Astrophysics II

Fall Semester 2019

Course and Contact Information

Department and Course:	Physics, PHYS 6730
Semester:	Fall 2019
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) 814-404-6378 (cell)
E-Mail:	kargaltsev@gwu.edu
Office Hours:	Wednesday, 11 am -noon

PHYS 6730— Astrophysics

Week	Date	Homework Due or Exam	Topics
1	Monday Aug 26		A Brief History of High-Energy Astronomy. Basic terminology.
1	Wednesday Aug 28		Review of radiation processes (covered in Astrophysics I).
2	Monday Sep 2		Labor Day (no class)
2	Wednesday Sep 4		Review of radiation processes (covered in Astrophysics I).
3	Monday Sep 9	HW#1	Basics of gas dynamics. Plasma physics.
3	Wednesday Sep 11		Basic magnetohydrodynamics. Reconnection. Dynamo.
4	Monday Sep 16		Shock waves. Sedov solution. Particle acceleration.
4	Wednesday Sep 18	HW#2	Accretion.
5	Monday Sep 23		Lives of massive stars. Related physical processes.
5	Wednesday Sep 25	HW#3	Telescopes and Detectors for X-rays and Gamma-rays.
6	Monday Sep 30		Basics of statistics and measurements.
6	Wednesday, Oct 2	HW#4	Sources of High-Energy Emission: Non-degenerate Stars, Isolated White Dwarfs.
7	Monday Oct 7		Sources of High-Energy Emission: Supernovae and Supernova Remnants.
7	Wednesday Oct 9		Sources of High-Energy Emission: Isolated Neutron Stars. Pulsars. Pair production. Pulsar winds.
8	Monday Oct 14		Other kinds of Isolated Neutron Stars.
8	Wednesday Oct 16	HW#5	White Dwarfs and Neutron Stars in Binary Systems. Review of previous material.
9	Monday Oct 21		FALL BREAK
9	Wednesday Oct 23		MIDTERM EXAM
10	Monday Oct 28		Stellar Black Holes in our Galaxy: Basics of Black Hole physics. Isolated Black Holes.

10	Wednesday Oct 30		Stellar Black Holes in our Galaxy: Black holes in binaries
11	Monday Nov 4		Gravitational Waves. Detections of binary mergers
11	Wednesday Nov 6	HW#6	Gamma-ray bursts: History and Observations
12	Monday Nov 11	Proposal outline is due	Gamma-ray bursts: Theory and Implications
12	Wednesday Nov 13		Fast radio bursts
13	Monday Nov 18		Astrophysics and observational manifestations of supermassive Black Holes, AGNs, tidal disruptions
13	Wednesday Nov 20	HW#7	Cosmic Rays, High-Energy Particle Astrophysics, Neutrino Astrophysics
14	Monday Nov 25	Proposal Progress Report	Dark matter and related topics
14	Wednesday Nov 27		**Thanksgiving Break**
15	Monday Dec 2		Practical demo: analyzing Chandra X-ray Observatory and Hubble Space Telescope data.
15	Wednesday Dec 4		Discussion of proposals.
	Monday Dec 9	FINAL FROJECT	Proposal presentations. There is no final exam!
16	**Wed Dec 11**		**Makeup Day (Date may be revised!)**

Detailed Course Description

COURSE DESCRIPTION: In this survey course of modern high-energy astrophysics you will learn about various high-energy processes, the 4th state of matter (plasma), extreme states of matter and space (neutron stars and black holes), basic astronomy and lives of massive stars, modern X-ray and gamma-ray observatories, recent developments in gravitational wave and neutrino astronomy, and basics of statistical data analysis.

PREREQUISITE: Astrophysics I (PHYS 6630). *If you have not taken Astrophysics (*PHYS 6630) *but still would like to take Astrophysics II (PHYS 6730) please talk to me before enrolling*. *Likely, you will need to commit to some extra work at home to catch up with those who took Astrophysics I.*

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. We may have guest and/or make-up lectures (if I need to travel). These will be arranged as needed later on. **The lecture content for the previous weeks and for the upcoming week, the reading assignments, and the homework will be posted in the Weekly Activities section of the Blackboad course page. Please check that page frequently, things may change. If needed, that page is updated announcements will be made through the Blackboard Announcements.**

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. Repeating the any calculations and derivations shown in class alone by yourself (with textbook closed);
5. Doing the homework by yourself and turning it in time.
6. Develop the observing proposal (this term project replaces the final exam).

LEARNING OBJECTIVES:

In this course, you will:

1. Acquire knowledge about high-energy 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.

TEXTBOOKS AND OTHER USEFUL BOOKS:

There are two **required** (you need to buy them or get them from the library) textbooks for this course:

* High-Energy Astrophysics
  F. Melia
  Princeton University Press, 2009
  ISBN: 978-0-691-14029-2

* Exploring the X-ray Universe: Second Edition
  F.D. Seward and P.A. Charles
  Cambridge University Press, 2010
  ISBN: 978-0-521-88483-9

Taken together, these two textbooks give good entry level introduction to high-energy astrophysics and astronomy.

There are other ***optional*** but good books on high-energy astrophysics that can be useful for various parts of this course and also for your future research. Here are some titles:

* Frontiers of X-ray Astronomy
  A.C. Fabian, K.A. Pounds, and R.D. Blandford
  Cambridge University Press, 2004
  ISBN: 0-521-53487-9
  Good reviews on selected topics in X-ray astronomy.

* Accretion Power in Astrophysics: Third Edition
  J. Frank, A. King, and D. Raine
  Cambridge University Press, 2002
  ISBN: 0-521-620538
  The book has excellent coverage of accretion physics.

* 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. An excellent reference resource.

* 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

* Radiative Processes in Astrophysics
  G.B. Rybicki and A.P. Lightman
  Wiley Interscience, 1979
  ISBN: 0-471-82759-2
  This excellent book is frequently used as a graduate level textbook for the course named alike.

*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.

* The Restless Universe: Understanding X-ray Astronomy in the Age of
Chandra and XMM-Newton
E.M. Schlegel
Oxford University Press, 2002
ISBN: 0-19-514847-9
Fairly recent, nontechnical, broad review of X-ray astronomy.

* 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 classic book covers the physics compact objects mentioned in its title. Very well written in places more advanced than undergraduate course.

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 as well purchase them in Amazon (they sell used books cheaper there).

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 each class. If something catches your attention, we can discuss it at the beginning of the class. This will count toward your class participation.

GRADING: Your grade will be based on homework (30%), the midterm exam (20%), class attendance/participation (20%), observing proposal term project (30%). Lectures are mandatory and meaningful class participation is required. 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 TEAM WORK 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!

I would like you to learn how to think independently and creatively. You will need this skill for your future careers. Therefore, I require that you work by yourself (alone) on each problem for an hour before you discuss it with anyone else or come to the office hours. Feel free to consult the textbooks and lecture notes but *do not* google for the solution. (I notice this in most case.) After you have made an honest attempt at 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. I will give a partial credit for the solution if you got wrong answer and even if you used wrong method but had a reasonable hypothesis about the underlying physics and showed an effort to solve the problem. Should a particular problem cause troubles for majority of students in the class, I will review the solution at the beginning of my next lecture.

It is VERY important to write you homework solution in a detailed and clear way. If I cannot follow the logic of your solution, I cannot assign any credit for it. 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 solution in the same way they are numbered in the homework assignment. Staple your homework before handing it in. Some homework sets may include more challenging for extra credit that can be used to compensate for poor performance in other course activities.

I will generally grade each problem (in the homework and in the exams) 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 equations are needed). Two points are awarded for correct solution of the equations. Final point is awarded is numerical answer (if it is required) is correct. For instance, if you got the wrong numerical answer but realized this fact and also wrote a more reasonable value you found somewhere. There may deviations from this grading scheme, if a problem does not require any equation solving or numerical answers.

If you disagree with your 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, it should 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** (no 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 the distributed material (unless the material was marked as optional). The exam will be closed book and closed notes (except for those that I may distribute myself). 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. A violation of this policy will cost you half the exam score. Please bring plain whitepaper and a writing utensil to the exam. 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 score as many points as possible. Do not get stuck with a single question for the entire exam period. An incomplete solution can get partial credit so, please, write at least something on paper. To get a full or partial credit, your written answers must be easily legible and must show 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 me as soon as possible regarding this matter.

TERM PROJECT: An observing proposal for a high-energy object or phenomenon to observatory of your choice (e.g., Chandra, XMM-Newton, NuStar, Swift, Hubble, etc.) is your independent term project. You will need to write the proposal and submit to the instructor by the specified date. You will also need to present it to the rest of the class and defend it (imagine it is the Time Allocation Committee). Examples of successful observing proposals will be distributed. There are some important intermediate steps in the process of proposal preparation. Please see the course schedule for details and due dates (pages 2 and 3 of this syllabus).

CLASS ATTENDANCE AND PARTICIPATION: The class attendance and participation is very important and is part of the grade (see above). To do well in this course , you should (1) come to class and pay attention to the lecture, (2) answer questions when they are posed by the instructor, (3) ask questions in class when you don't something, have an idea, or just curious about something related to the related to the lecture material, (4) perform simple tasks 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 me and I will try to find a different time to meet with you. If you are unhappy about something in the course, please let me know. It will help me to improve the course.

Academic Integrity: In this course, as in all of your courses, you are expected to abide by the Code of Academic Integrity (https://studentconduct.gwu.edu/code-academic-integrity). You will find that your learning of physics will be greatly enhanced through discussions with your professor, tutors and most importantly your fellow students. It is up to you to ensure that these collaborations never cross the line so that your work is not your own.

Religious Holidays: **Religious Holidays**: Students must notify the instructor during the first week of the semester of their intention to be absent from class on their day(s) of religious observance. The full University policy regarding religious holidays can be found at https://provost.gwu.edu/sites/g/files/zaxdzs626/f/downloads/Resources/Religious%20Holidays%202018-19.pdf

Disability Support Services are available to support all special needs. Special accommodation will only be arranged via DSS, who will determine exactly which conditions apply according to university policy. Should you require such support, please contact them as early in the semester as possible in order to allow us to effectively accommodate you during class and examinations. Further information can be obtained by phoning 202-994-8250, or here: https://disabilitysupport.gwu.edu/.

Counseling: Free counseling services are available from the University Counseling Service by calling 202-994-5300. Counselors are available 24 hours a day. More information can be found here: https://healthcenter.gwu.edu/counseling-and-psychological-services.

Classroom Emergency Preparedness and Response Information

To Report an Emergency or Suspicious Activity
Call the University Police Department at 202-994-6111 (Foggy Bottom) or 202-242-6111 (Mount Vernon). If the line is unavailable or you are calling from another University location, dial 911.

Shelter in Place – General Guidance
Although it is unlikely that we will ever need to shelter in place, it is helpful to know what to do just in case. No matter where you are on campus, the basic steps of shelter in place will generally remain the same:

- If you are inside, stay where you are unless the building you are in is affected. If it is affected, you should evacuate. If you are outdoors, proceed into the closest GW building or follow instructions from emergency personnel on scene.
- Shelter-in-place in an interior room, above ground level, and with the fewest windows. If sheltering in a room with windows, keep away from the windows. If there is a large group of people inside a particular building, several rooms maybe necessary.
- Shut and lock all windows (locking will form a tighter seal) and close exterior doors.
- Turn off air conditioners, heaters, and fans. Close vents to ventilation systems as you are able. (Facilities staff will turn off ventilation systems as quickly as possible).
- Make a list of the people with you and call the list in to UPD so they know where you are sheltering.
- Visit GW Campus Advisories for incident updates http://campusadvisories.gwu.edu or call the GW Information Line 202-994-5050. If possible, turn on a radio or television and listen for further instructions. If your e-mail address or mobile device is registered with Alert DC, check for alert notifications.
- Be comfortable and look after one other. You will get word as soon as it is safe to come out.

An **evacuation** will be considered if the building we are in is affected or we must move to a location of greater safety. We will always evacuate if the fire alarm sounds. In the event of an evacuation, please gather your personal belongings quickly (purse, keys, cell phone, GWorld card, etc.) and proceed to one of the nearest exits. Do not use the elevator. Once we have evacuated the building, proceed to meet in front at Corcoran Hall.

Alert DC provides free notification by e-mail or text message during an emergency. Visit GW Campus Advisories for a link and instructions on how to sign up for alerts pertaining to GW. If you receive an Alert DC notification during class, please share the information immediately.

GW Alert provides popup notification to desktop and laptop computers during an emergency. In the event that we receive an alert to the computer in our classroom, we will follow the instructions given. You are also encouraged to download this application to your personal computer. Visit GW Campus Advisories to learn how.

Additional information about emergency preparedness and response at GW as well as the University's operating status can be found on GW Campus Advisories http://campusadvisories.gwu.edu or by calling the GW Information Line at 202-994-5050.

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 6730 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 consult it frequently!

ABOUT YOUR INSTRUCTOR: Dr. Oleg Kargaltsev is an Associate Professor in the Department of Physics. He is a high[1]-energy astrophysicist working extensively with Chandra X-ray Observatory, X-ray Multi-Mirror Mission-Newton, NuStar Hard X-ray Observatory, Fermi Gamma-ray Observatory, Hubble Space Telescope, and other observatories to study the physics, evolution, and properties of neutron stars, black holes, and related high-energy environments. He is an author of >100 research papers and a Principle Investigator for many observing programs on various space observatories. You instructor is also a big fan of last century's science fiction.

[1] not extremely high, within a reasonable range