commons in an online format. See academiccommons.gwu.edu/tutoring

Writing and research consultations are available online. See academiccommons.gwu.edu/writing-research-help

Coaching, offered through the Office of Student Success, is available in a virtual format. See studentsuccess.gwu.edu/academic-program-support

Writing Center

GW's Writing Center cultivates confident writers in the University community by facilitating collaborative, critical, and inclusive conversations at all stages of the writing process. Working alongside peer mentors, writers develop strategies to write independently in academic and public settings. Appointments can be booked online. See gwu.mywconline.

Academic Commons

Academic Commons provides tutoring and other academic support resources to students in many courses. Students can schedule virtual one-on-one appointments or attend virtual drop-in sessions. Students may schedule an appointment, review the tutoring schedule, access other academic support resources, or obtain assistance at academiccommons.gwu.edu. Academic Commons offers several short videos addressing different virtual learning strategies for the unique circumstances of the fall 2020 and spring 2021 semesters. See academiccommons.gwu.edu/study-skills. They also offer a variety of live virtual workshops to equip students with the tools they need to succeed in a virtual environment. See tinyurl.com/gw-virtual-learning

Disability Support Services (DSS) 202-994-8250

Any student who may need an accommodation based on the potential impact of a disability should contact Disability Support Services to establish eligibility and to coordinate reasonable accommodations. disabilitysupport.gwu.edu

Counseling and Psychological Services 202-994-5300

GW's Colonial Health Center offers counseling and psychological services, supporting mental health and personal development by collaborating directly with students to overcome challenges and difficulties that may interfere with academic, emotional, and personal success. healthcenter.gwu.edu/counseling-and-psychological-services