

## Space Astrophysics

Spring Semester 2014

### **Course and Contact Information**

Department and Course: Physics, PHYS 6630  
Semester: Spring 2014  
Time: Tuesday and Thursday 02:20 PM - 03:35 PM  
Location: **Corcoran 209**  
Course Web Site: <http://blackboard.gwu.edu>

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**Instructor:** Prof. Oleg Kargaltsev  
Campus address: Samson 214 (office)  
Phone: 202-994-7225 (office)  
E-Mail: [kargaltsev@gwu.edu](mailto:kargaltsev@gwu.edu)  
Office Hours: Tuesday and Thursday, 4:00 PM - 5:00 PM

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PHYS 6630 — Space Astrophysics

<u>Week</u>	<u>Date</u>	<u>Homework Due or Exam</u>	<u>Topics</u>
1	Tuesday, Jan 14		A Brief History of High-Energy (X-ray & Gamma-Ray) Astronomy. Basic terminology.
1	Thursday, Jan 16		Radiation I: Electromagnetic Radiation and Basic Radiation Processes and Quantities.
2	Tuesday, Jan 21		Radiation II: Electromagnetic Radiation: Blackbody, Thermal Bremsstrahlung.
2	Thursday, Jan 23	HW #1	Radiation III: Line emission and Absorption in ISM. Cyclotron radiation.
3	Tuesday, Jan 28		Radiation VI: Synchrotron and Curvature Radiation.
3	Thursday, Jan 30	HW #2	Radiation V: Thomson and Compton Scattering. Basic Special Relativity.
4	Tuesday, Feb 04		Plasma physics. Basic MHD. Reconnection. Dynamo.
4	Thursday, Feb 06	HW #3	Shock waves. Sedov solution.
5	Tuesday, Feb 11		Particle acceleration. Accretion.
5	Thursday, Feb 13	HW #4	Accretion.
6	Tuesday, Feb 18		Telescopes and Detectors for X-rays and, Gamma-rays. Basics of statistics and measurements.
6	Thursday, Feb 20		Sources of High-Energy Emission: Non-degenerate Stars, Isolated White Dwarfs.
7	Tuesday, Feb 25	HW #5	Sources of High-Energy Emission: Supernovae and Supernova Remnants.
7	Thursday, Feb 27		Isolated Neutron Stars. Pulsars. Pair production.
8	Tuesday, Mar 04		Other manifestations of Isolated Neutron Stars
8	Thursday, Mar 06		<b>MIDTERM EXAM</b>
9	Tuesday, Mar 11		<b>Spring Recess</b>
9	Thursday, Mar 13		<b>Spring Recess</b>
10	Tuesday, Mar 18		Review of the previous material based on Midterm results.
10	Thursday, Mar 20		White Dwarfs and Neutron Stars in Binary Systems
11	Tuesday, Mar 25		Stellar Black Holes in our Galaxy: Basics of Black Hole physics. Isolated Black Holes.

11	Thursday, Mar 27	HW#6	Stellar Black Holes in our Galaxy: Black holes in binaries
12	Tuesday, Apr 01	Term project outline is due	Gamma-ray bursts: History and Observations
12	Thursday, Apr 03		Gamma-ray bursts: Theory and Implications
13	Tuesday, Apr 08	HW#7	Astrophysics and observational manifestations of supermassive Black Holes, AGNs
13	Thursday, Apr 10		Galaxy clusters and The Extragalactic High-Energy Background
14	Tuesday, Apr 15	Term project Progress Report is due	Cosmic Rays, High-Energy Particle Astrophysics, Neutrino Astrophysics, Gravitational Wave Astrophysics
14	Thursday, Apr 17	HW#8	Cosmology, Dark matter, Dark energy, and more
15	Tuesday, Apr 22		Practical demonstration: analyzing fresh Chandra X-ray Observatory and Hubble Space Telescope data.
15	Thursday, Apr 24	Term project is due, at 5:00 pm	Review of the course material. Answers to student questions.
16	<b>Tue Apr 29</b>		<b>Makeup Day (Date may be revised!)</b>
	<b>Thursday, May 8</b>		<b>FINAL EXAM (3-5 pm, same room as classes) (Date may be revised!)</b>

## **Detailed Course Description**

UNIVERSITY BULLETIN COURSE DESCRIPTION: Astrophysical examination of stellar evolution, including properties of stellar matter, equations of state, nucleosynthesis, red giants, supernovae, white dwarfs, close binary stellar systems, gamma-ray bursts. Overview of observational techniques, including photometry; IR, UV, X-ray observation, gamma-ray frequencies; astrophysical data analysis; evidence for stellar and cosmological models.

PREREQUISITE: Prerequisite: Phys 1022 or equivalent. You will need to know this material well to be successful in this course.

LECTURES: The lectures are meant to explain difficult concepts, to expand on the reading material, and to introduce topics not covered in the textbook such as examples from real observations and data. If you do not understand something, you are very much encouraged to ask questions during the lectures. If I am lecturing too fast or something is not clear please tell me right away. Due to some travel I have over the semester, there may be some guest and make-up lectures. 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 listed in the Weekly Activities section of the Blackboard 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(s);
2. Reading any additional materials distributed or assigned otherwise;
3. Participating in class discussions;
4. Repeating the any calculations and derivations done in class alone by yourself (with textbook closed);
5. Doing your homework yourself and turning it in time.

This will help you do well on the exams.

### **LEARNING OBJECTIVES:**

In this course, you will:

1. Acquire basic knowledge about cosmic sources of high-energy radiation;
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

Together these two textbooks give good introduction to high-energy astrophysics. I will provide some additional reading material which will be always available on the course in the Blackboard.

There are other good books on high-energy astrophysics that will be useful for various parts of the course, and you are strongly encouraged to use them as need arises in addition to your lecture notes. Most of them should be also on reserve in the GWU (Gelman) library.

\* 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 has copies of most of these books, and I have placed them on reserve for your use. If you are planning a professional career in astronomy/astrophysics, you will need to take a look at these books.

I also strongly encourage you to look through the preprints abstracts

<http://arxiv.org/list/astro-ph/recent> looking for articles relevant for 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 (20%), the midterm exam (20%), the final exam (30%), class attendance/participation (20%), term project paper (10%). 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** class starts on Thursday (unless it is specified otherwise in the course timetable; see pages 2-3). The homework problems will also be available through the Problem Sets section of the course in the Blackboard. Any homework turned in later and will be assigned only half of the credit. Please start working on your homework early and do not postpone it till the last day! If you have a medical excuse, you must contact me as soon as possible (e.g. by e-mail) to arrange a new due date.

I would like you to learn how to think independently and creatively and how to solve problems for yourself. You will need this skill regardless of whether you continue your graduate study in this field or not. I will give you partial credit for the problem if you got wrong answer and even if you used wrong method but had a reasonable hypothesis about the underlying physics. I insist that you work by yourself (alone) on each problem for an hour before you seek help from someone. Feel free to consult the textbooks and lecture notes but do not google for the solution. (I will notice this.) After you have made an honest attempt at a problem for at least 1 hour, you may discuss it with others currently in the course who have also made honest attempts at the problem. If your answers differ and you believe you are right you may defend yourself at a blackboard during the class, but you may not look at each others papers or copy things off the blackboard afterward. 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 your homework solution in a detailed and clear way. If I cannot follow your solution I cannot assign any credit for it. Detailed, well-structured solution will often result in at least partial (if not full) credit. 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 challenging problems for those who plan to go on to become professional astrophysicists or would like to earn extra credit.

If you disagree with your homework grade, you must e-mail your appeal to the instructor within two weeks 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 exams.

**EXAMS:** There will be one midterm exam and one final exam. **The exams will be based solely on the material covered during the lectures and in the homeworks.** The midterm exam will cover all material up to the day of the exam. The final exam will cover material for the entire semester. On the exams, you will be responsible for 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 exams will be closed book and closed notes (unless I specifically tell). You may use standard, non-programmable calculators on the exams. Cell phones, Ipads, 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 3-5 questions, and the final exam will have about 5-7 questions (each question may have multiple parts). Questions may include definitions, physical explanations, brief calculations, and brief derivations. The questions will generally get more challenging toward the end of the exam, although question difficulty is somewhat subjective. You should work efficiently to score as many points as possible. Do not get stuck with a single question for the entire exam period. Incomplete solution can get partial credit so please write at least something. To get 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.

No makeup exams will be given. If you have a medical excuse, you must contact me as soon as possible regarding this matter.

**TERM PROJECT:** This is your independent research project. You will need to write and submit to the instructor by the specified date a research paper (a proposal to observe a particular high-energy source or your own in-depth investigation of an astrophysical phenomenon/object relevant to the course, using available literature). Each student should hand in a one-paragraph outline of the project, on **Tuesday, April 1**. This outline should include the goal of the project, the data to be used, and a list of six or more relevant references to the journal articles. Here is a great place to search: [http://adsabs.harvard.edu/abstract\\_service.html](http://adsabs.harvard.edu/abstract_service.html). A Progress Report will be due on **Tuesday, April 15**. This is an expansion of the outline and should include your work to date, as well as any problems you are encountering with your project. Your final project report should include: a cover page with a title and abstract, introduction describing the question you have posed and would like to investigate, available data and literature, brief description of any relevant analysis methods or proposed observations, tabular/graphical results, images, conclusions, suggestions for future work, and reference list. The total length of the report (including figures) should not exceed ten pages using 11pt font, double spaced. Electronic copy of your term project must be e-mailed to me (can be done through the Blackboard) by **5:00 pm Thursday, April 24**. You can also turn in a printed copy of the project on **Thursday, April 24** before the class. If you do not understand what you should do or having problems with your term project, please, let me know in advance and I will help you. Late reports will not be accepted unless there is a valid (medical) reason.



**CLASS ATTENDANCE AND PARTICIPATION:** The class attendance and participation is important. To do well, you should (1) come to class and pay attention, (2) answer questions when they are posed by the instructor, (3) ask questions in class when you don't understand the lecture, (4) perform simple tasks when requested by the instructor, (5) be courteous and friendly to your fellow students and the instructor, and (6) follow the general points on classroom conduct given below. You must also make sure that everything taught is clear to you. Please feel free to ask questions regarding the previous class material at the beginning of the next class.

**GENERAL CLASSROOM CONDUCT:** Please turn off cell phones and Ipods before the start of each class. No food consumption during the lecture unless required for medical reasons (must notify instructor ahead of the lecture).

**OFFICE HOURS AND QUESTIONS:** You are strongly encouraged to come to my office during the office hours for help with the course material. If you cannot make the appointed times, please e-mail to make an appointment. If you are unhappy about something in the course please let me know, and I'll try to fix it if possible and I will discuss it with you.

**Academic Integrity:** In this course, as in all of your courses, you are expected to abide by the Code of Academic Integrity (<http://www.gwu.edu/~ntegrity/code.html>). 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.

**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: <http://gwired.gwu.edu/dss/>.

**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: <http://gwired.gwu.edu/counsel/>.

## 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 our primary rendezvous location **Honors Building**. In the event that this location is unavailable, we will 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 the PHYS 11 class. The address for the *Blackboard* web site is: **<http://blackboard.gwu.edu>**

After entering *Blackboard*, it is necessary for you to click on the ASTR 2161 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: Oleg Kargaltsev is a new Assistant Professor in the Department of Physics. Previously he was an Associate Scientist at University of Florida and before that a postdoc and graduate student at the Pennsylvania State University. Kargaltsev worked extensively with Chandra X-ray Observatory (NASA) the X-ray Multi-Mirror Mission-Newton (ESA), Suzaku X-ray Observatory (JAXA) and Hubble Space Telescope (NASA) to study the physics, evolution, and properties of neutron stars and other compact and high-energy objects. He is an author of ~90 research papers and Principle Investigator of many observing programs on the above mentioned NASA, ESA, and JAXA space missions. Kargaltsev's other interests include science philosophy and science policy, logical (especially recursive) puzzles, and science fiction.