PHYS 7903/AST 4953 – General Relativistic Magnetohydrodynamics – Syllabus Spring 2023

Prof. Richard Anantua | richard.anantua@utsa.edu | www.richardanantua.com

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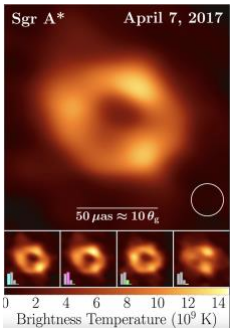
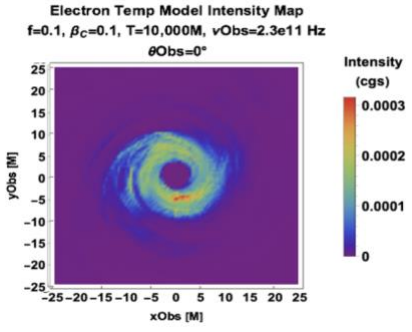
Solar Corona



Sagittarius A*



GRMHD Simulation

PHYS 7903/AST 4953 General Relativistic Magnetohydrodynamics

Spring 2023

COURSE INFORMATION

Course Description: A new interdisciplinary course for physics and astronomy enthusiasts alike including the history, development and broad applications of the recently unified subjects of general relativity (GR) and magnetohydrodynamics (MHD). Einstein's general relativity has been a pillar of modern physics since 1915, and has survived observational tests from Eddington's eclipse experiment to the GRAVITY collaboration's 2018 measurement of gravitational redshift of stars orbiting the Galactic Center. Magnetohydrodynamics has enjoyed broad success in predicting phenomena throughout physics, from electromagnetic-hydrodynamic waves (Alfvèn 1942) detected in near-Earth space by the NASA MMS mission to plasma confinement in laboratory spheromaks and tokamaks. We will cover these highlights and more through analytical and computational problems, textbooks and original sources, and movies such as "Interstellar." Since the first horizon scale images of the black holes M87* in 2019 and Sgr A* in 2022 by the Event Horizon Telescope, GRMHD simulations have been the primary tool enabling us to interpret these highest resolution images in astronomy. Course topics include black hole spacetimes (e.g. Schwarszchild and Kerr), exotic spacetimes (Alcubierre warp drive, Einstein-Rosen Bridge), magnetospheres (stellar and Kerr), plasma physics (Vlasov and Fokker-Planck equations, Landau damping, plasma turbulence) and GRMHD equations and simulations.

Course Fees: LRC1 $12; LRS1 $46.20; MEPA $18; STSI $21.60; DL01 $75.
A related course Phys 6123 Magnetohydrodynamics is generally offered: Spring.
Nota bene: This is a Q-rated course satisfying UTSA's Quantitative Scholarship requirement

Credit hours: [3]
Prerequisites/co-requisites: Prerequisite: Graduate standing, PHY 5103 (Classical Mechanics) and PHY 5203 (Electrodynamics), or consent of instructor.
Course Modality: Traditional in-person (confer One Stop Enrollment) M and W 1:00p-2:15p Flawn Building Room 2.01.02. Course registration number 39021

LEARNING GOALS

At the end of the course, you will be able to: Identify and interpret phenomena in strong gravity, (e.g., neutron stars, jets, accretion disks, black holes and galaxy clusters); and in MHD and GRMHD plasmas (magnetosonic waves, Kelvin-Helmholtz instability, magnetorotational instability, flux freezing). You will also be able to understand their physical consequences, and correct common misconceptions such as a flat Earth (in curved spacetime).

The course goals, scaffolded by Bloom's taxonomy, are to: Remember basic postulates and laws of relativity and MHD and some key spacetimes and wave equations, e.g., equivalence principle and ideal MHD; Understand plasma and particle behavior in various systems governed by MHD and GRMHD; Apply our physical knowledge to real-life problems using simulations; Analyze different models in GRMHD libraries of black hole images; Evaluate space policy, such as whether ngEHT should expand by placing antennae in new sites, e.g, Namibia; and Create your own model of routine for postprocessing GRMHD simulations.

COURSE MATERIALS

Required Textbook + Media

Modern Classical Physics

Interstellar Movie

3 hours credit. Prerequisite: Graduate standing, PHY 5103 and PHY 5203, or consent of instructor.

Modern Classical Physics by Kip Thorne and Roger Blandford. A Modern Classical option that can be rented cheaply from Amazon is (ISBN-13: 978-0691159027; ISBN-10: 0691159025).

To access this course online

-Login to Blackboard

-Go to Coursework

Blackboard Support can be found via UTSA Academic Innovation: Phone: **210-458-4520**

ACTIVITIES AND GRADING

How course activities and grades will be assigned and evaluated:

Homework	**45%**
Take Home Quizzes 1 and 2	**30%**
Final Presentation	**15%**
Participation	**10%**
Total	**100%**

Grade Distribution and Letter Grade

For this graduate course, I am far more concerned with giving students exposure and experience with the subject than ranking them.

ASSIGNMENT NUMERICAL GRADES WILL BE EVALUATED AND CONVERTED TO LETTER GRADES AS FOLLOWS:

Late homework (submitted after Mon class due dates) will docked 50 percentage points for each week late. Monitor one's grade progress in real time using Blackboard. The numeric-to-letter grade conversion is shown below:

>60% = GRADE A

50%-60% = GRADE B

<50% = WE'LL TALK ABOUT IT

ESSENTIAL STUDENT INFORMATION

- **Important:** Bookmark and visit the Common Syllabus Information webpage to find important and valuable resources about counseling services, transitory/minor medical issues, supplemental instruction, tutoring services, academic success coaching, sexual harassment and sexual misconduct, campus safety and emergency preparedness, inclusivity statement, and the Roadrunner Creed.
- For technical requirements, support, and academic resources, visit the Student Support Gateway, where you can find all your tech and academic support resources in one place.
- Follow Online Learning Netiquette standards for your online communication activities. Please be mindful of the communication tools available in your course and use them for learning purposes. Class discussions take place in a respectful and safe environment, whether online or in person. UTSA encourages everyone to openly share their ideas and opinions without penalty or judgment, but learning should always be based on facts and research. It is possible to disagree without being disagreeable.
- UTSA provides reasonable accommodations to students via the Student Disability Services. For more details on eligibility, policies, and requirements, please visit www.utsa.edu/disability or call (210) 458-4157.
- **UTSA Wellbeing Resources:** your wellbeing is a priority for us. UTSA is proud to partner with Wellness 360 and MySSP to provide students with access to quality health and mental health care. Visit the UTSA Students Wellbeing Resources to explore the services available.

INSTRUCTOR CONTACT INFORMATION

Instructor Name: **Prof. Richard Anantua**

Department and College: Department of Physics & Astronomy

Office Location: **AET 3.386 or Zoom**

Student hours: Th 1p-2p via Zoom *(email for appointment)*

Phone Numbers: **(210) 458-6564**

Email Address: **richard.anantua@utsa.edu**

COMMUNICATION PLAN

The following is an example of a communication plan.

There are several ways you can communicate with me.

My preferred method of communication is:

- **Email, you may email me at richard.anantua@utsa.edu. You may also use the Send Email tool in Blackboard.**
- **Course Messages tool in Blackboard, in case you need to send me a private message, for example, about a grade. This communication stays on Blackboard and is the only secure way to discuss your grade. You must log in to Blackboard to send and receive a course message.**
- **Post questions in the Course Q&A forum in Blackboard. This is a public forum provided for content and course-related questions. I encourage you to participate in this forum to get involved with your class.**

Don't hesitate to contact me and join the Student Support Hours

About Me

I am a new UTSA Assistant Professor excited to be part of your academic journey this semester. Intro to Astronomy is my first course here— and will thus be a learning experience for me and you.

My current research focuses on reverse engineering near-horizon supermassive black hole observations from intercontinental baselines of radio telescopes –primarily the Event Horizon Telescope (EHT)– using a methodology I call "Observing" Jet/Accretion flow/Black hole (JAB) Simulations. I lead the first EHT research group in Texas, primarily conducting research within the EHT Theory and Simulations Working Group. I also lead the EHT Outreach Group for the Americas, and have established nexuses between EHT and networks supporting diversity in the sciences such the NSBP/SAO EHT Scholars program.

My broad research interests have included: theoretical cosmology, high-energy theoretical astrophysics (e.g., Blandford-Znajek jets from supermassive black holes), high-energy theoretical particle physics (e.g., string theory [especially AdS/CFT correspondence]), condensed matter theory (e.g., strongly correlated fermionic systems with holographic dual).

My degrees are as follows:

Ph.D. in Physics; Stanford University 2016
Ed.M. in Education Policy and Management; Harvard University 2014
M.S. in Physics; Stanford University 2013
B.S. in Physics and Philosophy and B.S. in Economics and Mathematics; Yale University 2010

My Teaching Philosophy

My teaching philosophy can be found in this statement.

My Inclusivity Statement

The University of Texas at San Antonio, a Hispanic Serving Institution situated in a global city that has been a crossroads of peoples and cultures for centuries, values diversity and inclusion in all aspects of university life. As an institution expressly founded to advance the education of Mexican Americans and other underserved communities, our university is committed to ending generations of discrimination and inequity. UTSA, a premier public research university, fosters academic excellence through a community of dialogue, discovery, and innovation that embraces the uniqueness of each voice.

I have devoted much of my academic career to diversity and inclusion. Focusing on skills- and training-based initiatives as the key to leveling the educational playing field, I have started the NSBP/SAO EHT Scholars and UTSA-EHT Scholars and launch the next generation of diverse leaders. I look forward to championing and advocating for all my students.

ASSESSMENTS AND ASSIGNMENTS

Description of major assignments and assessments.

- Homework: We have a homework assignment or take-home quiz assessment due Mon 1p each week starting Mon Jan 30, 2023 ending Mon May 1, 2023 to support student success.
- Quizzes: We will have two take home quizzes complementing the homework. Research suggests early, frequent “low-stakes” assessment activities produce better outcomes. Refer to HOP Class Attendance and Policies for more details.
- Exams: This course will have Midterm Quizzes Feb. 20, 2023 and Mar. 27, 2023. There will be no final exam, rather a final presentation.
- Participation: To support student success, this course will incorporate “active learning” assignments. Research shows that hands-on, applied, collaborative, problem-based, and context-relevant assignments engage students and produce better outcomes.

COURSE SCHEDULE

For a list of important university-wide dates, review One Stop's academic calendar. In particular, for Spring 2023, some key dates are:

Spring 2023 Key Dates

Nota bene: There is a weekly **homework or assessment typically due in class Wed** from Jan. 30 to May 1— with two presentation dates. There will be three 4-week blocks of 3 homeworks followed by 1 an oral or written assessment, with **Quiz 1 due on 2/20/23, Quiz 2 on 3/27/23 and Final Presentations on 4/24/23 and 5/1/23**.

W Jan 18 – First Day of Class 1:00p-2:15p

M Jan 23 – **HW 0** Introduce yourself – email richard.anantua@utsa.edu your academic background (especially math and experience related to relativity and magnetohydrodynamics), expectations and what you hope to get from this course

M Jan 30 – **HW 1** due in class

M Feb 6 – **HW 2** due in class

M Feb 13 – **HW 3** due in class

M Feb 20 – GR **Midterm Quiz 1** (take home) due 1p

M Feb 27 – **HW 4**

M Mar 6 **HW 5** due in class; Midterm Grades Due,

M Mar 13- F Mar 17 – **Spring Break**

M Mar 20 – **HW 6**

M Mar 27 – GR and MHD **Midterm Quiz 2** (in class)

M Apr 3 – **HW 7**

M Apr 10 – **HW 8**

M Apr 17 – **HW 9**

M Apr 24 – **Final Presentations** in class

M May 1 - **Final Presentations** (cont.); Last Day of Class

Tu May 13 – Final Course Grades Due on ASAP

Topic/Module List

The course will be subdivided into:

Unit 0: Fundamentals – Ch. 1

Unit 1: General Relativity – Chs. 2,25,26

Unit 2: Magnetohydrodynamics – Chs. 13,15,16,19

Unit 3: GRMHD – Chs. *19*,20,23,*25*,*26*

COURSE MANAGEMENT AND POLICIES

Instructor-Initiated Drops

This course uses instructor-initiated drops for students who exceed the absence and/or missed assignment limit. Therefore, up to the last day for students to withdraw from an individual course, [3/27], you will be dropped for exceeding [10 absences or receiving and average of 50% or lower on assignments]. Students will receive at least one courtesy warning when approaching the absence/missed assignment limit. Notification will be sent via ASAP to the student's email address. A subsequent absence or missed assignment will result in being dropped from the course. Notification of being dropped will also be sent via ASAP to the student's email address. *This drop does not affect enrollment in other courses.* **Please consult the Dropping Courses webpage** for further details on the process and appeals.

Student Code of Conduct and Scholastic Dishonesty

The Student Code of Conduct is Section B of the Appendices in the Student Information Bulletin. Scholastic Dishonesty is listed in the Student Code of Conduct (Sec. B of the Appendices) under Sec. 203.

Copyright and Fair Use

It is important to understand the issue of intellectual property rights. You may not use the images or thoughts of others for profit or gain without their written permission. The UTSA library has a Copyright Laws and Public Performance Rights (PPR) page.

Students with Disabilities

The University of Texas at San Antonio, in compliance with the Americans with Disabilities Act and Section 504 of the Rehabilitation Act, provides "reasonable accommodations" to students with disabilities. Only those students who have officially registered with Student Disability Services and requested accommodations for this course will be eligible for disability accommodations. Instructors at UTSA must be provided official notification of accommodation through Student Disability Services. Information regarding diagnostic criteria and policies for obtaining disability-based

academic accommodations can be found at www.utsa.edu/disability or by calling Student Disability Services at (210) 458-4157. Accommodations are not retroactive.

Family Educational Rights and Privacy Act (FERPA)
FERPA grants students the right to control certain disclosures of their educational records. For a full explanation of your rights and to grant access to FERPA educational records, go to Student Catalog Annual FERPA Letter and One Stop Enrollment – FERPA Proxy Access. Without your consent or authorization of proxy access, UTSA may release Directory Information, such as but not limited to your name, email, phone, place of birth, and photograph, unless you have opted out of the release of Directory Information. To opt out, go to Restrict Directory Information Form. ***Mandatory Reporting of Sexual Misconduct and Reporting of Health and Safety Information***: If a student discloses an incident of sexual misconduct to any UTSA employee (other than to a designated confidential employee such as mental health counselor or PEACE advocate, a UTSA police officer using a pseudonym form or at a public awareness event), that information is not confidential, and the UTSA employee must report all known information to the UTSA Office of Equal Opportunity Services. Employees may also report any concerns about the health and safety of students or others to other school officials and/or law enforcement. For a complete list of exceptions to FERPA, please see Student Catalog Annual FERPA Letter and HOP 5.01.

Video and audio recording
As the instructor of this course, I may record meetings and lessons. You are expected to follow appropriate University policies and maintain the security of passwords used to access recorded lectures. Recordings may not be published, reproduced, or shared with those not in the class. If the instructor or a UTSA office plans any other uses for the recordings, consent of the students identifiable in the recordings is required before such use unless an exception is allowed by law. For more information on your privacy and class recordings, review Student Privacy (FERPA) in Virtual Classrooms and Other Educational Recordings and the Guide to Secure Video Conferencing Tools.

Note: The syllabus is subject to change at the instructor's discretion. Any changes/corrections to the course materials, assignment dates, or other updates will be communicated to the students ahead of time. You are responsible for checking Blackboard for corrections or updates to the syllabus.