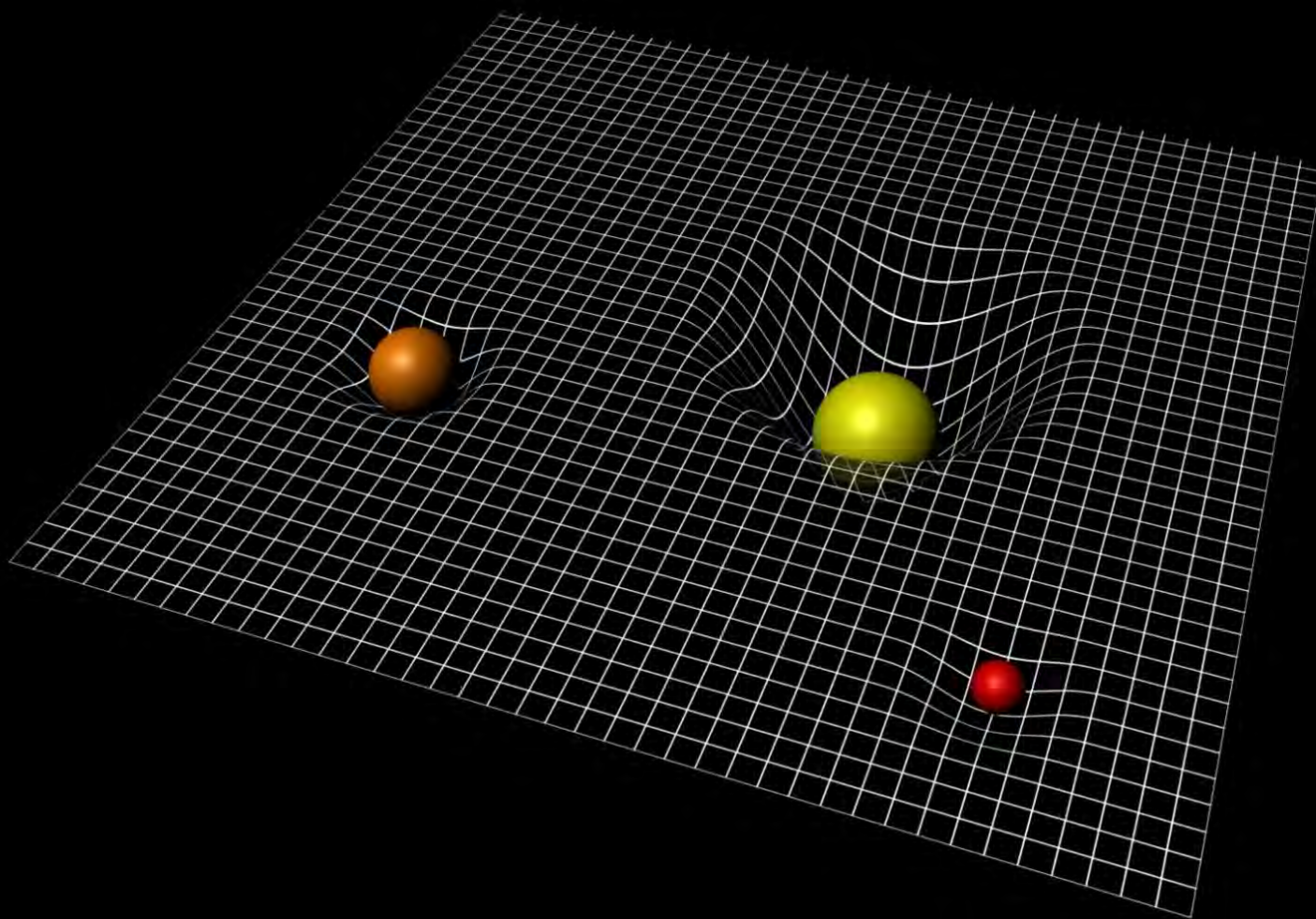




Black Holes in Science and the Arts

**Chris Impey
Distinguished Professor
University of Arizona**

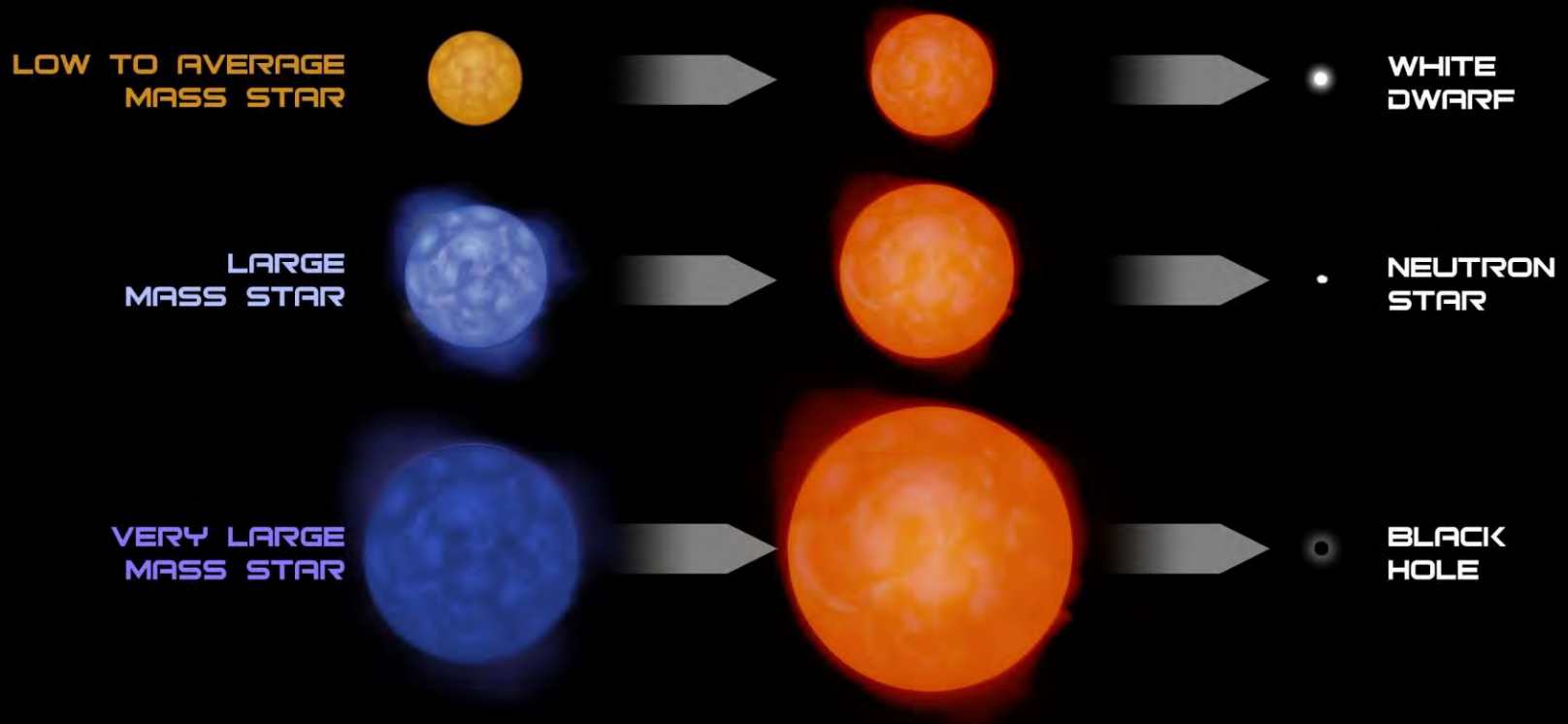
Mass-Energy Curves Space-Time



Gravity Slows Down Time



Black Holes and Star Death



When a massive star exhausts its fuel, if the core is more than three times the Sun's mass no force can resist the contraction.

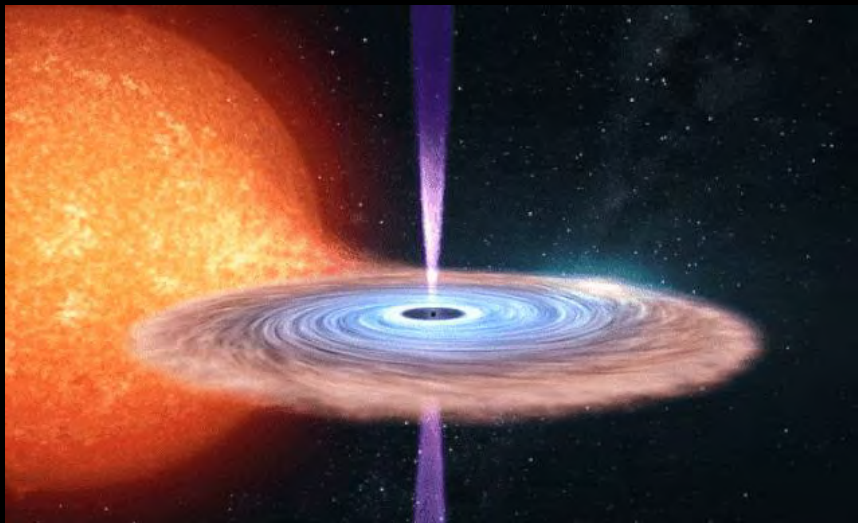
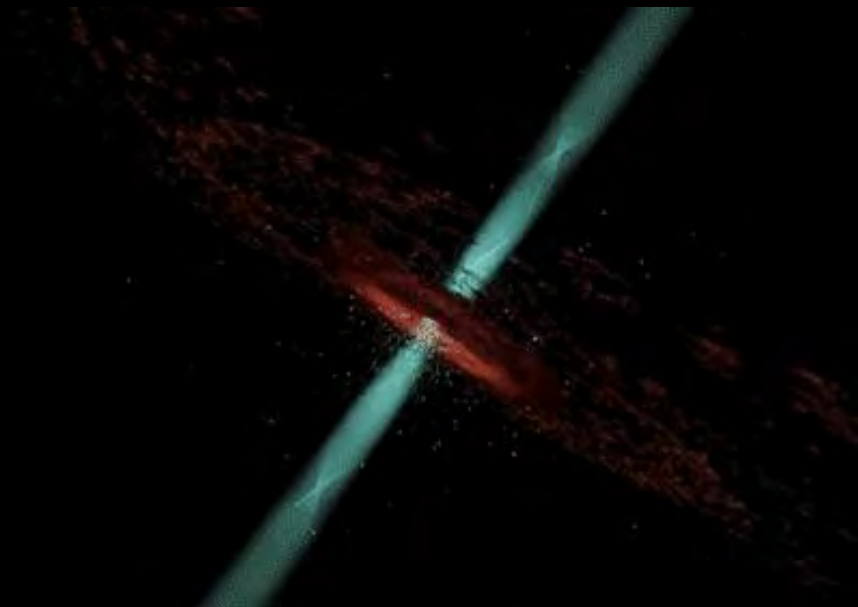
Black Hole Basics



here objects feel the gravity of the black hole, but light can still escape



Cygnus X-1



National Aeronautics and
Space Administration



CYGNUS X-1 PRESENTS:

DEVOURED BY GRAVITY

IT'S DINNER TIME AND YOU'RE THE MEAL!

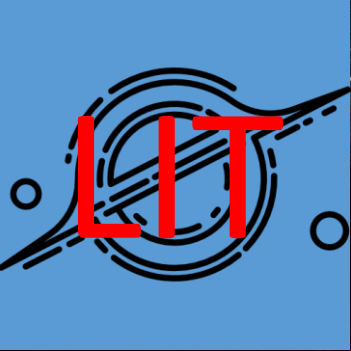
LURKING IN OUR GALAXY APPROXIMATELY 6,000 LIGHT YEARS FROM EARTH IS A MONSTER NAMED CYGNUS X-1. THIS BLACK HOLE, WHICH HAS ABOUT THE MASS OF OUR SUN, WILL STRIKE AND SQUEEZE ANYTHING IT CAPTURES IN HIS IMMENSE GRAVITY. CYGNUS X-1 IS WAITING, SNACKING ON HIS NEIGHBORING STAR... DON'T GET TOO CLOSE, OR YOU'LL BECOME HIS NEXT MEAL!

GALAXY
OF
HORRORS
exoplanets.nasa.gov

OBSERVED BY NASA'S NUSTAR
AND CHANDRA X-RAY TELESCOPES

BASED ON
REAL SCIENCE

www.nasa.gov



*"Stars, hide your fires;
Let not light see my
Dark and deep desires."*

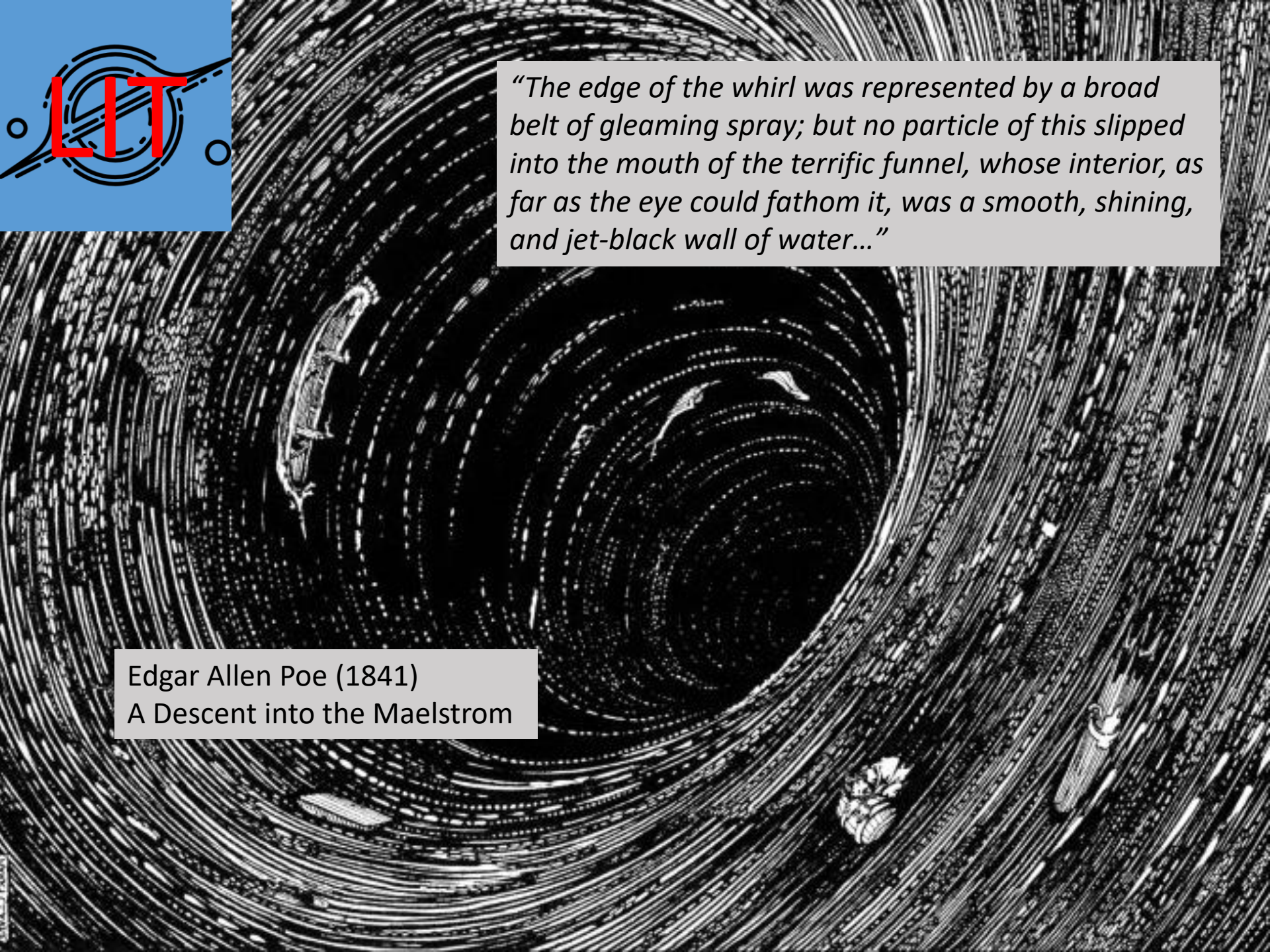
William Shakespeare
Macbeth (1606)
Act 1, Scene 4





“The edge of the whirl was represented by a broad belt of gleaming spray; but no particle of this slipped into the mouth of the terrific funnel, whose interior, as far as the eye could fathom it, was a smooth, shining, and jet-black wall of water...”

Edgar Allen Poe (1841)
A Descent into the Maelstrom





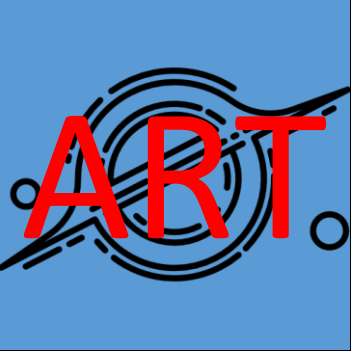
"Hawking understood black holes because he could stare at them. Black holes mean oblivion. Mean death. And Hawking has been staring at death his entire adult life."

Martin Amis (1997)
Night Train

*"Suicide is the night train,
Speeding your way to darkness."*

MARTIN
AMIS

NIGHT
TRAIN



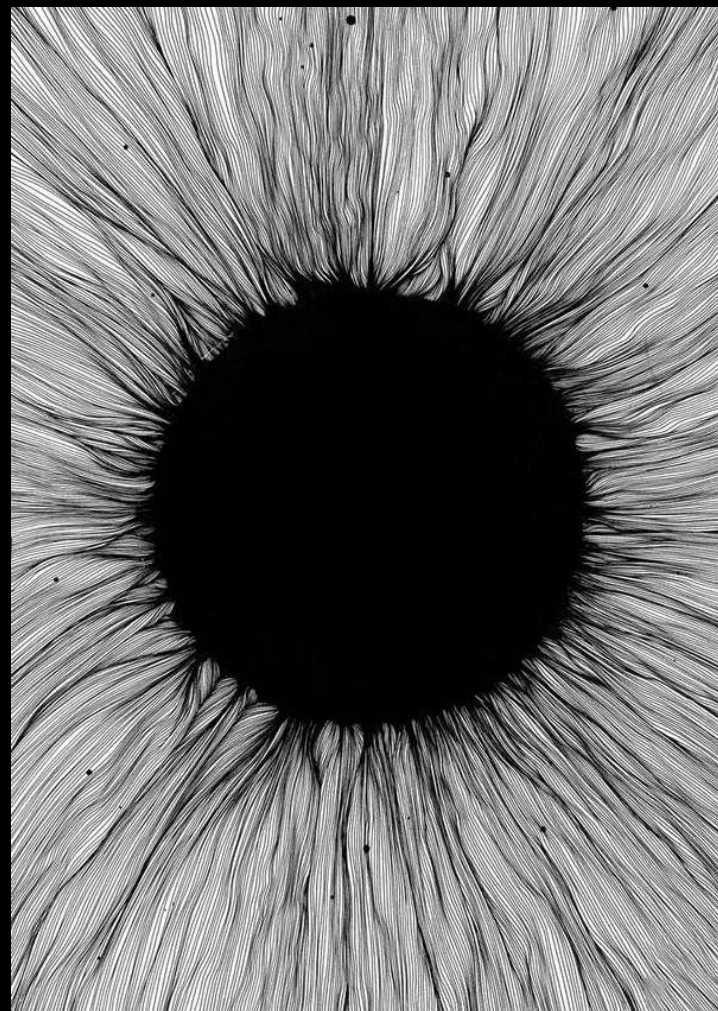
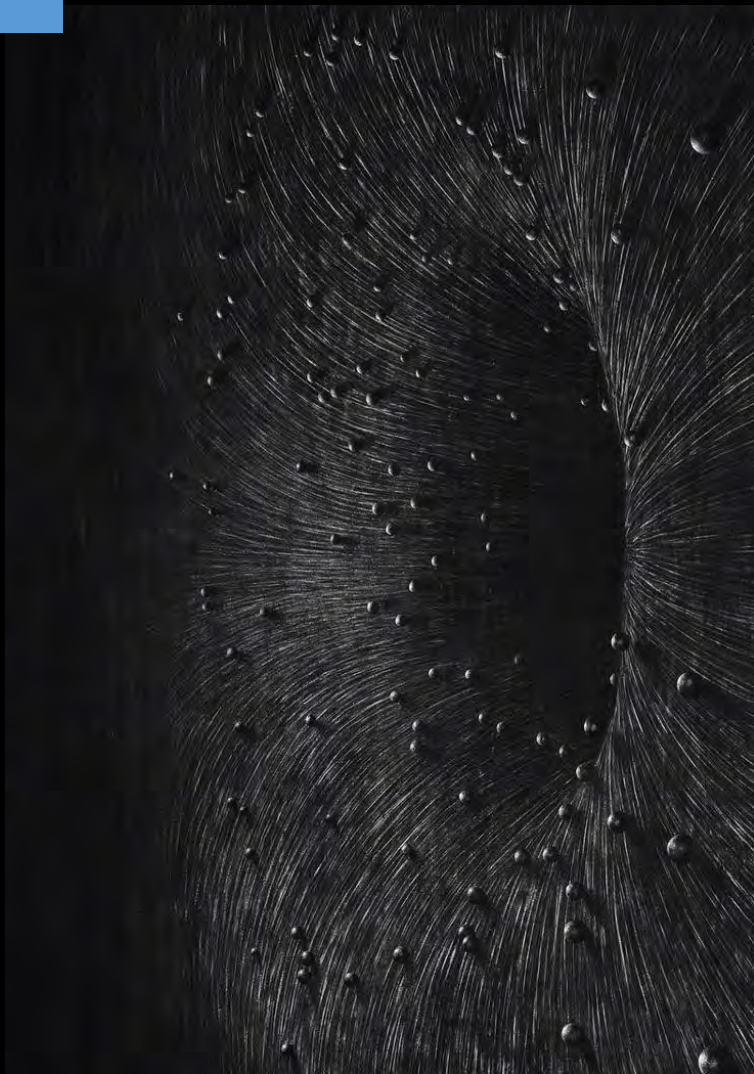
Vantablack
Anish Kapoor



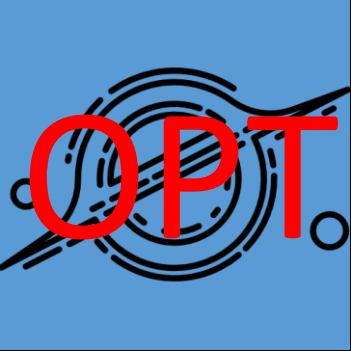
Descent into Limbo
Anish Kapoor



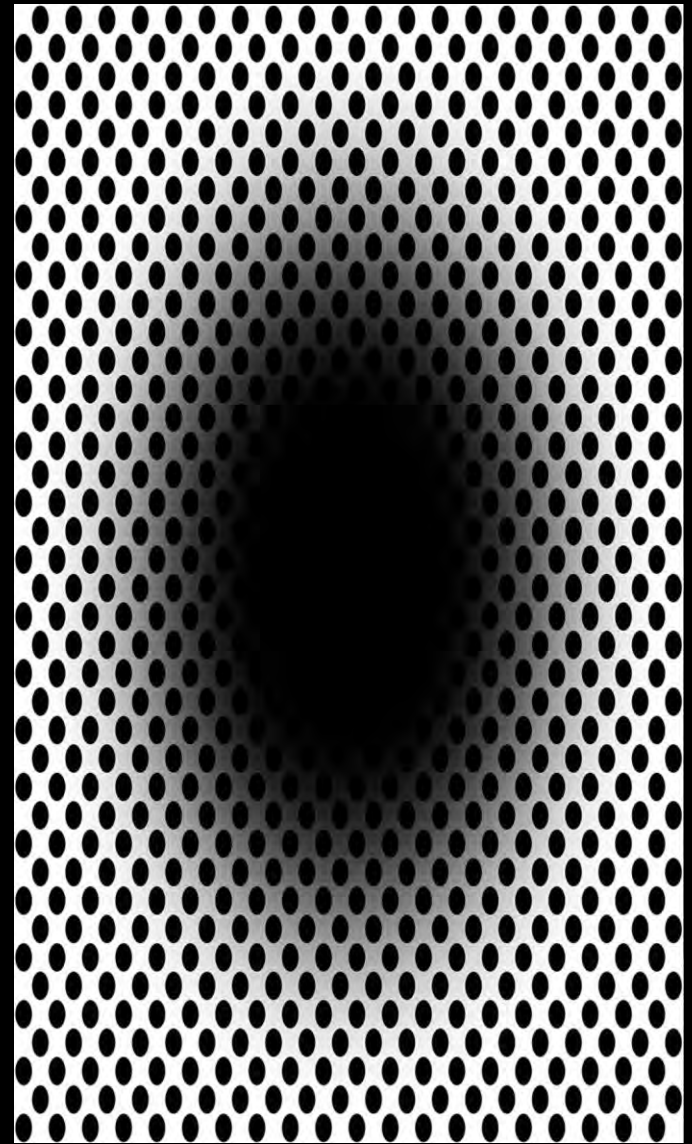
Hole
Levi van Veluw



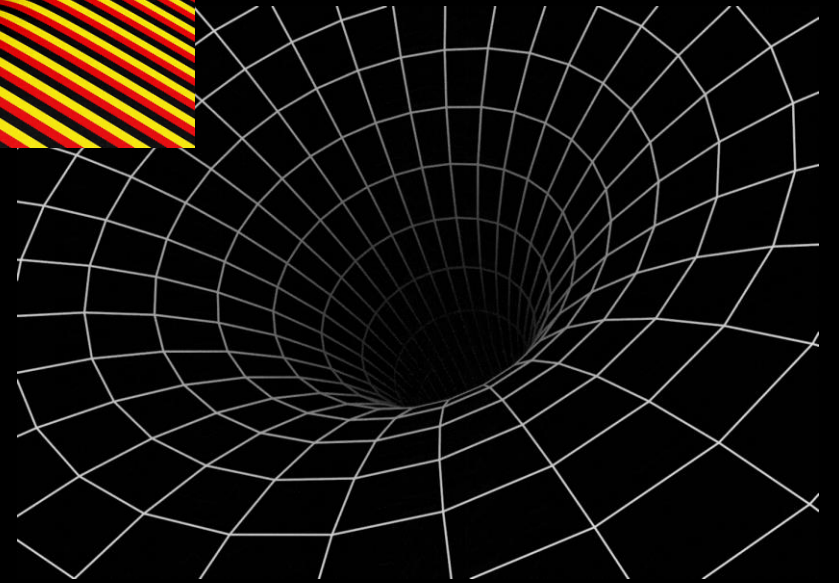
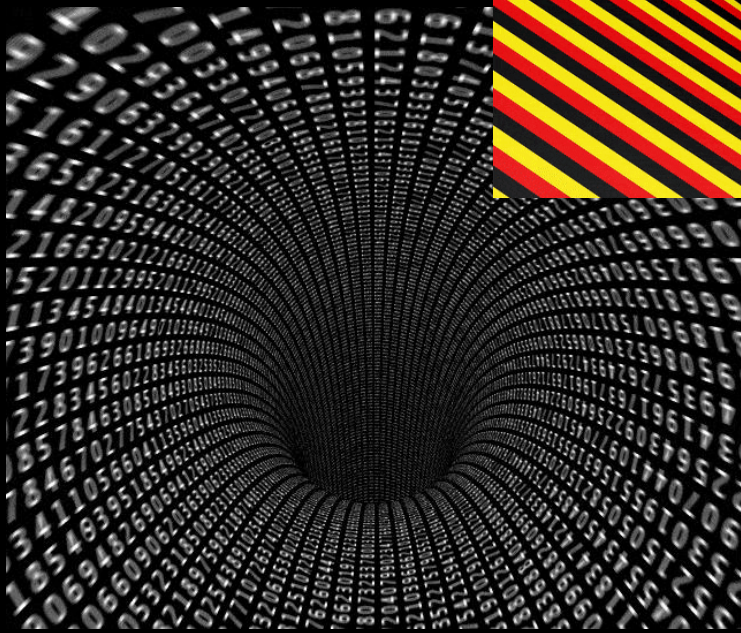
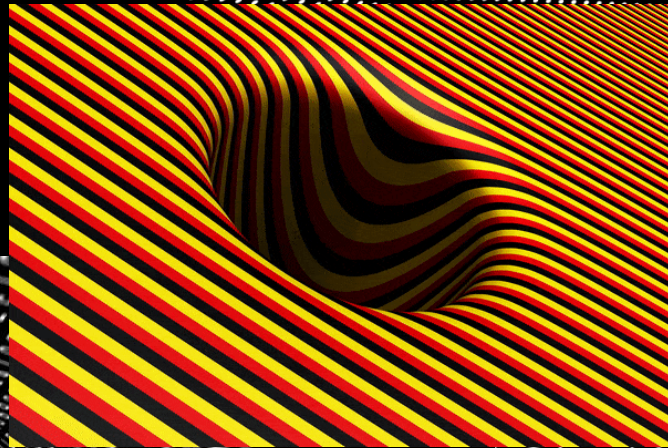
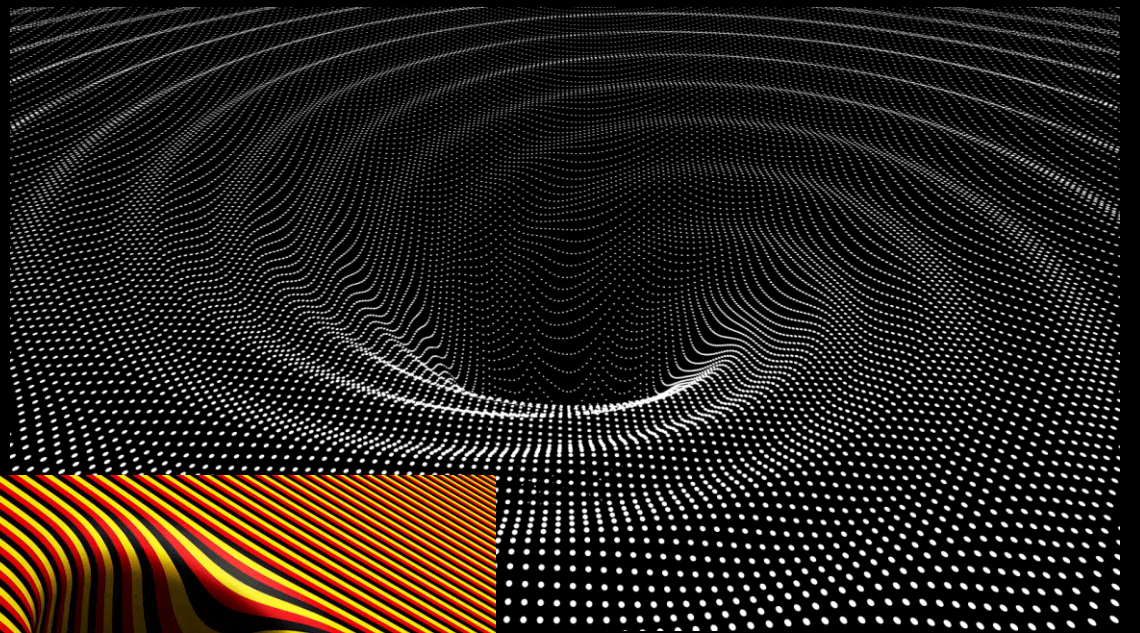
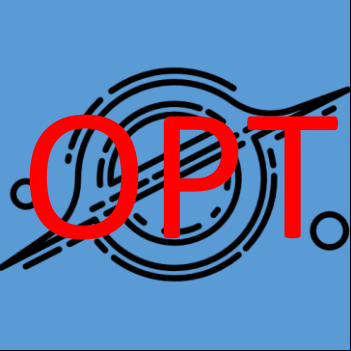
Line Abstract
Vasilj Godzh



Physical Illusion



Optical Illusion



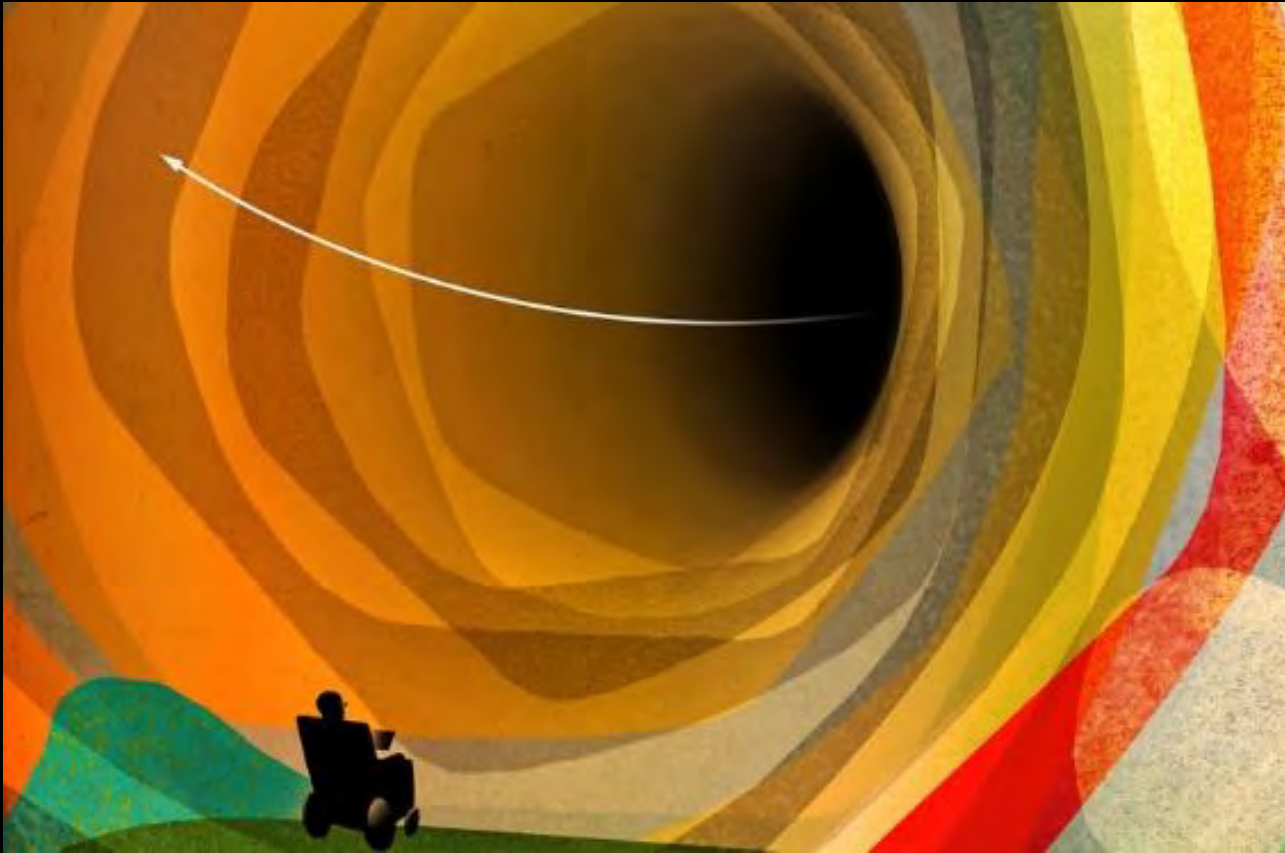
RUG



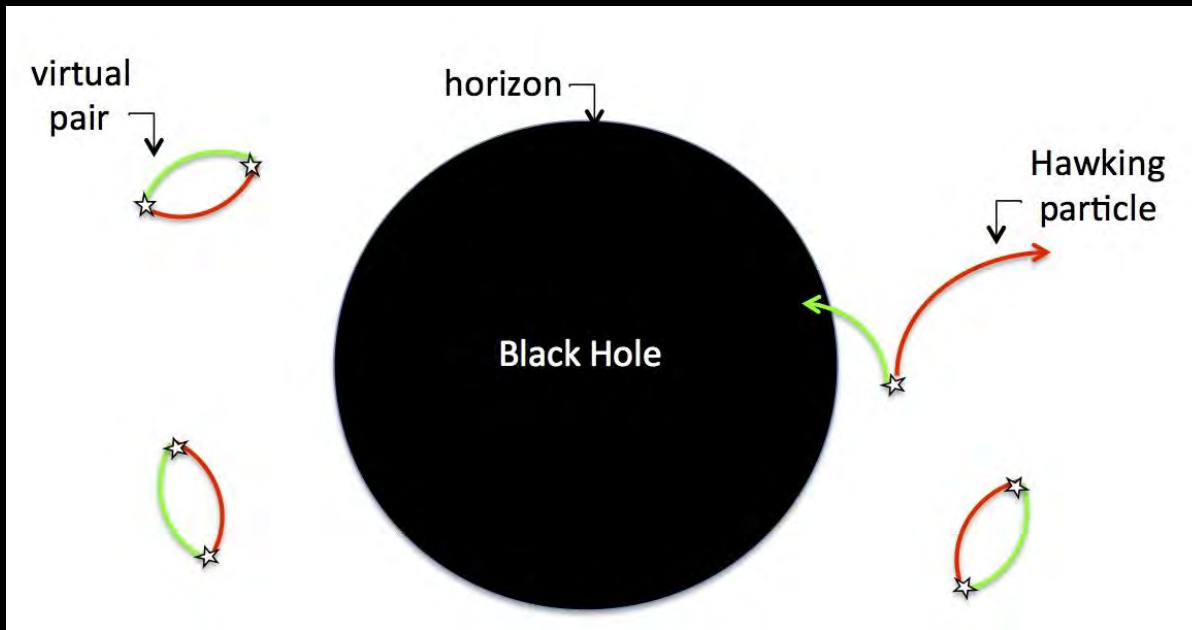
3D Vortex

Black Hole Illusion

Welcome to Hawking's World



Black Holes Are Not Black



Virtual particle and antiparticle pairs are always being created from radiation, then turning into radiation.

Hawking realized that one of a pair could pass into the event horizon, so black holes radiate, and will eventually evaporate.

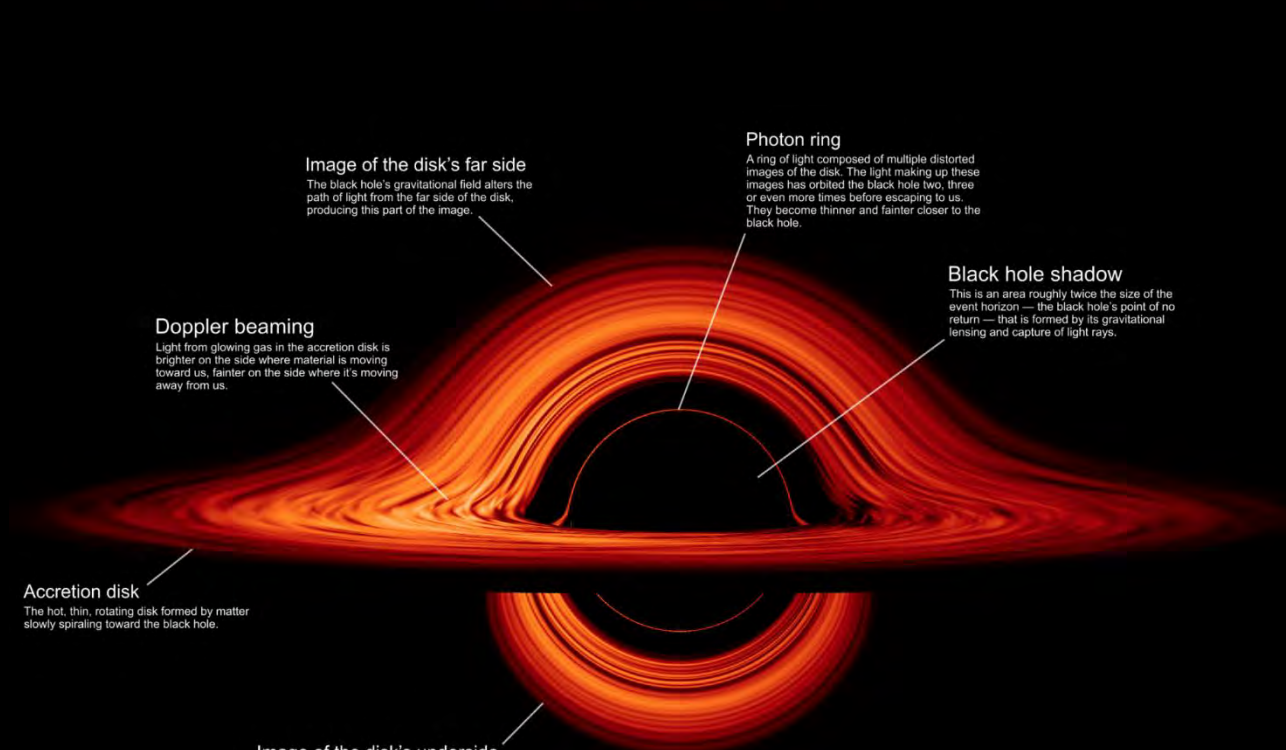
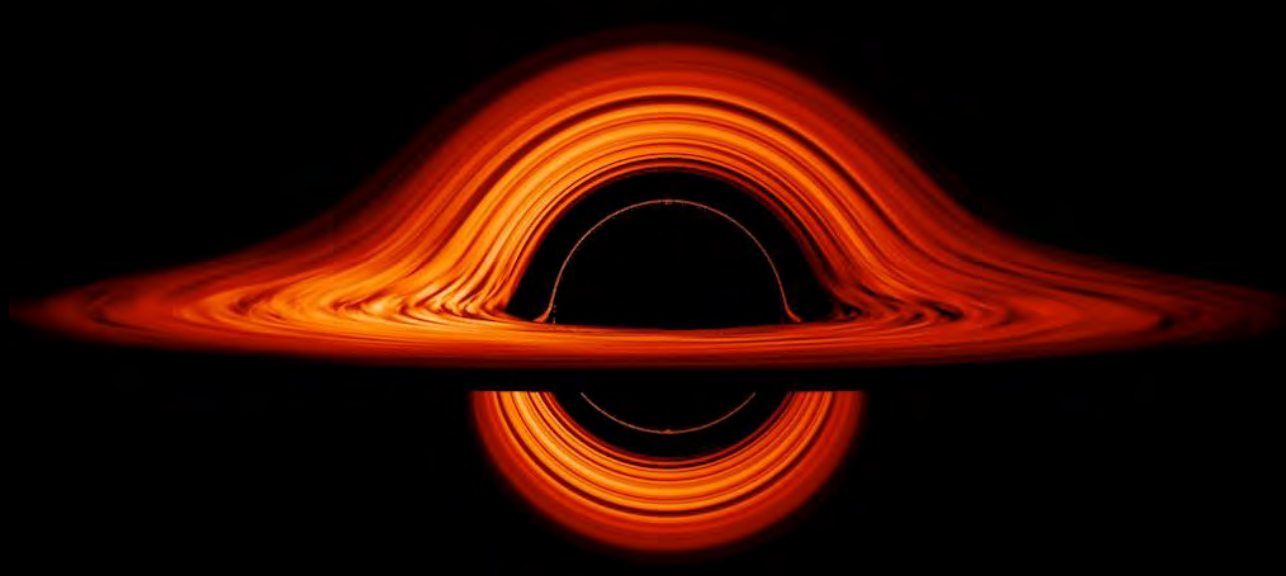


Image of the disk's far side
The black hole's gravitational field alters the path of light from the far side of the disk, producing this part of the image.

Photon ring
A ring of light composed of multiple distorted images of the disk. The light making up these images has orbited the black hole two, three or even more times before escaping to us. They become thinner and fainter closer to the black hole.

Black hole shadow
This is an area roughly twice the size of the event horizon — the black hole's point of no return — that is formed by its gravitational lensing and capture of light rays.

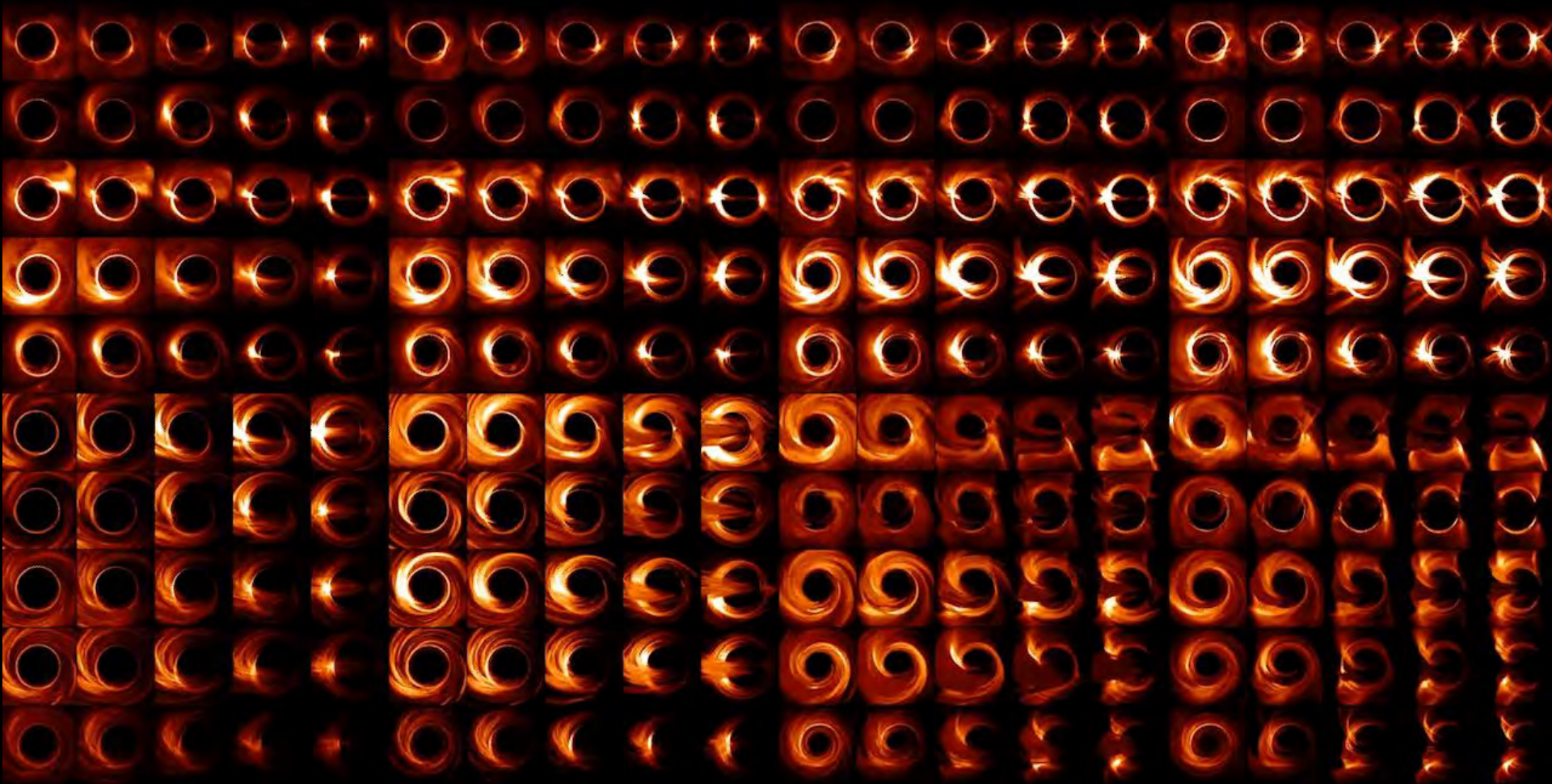
Doppler beaming
Light from glowing gas in the accretion disk is brighter on the side where material is moving toward us, fainter on the side where it's moving away from us.

Accretion disk
The hot, thin, rotating disk formed by matter slowly spiraling toward the black hole.

Image of the disk's underside
Light rays from beneath the far side of the disk are gravitationally "lensed" to produce this part of the image.



Accretion Disk Simulations







Black Hole Sun

$\text{♩} = 75$

Gsus B♭6/9 F5 E5

G D G C G D G B♭ D G C F C F C F C B E B E B

E♭sus D7 G6 B♭6 F5 Em

E♭ B♭ E♭ A♭ E♭ B♭ E♭ D C D A G B♭ F E

E♭ Dsus Gsus Fdim A♭ G6 B♭6 F5 Em

E♭ D G F A♭ G B♭ F E

E♭ Dsus G6 Fdim A♭ E♭sus Dsus

E♭ D G F A♭ E♭ D

I. C D C II. C

E♭ D7 C D B♭

E♭sus D7sus G G5/7 B♭ E♭ D7 C B♭

E♭ D G F B♭ E♭ D

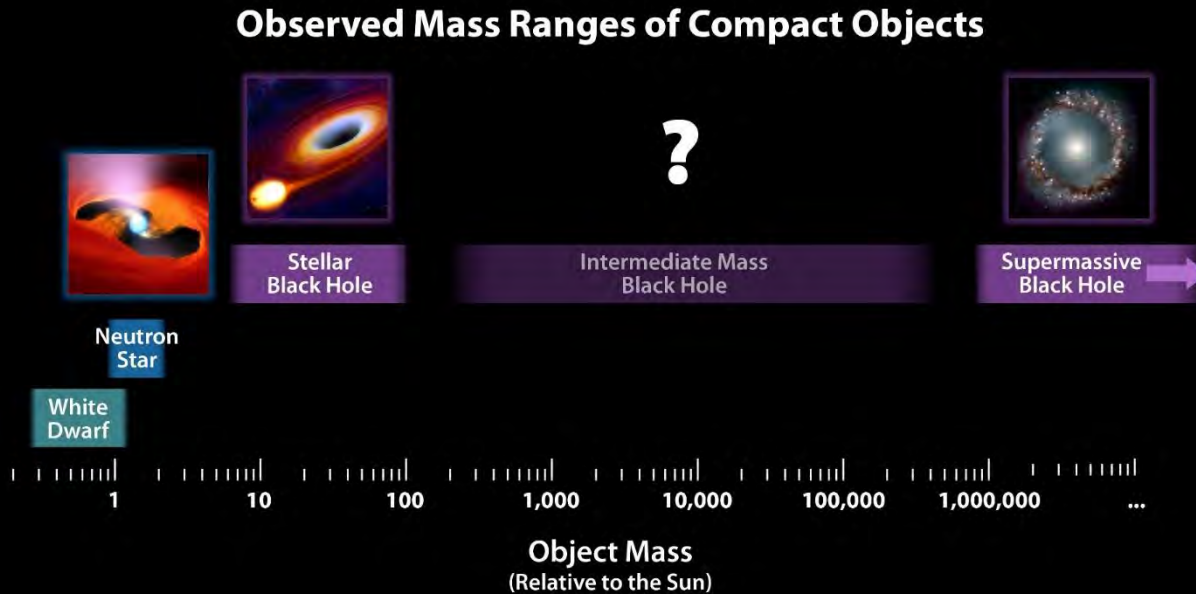
Supermassive Black Hole

Muse
Arranged by Amelia Rowe

$\text{♩} = 120$

A piano arrangement of the song 'Supermassive Black Hole' by Muse. The score is written for piano and includes a tempo marking of quarter note = 120. It consists of six systems of music, each with a treble and bass clef staff. The key signature has one sharp (F#) and the time signature is 4/4. The music features a driving, rhythmic melody in the right hand and a steady, chordal accompaniment in the left hand. The arrangement includes various musical notations such as slurs, ties, and dynamic markings.

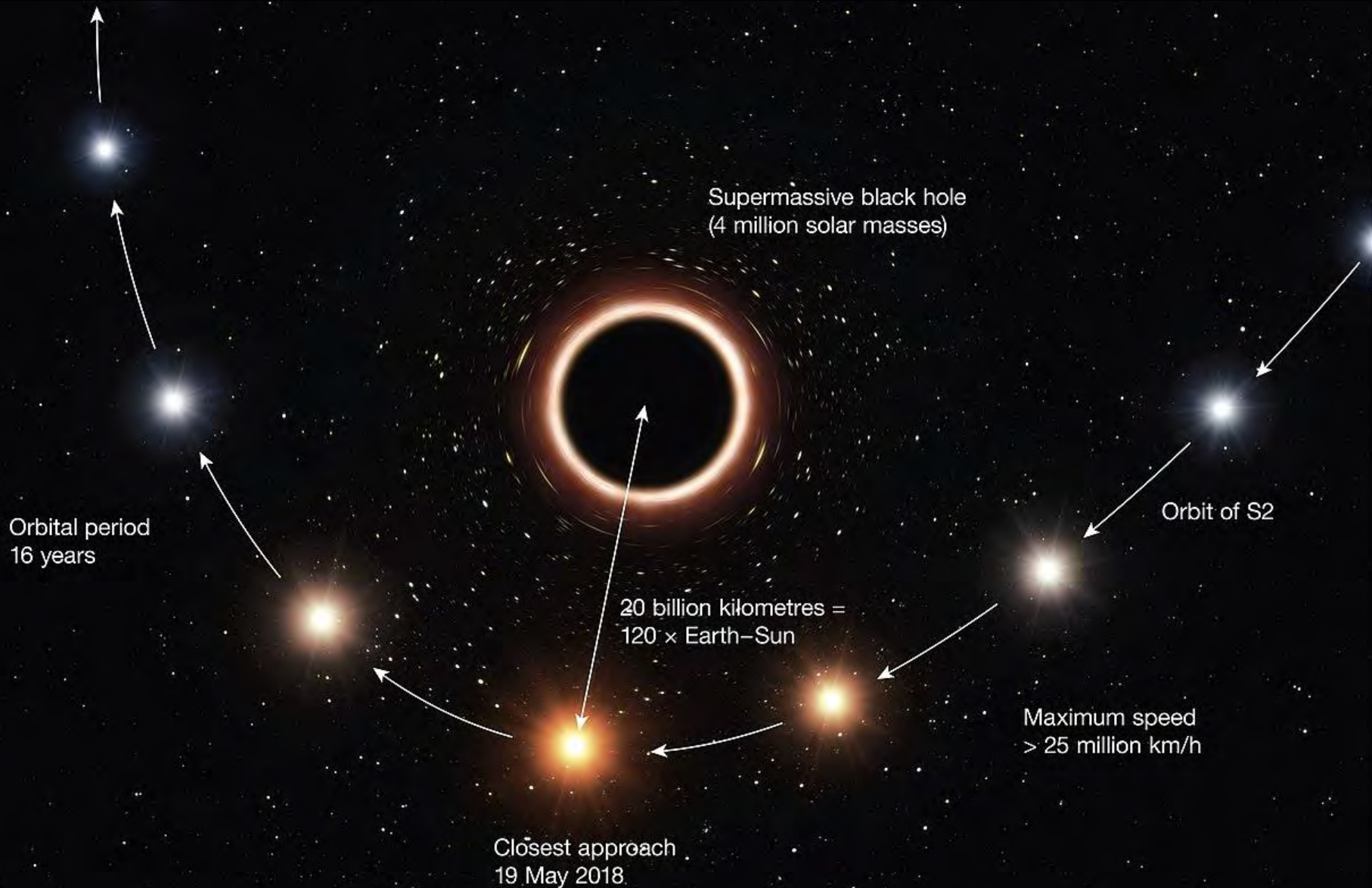
Massive Black Holes



Fifty black holes have measured masses in binary systems. They're nearest among 10 million in the entire galaxy.

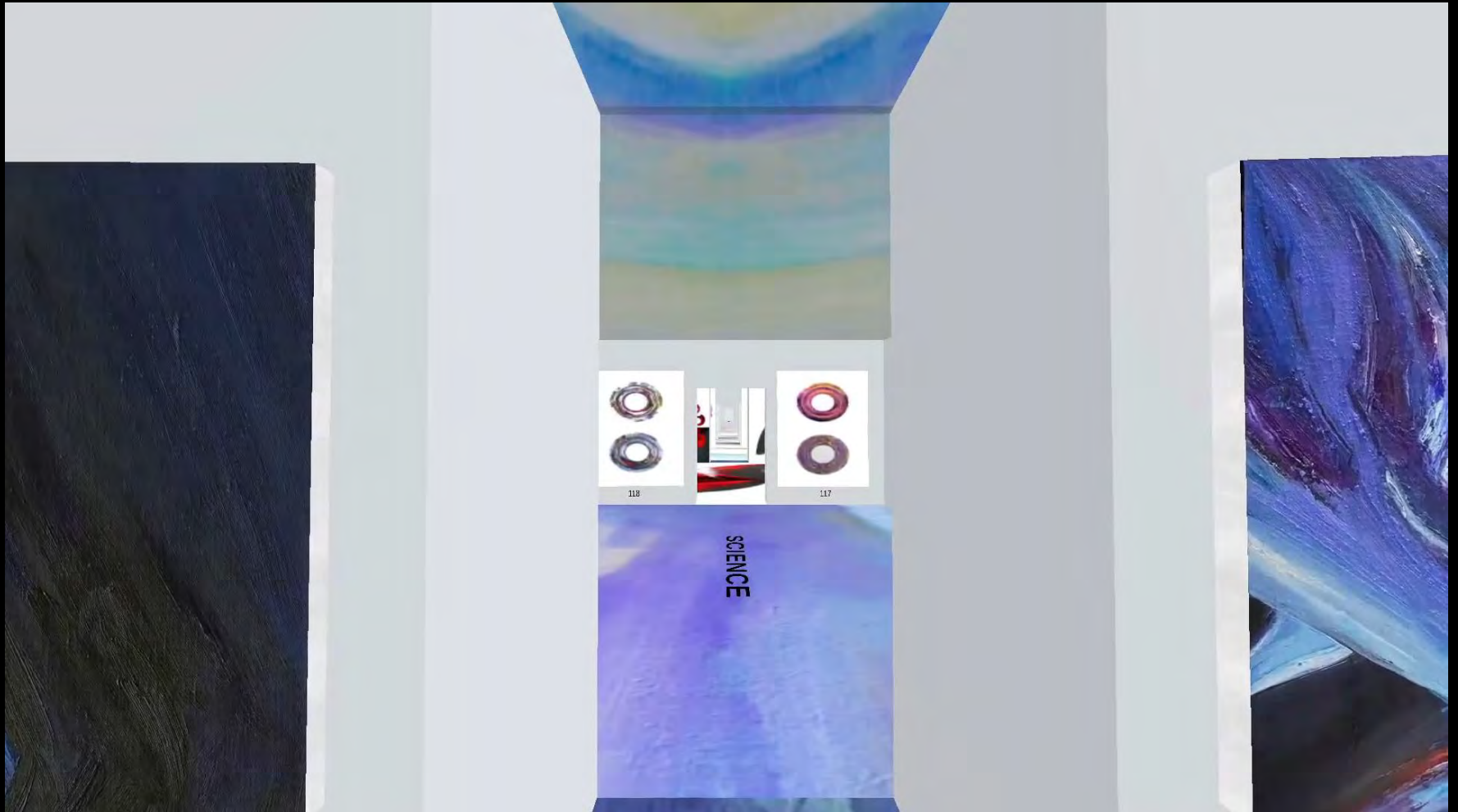
Intermediate mass black holes exist in globular clusters. There is a 4 million solar mass black hole in the center of our galaxy.

Dancing with Death





Black Hole Orbits Gallery
Pamela Davis Kivelson



COM

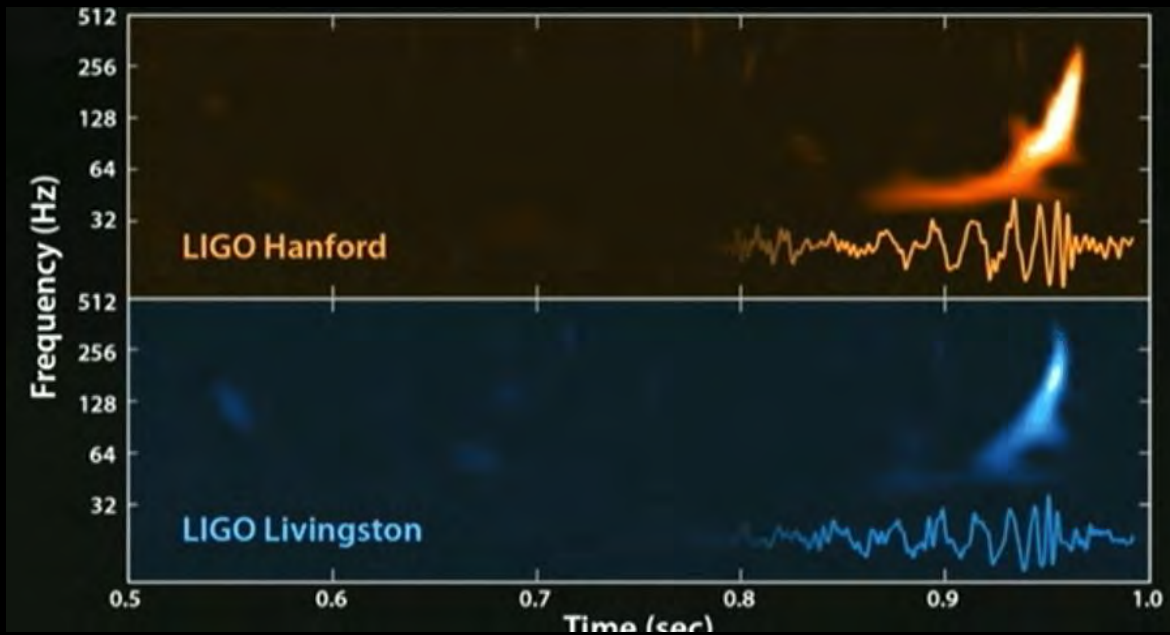
Black Hole
Charles Burns



...AND I COULD FEEL MYSELF FALLING FORWARD, TUMBLING DOWN INTO NOTHINGNESS.

Film of the Graphic Novel
Screenplay: Neil Gaiman
Director: David Fincher

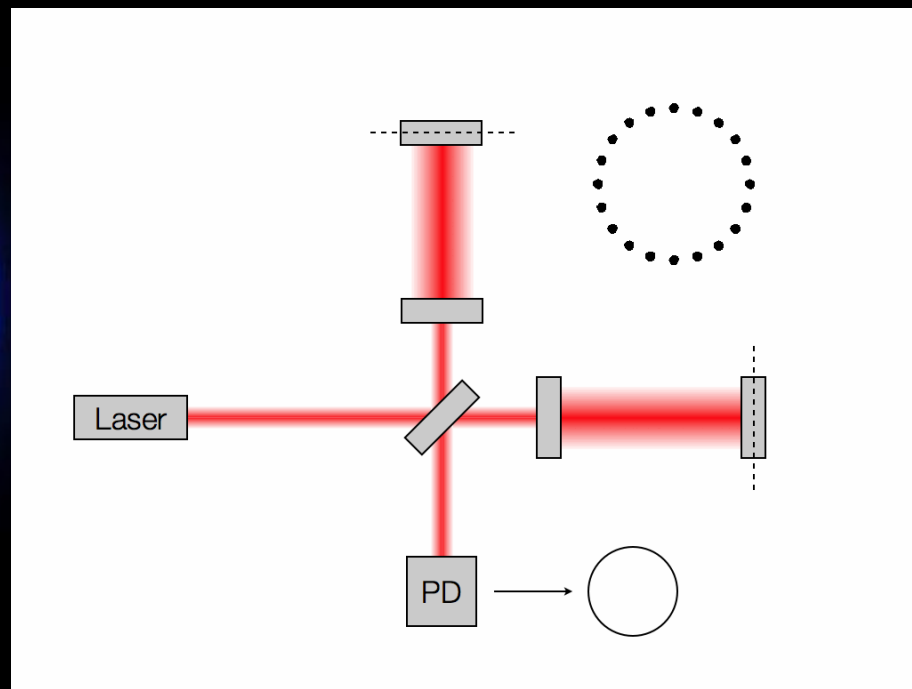
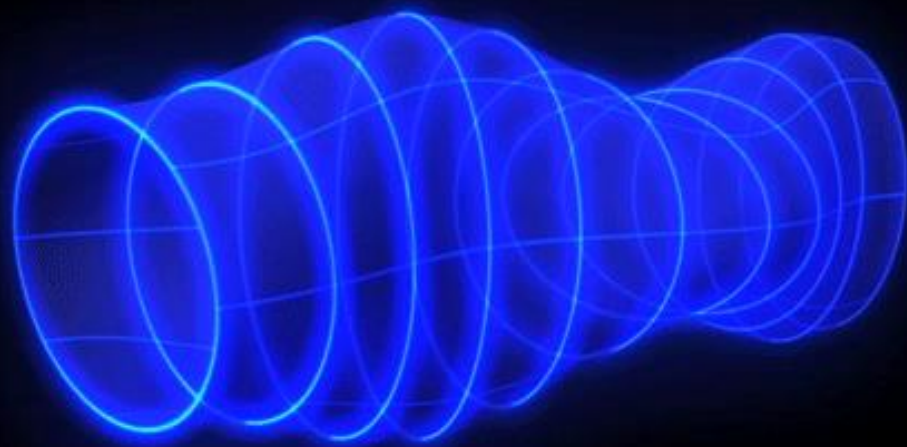
Gravitational Waves



The detection of space-time ripples from a merger of two black holes a billion light years away has opened up a new window onto the universe.

LIGO, the Laser Interferometer Gravitational Observatory, will soon be detecting roughly one black hole merger every week.

Detecting Space-Time Ripples



The LIGO Orrery



Time: -0.63 seconds

GW150914

GW151012

GW151226

GW170104

GW170608

GW170729

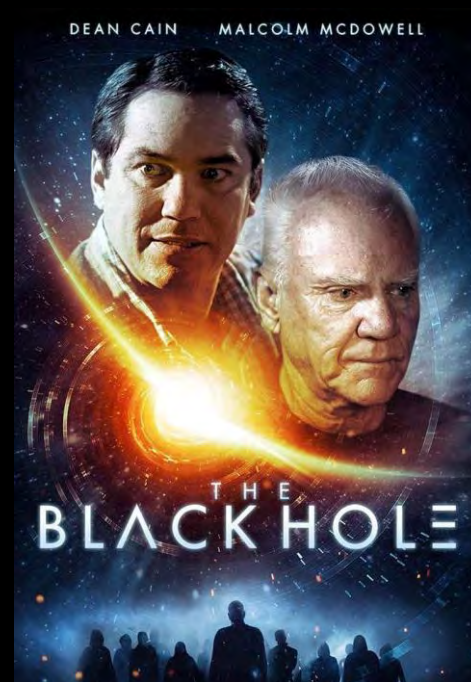
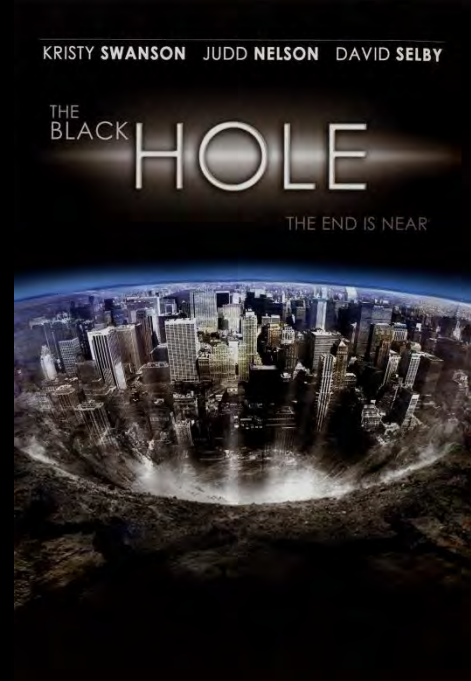
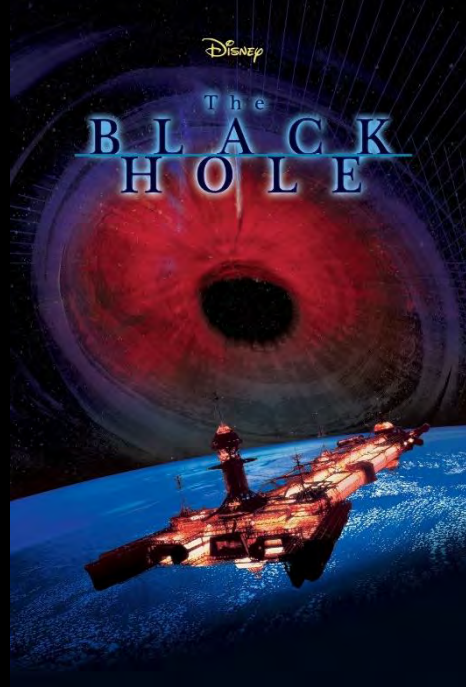
GW170809

GW170814

GW170818

GW170823

MOV

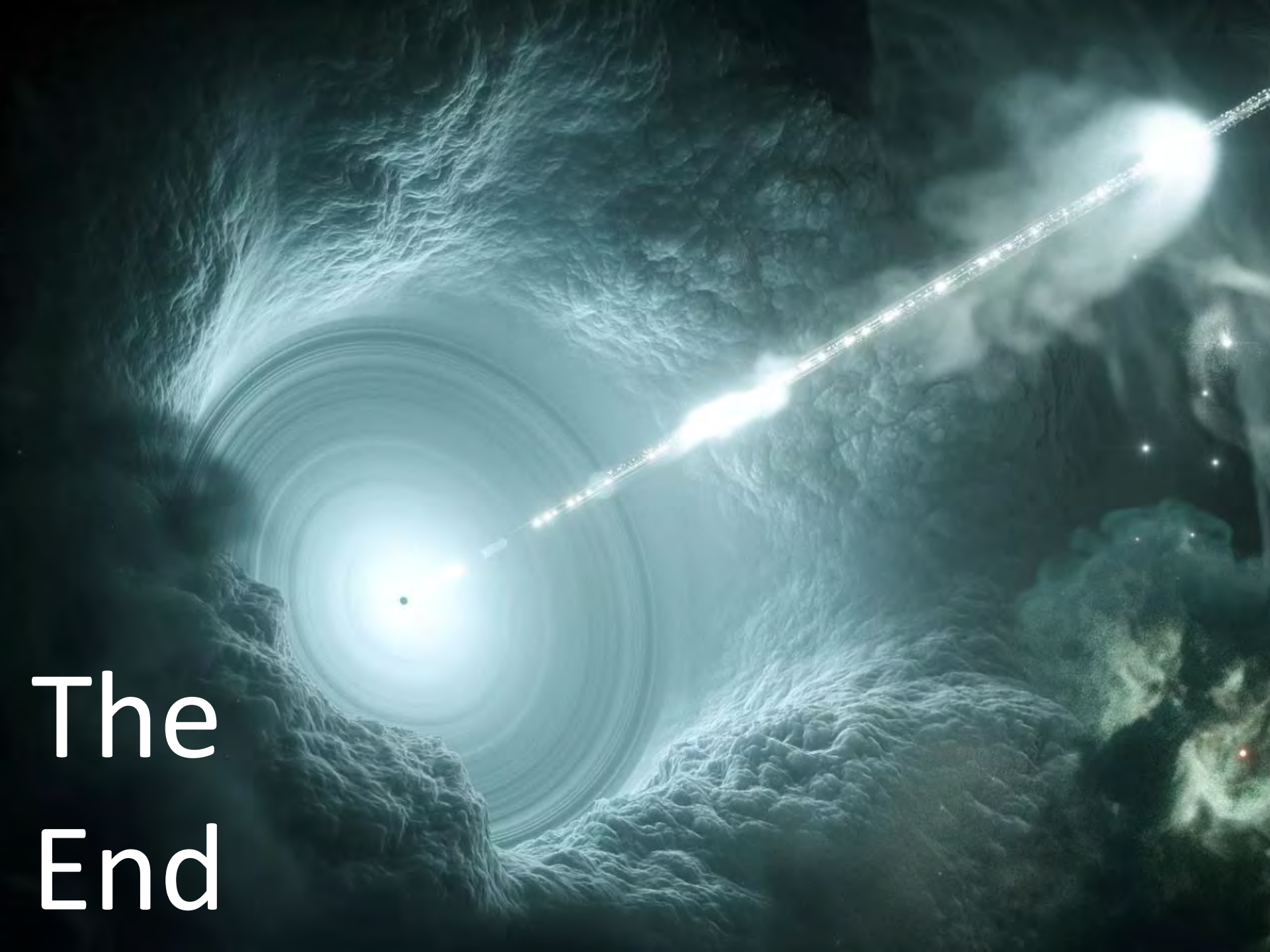


Death by Black Hole



Falling into a black hole resulting from massive star's would be a nasty fate: “spaghettification” at the level of muscles, bones, and tissues. The tidal forces are extreme.

But passage into a black hole over 1000 solar masses would be survivable. As seen from afar, time would slow asymptotically. In spinning black holes, the singularity is a ring, a time-like curve where you could meet previous and future versions of yourself.



The
End