GENERAL ARTICLE

Realism in the Age of the Simulated Image

Two Black Holes

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ABSTRACT

This paper examines the production and reception of two scientific images of black holes, the 2019 image of the M87 black hole and Gargantua from Christopher Nolan's 2014 film *Interstellar*. The author argues that these two images of unobservable phenomena crystallize a definition of contemporary realism. In an information-rich society, a simulated image achieves realism by compressing large amounts of data into an intelligible image using an algorithmic methodology that the viewer trusts as scientifically reliable and therefore realistic.

PUBLIC PRESENTATION

In the press conference for the public release of the Messier 87 (M87) black hole image in 2019, astrophysicist Shep Doeleman stated that "we have seen and taken a picture of a black hole" and that this image constitutes "the strongest evidence that we have to date for the existence of black holes" [1]. In one of the most popular YouTube videos on M87, the image was introduced with ecclesiastical music in the manner of a revelation [2]. For Christopher Nolan's 2014 film *Interstellar*, the Gargantua black hole was created as a theoretical simulation. It appeared onscreen for less than a minute but was the subject of much discussion in the computer graphics community [3] and resulted in its own scientific paper [4]. Astrophysicist Kip Thorne, who supervised the creation of Gargantua, wrote that "for the first time ever—and before any scientist—I saw in ultrahigh definition what a fast-spinning black hole looks like" [5]. Doeleman's description of taking "a picture" and Thorne's description of what a black hole "looks like" are, like the images themselves, simplifications designed to communicate. Both of these images compress complex and voluminous data into representations of something that we cannot otherwise see. For such realism to be achieved, each image had to balance what was scientifically accurate with what was visually intelligible and to communicate this balance to the audience.

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Orit Halpern suggests that by the mid-twentieth century, "a new aesthetic and practice of truth" had emerged, whereby the idea of vision "solely concerning optics and the eyes" had to reckon with the array of new sensing techniques, from radar to computer technologies, and the ability to find patterns, signals, beauty, and meaning from a world of informational abundance [6]. In an era when the volume of available data is impossibly large, an epistemic shift takes place where algorithms and simulations are needed to extract meaningful signals from noise, and therefore these algorithms and simulations are a critical function in realism and representation. The production and reception of these black hole images trace a story of scientific imaging that is both empirical and artistic and constitutes an important example of what we might consider "realism" in contemporary visual culture.

REPRESENTING TWO BLACK HOLES

The M87 black hole image was published in 2019 by the Event Horizon Telescope collaboration (EHT) and described by its authors across a series of six scientific papers. To produce small public-facing images such as Fig. 1, petabytes of information were compressed into their most visually relevant features and averaged to avoid esoteric errors of interpretation. After collecting the data from a global array of radio telescopes, the

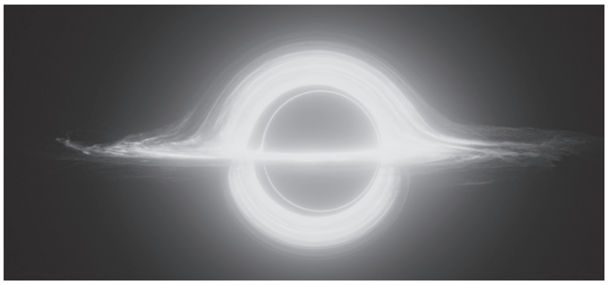

Fig. 1. The Event Horizon Telescope. EHT image of M87 from observations on 11 April 2017 as a representative example of the images collected in the 2017 campaign. (Used under the terms of the Creative Commons Attribution 3.0 license.)

EHT project organized four groups of imaging specialists and provided them with the same data. They used three separate imaging processes with different software pipelines and compared the resulting images to look for consistency and to remove outlying or spurious visual results [7]. Contrary to Doeleman's description of taking a photograph, the process behind the M87 image resembles a form of montage, where the most truthful image is the mathematical average of a variety of possible representations [8] (what EHT member Peter Galison later described as a "consensus image" [9]). Because the M87 image derives from radio waves rather than light from the visible spectrum, the fluctuations of the color hue and brightness of the image do not directly correlate to what the human eye might see; instead these fluctuations are something akin to a "heat map," where variations in radiation energy are calibrated to color maps and parsed through specialized noise filters. If a black hole could be viewed by the naked eye, the color of its glowing accretion disk (the ring of material around the black hole) would be a complex theoretical matter due to how extreme gravitational forces bend visible light. Astrophysicist Derek Fox states that "in the optical range, the ring around the black hole would likely appear white, perhaps tinged with blue or red" [10]. But by calibrating within the yellow and red spectrum, the EHT was able to visually communicate essential changes in flux density measured over radio waves, and, subjectively speaking, the central placement of the orange heat map on a wide black background conjures the apparitional quality of the image identified in its ecclesiastic reception. The legitimacy of Doeleman's claim of "taking a photo" of a black hole correlates to the rigor with which the EHT team both collected and translated radio waves into a graduated band of red and orange pixels representing a world first in scientific imaging. However, while outside the scope of this short article, it should be noted that this realism remains contingent on trust. In her extensive philosophical analysis of the EHT process, Galina Weinstein argues that the averaging efforts of the EHT collaboration might yet not be strong enough to justify belief in unobservable entities [11].

The concept for the film *Interstellar* came out of a collaboration between astrophysicist Kip Thorne and producer Lynda Obst. Their motivation was to make a science fiction film about black holes, gravity, and time anomalies with an accurate implementation of existing scientific knowledge. Early in their collaboration, Thorne proposed the following working principles to Obst:

1. Nothing in the film will violate firmly established laws of physics, or our firmly established knowledge of the universe.
2. Speculations (often wild) about ill-understood physical laws and the universe will spring from real science, from ideas that at least some "respectable" scientists regard as possible [12].

Gargantua (Fig. 2) was developed by Thorne and a team of engineers at the graphics company Double Negative. Thorne derived algorithms to predict the trajectories of light rays around the black hole, visualized them using Mathematica software, and then provided these visualizations and equations

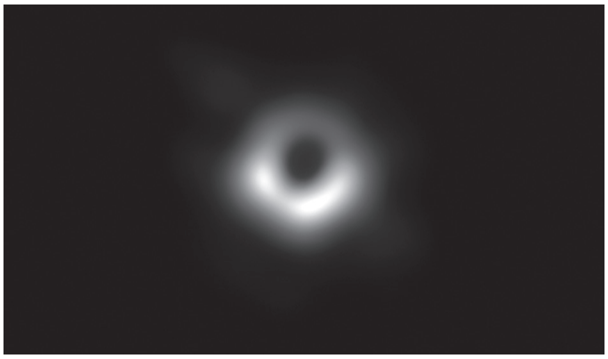

Fig. 2. Gargantua and a variant of the accretion disk seen in *Interstellar*. Figure created by the Double Negative team using Double Negative Gravitational Renderer, © Warner Bros. Entertainment Inc. (s15). (Used under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs 3.0 (CC BY-NC-ND 3.0) license.)

to Double Negative, who developed a customized render engine (the Double Negative Gravitational Renderer, or DNGR) that produced IMAX-quality visualizations of Thorne's theoretical models [13,14]. To produce an image that was scientifically accurate but visually intelligible, the team had to make several technical compromises. Nolan and Thorne agreed that the theoretical Gargantua must have an exceptionally thin accretion disk so that it would fit into the camera frame and implied visual field of the characters when viewed from their spaceship. The theoretical temperature of this accretion disk also had to be low so as not to annihilate the characters with gamma rays as they observed Gargantua from their ship. As Fox described it, relative to M87, the light of the accretion disk spinning toward the viewer would most likely appear blue or white, and light spinning away from the viewer would appear a dull red. Thorne and Nolan decided, however, that this might be too visually confusing for the cinema audience, so the light of the accretion disk was visualized within an orange-and-red hue range to create a "ring of fire" that is brighter nearer to the black hole and dimmer on its extremities. The orange color of Gargantua is a metaphorical depiction of "heat" rather than a strict simulation of what the human eye might see, which subjectively adds a narrative sense of danger and destruction. The computer graphics innovations required to visualize Gargantua at IMAX quality also generated empirical knowledge about how light is lensed around a black hole, as detailed in a 2015 scientific paper [15].

TRUTH AND REALISM

Having described their formal and technical qualities, I now advance the argument that these images demonstrate a form of contemporary algorithmic and simulated realism. Consequently, the terms "realism," "algorithmic," and "simulation" require closer attention. The art-historical use of "realism" is contextual. James Malpas points out that few artists would willingly describe their work as "unreal," and the term "realism" usually has a relationship to the avant-garde of its day (the emergence of Realism as a genre in the nineteenth century came as a reaction to the idealizations of Romanticism and the formalism of Neoclassicism) [16]. In scientific imaging, terms such as "realism" and "representation" are shaped by a similar contextual oscillation. Galison divides the history of scientific

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imaging into three epochs: the pre-nineteenth century "metaphysical image," when the insightful genius sought to depict the truth of nature that lay behind the eccentricities of the individual specimen; the nineteenth-century "mechanical image" that sought to combine the self-abnegation of the Victorian era with the discipline of the factory to produce images devoid of human subjectivity; and the twentieth-century "interpretive image" that employed simplifications, exaggerations, and nonhomomorphic techniques to communicate and summarize knowledge for a trained audience [17]. A member of the M87 imaging team, Galison describes the EHT process itself as an average of these epochs, seeking to combine consensus, mechanical objectivity, and trained expertise [18]. James Elkins argues that it is difficult to make a scientific image without relying on arbitrary visual conventions, and the division between the "informational" and the "artistic," or "decorative," image is blurred by the aesthetic decisions required to make images communicate effectively. He points out that scientific images such as the Hubble Space Telescope's 1995 image of the Eagle Nebula rely on arbitrary aesthetic influences ranging from romantic landscape painting to the "fantastical mountainscapes of Song Dynasty Chinese painting" to communicate complex data to a contemporary audience [19]. From the perspective of a computer, an "authentic" image of M87 might simply be the petabytes of voltage signal data collected by the telescopic array, but without normalizing these measurements into variations within the visual spectrum, the significance of what the array observed would be lost on the human audience, and no sense of "realism" would be achieved.

ALGORITHMIC AND SIMULATED SCIENTIFIC IMAGES

Halpern highlights that the etymological root of the word "vision," *videre*, is also the root of the word "evidence," and that in scientific images we encounter the history of how truth and knowledge are linked to the ability to make something visible [20]. Both Gargantua and the M87 image are what Shana Cooperstein calls "non-reproductive images," those that "could not exist as images in the absence of instrumental detection of data" [21]. While different in their empirical versus theoretical natures, both are calibrated to communicate using visual techniques largely indebted to photography. William J. Mitchell describes the "algorithmic" image as one that is constructed using data about an object that provides trustworthy information about the object that faced the imaging system and reveals little about the intention of the author of the image. Examples of this would be the photograph, which uses calibrated rules of the lens, a sensor, or film, and a development process to convert light photons into color values on a page or other forms of data visualization. The algorithmic image can represent objects outside the intention of the author; for example, a horse can accidentally walk into the background of a family photograph but a horse cannot accidentally appear in a painting. The non-algorithmic image is the product of intentional acts that reveal the mind of the artist but does not provide reliable evidence of the objects that are being observed [22]. Thinking back to Halpern's link between vision and evidence and Doeleman's claim that the M87 image helps prove that black holes exist, painting an image of a horse does not mean that the horse has to exist, nor can a painting claim to be an image of a particular horse, but a photograph of a horse requires the existence of horses and limits the photographer to representing one particular horse rather than the idea of horses in general.

M87 is an image of a particular black hole, whereas Gargantua is an image of a particular *type* of black hole. The M87 image is empirical and experimental due to its basis in radio telescope data, and the Gargantua image is simulated due to its basis in physics algorithms. When something cannot be studied by empirical methods, it can often be studied by theoretical principles tested in simulations. The simulation creates a counterfeit system of which scientists have precise knowledge to generate new data that might reflect on the behavior of a real phenomenon [23]. Even though an image or a representation might be the result of a simulation, it can achieve realism if the viewer accepts that the simulation accurately recreates the target phenomena. Bogna Konior demonstrates a shift toward simulated realism in her analysis of how climate simulations affect the popular understanding of the earth's climate and ecological well-being. Within the field of climate modeling, the absence of a "control earth" on which we can run climate experiments requires virtual Earths to be simulated from empirical data. For each virtual Earth, scientists update climatological data and compare results to previous simulations to extract trustworthy representations and to average out areas where the lack of data produces uncertainties, such as cloud behavior, future patterns of land usage, and so on [24]. Konior demonstrates that our general understanding of the earth is largely derived from the results published from virtual Earths and that our sense of planetary "realism" is therefore probabilistic and simulated. Benjamin Bratton argues that simulated or probabilistic realism has become the representational logic of the information age. Like Halpern, Bratton argues that unlike the struggle during the Enlightenment to collect samples and data points, the information age presents "oceans of chatter," and the challenge for contemporary representation is to interpret, analyze, and simplify this data to extract a meaningful signal [25]. Bratton's description of simulated realism as a reduction of an imperceptibly large dataset to a diagram standing in for the whole parallels Immanuel Kant's logic of the sublime. Like the diagram, the sublime is the conceptual Band-Aid plastered over the wound of our perceptual limitations. It is the sensation that stands at the cognitive rupture of what is too vast for the reasoning mind to comprehend. Simulated realism patches over our inability to comprehend the vastness of the dataset and synthesizes a representation that we can accept as "realistic" so long as we trust the efficacy of the simulation. Bratton points out that this type of realism was historically reserved for the religious and the metaphysical; the instantaneous, ubiquitous, and immediate qualities of data visualization in an information society reinstantiate the "classical immanence of the divine in the world" [26]. Both M87 and Gargantua result from reductions of information too vast or abstract to communicate, and on Halpern, Bratton, and Konior's terms, M87 and Gargantua are realistic algorithmic images of an information society. As a subjective correlation, perhaps the ecclesiastic reverence that M87 inspired in popular media derives from the sublime reduction that the image is performing, where petabytes of data are compressed into an intelligible algorithmic representation. Facing the paralysis of big data, algorithmic images and simulations can divine the realistic signal from the ocean of noise, and judging an image by the efficacy of its simulation can be a pathway for the viewer to accept the image as realistic, even in the absence of any perceptible phenomenon to compare it to.

CONCLUSION

It would be simple and cheap to make a counterfeit of the M87 image in Adobe Photoshop, and the producers of *Interstellar* could have sacrificed their adherence to scientific laws and made Gargantua from concept art and conventional 3D animation. While the visual difference from these shortcuts might not be easy to see, the claim to truth and realism would be lost. Both the M87 and Gargantua images sought to visualize something inaccessible to direct human observation, and to justify their realism, the authors published their algorithmic processes. Both involved the simplification of complex information into visually intelligible images, motivated by a compact between author and audience that this is what a black hole "would really look like." By having the audience trust their algorithmic methods, the authors achieve a form of evidentiary realism that Photoshopped counterfeits would not. The M87 image is a consensus average from petabytes of radio telescopic data, and Gargantua abides by the rules of Thorne's equations. Various scholars have argued that in an information society, realism is achieved by extracting signal from noise and balancing algorithmic simplification against aesthetic communication. In this paper, I have shown how these two images crystallize this notion of contemporary realism by providing a visual representation of unobservable phenomena that both the author and audience trust to be realistic.

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