Gravity in Extremes - Black Holes in the Universe
http://isites.harvard.edu/k89389

The existence of black holes was debated through the last decades of the 20th century. Now, it is believed they exist in most, if not all galaxies, including our own. What has changed? Have we developed instruments that allow us to "see" black holes? If not, why is their existence no longer debated in conventional astronomy? In this course, students will read from ``Gravity's Fatal Attraction" - a popular text on black holes, and popular articles (e.g. Scientific American, Nature and others) based on the latest scientific research to explore these questions and others, including how black holes form, how they might evaporate, and how we can try to measure their mass and spin. While the seminar will focus primarily on black holes, we will briefly investigate gravity associations with dark matter and dark energy. In the process, students will also gain perspective on the range of radio to gamma-ray telescopes and satellites enabling the latest breakthroughs.

Unique to the Harvard experience, the class will also be taken on a tour of the millimeter-wave telescope here at the Harvard-Smithsonian Center for Astrophysics and shown how dark matter can be measured from a Harvard building roof-top. We will also visit the Chandra X-ray satellite operations control center located here in Cambridge, where students will talk with mission control personnel about the details of satellite maneuvering, planning, and observations. (Chandra is the largest satellite to be operated away from a NASA center, and the millimeter-wave telescope, located at Harvard, is one of the few not run by a National facility.)

Succinct, clear, oral presentation skills is an important part of your training for whatever field you choose. A key goal of this course is to provide you with that training in a peer-friendly environment. This will be fostered through student presentations and group discussions, which will be the key components of this course. All students are expected to participate in discussion, and express their ideas. You will be effectively the teachers of this course. My role will be to provide feedback, coaching, advice, and support.

I am eager to make this a rewarding experience for you. This will be a rigorous course, but hopefully a fun one too.

Welcome to the gravitational orbit of Harvard.

LOGISTICS & COURSE TEXT

Contact Information

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I would like to be as accessible to you as possible. To this end, I encourage you to email me with questions if you need advice on your presentations, or need advice in general. I hope to respond asap, and/or if the situation warrants arrange a time ot meet in person. Please know however that I cannot always reply right away. We will work together to develop a system to work to the mutual benefit of all.

COURSE TEXT:

All required will be on reserve at Cabbot and Wolbach (located at the Harvard-Smithsonian Center for Astrophysics on 60 Garden Street).

REQUIRED: Gravity's Fatal Attraction (GFA) by Mitchell Begelman and Sir Martin Rees
This text will serve as the basis for our weekly discussions and your presentations.

Popular research related articles
Each week, you will also be given additional articles, often highlighting research, that will demonstrate key principles outlined in GFA. These will be provided to you either as links on the course isites page or as handouts the week they are assigned.

Gravity from the ground up by Bernard Schutz
On occasion, you will be given reading from this book instead of / in addition to popular research related articles.

INTERESTING HISTORICAL PERSPECTIVES

Space Time and Gravitation: An outline of the general relativity theory by Sir Arthur Eddington

Practical Mystic: Religion, Science & A.S. Eddington by Matthew Stanley (2007)

ADVANCED

Astronomy: A Physical Perspective (2nd ed.) by Marc L. Kutner, Cambridge University Press (2003)

An Introduction to Modern Astrophysics (2nd ed.) by Bradley W. Carroll and Dale A. Ostlie (2007).

HOMEWORK ASSIGNMENTS:

Each week you will be assigned reading from GFA and popular articles of relevance. Students will then be assigned to groups responsible for specific topics to present in class the following week. Until the next class meeting, you will work with your assigned groups to develop a 30-minute presentation (using your own media of choice: e.g. power-point, movies, chalkboard, etc.) to instruct on your chosen subject matter. Each week, at the beginning of class, I will select, at random, students who will be presenting **that day**, or the group as a whole, so that you will **all** need to come to class prepared to present. All students not presenting are expected to participate in discussion, ask questions, and express their ideas.

This is a P/NP class so I hope you will find this a friendly and safe environment to explore new horizons by stretching beyond your comfort level.

PRESENTATION FORMAT:

- Introduction
- Key Concepts
- Explanations in support of key concepts
- A modern day application of the material – commercial use, in movies, etc.
- Your specific interest in one aspect of the material – be prepared to explain

COLLABORATION

Collaboration is encouraged in this course, but plagiarism is a serious offense at Harvard, which can lead to expulsion in the worst-case scenario. For your presentation, (1) you should list your group members since you will be collaborating with them on preparation, **and** (2) cite references used (including e.g. Wikipedia, utube, etc.). There is no limit on the amount of sources you use to help prepare for presentations. If you are concerned about how to reference material, or need general advice, I am here to help you.

Be creative and let's make this a fun course for everyone!

FALL 2012 FRESHMAN SEMINAR 23U READING LIST

- **Week 1 (9/5)** GREET AND MEET + LOGISTICS
- **Week 2 (9/12)** GRAVITY'S ROLE IN THE UNIVERSE: NEWTON VERSUS EINSTEIN
  - *GFA Chapter 1 presentations: Gravity Triumphant and related articles*
- **Week 3 (9/19)** MAKING BLACK HOLES AND OTHER ASTROPHYSICAL EXOTICA
  - *GFA Chapter 2 presentations: Stars and their Fates*
- **Week 4 (9/26)** ARE THERE BLACK HOLES IN OUR OWN MILKY WAY?
  - *GFA Chapter 3 presentations: Black Holes in our Backyard and related articles*
- **Week 5 (10/3)** FIELD TRIP TO CHANDRA X-RAY SATELLITE MISSION CONTROL
- **Week 6 (10/10)** WHAT IS DARK MATTER AND HOW DO WE KNOW IT'S THERE?
  - *GFA Chapter 4 presentations: Galaxies and their Nuclei & Gravitational Lensing, and related articles*
- **Week 7 (10/17)** MEASURING DARK MATTER FROM CAMBRIDGE, AN ON-SITE LOOK
  - *"The Molecular Milky Way" by Thomas Dame 1988, Sky and Telescope*
  - TOUR OF THE MM-WAVE TELESCOPE AT THE HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS
- **Week 8 (10/24)** A SUPERMASSIVE BLACK HOLE IN OUR OWN MILKY WAY?
  - *GFA Chapter 8 presentations: Black Holes in Hibernation*
- **Week 9 (10/31)** SUPERMASSIVE BLACK HOLES IN OTHER GALAXIES
  - *GFA Chapter 5 presentations: Quasars & Kin and related articles*
- **Week 10 (11/7)** RELATIVISTIC JETS EXPLODING FROM SUPERMASSIVE BLACK HOLES
  - *GFA Chapter 6 presentations: Jets and related articles*
- **Week 11 (11/14)** GAMMA RAY BURSTS
  - *GFA Chapter 7 presentations: Blasts from the Past and related articles*
- **Week 12 (11/21)** Thanksgiving Recess - no class
- **Week 13 (11/28)** SCIENCE FICTION OR SCIENCE FACT?
  - *GFA Chapter 10: Checking up on Einstein (select topics) and related articles*
  - *GFA Chapter 11: Through the Horizon*
  - *Popular news articles from 2011 announcement of Nobel Prize in Physics*
  - *NPR podcast interview with Nobel Laureate Saul Perlmutter*

GFA ≡ Gravity's Fatal Attraction

PRESENTATIONS:

These can take any form you want – powerpoint, movies, black board, some new media craze I have yet to find out about ... or any combination of the aforementioned.

READING MATERIAL

- REQUIRED READING of ALL

  Both groups 1 & 2 are required in their presentations to highlight key points from this chapter, and consider the relevance of the different types of gravity in the context of Astrophysical objects and/or the Universe.

  - GFA Chapter 1 Gravity Triumphant
    *This is the introductory chapter to the book and the types of gravity we encounter in the Universe. There is **a lot** of material that is introduced but do not worry, what I want you to get out of this is a general overview of the various topics that will be covered over the course of this semester.*

  - Suggestion: "Orbits program" http://www.gravityfromthegroundup.org/
    It may be instructive to play with this program to better understand when one might deviate from a Newton gravity prescription – e.g. is Newton's inverse square law a requirement for closed orbits, or is a r^{-3} law ok? For the computer geniuses, you can even modify the program yourself!

- SUPPLEMENTAL READING, BY GROUPS

  There is a lot of material to digest, although most is to give you an overview of the course topics and historical and social perspective on the history of science. (Human behavior is not necessarily so different today.) Each group will be responsible for educating their classmates and me (through presentations) about their assigned topic. You are of course encouraged to read, or at least skim, all material to get the most out of the discussion, but this is not required of this reading assignment.

  GROUP 1: Newtonian Gravity

  G1's job will be to instruct on Newtonian gravity and applications, with specific focus on the tides, as relevant to the reading:

  - Gravity from the ground up Ch.5
    "Tides and Tidal Forces: the real signature of Gravity"

  - Suggestion: you may want to include the orbit program as part of your presentation to illustrate Newtonian physics begins to break down.

GROUP 2: Einstein's Gravity – a more historical and social perspective

G2's job will be to discuss specific case(s) where Newtonian gravity has proven insufficient, focusing on two famous examples: (1) the advance of the perihelion of Mercury, and (2) Eddington's solar eclipse expedition. Since it is impossible to discuss these without advanced mathematics, i.e. GR, your job will be to present primarily from a historical/social perspective. Be sure to describe what observational evidence showed that GR was needed. Reading to aid you:

- Chapter from Practical Mystic: Religion, Science & A.S. Eddington
  "Internationalism: The 1919 Eclipse & Eddington as Quaker Adventurer"
  – pp 100-120 likely most relevant; else, rest of text interesting for the politics of science

- Chapter from Space, Time and Gravitation by Sir Arthur Eddington -- "Weighing Light"
  This features Sir Eddington's own accounting of his expedition to try to prove Einstein's theory of GR that light an be bent.

- Suggestion: Orbits program may help with illustrating Advance of Perihelion of Mercury problem.