



Class 1 : Introduction and Welcome

ASTR350 Black Holes (Spring 2020)
Prof. Richard Mushotzky

Today's class

- Introduction – what is this course about?
- Course logistics
- Initial discussion

What is this course about?

I 'Classical' Physics of Black Holes (Lectures 1-9)

- Theories of gravity, from Newton to Einstein
- Einstein's Theory of General Relativity (GR), horizons, and black holes
 - Structure of a (rotating) black hole in GR

Primarily Theoretical

Class 1 Introduction

Class 2 Newtons Laws (in 3 acts)

Class 3 Newtonian Gravity

Class 4 Special Relativity

Class 5 Special Relativity II

Class 6 General Relativity

Class 7 General Relativity II

Class 8 Schwarzschild Black holes

Class 9 Kerr Black Holes

What is this course about?

II Stellar-Mass Black holes (Lecture 10-14)

- Black holes (and pulsars) from stellar death
- Discovery of the first black hole
- Accretion – how black holes shine!

Primarily involves interpretation and analysis of observations

- why do we think these objects are Black holes, how did they get that way, how do we observe BHs ?

How to Create a Stellar Mass Black hole



Handout **NASA's Guide To Black Hole**
Safety <https://svs.gsfc.nasa.gov/13322>

What is this course about? (cont)

III Supermassive black holes (Lectures 16-22)

- *Quasars** and active galactic nuclei
- 'Dead' quasars and the center of our Galaxy
- Black holes and their role in galaxy formation
- Origin of supermassive black holes

Interpretation and analysis of observations

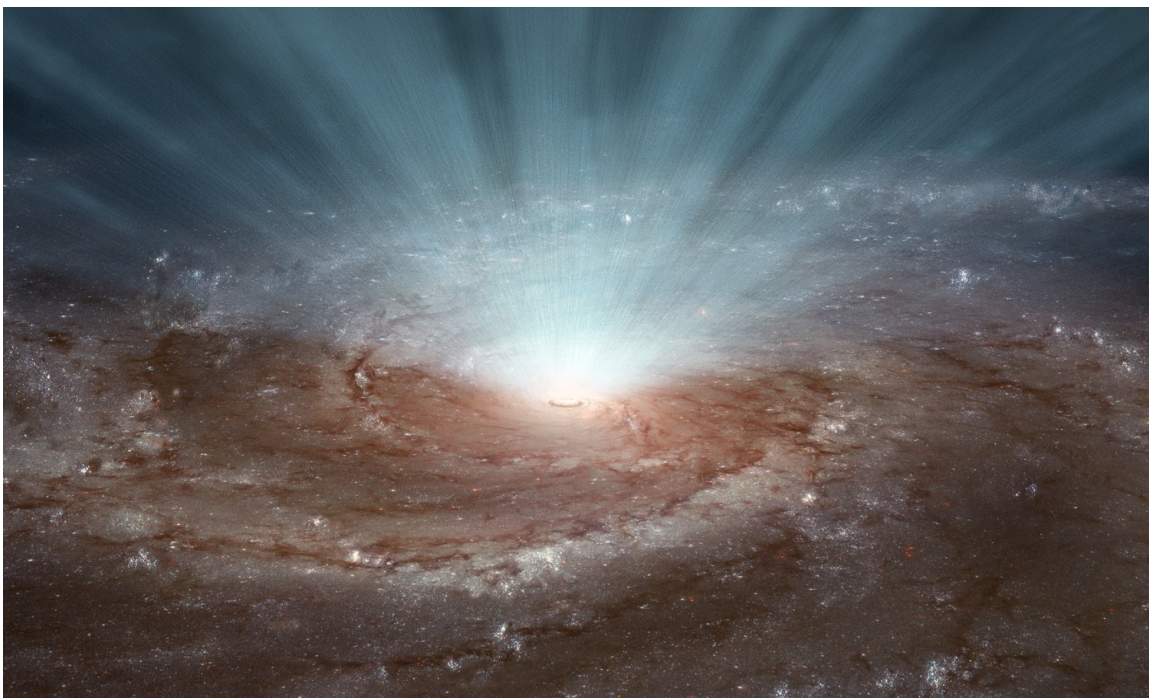
- why do we think these objects are Black holes
- origin of a surprising connection between black holes and their 'host' galaxy

***Notice the introduction of jargon**



"It's black, and it looks like a hole.
I'd say it's a black hole."

Quasar in the center of a galaxy



Often a SMBH can out shine its host galaxy

What is this course about? (cont)

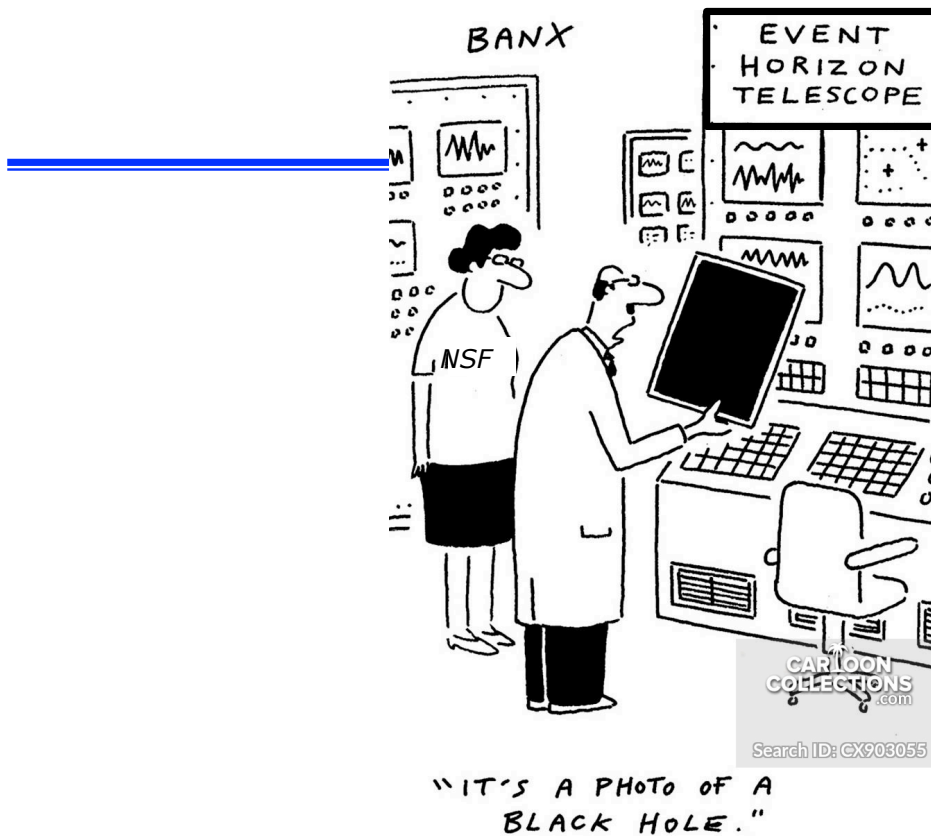
IV Black holes and the frontiers of physics (Lectures 23-26)

- Tests of General Relativity
- Gravitational radiation
- Hawking radiation, firewalls & the Information Paradox
- Imaging a black hole

Connection between theory and
observation-*pushing physics to the limit*

Possible New Physics??

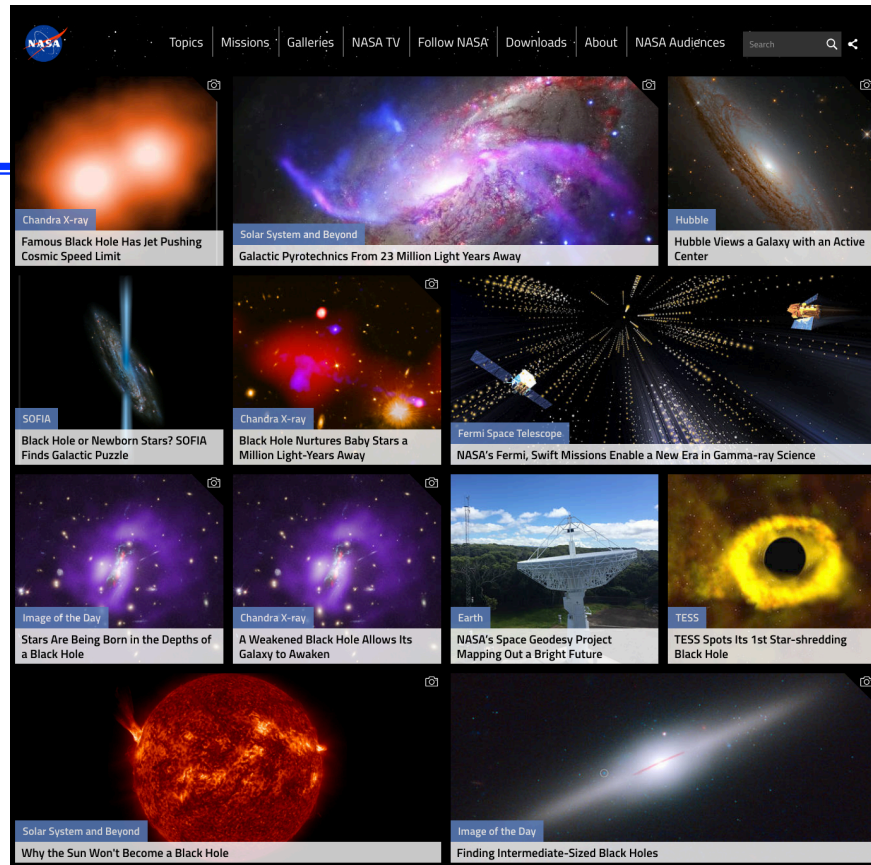




Black holes in the News

Thanks to enormous strides in technical progress there have been major new results on black holes in the last few years

<https://www.nasa.gov/subject/6895/black-holes>



Gravitational waves, Einstein's ripples in spacetime, spotted for first time-2016

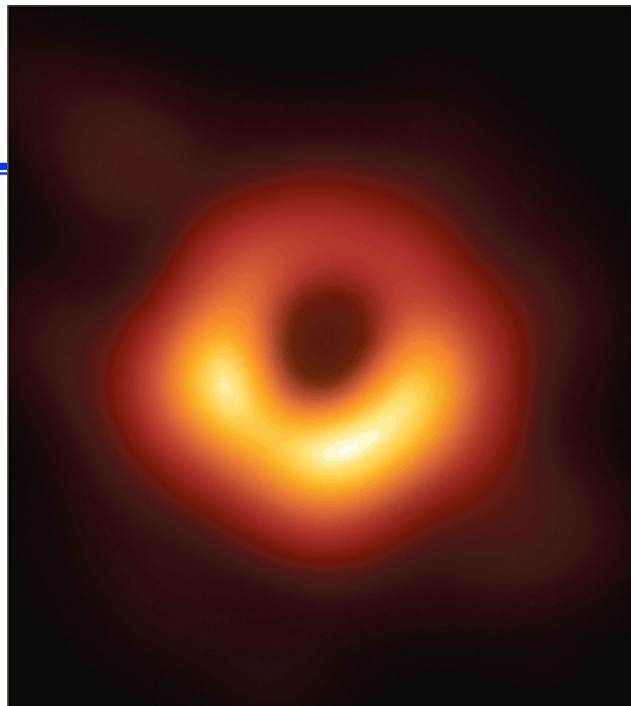


In the Media

- <https://www.youtube.com/watch?v=ajZojAwfEbs&t=13s>
- Gravitational Waves Hit the Late Show

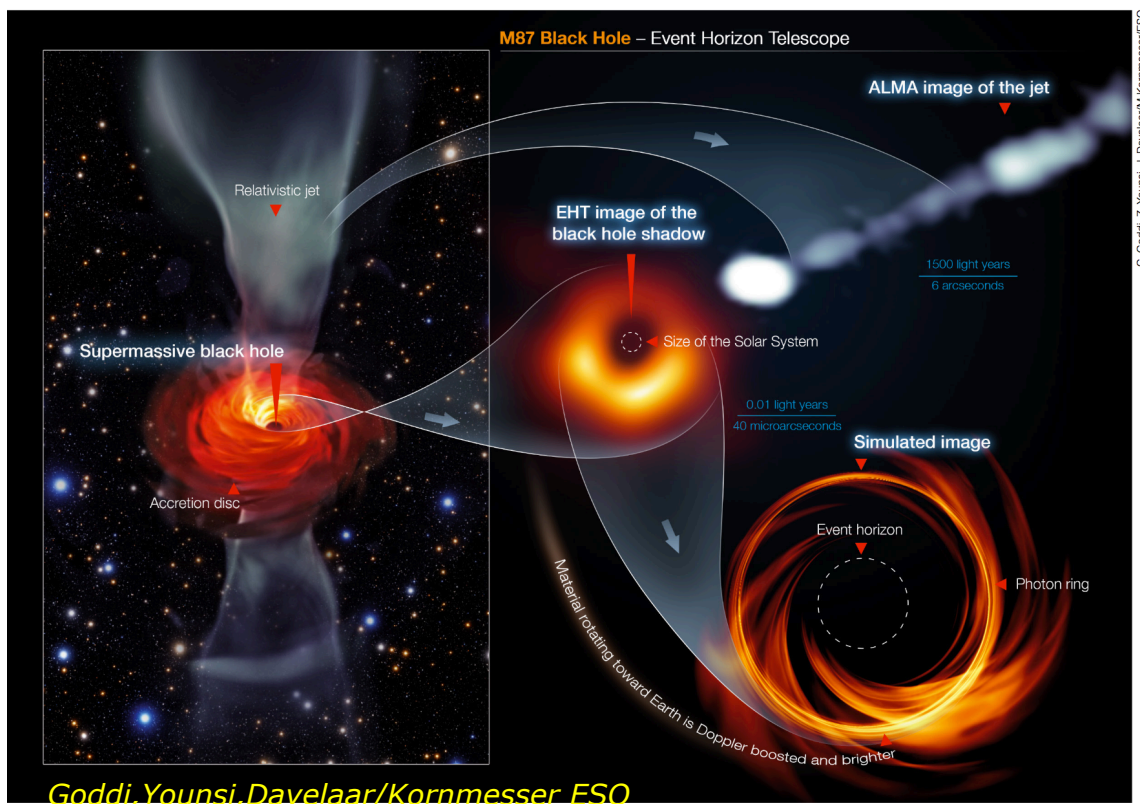
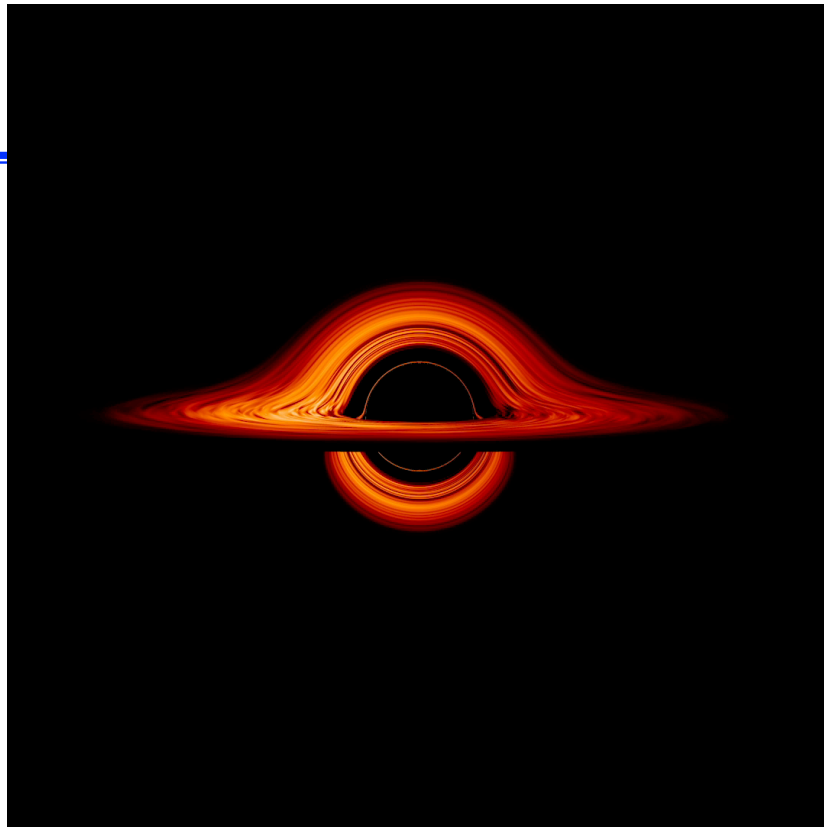
Breakthrough of
the Year

*An 'image' of the
black hole at the
center of the
galaxy M87*



[https://science.sciencemag.org/
content/366/6472/1434](https://science.sciencemag.org/content/366/6472/1434)

Full Up Model of EHT Image



Massive, common, and in some cases as big as our Solar System, black holes "hide in plain sight".

The effect of their gravity on objects around them and, lately, the gravitational waves emitted when they collide reveal their presence.

SHARE



NEWS

Darkness made visible

Daniel Clery

[+ See all authors and affiliations](#)

Science 20 Dec 2019:
Vol. 366, Issue 6472, pp. 1434-1435
DOI: 10.1126/science.366.6472.1434

[Article](#)
[Info & Metrics](#)
[eLetters](#)
[PDF](#)

An international team of astronomers has produced the first ever image of a black hole.

Black Holes -Often are in the News

In science news, some astronomers at a party, after several rounds of tequila shots, take a blurry snapshot of a flaming gas-stove burner and release it to the news media, claiming that it's the first-ever photograph of a black hole. The photo instantly becomes worldwide news, much to the delight of the astro-pranksters, who begin work on a plan to pass off a dental X-ray as the Loch Ness Monster.

In golf, Tiger Woods wins his fifth Masters tournament, catching and passing leader Francesco Molinari after two of Molinari's shots — on the 12th hole and then again on the 15th — hit NFL referee crews that have strayed onto the fairway.

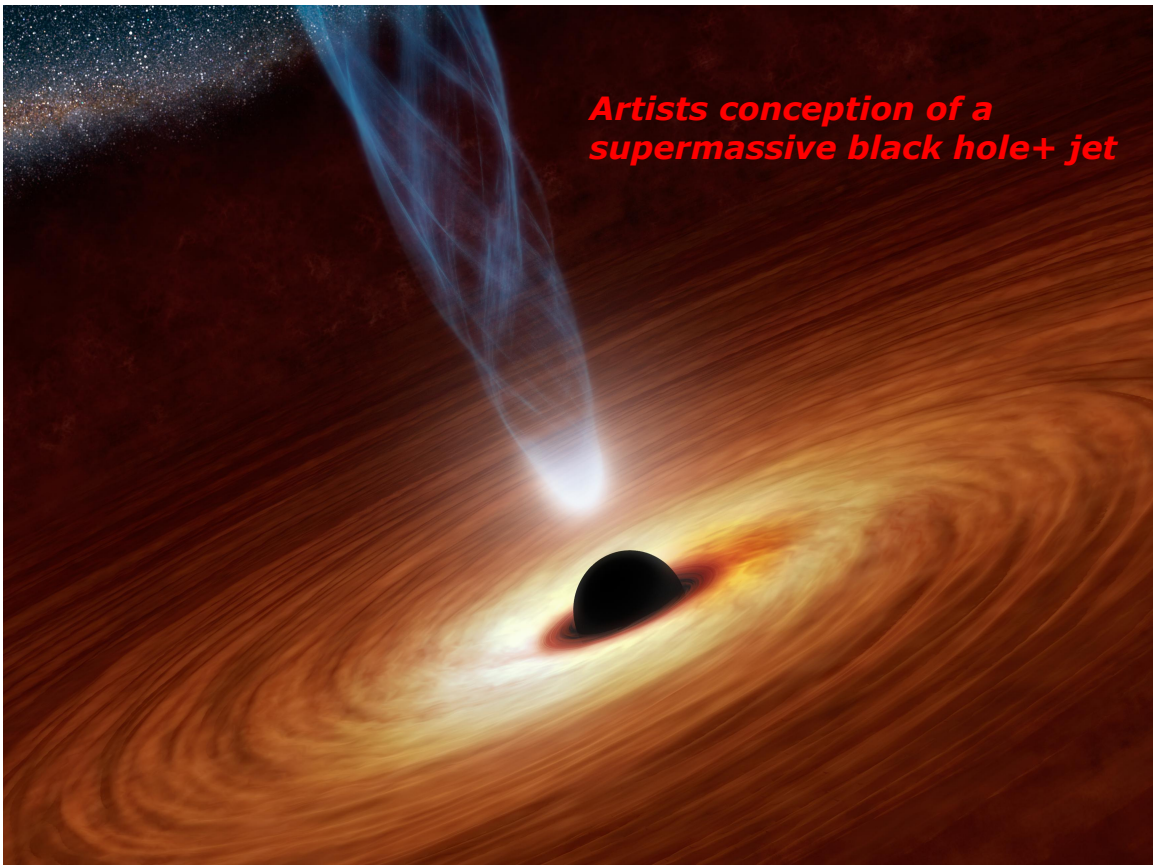
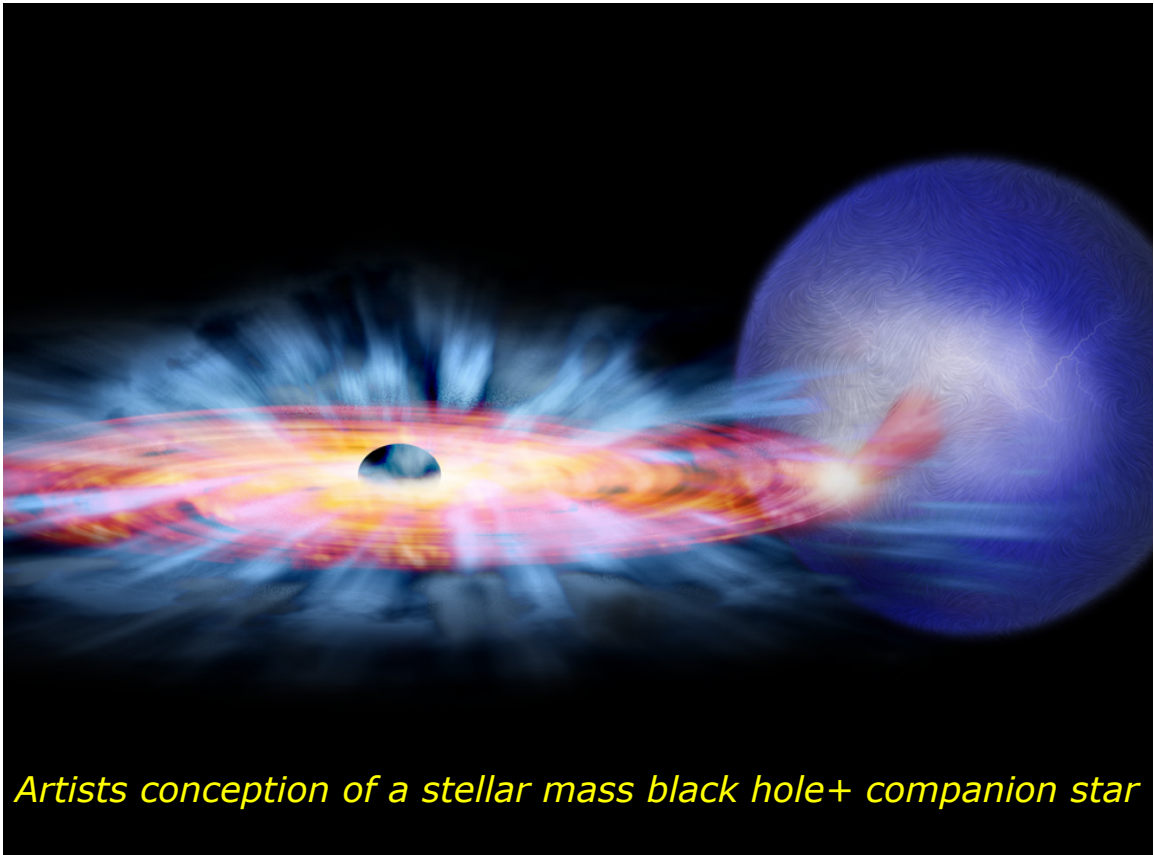
In entertainment news, "Avengers: Endgame" breaks box office records, proving that now, more than ever, people crave stories about time-traveling superheroes using magic stones to defeat a genocidal intergalactic warlord with no neck.

Speaking of long-running dramas, in ...

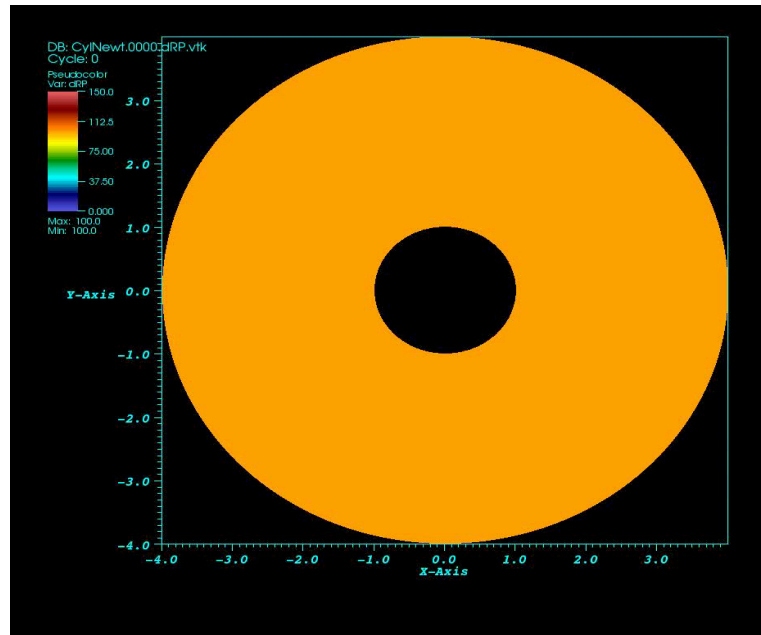
Washington Post

Magazine Dec 2019

We will learn how to distinguish a dental x-ray from a black hole



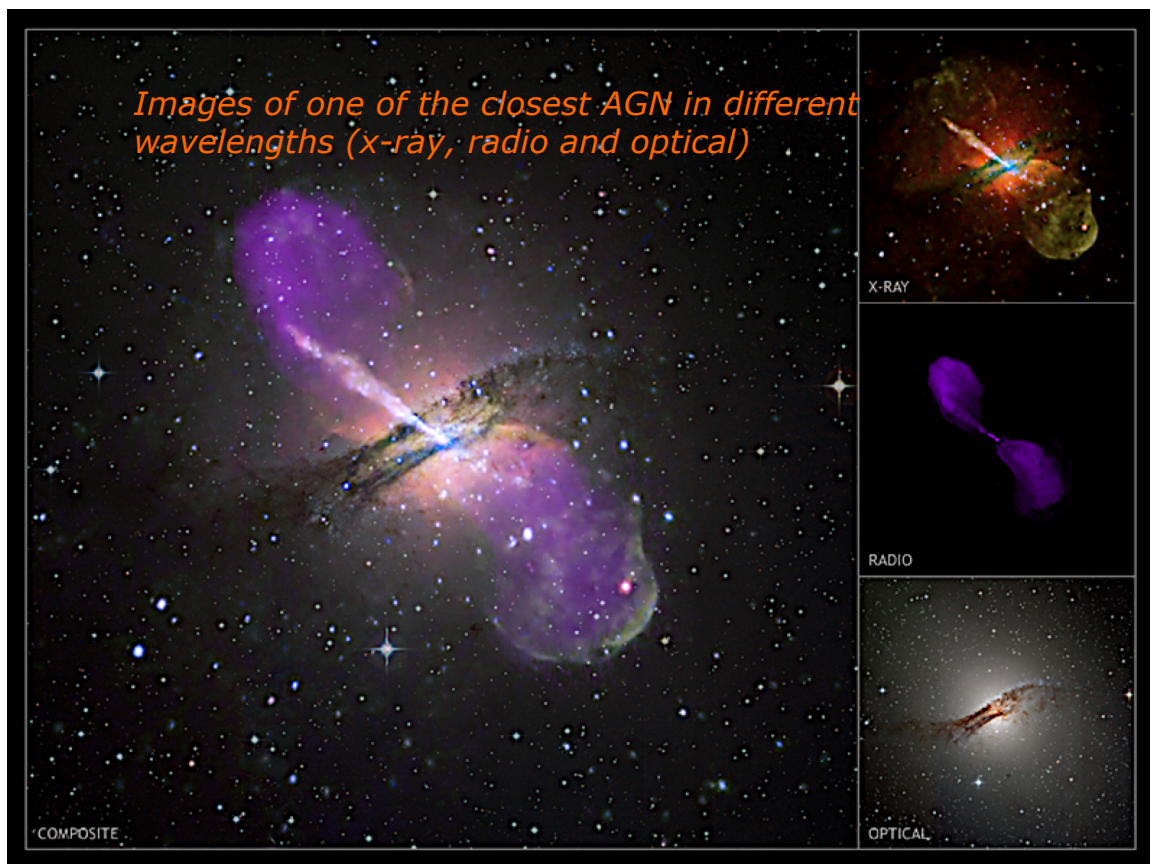
Material falling into a black hole via an accretion disk



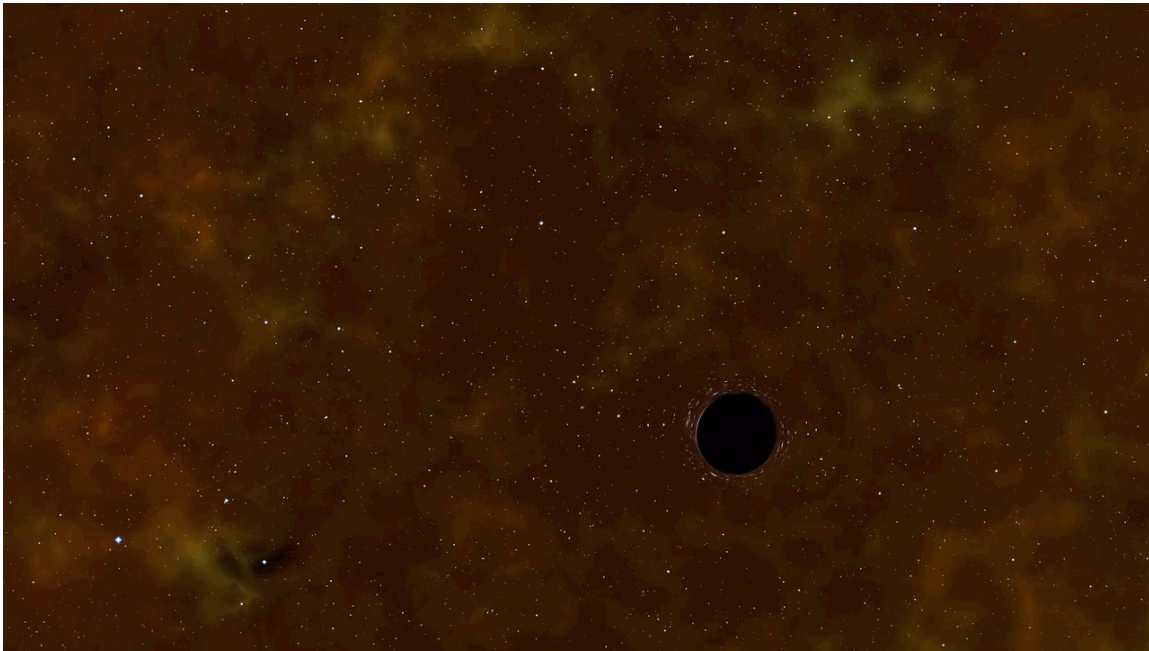
1/26/20

Darwin Science Talk

25



Black Holes Can Tear Stars Apart



<https://www.nytimes.com/2019/09/27/science/black-hole-week.html>

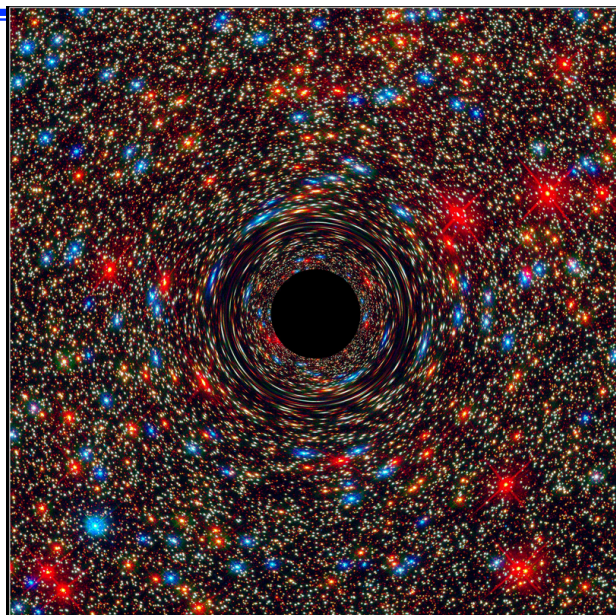
The Effect of a Black hole on Space Time

Computer-simulated image of a supermassive black hole at the core of a galaxy.

The black region in the center represents the black hole's event horizon, where no light can escape.

The black hole distorts space around it and light from background stars is stretched and smeared.

NASA, ESA, D. Coe, J. Anderson, and R. van der Marel



<https://www.thoughtco.com/black-holes-information-3072388>

Grading scheme

■ Tentative Distribution

- HW 30%
- Midterm 30%
- Final 40%

■ Letter grade

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

Office: PSC 1154

*Office hours: Tuesday and Thursday
2:00-3:30, or by appointment*

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*Office hours: Monday 1:00-2:00 or by
appointment*

No Textbook

Important Dates

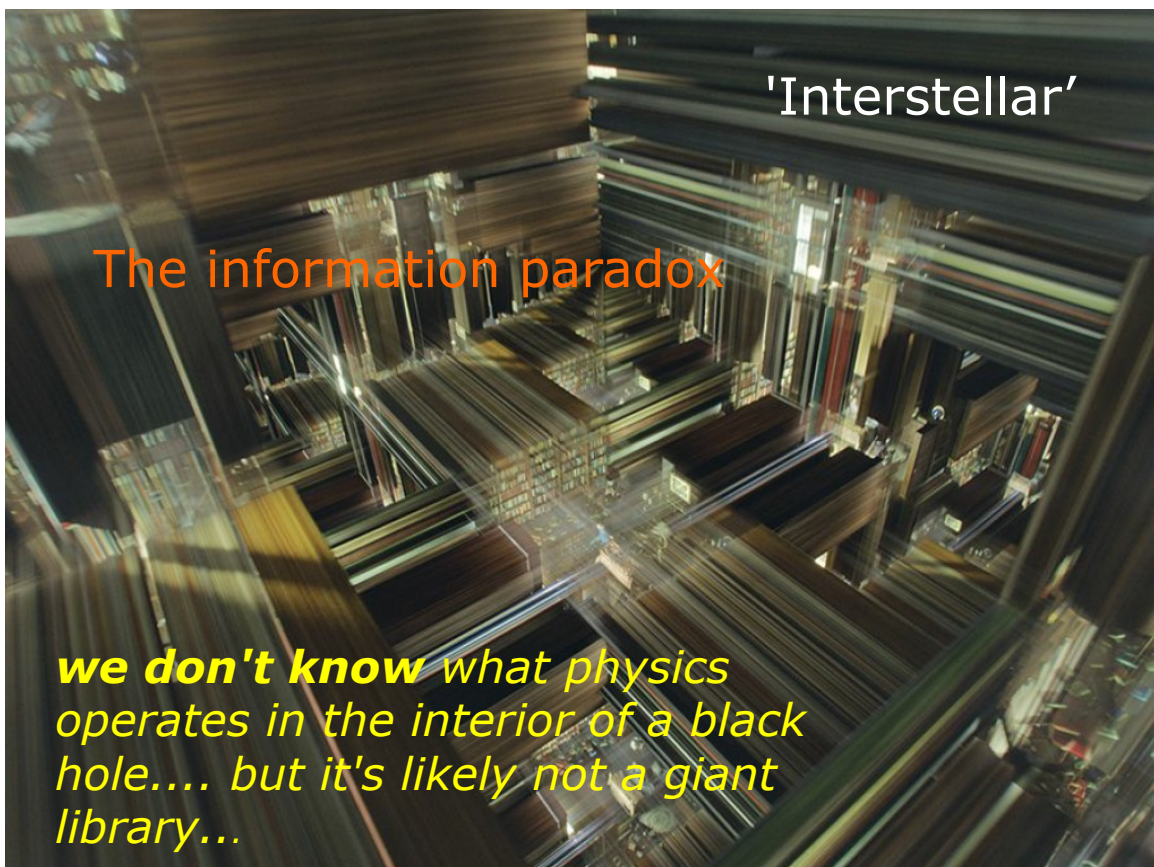
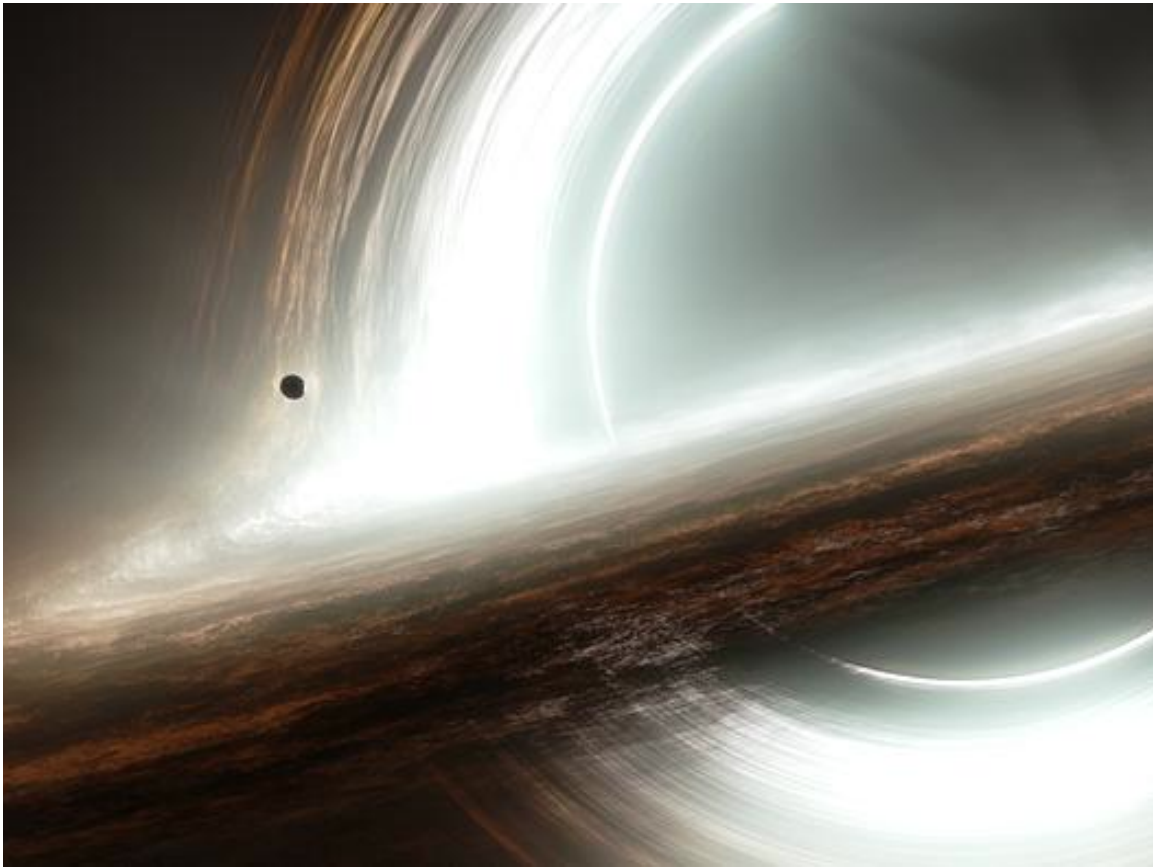
- Last day to add or drop a course without a W:
Friday, Feb. 7
- Spring break: Saturday, Mar. 14 - Sunday, Mar. 22
- **Midterm March 12**
- Last day for students to drop a course with a W:
Friday, Apr. 10
- Good Friday: Friday, Apr. 10
-first days of Passover: sundown Thursday, Apr. 8 -
Friday, Apr. 10
- Last day of classes: Tuesday, May 12
- **Final exam: Thursday, May 14 8:00-10:00am**

Absences, academic honesty

- Follow University policy...
- Regular “one-off” absences
 - Please make all reasonable effort to contact me beforehand
 - If absence leads to a missed homework deadline, please provide documentation (self-signed note ok).
- Absence from an exam
 - Midterm and final exam are “major scheduled grading event”
 - Absence must be documented (self-signed note NOT ok)... must also make all reasonable attempts to contact me before the exam
- Academic dishonesty
 - Zero-tolerance policy
 - Absolutely no copying of homeworks or exams!
 - Must list all references used to complete an assignment

Discussion!

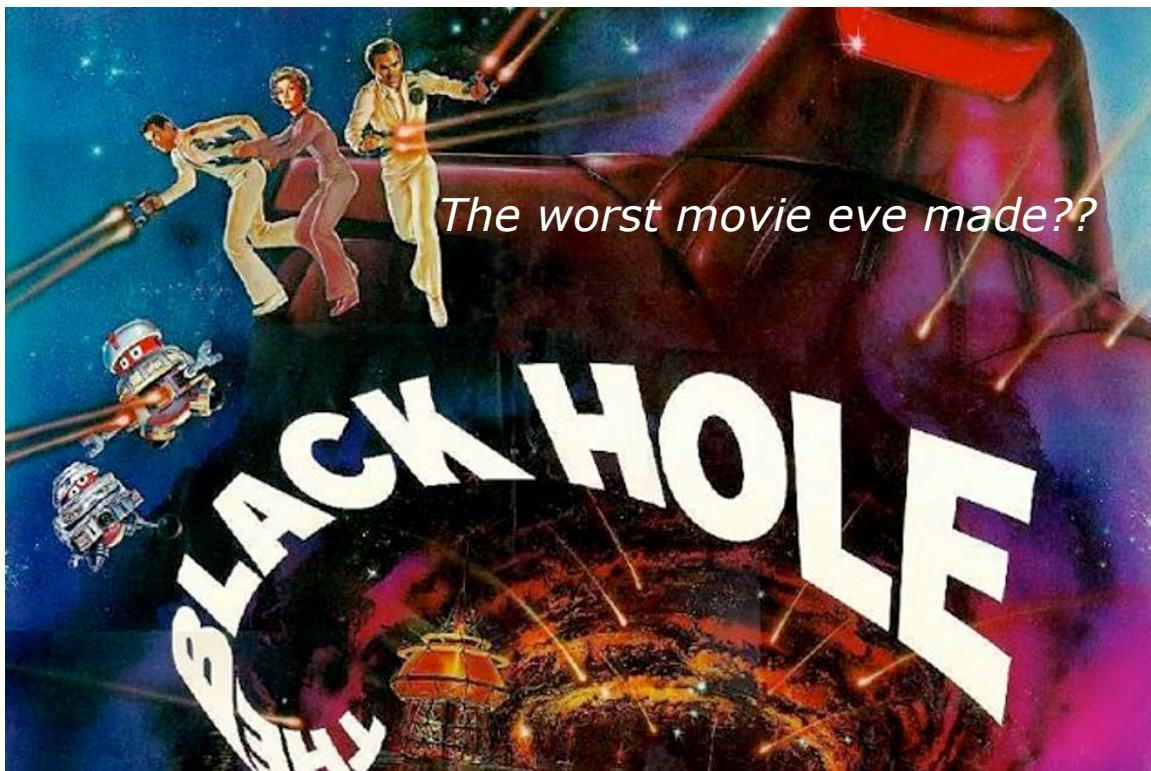
- In groups of 4—5...
- Using what you currently know, try your best to answer the following questions:
 - What is the evidence that black holes actually exist?
 - Suppose you fell into Gargantua, the huge (spinning) black hole from the movie Interstellar. What you would feel/experience as you fell in?



'Interstellar'

The information paradox

we don't know what physics
operates in the interior of a black
hole.... but it's likely not a giant
library...



The worst movie eve made??

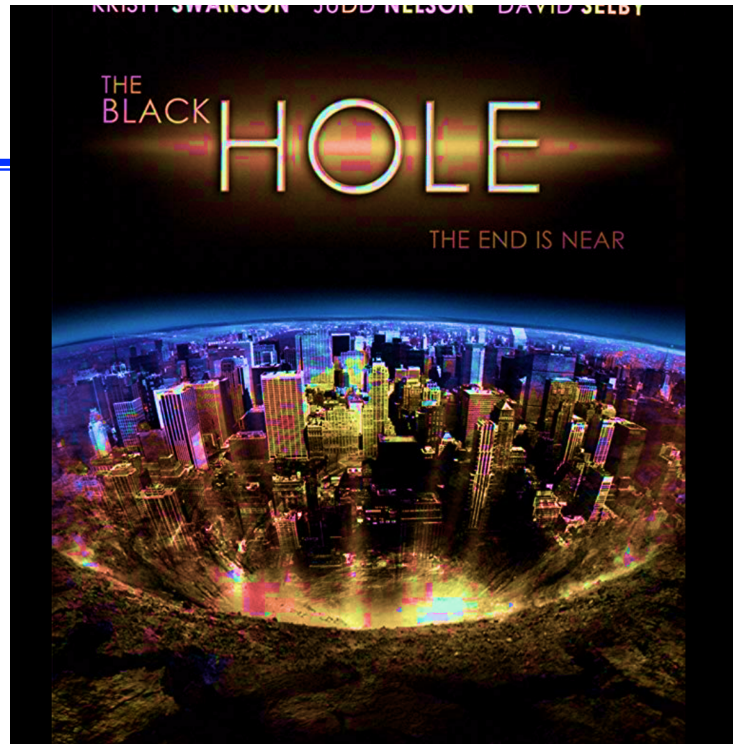
This week's assignments

- HW1 : by next Tuesday (Feb 4)
 - Watch online talk "A century of black holes"
 - <http://online.kitp.ucsb.edu/online/friends/jacobson/>
 - Then submit in writing to elms
 - Statement of what you found most interesting
 - Statement of at least one thing you didn't understand
 - A question that arises from the talk that you might be interested in pursuing in a class discussion.

Posted on ELMS

Next lecture

Newtons laws in
3 acts



Some Additional Introductory Material

- **Black Holes, explained**

<https://www.nationalgeographic.com/science/space/universe/black-holes/>

- **Exploring Black Holes**

https://www.nsf.gov/news/special_reports/blackholes/#what

- **What Is a Black Hole? Here's Our Guide for Earthlings**

<https://www.nytimes.com/2019/04/10/science/what-is-black-hole.html?>

[action=click&module=RelatedCoverage&pgtype=Article®ion=Footer](#)

- **Gravitational Waves Detected, Confirming Einstein's Theory**

<https://www.nytimes.com/2016/02/12/science/ligo-gravitational-waves-black-holes-einstein.html?>

[action=click&module=RelatedLinks&pgtype=Article](#)

- **The Physics of Black Holes** - with Chris Impey -

YouTube<https://www.youtube.com/watch?v=roM1QPr8INo>