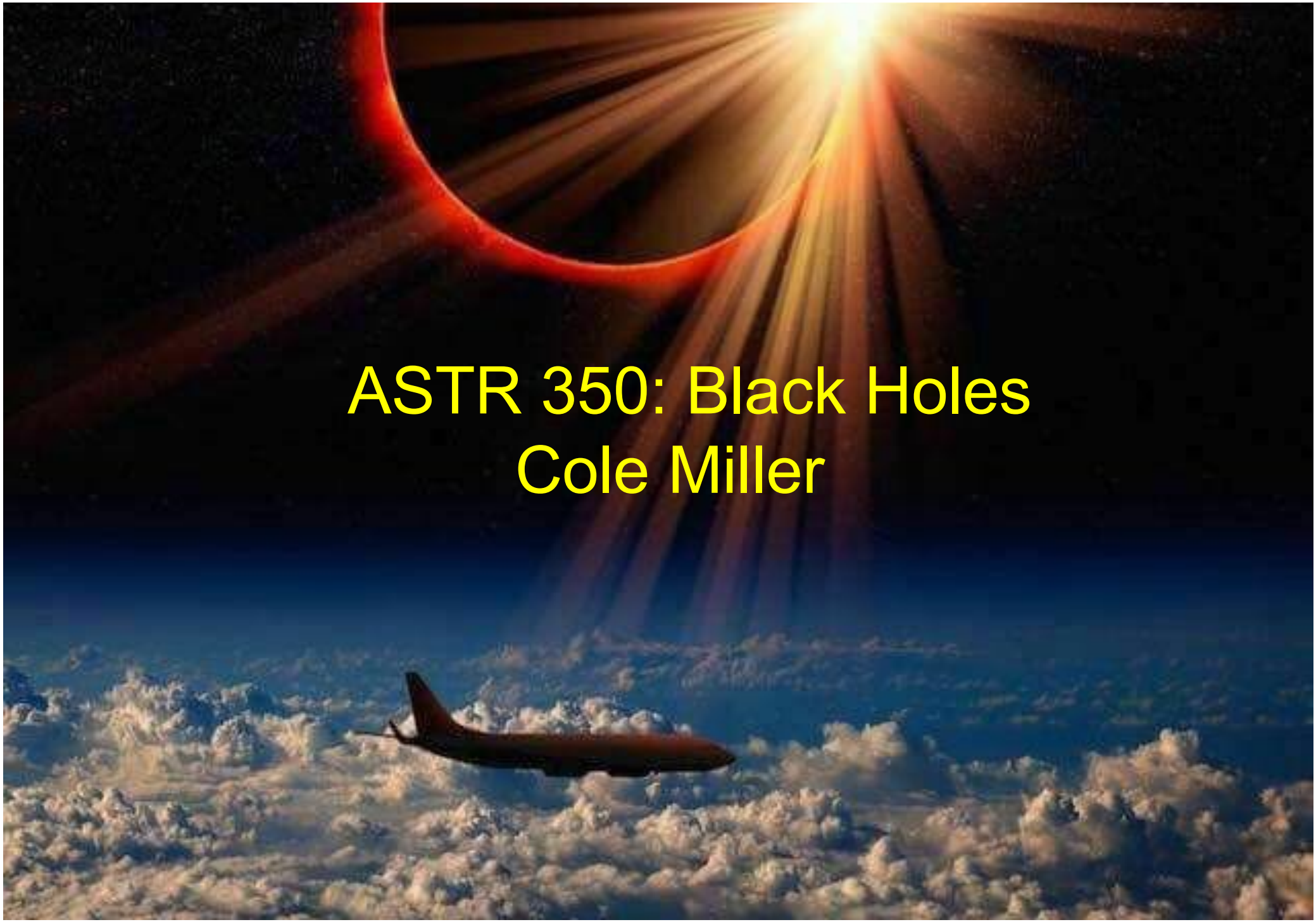


ASTR 350: Black Holes

Cole Miller

Today's class

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

What is this course about?

I 'Classical' Physics, Relativity and Black Holes (Lectures 1-9)

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

III Supermassive black holes (Lectures 16-22)

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

Involves theory, interpretation and analysis of observations, and connection between theory and observations; pushing physics to the limit!

Astronomy 350—ASTR350

Professor	Dr. Cole Miller
Office	PSC 1114
Phone	301-405-1037
E-mail	miller@astro.umd.edu
Office Hour	Wed 1–2 pm, or by appointment
Lectures	TuTh 12:30 pm–1:45 pm
Textbooks	None (just these notes; I'm saving you money!)
Online Materials	https://umd.instructure.com/courses/1318887
Graders	Katie Futrowsky (ATL 1243; office hour Mon 10-11 am)
	Rachel Weller (ATL 1243; office hour Tue 9-10 am)

Grading

- Total of 100 points
- Homework is 30, midterm is 20, final is 30, term paper is 20.
- I guarantee your letter grade will be no *worse* than:

  A- if you have 90-100 points
  B- if you have 80-89 points
  C- if you have 70-79 points
  D- if you have 60-69 points

  Your letter grade *might* be higher than this, depending on the class average.
- The only extra credit will be on exams and possibly some homeworks. If you don't do work, you can't make it up!

Homework and Exams

- All homeworks are included in the syllabus; they are due at 12:30 pm (i.e., the start of class) on the due date. After 12:45 pm they will be docked 20+%.
- Homeworks are submitted online, in ELMS. Must be in typed pdf form; our graders need to be able to read what you write!
- Exams will be during class time, closed book, no notes. You will use calculators during the exams.
- For valid emergencies (see syllabus), contact me by email or voice mail before the start of the class or exam. A valid written excuse must be submitted and documented.

Academic Integrity

- Taken very seriously by the University!
- See the syllabus and the Code of Academic Integrity (URL in syllabus). Examples include:
- Homework must be written in your own words. Working with a friend is fine, but copying from a book or website or from others' work *or allowing yours to be copied* is a violation.
- All sources must be credited. This includes books and Web sites, among others (including our textbook!).
- Copying on an exam, bringing cheat sheets, or forging excuses is a violation.
- If you have questions, ask!

The First Few Minutes

- In the first few minutes of the class, I will be happy to discuss any astronomy topic you bring up!
  Doesn't have to be related to the day's class; could be something in the news, or just a point of curiosity
- We also have a part of the class website called "Muddiest Points"; read the notes prior to class and enter your questions if you have them; these will be anonymous
- Also: if you find a <2 minute video related to the topic of the class and send the link to me >=1 day in advance, I might show it. Could be movie clip or something whimsical!

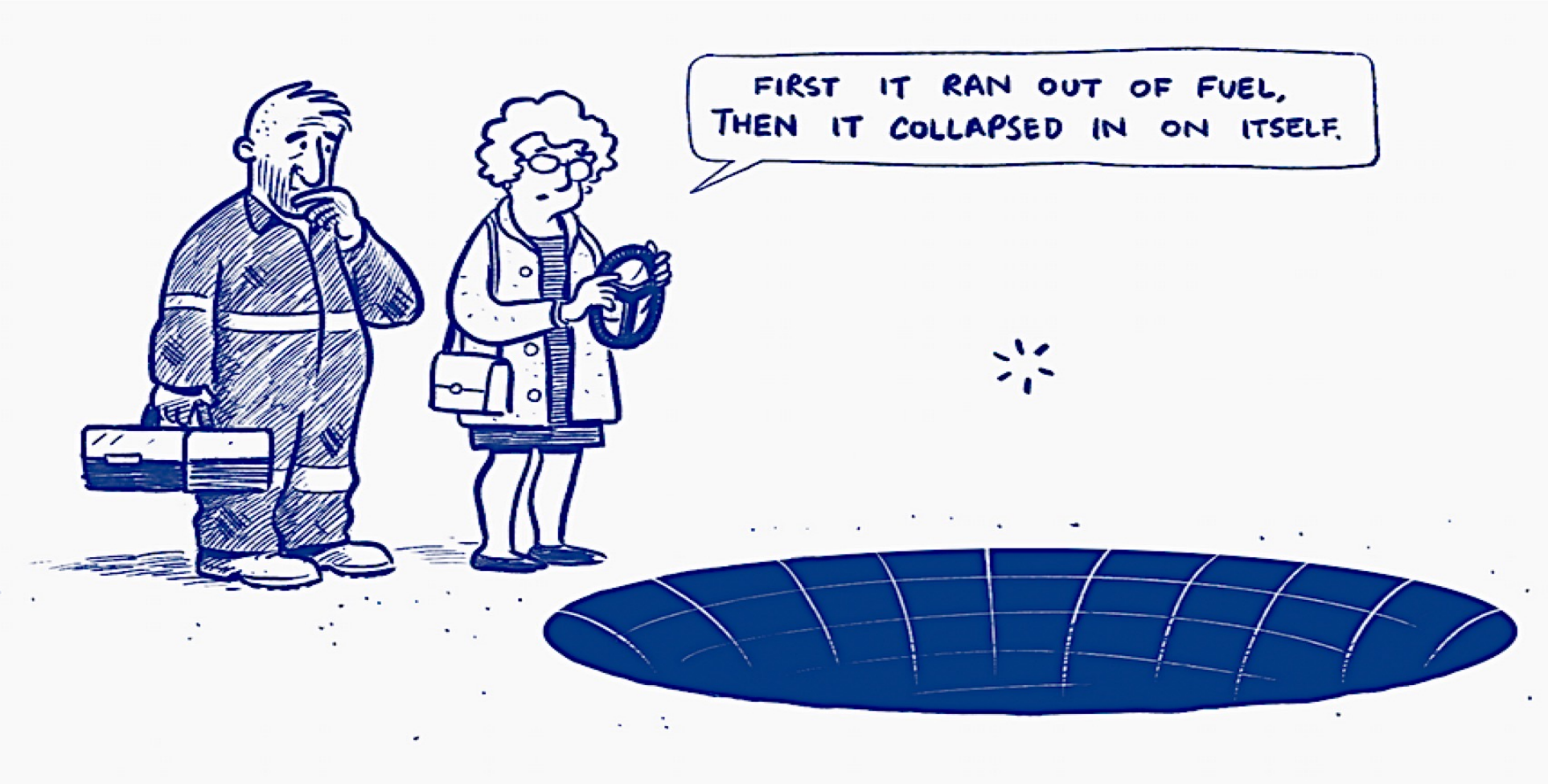
How to Succeed in this Class

- Study and think about concepts as they are introduced, not just before exams
- Test yourself as part of your studying; work with others
- Elaborate on material to make meaningful connections rather than engaging in activities that involve simple repetition of information
  Example: explain materials to others in your group!
- That is, try to *understand* the material. Don't just memorize; you won't understand as well, and your grades will suffer. Connections are one of the most enjoyable aspects of astrophysics!
  Please encourage, support, be open to adding new members!

How to Succeed in this Class, pt 2

- The condensed points (useful for most classes!):
  Read and think about material when it is assigned
  If you don't understand something, discuss it!
  Specifically: please talk and work supportively with others
  Set aside time to think about classes, shortly after class
  Start reading (and doing!) homework early
- Cramming is common; this would mean starting homework the day before it is due, or studying material only just before exams
- Think about this like eating; would it be a good idea for you to have one, really large, meal per week? ☺
- But ultimately it is your responsibility; if you use sub-optimal strategies for studying, that's your decision!

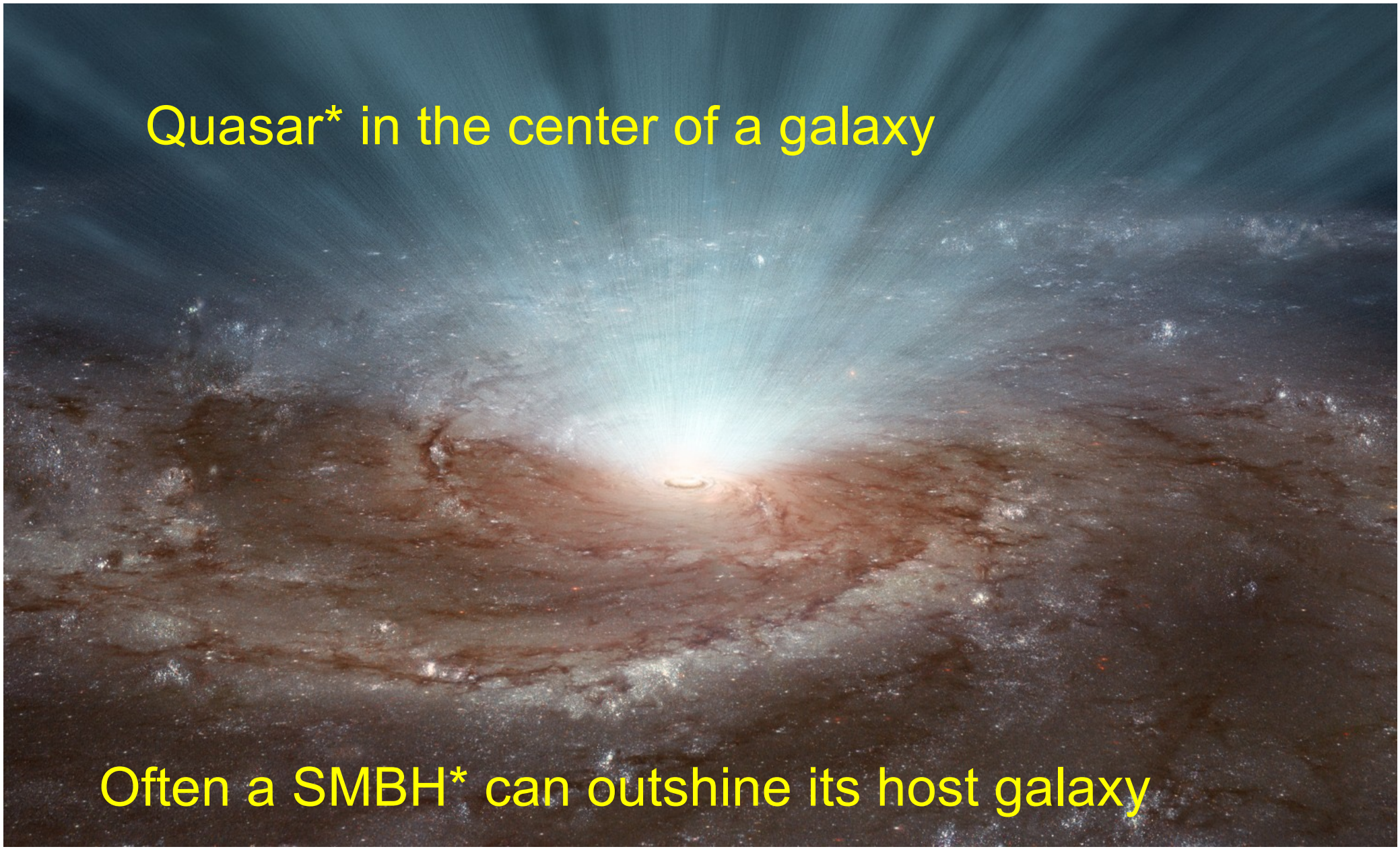
How to Create a Stellar Mass Black hole



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

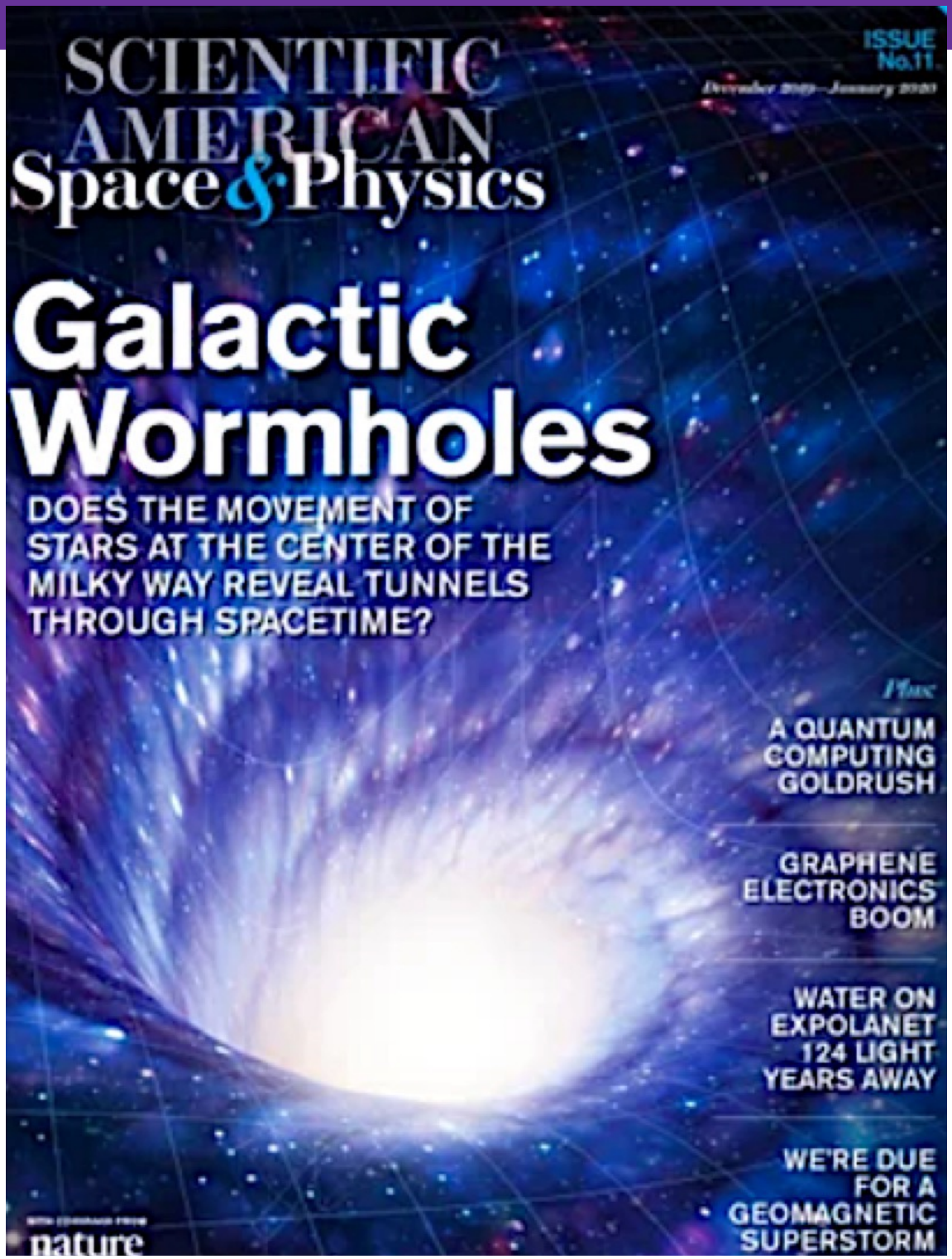
Black Holes as Depicted by Young Artists

https://www.instagram.com/explore/tags/astroarteagujero/



SMBH- supermassive black hole, quasar is a radiating SMBH

Possible New Physics??



New results

New technology, instruments and telescopes have very recently produced exciting new results on black holes

These include

- 'imaging' of a black hole
- detection of gravitational waves from merging black holes

and

- direct measurements of the region around a black hole

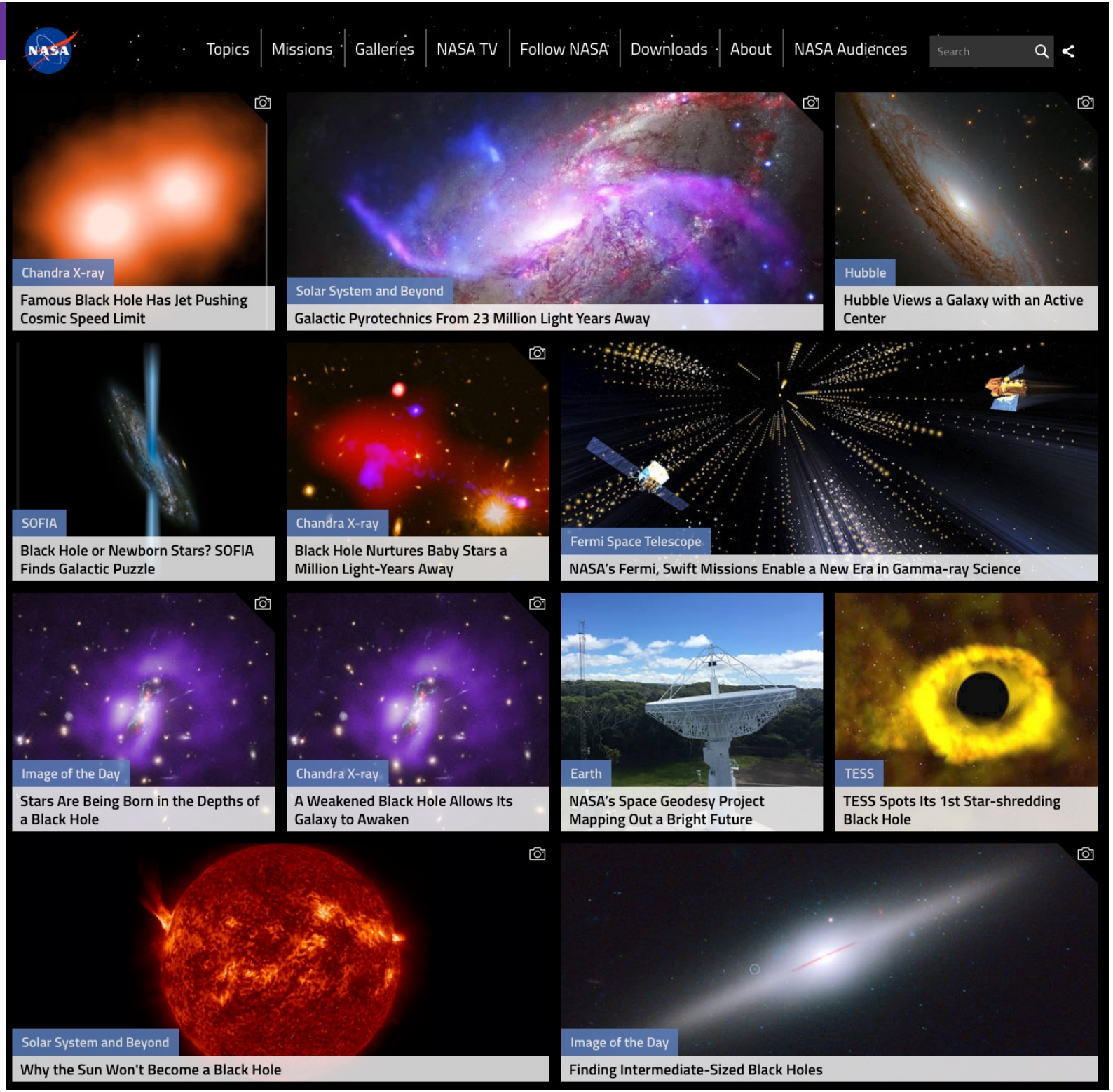
This is a VERY active field

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

Some of the NASA press releases on black holes in the last few years



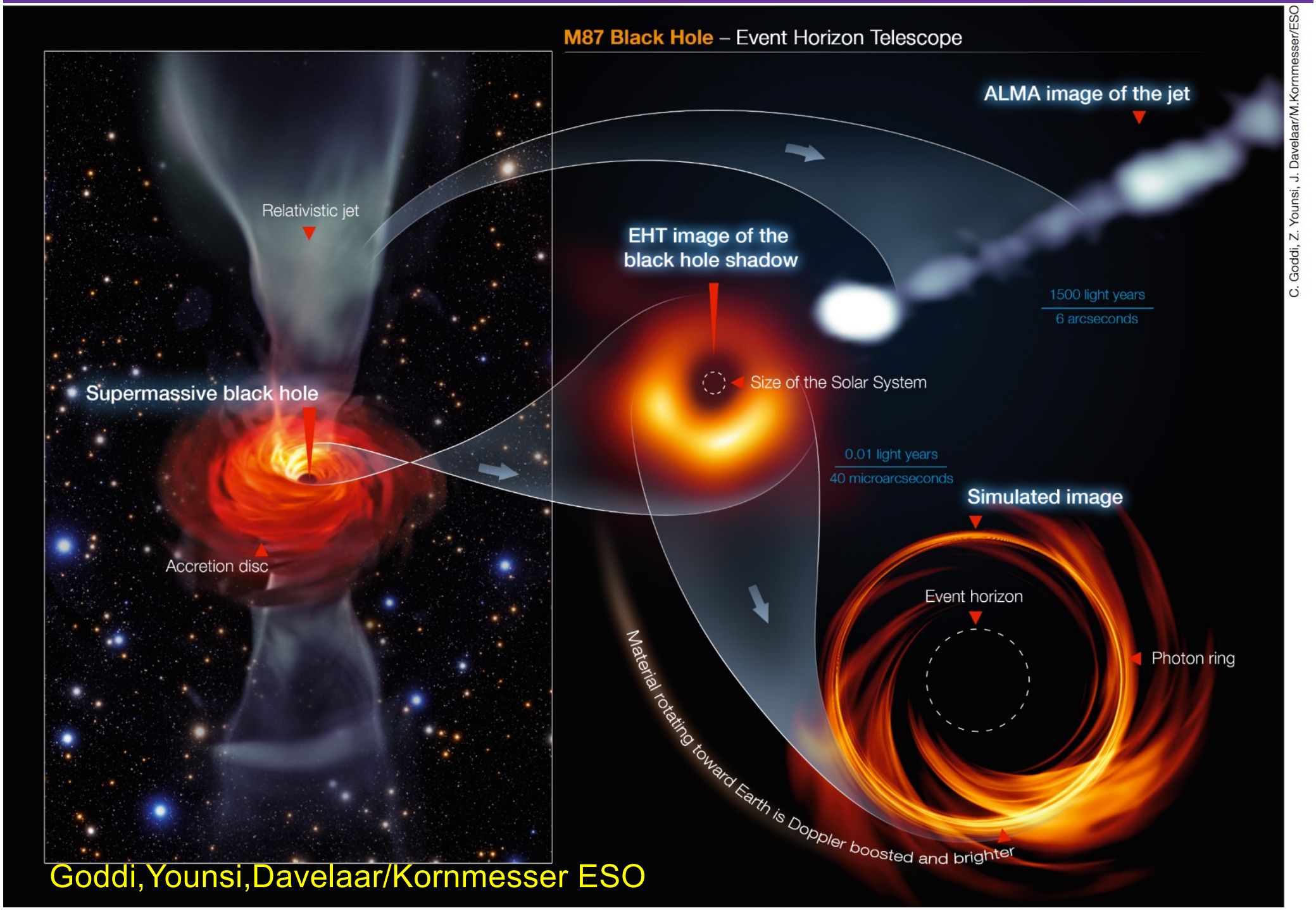
In the Media

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

Science Breakthrough of the Year 2020

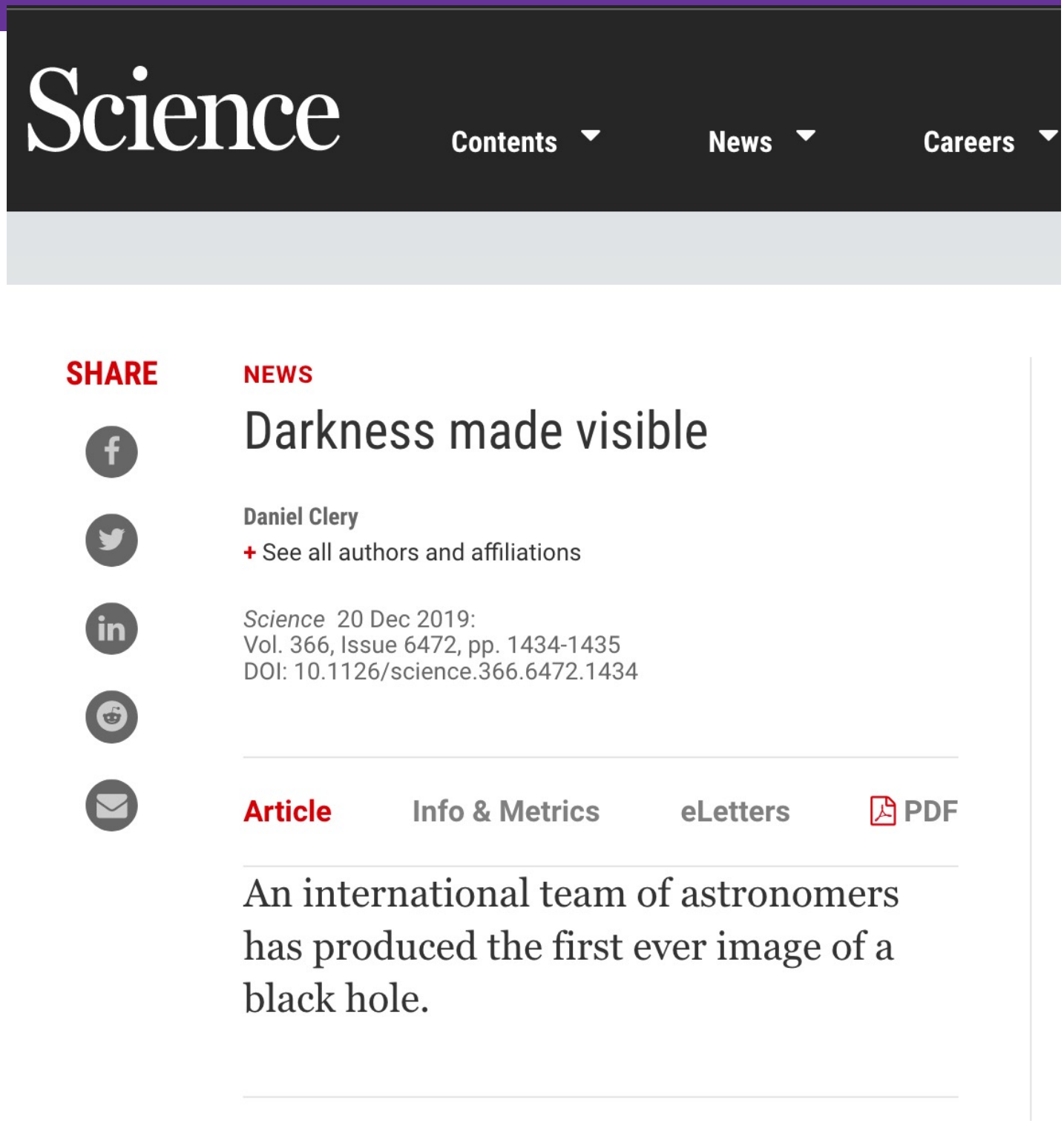
An 'image" of the black hole at the center of the galaxy M87

https://science.sciencemag.org/content/366/6472/1434


M87 Black Hole – Event Horizon Telescope
ALMA image of the jet
Relativistic jet
EHT image of the black hole shadow
1500 light years
6 arcseconds
Supermassive black hole
Size of the Solar System
0.01 light years
40 microarcseconds
Simulated image
Accretion disc
Event horizon
Photon ring
Material rotating toward Earth is Doppler boosted and brighter
C. Goddi, Z. Younsi, J. Davelaar/M.Kornmesser/ESO
Goddi,Younsi,Davelaar/Kornmesser ESO

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.



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.

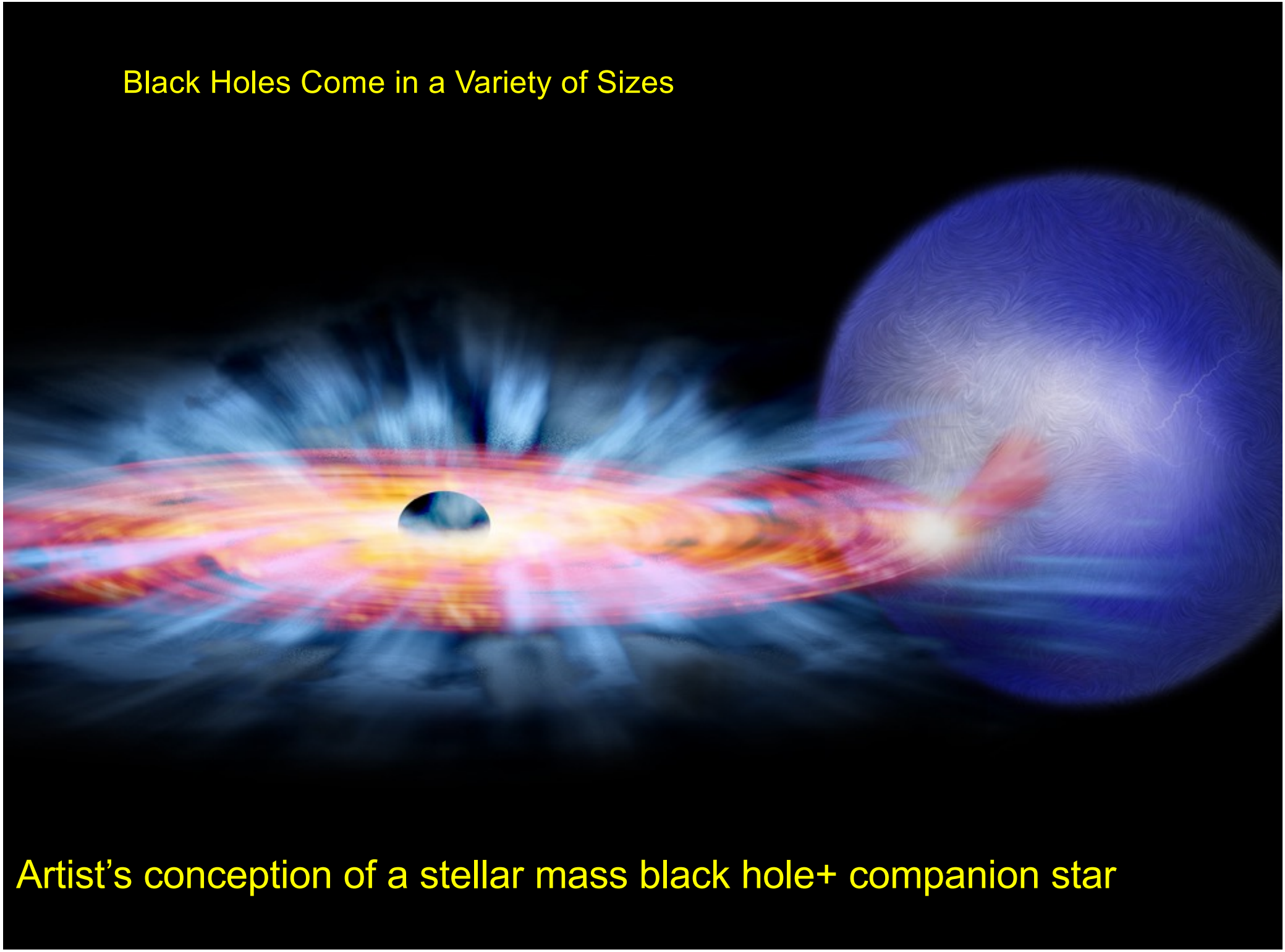
In entertainment news, "Avengers: Endgame" breaks box office records, proving that now, more than ever, people crave stories about time-traveling superheroes using magic stones to defeat a genocidal intergalactic warlord with no neck.

Speaking of long-running dramas, in ...

Washington Post Magazine
Dec 2019

Dave Barry's year in review, 2019...

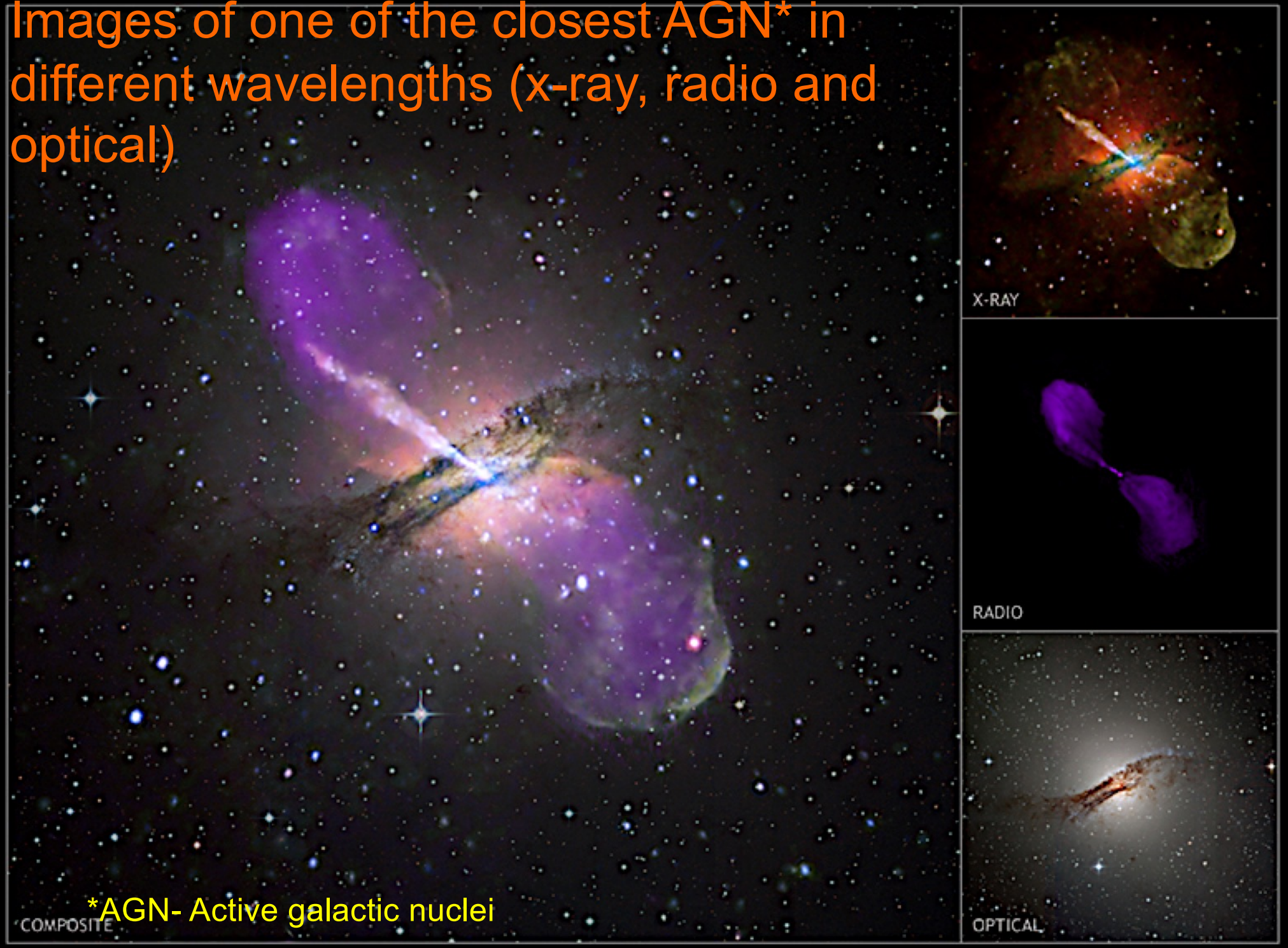
Black Holes Come in a Variety of Sizes



Artist's conception of a stellar mass black hole+ companion star


Artist's conception of a supermassive black hole+ jet+accretion disk

Images of one of the closest AGN* in different wavelengths (x-ray, radio and optical)



*AGN- Active galactic nuclei

Black Holes Can Tear Stars Apart

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

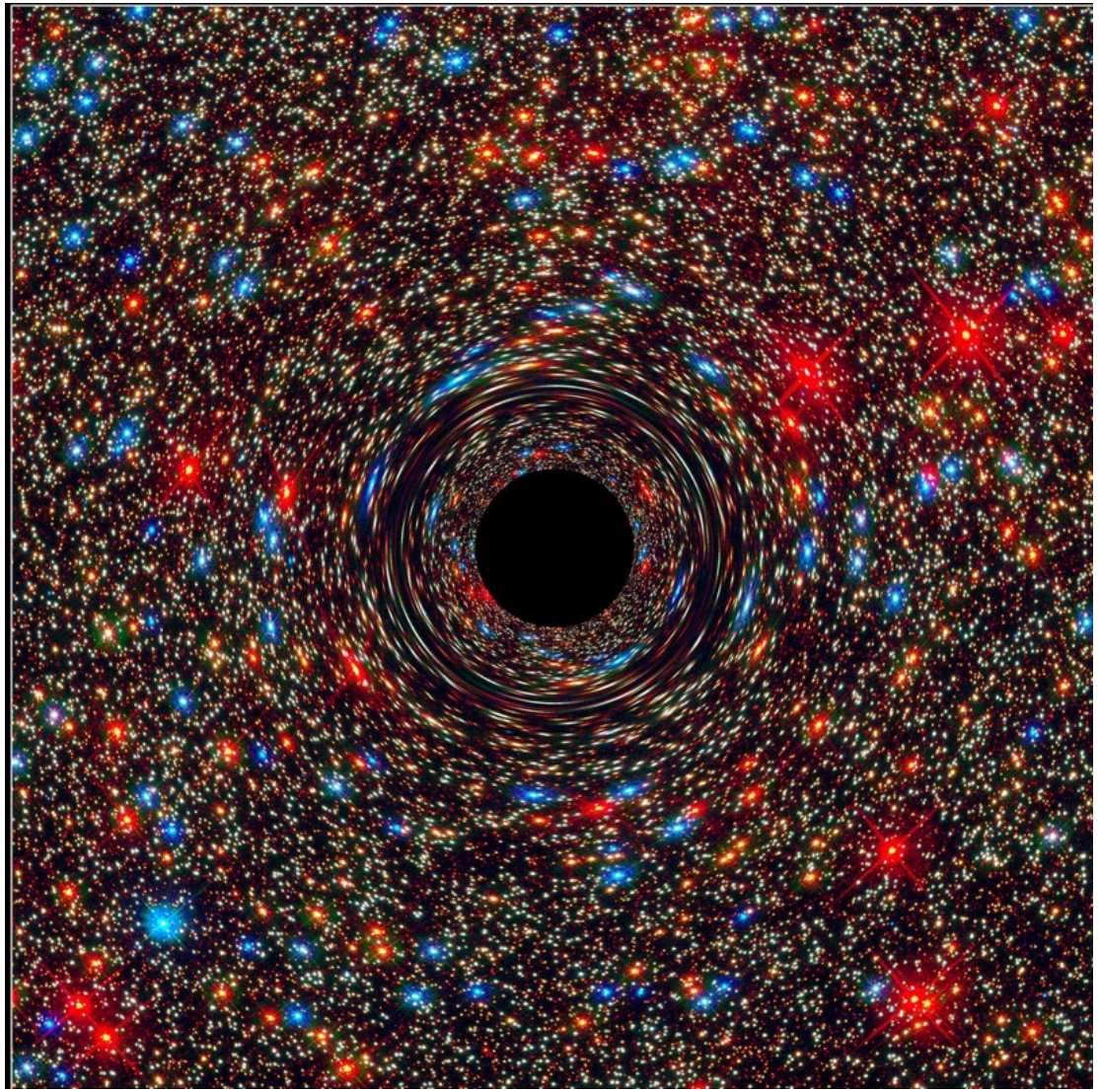
The Effect of a black hole on spacetime

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.

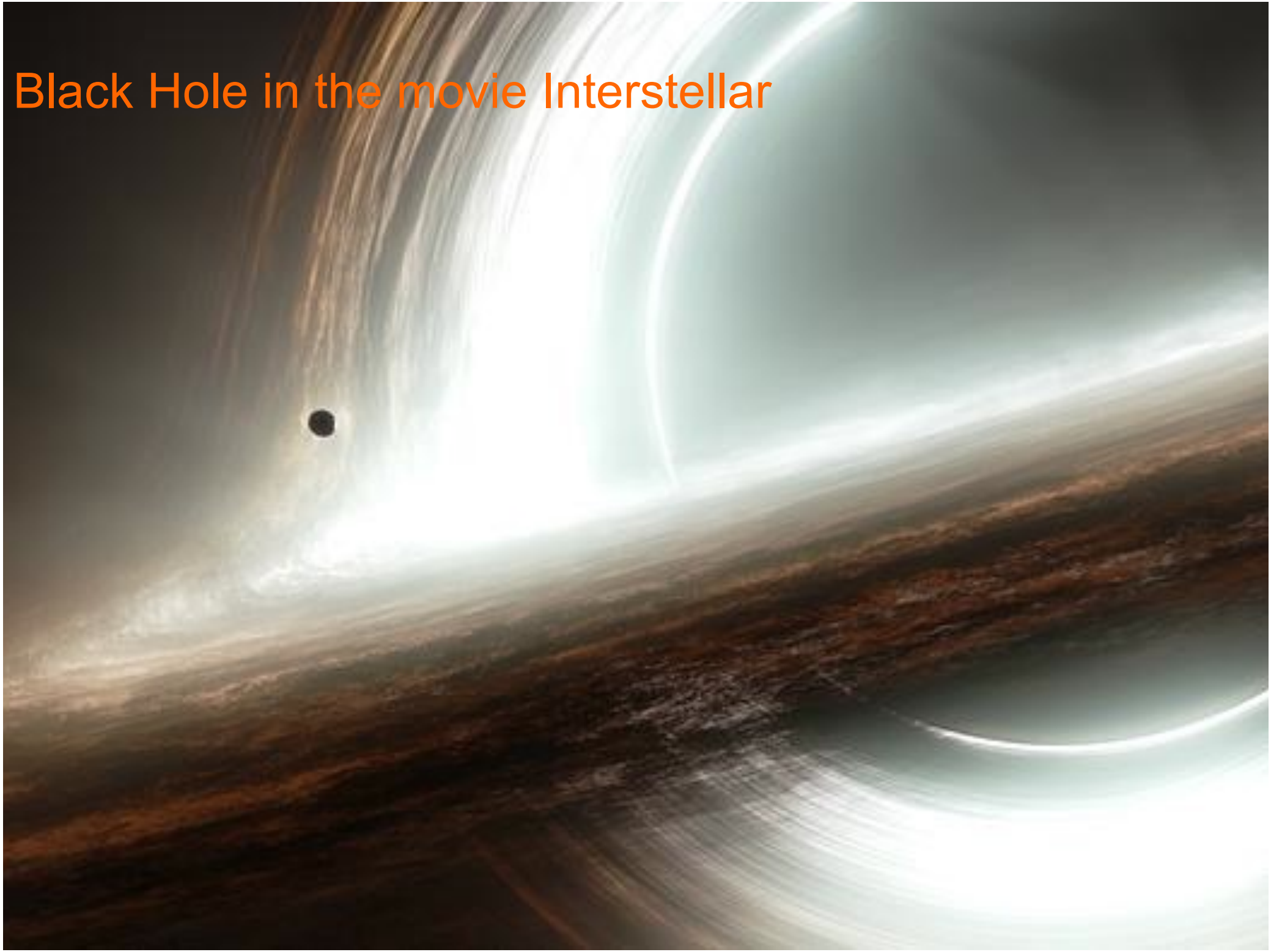
The black hole distorts space around it and light from background stars is stretched and smeared.

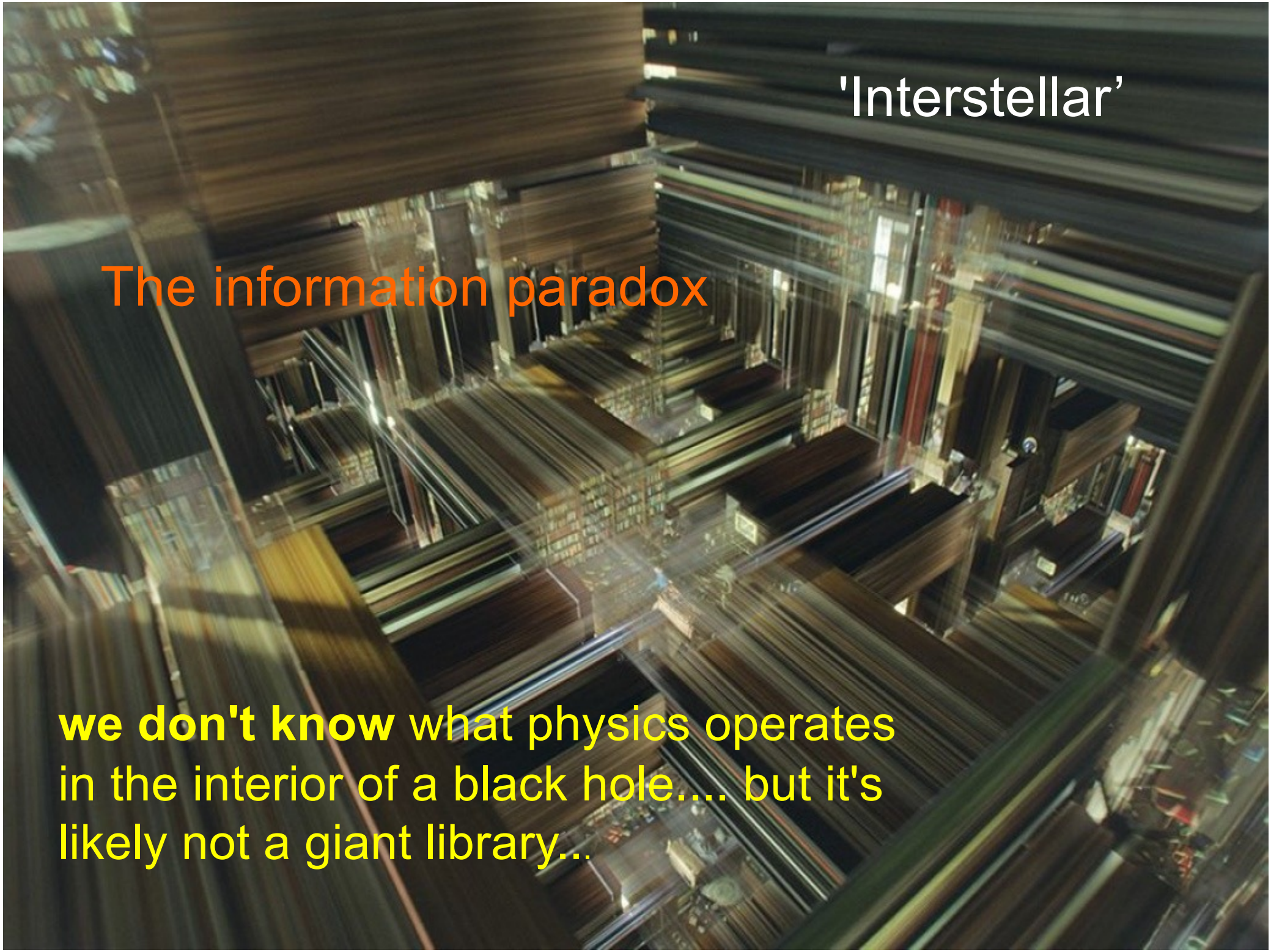
NASA, ESA, D. Coe, J. Anderson, and R. van der Marel

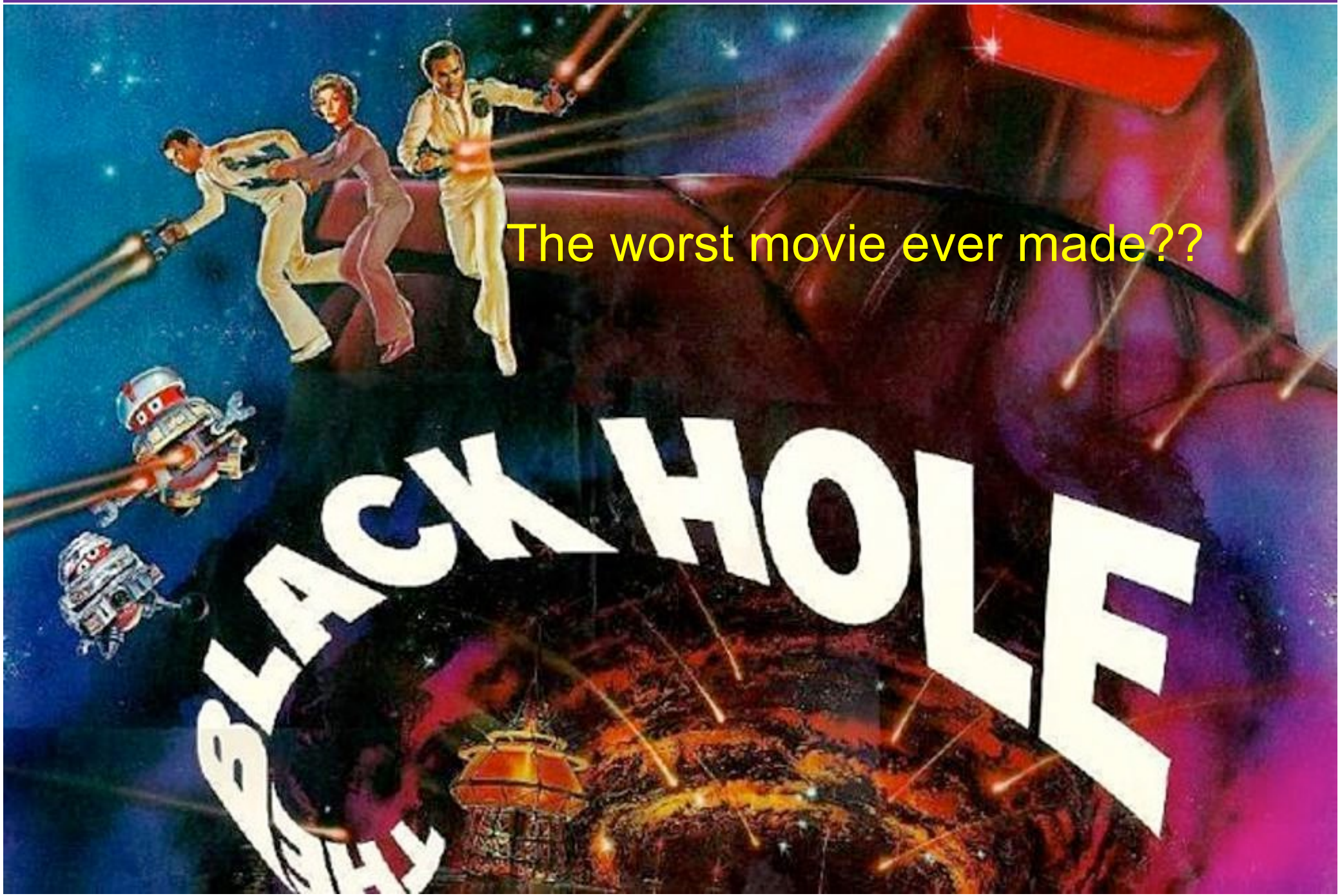


https://www.thoughtco.com/black-holes-information-3072388

Black Hole in the movie Interstellar

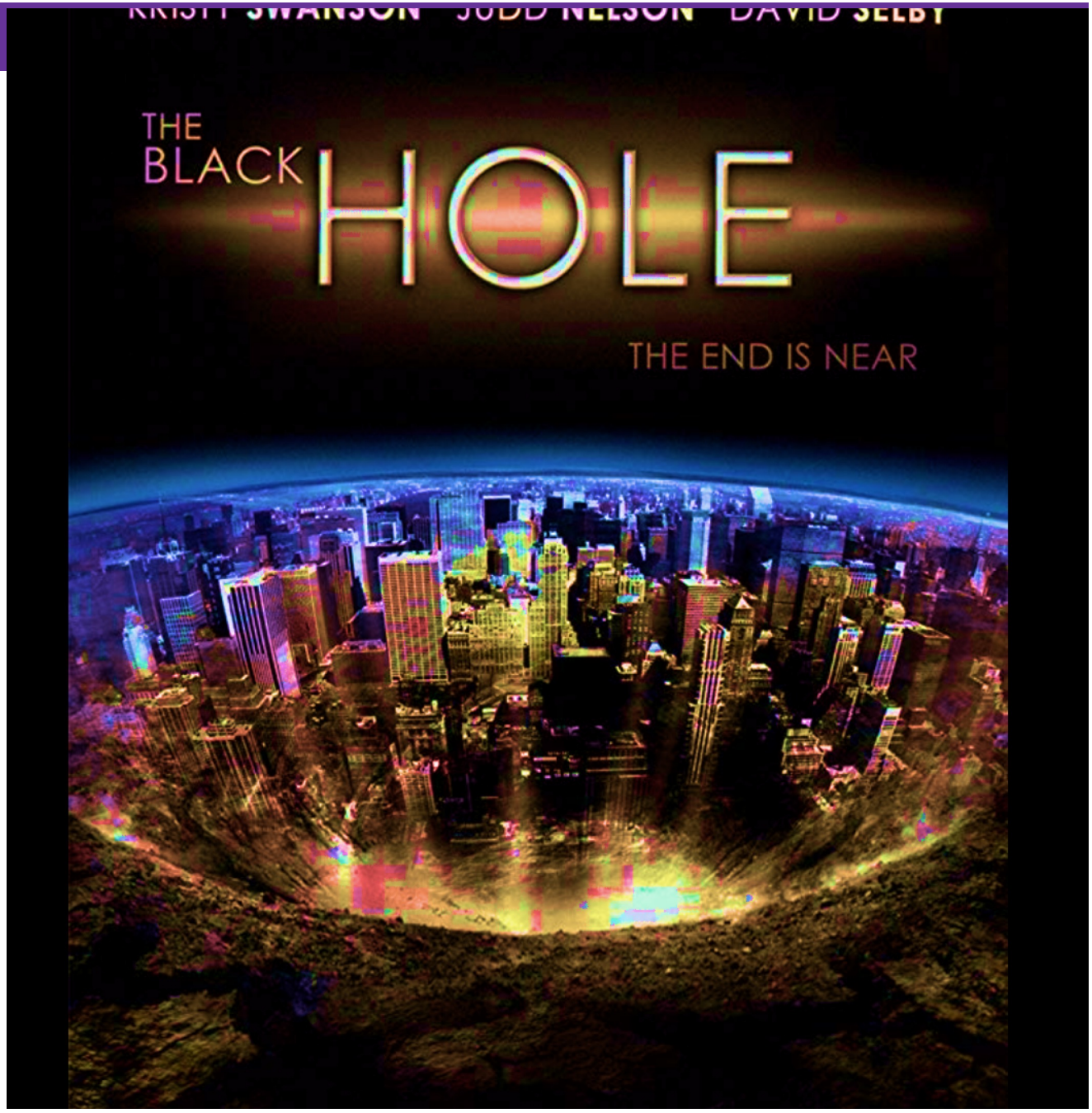



'Interstellar'
The information paradox
we don't know what physics operates in the interior of a black hole.... but it's likely not a giant library...


The worst movie ever made??
BLACK HOLE

Next lecture

Newton’s laws in 3 acts



Things Black Holes are Not

They are not wormholes (or Einstein-Rosen bridges), providing shortcuts between different points in space. Once you're in a black hole, you can't leave.

Contrary to popular belief, black holes are not cosmic vacuum cleaners. They don't suck in all other matter. From far enough away, their gravitational effects are just like those of other objects of the same mass.

They are not portals to other dimensions or universes. Even if you could escape a black hole, it wouldn't be a very nice form of transportation due to the side effects.

Interesting Facts About Black Holes

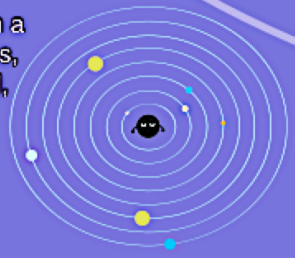
Stellar-mass black holes can be created when two neutron stars merge. And two black holes can merge to make a larger one! We're not sure how the universe makes supermassive black holes, though.

Albert Einstein rejected the idea that black holes might exist.

The closest known black hole, called 1A 0620-00, is 3,000 light-years away. For comparison, our nearest stellar neighbor is 4.2 light-years away.

The first time we saw a real image of a black hole was in 2019. That was when the Event Horizon Telescope shared an image of M87*, a supermassive black hole 55 million light-years away.

If you replaced the Sun with a black hole of the same mass, nothing would happen! Well, it would be a lot colder, but the planets would stay in the same orbits.



FS-2019-9-437-GSFC

National Aeronautics and Space Administration

BLACK HOLE

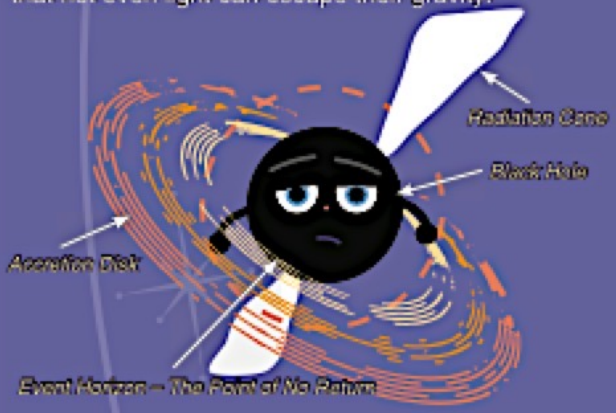
Safety Information Card

www.nasa.gov

What Should I Know About Black Holes?

Black holes are physical objects in space, just like everything else we see in the night sky.

But they pack so much mass into so small a space that not even light can escape their gravity.



Known black holes fall into two classes:

- Stellar mass: 5 to tens of times the Sun's mass
- Supermassive: 100,000 to billions of times the Sun's mass

"Middleweight" black holes may exist between these classes, but none have been found to date.

Signs a Black Hole is Near

Black holes can be surrounded by rings of gas and dust called accretion disks. The material in the disk gets hot enough to generate X-rays and other light.

You can also find black holes by tracking stars' orbits over many years. This is how scientists learned there's a supermassive black hole at the center of our galaxy!

Credit: ESO/M. Parsa/L. Calçada

Keep an eye out for ripples in space-time called gravitational waves. They can be created when two black holes rotate around each other or when a star orbits close to a black hole.

Credit: LIGO/T. Pyle

Please be aware that black holes could be present in any direction in space.

Warning Signs You're Too Close to a Black Hole

Radiation Gravity compresses and heats debris in the accretion disk to millions of degrees, producing lots of lethal radiation.

Time dilation As you get closer to the black hole, time appears to be passing faster for distant objects. Anyone watching you will notice time passing more slowly for you, but you feel like time is speeding up for everyone else.

Spaghettification As objects approach the event horizon, they're horizontally compressed and vertically stretched, like a noodle.

Once you enter the event horizon, escaping the black hole requires traveling faster than light. As this technology is currently unavailable, please maintain a safe distance from black holes at all times.