ASTR398B: Black Holes
(Fall 2015; Reynolds)

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Textbook: Gravity’s Fatal Attraction by Begelman & Rees (2nd Ed.)

Course description

Black holes are the most exotic prediction of Einstein’s Theory of General Relativity and, amazingly, the Universe seems to manufacture these bizarre objects in copious numbers. As well as being the ultimate laboratory for studying the nature of space and time, they drive some of the most energetic and extreme phenomena known to astronomers (with quasars and gamma-ray bursts being just a couple of examples.)

Astronomy 398B is an introduction to the physics and astrophysics of black holes. We start by examining the basic physics of black holes, which fundamentally means understanding gravity. We then look at the nature of stellar-mass black holes (that result from the death of stars) and supermassive black holes (whose origin is closely ties to the formation of the galaxies themselves). We will discuss the fairly recent realization that black holes may be crucial agents for regulating the growth of galaxies. Finally, we dive
into the realm of theoretical physics and probe how black holes may provide a route for uncovering new laws of physics governing the structure of space and time.

The course website is at

http://www.astro.umd.edu/~chris/Teaching/ASTR398B_Fall_2015/ASTR398B_Fall_2015.html

It will contain links to course information, and copies of past homeworks and lecture notes. Course materials are also available via ELMS.

**Course Pre-requisites**

It is assumed that you have completed the CORE Distributive Studies requirement in Mathematics and Sciences, or that you have completed the General Education Fundamental Studies requirement in Mathematics. We also assume that you have completed one of the Introduction to Astronomy courses (ASTR100, ASTR101 or equivalent). While this is a non-technical course on cosmology, quantitative reasoning and some mathematics will be required.

**Course expectations**

**Attendance:** In order to successfully complete this course, I expect you to attend class 2 times a week. If you have to miss a lecture, please be sure to obtain a copy of the notes (either from another student, the web-site, or from me) and make sure that you understand what you missed. There will also be times when I will ask for class participation either in small groups or as individuals.

**Preparation:** I expect you to be prepared to work. We will be covering some fascinating but very challenging concepts - you will understand this material much more easily if you preview the recommended chapter of the course book ahead of time, as well as giving it a more careful read after the lecture. You also should review your class notes sometime before the next lecture to make sure everything is clear. I encourage you to ask questions in the lectures or during my office hours.

**Study Habits:** Study wisely and ask for help if you need it. It is better to keep up with the material on a daily basis than cram the night before the exam. I encourage you to chat about problems with your friends and classmates — you will learn a huge amount from trying to explain confusing issues to each other. *However, please keep in mind that all graded materials, including class-assignments and home-works, must be your own thoughts in your own words.*
Grading

Grades are based on homeworks, class participation, one midterm exam, and the final exam. These three components contribute to the grade according to the following weights:

<table>
<thead>
<tr>
<th>Component</th>
<th>Weight</th>
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<tbody>
<tr>
<td>Homeworks</td>
<td>25%</td>
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<tr>
<td>Participation</td>
<td>10%</td>
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<tr>
<td>Project</td>
<td>10%</td>
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<tr>
<td>Midterm</td>
<td>25%</td>
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<tr>
<td>Final</td>
<td>30%</td>
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Your percentage grade will be converted to a letter grade. Below are the guaranteed grade boundaries – any “curving” will only be in the direction of giving you a better grade than indicated:

- A >90%
- B 80—90%
- C 70—80%
- D 60—70%
- F <60%

Midterm exam

There will be one in-class examination on the 21st October 2015. This exam will be closed book. The exam will consist of a section of short answer questions, followed by longer essay and problem solving questions.

The midterm exam is a “major scheduled grading event” and is covered by the relevant University rules for excused absence. If you are not able to take an exam due to illness or other legitimate reasons, you must make every reasonable attempt to contact me on or before the day of the exam either by email or voice mail. In addition, you must provide documentation detailing the reason for your absence. A self-signed note is insufficient. A make up exam must be taken promptly. I will give at most one make-up exam. If you must miss both the midterm and its make-up exam, I will give an oral examination.

If, for whatever reason, the University is officially closed on the day of the exam, the exam will be re-scheduled for the next lecture date.

Final exam

Since this course is scheduled in a non-standard time-slot, the University mandated date of the final exam has not yet been posted. I will announce the exam date once it has been
decided by the University (https://ntst.umd.edu/soc/exam/201508). The final exam is cumulative in the sense that it will cover all material discussed in this course. The format of the final exam will be the same as the midterm exam, with a section of short answer questions and a section of longer essay or problem solving questions. Again, the final exam is a “major scheduled grading event” and is covered by the relevant rules for excused absence (see above).

Homeworks

A homework set will be assigned approximately once every two weeks. On the due date, homeworks should be handed in at the front of the class. Homeworks will be considered late by the end of class. Late homeworks will be accepted for a week after the due-date and will be subjected to a penalty of up to 30%. If you cannot make it to class when homework is due, you should either ask a friend/classmate to hand it in for you, or make sure that it gets to me (room CSS1243) before the time that it is due. If you have a valid emergency that prevents you from making a homework deadline, you should make all reasonable efforts to contact me before the due date telling me the nature of the emergency. Please document all such emergencies; a self-signed note is sufficient provided that it contains a statement that (1) the information is true and correct and (2) providing false information is prohibited under the Code of Student Conduct.

If, for whatever reason, the University is officially closed on the day of the due date, the due date will be moved to the next lecture.

Project

A portion (15%) of the grade for this class will be based on a Project — details on this project will be announced later in the semester.

Academic Integrity

The University’s policies and rules on academic integrity are described in http://www.president.umd.edu/policies/docs/III-100A.pdf. In essence, you must never engage in acts of academic dishonesty at any time. Acts of academic dishonest include cheating, fabrication, plagiarism, or helping any other person to do any of these things. These rules apply to homeworks and quizzes as well as exams. As a part of these rules, you must give credit to any book (including the course textbook!), published article or web-page that you have used to help you with a particular assignment. The University takes these issues extremely seriously, as do I.

To underscore the need for academic integrity, the University asks you to write the following pledge on any assignment or exam: “I pledge on my honor that I have not given or received any unauthorized assistance on this assignment/examination.”
### Preliminary course outline

#### INTRODUCTION
- **2-Sep-2015** Course introduction

#### CLASSICAL THEORY OF BLACK HOLES
- **4-Sep-2015** Newton’s Laws
- **9-Sep-2015** Newtonian Gravity
- **11-Sep-2015** Special Relativity I
- **16-Sep-2015** Special Relativity II
- **18-Sep-2015** General Relativity I
- **23-Sep-2015** General Relativity II
- **25-Sep-2015** General Relativistic View of Black Holes
- **30-Sep-2015** Spinning Black Holes

#### STELLAR-MASS BLACK HOLES
- **2-Oct-2015** Evolution of stars and stellar death
- **7-Oct-2015** Pulsars
- **9-Oct-2015** X-ray Binaries and the Discovery of Black Holes
- **14-Oct-2015** Gamma-Ray Bursts
- **16-Oct-2015** Accretion Disks
- **21-Oct-2015** Midterm Exam (in class)

#### SUPERMASSIVE BLACK HOLES AND COSMIC FEEDBACK
- **23-Oct-2015** Quasars and AGN
- **28-Oct-2015** Radio Galaxies and Jets
- **30-Oct-2015** Center of Our Galaxy
- **4-Nov-2015** Brief History of Galaxy Formation
- **6-Nov-2015** AGN Feedback
- **11-Nov-2015** GUEST LECTURE
- **13-Nov-2015** Origins of Supermassive Black Holes

#### DOWN THE RABBIT HOLE
- **18-Nov-2015** Testing General Relativity with Black Holes
- **20-Nov-2015** Gravitational Radiation
- **25-Nov-2015** Hawking Radiation and Black Hole Evaporation
- **27-Nov-2015** THANKSGIVING RECESS
- **2-Dec-2015** The Information Paradox
- **4-Dec-2015** Firewalls
- **9-Dec-2015** Wormholes and Timewarps
- **11-Dec-2015** Review

Final Exam date to be announced later.