SPRING 2025 Department of Physics & Astronomy, UGA
PHYS 8900 The Physics of Black Holes (as of Dec. 12/2024)
The course syllabus is a general plan for the course; deviations announced to the class by the instructor may be necessary.

Course Description:	**The aim of this course is to make a quick, directed thrust through the fascinating subject of general relativity by developing simple tools to answer questions and carry out calculations about curved spacetime near Earth and black holes. Prerequisites include basic calculus, some familiarity with Lagrangian mechanics, and special relativity.**
Grading System:	A-F (Traditional)
Instructor:	Dr. Andrei Galiautdinov
Office:	Physics 220 (Phone: 706-583-8224)
Preferred method of communication:	In-class and during office hours
Email:	ag1@uga.edu
Section:	**68175** 10:20am – 11:10am (Physics, Rm. 254, MWF)
Office hours:	*TBD*
Prerequisites:	Basic calculus, Lagrangian formulation of mechanics (Feynman's take), special relativity.
Main Texts:	**The foundational material will be structured around and expanded upon:** E. Taylor and J. A. Wheeler, "*Exploring Black Holes: Introduction to General Relativity*," (**1st edition, Addison Wesley Longman, 2000**; 2nd edition, 2016, will also be consulted). *I prefer the 1st edition, as it is short and direct, but will use the 2nd edition if needed.* Notice that one of the authors, John Wheeler, who was Feynman's PhD advisor, was the driving force behind the revival of interest in General Relativity in the US in the 1960s, so anything written by him is of interest to us. **Advanced topics and student presentations will be drawn from:** V. Frolov and I. Novikov, "*Black Hole Physics: Basic Concepts and New Developments*," (Kluwer, 1998), **as well as other, more recent sources.**
Special Relativity prerequisites:	***ATTENTION:*** *Prior to the start of the semester, please familiarize yourself with the following relativistic concepts:* - *Galileo's Law of Inertia*, - *Inertial Frames of Reference*, - *Relativity Principle*, - *Einstein's Second Postulate*, - *Simultaneity*, - *Lorentz Transformation*, - *proper time*, - *proper length*, - *time dilation*, - *length contraction*, - *relativistic velocity addition formula*, - *stellar aberration*, - *Doppler effect (both relativistic and non-relativistic)*, - *spacetime interval*, - *Minkowski spacetime*, - *Minkowski diagram*, - *worldline*, - *light cone*, - *relativistic energy and momentum*, - *4-momentum*, - *Kepler's Laws of Planetary Motion (non-relativistic)*, - Lagrangian formulation of mechanics (Feynman's take), **Any source would do, for instance:** 1. E. Taylor and J. A. Wheeler, "*Spacetime Physics*," 2nd ed., available for free on Edwin Taylor's website: https://www.eftaylor.com/spacetimephysics/

Mathematics prerequisites:	*In addition, review the following mathematical concepts:* - *Derivative and integral,* - *Pythagorean Theorem,* - *circle, hyperbola, parabola,* - *circumference and area of a circle,* - *area and volume of a sphere,* - *Cartesian, polar, and spherical coordinates,* - *parametric equation of a curve,* - *scalar product,* - *tensors*
Grades:	Your grades will be posted on the eLC, http://elcnew.uga.edu
Grading policy:	**60% Homework** **20% Midterm Exam** **– Final Exam (optional make-up of the Midterm)** **20% Power Point Presentation**
Cut-offs:	F: [0, 10) D: [10, 20) C–: [20, 30) C: [30, 40) C+: [40, 50) B –: [50, 60) B: [60, 70) B+: [70, 80) A–: [80, 90) A: [90, 100]

List of Topics for Student Presentations (not exclusive, more will be added, based on students' interests):	- *Topic 1 - Kruskal Extension*
	- *Topic 2 - Direct BH Observation - Event Horizon Telescope Results*
	  - *Topic 2a - M87*
	  - *Topic 2b - Sagittarius A*
	- *Topic 3 - Direct Blazar Observation - Event Horizon Telescope Results*
	- *Topic 4 - Luminet's early work on BH imaging simulations*
	- *Topic 5 - BH imaging simulations in movie "Interstellar"*
	- *Topic 6 - The No-Hair Theorem*
	- *Topic 7 - Disappearing Massive Stars*
	- *Topic 8 - Global Positioning System (GPS)*
	- *Additional Topics - TBD*

List of questions to be addressed:	- Can I see a black hole at all? - If I can see it, what does a black hole look like? - Does it look black? - Where do black holes exist in the Universe? - Does the black hole look different when I fall toward it? - What does it feel like to fall into a black hole? Am I comfortable? - Do I see the stars overhead as I fall into a black hole? If so, do these stars change position or color as I fall? - How fast do I fall? Does my speed reach or exceed the speed of light? - Once inside, can I receive messages and packages from my friends on the outside? - Is it true that, once inside, I cannot send anything to my friends on the outside, not even a light signal? Why can't I send them messages? - How long do I live once I fall into a black hole? - Will I reach the center alive? - Can I see the crunch-point ahead of me? - What is the last thing I see? - Is the end quick and painless? - What happens to the mass of a black hole when it swallows me or some other object? - How does the orbit of an object around a black hole differ from the orbit of a planet around our Sun? - Newton says a planet stays in orbit because the Sun exerts a gravitational force on it. How does Einstein explain this orbit? - If Newton and Einstein disagree, how do we decide between them? - How close to a black hole can I move in a circular orbit? - Can I use a black hole to travel rapidly forward in time? Backward in time? - What are the upper and lower limits on the mass of a star, a white dwarf, a neutron star, a black hole? Which of these bodies require general relativity for its correct description? - In what sense are space and time unified? - Why do things fall in my everyday life on Earth? - Does the term relativity mean that everything is relative? - What does curvature mean? How can I observe curvature? - How many different observed effects does curvature account for? - How does the Global Positioning System fail if we ignore general relativity?

	- How much does light change direction as it passes the Sun or a black hole? - Does the amount of change in direction depend on the color of the light? - How does an astronomical object focus light from a distant galaxy and what does the image of that distant galaxy look like? - Can light go into a permanent orbit around a black hole? - How fast can a black hole spin? - Does a spinning black hole drag space around with it? What does "drag space" mean; how can I observe it? - Can I extract energy from a spinning black hole? - What is a quasar? Do spinning black holes power quasars; if so, how? - How cold is a black hole? What is its temperature? - Does a black hole have entropy? - What happens to information when it gets swallowed by a black hole? - White holes and their properties. Do they exist? - *… to be continued…*
Academic Honesty:	*As a University of Georgia student, you have agreed to abide by the University's academic honesty policy, "A Culture of Honesty," and the Student Honor Code. All academic work must meet the standards described in "A Culture of Honesty" found at: www.uga.edu/honesty. Lack of knowledge of the academic honesty policy is not a reasonable explanation for a violation. Questions related to course assignments and the academic honesty policy should be directed to the instructor. The link to more detailed information about academic honesty can be found at: http://www.uga.edu/ovpi/honesty/acadhon.htm* ***UGA Student Honor Code:*** *"I will be academically honest in all of my academic work and will not tolerate academic dishonesty of others." A Culture of Honesty, the University's policy and procedures for handling cases of suspected dishonesty, can be found at www.uga.edu/ovpi*
Hardship withdrawals:	If your course performance is significantly affected by issues beyond your control, please seek assistance promptly from Student Care and Outreach 706-542-7774 or visit https://sco.uga.edu. They will help you navigate any difficult circumstances you may be facing by connecting you with the appropriate resources or services. It is always easier to address exceptional circumstances when you raise these concerns as early as possible. Waiting until the end of the semester to take action may limit the University's ability to provide appropriate support.
Mental Health and Wellness Resources:	• If you or someone you know needs assistance, you are encouraged to contact Student Care and Outreach in the Division of Student Affairs at 706-542-7774 or visit https://sco.uga.edu/. They will help you navigate any difficult circumstances you may be facing by connecting you with the appropriate resources or services. • UGA has several resources for a student seeking mental health services (https://www.uhs.uga.edu/bewelluga/bewelluga) or crisis support (https://www.uhs.uga.edu/info/emergencies). • If you need help managing stress anxiety, relationships, etc., please visit BeWellUGA (https://www.uhs.uga.edu/bewelluga/bewelluga) for a list of FREE workshops, classes, mentoring,and health coaching led by licensed clinicians and health educators in the University Health Center. • Additional resources can be accessed through the UGA App

2025 Spring Schedule

Week	Day	Date	Reading ("Exploring Black Holes", 1st edition)	Topic	Notes
1	M	Jan. 06		**Part I FOUNDATIONS** Intro to this course. Why curved spacetime?	
	T	Jan. 07			
	W	Jan. 08		**0. Review of Special Relativity (traditional approach)**	
	R	Jan. 09			
	F	Jan. 10		(cont.)	**Drop/Add ends**
2	M	Jan. 13		(cont.)	
	T	Jan. 14			
	W	Jan. 15	Ch. 1 Speeding	**1. Review of Special Relativity (Wheeler's way)**	
	R	Jan. 16			

	F	Jan. 17		(cont.)	
3	M	Jan. 20			MLK Day
	T	Jan. 21			
	W	Jan. 22	Ch. 2 Curving	**2. From Special to General Relativity (Metric as the Foundation of All)**	
	R	Jan. 23			
	F	Jan. 24		(cont.)	
4	M	Jan. 27	Ch. 3 Plunging	**3. Falling into a Black Hole**	
	T	Jan. 28			
	W	Jan. 29		(cont.)	
	R	Jan. 30			
	F	Jan. 31		(cont.)	
5	M	Feb. 03	B. Inside the Black Hole	**4. Inside the Event Horizon**	
	T	Feb. 04			
	W	Feb. 05		(cont.)	
	R	Feb. 06			
	F	Feb. 07		(cont.)	
6	M	Feb. 10		**5. Review of the Kepler Problem**	
	T	Feb. 11			
	W	Feb. 12	Ch. 4 Orbiting	**6. Orbiting a Black Hole**	
	R	Feb. 13			
	F	Feb. 14		(cont.)	
7	M	Feb. 17			
	T	Feb. 18			
	W	Feb. 19	C. Advance of the Perihelion of Mercury	**7. Advance of the Perihelion of Mercury**	
	R	Feb. 20			
	F	Feb. 21		(cont.)	
8	M	Feb. 24	Ch. 5 Seeing	**8. Orbits of Light around a Black Hole**	
	T	Feb. 25			
	W	Feb. 26		(cont.)	
	R	Feb. 27			
	F	Feb. 28		(cont.)	
9	M	Mar. 03			
	T	Mar. 04			
	W	Mar. 05			SPRING BREAK
	R	Mar. 06			
	F	Mar. 07			
10	M	Mar. 10	D. Einstein Rings	**9. Gravitational Lensing**	
	T	Mar. 11			
	W	Mar. 12		(cont.)	
	R	Mar. 13			
	F	Mar. 14		(cont.)	
11	M	Mar. 17	E. Light Slowed Near Sun	**10. The Shapiro Effect**	
	T	Mar. 18			
	W	Mar. 19		(cont.)	
	R	Mar. 20			
	F	Mar. 21		(cont.)	
12	M	Mar. 24	F. The Spinning Black Hole	**11. Spinning Black Holes and Penrose Process**	
	T	Mar. 25			
	W	Mar. 26		(cont.)	
	R	Mar. 27			

	F	Mar. 28		(cont.)	
13	**M**	**Mar. 31**		**Midterm Exam**	
	T	Apr. 01			
	W	Apr. 02		**Part II ADVANCED TOPICS**	
	R	Apr. 03			**Withdrawal deadline**
	F	Apr. 04		Black Hole Thermodynamics	
14	M	Apr. 07		*TBD*	
	T	Apr. 08			
	W	Apr. 09		(cont.)	
	R	Apr. 10			
	F	Apr. 11		(cont.)	
15	M	Apr. 14		(cont.)	
	T	Apr. 15			
	W	Apr. 16		(cont.)	
	R	Apr. 17			
	F	Apr. 18		(cont.)	
16	M	Apr. 21		PRESENTATIONS	
	T	Apr. 22			
	W	Apr. 23		PRESENTATIONS	
	R	Apr. 24			
	F	Apr. 25		PRESENTATIONS	
17	M	Apr. 28		PRESENTATIONS **Classes End**	
	T	Apr. 29		**Reading Day**	
	W	Apr 30			
	R	May 01			
	F	**May 02**		**Optional Final Exam (8:00 - 11:00 am)**	
18	M	May 05			
	T	May 06			
	W	May 07			
	R	May 08			
	F	May 09		Commencement	
19	**M**	**May 12**			**Grades due (12:00 PM)**
	T	May 13			