

# Black Holes in Science and the Arts

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**Abstract.** Black holes exert an inexorable grip on the imagination. They were predicted by the theory of general relativity, but even the author of the theory, Albert Einstein, thought they were purely mathematical constructs. When massive stars die, they leave behind objects from which nothing can escape. More surprisingly, there are black holes at the centre of every galaxy, ranging up to behemoths ten billion times the mass of the Sun. These enigmatic objects have suffused science fiction, and they have been represented in the visual arts, music, television, and movies. From Larry Niven to Gregory Benford, from Kazimir Malevich to Anish Kapoor, from Soundgarden to Muse, from *Star Trek* to *The Simpsons*, from *The Black Hole* to *Interstellar*, black holes are cultural metaphors for death, loss, and sometimes, salvation. Even as black holes are embraced by the arts, facts about them can seem as strange as fiction.

## **Black Holes are Real**

Black holes are the most familiar yet least understood objects in the universe.<sup>1</sup> The term is used colloquially to talk about an entity that sucks in everything around it. Black holes appear onscreen and in fiction, and they have been co-opted by pop culture. A black hole is shorthand for something enigmatic, with a sinister edge. I have called them ‘Einstein’s monsters’ as a metaphor.<sup>2</sup> They are powerful and beyond anyone’s control. Einstein did not create black holes, but he developed the best theory of gravity that we have for understanding them.

What many people think they know about black holes is wrong. They are not cosmic vacuum cleaners, sucking in everything in the vicinity. They only distort space and time very close to their event horizons. Black holes represent a small fraction of the mass of the universe, and the nearest

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<sup>1</sup> Kip Thorne, *Black Holes and Time Warps: Einstein’s Outrageous Legacy* (New York: Norton, 1995).

<sup>2</sup> Chris Impey, *Einstein’s Monsters: The Life and Times of Black Holes* (New York: Norton, 2018).

examples are hundreds of trillions of miles away.<sup>3</sup> It is unlikely that they can be used to time-travel or visit other universes. Black holes are not even totally black. They emit a fizz of particles and radiation.<sup>4</sup> Black holes are not necessarily hazardous.<sup>5</sup> You could fall into the black hole at the centre of most galaxies and not feel a thing, although you would never get to tell anyone what you saw.

Black holes are conceptually simple because they are fully defined by their mass, size, and spin. However, the mathematics needed to understand them is fiendishly complex. They cannot be understood without Einstein's theory of general relativity, developed a century ago, which says that space and time are distorted by matter.<sup>6</sup> In the extreme case where mass is highly concentrated, a region of space becomes 'pinched off' from the rest of the universe and nothing can escape, not even light. That is a black hole. But even Einstein was sceptical of their reality.<sup>7</sup> He was not alone; many notable physicists doubted that they existed.

Black holes do exist. Evidence has accumulated for sixty years that when massive stars die, no force in nature can resist the gravitational collapse of their cores. A gas ball ten times the size of the Sun crunches down to a dark object the size of a small town. A single black hole in space is dark and nearly impossible to detect. The first few dozen black holes were discovered in binary systems, where a black hole is in a gravitational waltz with a normal star. As the black hole sucks gas from the atmosphere of its normal star companion, the gas heats up and glows in X-rays. The black hole is invisible but the zone around it emits intense radiation.

Over the past few decades, it has become clear that the centre of every galaxy contains a massive black hole.<sup>8</sup> The best evidence for any black hole is found just 28,000 light years away at the centre of our own galaxy,

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<sup>3</sup> Brian Cox and Jeff Forshaw, *Black Holes: The Key to Understanding the Universe* (Boston, MA: Mariner Books, 2023).

<sup>4</sup> Michael Imseis, 'A Pedagogical Review of Black Holes, Hawking Radiation and the Information Paradox', Preprint, 2021, [https://www.researchgate.net/profile/Michael-Imseis/publication/356129307\\_A-Pedagogical-Review-of-Black-Holes-Hawking-Radiation-and-the-Information-Paradox.pdf](https://www.researchgate.net/profile/Michael-Imseis/publication/356129307_A-Pedagogical-Review-of-Black-Holes-Hawking-Radiation-and-the-Information-Paradox.pdf).

<sup>5</sup> Neil Tyson, *Death by Black Hole: And Other Cosmic Quandaries* (New York: Norton, 2014).

<sup>6</sup> Robert Wald, *General Relativity* (Chicago, IL: Chicago University Press, 1984).

<sup>7</sup> Jeremy Bernstein, 'The Reluctant Father of Black Holes', *Scientific American*, April Issue, 2007.

<sup>8</sup> Mitchell Begelman, 'Evidence for Black Holes', *Science*, Vol. 300 (2003): pp.1898–1903.

where stars swarm like angry bees around a dark object four million times the mass of the Sun. However, our galaxy's black hole is puny compared to behemoths at the centre of some large galaxies, which range up to twenty billion times the mass of the Sun (Fig. 1). When the massive black holes that all galaxies harbour rouse from their slumber and begin feeding on nearby gas and stars, the energy they release means they can be seen across distances of billions of light years.<sup>9</sup> These gravitational engines are the most powerful sources of radiation in the universe.



Fig. 1. Black Hole Art. Artist's impression of a supermassive black hole. It is surrounded by an accretion disk, hot gas that swirls around the black hole, drawn into it by gravity. The outflowing jet of high energy particles is powered by the black hole's spin. Credit: NASA/JPL-Caltech/R. Hurt (IPAC).

<https://www.nustar.caltech.edu/image/nustar130227a>.

Recently, physicists have learned to see with gravity 'eyes' by detecting gravitational waves.<sup>10</sup> When two black holes collide, they release ripples in space-time that race outward at the speed of light and contain information about the violent cosmic encounter. These observations have opened a new window onto black holes, as well as onto all situations where

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<sup>9</sup> Natalie Wolchover, 'Physicists Identify the Engine Powering Black Hole Energy Beams', *Quanta Magazine*, 2021, <https://www.quantamagazine.org/physicists-identify-the-engine-powering-black-hole-energy-beams-20210520/>.

<sup>10</sup> Coleman Miller and Nicolas Yunes, 'The new frontier of gravitational waves', *Nature*, Vol. 568 (2019): pp.469–76.

gravity is strong and changing. Gravitational waves provide unequivocal proof, if any were still needed, that black holes exist.

Black holes also allow general relativity to be tested in new ways: nobody knows if these tests will affirm the theory or lead to its downfall.<sup>11</sup> There is a vigorous debate over information loss in black holes and whether or not the information is somehow coded on the event horizon.<sup>12</sup> Theorists are hoping that black holes might be places where string theory can be verified, finally realizing Einstein's quest to unify the two foundational theories of modern physics: quantum mechanics and general relativity.<sup>13</sup>

We can imagine that intelligent creatures on many of the trillions of habitable worlds in the cosmos have deduced the existence of black holes.<sup>14</sup> Perhaps some are far more advanced than we are technologically and have learned how to create them and harness their power. Humans are a young species, but we can be proud to be members of the special club that knows of black holes.

### **Black Holes in Fiction**

Four hundred years before black holes were theorised, Shakespeare wrote this: 'Stars, hide your fires; Let not light see my dark and deep desires'.<sup>15</sup> While he did not anticipate a form of matter so dense that nothing could escape, he did describe a plea by Macbeth that starlight be quenched to conceal his dark thoughts. Macbeth knows he will have to kill Duncan to become king, so darkness is twinned with death and oblivion. This metaphor is present in the origin story of the term black hole. In the conventional telling, the physicist John Wheeler coined 'black hole' in 1968 to avoid having to use the cumbersome description 'gravitationally completely collapsed object'. In fact, the term originated with his colleague Robert Dicke in 1963, in an allusion to the 'black hole of Calcutta', an incident in colonial British India where over a hundred prisoners died in a

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<sup>11</sup> Kent Yagi and Leo Stein, 'Black Hole Based Tests of General Relativity', *Classical Quantum Gravity*, Vol. 33 (2016): 054001.

<sup>12</sup> Suvrat Raju, 'Lessons from the information paradox', *Physics Reports*, Vol. 943 (2020): pp.1–80.

<sup>13</sup> Juan Maldacena, 'Black Holes in String Theory', Ph.D. Thesis, Princeton University, 1996, <https://arxiv.org/abs/hep-th/9607235>

<sup>14</sup> Chris Impey, *Worlds Without End: Exoplanets, Habitability, and the Future of Humanity*, (Cambridge, MA: MIT Press, 2023).

<sup>15</sup> William Shakespeare, *Macbeth*, Act 1, Scene 4 (London: Blount and Jaggard, 1623).

hideously overcrowded jail cell.<sup>16</sup> Shakespeare inadvertently anticipated black hole terminology when he wrote: ‘To fill with wormholes stately monuments, to feed oblivion with decay of things’.<sup>17</sup> John Wheeler brought us full circle when he coined ‘wormhole’ to replace the physics term ‘Einstein-Rosen bridge’.<sup>18</sup> In his analogy, the worm munches through an apple, but the apple is space-time.

Black holes get their fullest expression in the popular culture through science fiction. Sometimes black hole science is accurately conveyed, but often liberties are taken, and sometimes black holes are used as a crutch or a contrivance.<sup>19</sup> The mind-bending attributes of black holes have spurred a lot of creativity in the science fiction community. Some writers dodged the narrative dead end implied by destruction within a black hole, such as Joan Vinge in *The Snow Queen* and George R.R. Martin in *The Second Kind of Loneliness*.<sup>20</sup> Others explored the possibilities of miniature black holes, such as Larry Niven in *The Hole Man* and Gregory Benford in *Artifact*.<sup>21</sup> With black holes played out exhaustively in dozens of short stories and novels, they have receded to become a familiar fictional wallpaper.<sup>22</sup>

Science fiction has struggled to gain respectability as literature, but it is a dynamic, diverse genre.<sup>23</sup> In the realm of ‘serious’ literature, black holes are rarely featured, because non-scientists often struggle to capture their nuances. One notable exception was Edgar Allen Poe, whose prose poem

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<sup>16</sup> Carlos Herdeiro and Jose Lemos, ‘The black hole fifty years after: Genesis of the name’, 2019, <https://doi.org/10.48550/arXiv.1811.06587>.

<sup>17</sup> William Shakespeare, *The Rape of Lucrece* (New York: Thomas Y. Crowell Company, 1912). Line 946–947. [https://internetshakespeare.uvic.ca/doc/Luc\\_Q1/complete/index.html](https://internetshakespeare.uvic.ca/doc/Luc_Q1/complete/index.html).

<sup>18</sup> Albert Einstein and Nathan Rosen, ‘The Particle Problem in the General Theory of Relativity’, *Physical Review*, Vol. 38, No. 73 (1935): pp.73–77.

<sup>19</sup> Barry Luokkala, *Exploring Science Through Science Fiction* (Berlin: Springer Nature, 2019), pp. 35–41.

<sup>20</sup> Joan Vinge, *The Snow Queen* (New York: Dail Press, 1980); George R.R. Martin, ‘The Second Kind of Loneliness’, *Analog Science Fiction/Science Fact*, December Issue, 1972.

<sup>21</sup> Larry Niven, ‘The Hole Man’, *Analog Science Fiction/Science Fact*, January Issue, 1974; Gregory Benford, *Artifact* (New York, Harper Voyager, 1998).

<sup>22</sup> *Black Holes*, The Encyclopedia of Science Fiction, [https://sf-encyclopedia.com/entry/black\\_holes](https://sf-encyclopedia.com/entry/black_holes) [accessed 5 January 2023].

<sup>23</sup> Roger Luckhurst, ed., *Science Fiction: A Literary History* (London: British Library Press, 2017).

*Eureka* in 1848 anticipated a remarkable amount of modern science, from the expanding universe and mass-energy equivalence to black holes.<sup>24</sup>



Fig. 2. Maelstrom-Clark. Illustration by Harry Clark for the Edgar Allen Poe story *Descent into the Maelstrom*, published in London in 1919 by George Harrap and Company as part of the book *Tales of Mystery and Imagination*. Credit: Illustration by Harry Clark (Public Domain).

In his short story *A Descent into the Maelstrom* from 1841 (Fig. 2), he wrote: ‘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...’ The description is more than just an allusion.

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<sup>24</sup> Paolo Molaro and Alberto Cappi, ‘Edgar Allan Poe’s Cosmology in *Eureka*’, *Culture and Cosmos*, Vol. 16 no 1 and 2, Spring/Summer and Autumn/Winter 2012, pp.225–39.

Fluid vortices are described by the same mathematics that describes black holes. Poe's 'broad belt of gleaming spray' is like the photon sphere, a surface of light with circles the black hole without entering it. The vortex boundary in a turbulent fluid contains a singularity, just like an astrophysical black hole. Two black hole analogues were found in the South Atlantic Ocean.<sup>25</sup>

One more modern example can be quoted. Martin Amis is an acclaimed British novelist and essayist. In the novel *Night Train*, which is written in a terse, noir style, a detective investigates the shocking death of a female astronomer who did research on black holes. She has committed suicide; an allusion made by the title of the book. While she was staring into her personal psychological abyss, she thought of Stephen Hawking: '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'.<sup>26</sup> Death, like the black hole, is Shakespeare's 'undiscovered country' in the play *Hamlet*, from which no traveller returns.<sup>27</sup>

### **Black Holes in Art**

Black hole images exist in such profusion that it would be impossible to describe or classify them. They run the gamut from fine art renditions to graphic art and cartoons. The colour black is sometimes controversial in the art world. When the Russian artist Kazimir Malevich painted a black square in 1915, closely followed by a black circle, it caused a sensation at the Last Futurist Exhibition.<sup>28</sup> Its formal simplicity represented the decisive break between representational painting and abstract painting (and the following year would witness a decisive break between linear Newtonian gravity and the curved space-time of Einstein's general relativity). Much as Malevich's paintings were austere, simple, and not about any one thing, black holes are singular objects, mute to whatever they might contain.

A web search of the term 'black hole art' returns nearly half a million results. Modern examples of black holes expressed in art and design have

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<sup>25</sup> George Haller and Francisco Beron-Vera, 'Coherent Lagrangian vortices: The black holes of turbulence', 2013, <https://doi.org/10.48550/arXiv.1308.2352>.

<sup>26</sup> Martin Amis, *Night Train* (London: Johnathan Cape, 1997), p.114.

<sup>27</sup> William Shakespeare, *Hamlet*, Act 8, Scene 1 (London: N.L. and John Trundell, 1603).

<sup>28</sup> Tatyana Tolstaya, 'The Square', *The New Yorker*, June 12, 2015, <https://www.newyorker.com/culture/cultural-comment/the-square>.

been collected by the artist Astrid Perlaan.<sup>29</sup> She includes a charcoal drawing by Levi van Heluw in which the shading and perspective cleverly combine to pull the viewer in, and a pen ink drawing by Vasilj Godzh which achieves a similar immersive effect, while Diana Policarpo has returned to the sparse abstract expression of Malevich. The most notable example of a black hole in installation art is ‘Descent into Limbo’ by the British-Indian sculptor Anish Kapoor, the first living artist to have a solo exhibition at Britain’s Royal Academy of Art. Kapoor’s installation is a cube-shaped building with a 2.5-meter-deep hole in the floor that is painted matte black.<sup>30</sup> Kapoor has experimented with Vantablack, a pigment that absorbs 99.965% of visible light. However, in 2016 he caused controversy when he bought exclusive rights to use Vantablack as an art material.<sup>31</sup> Artists were appeased in 2019 when MIT engineers released at modest cost a material that absorbs 99.995% of visible light. The world of art was roiled in 2021 when OpenAI released DALL-E, a system based on machine learning that generates digital images from any description.<sup>32</sup> Figure 3 shows four images generated by GPT-3, the OpenAI large-scale language generation model, using the application called DALL-E, entering the term ‘black hole’ and names of famous artists from different eras.<sup>33</sup> It is a matter of continuing debate whether AI creates images that are merely derivative or have intrinsic and creative value.

### Black Holes in Music

The archetypal example of a black hole invoked in popular music was written about the archetypal black hole, Cygnus X-1. The 1977 song by the Canadian power trio Rush is actually titled ‘Cygnus X-1’ and appeared on their album *A Farewell to Kings*. The lyrics begin, ‘In the constellation of

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<sup>29</sup> Astrid Perlaan, ‘Black holes in art and design’, 2023, <http://cargocollective.com/expeditionblackhole/4-Black-Holes-in-art-and-design> [accessed 15 January 2023].

<sup>30</sup> Anish Kapoor, ‘Descent into limbo’, 1992, <https://anishkapoor.com/75/descent-into-limbo> [accessed 15 January 2023].

<sup>31</sup> Truman Chambers, ‘The Vantablack controversy: Anish Kapoor vs. Stuart Semple’, 2021, <https://www.thecollector.com/vantablack-anish-kapoor-stuart-semple-controversy/> [accessed 15 January 2023].

<sup>32</sup> Avijit Ghosh and Genoveva Fossas, ‘Can there be art without an artist?’, 2022, <https://doi.org/10.48550/arXiv.2209.07667>.

<sup>33</sup> DALL-E, OpenAI, <https://openai.com/dall-e-2/>.





Fig. 3. DALL-E Black Hole. Images generated by the AI application DALL-E using the term “black hole” and names of the artists Vincent van Gogh (top left), Hieronymus Bosch (top right), Albrecht Durer (bottom left), and Pablo Picasso (bottom right). Credit: DALL-E and GPT3 (OpenAI).

Cygnus, there lurks a mysterious, invisible force. The black hole of Cygnus X-1. Six stars of the Northern Cross mourning their sister’s loss’.<sup>34</sup> In 1994, the rock band Soundgarden penned a song called ‘Black Hole Sun’ that got heavy rotation on FM radio at the time. Lead singer Chris Cornell said of the song, ‘It’s a void, a giant circle of nothing, and then you have the Sun, the giver of all life. It was this combination of bright and dark, this sense of hope and underlying moodiness’.<sup>35</sup> In 2000, the Dutch musician Arjen Lucassen released the album *Flight of the Migrator*, featuring the odyssey of the last human being who travels from Mars to quasars, pulsars, and wormholes. The narrator travels to the first confirmed quasar, 3C 273, hoping that it will transport him through the universe. Traveling through a black hole had migrated from science fiction to progressive metal. Black

<sup>34</sup> Rush, ‘Cygnus X-1’, <https://www.lyrics.com/lyric/33231676/Rush/Cygnus+X-1> [accessed 24 June 2023].

<sup>35</sup> Song Facts, Black Hole Sun by Soundgarden, <https://www.songfacts.com/facts/soundgarden/black-hole-sun> [accessed 15 January 2023].

holes migrated into dance-rock with the song ‘Supermassive Black Hole’ by the English band Muse.

All these songs have at most a metaphorical or allegorical relationship to black holes. A more direct connection to music comes from sonification, where astrophysical data is directly mapped into sound. This process has an important role in research, as well as education and outreach.<sup>36</sup> NASA created a sonification of the black hole at the centre of the Perseus Cluster in 2022 in part to rebut the common misconception that sound does not travel through space. In the diffuse plasma in the galaxy cluster, pressure waves emitted by the black hole could be translated to a note, but it is 57 octaves below middle C, inaudible to the human ear. Scaled quadrillions of times higher in frequency, and scanned in all directions, the black hole generates an eerie kind of music.<sup>37</sup>

### **Black Holes in TV and Film**

Black holes have featured in television and film for over half a century. As in much science fiction, it is irresistible to use black holes as plot devices to represent danger or hazard, or to convey the ineffable. The best single compilation of black holes in movies (and books) comes from Andrew Hamilton, a professor at the University of Colorado. He has been teaching a course on black holes to non-science majors for twenty years, and part of the course involves contributions from students, accumulating to over 100 entries.<sup>38</sup> By crowd-sourcing the aggregation of black holes in the popular culture to students, Hamilton has done a valuable service to anyone who is interested in black holes as entertainment. Each entry in the list contains a short review and link to a plot or episode summary.

In film and television, where entertainment is the primary motivation, a black hole or wormhole is often invoked as a *deus ex machina*, or a plot device that conveniently solves a problem or moves the story forward. The level of scientific accuracy is not generally as high as good ‘hard’ science

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<sup>36</sup> Anita Zanella, ‘Sonification and sound design for astronomy research, education and public engagement’, *Nature Astronomy*, Vol. 6, (2022): pp.1241-48.

<sup>37</sup> NASA, ‘New NASA black hole sonifications with a remix’, 2022, [https://www.nasa.gov/mission\\_pages/chandra/news/new-nasa-black-hole-sonifications-with-a-remix.html](https://www.nasa.gov/mission_pages/chandra/news/new-nasa-black-hole-sonifications-with-a-remix.html) [accessed 15 January 2023].

<sup>38</sup> Andrew Hamilton, ‘Spring 2019 ASTR 2030 Black hole books, movies’, 2019, [https://jila.colorado.edu/~ajsh/courses/astr2030\\_19/bhmovies.html](https://jila.colorado.edu/~ajsh/courses/astr2030_19/bhmovies.html).

fiction. *Star Trek* provides illustrative examples.<sup>39</sup> In 1967, the term black hole was not yet in common usage so, in a TV episode called ‘Tomorrow is Yesterday’, the crew ventured too close to the gravitational pull of a ‘black star’. While time dilation would occur close to the event horizon, this idea was distorted into time travel in the episode. A few years later the first *Star Trek* movie violated a core principle of black hole physics when a space probe escaped from a black hole. In season three of *The Next Generation*, black holes feature in two episodes. In one, a black hole is used plausibly to deflect an object out of its orbit, but in the other a wormhole appears and disappears regularly, in a way the cast compares to the Old Faithful geyser back on Earth. In season four, a wormhole is evoked in one episode and in another a cosmic string is implausibly characterized as a two-dimensional black hole.<sup>40</sup> The *Star Trek* movie of 2009 takes perhaps the greatest liberty with science, when the Romulans drop magic ‘red matter into the core of the planet Vulcan, turning it into a black hole.

To get a sense of the evolution in the sophistication with which black holes are treated in celluloid, consider two films made thirty-five years apart: *The Black Hole* from Disney Studios in 1979 and *Interstellar* from Paramount in 2014. Disney’s film launched on a wave of anticipation. It pioneered the use of computer technology for visual effects, it was the studio’s most expensive film to date, and it was the first Disney film with a PG rating. But it also underwent numerous script revisions, and it was burdened with a cumbersome plot. Reviews were mixed, and the review aggregator web site Rotten Tomatoes recorded an audience score of 45% together with this critic’s consensus: ‘while lavishly crafted and brimming with ambitious ideas, *The Black Hole* probes the depths of space with an unexciting story and hokey melodrama’.<sup>41</sup> Nonetheless, it is a cult classic in some quarters.

The film *Interstellar* was a popular and critical success. On the web site Rotten Tomatoes, it has an audience score of 86% and a highly positive critic’s consensus: ‘*Interstellar* represents more of the thrilling, thought-provoking, and visually resplendent filmmaking moviegoers have come to

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<sup>39</sup> ‘Popular TV Shows Featuring a Black Hole’, StarDate, <http://blackholes.stardate.org/popculture/list-pt-2.html>.

<sup>40</sup> Lawrence Krauss, *The Physics of Star Trek* (New York: Harper Perennial, 1995), pp.194–96.

<sup>41</sup> ‘The Black Hole’ (1979), Rotten Tomatoes, [https://www.rottentomatoes.com/m/1002497-black\\_hole](https://www.rottentomatoes.com/m/1002497-black_hole) [accessed 15 January 2023].

expect from writer-director Christopher Nolan'.<sup>42</sup> The film took black hole realism to a new level. Caltech physicist Kip Thorne, who won a Nobel Prize in 2017 for the observation of gravitational waves from merging black holes, was the lead scientific consultant on the film. The film uses a gigantic spinning black hole called Gargantua to slow down time (Fig. 4), and Thorne worked with the animators to ensure that the visuals were scientifically accurate.<sup>43</sup> Some frames took 100 hours to render and the data for the film pushed close to a million gigabytes. Thorne made a scientific discovery from the simulations that led to a research paper.<sup>44</sup> From his perspective the images are beautiful, but he thinks they are also beautiful because they are true.

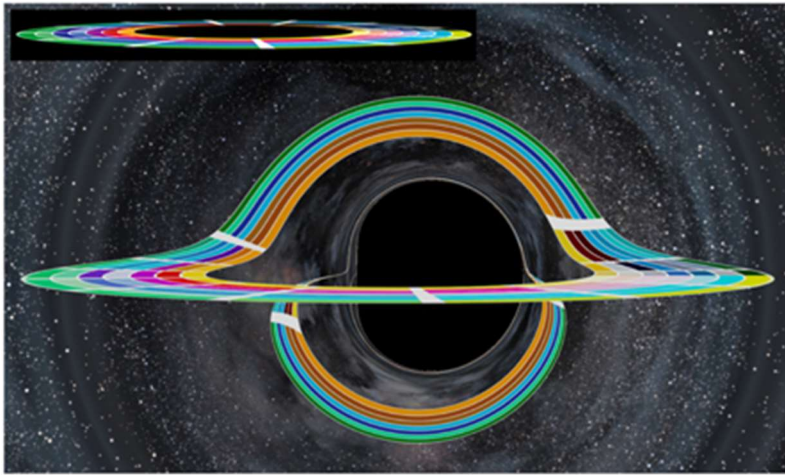


Fig. 4. Accretion Disk. A relatively realistic accretion disk around a supermassive black hole, rendered by artists and created based on astrophysical simulations to be part of the movie *Interstellar* (2014). Credit: O. James/Institute of Physics (CC 3.0). <https://iopscience.iop.org/article/10.1088/0264-9381/32/6/065001/meta#cqg508751f13>.

### Black Hole Science as Art

<sup>42</sup> 'Interstellar' (2014), Rotten Tomatoes, [https://www.rottentomatoes.com/m/interstellar\\_2014](https://www.rottentomatoes.com/m/interstellar_2014) [accessed 15 January 2023].

<sup>43</sup> Kip Thorne, *The Science of Interstellar*, (New York: Norton, 2014).

<sup>44</sup> Oliver James, Eugenie von Tunzelmann, Paul Franklin, and Kip Thorne, 'Gravitational lensing by spinning black holes in astrophysics, and in the movie *Interstellar*', *Classical and Quantum Gravity*, Vol. 32 (2015): 065001.

To bring this short review of black holes in science and the arts full circle, we consider the first image ever made of a black hole. In 2017, eight radio telescopes combined to make an image of the centre of the giant elliptical galaxy M87. The galaxy is fifty-four million light years away and it houses a black hole seven billion times the mass of the Sun. It was only possible to make an image of the black hole by combining data from the eight radio dishes to simulate a telescope the size of the Earth. Figure 5 shows the glowing gas in an accretion disk surrounding the black hole. The black hole's boundary, the event horizon is 2.5 times smaller than the shadow it casts, about 40 billion kilometres across.<sup>45</sup> The ring has an angular size equivalent to the size of a golf ball on the surface of the Moon. This radio image is decisive evidence for the existence of black holes. It is also evocative and beautiful and demonstrates that there is no concrete boundary between science and art.

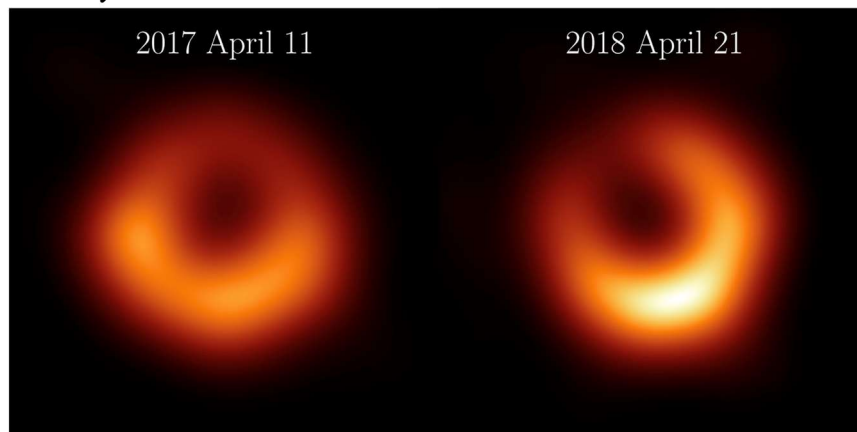


Fig. 5. M87 Black Hole. The supermassive black hole at the centre of the elliptical galaxy M87, as imaged by a set of eight radio dishes called the Event Horizon Telescope. The image shows hot, glowing gas orbiting the black hole. Credit: Event Horizon Telescope (CC 4.0).

<https://eventhorizontelescope.org/M87-one-year-later-proof-of-a-persistent-black-hole-shadow>.

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<sup>45</sup> The Event Horizon Telescope Collaboration, 'First M87 Event Horizon Telescope results. I. The shadow of the supermassive black hole', *The Astrophysical Journal*, Vol. 875 (2019): pp.1–18.