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Black Holes and Objectivity

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Abstract
The first ever direct image of a black hole, released in April 2019, was a paradigm shift not just in scientific imaging, but also in the cultural appreciation of the unknown. Its realisation demanded a global technological collaboration on hitherto unseen scales and also the application of new and rigorous forms of objectivity. This text discusses how complex and esoteric planet-wide scientific apparatus and observations at the cutting edge of fundamental science demand a heightened awareness of objectivity and the implementation of transdisciplinarity.

Keywords
Black hole, objectivity, observation, physics, Galison, networks

Agujeros negros y objetividad

Resumen

La primera imagen directa de un agujero negro, tomada en abril de 2019, representa un cambio de paradigma no solo en lo que respecta a las imágenes científicas, sino también en la apreciación cultural de lo desconocido. Para lograr este hito fue necesario contar con una colaboración tecnológica global a una escala nunca vista, así como la aplicación de nuevas y rigurosas formas de objetividad. Este texto quiere reflexionar sobre la necesidad de que los complejos y esotéricos aparatos y las observaciones científicas de la ciencia fundamental más recientes vayan acompañados de una mayor conciencia de la objetividad y de la implementación de la transdisciplinariedad.

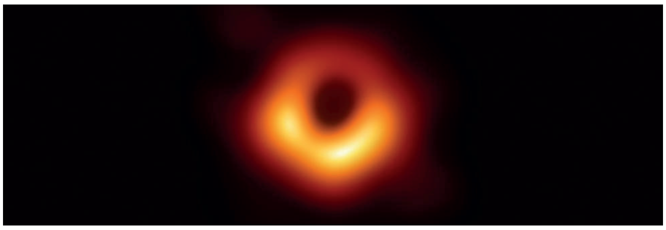
Palabras clave

Agujero negro, objetividad, observación, física, Galison, redes

The Black Hole in M87

Over the past century we have witnessed certain paradigm changes in how we observe and understand the Universe. Each has simultaneously overturned and built on established scientific theory that went before them, theories that also worked perfectly well for the purpose. Some of these accurately describe phenomena and properties at observable and/or tangible scales, while we also understand that they do not provide a complete picture of nature. One of the fundamental questions in physics is how to unify general relativity and quantum physics. There is one partly understood cosmological phenomenon which lies at the heart of this question, and whose study may be able to provide insights into this reconciliation; and those objects are black holes.

Earlier this year, in April 2019, we were enthralled by the first ever image taken of a black hole. This incredible image was produced by a team of 200 scientists from 59 institutes across 18 countries drawing on data collected by eight telescopes located in Hawaii, the Atacama desert and the South Pole, amongst others. This global network of radio dishes is known as the Event Horizon Telescope (EHT), referring directly to its mission to directly observe the immediate environment of a black hole, and effectively creates an Earth-sized interferometer which exploits the rotation of the planet. The black hole imaged by the EHT is located at the centre of Messier 87, a massive galaxy in the nearby Virgo galaxy cluster, 55 million light-years from Earth and having a mass 6.5 billion times that of the Sun. However, in the image we are not actually seeing the black hole, we are seeing its shadow, surrounded by an asymmetric emission ring with a diameter of 0.01 light-years. This distance is equivalent to 632 astronomical units, or 58.8 billion miles, or more than 14 times the distance of the Sun to Pluto. The bright crescent shape visible in the image is due to the black hole's rotation. It is not an image of a black hole, it is an image of the phenomena surrounding and produced by a black hole. If immersed in a bright region, like a disc of glowing gas, we expect a black hole to create a dark region similar to a shadow — something predicted by Einstein's general relativity that we've never seen before, explained chair of the EHT Science Council Heino Falcke. «This shadow, caused by the gravitational bending and capture of light by the event horizon, reveals a lot about the nature of these fascinating objects and allowed us to measure the enormous mass of M87's black hole.» [1]



Using the Event Horizon Telescope, scientists obtained an image of the black hole at the centre of galaxy M87, outlined by emission from hot gas swirling around it under the influence of strong gravity near its event horizon. Credits: Event Horizon Telescope collaboration et al.

At the same time that the EHT was imaging the object, several NASA spacecraft were also observing the black hole using different wavelengths of light. The Chandra X-ray Observatory, Nuclear Spectroscopic Telescope Array (NuSTAR) and Swift Observatory space telescope missions, all looked at the object with different varieties of X-ray light. Meanwhile the Fermi Gamma-ray Space Telescope was also watching for changes in gamma-ray light from M87 during the EHT observations. If EHT observed changes in the structure of

1. (https://eventhorizontelescope.org/press-release-april-10-2019-astronomers-capture-first-image-black-hole)

the black hole's environment, data from these missions and other supporting telescopes could be used to work out what was going on. The scale and complexity of this observation, and the processing of the data into the image, is breathtaking.

So the image produced by this mammoth observation throws up some very interesting and intricately linked issues. Some of these issues relate to how we see the data we get from scientific observation, and how we deal with very real 'filters' and 'lenses' that might colour our perceptions. Others relate to the complexity of experiments at the edges of fundamental physics and the transformation of the planet into a vast and interconnected sensory system. By focussing on some of the interesting and challenging notions thrown up by the incredible achievement of imaging the black hole in M87, maybe we can shed some light on how these factors shape our culture and our sense of reality.

Mechanical Objectivity

The philosopher of science, Peter Galison has discussed in great depth how these forms of complex observation would be possible via the achievements of large-scale scientific, and transdisciplinary collaborations. He was also concerned with how languages could be developed that would connect scientific subcultures and establish 'trading zones' where ideas and perceptions and methodologies could come together.[2]

Through exploring the complex interactions between the three principal subcultures of physics; experimentation, instrumentation, and theory, and applying his own philosophy of interpretations he has discussed how the image of the black hole in M87 was produced and the efforts to eradicate unwanted human subjectivity in the analysis and development of it. His particular interest in black holes, incidentally, led him to be one of the founder members of the Black Hole Initiative, an interdisciplinary program at Harvard University that includes the fields of Astronomy, Physics and Philosophy, to focus on the study of black holes.[3]

The black hole offered a particularly obtuse challenge, namely how to image something in the visual realm from which light does not escape. This conundrum challenges not just the technical and experimental prowess of the scientists and engineers involved, but also the philosophical factors of how our desire to see something can colour the way we see it. Members of the EHT board expressed the difficulties of being sure of the image they had from their own perspectives;

> *«Once we were sure we had imaged the shadow, we could compare our observations to extensive computer models that include the physics of warped space, superheated matter and strong magnetic fields. Many of the features of the observed image match our theoretical understanding surprisingly well," remarks Paul T.P. Ho, EHT Board member and Director of the East Asian Observatory. "This makes us confident about the interpretation of our observations, including our estimation of the black hole's mass.»* [4]

As humans, the overwhelming majority of us need our information to be presented to us in visual form. As still or moving images that allow us to project ourselves into their representation. Unfortunately however, most scientific data comes in the form of numbers, graphs and spectra. Therefore, the ways of seeing and translation become critical territories. As part of our evolution for survival our brains have become trained to interpret patterns and recognise known things from basic and incomplete inputs, and this instinct subconsciously colours just about all of our visual language. It is difficult to bypass seeing what we know and to just see. Lorraine Daston talks of a question "framed in neo-Kantian terms: Was there or was there not such a thing as scientific observation uncontaminated by theory? This was a question posed against a background of fears about how preconceived ideas, wishful thinking, and other subjective 'lenses' might 'filter' or 'distort' objective empirical results".[5]

In order to avoid this risk of seeing what we want to see, of seeing what we see as opposed to what we know, the idealised image of a thing, Galison developed and updated the idea of 'mechanical objectivity'. In his view, trained judgment supplemented mechanical objectivity, recognising that, in order for images or data to be of any use, scientists needed to be able to see scientifically; that is, to interpret images or data and identify and group them according to particular professional training, rather than to simply depict them mechanically. Objectivity now came to involve a combination of trained judgment and mechanical objectivity.[6]

Mechanical Objectivity is in many ways a reaction to the modes of scientific observation and visualisation of the 18th and 19th century, where it was common to represent an idealised form of the object rather than its true character as seen at that moment, for that individual data set or observation. The purpose of these forms of imaging were to standardise the observing subjects and observed objects of the discipline by eliminating idiosyncrasies, not only those of individual observers but also those of individual phenomena. While this might work averaged out over huge data sets, it gives us no real clues as to

2. Galison, Peter. "Trading with the Enemy". Trading Zones and Interactional Expertise: Creating New Kinds of Collaboration, edited by Michael E. Gorman, MIT Press, 2010
3. https://bhi.fas.harvard.edu/
4. (https://eventhorizontelescope.org/press-release-april-10-2019-astronomers-capture-first-image-black-hole)
5. Daston, Lorraine. "On Scientific Observation". Isis, Vol. 99, No. 1, 2008
6. Dason, Lorraine and Galison, Peter. "The Image of Objectivity". Representations, No. 40, Special Issue: Seeing Science. University of California Press 1992

how individual variations and particular phenomena really are. It also tempts us to cheat the data, a subjective and idealised approach over a truly objective one. However, certain visionaries such as the French physiologist E.J. Marey in the late 19th Century began to realise that this approach would quickly prove inadequate and foresaw the use of machines to aid us in our interpretations. While the phrase *'Let nature speak for itself'* became something of a motto of a new brand of scientific objectivity, Marey and his contemporaries turned to mechanically produced images to eliminate suspect mediation. Employing polygraphs, photographs, and a host of other devices they sought to free scientific observation from human interference.

Fast-forwarding 150 years, in his lecture 'The Philosophy of the Shadow', Galison discusses how mechanical objectivity was employed in his work involved in the development of the image of the black hole in M87. The petabytes of data accumulated through the observation was first resolved into a fairly noisy 'dirty' image. The challenge was then to remove the noise, improve the resolution and deliver the final, more accurate version. The traditional method in astronomy is to use a process succinctly called 'Clean' which involves iterations of Fourier transforms, centring, blurring and trimming. This is a highly effective method for point sources when performed by highly skilled operators with previous knowledge of what they are looking for. It works well for objects we reasonably understand and have seen before; stars, galaxies, etc. However, it can also tend to build in the idiosyncrasies of the operator. For the image of the black hole the problem was deepened by there being absolutely no prior information on which to build the analysis, and the scope for assumptions based on best guesses became huge. So, how can you bring together enough assumptions to bring something out of the dirty image without those assumptions colouring what it is you want to find?

By sharing out the same data sets to different groups, and by asking them to apply all the processing tools at their disposal, while being prepared to reveal something they weren't necessarily expecting, Galison proposed that the truth of the image would come out. They believed that if differing resolutions were achieved, the points at which they coincided would tell them what they could actually believe. Eventually through iterations of isolated working groups, application of different processing algorithms and comparisons of results, an application of mechanical objectivity revealed the famous image of the black hole that was transmitted around the world on April 10th 2019.[7]

This dedication and rigour to produce accurate and representational visual artefacts can be contrasted with the less precise processes that underpin them. Science (and also philosophy) employ models, idealizations, metaphors and thought experiments that are for all intents and purposes separate from truth in order to achieve other cognitive ends. While the scientific objective may be to achieve the truth, argues Catherine Elgin, the relation between truth and epistemic acceptability is both more tenuous and less direct than it is standardly taken to be. Sometimes it is epistemically responsible to prescind from truth to achieve global cognitive ends.[8] Therefore we can see that the methodology of extracting 'true' images from imprecise assumptions can often be complicated and weighed down by human subjectivity. It is striking that the production of the image of the M87 black hole has embraced a scientific and philosophical approach in order to render it as accurate as possible and to bypass such lenses and filters.

The Earth as Complex Instrument

As we strive to understand the Universe, its scope, its beginning and its probable end, we use an ever more complex suite of ever larger instruments, hidden in ever more inaccessible and exotic places. We have accelerator and detectors hidden underground, about 100 m underground next to the Jura mountains at the Large Hadron Collider at CERN, Geneva. Embedded 2.5 kilometres down in the Amundsen-Scott South Pole Station in Antarctica at the Geographic South Pole is the IceCube Neutrino Observatory. In space we have the Hubble telescope, radical missions such as the solar probe Parker, LIGO/Virgo, as well as the aforementioned terrestrial observatories. In the high desert of the Atacama in Chile we have the European Southern Observatory where we find the Very Large Telescope, the Atacama Large Millimeter Array and the High Accuracy Radial Velocity Planet Searcher, amongst others. Similar research and observation sites are spread across the planet in distant and surprising locations. This massive infrastructure, hidden from everyday spheres and lives is what is observing and measuring our existence and sense of reality. They are the mysterious and secretive nodes of a planetary techno-consciousness and the infrastructure of knowledge capital.

The German media philosopher Erich Hörl talks of the becoming-technology of the environment, and cites *'Environmentality' as the dominant form of governmentality in the age of the Technocene.* What he refers to with this terminology is the total technological deployment of sensors into the environment – or earth – and this process being so pervasive as to contribute to the development of a new contemporary rationality of power across the globe.[9] What we are talking about here is a subtle alteration of how we see and use the Earth. The ubiquity of large scale scientific infrastructure across the globe creates a shift in our human relationships with nature, establishing the planet as oracle and test site at the same time. Concurrently the creation

7. Galison, Peter. Inaugural Yip lecture, Harvard CMSA, April 2019).
8. Elgin, Catherine Z. "True Enough". Philosophical Issues 14. 2004
9. Hörl, Erich. "Introduction to General Ecology: The Ecologization of Thinking". Bloomsbury Academic. 2017

and dispersion of new knowledge becomes the product of a global network with its own social and political responsibilities and nuances.

Through this total technological deployment of sensors into the environment we are attempting to unravel the mystery of who and what we are, where we come from and where we are going. A profound expression of human curiosity. By simulating the physics as close as possible to the Big Bang, by projecting into the future of the Universe while simultaneously looking back in time, and by probing into the nature of matter until matter itself begins to disappear, we reveal and pick apart what reality really is. Through science of this magnitude, across distances and times and scales, we distinguish ourselves ontologically. Modifying and enhancing our environment in order to understand how we got here, and maybe even if it actually means anything. These are all experiments way beyond the human scale.

The experiments around the LHC at CERN are 100 metres below the ground and occupy caverns of enormous size. The beam tubes are the emptiest space in the solar system, at times 100,000 times hotter than the Sun, or colder than outer space. It is the most powerful computer ever built. The beam tubes at LIGO are 4 kilometres long. When one instrument is not large enough, and therefore sensitive enough, in isolation it is networked with others around the globe. The planet Earth becomes the scale and the site of the experiment. Studying the Universe through interferometry, through particle collisions, through gravitational waves, and deciphering the information gleaned by these technologies requires new ways of seeing, and new ways of studying the nature of being.

> *«The IceCube Neutrino Observatory represents one of the largest, strangest, and most complex collaborations in the history of scientific research. The collaboration essentially spent 300 million dollars to stare into ice. Nostradamus stared into Obsidian. Hamlet scryed a cloud. Like so many ancient forms of crystallomancy, hydromancy, and geomancy, the IceCube apparatus captures visions of another world in a translucent body. Visions looking both forward and back: tracing the outlines of dying stars millions of light-years away, or looking beyond the cosmic microwave background to see the first 380,000 years of the Cosmos.»* [10]

The proliferation of particle accelerators, deep space probes, neutrino traps, dark matter detectors and networked observatories effectively extends our human sensory cortex across new domains and dimensions. While our scientific advancement has led us to apply the study of subatomic particles, the phenomena of fundamental physics, to model exotic states or properties of materiality (of matter), to reproduce at some scale the conditions of the Big Bang and to depict black holes, our infrastructure has grown to opposite extremes. It seems that the smaller, and more esoteric our targets become, the larger and more powerful becomes the apparatus we use to study them. Thus our relationships with nature are ever more mediated through technological apparatus of a scale and complexity that most of us are unable to grasp. We cannot continue viewing fundamental research stations as isolated nodes while contemporary cutting-edge science demands networks, interactions and the transcending of disciplines. The siting of this machinery in exotic and far-flung locations adds to its sense of mystery, almost bestowing magical properties. How do we get meaning out of these machines? In what format does it arrive, and how to we read it?

Human Cultural Reactions

There has been a transition in the notion of the sublime; from a phenomenon of our relationship with nature to one of our relationship with technology. More succinctly in many ways we find ourselves in the sublime of technologised nature. Before it was nature that awed us, that stirred a primal fear due to its great unknowns wrapped up in its great beauty. Now, as we begin to believe that we understand nature, to be in control of it, our awe and fear, with a generous hint of expectation and again a sense of beauty, has shifted to technology. That other great power that nurtures and enables us whilst suggesting that it has become much bigger and more powerful than we can understand. Our creation has outgrown us and now dominates us. The possibilities suggested by Artificial Intelligence, genetic engineering and geophysical manipulations are beyond our common understanding and thus beyond our general control. Technology has become unknowable and exerts power over us. That advanced technology we feel in control of, such as the detectors found around the LHC, produces abstract information that borders on the esoteric. The tangible unknowable begets the intangible unknowable. Technology manifests magnificence and we submit ourselves to it. It is awesome, overwhelming and alluring.

This uncertainty, fear and awe we feel when confronted by big technology pulls us in and inexorably draws us towards it. As we once did exclusively with nature, we actively seek out those experiences bigger and more powerful than us. Witness the thousands of people that attended the Apollo and later Space Shuttle launches, the droves that attend a large scale demolition, that are beguiled and fascinated by the scale and scope of CERN. As historian David Nye points out, by attending these quasi-religious events «the event is less a matter of spectatorship than a pilgrimage to a shrine where a technological miracle is confidently expected». The metaphor of high technology as god is tired and overworked, but it is easy to see how it came about. [11]

10. Thomson, Jol. "Ve Vm Vt. The Ideal Cosmic Messengers". Technosphere Magazine. November 2016
11. Sacasas, LM. "The Technological Sublime, Alive and Well". April 2012

These massive, intra-planetary scientific constellations are probing the Universe across space and time with more power and high resolution than we have ever known. The phenomena we are able to predict, search for and observe are increasingly difficult to pin down. Too small, too fleeting, to distant, too unknown. All too often the data we are receiving does not match anything we have seen before and requires a rigour of perception and interpretation beyond what was previously required. This is not to say that previous grand breakthroughs in observational science were easy; the discovery of bacteria and the heliocentric nature of the Solar System, for example, required great minds, great imaginations and refined instruments. But the hunting for exoplanet atmospheres, for neutrinos, for the nature of dark matter and for imaging black holes requires instrumentation and imagination right at the extreme of human capacity. So much so that the realisation is finally becoming accepted that without the application of philosophy and culture to the problems they will be very difficult to solve and even harder to make sense of.

It is interesting to consider a certain resetting of objectivity over the past 200 years, as not just the precision of measurement has needed to be constantly refined, but also the way we interpret it. From the 'truth to nature' approaches of the early 18th Century, through the development of mechanical objectivity, and finally to what we refer to as trained judgement. While such methodologies are being employed widely across all kinds of data sets from all kinds of experiments, the image of the black hole in M87 released to the world on 10th April 2019 was the moment when we were all thrilled, enlightened, and certainly awed by the results of contemporary scientific objectivity.

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CV

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Andy Gracie works across various disciplines including installation, robotics, sound, video and biological practice. This work is situated at a point of separation between the arts and the sciences, creating situations of exchange which allow new understandings and knowledge systems to develop. Much of his work involves reactions to and engagements with the science of astrobiology and other forms of space research. He looks at space as a non-human and unfeeling environment, balancing wonder with awe and fear. His practice employs scientific theory and practice to question our relationships with exploration and experiment whilst simultaneously bringing into focus the very relationship between art and science, and how new knowledge is culturally assimilated. Much of the work also features an ongoing engagement with semiotics, simulation theory and apocalyptic scenarios. His work has been exhibited widely and internationally in both solo and group shows and has included several special commissions for new works. He presents regularly at conferences and seminars across the globe and has published a number of articles and papers. His work has received honourable mentions from VIDA and Ars Electronica in 2007 and Ars Electronica in 2015.

CV

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Mónica Bello (born 1973) is a Spanish curator and art historian. Over the last 12 years she has focused on the multidisciplinary perspectives and the narratives of today's techno-scientific culture. In her curatorial research and projects she discusses the way artists instigate new conversations around emergent phenomena in our society and culture, such as the role of science and new knowledge in the perception of reality. She is currently the Head of Arts at CERN at the European Organization for Nuclear Research in Geneva, where she curates the research-led artistic residencies and the new art commissions that reflect on the conversations and interactions between artists and particle physicists. Prior to her arrival to Geneva she held the position of Artistic Director of VIDA (2010-2015) at Fundación Telefónica, Madrid (Spain), a pioneering award that fostered cross cultural expressions around the notion of life. She initiated and ran (2007-2010) the Department of Education at Laboral Centro de Arte, Gijón (Spain). She has curated exhibitions and events internationally with contemporary artists, creators and thinkers of different disciplines. As an internationally recognised figure within art and science networks, Bello is a regular speaker at conferences and participates in selection committees, advisory boards and mentorship programs.