Brian Cox and the New Enlightenment

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Abstract:

This paper studies the Royal Society's public rhetoric of science by analysing Brian Cox, whose rise to science prominence corresponded with his period as a Royal Society University Research Fellow from 2005 to 2013. The first study to address this major figure in popular science, the paper analyses his goals and methods in light of the 'new Enlightenment' that was advocated by the Society's then President, Paul Nurse, in 2012. Like the founders of the national science academy in the 1660s, Nurse hailed Francis Bacon as a lodestar when it comes to inspiring awe and respect of rationality and of what science can do both in Britain and globally. Appointed as the Society's first Professor for Public Engagement in Science in 2015, Cox has worked to achieve the Society's goals of creating enthusiasm and 'demonstrating the value of science to everyone'. He has also been instrumental in recruiting more young people to pursue a career in science. Through rhetorical analysis of a lecture video and other online material, the paper identifies some key features in his style of performance, especially regarding his methods of producing awe and wonder.

Keywords: rhetoric of science; popular science; public understanding of science; science communication; philosophy of science.

Introduction

This paper discusses the public rhetoric of the British particle physicist Brian Cox (b. 1968) by analysing a selection of material, including some live recordings, produced in the ten-year period from 2007 to 2017. A Professor at Manchester University and researcher at CERN, Cox is best known for presenting the BBC TV series *Wonders of the Solar System* (2010) and *Wonders of the Universe* (2011), and for co-authoring bestsellers like *The quantum universe* (2011) and *Universal: a journey through the cosmos* (2016).[1] Since 2015, he has acted as the Royal Society's Professor for Public Engagement in Science, the first to hold this special position in a national academy representing all areas of science, technology, engineering, mathematics and medicine. The essay will discuss his aims and methods in light of both the Society's official communication strategy and such forms of public address as former President Paul Nurse's lecture on 'The new enlightenment', which was broadcast on BBC One on 28 February 2012.[2] Cox is an important figure to consider both in a recent historical perspective and in view of the Society's long tradition of seeking to persuade audiences and win public support, a tradition that began with the publication of *The History of the Royal Society* by Thomas Sprat in 1667.[3] As several scholars have noted, there is a scarcity of

historical studies of late-modern popularization, which may encompass both popular science and science in popular culture.[4] As a performer and TV presenter, Cox may be said to transverse between those categories, at one time even guest starring in a toy version on *Postman Pat*.[5] I shall be looking at his achievements with the eyes of a rhetorician, presenting an analysis that will hopefully be of interest to science historians: an analysis of Cox as a highly successful embodiment of the Royal Society's longstanding tradition of public engagement. Because he has been formally appointed to inspire enthusiasm and support among lay audiences, he might also be subject to contextual studies in the field of research known as PUS (public understanding of science). The main purpose of this paper, however, is to demonstrate that he merits special attention from the perspective of rhetoric of science, a field of textual criticism that may overlap with both history of science research and PUS.

In an influential essay published in 1986 and reissued in 1998, Jeanne Fahnestock observed that most of the rhetoric of science scholarship had focused on scientific writing or communication among peers, and not on material that has been accommodated to a general readership.[6] Since then, there has been a growing body of rhetorical criticism.[7] Yet there may still be a need for more work addressing the problem that Fahnestock identified in the 1980s and 90s, which is a problem that has not become any less noticeable in recent decades, namely that: when science is popularized, this usually implies a shift away from the 'forensic' or pro- and contra-oriented style of argumentation that dominates in academic publications.[8] Instead, one will employ a mode of communication that involves demonstrative praise, known as 'epideictic' speaking in the classical rhetorical tradition. This shift of genre can have some serious consequences, because the scientific findings might then appear as something to be celebrated rather than evaluated.[9] Such ceremonial rhetoric may also dominate in science communication at an institutional level. In a study of John H. Marburger III, science advisor to George Bush in the 2000s, Lisa Keränen and others have critiqued the idea that was communicated, as it were, from above, about how science can provide a plain and neutral path to both rational truths and economic prosperity, provided that this path is kept free of politics and any unfounded beliefs.[10] Adding to Keränen *et al*., one might argue that this view of science constitutes an ideology in its own right, an ideology that draws on values inherited from the Enlightenment period, which has been thought to have furthered 'the disenchantment of the world'.[11] Major historians of science such as Peter Dear have challenged the idea of the Enlightenment as 'an unambiguous triumph of rationality over obfuscation' and indeed of modern science as 'a neutral and inevitable product of progress'.[12] Arguably, popular science still tends to draw on ideals inherited from a past era, telling progressivist stories about revolutionary and wonder-inducing breakthroughs. Alan G. Gross, a leading figure in rhetoric of science, has claimed in *The scientific sublime* (2018) that 'popular science unravels the mysteries of a universe' in a way that recollects eighteenth-century modes of worshipping the sublime wonders of nature.[13] Another important monograph in recent rhetoric of science scholarship is Leah Ceccarelli's *On the frontier of science* (2013), which criticises the heroic and patriotic metaphors of scientific exploration in twentieth-century America.[14]

This paper examines a voice for British science that might be characterized in equal terms as being overly epideictic and patriotic. Over the years, Cox has joined the Society's Presidents—from Martin Rees, via Paul Nurse to Venkatraman 'Venki' Ramakrishnan—in describing the UK as 'a global scientific powerhouse' and 'a world leader' in research and

innovation.[15] When Cox took up his post as Professor for Public Engagement, he made it clear that the British are justified in claiming that 'we are a global scientific powerhouse; more efficient than any of our international competitors', given that, as the press release dated 30 January 2015 stated, 'the UK currently has 1% of the world's population, 3% of the investment in science and produces 14% of the highest impact research papers'.[16] His role would be to secure general support of an increased GDP investment, to help the UK 'really capitalise on its world leading position', an ambition that was seconded by Nurse, the Society's then President.[17] In a way that illustrated the sociologist Robert K. Merton's famous paradox about the 'competitive cooperation' in science, Nurse in 'The new enlightenment' had previously encouraged his fellow scientists 'to think big, bigger than our competitors' and 'to convey the wonder of science, and what it contributes to our culture and our civilization'.[18] Referring back to the great ages of exploration and innovation, he said: 'We need a new Enlightenment, an Enlightenment for the 21st century, and Britain is the place to do it with its history of freedom, rationality, and scientific achievement'.[19] He further argued that 'we should reawaken the spirit of the Enlightenment' and 'revive the energy of the Industrial Revolution'.[20]

Such references to achievements in the past have been a very distinct feature of the Society's public rhetoric. Marking the Society's 350th Anniversary in 2010, astrophysicist and then President, Martin Rees, wrote that Francis Bacon thought science should be driven by 'the search for enlightenment' as much as 'the relief of man's estate'.[21] Just as Hooke, Boyle, Wren and the other founding members of the Society were motivated by the legacy of Bacon, scientists today should seek inspiration in the founders' 'curiosity and enthusiasm' and 'broad engagement with society and public affairs', which ranged from 'the rebuilding of London after the Great Fire' to 'the exploration of the New World'.[22] These gentlemen 'sought enlightenment: they were, in Francis Bacon's phrase, "merchants of light"', Rees argued, insisting that 'some values endure' across all historical changes.[23] His successor, Nurse, has similarly traced the 'enlightened' outlook back to this early period: 'In England at the turn of the seventeenth century and the beginning of the Enlightenment, Francis Bacon, courtier, statesman and philosopher, laid out his approach to science'.[24] While this tendency to conflate the search for enlightenment with the Enlightenment period properly defined seems anachronistic, the verbal echoes can offer fascinating materials for rhetorical study. Those familiar with seventeenth-century rhetoric of science might be struck, for example, by the similarities of expression between present-day publicity and propagandistic publications such as Sprat's *History of the Royal Society* from 1667. Hired to promote the new 'experimental knowledge', Sprat promised that its proponents would fulfil 'Lord Bacon's' plan of destroying the 'false superstitions' that were lying 'like Monsters in their way'.[25] Cox employed some very similar metaphors in his Faraday Prize lecture, 'Making Britain the Best Place in the World to Do Science' at the Royal Society in 2013. Looking ahead to the next general election in 2015, he hoped the leader of the winning party would proclaim that: 'An educated and informed population is the only way to finally banish the demons of superstition that have been hiding in the darkness'.[26] Popular science evidently plays an important part in this project of enlightenment. After having reviewed the candidates for the 2017 Science Book Prize, Cox said that he considered all of them as 'a vital part of the battle to reestablish the factual world, which is the one we all live in whether we like it or not'.[27] As Professor for

Public Engagement in Science he has been assigned with four tasks, all of which may be said to relate to this 'battle to reestablish the factual world':

> Contribute to a greater public understanding of science and the importance of experiment, evidence and understanding uncertainty; Increase public understanding of scientific issues which inform policy debates on important issues; Engage with the public to strengthen the case for increased support for science; Stimulate greater public interest and enthusiasm for science.[28]

While these designated tasks will serve as cornerstones for my discussion, I shall also consider his additional duty of recruiting more young people to careers in science, engineering and technology. When the appointment of Cox was announced in January 2015, Nurse reminded the press that it had been estimated that the UK would need over a million new professionals in these fields by 2020, and that it therefore constituted a problem if science was generally regarded as 'something difficult' that is 'removed from ordinary people'.[29] 'How many of us encourage our children to be a scientist?' he asked rhetorically. As this need to engage more young people has been singled out as a focus area, we shall be paying particular attention to Cox's methods of appealing to young audiences in material such as 'GCSE Science Brought Down to Earth'. This lecture on the observable universe was given to visiting schoolchildren and their teachers at Manchester University on 8 June 2011, a video recording also being made available online. As part of his lecture, Cox showed the schoolchildren a historical video clip of 'a brilliant teacher and a brilliant lecturer', the American Nobel Prize-winning physicist Richard P. Feynman (1918–1988).[30] Both then and on later occasions, such as the Starmus festival in 2016, Cox has embraced Feynman's view of scientific method as a wonderfully simple but satisfying procedure of making guesses and checking them through experimentation.[31] Nurse took a similar 'down-to-earth' approach in 'The new enlightenment', arguing that 'there is a little bit of the scientist in all of us, especially when we are children', for, as he said, doing science is nothing more mysterious than 'to observe, to experiment, to think, and to try and understand'.[32] A Nobel Prize-winning geneticist, Nurse claimed his 'passion for science' began when at the age of nine he spotted an unusually bright and rapidly moving 'star': Sputnik Two.

Both as a pedagogue and popularizer, Cox has paid tribute to the Society's longstanding commitment to 'curiosity-driven research', exhibiting enthusiasm for topics outside his research specialism.[33] Like Feynman, he has cultivated a form of address that makes each member of his audience feel they are being personally addressed and treated with respect.[34] As *The Guardian*'s reviewer noted after having watched 'Professor Brian Cox Live', the thing that he appreciated the most was 'not to be talked down to'.[35] The essay will consider Cox's methods of winning the audience's good will and attention; described under the heading of *captatio benevolentiae* in the classical rhetorical tradition. According to the Roman rhetorician Quintilian, the aim of all oratory should be 'to instruct, to move, and to delight', which seems highly relevant to discussing the scientist's wish to both educate and entertain, enlighten and enchant the public.[36] The essay will identify the most characteristic means by which Cox has sought to engage the audience, both verbally and visually, through gestures and facial expressions. In addition to the lecture just mentioned, 'GCSE Science

Brought Down to Earth' (2011), we shall be considering the following primary material (in the order in which it appears in the essay): the educational video 'In Search of Giants' (2007); a radio interview on YouTube 'CERN! Prof. Brian Cox Reveals the Truth' (2017); a blog posting on 'The Difference between Science and Entertainment' (2014); and a clip on YouTube with the title 'Professor Brian Cox exposes & destroys One Nation's Malcolm Roberts' (2016). Taken together, this material exemplifies the most important aspects of Cox's public engagement activities, from his earliest attempts to inspire young audiences to his recent interventions in debates about climate change. Another reason for selecting this material is that it has been publicly accessible online for free, thus potentially reaching more people besides those who actively commit to watching a DVD or TV broadcast or getting a ticket for a live performance. The Faraday Award lecture that Cox gave in February 2013 when receiving the Royal Society's communication prize for the year 2012 will also be given special attention, because it gives insight into Cox's political ambition of 'Making Britain the best place to do science'. Additionally, I shall refer to a documentary film from 2008, *Do you know what time it is?* and a podcast episode of the American *Joe Rogan Experience* from 2015. Questions will be raised about the epideictic and patriotic language that is used to promote British science, and the essay will also analyse Cox's methods of winning the audience over. How does he propose to evoke curiosity and wonder? The final part of the essay will consider his somewhat different task of engaging in public debates about issues of great societal concern. I shall argue that the debates about global warming have forced Cox to divert from his preferred mode of speaking.

Throughout the period studied in this essay, Cox has worked to catch the audiences' attention and inspire them, while also aiming to convince them of the importance of public spending on science research and education. One might still ask, however, what makes this particular popularizer special, and how does he fit in with the Royal Society's communication strategy? The next two introductory sections will aim to clarify these questions.

Just Another Celebrity Scientist?

There is as yet no scholarly study dedicated to discussing Cox. Peter Collins in *The Royal Society and the promotion of science since 1960* (2016) only mentions him very briefly, despite his having received an OBE in 2011 for his longstanding efforts 'to publicise science' and also the Michael Faraday Prize in 2012 for his 'outstanding achievements in popularising science' and his 'dedication to influencing politicians and science funders'.[37] This popular and highly professional communicator can be argued to personify all of the skills that Bruno Latour has considered vital for scientific research and institutions to be allowed to continue, including not only various technical, professional and collaborative skills, but even those of handling the media and catering for 'the public representation of science'.[38] One of Cox's greatest strengths is that he can explain extraordinary breakthroughs in language that is easily understandable, while at the same time managing to emphasize the sensational value of science. When the discovery of the Higgs Boson was announced in July 2012, he described it as 'one of the biggest scientific discoveries of all time' and claimed it was 'not too hyperbolic' to say that it represented another step on 'the road to civilization'.[39] His various TV successes have further testified to the shift that has taken place in Britain and elsewhere, whereby scientists no longer serve only as sources to be interviewed, but as broadcasters and

presenters in their own right.[40] Many of the best-known presenters and science writers have come from the field of physics, among them Stephen Hawking, Brian Greene, and, most recently, the Italian, Carlo Rovelli, whose *Seven brief lessons on physics* has been translated into forty-one languages.[41] It may seem paradoxical that this is a field that is considered to be less accessible and therefore more difficult to communicate than any other science.[42] Indeed, historian of science Bernadette Bensaude-Vincent has argued that the developments in physics after Einstein created an increased gap between science and the public, or between those who were able to master the mathematics required and the rest of the population, whose common-sense views of the physical reality were no longer to be considered valid.[43] Perhaps for this very reason, contemporary physicists have had to make exceptional efforts to perfect a second language for use with popular audiences. According to Neil deGrasse Tyson, 'we learned earlier than in other fields the general value of bringing the fruits of our research to the public,' his case in point being the way in which Carl Sagan was able to capture the popular imagination with the *Cosmos* series in the 1980s.[44] When this documentary was first broadcast in 1980, Sagan's colleagues criticised him for appearing on popular talk shows such as *The Tonight Show*, but when they saw their budgets rise this changed, Tyson has said.[45]

Cox is clearly riding on a wave that, according to Lynda Walsh, was set in motion by figures such as Sagan, Hawking and Stephen Jay Gould.[46] Nevertheless, Declan Fahy has suggested in a study of *The new celebrity scientists* (2015) that Cox represents something new compared to the names just mentioned and present figures such as Brian Greene, because 'he is the first star scientist to emerge from within a developed celebrity culture', referring to Cox's former career as a keyboardist in the bands Dare and D:Ream.[47] Besides labelling Cox as 'a telegenic salesman for wonder, a machine-tooled mouthpiece for the glory of science', Fahy does not, however, discuss him any further.[48] Nor does Cox figure in any of the existing rhetoric of science scholarship. The presenter of the *Wonders* series is not featured in Gross's study of *The scientific sublime* either, a book discussing the wonder-inducing efforts of Feynman, Steven Weinberg and Lisa Randall, in addition to Greene and Hawking.[49]

When compared to other British scientists that have held a high public profile, Cox has been less controversial than, for example, the evolutionary biologist and self-declared atheist Richard Dawkins, who served as the first Professor for Public Understanding of Science at Oxford from 1995 to 2008.[50] Cox's level of engagement with the UK's national science academy also makes him stand out from the number of popular scientists that were interviewed by Paul Merchant for *National Life Stories* at the British Library in 2015 and 2016.[51] These interviews led Merchant to correct the common assumption that popularization is an integral part of doing science and of doing service to the scientific community. For when he asked what motivated his interviewees to become active in writing popular books and participate in the media from the 1980s onwards, they were not necessarily concerned with making lay audiences see the value in continued or increased public spending on science research and education. Instead, the reason why they decided to become publicly visible could quite simply be that they enjoyed the attention or found some other personal satisfaction in it.[52] Although this paper does not consider any comparable material revealing Cox's inner motivations, the fact that he has labelled himself 'a political animal' indicates a different level of ambition, as does his constant participation in various hands-on activities such as political

lobbyism and school visits.[53] The statement that he gave when he took up his new position with the Society may provide further evidence of his personal dedication:

> In my new position at the Royal Society, I want to help change the perception of science. I want to see our great cultural and scientific institutions—the universities, the learned societies, museums, schools, the BBC—work together to raise the cultural and political profile of science, research and education. I want to see our investment in science, and particularly in young scientists, rise to levels at or beyond our competitors. I passionately believe that science can be a vehicle for the redistribution of opportunity in our society as well as a driver for economic growth.[54]

Repeating the first-person pronoun at the start of each sentence, he made use of *anaphora*, a stylistic device that has a long history in political oratory. Here it reinforced his message that 'the UK must aspire to be the best place in the world to do science', a message that he has voiced on various previous occasions and that has also been adopted by several politicians.[55] In terms of societal impact, the 'Brian Cox effect' has been argued to have contributed to 'a boom in maths and sciences at A-level' since 2011 and an increase in university physics applications by more than fifty per cent.[56] According to the School of Physics and Astronomy at Manchester, physics is no longer to be considered as 'the preserve of nerds and boffins', because 'Professor Brian Cox has changed this public perception of physics in Britain'.[57] The American Physical Society has accordingly portrayed Britain's unofficial 'face of science' in a way that can make a career in physics appear attractive, even proving that a physics professor can be voted as one of the 'Sexiest Men Alive'.[58]

The most significant aspects of Cox's physical appearance remain to be considered, however, for he tends to use body language very skilfully, as if he were a trained orator or actor. Other popular science presenters such as Sagan have excelled in the same medium and the creation of different types of visual effects was no doubt essential to the success of *Cosmos*. As Karen Schroeder Sorensen has demonstrated in *Cosmos and the rhetoric of popular science* (2017), Sagan managed to exploit both the TV medium and the *kairos* or opportune moment of audience receptivity to the full, presenting a compelling 'enlightenment' narrative about humanity's conquest of the unknown.[59] This narrative was set in the context of the Cold War and the fear of 'nuclear winter', the potential threat of an 'impending apocalypse' underscoring Sagan's urge to travel further into space.[60] Like Sagan, Cox has popularized science in a time of global challenge, inviting his listeners and viewers to share both his fascination with the wonders of nature and his concerns with climate change. Both of these TV presenters could be said to have cultivated a style of communication that seemingly allows their agreeable personalities to shine through and to give an impression that they are one the same terms with their viewers. When discussing Sagan's 'rhetorical art' Sorensen has briefly taken into account how small details about the way he looks (eyes 'squinting', hair whipping in the wind) might play a role in conveying his quizzical yet trustworthy 'everyman' persona.[61] My method of analysis contrasts with this work by paying much closer attention to aspects of rhetorical delivery (*actio*). Whereas the Royal Society has been known to employ spectacle and display to attract various types of audiences in earlier historical periods, I would argue that in our present screen culture there is a renewed emphasis

on delivery.[62] As a performer and an advocate for rational authority, Cox has found a place in a rhetorical culture that is inherent to the science academy. While he is generally capable of securing the audiences' good favour, he also has an insistent manner that has surfaced particularly in confrontations with climate sceptics.

Performing Science

The appointment of Cox in the role of Professor for Public Engagement in 2015 was part of 'a wider grass roots programme' by which the Royal Society sought 'to involve the UK's best scientists in getting the public excited about science'.[63] Why did the national science academy feel they needed to create a designated position for public engagement at this time? The explanation given in Collins's book on *The Royal Society and the promotion of science since 1960* is that the new arrangement represented a culmination of the goals that were set out in a 1985 report known as the Bodmer report, urging that 'the Royal Society should make improving public understanding of science one of its major activities'.[64] Initially, this involved installing a Committee on Public Understanding of Science (COPUS) and a popularization prize, the Faraday Award.[65] The aim at this stage was to convince the scientific community to see the value in public outreach, a goal that, according to Collins, was largely accomplished by the time COPUS was closed in 2002.[66] In the ten-year period that followed, more ambitious goals were formulated, requiring even greater persuasive efforts: first to 'inspire an interest in the joy, wonder and excitement of scientific discovery' among general publics, and then to make sure 'that everyone has the opportunity to appreciate the value of and engage with science, whether through top quality formal education or through other resources and events'.[67] While the arts and sciences taken together had been losing ground to vocational training and applied study programmes since the 1980s, the Society made 'education and public engagement' one of its five strategic priorities.[68] In the strategic plan extending until 2022 the goal of 'demonstrating the importance of science to everyone' was upgraded to one of only three priorities, next to those of promoting excellence in science and supporting continued international collaboration and mobility in the face of the UK's planned exit from the European Union.[69]

Yet how exactly does one go about making people see the value of science or getting them excited about recent innovations and discoveries? The fact that the Royal Society is 'the oldest scientific academy in continuing existence' bringing together 'many of the world's most eminent scientists' does not necessarily draw crowds.[70] Thanks to popular figures such as Cox, however, people have been queuing outside Carlton House Terrace in London to hear him explain why he thinks 'the communication of science is absolutely vital for Britain … and for the progress of our civilization'.[71] The creation of a designated position as Professor for Public Engagement evidently springs from a realization that even if one has a professional Public Engagement Team, a Policy Centre and a team of professionals handling public relations, one might still need someone to engage face-to-face with individual citizens and groups, and especially with schoolchildren or future generations of taxpayers. With the increased demand for accountability and applicability in all fields of research in both the UK and other countries, it is more important than ever for scientists and scholars to appeal to audiences outside the academe.[72] Although, as the ancient rhetoricians reasoned, a good case may speak for itself, the chances of getting support may increase with a good ambassador.[73]

In recent years, the Royal Society has also been looking for new ways 'to excite audiences' and 'reach new audiences' via Facebook, Twitter and a special policy blog, *In Verba*.[74] The Society has been at the very forefront in employing these digital tools, something that has not been recognized in the relevant scholarship.[75] In today's visual and electronic culture, the public rhetoric of science has increasingly taken shape through an ongoing virtual performance on webpages and streamed TV shows or videos.

While assisting the BBC in their mission to 'bring people in' to a variety of science programmes, Cox has also taken part in the tradition for itinerant science, visiting schools and public venues offering 'a flavour of the fun that can be had bringing science to life'.[76] Both of these ideas—of bringing people in and bringing science to life—are pivotal to understanding his methods of introducing his audience to the wonders of science. Whereas Cox has continued to present BBC series such as *Forces of Nature* (2016), his public role has increasingly been performed live on stage, in shows like *Stargazing Live* and the popular BBC live show and radio programme, *The Infinite Monkey Cage*. Hosted together with the stand-up comedian Robin Ince, it recreates the atmosphere of Victorian variety shows and of early modern live performances, examples being the demonstrations of Boyle's air-pump at the Royal Society in the 1660s or the popular lectures on Newtonian science in eighteenth-century coffee houses.[77] When visiting the US in 2015, Cox also found a parallel in the American tradition, describing the 'Monkey Cage' as 'a variety show' like the ones featuring Dean Martin, only that this time it is 'Dean Martin at a PhD, with a bit of singing, a bit of dancing, and a bit of quantum mechanics'.[78] In 2017, he broke his earlier Guinness World Record in ticket sales for a science tour with more than 150,000 tickets sold for *Professor Brian Cox Live*, also with Ince.[79] His biggest success to date, it was followed by another world tour staring in 2019, *Universal: Adventures in Space and Time*. Downplaying his own popularity, Cox has claimed that he really only appreciates the largest venues such as Wembley with its 90,000 seats capacity for providing an opportunity to use a big screen that 'does justice to the astonishing images of the Universe' produced by the Hubble Space Telescope and the now historical Cassini spacecraft.[80] The only real challenge when performing live seems to be that he needs to be able to not only catch the audience's attention but keep it throughout an entire evening. *The Guardian*'s reviewer admitted to being so number-numbed after just one hour of watching 'Professor Brian Cox Live' that he found it difficult to share the physicist's immense thrill that there are actually two trillion galaxies in the cosmos, and not just 350 billion.[81] As Carl Sagan once remarked: 'It's hard to talk about the Cosmos without using big numbers'.[82] Yet Cox's most efficient means of communication might not necessarily depend on big numbers or words, nor even on state-of-the-art visuals, however astonishing they may be. If one studies his stage performances more closely, it becomes apparent that he also cultivates some ancient and basic, but no less efficient, techniques involving the use of his face, voice and hands.

In analysing Cox's style of performance, I shall mainly employ rhetorical theory, also briefly referring to Adam Kendon's *Gesture* (2004), which has previously been used by scholars working with mathematical pedagogy and cognitive science.[83] The analysis may be taken to contribute to a broader, ongoing discussion about the importance of visualization in science education and communication. In rhetorical theory, visible gestures have long been credited with a special power to communicate ideas 'more speedily to the mind' than the

voice, the sense of sight being the 'quickest'.[84] In their book published in 2013, Alan G. Gross and Joseph E. Harmon have studied the close connection between sight and insight, focusing on the numerous ways in which scientists illustrate meaning. While they provide in-depth discussions of both historical and recently developed contexts and tools such as PowerPoint and Internet visuals, they do not take into account the renewed significance of physical gestures in digital and electronic media.[85] According to Gross and Harmon, Martin Heidegger was the first to fully comprehend the importance of visualization in the sciences, his main example being the way in which seventeenth-century physics and astronomy conceived of the world 'as a picture of spatiotemporal magnitudes of motion'.[86] Since Einstein, pictures and visual analogies have become even more indispensable in providing a qualitative understanding of general relativity and the concept of curved space-time.[87] In recent decades, research has also been done on the way in which scientists employ gesticulation. Whereas rhetorical theory has tended to highlight the special power of gestures to convey feelings and 'excite similar, or analogous emotions' in the listeners, research in cognitive science has shown that the gestural medium can also contribute significantly to explaining abstract concepts.[88] Empirical studies have shown that both teachers and advanced practitioners of mathematics are prone to move their arms and hands when describing or discussing concepts and objects.[89] When Einstein explained the theory of relativity in his first lecture at Princeton 9 May 1921, he was reported in the newspaper as 'drawing imaginary lines' in the air, chalk in hand, like an 'orchestra leader'.[90] One may also consider Rafael Núñez's analysis of a historical video clip showing Cox's great inspiration, Feynman, in action: rapidly waving his arm to illustrate the random movements of the particles, he then suddenly strikes down on an invisible particle, pointing his finger at an idealized entity that is at the same time meant to represent a real, material object.[91]

Watching Cox, one may be struck by how his body language appears to be carefully calculated, as if he were an actor conveying a certain character or motivation, or, indeed, an orator aiming to engage the auditors' intellect and emotions. Perhaps the best example one can find online is the lecture 'GCSE Science Brought Down to Earth' held at Manchester University on 8 June 2011. This was one in a series of 'Star Lectures' that were 'beamed into hundreds of classrooms by live webcast' before being divided into 'bite-size clips' to be broadcast on YouTube along with a full-length recording.[92] According to the university's website, the purpose was to give schoolchildren a chance 'to be enthralled' by a 'rock star scientist', while at the same time their teachers could learn from 'the cult academic' how to introduce beginners to 'the wonders of space'.

A Stellar Lecturing Style

Recorded while Cox was engaged in the ATLAS experiments at CERN, the lecture with the title 'GCSE Science Brought Down to Earth' addresses an immediate audience of schoolchildren and teachers visiting Cox's home university in Manchester.[93] His topic is the size and constituents of the observable universe, explored through a combination of screen images, physical gesturing and verbal imagery, with strategic use of comparisons, repetition and skilfully developed series of sizes and dimensions. These are well-known techniques of expanding upon and aggrandizing the value of one's topic; considered under the heading of amplification (*amplificatio*) in classical rhetoric. As Fahnestock has shown in *Rhetorical*

figures in science (1999), these techniques have proven to be highly effective for building up a scientific argument.[94] In the course of his lecture, Cox expands and occasionally narrows down his naturally vast topic, zooming in and zooming out in a conceptually dynamic and appealing manner.

While it is always important to make one's audience 'well disposed, attentive, and ready to learn', this seems especially necessary in a pedagogical setting.[95] As Quintilian explains in *The orator's education*, the 'eloquent teacher' must also be prepared to come down to his pupil's level and use only clear and simple language.[96] In his attempt to 'bring science down to earth', Cox tries to reduce the distance between the star professor and those watching at Manchester or online by telling them about his childhood experiences in his hometown, Oldham. When he describes how, at the ages of five, six and seven, he would stand gazing at the stars, completely mesmerized, it is a feeling with which the young people in the audience could identify.[97] Just like them, he also used to watch science documentaries on TV, especially *Cosmos* with Sagan ('a powerful communicator'), and, as he tells the schoolchildren somewhat later in the lecture: if they will only do their maths now, they might get to do the same 'fun' and 'wonderful things' he is doing, like 'the exploration of the universe'.[98] Perhaps they will be the ones to find out what the dark energy is that makes the universe expand? 'We don't know what it is at all, so it's a great question and maybe you can answer it in a few years'.[99]

Quintilian said that 'one cannot reach the top in any subject without going through the elementary stages', his chosen parallel being with 'buildings', whose ornate rooftops must rest on hidden foundations.[100] An eloquent teacher, Cox builds his lecture in such a way as to catch the pupils' attention and draw them in. He starts by employing a metaphor that might be unfamiliar—and therefore potentially striking—to his young audience, namely that our understanding of the universe rests on 'two pillars'; the theory of relativity and quantum mechanics.[101] Leading them through this entrance that he has created, he says that these are pillars 'that we've built over the last century and [that] we're still building', and which he hopes the students will 'contribute to building in the future'. This type of imagery has traditionally been considered as a particularly effective means of assisting memory. As Robert Kirkbride has put it in a review of the relations between rhetoric and architecture, such images can serve as 'perches' on which 'the birds of thought' may land, so as to recollect themselves before taking off again.[102] Cox also employs other, well-proven memorization tools, as when repeating the same word 'pillars' (a device known as *ploche*) and the same word with some variations in 'built'/'building' (*polyptoton*).[103] As this is not an actual teaching session but an event to spark enthusiasm, he seems very intent on exaggerating 'the sheer size of the problem', so as to capture their imaginations in the same way as he says happened to him when he was young.[104] Zooming in on the 'tiny piece of sky' to which the Hubble space telescope has since 'turned its gaze', he asks them 'to focus' on this very spot on the big screen behind him, helping them to stay focused by mentioning the 'piece of sky' seven times in just forty seconds.[105] His use of *antithesis* (a form of contrast) stresses that the picture Hubble took looks 'empty' although, in fact, it is 'not empty' but filled with an almost unfathomable number of 'blobs' or galaxies.[106] The space that was decreased to a tiny spot is thus magnified again, and to give them 'a sense of the scale', he first mentions the distance, informing them that the 'little line' up there is actually a sign of just how big the observable

universe is ('the 1 billion light year line').[107] He then multiplies the number of stars to a 'ridiculous number' ('thirty thousand million million million stars just like our Sun'), even though we have 'pretty strong evidence' that the universe is even bigger than that. These are rhetorical techniques known as *incrementum*, involving a successive, increasing enumeration from a point or degree that is already quite impressive, building up to a climax and if possible even exceeding that by pointing to something even further beyond.[108] Allowing his listeners' imaginations to take flight, he brings them back again, breaking off with an anaphoric repetition: 'all those facts that I've said to you or all those numbers that I've given out…'.[109] The effect is like saying: Look at me! Listen!

Later he shows the schoolchildren a video of the glowing sun—'not a computer graphic', but 'a *real movie* of the sun', as if permitting them to do the forbidden thing and look at it directly.[110] Moving on from this 'dynamic and violent place', his lecturing style becomes very graphic and lively. His closed fist is a nucleus, his other hand circling around it to illustrate the movement of the electrons. He draws different trajectories of electrons in the air, one after the other, as if visualizing the types of diagrams one will find in textbooks. His open hand pushes into the palm of his other hand, like starlight permeating the elements in the stars' atmosphere (and here he uses both arms to create a circle). Aiming to explain the speed of light, he gestures towards the nearest spotlight, his arm shooting up in the air like an arrow. Shooting down again, it illustrates 'how light journeys from distant galaxies to us'.[111] A supernova explodes: he shows us his hand, fingers opening and closing in a rapid succession, his white palm beaming like a flashlight. In technical terms, one can say that he mainly combines 'modelling' and 'enactment' (or pantomime), with some added 'depiction'.[112] First, modelling is involved when he lets his hand stand in for an object such as a nucleus, electron or photon. Second, when his hands engage in a pattern or action similar to that which is referred to, this may be described as 'enactment'. Examples are when the movements of his arms or hands are intended to illustrate the positioning of electrons or the velocity of photons. Third, he also draws shapes in the air, as when 'depicting' a circle or some form of diagram.

At one point in the lecture, he projects a picture of Einstein and a graphic illustration of his light clock on the screen behind him.[113] When Cox starts moving his hands and fingers to show how the clock works, he not only draws a corresponding shape in the air, depicting the same object as is shown in the picture on the screen, but he effectively creates an animated version of the same picture, as if making the clock drawing come alive. The spectators are thus required to relate his gestural depiction to the visual model on the screen, which allows for a multimedia-type of learning experience that involves the lecturer's carefully calculated gestures. Empirical studies in cognitive science have indicated that if someone depicts the most important features of an object or idea in the air, this can be more effective than showcasing a real object involving all possible distractions.[114] It has also been suggested that the simultaneous combination of speech and bodily gesture is more efficient in supporting children's learning than the mere combination of text and image.[115] From the viewpoint of a rhetorician, one might take this as evidence that oral delivery beats all. To have someone like Cox explaining science to popular audiences and schoolchildren may therefore be extremely valuable. He also uses body language for similarly deliberate purposes in an educational video to which we now turn before moving on to a broader discussion of the ways in which he has sought to engage the general public.

A Giant Past

In Search of Giants was made for Teachers TV (www.tes.com) in 2007, at an early stage of Cox's broadcasting career. In this tripartite video, Cox is explaining the development of particle physics while being filmed on various locations including the University of Cambridge and CERN in Geneva. At this time, his style as a TV presenter had not yet been perfected and there is an odd stiffness to his way of walking while talking. Yet when the filmmaker Alom Shaha lets him play with different technical instruments used for demonstrating the forces of electricity, electromagnetism and gravity, he shows an enthusiastic willingness to perform and entertain that seems characteristic of most of his subsequent appearances on stage and on screen. In a particularly playful scene, Cox enters the picture in a way that is both fun and unexpected. This occurs at the end of a sequence showing an elaborate, purpose built demonstration of the forces of nature, involving squirting water and a burning flame.[116] The homemade but carefully engineered technical apparatus is set in motion by a tiny robot and the series of mechanical movements end with an apple rolling down a slide before being caught in—surprise—someone's suddenly appearing hand. The hand, it turns out, belongs to Cox, as if he too, were a robot, his programmed scoop-like arm reaching out at the exact moment when the apple is released. Instead of operating the apparatus, he seems part of it, the merger between man and machine inviting one to think about how 'the experimental ethos' that has always been associated with British scientists might materialize in the actual performance of science.[117] The fact that it is an apple falling down from the curious apparatus obviously alludes to Newton's legendary discovery of gravity. In addition, the title *In Search of Giants* recalls Newton's famous saying that: 'If I have seen further, it is by standing upon the shoulders of giants', which has become a credo for subsequent appraisal of British achievements.[118] *In Search of Giants* draws a line between the massive accelerator complex at CERN (which 'thousands of scientists around the world have spent billions of pounds to build') and the accelerator that was used when the Englishman J. J. Thomson (a Fellow of the Royal Society) discovered the electron at Cambridge in 1897.[119] 'I'm standing a hundred meters below the ground at CERN in Geneva and this is the CMS detector, part of the largest and most complicated scientific experiment ever attempted', Cox announces, adding that 'it's a long way from when Isaac Newton pondered the laws of gravity, but all part of the same story'.[120]

The filmmaker's script perfectly captures the celebratory tone that is typically used for narrating the history of science: 'The story of the Royal Society is the story of modern science', the Society's webpages make clear.[121] 'It is impossible to list all the ways that the Royal Society has influenced the world', Bill Bryson wrote in his epideictic introduction to the 350th Anniversary anthology entitled *Seeing further: The story of science and the Royal Society* (2010).[122] 'If we have an Earth worth living on a hundred years from now, the Royal Society will be one of the organisations our grandchildren will wish to thank', Bryson declared, a claim that Rees repeated at the end of his Anniversary Address the same year.[123] One may recognize this adulatory language from the second Royal Charter issued in 1663, where King Charles II expressed his resolve 'to extend not only the boundaries of the Empire, but also the very arts and sciences'.[124] He thereby granted the founding members 'and their successors' permission to promote, 'by the authority of experiments', new knowledge 'of

natural things and of useful arts, to the glory of God the Creator, and the advantage of the human race'. The charter was reissued with a supplement in 2012 by Queen Elizabeth, the Society's current patron, and its 'fundamental purpose' is still 'to recognise, promote and support excellence in science and to support the development and use of science for the benefit of humanity'.[125]

Repetition is, of course, a very powerful persuasive tool and the Society seems eager to create an idea that even history is repeating itself. The best example to date is the public address by Nurse on 'The new enlightenment', where he claimed that 'science is, and always has been, one of Britain's greatest assets'.[126] One might question, however, whether the repeated appeals to national pride are actually very effective in increasing public support for science. If British science has always been—and continues to be—the best in the world, then why do people need to get engaged in questions about research priorities and funding? As if expecting this type of objection, Cox has made an argument that, precisely because his home country is already in a 'world-leading' position, the UK must seize this 'unique opportunity' for becoming 'the best place in the world to do science' in a future perspective.[127] Here the Professor for Public Engagement in Science has sounded every bit as patriotic as Thomas Sprat, the man that was hired by the founders of the Society in the 1660s to convince his countrymen that they must 'lay hold of this opportunity, to deserve the applause of Mankind' and set an example to 'all Countries round about us'.[128] In one of his most remarkable performances, Cox allowed himself to speculate on what would happen if he were to become Britain's next prime minister: 'If I ruled the country, what would I do? How would I make my utopia in Britain?'[129] Standing there, uncharacteristically bent over his manuscript, he read out a 'fake speech' he had written promising a doubling in research and education spending.[130] This occurred at the end of his Faraday Prize lecture on 'Making Britain the Best Place in the World to Do Science'. Speaking in the guise of a visionary statesman, he cast the world's entire population as a civilizing colonizer of a vastly unexplored space, inviting everyone to 'come together with the goal of expanding our knowledge and understanding of nature for the good of all mankind'. Turning this have-a-dream-speech into an astrophysicist's hopeful dream, he announced: 'Today, we take our first step on our journey to the stars'. Stepping out of the statesman role, he then urged both 'scientists, engineers and academics of arts and humanities' to 'come together and lobby in one voice', as if alluding to the legendary purpose of Bacon's utopian collective, Solomon's House.[131]

Yet from the perspective of the humanities and social sciences it might not seem so obvious that space travels are the answer and that 'our long-term survival depends solely on our understanding of nature'.[132] Both Cox and Nurse have further recognized that there is a general need to increase the support for science in society, wishing they could find a way to 'reawaken', 'revive' and 'rediscover' the passion for new discoveries and innovations that has been associated with earlier historical periods.[133] 'We need to convey the wonder of science', Nurse has argued.[134] The next section will argue that there are certain elements in Cox's physical performance contributing very strongly to evoking curiosity and wonder. In the past, there have been many overarching theories on how to affect the audience's mood, the most important deriving from classical oratory. Presenting a close-up of 'the face of British science', I shall experiment with using a variety of historical sources, including an influential painter's manual by the Frenchman Charles Le Brun (1619–1690) and Charles Darwin's

treatise on *The Expression of the Emotions in Man and Animals* (1872). These ideas can still offer some valuable clues for understanding the mechanisms behind Cox's methods of appealing to his audiences.

States of Wonder

The face that Cox projects on stage and on screen typically wears an expression of mild astonishment and wonder. Often, he is smiling. Eyes shining, he looks the very image of admiration as it was described in Le Brun's painting manual from 1698 on how to portray the 'exterior motions' of inner emotions, and then later by Darwin: 'When vividly felt, the eyes are opened and the eyebrows raised; the eyes become bright, instead of remaining blank, as under simple astonishment; and the mouth instead of gaping open expands into a smile'.[135] Following René Descartes very closely, Le Brun described 'l'admiration' (admiration or wonder) as 'a surprize, which enclines the Soul attentively to consider the objects that seem rare and extraordinary to her'.[136] As was already observed by Aristotle, these kinds of experiences can be very useful in evoking a desire to learn something new.[137] From the perspective of classical rhetoric, wonder and admiration constitute an ideal emotional state, because it is not considered violent in any way and therefore not likely to threaten the gentle and good-natured *ethos* that is required in order for the speaker to appear sensible and convincing.[138] Nor indeed will this sober emotion disturb the listener's rational capacity for processing information.

To the extent that these past theories hold water, the aim of producing wonder seems especially viable in popular science, which usually aims to both educate and entertain. Cox will most often attempt to inspire awe in the audience by admiring nature's wonders together with them. Watching him, one may be reminded of the ancient rhetoricians' dictum that in order to influence the listeners' state of emotion, the speaker must appear moved by the same emotion himself.[139] There is nonetheless a risk that his characteristic, amazed expression might appear static and caricatured, like the big-eyed toy version of Cox in *Postman Pat*. As a professional performer, he might be susceptible to the type of warnings that were voiced by Constantin Stanislavski, the father of method acting, who stressed that an actor must be careful to control 'the mimetics' of the eyes and face so as to 'remain in direct relationship with inner emotions' and avoid 'artificiality'.[140] This resonates well with Quintilian's comment that if one wishes to put the audience in a certain mood, it will not do just to imitate the way it typically looks and sounds when someone is affected in such or such a way, but 'we should ourselves be moved' to such a degree that we seem to be experiencing the things described at the very moment of speaking.[141] A favourite technique employed by Cox in this respect is to build on the *pathos* of his childhood stargazing. When he recalls his old stargazing self this accords with both Quintilian's ideas about how to use one's imagination and Stanislavski's method of 'emotion memory', which involves an attempt to 'relive' an experience from real life on stage.[142] Aided by his boyish round face and big brown eyes, Cox can easily project a face imitating a wide-eyed child. His voice, too, seems filled with wonder. Listening to his softly modulated lyrical tenor might work wonders even on those who were prone to dread maths and physics at school. Instead, one might be overcome by fear and awe at the vastness of the cosmos and 'the sheer ambition' of learning more about it.[143]

The type of effects produced here are clearly compatible with the phenomenon that Gross has termed the scientific sublime. In the eighteenth century the notion of the sublime, which originally served for appreciating literary works of art, gradually came to be used for describing experiences with nature.[144] According to Gross, the ideas about the 'natural sublime' were developed by British and Scottish writers and thinkers such as Joseph Addison and Adam Smith, and expanded upon by Immanuel Kant in *The critique of judgment* (*Kritik der Urteilskraft*, 1790).[145] The fullest definition of the scientific sublime occurs in Smith's essay on 'The History of Astronomy' (1795), which grants that the 'wondering' produced when witnessing spectacular events such as a solar eclipse tends to inspire further scientific enquiries.[146] Even though such experiences might leave one with an overwhelming, almost religious feeling, it is science—not religion—that holds the key to unravelling the vast and minute mysteries of nature.[147] Here Gross could have referred to Feynman's public address on 'The Value of Science' (1955), which contends that 'few unscientific people have this particular type of religious experience'.[148] In the same speech, Feynman praised the 'wondrous capacities of human beings' to raise questions and continue in their quest for knowledge, describing scientists as public proponents of 'a satisfactory philosophy of ignorance'.[149] Moving on from the discussion of the appeals to wonder, we shall now consider some of the implications of the praise of ignorance, which has re-emerged in Cox's public rhetoric. In honour of Feynman, Cox has said that 'the celebration of uncertainty' should underpin every science documentary.[150] As we shall see, he dares his audiences to question even the most widely accepted theories. Because he likes to emphasize how scientific research is conditioned by shifting historical and conceptual contexts, he seems an obvious representative of the 'pragmatic' rationality that philosopher of science Theodore J. Kisiel has deemed typical of scientific practices since the 1980s.[151] Whether or not one agrees with Kisiel's claim that the 'declarative mood' of positivist verification has generally been outmoded, one can easily agree that the 'interrogative mood' tends to dominate in the popular physics for which Cox has become famous.[152] By inviting his auditors to join in his quest for knowledge, he ideally transforms them into accomplices and supporters of the sciences. At the same time, they might learn to appreciate the deeper values of scientific methods, for, as Cox has insisted, quoting Feynman, 'the only way you can run a society or country is by a trial and error system'.[153] Nevertheless, the task of helping people understand and appreciate uncertainty in the sciences appears more challenging and risky than any of the other duties that have been assigned to the Professor for Public Engagement. While Cox tends to employ an open and playful tone to educate and entertain, he sounds quite different when provoked to defend the status of scientific evidence.

The Celebration of Uncertainty?

Cox generally likes to accentuate the things that remain to be understood. He not only manages to make complicated questions appear simple, but he also makes seemingly simple questions more complex. 'What time is it?' he asks in a BBC documentary from 2008. The answer is 'nowhere near as straightforward as one might think' because as he gladly confesses: 'We don't know what happens when time passes. I can't even tell you at the moment what the moment is. Not even momentarily'.[154] In what follows Cox points out that the question of what time is has perplexed mankind throughout history, from the Maya two

thousand years ago via Newton to Einstein. He thus seems to suggest that finding answers to the enigma of time is an ongoing, collective endeavour and that everyone can participate in the discussion (or at least encourage their children to study physics).

A similar inquiring attitude has characterized his popularization of the theory of the inflationary multiverse. In an audio recording that was uploaded to YouTube in August 2017 with the title 'CERN! Prof. Brian Cox Reveals the Truth', the truth turns out to be that 'we are not so sure' any more that the Big Bang was the beginning of space-time.[155] Nor have we arrived at any certainty when it comes to deciding the validity of the alternative (and in Cox's opinion 'attractive') theory that there was a pre-existing phase of inflation leading to multiple, and possibly ongoing big bangs:

> We don't know really if these theories are right and how long that process has been going on for. … We also don't know whether the laws that we see today are the only way they could be. We don't know how much freedom a creator would have if they wanted to dial the dials a little bit and change the strength of the forces and the mass of the particles. We don't know. But it certainly looks as if we are fortunate in the sense that we live in this beautifully balanced universe.[156]

The insistent, anaphoric repetition of 'we don't know' is here counterpoised by a positive affirmation that humanity seems in a fortunate position. When Cox refers to dials and dialling he might be playing with seventeenth-century debates about the Creator's role in his clockwork universe.[157] Cox has been very clear that he does not think the questioning of the origins of our universe 'precludes any kind of faith or religious belief', for there could still be 'some structure in place that allows all this wonderful stuff to happen'.[158] Yet in our secular era, the speculation about what lies beyond 'the laws that we see' does not tend to end in mere worshipping of the Divine, as in Kant's philosophy of the natural sublime.[159] Despite all other differences, Cox and Kant might easily have agreed, however, that nature's great mysteries cannot be unravelled by speculation alone, without any empirical support. In the radio interview just quoted, Cox allows the listeners to consider, on the one hand, the orthodox theory that nothing existed before the Big Bang 13.8 billion years ago and, on the other, the alternative theory that space-time is an ever-expanding fabric.[160] His juxtaposition between these two hypotheses about the origin of the universe recalls Kant's first antinomy in the *Critique of pure reason*, which showed that it could be logically proven both that the cosmos did have a beginning in time as well as a spatial limit, and that it did not have any of those things.[161] By showing that both of those contradictory theses might be considered as logically valid, Kant demonstrated the limitations of reason when operating in isolation.[162] With regard to the origin and nature of the cosmos, Kant did not think it would ever be possible to reach a conclusion for lack of any means to experience and assess 'the absolute totality of the sum of existing things'.[163]

Despite the great advances that have been made in observational cosmology since the age of Kant, Cox and other physicists still feel compelled to underpin the limitations in our knowledge. The increased possibilities for experimental verification have not put an end to the existence of competing and conflicting theories, which scientists like to present as

wonderful opportunities for future breakthroughs. This may be the case not only in popular science but in scholarly communication as well. In their preface to *Inflation and string theory* (2015) Daniel Baumann and Liam McAllister review the observations of supernovae that have been made in the past two decades along with measurements of temperature fluctuations in the cosmic microwave background, arguing that although these have provided ground-breaking insight into how the universe developed by expansion, 'the microphysical origin of inflation remains a mystery, and it will require a synergy of theory and observations to unlock it'.[164] Cox exhibited a similar blend of modesty and bold capacity for further discovery when he told the listeners of the *Joe Rogan Experience* that: 'The physics inside black holes is not understood. We don't know. Our theories don't work. We need what's called a quantum theory of gravity to make progress there'.[165] It hardly counts as a weakness if one admits to having difficulties when dealing with such vast topics. 'There is a natural prejudice in favour of people who have difficulties', Quintilian noted in his instructions on how to frame a favourable *ethos* in defending one's cause or topic, recommending that 'one's self-confidence ought not to be too obvious even when the Cause admits no room for doubt'.[166] The question of the origin of the universe is arguably the greatest mystery of all, and Cox may therefore safely appear astounded when lecturing about the nature of black holes and their role in the formation of galaxies. Chances are his audience will only be more able to identify with his feelings of wonder. If he can make them feel equally awed and impressed, he could be one step closer to convincing them that space exploration is important enough to deserve further encouragement and support.

In other areas, however, it might not seem serviceable at all to engage in a celebration of uncertainty. When it comes to contested issues such as public health or environmental policies, scientists will be expected not to profess 'a satisfactory philosophy of ignorance', but to offer safe guidance or, if possible, clear answers. As Lynda Walsh has argued, their role is then to act as a kind of prophet, a role that was cast in the seventeenth century, when the Royal Society and the new experimental philosophy laid claims to representing 'the new civic oracle of England'.[167] Indeed, scientists have traditionally been tasked—or charged—with manufacturing certainty.[168] In the most controversial science policy issues, where even the slightest doubt or disagreement among experts may cause headlines, understanding uncertainty can posit a major challenge. Taken out of context, a quote from a report or article in the media can make it sound as if the authors are in doubt, even when their conclusions are very solid. As the CEO of The New York Times Company, Mark Thompson, has argued, the conventional disclaimers that are used in scientific writing to qualify and strengthen the argument and findings could be interpreted as signs of weakness, as if the results presented cannot be trusted.[169] A common effect of this type of misinterpretation is that scientific judgements and evidence are treated as mere opinions among many others.[170] Another effect can be that of 'manufactured scientific controversy', explained by Ceccarelli as 'manufacturing an ongoing scientific debate in the face of overwhelming scientific consensus'.[171] This might be for political reasons or to create headlines.

Cox addressed these challenges directly in a blog posting on 'The Difference between Science and Entertainment' in 2014: 'One has to be careful when communicating uncertainty in science, especially in politicised areas such as science. The reason is that uncertainty is often misunderstood and occasionally misused'.[172] His targets were the 'magazine editors'

and ‘opinion formers’ operating online as part of ‘the entertainment industry’. With reference to the Intergovernmental Panel on Climate Change (IPCC), he contended that the only type of critique coming from a non-expert that can have any value is that which can ‘question specific methodologies, assumptions or conclusions within the IPCC reports in a well-structured and precise way’. Granting that ‘scientific predictions are always uncertain’ and that ‘consensus may change’ in light of any new evidence, Cox assured his readers that if there is one thing we can always be sure of, it is that ‘the consensus scientific view is the best we can do at any given time, given the available data and our understanding of it’. Diverging from his usual interrogative mode, Cox declared that ‘it is not legitimate … to criticise a scientific prediction because you don’t like it’. We see an example of this departure from the interrogative mode in the *Q & A* show on Australian TV 15 August 2016: highlights of Cox’s ‘clash’ with notorious climate sceptic Malcolm Roberts were shown on BBC News the next day, a full video recording also circulating on YouTube with the biased title ‘Professor Brian Cox exposes & destroys One Nation’s Malcolm Roberts’.[173] This shows Cox reprimanding the Australian Senator: ‘The absolute, absolute consensus is that human action is leading to an increase in average temperatures. Absolute consensus. I know you may try to argue with that, but you can’t’. ‘Not I *may*. I will!’ the notorious sceptic responds, claiming to be ‘absolutely stunned’ that someone who is inspired by Feynman should be ‘quoting consensus’ without any ‘empirical evidence’. Visibly provoked, Cox almost shouts: ‘You’ve seen the graph!’ Standing up, he throws a paper across the table: ‘Here’s the evidence!’ His reaction was very similar to that of the late Stanford professor Stephen Schneider when attempting to confront a group of professed climate sceptics on Australian TV in 2010. According to Jean Goodwin, an expert on science communication, Schneider ended up simply declaring the audience wrong: the problem arose when the laypeople in the audience started contradicting the climate scientist, assuming they were on the same level in the debate.[174]

Cox and the Royal Society do not claim to have all the answers in public controversies about scientific issues, but they stand firm on the precedence of ‘reproducible and reliable evidence’ and demand respect for what they know to be the consensus views of expert scientists.[175] In his Anniversary Address of 2012, Nurse promised that the Society will continue to counter prejudiced beliefs and opinions by ‘rational, consistent and objective argument’: only through the methods and values of science can one know for sure what is objectively *not* true, so as to find better answers.[176] Because society sometimes demands ‘clear and simple’ solutions at times when there still are none, he said the Society must strive to provide the best possible advice at any given time: ‘It has been doing that for 350 years and will be needed even more in the future as society becomes increasingly dependent on science and technology’, he concluded.[177] As has been typical in the period studied in this essay, he found support by reference to the past. In ‘The new enlightenment’ lecture given earlier that year, he quoted Bacon’s aphoristic claim that: ‘If a man will begin with certainties, he shall end in doubts, but if he will be content to begin with doubts, he shall end in certainties’.[178] Ramakrishnan, the Nobel Prize-winning biologist who succeeded Nurse in 2015, has since urged his colleagues throughout the Commonwealth to engage with policy issues, ‘not in the expectation that scientific evidence will be the only consideration, but in the expectation that decisions will be informed by the evidence’.[179] The same message has been communicated to popular audiences, as when Cox wrote on his blog that: ‘The only logical way to make a

decision is to base it on the best science available at the time because there is no other way'.[180] Although the Society has wanted an 'exchange of thinking and dialogue' with both policy makers and 'people from all walks of life' so as 'to listen to their views', the underlying premise seems to be that there is a time for everything and that science must come first.[181] Nurse made this very explicit when he said that 'the time for politics is after the science not before'.[182]

This self-assured position is nowhere more evident than in the Society's goal of 'demonstrating the importance of science to everyone'. The choice of words in the Strategic Plan extending until 2022 gives associations to the closed method of reasoning that Chaïm Perelman and Lucie Olbrechts-Tyteca deemed typical of the natural sciences in their 1958 article 'On Temporality as a Characteristic of Argumentation'.[183] The strategic goal does not invite dialogue about what the importance of science might consist of, nor indeed about whether or not the proposed methods and solutions are adequately suited for our present or future needs. Instead, the Society's role as provider of 'authoritative' knowledge is to be taken for granted.[184] As I argue, the goal of 'demonstrating the value of science to everyone' implies a temporal structure of argumentation that treats this value as a given premise from which everything else must follow. Whereas the UK science academy has been at the very forefront in using a wide range of channels to engage with different audiences, its latest strategy implies a traditional linear and authoritative model of communication and rhetorical effort.

Conclusion

In this paper, we have studied the public rhetoric favoured by the Royal Society and its foremost populariser in recent decades. An important purpose has been to analyse for the first time the ways in which Brian Cox has engaged with popular audiences, not least young audiences, in the period surrounding his appointment as the Society's first Professor for Public Engagement in Science. Many will agree that he possesses exceptional oratorical and acting skills; this essay has brought to the fore exactly how he manages to convey and inspire curiosity and wonder through his actual performances on stage, online or on screen. The discussion has also highlighted the problem of communicating uncertainty in science, which has been one of Cox's designated tasks as Professor for Public Engagement. Debates about global warming have made him diverge from his preferred stance of celebrating uncertainty, a stance that pays homage to Richard Feynman. As we have seen, Cox and the science academy do not hesitate to use a censorious tone in cases where they find it necessary to assert power and authority. Depending on the context, Cox and the Royal Society have had to juggle between different rhetorical purposes, some of which have been demonstrative of what classical rhetoric terms 'epideictic' (for use when praising or blaming some current state of affairs) and others political or 'deliberative', as when providing guidance and advice for the future. From a rhetorical perspective, it does not seem problematic at all when popular scientists such as Cox strive to combine different strategies, seeking to educate and entertain at the same time. Traditionally, this is what all orators should aim to do. The problem only arises when the audience refuses to listen, whether out of defiance or lack of interest. The voice of science is one of very many voices competing for public attention; demanding respect, but not always getting it. As I have argued, the past few presidents of the Society have ventured to recall Britain's proud history, drawing parallels with the 'search for

enlightenment' and 'relief of man's estate' that they associate with Bacon and the natural philosophers who founded the Royal Society of London for Improving Natural Knowledge. This involves promoting a belief that scientific and technological advances are the primary motors of economic growth and human well-being, representing steps on the road to civilization. Fears that the UK is lagging behind other countries when it comes to science investments have fuelled the calls for 'a culture shift' in Nurse's lecture on 'The new enlightenment' in 2012, or 'a step change for science', as Cox put it when taking up his new position with the Royal Society in 2015.[185]

More work is needed to understand the deeper historical reasons behind this professed need for a new enlightenment and renewed public engagement. This work falls outside the scope of this paper and it was not sufficiently addressed by Collins either in his book on *The Royal Society and the promotion of science since 1960*. Two factors seem important, however, the first being the emergence of an increasingly oblique and to some extent even post-factual media reality. In the era of 24/7 digital media, the access to information has never been greater, but there seems to be an overload of infotainment and tendentious or irrelevant material, creating a stronger need for agencies to reach out to broader publics and help them see the value of judgements based on careful, rational and evidence-based examination.

Another, related, factor, is the media debate about climate change, which has put unprecedented pressure on scientific institutions when it comes to explaining the difference in status between scientific consensus views and ordinary opinions. The controversies about environmental policies have placed the issue of communication at the very front of the scientific endeavour, leaving researchers with a severe responsibility to disseminate their knowledge widely. As Rees wrote when the Royal Society celebrated its 350th anniversary in 2010, this is the first time 'in our planet's history where one species—ours—has Earth's future in its hands'.[186] The climate controversy appears to have created an increased need for public engagement—and, if you will, enlightenment.

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Notes:

[1] Both of the books mentioned were co-authored with Jeff (Jeffrey) Forshaw, who is also a professor of particle physics at Manchester, *The quantum universe: everything that can happen does happen* (London, Allen Lane, 2011); *Universal: a journey through the cosmos* (London, Allen Lane, 2016).

[2] 'The new enlightenment' was the title given when Nurse held the annual Richard Dimbleby Lecture 2012 at the Royal College of Physicians in London. A video recording was also made available on various channels online. Further references to Nurse's lecture will be to the PDF text at https://royalsociety.org/~/media/Royal_Society_Content/people/fellows/2012-02-29-Dimbleby.pdf (last accessed 2 January 2019). All of the other URLs cited in this article were last accessed on 26 April 2019.

[3] For a detailed discussion of Sprat's apologetic and persuasive efforts on behalf of the early Royal Society and its experimental programme, see Tina Skouen, 'Science versus rhetoric? Sprat's *History of the Royal Society* Reconsidered', *Rhetorica: a journal of the history of rhetoric*, **29**(1), 23–52 (2011). Sprat's work remains 'a locus classicus in the study of scientific style' in early modern and enlightenment prose, see Peter Walmsley, 'Rhetoric and Science', in *The Oxford handbook of rhetorical studies* (ed. Michael J. MacDonald), pp. 547–557 (Oxford, Oxford University Press, 2017), at p. 548, citing Skouen, *op. cit.*, and two earlier studies referring to Sprat's work: Brian Vickers, 'The Royal Society and English prose style: a reassessment', in *Rhetoric and the pursuit of truth: language change in the seventeenth and eighteenth centuries* (Los Angeles, William Andrews Clark Memorial Library, University of California, 1985), pp. 3–76; Thomas M. Conley, *Rhetoric in the European tradition* (New York, Longman, 1990), pp. 168–169.

[4] Paul Merchant, 'Particular popular science: British scientists writing, speaking and broadcasting on science and religion from the 1980s', *Notes Rec. R. Soc.* **72**, 365–381 (2018), at pp. 366–367. Merchant, *ibid.*, 366, cites Andreas W. Daum's observation that there is an 'astonishingly small number of studies on the history of popular science in the twentieth century', an observation made in Daum's 'Varieties of popular science and the transformations of public knowledge: some historical reflections', *Isis* **100**(2), 319–332 (2009), at p. 326 (https://doi.org/10.1086/599550). According to Alan G. Gross, there is a particular scarcity of monographs addressing 'the wave of books and essays on popular science that begins in the latter half of the 20th century'. See Gross, *The scientific sublime: popular science unravels the mysteries of the universe* (Oxford, Oxford University Press, 2018), pp. 1, 19 (p. 19). He has only found one book-length study worth mentioning, namely Elizabeth Leane, *Reading popular physics: disciplinary skirmishes and textual strategies* (Aldershot, Ashgate, 2007). Leane gives a helpful overview of the 'diverse range' of research fields that are represented in the existing criticism on science popularization, *ibid.*, pp. 13–16 (p. 13). Any survey of earlier work in this field is bound to acknowledge that there have been relatively few studies of non-English contexts. Among the most notable exceptions are James T. Andrews, *Science for the masses: the Bolshevik state, public science, and the popular imagination in Soviet Russia, 1917–1934* (College Station, Texas A & M University Press, 2003); Sigrid Schmalzer, *The people's Peking man: popular science and human identity in twentieth-century China* (Chicago, University of Chicago Press, 2008). A special edition of *Public understanding of science* appearing in 2013 further addressed the tendency toward Anglo-centrism, offering insights from both Spain and China, see Alice R. Bell and Hauke Riesch, 'Researching popular science: more diverse than the limitations of apparent publishing "booms"', *Public Underst. Sci.* **22**(5), 516–520 (2013), at p. 517 (https://doi.org/10.1177/0963662513490598); Jon Turney, 'Commentary for public understanding of science special issue', *ibid.*, 570–574, at p. 571 (https://doi.org/10.1177%2F0963662513492048). For discussions of the distinctions between popularization of science and science in popular culture, see Jonathan Topham, 'Historicizing "popular science",' *Isis* **100**(2), 310–318 (2009), at pp. 310, 315 (https://doi.org/10.1086/599551); Lynn K. Nyhart, 'Historiography of the history of science', in *A companion to the history of science* (ed. Bernard V. Lightman), pp. 7–22 (Malden, Wiley Blackwell, 2016), at pp. 13–14.

[5] 'Postman Pat and the space suit', on BBC's CBeebies channel 28 March 2017 (Television programme).

[6] Jeanne Fahnestock, 'Accommodating science: the rhetorical life of scientific facts', *Written communication* **15**(3), 330–350 (1998), at p. 332 (https://doi.org/10.1177%2F0741088398015003006). The reference here was primarily to material produced by science journalists.

[7] Among the most recent book-length rhetorical studies are Gross, *op. cit.* (2018); Leah Ceccarelli, *On the Frontier of science: an American rhetoric of exploration and exploitation* (East Lansing, Michigan State University Press, 2013); Lynda Walsh, *Scientists as prophets: a rhetorical genealogy* (New York, Oxford University Press, 2013); Karen Schroeder Sorensen, *Cosmos and the rhetoric of popular science* (Lanham, Lexington Books, 2017). The field of rhetoric of science has been defined, along with a survey of some of the most important contributions, in the revised edition of Alan G. Gross, *The rhetoric of science* (1990), published as *Starring the text: the place of rhetoric in science studies* (Carbondale, Southern Illinois University Press, 2006), pp. 3–45. According to Jean Dietz Moss, it was Galileo Galilei that first brought about 'the rhetorical revolution in science', because by addressing an audience that 'was greatly enlarged beyond an elite', he made science into 'a rhetorical enterprise', see *Novelties in the heavens: rhetoric and science in the Copernican controversy* (Chicago, University of Chicago Press, 1993), p. 332. See also Jeanne Fahnestock, 'The rhetoric of the natural sciences', in *The Sage handbook of rhetorical studies* (ed. Andrea A. Lunsford, Kirt H. Wilson and Rosa A. Eberly), pp. 175–195 (Thousand Oaks, Sage, 2009).

[8] Fahnestock, *op. cit.* (1998), pp. 333–334.

[9] *Ibid.*, pp. 333–338.

[10] Lisa Keränen, Jason Lesko, Alison Vogelaar and Lisa Irvin, '"Myth, mask, shield, and sword": Dr. John H. Marburger III's rhetoric of neutral science for the nation', *Cultural studies ↔ Critical methodologies* **8**(2), 159–186 (2008), at pp. 162, 165–169, 171–172, 180 (https://doi.org/10.1177%2F1532708607308100).

[11] Quotation from Max Weber's 1917 lecture on 'Science as vocation', as cited in Walsh, *op. cit.*, p. 6. Consider also Steven Pinker's argument that the Enlightenment thinkers decided to always go by the standards of reason and never 'fall back on generators of delusion like faith, dogma, revelation, authority, charisma, mysticism, divination, visions, gut feelings, or the hermeneutic parsing of sacred texts'. In Pinker, *Enlightenment now: the case for reason, science, humanism, and progress* (London, Allen Lane, 2018), p. 8.

[12] Peter Dear, *Revolutionizing the sciences: European knowledge in transition*, 3rd ed. (London, Red Globe Press, 2019), p. 2. In 2013, Paul Kléber Monod summarized the state of research by commenting that 'few scholars would argue that science progressed in a linear fashion through revolutionary leaps, or by simple binary oppositions between right and wrong', see *Solomon's secret arts the occulting in the age of Enlightenment* (New Haven, Yale University Press, 2013), p. 15.

[13] Gross, *op. cit.* (2018) has chapters on five physicists (Richard Feynman, Steven Weinberg, Lisa Randall, Brian Greene and Stephen Hawking) and five biologists (Rachel Carson, Stephen Jay Gould, Steven Pinker, Richard Dawkins and E. O. Wilson).

[14] Ceccarelli, *op. cit.* (2013), pp. 10–11, 23, 66. Ceccarelli provides an insightful historical background for Keränen *et al.*, who describe the rhetoric of science in the Bush era as 'decidedly nationalistic, epideictic, and expansionist', *op. cit.*, p. 169.

[15] Ramakrishnan, who was elected as President of the Royal Society for five years in 2015, characterized the UK as 'a global scientific powerhouse' in a press release dated 4 May 2017, at https://royalsociety.org/news/2017/05/UK-national-academies-researcher-mobility-international-collaboration-survey/. See also his reference to the UK being 'a global scientific power' in a press release on 6 September 2017, at https://royalsociety.org/news/2017/09/royal-society-response-to-science-and-innovation-position-paper/. Ramakrishnan has further presented the UK as 'a world leader in research' in a press release on 22 November 2017, at https://royalsociety.org/news/2017/11/royal-society-autumn-budget-response/. His predecessor, Paul Nurse, described the UK as 'a world leader in science and engineering' on 6 June 2014, at https://royalsociety.org/topics-policy/projects/vision/. Nurse's predecessor, Martin Rees, said that 'the UK is a global leader in research, with a deserved reputation as a valuable hub in international innovation', in the Anniversary Address 2009, *Notes Rec. R. Soc.* **64**, 163–173 (2010), at p. 169.

[16] Press release dated 30 January 2015 announcing the appointment of Cox as Professor for Public Engagement at https://royalsociety.org/news/2015/01/professor-for-public-engagement-brian-cox/.

[17] *Ibid*., with the additional information that 'the UK invests 1.8% of GDP; USA 2.7%; Germany 2.8%; South Korea 4%'.

[18] Nurse, *op. cit.*, p. 17. The paradox of 'competitive cooperation' features in the essays collected in Robert K. Merton, *The sociology of science* (ed. Norman W. Storer) (Chicago, University of Chicago Press, 1973), at pp. 273–274; 339.

[19] Nurse, *op. cit.*, p. 17.
[20] Nurse, *op. cit.*, p. 15.
[21] Martin Rees, 'Conclusion: looking fifty years ahead', in *Seeing further: the story of science & the Royal Society* (ed. Bill Bryson) (London, Harper Press, 2010), p. 468. In his Anniversary Address 2008 Rees said that: 'science has, as Francis Bacon taught our founders, two goals: enlightenment, and "the relief of man's estate",' in *Notes Rec. R. Soc.* **63**, 183–190 (2009), at p. 184.
[22] Rees, *op. cit.* (2010), p. 469; Anniversary Address 2009, *Notes Rec. R. Soc.* **64**, 163–173 (2010), at p. 173.
[23] Anniversary Address 2009, p. 173.
[24] Anniversary Address 2014, *Notes Rec. R. Soc.* **69**, 217–222 (2015), at p. 218.
[25] Thomas Sprat, *The History of the Royal Society* (1667) (ed. Jackson I. Cope and Harold Whitmore Jones) (Saint Louis, Washington University Studies, 1958), p. 35.
[26] The lecture with the title 'Making Britain the Best Place in the World to Do Science' was held at the Royal Society in London on 19 February 2013, in connection with Cox receiving the Faraday Prize for 2012. Quoted from the recording at https://royalsociety.org/science-events-and-lectures/2013/brian-cox/ [58:20]. Subsequent references to this lecture will be given as 'Making Britain the Best Place', citing the start time in minutes and seconds as it will appear in any player online. The same citation system will be used for audio and video recordings throughout this essay.
[27] Press release dated 19 September 2017, announcing the 30th Anniversary Royal Society Insight Investment Science Book Prize, at https://royalsociety.org/news/2017/09/cordelia-fine-wins-30th-anniversary-royal-society-insight-investment-science-book-prize/.
[28] https://royalsociety.org/grants-schemes-awards/grants/professorship-public-engagement/.
[29] Both here and in my next sentence I quote from the press release dated 30 January 2015 at https://royalsociety.org/news/2015/01/professor-for-public-engagement-brian-cox/.
[30] Quoted from the full recording of 'GCSE Science Brought Down to Earth' at https://www.manchester.ac.uk/discover/events/star-lectures/archive-cox-2011/ [15:41]. Subsequent references will be given as 'GCSE Science'.
[31] *Ibid.* [17:12]. Cox promotes Feynman's essay on 'The value of science' in the filmed stage conversation with deGrasse Tyson at Starmus 2016, on YouTube, https://www.youtube.com/watch?v=CSccnpSWefs&t=4s [03:47]. Subsequent references to this video will be given as 'Communicating Science'.
[32] Nurse, *op. cit.*, p. 4. The quotation in my next sentence is from the same place. Nurse was awarded the Nobel Prize in Physiology or Medicine in 2001 together with Leland Hartwell and Tim Hunt.
[33] The commitment to 'curiosity-driven' research has been stated in the Strategic Plan 2017–2022, p. 5 and see the last unnumbered page of the Strategic Plan 2012–2017. Note also Rees, *op. cit.*, p. 468: 'Christopher Wren, Robert Hooke, Robert Boyle and the other "ingenious and curious gentlemen" who regularly convened in Gresham College were enthusiasts for what we would now call "curiosity-driven" research. But they engaged also with the practical life of the nation'.
[34] Gross discusses the audience's feelings toward Feynman, *op. cit.* (2018), p. 29.
[35] Brian Logan, review of 'Professor Brian Cox Live' in Northampton, *The Guardian*, 16 October 2016, at https://www.theguardian.com/science/2016/oct/16/professor-brian-cox-live-review-cosmology-northampton.
[36] Quintilian, *Institutio oratoria* 3.5.2, in *The orator's education* (ed. and trans. Donald A. Russell) (Cambridge, Mass., Harvard University Press, 2001), p. 39. Further references to Quintilian will be given as *Inst. or.* (citing page numbers in this translated edition). The idea that one can join pleasure with instruction played an important role in classical oratory and poetic theory. See *ibid.*, p. 38 (note 4, citing Cicero and some other classical sources). See also Horace's *Art of poetry*, which asserts that: 'The poet winning every vote blends the useful with the sweet,/ giving pleasure to his reader while he offers him advice' (*aut prodesse volunt aut delectare poetae* from *Ars poetica* 333), in Horace, *Satires and epistles*, trans. Jacob Fuchs (New York, Norton, 1977), p. 92.
[37] Peter Collins, *The Royal Society and the promotion of science since 1960* (Cambridge, Cambridge University Press, 2016), pp. 138, 139. Collins does not discuss the public rhetoric of past Presidents Rees and Nurse either, despite naming them as 'natural communicators who made full use of the scope that the presidency provided', *ibid.*, p. 24. Quotations taken from http://www.manchester.ac.uk/discover/news/rock-star-scientist-professor-

brian-cox-is-made-an-obe-for-services-to-science/ and https://royalsociety.org/science-events-and-lectures/2013/brian-cox/.

[38] Bruno Latour, *Pandora's hope* (Cambridge, Mass., Harvard University Press, 1999), pp. 104–106, at p. 106.

[39] Interview with BBC News, uploaded on YouTube 6 July 2012, with the title 'Brian Cox Higgs Boson Particle Discovery BBC' at https://www.youtube.com/watch?v=yKz07k04D70 [02:45] (Online video). See also the interview that was uploaded to the BBC News website 4 July 2012 at http://www.bbc.com/news/av/science-environment-18708281/brian-cox-great-day-in-the-history-of-science [03:24] (Online video).

[40] Peter J. Bowler, *Science for all: the popularization of science in early twentieth-century Britain* (Chicago, University of Chicago Press, 2009), p. 276. See also David Kirby, 'Film, radio, and television', in *A companion to the history of science* (ed. Lightman), *op. cit.*, pp. 428–441.

[41] The first Italian edition, *Sette brevi lezioni di fisica*, appeared in 2014, see the overview at the author's homepage, http://www.cpt.univ-mrs.fr/~rovelli/.

[42] Leane, *op. cit.*, p. 7, citing Bernadette Bensaude-Vincent, 'A genealogy of the increasing gap between science and the public', *Public Underst. Sci.* **10**(1), 99–113 (2001), at p. 109 (https://doi.org/10.3109%2Fa036858).

[43] Bensaude-Vincent, *op. cit.*, at p. 107.

[44] Quoted from 'A Compilation of Neil deGrasse Tyson's Best Arguments, Part Two' by ScienceToday, widely circulated on YouTube, as on 23 June 2017 at https://www.youtube.com/watch?v=s3yKTEV6whM [03:03].

[45] *Ibid*. Allegations that Sagan was a publicity-seeker and not a serious scientist have been considered an important reason why he was denied tenure at Harvard University, finding his place at Cornell University instead, see Keay Davidson, *Carl Sagan: a life* (New York, Wiley, 2000), pp. 208–209.

[46] Walsh, *op. cit.*, p. 137.

[47] Declan Fahy, *The new celebrity scientists: out of the lab and into the limelight* (Lanham, Rowman and Littlefield, 2015), p. 15.

[48] *Ibid*., p. 218.

[49] The chapters discussing the five physicists mentioned are in Gross, *op. cit.* (2018), pp. 25–130.

[50] Dawkins's 'polemical skills' are reviewed *ibid.*, pp. 217–236. For the Oxford Simonyi Professor for the Public Understanding of Science, see https://www.simonyi.ox.ac.uk/about-marcus/the-oxford-simonyi-professor-for-the-public-understanding-of-science/.

[51] Merchant, *op. cit.*, pp. 376–377. The interviewees were Peter Atkins, Nicholas Humphrey, Steve Jones, John Polkinghorne, Russell Stannard and Lewis Wolpert.

[52] *Ibid*., p. 377.

[53] In an interview with the *Sydney Morning Herald* while on tour in Australia 1 Nov 2017, http://www.smh.com.au/technology/sci-tech/science-offers-alternatives-to-advance-of-comedians-and-clowns-brian-cox-20171101-gzcico.html

[54] https://royalsociety.org/news/2015/01/professor-for-public-engagement-brian-cox/.

[55] *Ibid*. 'Making Britain the Best Place in the World to Do Science' was also the title of Cox's Faraday Prize lecture in 2013. The same title was used for a lecture given by former Science Minister Jo Johnson (Conservative) on 27 January 2016, which named Cox as one of the 'stars' that had contributed the most to 'mainstreaming science' in the UK. See https://www.gov.uk/government/speeches/making-britain-the-best-place-in-the-world-for-science. On 25 April 2014, Chancellor of the Exchequer George Osborne (Conservative) said that 'if Britain is to become the best place to do science and apply it: we have to give British science the funding it needs for the long term', at https://www.gov.uk/government/speeches/chancellor-of-the-exchequers-speech-on-science-in-cambridge. On 8 October 2010 Minister for Universities and Science, David Willetts, was reported by the Royal Society's *In Verba* blog to have 'latched on' to an argument made by Cox at a science policy event that: 'If you invested another £1 billion, you could make the UK the best place to do science in the world. And what could that do for our economy?' http://blogs.royalsociety.org/in-verba/2010/10/08/friends-of-science/.

[56] The increase at A-level over a five-year period credited to the 'Brian Cox effect' was featured in *The Guardian* 18 August 2011. According to the University of Manchester website, there was an increase of 54% in applications in physics from 2008 to 2012, https://www.physics.manchester.ac.uk/research/impact/the-brian-cox-effect/.

[57] *Ibid*. (University of Manchester website).

[58] At https://www.aps.org/careers/physicists/profiles/cox.cfm. The 'sexiest' poll was by *People Magazine* 2009, see Ben Falk, *The wonder of Brian Cox: the unauthorised biography of the man who brought science to the nation* (London, John Blake Publishing, 2012), p. xiii. The 'sexualized' media image of Cox has been analysed alongside that of Laura Grant in Frederick Thomas Attenborough, 'Complicating the sexualization thesis: the media, gender and "sci-candy"', *Discourse & society*, **22**(6), 659–676 (2011), esp. at pp. 666–667 (https://doi.org/10.1177%2F0957926511411693). The physicist's ubiquitous media presence has been critiqued in Quentin Cooper, 'A quantum leap for science writing (but that doesn't mean giant)', *British Journalism Review* **21**(3), 39–45 (2010), esp. at pp. 40–41 (https://doi.org/10.1177%2F0956474810383772).
[59] Sorensen, *op. cit.*, pp. 71, 100–101, 102–106, 112–114, 116–117 (p. 117). The most important earlier studies focusing mainly on Sagan's verbal rhetoric are Thomas M. Lessl, 'Science and the sacred cosmos: the ideological rhetoric of Carl Sagan', *Quarterly journal of speech* **71**(2), 175–187 (1985) (https://doi.org/10.1080/00335638509383727); Thomas M. Lessl, 'The priestly voice', *Quarterly journal of speech* **75**(2), 183–197 (1989) (https://doi.org/10.1080/00335638909383871).
[60] Sorensen, *op. cit.*, pp. 64–65; Lawrence Badash, *A nuclear winter's tale: science and politics in the 1980s* (Cambridge, Mass., MIT Press, 2009), pp. 47–115; Matthias Dörries, 'The politics of atmospheric sciences: "nuclear winter" and global climate change', *Osiris*, **26**(1), 198–223 (2011), at pp. 209–211 (https://doi.org/10.1086/661272).
[61] Sorensen, *op. cit.*, pp. 112–113.
[62] I am thinking specifically of Simon Schaffer, 'Natural philosophy and public spectacle in the eighteenth century', *Hist. Sci.* **21(**1), 1–43 (1983) (https://doi.org/10.1177%2F007327538302100101). See also Bernadette Bensaude-Vincent and Christine Blondel (eds), *Science and spectacle in the European Enlightenment* (Aldershot, Ashgate, 2008).
[63] https://royalsociety.org/grants-schemes-awards/grants/professorship-public-engagement/.
[64] Collins, *op. cit.*, pp. 137–139. See also the report on 'The Public Understanding of Science', p. 6, at https://royalsociety.org/~/media/Royal_Society_Content/policy/publications/1985/10700.pdf. According to Walter Bodmer, the chairman of the working group responsible for this report, it was not until the early 1980s that the Royal Society began to consider popularizing as 'central' to its 'interests and activities', and for younger scientists aspiring toward election, 'the fear of opprobrium was a definite disincentive to becoming too popular'. See Bodmer, 'Public understanding of science: the BA, the Royal Society and COPUS', *Notes Rec. R. Soc.* **64**, S151–S161 (2010), at S152. The background for this report is also discussed in Nicholas J. Russell, *Communicating science* (Cambridge, Cambridge University Press, 2010), pp. 70–74.
[65] Collins, *op. cit.*, pp. 136–137.
[66] *Ibid.*, p. 139.
[67] The first quotation is from 'Royal Society Response to Government's Proposed Vision for Science and Society' (December 2007), p. 1, at https://royalsociety.org/~/media/Royal_Society_Content/policy/publications/2007/7986.pdf. The second quotation is from the Strategic Plan 2012–2017, unpaginated seventh page, at https://royalsociety.org/~/media/Royal_Society_Content/about-us/governance/Strategic-Plan.pdf?la=en-GB. These sources are also cited (without precise references) in Collins, *op. cit.*, p. 139.
[68] Strategic Plan 2012–2017, unpaginated seventh page. One of the most important voices debating the mentioned developments in British higher education has been Stefan Collini, *What are universities for?* (London, Penguin, 2012), esp. pp. 32, 36–37. Identifying a similar trend in the US, Thomas Bender and Wilson Smith have argued that 'beginning in the 1980s, education, like research, lost much of its intrinsic value', in their introduction to *American higher education transformed, 1940–2005: documenting the national discourse* (ed. Thomas Bender and Wilson Smith) (Baltimore, Johns Hopkins University Press, 2008), p. 9.
[69] Strategic Plan 2017–2022, p. 11, at https://royalsociety.org/~/media/about-us/governance/royal-society-strategic-plan-2017-2022.pdf?la=en-GB.
[70] https://royalsociety.org/about-us/.
[71] 'Making Britain the Best Place' [04:50].
[72] The UK government's Research Excellence Framework scheme has included an increasing emphasis on public impact of research, as indicated by the latest submission guidelines at

https://www.ref.ac.uk/media/1092/ref-2019_01-guidance-on-submissions.pdf. The biggest EU research and innovation programme, Horizon 2020, is also dedicated 'to fostering more societally relevant and desirable research and innovation outcomes', see https://ec.europa.eu/programmes/horizon2020/en/h2020-section/public-engagement-responsible-research-and-innovation.

[73] Quintilian, *Inst. or.* 4.1.6, with reference to Cicero, *De inventione* 1.22 and other standard rhetorics, in *The orator's education*, *op. cit.*, p. 182 (note 5), p. 183.

[74] Strategic Plan 2017–2022, p. 12.

[75] For a general discussion of the ways in which social media have served as channels for science communication, see Ashley R. Kelly and Carolyn R. Miller, 'Intersections: scientific and parascientific communication on the Internet', in *Science and the Internet: communicating knowledge in a digital age* (ed. Alan G. Gross and Jonathan Buehl), pp. 221–245 (New York, Routledge, 2017), at pp. 226–231. The Royal Society is also absent from the discussion in Alan G. Gross and Joseph E. Harmon, *The Internet revolution in the sciences and humanities* (Oxford, Oxford University Press, 2016).

[76] The first quotation is from 'Communicating Science in the 21st Century' [15:55]. The second is from https://royalsociety.org/news/2015/01/professor-for-public-engagement-brian-cox/.

[77] Steven Shapin and Simon Schaffer, *Leviathan and the air-pump: Hobbes, Boyle, and the experimental life* (Princeton, Princeton University Press, 1985; paperback reissue with a new introduction, 2011), esp. 30–32. For the early Royal Society, see also the introduction to *Rhetoric and the early Royal Society: a sourcebook* (ed. Tina Skouen and Ryan J. Stark), pp. 1–50 (Leiden, Brill, 2014), at pp. 24–32. One of the best known popularizers of Newtonian science was John Theophilus Desaguliers (1683–1744), who also served as an official demonstrator during Newton's presidency of the Society. See Larry Stewart, *The rise of public science: rhetoric, technology, and natural philosophy in Newtonian Britain, 1660–1750* (Cambridge, Cambridge University Press, 1992), pp. 101–141, 213–242, 392–394; Barbara Maria Stafford, *Artful science: Enlightenment, entertainment, and the eclipse of visual education* (Cambridge, Mass., MIT Press, 1994), esp. 176–178.

[78] *Joe Rogan Experience*, episode 610, 9 February 2015, on Vimeo https://vimeo.com/119212417 [02:29] (Podcast). Subsequent references will be to *Joe Rogan Experience*.

[79] Press release 4 May 2017 at http://www.guinnessworldrecords.com/news/2017/5/professor-brian-cox-beaks-own-record-for-science-tour-ticket-sales-470801.

[80] *Ibid*.

[81] Logan, *op. cit.*, review of 'Professor Brian Cox Live'.

[82] Carl Sagan, *Billions and billions: thoughts on life and death at the brink of the millennium* (New York, Ballantine, 1997), p. 3.

[83] Adam Kendon, *Gesture: visible action as utterance* (Cambridge, Cambridge University Press, 2004). Kendon provided a theoretical framework for Tyler Marghetis and Rafael Núñez, 'Dynamic construals, static formalisms: evidence from co-speech gesture during mathematical proving'. University of California, San Diego, Center for Research in Language Technical Reports **22**(1), 3–9 (unpaginated final pages) (2010), at 7–8. Available at http://www.cogsci.ucsd.edu/~nunez/web/CRL-22-1.pdf.

[84] See, for example, John Ward, *A System of Oratory, Delivered in a Course of Lectures Publicly Read at Gresham College* (London, 1759), vol. 2, pp. 344–345, 354 (p. 345), retrieved from *Eighteenth century collections online*, at http://find.galegroup.com/ecco/infomark.do?&source=gale&prodId=ECCO&userGroupName=oslo&tabID=T001&docId=CW105824904&type=multipage&contentSet=ECCOArticles&version=1.0&docLevel=FASCIMILE. Ward (*ibid*., 345) refers to Cicero's description of gesture or action (*actio*) in book three of *De oratore* (On the orator) as being 'the language of the body, since it is capable in so lively a manner to convey both our ideas and passions'. Quintilian treats hand movements as 'the common language of the human race' in *Inst. or*. 11.3.87, *op. cit*., p. 129. There is a useful chapter outlining the interest taken in gesture from the ancient Greek and Roman period to the elocutionary movement of the eighteenth century in Kendon, *op. cit*., pp. 17–42.

[85] Gross and Harmon, *Science from sight to insight: how scientists illustrate meaning* (Chicago, University of Chicago Press, 2013). For PowerPoint, see Chapter 7 discussing its influence on the public science lecture, *ibid.*, pp. 231–265. For Internet visualization, see Chapter 8, *ibid.*, pp. 266–305; and Gross and Harmon, *op. cit.* (2016), esp. pp. 38–47.

[86] Gross and Harmon, *op. cit.* (2013), pp. 82–83 (p. 83).

[87] For the continued importance of Einstein's cloth analogy in popular science and science education, see Magdalena Kersting and Rolf Steier, 'Understanding curved spacetime: the role of the rubber sheet analogy in learning general relativity', *Science & education*, **27**(7–8), 593–623 (2018), at pp. 596–597 (https://doi.org/10.1007/s11191-018-9997-4).

[88] Quoted from Thomas Sheridan, *A Course of Lectures on Elocution* (London, 1762), p. 113, retrieved from *Eighteenth century collections online*, at http://find.galegroup.com/ecco/infomark.do?&source=gale&prodId=ECCO&userGroupName=oslo&tabID=T001&docId=CW110911836&type=multipage&contentSet=ECCOArticles&version=1.0&docLevel=FASCIMILE.

[89] Nathalie Sinclair and Shiva Gol Tabaghi have suggested that 'gesture offers more possibility than spoken language for expressing continuity, time and motion', in 'Drawing space: mathematicians' kinetic conceptions of eigenvectors', *Educational studies in mathematics*, **74**(3), 223–240 (2010), at p. 235 (https://doi.org/10.1007/s10649-010-9235-8). See also Marghetis and Núñez, who claim to be the first to have studied quantitatively the importance of combined speech and gesture 'during expert mathematical practice', *op. cit.*, at p. 7 (unpaginated).

[90] Quotation from the *Philadelphia Evening Standard* in Hanoch Gutfreund and Jürgen Renn, *The formative years of relativity: the history and meaning of Einstein's Princeton lectures* (Princeton, Princeton University Press, 2017), p. 363, citing from József Illy, *Albert meets America: how journalists treated genius during Einstein's 1921 Travel* (Baltimore, Johns Hopkins University Press, 2006), p. 172.

[91] Rafael Núñez, 'Do real numbers really move? Language, thought, and gesture: the embodied cognitive foundations of mathematics', in *Embodied artificial intelligence* (ed. Fumiya Iida, Rolf Pfeifer, Luc Steels and Yasuo Kuniyoshi), pp. 54–73 (Berlin, Springer-Verlag, 2004), at p. 68, available at https://link.springer.com/content/pdf/10.1007%2F978-3-540-27833-7_4.pdf.

[92] Both here and in my next sentence I quote from the University of Manchester's webpage announcement on 21 June 2010, at https://www.manchester.ac.uk/discover/news/brian-coxs-star-lectures-to-teach-children-the-wonders-of-space/.

[93] 'GCSE Science' [09:49].

[94] Jeanne Fahnestock, *Rhetorical figures in science* (New York, Oxford University Press, 1999), esp. pp. 43–44. The most comprehensive overview of the various techniques of amplification is that provided in Heinrich Lausberg, *Handbook of literary rhetoric: a foundation for literary study*, trans. Matthew T. Bliss, Annemiek Jansen and David E. Orton (Leiden, Brill, 1998), §§400–409, pp. 189–196. Quintilian writes that 'the whole power of the orator' lies in his mastery of amplification, *Inst. or.* 8.3.89, *op. cit.*, p. 391.

[95] Quoted from Quintilian, *Inst. or.* 4.1.5, *op. cit.*, p. 183.

[96] *Inst. or.* 2.3.7–8, p. 279. See also *Inst. or.* 1. Pr. 5, *op. cit.*, p. 55.

[97] 'GCSE Science' [10:14].

[98] *Ibid.* [69:02].

[99] *Ibid.* [63:00].

[100] *Inst. or.* 1. Pr. 4, *op. cit.*, p. 55.

[101] 'GCSE Science' [09:06]. The quotations in my next few sentences are from what immediately follows.

[102] Robert Kirkbride, 'Rhetoric and architecture', in *The Oxford handbook of rhetorical studies* (ed. MacDonald), *op. cit.*, pp. 505–522, at p. 505.

[103] The same figures of repetition are highlighted in Chapter 5 of Fahnestock, *op. cit.* (1999), pp. 156–194.

[104] 'GCSE Science' [10:12].

[105] *Ibid.* [10:38].

[106] *Ibid.* [11:22].

[107] *Ibid.* [13:30]. The quotations in my next few sentences follow immediately as part of the same sequence.

[108] See Lausberg, *op. cit.*, §403, p. 191, with reference to Quintilian *Inst. or.* 8.4.4: 'the process not only goes to the top, it sometimes in a sense goes beyond it'. See also Fahnestock *op. cit.* (1999), p. 92.

[109] 'GCSE Science' [15:03].

[110] *Ibid.* [17:48], with the quotation in my next sentence immediately following.

[111] *Ibid.* [21:30].

[112] Kendon, *op. cit.*, p. 160.

[113] 'GCSE Science' [48:48].

[114] Miriam A. Novack, Eliza L. Congdon, Elizabeth M. Wakefield and Susan Goldin-Meadow, 'Gesture's role in reflecting and fostering conceptual change', in *Converging and complementary perspectives on conceptual change* (ed. Tamer Amin and Olivia Levrini), pp. 97–104 (New York, Routledge, 2017), at p. 101.
[115] *Ibid*., pp. 100–101.
[116] 'In Search of Giants Part 2—The Forces of Nature', on YouTube since 7 November 2011, at https://www.youtube.com/watch?v=nNNwypIykcw [01:08].
[117] The quotation is from Walsh, *op. cit.*, p. 41.
[118] Quoted from BBC's standing collection of popular sayings at http://www.bbc.co.uk/worldservice/learningenglish/movingwords/shortlist/newton.shtml.
[119] 'In Search of Giants Part 1—The Building Blocks of Matter', https://www.youtube.com/watch?v=-FWxd78sOZ8&feature=youtu.be [02:16]; 'In Search of Giants Part 2' [01:37].
[120] *Ibid*. [01:43, respectively, 02:03].
[121] https://royalsociety.org/about-us/history/.
[122] See Bill Bryson's introduction in *Seeing further* (ed. Bryson), *op. cit.*, p. 15.
[123] *Ibid*., p. 13; Anniversary Address 2010 (Rees), *Notes Rec. R. Soc.* **65**, 197–205 (2011), at p. 204.
[124] Both here and in my next sentence I quote from the new English translation of the original Latin text that was provided in the Supplemental Charter of 2012, at https://royalsociety.org/~/media/Royal_Society_Content/about-us/history/2012-Supplemental-Charter.pdf?la=en-GB.
[125] https://royalsociety.org/about-us/mission-priorities/.
[126] Nurse, *op. cit.*, p. 17.
[127] https://royalsociety.org/news/2015/01/professor-for-public-engagement-brian-cox/.
[128] Sprat, *op. cit.*, p. 437.
[129] 'Making Britain the Best Place' [50:40].
[130] The fake politician's speech delivered at the very end of the lecture is about three minutes long. All of my subsequent quotations are from this sequence of 'Making Britain the Best Place' [56:50].
[131] *Ibid*. [01:02:25].
[132] *Ibid*. [59:09].
[133] Quotations taken from Nurse, *op. cit.*, p. 15; https://royalsociety.org/news/2015/01/professor-for-public-engagement-brian-cox/. It has been argued that the sixteenth and seventeenth centuries constituted the last great age of wonder, see John Onians, '"I wonder…": a short history of amazement', in *Sight and insight: essays on art and culture in honour of E. H. Gombrich at 85* (ed. John Onians), pp. 11–33 (London, Phaidon Press, 1994), at p. 26.
[134] Nurse, *op. cit.*, p. 17.
[135] Le Brun, *A Method to Learn to Design the Passions […] Translated into English […] By John Williams (1734)* (ed. David Stuart Rodes) (Los Angeles, William Andrews Clark Memorial Library, 1980), p. 24. The work originally appeared as *Conférence de M. Le Brun sur l'expression générale et particulière* (1698). Charles Darwin, *The Expression of the Emotions in Man and Animals* (London, John Murray, 1872), p. 289, retrieved from *Darwin online* at http://darwin-online.org.uk/content/frameset?pageseq=315&itemID=F1142&viewtype=side. The same passage from Darwin is quoted in Onians, *op. cit.*, p. 14.
[136] Le Brun, *op. cit.*, p. 16. Compare 'Article 70. About Wonder. Its definition and its cause', in Descartes *The passions of the soul* [*Les passions de l'âme*], trans. Stephen Voss (Indianapolis, Hackett, 1989), p. 56. For Le Brun's general indebtedness to Descartes, see Stephanie Ross, 'Painting the Passions: Charles Le Brun's Conference Sur L'Expression', *Journal of the history of ideas*, **45**(1), 27–31 (1984). Retrieved from *JSTOR*, www.jstor.org/stable/2709329.
[137] 'Article 75. Wherein Wonder in particular is serviceable', in Descartes, *op. cit.*, p. 59. Aristotle explained in *Rhetoric* I.xi.21 that 'admiring implies the desire to learn', see *The 'art' of rhetoric*, 2nd ed. (ed. and trans. J. H. Freese) (Cambridge, Mass., Harvard University Press, 1926; repr. 1991), p. 125.
[138] Aristotle, *Rhetoric* II.i.5–6, *op. cit.*, p. 171. Admiration or wonder came to be regarded as 'the chief and most temperate of all the Passions', see Le Brun, *op. cit.*, p. 24.
[139] Quintilian, *Inst. or.* 6.2.26, *op. cit.*, p. 59. See also p. 58 (note 9), identifying similar thoughts in Aristotle's *Poetics* 17, Horace's *Ars poetica* 101–107, and Cicero's *De oratore* 2.189.

[140] Constantin Stanislavski, *Creating a role*, trans. Elizabeth Reynolds Hapgood (New York, Routledge, 1989), p. 113. According to Quintilian 'the face is sovereign'; it 'makes us understand many things', sometimes replacing words altogether, see *Inst. or.* 11.3.72, *op. cit.*, p. 123. The eyes are the most important feature of the face, *Inst. or.* 11.3.75, *ibid.*, p. 125.
[141] *Inst. or.* 6.2.28, *ibid.*, p. 59.
[142] *Inst. or.* 6.2.29, *ibid.*, pp. 59–61. Quotations taken from Stanislavski, *op. cit.*, p. 139; Stanislavski, *An actor prepares*, trans. Elizabeth Reynolds Hapgood (New York, Routledge, 1989), p. 182.
[143] 'GCSE Science' [10:05].
[144] The ancient Greek critic Longinus observed (*On the sublime,* 1st century CE) that 'it is always the unusual which wins our wonder', cited in Gross, *op. cit.* (2018), p. 6.
[145] *Ibid*., pp. 6–19.
[146] *Ibid.*, pp. 16–17 (p. 17).
[147] Gross, *op. cit.*, pp. 2, 16. Gross writes: 'For Kant, the sublime is an effect of the vastness and the power of nature. It is through its vastness that we experience the first category of the sublime, the mathematical. … In Kant's second category, the dynamic sublime, our imagination is overwhelmed by nature's power', *ibid.*, pp. 8–9. Edmund Burke realized that 'the wonders of minuteness' could produce similar effects, see *ibid.*, p. 16.
[148] Feynman, 'The value of science', *Engineering and science* **19**(3), 13–15 (1955), at p. 14, available at http://calteches.library.caltech.edu/1575/1/Science.pdf. Gross does not consider this text by Feynman in his chapter on 'Richard Feynman: The consensual sublime', Gross, *op. cit.* (2018), pp. 25–46.
[149] Feynman, *op. cit.*, p. 15.
[150] 'Communicating Science in the 21st Century' [05:28]. In 'Communicating Science' Cox also quotes Feynman's idea of 'the satisfactory philosophy of ignorance' [04:21].
[151] Theodore Kisiel, 'Heidegger and the new images of science', in *Martin Heidegger: critical assessments*, vol. 4 (ed. Christopher E. Macann), pp. 325–341 (London, Routledge, 1992), at p. 327.
[152] *Ibid.*, pp. 327–328.
[153] 'Communicating Science in the 21st Century' [05:09]; Feynman, *op. cit.*, p. 15. The claim that scientific procedures of trial and error constitute exemplary models to be copied outside the academe was first made in 1945 by the Austrian-born British philosopher Karl Popper, see Ian Jarvie, 'Popper's ideal types: open and closed, abstract and concrete societies', in *Popper's open society after fifty years* (ed. Sandra Pralong and Ian Jarvie) pp. 71–82 (London, Routledge, 1999), at pp. 72–75. Nurse cited Popper's trial and error system in his Anniversary Address 2014, *Notes Rec. R. Soc.* **69**, 217–222 (2015), at pp. 217–218.
[154] 'Do You Know What Time It Is?' Directed and produced by Paul Olding, BBC Horizon, 2008, http://www.bbc.co.uk/programmes/b00fyl5z. The full documentary has been made available on various online channels such as Documentary Heaven at http://documentaryheaven.com/do-you-know-what-time-it-is/ [00:23, respectively, 00:37]. The reference in my next sentence is to [04:58].
[155] 'CERN! Prof. Brian Cox Reveals the Truth', at https://www.youtube.com/watch?v=AHpBzsIuMKc [22:33, respectively, 24:13] (Audio recording online). This recording is from a radio interview where Cox talks about the Multiverse as it is discussed in Cox and Forshaw, *op. cit.* (2016), pp. 262–264, 267–268, 271–272.
[156] *Ibid.* [25:20, respectively, 26:55].
[157] Comp. Edward Dolnick, *The clockwork universe: Isaac Newton, the Royal Society, and the birth of the modern world* (New York, HarperCollins, 2011), pp. 18, 182–183, 313–314.
[158] 'GCSE Science' [73:17, respectively, 74:06]
[159] Gross, *op. cit.* (2018), pp. 9, 12.
[160] The careful weighing of alternatives is also very noticeable in 'Do You Know What Time It Is?' [26:20].
[161] Kant, *Critique of pure reason* [*Kritik Der Reinen Vernunft*]. Unified edition (with all variants from the 1781 and 1787 editions), trans. Werner S. Pluhar (Indianapolis, Hackett, 1996), p. 458. I have also consulted S. Gardner, *Routledge philosophy guidebook to Kant and the* Critique of pure reason (New York, Routledge, 1999), pp. 231–233.
[162] Kant's Preface to the second edition of the *Critique of pure reason*, p. 20.
[163] In the opening section of 'The Antinomy of Pure Reason' discussing the 'System of Cosmological ideas', *ibid*., p. 453.

[164] Daniel Baumann and Liam McAllister, *Inflation and string theory* (Cambridge, Cambridge University Press, 2015), p. xv.
[165] *Joe Rogan Experience* [01:48:06].
[166] Quintilian, *Inst. or.* 4.1.9; *Inst. or.* 4.1.55, *op. cit.*, pp. 185, 207.
[167] Walsh, *op. cit.*, p. 39. The image of the priest or prophet is also a trope in history of science, see Harold Fisch, 'The scientist as priest: a note on Robert Boyle's natural theology', *Isis* **44**(3), 252–265 (1953) (https://doi.org/10.1086/348227); Michael Hunter, *Between God and science* (New Haven, Yale University Press, 2010), pp. 73–74; Rob Iliffe, *Priest of nature: the religious worlds of Isaac Newton* (Oxford, Oxford University Press, 2019), esp. pp. 16–17, 244.
[168] Walsh, *op. cit.*, p. 2.
[169] Mark Thompson, *Enough said: what's gone wrong with the language of politics?* (London, Bodley Head, 2016), pp. 206–207.
[170] *Ibid*., p. 206.
[171] Ceccarelli, 'Manufactured scientific controversy: science, rhetoric, and public debate', *Rhetoric and public affairs* **14**(2), 195–228 (2011), at p. 197. Retrieved from JSTOR, http://www.jstor.org/stable/41940538.
[172] Both here and in my next few sentences I quote from 'The difference between science and entertainment' at http://www.apolloschildren.com/blog-item.php?id=27 (Blog post). The publication date is not given, but the post comments on a debate Cox participated in on 2 September 2014, at the Royal Society of Biology. Similar arguments about the differences between popular beliefs and the consensus views of climate scientists have been made e.g. in Nurse's Anniversary Address 2012, *Notes Rec. R. Soc.* **67**, 77–81 (2013), at pp. 77–78. The Royal Society has been actively engaged in public controversies about climate change since its publication of *The greenhouse effect: the scientific basis for policy* in July 1989, see Collins, *op. cit.*, pp. 150–153. See also Thompson, *op. cit.*, pp. 207–211.
[173] The cited full recording was uploaded to YouTube the same day the programme was aired, on 15 August 2016, at https://www.youtube.com/watch?v=_TTsTYCpKUY. The quotations in my next few sentences are from the 1.5-minute clip shown on BBC News on 16 August 2016, 'Change: Professor Brian Cox clashes with sceptic Malcolm Roberts – BBC News' at https://www.youtube.com/watch?v=sG8gLt4GChg.
[174] Jean Goodwin, 'Comment exercer une autorité experte? Un scientifique confronté aux sceptiques', *Argumentation et analyse du discours* **15**, 1–19 (2015), available in English translation at https://jeangoodwin.files.wordpress.com/2017/09/goodwin-schneider-2015.pdf. Schneider's reaction served as a teaser with SBS Insight, see https://www.youtube.com/watch?v=ZxHwQh3Dhm4.
[175] Strategic Plan 2017–2022, p. 5.
[176] Anniversary Address 2012, *Notes Rec. R. Soc.* **67**, 77–81 (2013), at p. 77.
[177] *Ibid*., pp. 77, 81.
[178] Nurse, *op. cit.*, p. 7.
[179] Ramakrishnan was awarded the Nobel Prize in Chemistry in 2009 together with Thomas A. Steitz and Ada E. Yonath. Quoted from a press release 30 June 2017 at https://royalsociety.org/news/2017/06/commonwealth-science-conference-2017-opening-ceremony-venki-ramakrishnan/.
[180] Cox, 'The Difference between Science and Entertainment'.
[181] Strategic Plan 2017–2022, p. 11. The one reference to 'people from all walks of life' is from Nurse, *op. cit.*, p. 15.
[182] Nurse, *op. cit.*, p. 9.
[183] Strategic Plan 2017–2022, p. 11. The article by Perelman and Olbrechts-Tyteca was first published as 'De la temporalité comme caractère de l'argumentation' (*Archivio di filosofia*, 1958) and appeared in English for the first time in Michelle K. Bolduc and David A. Frank, 'Chaïm Perelman and Lucie Olbrechts-Tyteca's "On temporality as a characteristic of argumentation": commentary and translation', *Philosophy and rhetoric* **43**(4), 308–336 (2010), at p. 316 (Project MUSE, doi:10.1353/par.2010.0003).
[184] Strategic Plan 2017–2022, p. 4.
[185] Nurse, *op. cit.*, pp. 15, 17 (p. 15); https://royalsociety.org/news/2015/01/professor-for-public-engagement-brian-cox/.
[186] Rees, *op. cit.*, p. 484.