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ALICE and the Apocalypse: Particle Accelerators as Death Machines in Science Fiction

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Abstract: While the general public has expressed an interest in the cutting-edge science done at particle accelerators such as CERN's Large Hadron Collider (LHC), there is a simultaneous lack of general understanding of that science. Examples include the ongoing scientific debate as to whether or not microscopic black holes could be created in the LHC, as well as the fundamental nature of the Higgs boson. This disconnect results in an atmosphere of fear and distrust as to the safety of these machines. Science fiction films such as *The Black Hole* (2006) and *Annihilation Earth* (2009), as well as the science-based thriller novel *Angels and Demons* (2000), capitalized on these fears and misconceptions, as well as shed further light upon them. The success of both popular media and conspiracy websites in feeding these fears has also demonstrated the difficulty faced by the particle physics community in effectively communicating to the general public exactly what separates science fact from science fiction. This essay illustrates how popular media has capitalized upon this new brand of apocalyptic fears and analyzes the successes and missteps of the particle physics community in communicating with the general public.

Keywords: *Angels and Demons*; *Annihilation Earth*; *The Black Hole*; Dan Brown; Large Hadron Collider; particle accelerators; particle physics; physics; public perception; science fiction; science fiction film

Mad Scientists and Misinformed Citizens

Despite the significant slowdown in nuclear arms proliferation over the decades since the end of the Cold War, the atom continued to haunt our dreams and our science fiction media. For as the accidents at Three Mile Island, Chernobyl, and Fukushima vividly demonstrated, science cannot always control the genie it has summoned, even when the goal is the peaceful creation of energy without the emission of climate-changing greenhouse gases. From the serious drama *The China Syndrome* (1979) to the gore festival of the zombie film *The Children* (1980) and the SyFy Channel's over-the-top *Atomic Twister* (2002) – featuring a tornado hitting a nuclear power plant – directors openly preyed upon the nagging fears many people have concerning the safety of nuclear power plants.

Although viewers (hopefully) understood that they were engaging with a work of science fiction, in general they had little idea as to how much science was actually interwoven with that fiction. While some films – such as the nuclear war depictions in *Threads* (1984) and *The Day After* (1983) – strove to portray their topics with as much scientific realism as possible, the same cannot be said of all similar works. Part of the reason why such works have been successful in frightening their audiences has been that they not only relied on realistic concerns about the potential destructive power of nuclear reactions, but exploited the audience members' inability to discern scientific fact from fiction, as well as their basic distrust of so-called mad scientists. The American public's lackluster performance on tests of scientific literacy has been well documented; for example, only about half of the adults surveyed in 2012 knew that electrons are smaller than atoms (National Science Board, 2016). This problem is exacerbated by the wide disparity in opinions between scientists and the general public on science-based controversial topics. For example, only 37% of the American public believes that genetically modified foods are safe for consumption, while 88% of member scientists in the American Association for the

Advancement of Science (AAAS) hold such an opinion. It is therefore not surprising that 84% of AAAS scientists (but only 14% of the American public) consider the scientific illiteracy of the American public to be a "major problem" (Funk, 2015).

In a 1956 letter, J.R.R. Tolkien condemned "the most widespread assumption of our time: that if a thing can be done, it must be done. This seems to me wholly false" (Carpenter, 2000, p. 246). More recently, this same sentiment was reflected in the words of *Jurassic Park*'s Ian Malcolm: "Science can make a nuclear reactor, but it cannot tell us not to build it. Science can make a pesticide, but cannot tell us not to use it" (Crichton, 1990, p. 314). But the archetype of a scientist playing God, seeking knowledge that brings with it considerable peril, is not a modern construct. In reality, it is even older than Mary Shelley's *Frankenstein* (1818) or Christopher Marlowe's *Doctor Faustus* (1604), hearkening back to the myth cited in the subtitle of Shelley's novel, that of Prometheus. Silver (1998) argued that the story of this Greek god

> speaks to us because it condenses, in the hideous sufferings of the protagonist, the danger and the occasional sense of transgression that accompany our probing of the natural world. And it symbolizes a very real problem...: Is the scientist to be permitted to investigate everything in nature? (p. 482).

With the advent of the Internet, such debates have moved from the inner circles of scientists and ethicists to ordinary citizens, who make their opinions known in blogs, petitions, and thematic websites. In a perfect world, the general public would skeptically read these opinions alongside those of the experts in the field and make informed decisions as to what the actual truth of the matter might be. However, when the topics are abstruse, the disaster scenarios compelling, and scientists either unable or unwilling to communicate effectively with the public (and their critics) in a respectful and transparent manner, the result has been paranoia. An important example is current research done in high energy particle accelerators, which brings together a number of scientific topics about which the general public has numerous misconceptions and anxieties, including black holes, radiation, and electromagnetism. This essay will explore how novelists, screenwriters, and other creators of popular media have successfully exploited this new Frankenstein's monster, the possibility that an "atom smasher" will, quite literally, smash the earth, creating a black hole – or something worse. It will be demonstrated that the debate over the safety of particle accelerators has been effectively integrated into science fiction literature, television series, and films, capitalizing upon apocalyptic fears fueled by the general public's fundamental misconceptions.

Accelerators and Demons

Perhaps the best-known work to draw attention to the potential catastrophic nature of particle accelerator research has been Dan Brown's *Angels and Demons* (2000). While widely classified as a thriller rather than science fiction, the novel's heavy reliance on science (and its liberties taken with said science) certainly support an analysis of it through a science fiction lens. The novel begins with a self-proclaimed fact concerning the world's largest accelerator facility, CERN (Conseil European Pour la Recherche Nucléaire), run by a consortium of 20 member states and straddling the France-Switzerland border: CERN had "recently succeeded in producing the first particles of antimatter" (Brown, 2000, p. ii). Brown's description of the basic properties of antimatter – including its propensity to immediately destruct upon contact with matter – is correct. He also notes that at that time only small amounts of antimatter had been produced by CERN, but that its Antiproton Decelerator has the potential to produce far more antimatter. He leaves the reader with the central question that frames the plot of his novel: "Will this highly volatile sub-

stance save the world, or will it be used to create the most deadly weapon ever made?" (Brown, 2000, p. ii).

The novel also dramatizes the antagonism between science and religion, both figuratively and literally. Leonardo Vetra, a Catholic priest and physicist, is murdered after he creates and contains a sample of antimatter. His intention was to "fuse science and religion" into a field he dubbed "New Physics" (Brown, 2000, p. 56). The murder of Vetra and a number of candidates for Pope (and the threatening of the Vatican with destruction by matter-antimatter annihilation) is blamed on atheist scientists, including the CERN director Kohler, and the Illuminati, a supposed secret society of scientists fighting against repression by the Church. In actuality, Camerlengo Ventresca, a close associate of the current Pope (as well as his biological son through the scientific wonders of in vitro fertilization) is the mastermind behind the entire plot. His goal is to drive a wedge between science and religion, and return people's faith to the Church and away from the secular miracles of the laboratory. One take-away message from the novel is that extremism of any form – whether in science, religion, or any other human endeavor – is dangerous. Another is that antimatter, and by association the creation of antimatter, is also inherently dangerous. There is also the classic Frankensteinian message: science cannot control that which it creates, despite its insistence to the contrary.

For example, the Camerlengo voices what he sees to be the inherent evil in both science in general, and specifically Vetra's work:

> What kind of God gives a child fire but does not warn the child of its dangers? The language of science comes with no signposts about good or bad. Science textbooks tell us how to create a nuclear reaction, and yet they contain no chapter asking us if it is a good or a bad idea.... (Brown, 2000, p. 477)

The risk posed by the possible misuse of antimatter (like any scientific discovery) should be part of the conversation between real scientists and the greater society in which they live. Even if scientists remain silent on these issues, other voices – voices less well-versed in the science, such as the fictional Camerlengo – will not.

The factoid noted in the novel's introduction was probably a reference to CERN's January 1996 announcement that it had created eleven antihydrogen atoms (made of an antielectron orbiting around an antiproton). The announcement of the discovery had been held back for several months in order for the results to be independently verified by other scientists (Browne, 1996). By 2002, CERN had created far larger amounts of antimatter, in fact over 50,000 individual anti-atoms, but they had all quickly and safely destroyed themselves in natural interactions with matter (Overbye, 2002). In November 2010 CERN announced that it had succeeded in trapping a small number of antimatter atoms (38 in all) using magnetic fields, a far cry from the portable antimatter containment devices featured in Brown's novel (Shaikh, 2010). In terms of the amount of antimatter that CERN is able to create at one time, a groundbreaking experiment reported in December 2016 was able to simultaneously trap 14 antihydrogen atoms, a sufficient number to demonstrate that, as expected, antihydrogen is the perfect reflection of hydrogen in is physical properties (Jarlett, 2016). Therefore, while Brown's novel does contain a kernel of scientific truth, it has been greatly inflated for the sake of reader interest.

But as noted by Joshua Krisch (2016) on the *Popular Mechanics* website, CERN is a "natural successor to Area 51" and as a "secret underground laboratory" the facility "just begs conspiracy theorists to speculate wildly." In response to such speculations, CERN (2011) developed its own "*Angels and Demons*: The Science Behind the Story" website to answer a barrage of questions about what CERN scientists do – and more importantly do not do – in their laboratories. The

website's frequently asked questions section also addresses issues not brought up in Brown's work, but which have recently been central to the increasing paranoia surrounding particle accelerators, including the possibility that CERN will create a black hole in the laboratory (an issue that will be discussed later in this essay). Thus in embracing public interest in the facility in light of the success of Brown's work, CERN has attempted to turn interest into good will, but, as will be seen, with mixed results.

Brookhaven and the Genesis of Fear

Fear of particle accelerators entered the public consciousness in March 1999, after the publication of an article in *Scientific American*. With the provocative title "A Little Big Bang," the article explained with great enthusiasm the scientific expectations for Brookhaven National Laboratory's soon-to-be-commissioned RHIC (Relativistic Heavy Ion Collider). By smashing together protons and atomic nuclei at high velocities, RHIC would attain temperatures and densities not "seen in the universe for several billion years" (Mukerjee, 1999, p. 60). Using "processes that mimic the big bang – but again are extremely hard to calculate," the experiment had the possibility to create conglomerates of quarks and antiquarks "and innumerable other hypothetical phenomena" (Mukerjee, 1999, pp. 63-4). The experiment could even create phenomena "as yet unimagined by theorists" (Mukerjee, 1999, p. 67). If the possible results were "hard to calculate" and possibly "unimagined," was it possible that the experiment was patently unsafe? More than one reader thought so and wrote to the periodical to voice their concerns.

A letter by Walter Wagner, a lawyer with a B.S. in biology and a minor in physics, published in the July 1999 issue, inquired if RHIC could possibly create miniature black holes, such as those proposed in the late 1970s by famed physicist Stephen Hawking. Wagner (1999) further posed the possibility that such a mini black hole could be "drawn by gravity toward the center of the planet, absorbing matter along the way and devouring the entire planet within minutes" (p. 8). Having already raised the alarm, he then threw some water on the fire by stating that his calculations showed that this would not occur, adding, "however my calculations might be wrong" (Wagner, 1999, p. 8). *Scientific American* gave rebuttal space to Princeton physicist (and later Nobel Prize recipient in physics) Frank Wilczek, who had been quoted in the original article. Wilczek (1999) acknowledged that all new explorations in science raise questions as to "whether we might unwittingly trigger some catastrophe," and therefore scientists must take such concerns "very seriously – even if the risks seem remote – because an error might have devastating consequences" (p. 8). He then affirmed that RHIC could not create Hawking mini black holes. However, to the chagrin of Brookhaven scientists, Wilczek then posited that strangelets – stable chunks of rare strange quarks – could not only be produced, but could "grow by incorporating and transforming the ordinary matter in its surroundings," something he compared to the "ice 9" scenario in Kurt Vonnegut's science fiction novel *Cat's Cradle* (Wilczek, 1999, p. 8). Wilczek attempted to calm fears by ending with the comforting thought that strangelets "if they exist at all, are not aggressive, and they will start out very, very small. So here again a doomsday scenario is not plausible" (Wilczek, 1999, p. 8).

Despite Wilczek's assurances, the damage had been done. The possibility that black holes and strangelets potentially created in a particle accelerator could pose a threat to the planet gained traction in the popular press. In response, the director of Brookhaven convened a commission of four scientists from Yale, MIT, and Princeton, including Wilczek, to craft a safety report that would hopefully allay fears. The report was released on September 28, 1999 and addressed three possible doomsday scenarios: the creation of a mini black hole or strangelet, or the transition of our universe into a new vacuum energy state. The report found that the collisions were not powerful enough to create black holes, the

production of strangelets could only occur if they came in doubly unexpected negatively charged and stable configurations (Busza et al., 1999, p. 4), and if it were possible to transition the universe to another state of being, natural processes would have already done it by now. Therefore there was nothing to worry about.

Similar conclusions were independently reached by three theoretical physicists at CERN. The trio even went so far as to assert that the RHIC experiment would produce no harmful effects in five million years of operation (Dar, De Rujula, & Heinz, 1999, p. 8). As CERN scientists, Dar et al. were not exactly unbiased observers of the Brookhaven situation. As noted in their paper, at that time CERN was constructing a new, larger collider project dubbed the Large Hadron Collider (LHC), and one of its experiments, named ALICE (A Large Ion Collider Experiment) was expected to produce energies thirty times higher than RHIC when completed (Dar et al., 1999, p. 8). Although public concerns over RHIC died down after the release of these documents, the battle was just beginning as far as the LHC was concerned, and the first salvos came from within the scientific community itself.

In 2000, Italian physicist Francesco Calogero challenged the RHIC safety reports, citing conflicts of interest among the writers and "an overarching preoccupation with the public relations consequences of what is said" (Johnson, 2009, p. 831). He specifically criticized the "lack of candor in discussing these matters" (Calogero, 2000, p. 198). Three years later, Cambridge University physicist Adrian Kent criticized the RHIC reports as well, pointing out that they were incorrectly calculating the short-term risk of producing strangelets (Johnson, 2009, p. 895). Although one might think that such arguments between scientists would be conducted out of the public eye, with the rise of electronic databases for scientific papers, especially the arxiv.org preprint archive, the dirty laundry of the physics community became visible to anyone with an Internet connection. However, how many of those from the general public who read these papers understood the physics and mathematics being debated? Regardless, the idea that the scientific community was not completely in agreement as to the likelihood of producing potentially hazardous particles became fodder for apocalyptic science fiction. Thus was born *The Black Hole* (2006).

This SyFy Channel production opens with a flyover of St. Louis, and the following subtitled text:

> In July of 1999, a panel of nuclear physicists discussed the possibility that a heavy ion collider experiment could result in the formation of a black hole.
>
> After an extended debate, the panel decided that such a scenario was not just highly unlikely, but impossible.
>
> They were wrong. (Takács, Baddish, & Davidson, 2011)

The action begins in the Midwestern Quantum Research Laboratory (MQRL), where Dr. Hauser and his associates are conducting an experiment in the dead of night. As he readies the controls, Hauser smugly notes, "let's see what God has in store for us tonight" (Takács et al., 2011). While the reference may be to the power of man to play God, it is possibly also a reference to the Higgs particle, whose existence is so central to our understanding of matter that Nobel Prize winning physicist Leon Lederman gave it the controversial nickname the God Particle.

Predictably, the experiment has a glitch, and when Hauser and an associate explore the accelerator tunnels they discover that the experiment has not only inexplicably spawned a far-from microscopic black hole, but an electromagnetic monster, along with an ever-increasing series of earthquakes. Hauser is killed by the creature, the associate is sucked into the black hole, and colleague Shannon Muir is left to deal with the

military response to the accident. Scientist Eric Bryce, one of the team's founding members, is brought back by the military to assess the situation. Bryce offers that their work "was only theoretical, and we were years from doing anything like this," but learns that his former teammates decided to accelerate their timeline due to competition from a Chinese laboratory (Takács et al., 2011).

Predictably the military's planned response is to bomb the black hole out of existence, but Bryce explains that the black hole will absorb the energy of the bomb and grow in response. He and Muir seek an alternative (non-military) response to the problem, and as the scientists track the electromagnetic monster along the city's transmission lines, the military evacuates the facility when the black hole breaches the containment walls. A local TV station's helicopter films the growth of the black hole as the increasing destruction plays out live. With the earthquakes growing in intensity, the government finally calls for an evacuation of St. Louis. Bryce argues to the skeptical military that the creature must be using wormholes to travel across the universe, and that Hauser's experiment created a weak spot in the space-time fabric of the universe that allowed the black hole – one of the mouths of the wormhole – to open up in the lab. Thus the screenwriter attempts to drag the black hole disaster scenario even further into the realm of hard science fiction. General Tate correctly summarizes the sentiments of the casual viewer: "this is just a bunch of egghead mumbo jumbo" (Takács et al., 2011). As the military prepares to drop a small nuclear missile on St. Louis, Bryce and Muir manage to lure the monster into the black hole by using a souped-up electric generator truck, sending both entities somewhere else in space and time, thus saving the world.

The film certainly raises questions about whether or not scientists could be wrong about the possibility of creating a black hole in the laboratory. It must also be acknowledged that the general public as a whole has misconceptions and fears concerning black holes themselves. For example, the average nonscientist does not understand the difference in behavior between the hypothetical microscopic Hawking black holes (theorized to have been created in the early universe and hypothetically creatable in a particle accelerator) and the garden-variety black holes formed from the deaths of stars many times heavier than our sun. Also common is the misconception that black holes are akin to cosmic vacuum cleaners, swimming through the galaxy like cosmic sharks actively seeking innocent planets, stars, and gas clouds to devour (Chandra X-ray Center, 2008). In actuality, a black hole is more parasitic than carnivorous, growing more massive only by taking advantage of easily accessible material in close proximity to it. However, scientists sometimes unwittingly bolster such misconceptions through the use of sensational language (in an attempt to capitalize on the public's fascination with these mysterious objects). For example, a podcast by the Chandra X-ray Center graphically says of the atoms in the accretion disk of a black hole that they "jostle each other with increasing ferocity as they rub together in a spiraling mosh-pit death dance as they are pulled towards the hole. So in some ways, these particles are fighting for their cosmic lives" (2008). Barry Luokkala's conjecture that part of the blame for the subsequent public misconceptions and fears concerning the LHC could be due to *The Black Hole* therefore appears to be reasonable, but fails to take into account that the scientists themselves may have fed the monster that Hollywood had created (2013).

Safety and the Large Hadron Collider: the Debate Widens

In 2008, construction of CERN's LHC was completed, and initial testing was scheduled for September. Like RHIC, the LHC would also try to recreate conditions found in the early universe, raising earlier concerns about black holes, strangelets, and other subatomic monsters. The

holy grail would be a detection of the elusive Higgs particle, the pervasive field that gives all particles in the universe their respective masses. It was anticipated that the discovery of the Higgs particle would undoubtedly earn a Nobel Prize, not only for Peter Higgs, who had initially suggested the Higgs mechanism that bears his name, but perhaps for the CERN scientists who actually found evidence of the particle.

Despite the CERN public relations office's attempt to sell its science to the general public and allay fears, too much had been written in the physics community in the preceding years that raised new specters of planet-wide destruction. Black holes had been summarily dismissed as potential problems in the case of the RHIC not only because it would not produce sufficient energy to create them, but because microscopic black holes would tend to shrink, not grow, through so-called Hawking radiation. But there has never been observational confirmation that Hawking radiation exists, and the basic calculations were originally only done for black holes formed in our normal three-dimensional space. What if the universe has more than three spatial dimensions (as predicted by string theory, and its successor, M-theory)?

A 2001 paper by physicists Stephen Giddings and Scott Thomas came to the unexpected conclusion that if space has more than three dimensions, then black holes could be created at significantly lower energies than previously predicted. In their words, "future hadron colliders such as the Large Hadron Collider will be black hole factories" (p. 1). After their paper was posted on the public arxiv.org archive, a reporter contacted Giddings, inquiring what would happen if the Hawking radiation mechanism couldn't take care of such black holes. The result was a second paper, "Black Hole Production in TeV-Scale gravity, and the Future of High Energy Physics," which demonstrated that if black holes were potentially a problem, natural high energy collisions between particles from space and our atmosphere (and other objects in space) would have already resulted in observable catastrophic events. Giddings also warned the physics community that "journalists regularly read our electronic archives!" (2001, p. 2).

The shadow of planetary annihilation had reared its head once more in the public eye, and CERN responded by issuing a lengthy safety study in 2003. All suggested catastrophe scenarios brought up in the RHIC report were revisited in light of advances in theoretical knowledge, and it was acknowledged that if space had more than three dimensions, microscopic black holes might be produced at the LHC. However, the report affirmed that the Hawking mechanism would destroy such objects before they could begin to pose a threat. In the techno-speak of the report, "black hole production does not present a conceivable risk at the LHC due to the rapid decay of the black holes through thermal processes" (Blaizot et al., 2003, p. 12). In light of the aforementioned paper by Kent and other criticism, CERN commissioned a second safety report in 2008 that similarly came to the conclusion that the LHC and its experiments did not pose a threat to the planet (Ellis et al., 2008). The result was a flurry of papers confirming and disputing the results, especially as concerned mini black holes and Hawking radiation. As CERN was forced to increasingly produce evidence that its soon-to-be commissioned machine was safe, its communications became proportionally more defensive. Their public web page "The Safety of the LHC" (CERN Press Office, n.d.) listed numerous papers and quotations from physicists and professional organizations that agreed with the findings of the 2008 safety report and dismissed critics.

One of CERN's most vocal opponents has been Walter Wagner, the author of the letter to *Scientific American* that started the backlash against RHIC in 1999. Wagner and others went so far as to file lawsuits in both Europe and America seeking to stop the initial testing at the LHC in September 2008. Despite the failure of these lawsuits, online criticism of the LHC did not

diminish. Notably, online criticism has been far more pseudoscience than science. For example, the online article "LHC restarts and 9.1 earthquake: Why?" attempts to connect the LHC to the earth's magnetic field, magnetic fields to earthquakes, and hence the LHC to recent earthquakes (Sanchez, 2011). While the statement "Earthquakes are caused by change in magnetic fields on the planet" would be considered laughable by geologists, viewers of *The Black Hole* might deem this connection plausible. Combining this with the widespread erroneous rumor that the earthquake activity occurring in recent years is somehow abnormal, one can see how some in the general public might be swayed by such a website (USGS, 2017).

The Internet has therefore been a breeding ground for criticism and hysteria concerning the LHC and other particle accelerators. For instance, an online petition by "Stephen" urged signers to protest the initial testing of the LHC, because "Many people believe the the L.H.C. can generate enough energy that could end the world. Weather it may be One Mini-Black Hole per Second, one big Black Hole, and God knows what eles [sic]." Although the petition had a stated goal of 5000 signatures, only around 1400 were collected before the petition was closed. Comments to this petition demonstrated that many of the same people who believed in the possibility of an LHC apocalypse also subscribed to the so-called 2012 hoax, the idea that the Mayan calendar predicted the end of the world on December 21, 2012. For example, one anonymous post to the petition dated January 23, 2009 (well after the LHC began operation) warned "This is a major mistake to let this thing go. The Mians [sic] and Chinese calendars both predict the world endeing [sic] in December of 2012. Could this machine be the reason?" It is therefore no surprise that a viral Internet post that began circulating in August 2008 (a month before the LHC began testing) entitled "Seven Reasons the World Will End in 2012: Scientifically Proven" listed the LHC as one of the seven causes for the presumed 2012 apocalypse (Larsen, 2013).

LHC Take Two: Annihilating Earth?

While one can discount the rants of conspiracy websites, it was far harder for the general public to ignore news stories circulating around the September 2008 opening of the LHC, with sensational headlines such as "Will man-made black holes swallow Earth?" and "Are we all going to die next Wednesday?" Not surprisingly, a poll taken by the BBC at this time found that 66% of people surveyed believed the LHC was too dangerous to switch on, and 61% of those surveyed in an AOL news poll agreed with this assessment (Sample, 2010, p. 160). The public fears also resulted in death threats against physicists, who were perceived as mad scientists bent on destroying the planet (Zahn, 2008). While the LHC did not destroy the world when it was first switched on in September 2008, it did suffer a serious accident, when a faulty electrical connection between two of its powerful magnets created a spark. This resulted in damage to several of the magnets, with some torn from anchors embedded in a concrete base (CERN Press Office, 2008). Such an accident certainly did little to bolster public confidence in the machine.

Complicating matters were statements made to the media by Sergio Bertolucci, Director for Research and Scientific Computing at CERN, in anticipation of the LHC's return to service in November 2009. The Register, a British technology website, reported on a news conference in which Bertolucci enthusiastically described the possibility that the LHC might create "unknown unknowns" including a temporary doorway to another dimension (Page, 2009). In particular, Bertolucci was quoted as offering that "Out of this door might come something, or we might send something through it," further explaining in a follow up communication with the website that although such a doorway could only be opened for a miniscule fraction of a second, "during that infinitesimal amount of time we would be able

to peer into this open door, either by getting something out of it or sending something into it" (Page, 2009). While Bertolucci added that such a connection to another dimension would pose "no risk to the stability of our world," the damage had already been done in terms of the online conspiracy community (Page, 2009). The Register's story was widely reported on conspiracy websites, including Rapture Ready, where Matt Ward (2017) wrote that he found "disturbing" the idea that both Bertolucci and Director General Rolf Heuer "admitted that one of the key overall aims of CERN's Large Hadron Collider is to open a portal to another dimension." A controversial series of papers written by physicists Holger Bech Nielsen and Masao Ninomiya smacked of conspiracy themselves, this time on the part of the universe. As reported in The New York Times a month before the collider returned to service, Nielsen and Ninomiya predicted that all experiments that sought to find the Higgs particle would be doomed to fail (i.e. suffer some sort of calamity that prevented their success), because Nature "hates Higgs particles, and attempts to avoid them"(Overbye, 2009).

In the end, even the most basic experiments sounded scary to the unprofessional ear: for example, if the Higgs particle could grant mass, could it grant enough mass to create a black hole? This scenario became the basis for perhaps the most fear-provoking of particle physics disaster films, *Annihilation Earth* (2009). This SyFy Channel original film is set in 2020, and begins with a ghostly cloud travelling along the underground tunnel of a huge particle accelerator modeled on CERN. The cloud impacts a target in a flash of light, and the scene morphs to scientists in radiation suits carefully walking through the ruins of a large city. The message is unmistakable, and only gains traction as the plotline unfolds.

Events in the movie are revealed to take place along a timeline beginning some 80 hours before "extinction," according to the subtitles that occasionally appear on the screen (Jordan & Lyon, 2009). United Nations representative Paxton informs head scientist David Wyndham that security at the Orleans, France accelerator (part of the EVE or Electromagnetic Vacuum Energy project) has been breached. At the subsequent press conference, Paxton explains that the EVE project has provided "a clean, renewable, almost limitless energy source which has reduced fossil fuel use by 65%" by remotely linking three supercolliders at Orleans, Barcelona, and Geneva, the last a direct nod to CERN (Jordan & Lyon, 2009). Representatives from the oil producing nations of the Middle East (portrayed as blatant and negative stereotypes of Arabs throughout the film) not only object to the fact that they have been left out of this technology, but that their oil is increasingly losing value. Wyndham's friend and scientific colleague, Raja Raheem Bashir, himself an Arab, has moral quandaries about the project, beyond the fact that the Arab states are being left out in the cold. "We didn't create a weapon, Raj," Wyndham tries to assure him. But Bashir ominously mentions "a program, David, that is a Pandora's Box" (Jordan & Lyon, 2009).

Bashir is afterwards framed for the security breach, and the subsequent destruction of the Orleans supercollider (with the resulting deaths of 20-30 million people), acts actually committed by known Arab terrorist Aziz Khaled. It is revealed that the metaphorical Pandora's Box has been opened, a simulation called the Doomsday Equation, through which someone might manipulate the supercolliders' system codes in such a way as to begin making Higgs fields. When she is finally told of the Doomsday Equation, Paxton accosts Wyndham: "You and Raj knew there was a 1 in a 1000 scenario where your collider system would destroy the planet and you decided to keep this information to yourselves?" (Jordan & Lyon, 2009). This accusation and the references to the Higgs field (with the inclusion of the term vacuum energy in EVE's name) all point to the screenwriters' use of the LHC safety debate as source material for their screenplay.

As the film continues, the earth's magnetic field and plate tectonics become unstable (although as previously noted there is no real connection), and as planes, satellites, and the International Space Station fall from the sky and Middle Eastern fault lines shift, Wyndham and his team survey the remains of Orleans searching for evidence that a Higgs field has been created. Wyndham explains that during the program's early days "alarmists believed that smashing together protons at these kinds of speeds would create some kind of a mini black hole which inevitably leads to the end of the world" (Jordan & Lyon, 2009). When a colleague dismisses that possibility as the delusions of "a bunch of conspiracy theorists," Wyndham has to admit that he and Bashir had discovered that it wasn't impossible, but someone would have to intentionally alter the codes of the system to achieve the Doomsday Equation (Jordan & Lyon, 2009). The presumed connection to Higgs fields is never clarified, other than the comment of an anonymous team member that "until now we never knew for sure what effects a Higgs field might have on a massive scale" (Jordan & Lyon, 2009).

Bashir is kidnapped by Khaled, who brings the scientist to the Barcelona facility and attempts to force him to destroy that collider. Bashir kills Khaled and contacts Wyndham, who is now at the Geneva facility with his family and Paxton. Bashir tries to convince Wyndham that the two remaining colliders are preventing the Higgs field from expanding, while Wyndham believes that they are feeding the Higgs field and must be shut down and rebooted. Bashir warns Wyndham that if he shuts down the Geneva facility it will create a black hole, but in the end Wyndham succumbs to Paxton's repeated exhortations that Bashir is a terrorist, and he shuts down the machine. After Wyndham tells his son that they will be okay, Wyndham, his family, and the entire earth are destroyed in a flaming explosion. White letters type across the backdrop of the debris of our planet: "Extinction" (Jordan & Lyon, 2009).The film therefore not only plays on numerous fears surrounding the LHC (and the public's inability to separate fact from fiction), but the rampant fear of terrorism in general, and Middle Eastern terrorism in particular. It is no coincidence that posts to various online LHC protest sites refer to the CERN scientists as "terrorists" bent on destruction. It is also an interesting coincidence that several months before the premiere of *Annihilation Earth* an LHC scientist was arrested (and later convicted) on suspicion of working with Al Qaeda ("Former CERN Scientist…", 2012).

The science behind *Annihilation Earth* appeared to be a mishmash of all the proposed LHC disaster scenarios previously mentioned in this paper, as well as one that so far has not – the bosenova scenario. In this case, the coolant in the LHC system would create a "super atom" that would interact with the intense magnetic fields of the machine and could theoretically erupt in a miniature version of a star exploding as a supernova. Although this scenario involves coolants other than the liquid helium used in the LHC, some LHC conspiracy hawks have nevertheless put forth this scenario as a possibility (Johnson, 2009, p. 833-4). Therefore, while this vacuum energy-Higgs-black hole-bosenova explosion dreamed up by the writers of *Annihilation Earth* is decidedly unfaithful to science, it may accurately reflect the general public's limited understanding of the issues surrounding supercolliders.

Annihilation Earth is just one extreme example of science fiction popular media that capitalized on the public's wary interest in the LHC at its 2009 restart. For example, concurrent with the return of the LHC to service, Lexus car company's L Studio posted a rather unsettling online short film called "Rift." The film, which focuses on an experiment at a particle accelerator that seeks to discover a parallel universe through the intentional creation of black holes, is seen through the eyes of the main scientist/spokesman, Blake Loch. As he ominously explains to reporters shortly before giving the signal to start the experiment, "Great scientific discoveries never occur without risk," but when he jokes, "I promise

you all, the sun will come up tomorrow," there is an uneasy lack of laughter (Huang, 2009). The experiment initially malfunctions (causing an earthquake and impressive electric spark) but apparently succeeds, as Loch unwittingly shifts from one reality to another.

In a trio of science-based suspense novels penned by Patrick Lee – *The Breach* (2010), *Ghost Country* (2011), and *Deep Sky* (2012) – the reader is led to believe that the 1978 inaugural test of the fictional Very Large Ion Collider accidentally created a dangerous wormhole that threatened the planet. Over the course of the series, it is revealed that the scientists themselves are largely the victims of a massive conspiracy involving not only the usual rogue politicians and billionaires, but travel through time and space and the search for human immortality. The wormhole (the eponymous Breach) was the intentional creation of future versions of several main characters for the purpose of influencing the past/present. However, producer Lorenzo di Bonaventura has hyped his upcoming film treatment of *The Breach* by describing it as "a story about what happens when the supercollider goes wrong… We've always heard that a black hole could open up. Something actually that no one's ever hypothesized, but a variation on it, occurs which creates a life-threatening situation for the entire world" (Chitwood, 2014). A massive conspiracy also attempts to cover up a world changing disaster at the Large Hadron Collider in the never completed (2011-12) Internet series The Apocalypse Diaries (Frost, 2016).

It is interesting to note that a group of CERN physicists actively capitalized on the public's lack of understanding (and fear) of accelerators in general, and the Higgs mechanism in particular, in creating an extremely low budget (£2,000) zombie film released online entitled Decay (Thompson & Mazur, 2012). Ph.D. student Luke Thompson was motivated to make the film by his time spent in the tunnels in the facility that connect the various buildings, convinced that "they were very creepy and would make a great setting for a horror film" (Reisz, 2013). The film was meant as a satire of the hysteria surrounding the LHC and opens with a disclaimer explaining that the film was not "authorized or endorsed by CERN. It is purely a work of fiction" (Thompson & Mazur, 2012). The plot centers on a conspiracy by the fictional Director General of CERN, who wants to continue experiments on the effects of "Higgs radiation" on living tissue at any cost, including the murder of CERN staff members and hapless graduate students. It is discovered that the Higgs radiation affects the brain, killing all parts of the organ except for the brain stem, turning a CERN scientist and his assistants into zombies when they are intentionally exposed to the radiation by the nefarious Director General. An army of the undead is unleashed upon the Geneva countryside while the Director General murders the last surviving witness to his crime in order to cover his tracks. Thompson opines that his film's "scientists are even worse than the bad scientists in Hollywood movies" (Riesz, 2013), but if one puts aside the zombies, the basic plotline is uncomfortably close to wild accusations made by Internet conspiracy theorists against CERN.

In recent years television series have also preyed upon media coverage of anxieties surrounding the LHC's return to service. *The Sparticle Mystery* (2011-15) was a British science fiction television series marketed for children. The series followed a group of children after an accident at a large particle accelerator called the Sparticle Project sent anyone aged 15 and over into a parallel dimension. Over the course of the series the children attempt to realign the two parallel universes and bring their parents home (which they succeed in doing in the final episode). When asked about the inspiration for the series, creator Alison Hume explained that

> The idea came from the Large Hadron Collider at CERN which is the biggest experiment in the world. There was a lot of media speculation about what might happen when they switched the LHC on and that got me thinking. What would children like to happen? For

> their parents, carers and the world's adults to disappear off the face of the earth of course! (Shelley, 2011)

The short-lived Fox Network science fiction series *Terra Nova* (2011) painted a portal between parallel realities in perhaps less sinister terms, but it was still portrayed as an unexpected outcome of a particle accelerator experiment. *The Boat/El Barco* (2011-13) was a Spanish television series in which a cataclysmic accident occurs at a particle accelerator in Geneva, after there had been ample warnings that the experiment was dangerous. The series focuses on a dozen college-aged students and the crew of a ship named the Pole Star who initially believe that they alone have survived a catastrophe that appears to have destroyed most of the land on earth.

In keeping with their use of Dan Brown's novel *Angels and Demons*, CERN worked with author Robert J. Sawyer to educate the public on the science and the fiction of his use of the LHC in his thriller *FlashForward* (1999). In the novel (set at the LHC in 2009), Higgs experiments cause everyone on earth to lose consciousness at the same time, as their consciousness is momentarily transported over twenty years into the future. Sawyer noted in an interview published on the CERN website that when he wrote the novel he had been aware that the LHC would be going online in 2009 and integrated that into his story from the start (Del Rosso, n.d.). An article in the CERN Bulletin noted that

> it was certainly not Sawyer's intention to create another scare story on the safety of the LHC. As he points out "*FlashForward* was first published in 1999, long before this nonsense started circulating about the LHC possibly creating a black hole or otherwise destroying the world. If I'd known that all of that was going to erupt in the media, I might have chosen another setting for my novel!" (Stracy, 2009, p. 4)

In the novel, the FlashForward is eventually discovered to have been caused by a natural astronomical event wreaking havoc with the experiment, and is therefore not the scientists' fault. However, the short-lived television adaptation (2009-10) turns the event into a terrorist attack and grand conspiracy, playing on the very same Internet fears that Sawyer had wished to avoid feeding. Therefore appearances of the LHC and other particle accelerators in popular culture during the LHC's initial scientific run overwhelmingly tended to emphasize the potential for disasters, playing on concerns for safety and sensational comments made by both scientists and conspiracy websites alike.

Post-Higgs Sound and Fury

In February 2013 the LHC completed its first run of experiments without either creating black holes or destroying the world. It was, thankfully, successful in detecting the Higgs particle in 2012 (CERN Press Office, 2012), resulting in Peter Higgs receiving a share in the 2013 Nobel Prize in Physics. Among other triumphs was the experiment ALICE achieving the hottest temperature ever created in a laboratory, around five trillion degrees Celsius or over 7 trillion degrees Fahrenheit (Hand, 2012). After a 27-month servicing shut down, the LHC fired up again in June 2015, at twice the collision energy of its earlier experiments and with the promise of further exciting discoveries to come (CERN Press Office, 2015). No planet-exploding bosenovas were produced, nor strangelets, black holes, or unstable vacuum states. There was, however, a temporary power outage in April 2016 caused by a weasel eating through electrical wiring, a problem reminiscent of a 2009 incident in which a similar loss of power was caused by a bird dropping a baguette on wiring (Imam, 2016).

Given the demonstrated safe (and successful) operation of the facility and the likewise safe (and uneventful) passing of the supposed doomsday of December 21, 2012, it might be logical to presume that both popular media and

conspiracy websites might lose their appetite for potential particle accelerator disaster scenarios. However, the reverse has actually been the case. The American television series *The Flash* (2014-) is based on the central premise that the explosion of a particle accelerator experiment (as in the case of *Annihilation Earth*, meant to provide clean energy) creates humans with super powers, including the eponymous character. While past science fiction authors have certainly appealed to high energy radiation to mutate ordinary citizens into superheroes and supervillains (perhaps most notably Dr. Bruce Banner/ The Hulk), the timing of this series, and the very specific plotline of a particle accelerator accident as the source of the radiation (an origin story that is not in the original DC Comics), is suspicious, to say the least (Hawkins, 2014). The third installment in the popular *Cloverfield* movie franchise (slated to be released in October 2017) is reportedly based on a script originally entitled "God Particle" that features an accident involving a particle accelerator and the Higgs boson. As Valerie David (2016) observed, the film's screenplay was

> originally conceived during the Large Hadron Collider's initial testing phase, which ran from 2008-2013. The enormous particle accelerator sparked many doomsday fears, including the creation of black holes and the destruction of the entire planet. While scientists insist the experiments are safe, it's easy to see how the upcoming film will tap into viewers' concerns about messing with the fabric of reality.

It is important to note that this is not a solely American phenomenon. For example, the 2013 German-Austrian disaster film *Heroes – When Your Country Needs You* (*Helden – Wenn dein Land dich braucht*), produced by television station RTL, was an unimaginative rip-off of *The Black Hole*. An accident at a Geneva particle accelerator creates a black hole that destroys much of the city, causes satellites and planes to fall from the sky, and is ultimately bombed by NATO to make it collapse. Blogger Luboš Motl (2014) laments that "the lousiness of this movie went well beyond their ludicrous opinions about physics and the scientific method.... One could be frustrated by seeing that many people – even in the cultural 'front' of the would-be pro-scientific European continent – are so hostile to particle physics."

The online community has also been busy concocting new threats, doomsday scenarios, and conspiracies concerning CERN and the LHC. For example, a statue of the Hindu deity Shiva (often called The Destroyer) on the CERN grounds (a gift from the member country of India) has been touted as evidence of the nefarious intentions of the CERN scientists. A representative claim made by blogger twclark66 (2015) insists that the statue is proof of CERN's connection to both the Illuminati and a supposed Egyptian cult of Osiris whose purpose is to build an "inter-dimensional portal" or "Stargate," apparently a reference to the film and television series of the same name. An attempt at related humor by CERN staff in 2016 backfired dramatically. A video purporting to show a human sacrifice to Shiva at CERN made the rounds on the Internet, not only forcing the facility's public relations team to officially disavow the unauthorized prank and promise an investigation (Griffin, 2016), but causing the debunking site Snopes.com to officially add the video to its repository of Internet hoaxes (LaCapria, 2017). Also publicized on the Internet was a photograph claiming to show a portal to another dimension opening up in a violent storm over CERN. Featured in a widely circulated online video created by conspiracy theory group Freedom Fighter Times, the image is actually of a thunderstorm occurring elsewhere in Switzerland taken by photographer Christopher Suarez and used without his permission (Palma, 2016).

Thus fears over the potential for the LHC to create doomsday scenarios have not been quelled. For example, as recently as February 2016, Don Lincoln, a physicist conducting research on

the CMS experiment at the LHC, wrote an oped for LiveScience.com once again debunking the pseudoscience and dispelling the concerns documented in this essay. Interestingly, Lincoln spun the potential discovery of microscopic back holes at CERN as a cause for celebration:

If we do see tiny black holes, we'll have figured out why gravity seems so weak. We'll probably have established that extra dimensions of space exist. We'll be that much closer to finding a theory of everything, a theory that is so persuasive, simple and concise that we can write its equation on a T-shirt. (Lincoln, 2016)

Likewise, some scientists are now hard at work trying to explain why the LHC hasn't created Hawking black holes as of yet (Ali, Faizal, & Khalil, 2015).

Conclusion: A Teachable Moment in Communicating Science

Misconceptions and fears concerning black holes and the Higgs particle are only two sources of the public's anxieties about the LHC. A major trigger for public fears when it comes to anything science-related is the word radiation. This term is generally used very differently in science versus the common vernacular and has a "frightening connotation for the majority of people" (Neumann, 2014, p. 358). In particular, the term is most often associated with nuclear weapons (Burgess 2004). Olof Hallonsten (2016) points out that the study of particle physics directly benefitted from the rise of the so-called Military-Industrial-Complex after World War II, and Big Science projects that are largely funded by and the product of governmental policy decisions are often viewed with suspicion by the general public (Noë 2017). There has also been a disturbing rise in the mistrust of science in some political and ideological segments of the American population over recent decades (Gauchat 2012). The open spirit of debate that is the hallmark of the scientific method is now turned against the scientific community by its critics: after all, how can scientists be trusted if they don't all agree 100% on the possibility of black holes being created in the LHC? The general public wants the comfort of certainty, whereas modern science (especially anything dealing with quantum mechanics or statistical mechanics) deals in probabilities.

It is therefore imperative that scientists accept the lessons taught by these works of science-based fiction, and put concerted effort into communicating accurate science for the general public in an engaging, respectful, and accessible manner. For example, scientists-turned-novelists Gregory Benford and David Brin have successfully incorporated the possibility of black holes being created in a laboratory in a positive manner into their respective novels *Cosm* (1998) and *Earth* (1990). It is likewise the job of responsible journalists to aid the scientific community in passing along the truth rather than succumbing to the hype. This also requires particle physicists to work with writers and directors to integrate the inherently exciting science into their art in ways that entertain without unnecessarily causing fear. The film *Interstellar* (2014) was an excellent example of productive teamwork, with black hole expert Kip Thorne acting as science advisor (Billings, 2014).

But what, precisely, is the best way to replace misconceptions and pseudoscience with proper science in the minds of the general public? Clearly words matter. Scientists need to understand that public statements about the possibility of the creation of black holes in the laboratory, attaining energies never seen since the early seconds of the early universe, or making a connection to another dimension sounds like science fiction to the general public and can evoke fears in the minds of those who are not experts in the field. However, research has shown that it is not merely a matter of improving scientific knowledge/literacy among the general public (although this should continue to be a goal of

the scientific community). Attitudes towards science are, not surprisingly, also affected by an individual's political and religious views as well as their overall trust in science/scientists, and can vary from one scientific issue to the next (National Academies of Sciences, Engineering, and Medicine, 2016). John Cook and Stephan Lewandowsky also warn that many attempts to debunk misconceptions actually strengthen belief in them. These so-called "backfire effects" result from making the misconception too familiar (so it sticks in the individual's mind), utilizing arguments that are too complicated, or directly threatening an individual's worldview (2012, p. 1). Effective countermeasures to misconceptions hinge upon presenting plainly written, concise information focusing on the main facts while clearly differentiating the real science from the pseudoscience (Cook and Lewandowsky, 2012).

The public relations staff at CERN deserves credit for beginning to implement these lessons in their statements to the general public. An example is a communication strategy utilized when conspiracy websites implicated CERN in a supposed Biblical prediction for the end of the world on September 23, 2015. Rather than draw further attention to the online conspiracy theory through an official press release, CERN quietly addressed it on their special FAQ page devoted to answering some of the specific claims circulating on social media. It tackles some of the more lurid conspiracy theories described in this paper (such as the Shiva statue and the supposed human sacrifice) in brief, pointed, and confident statements. For example, the hoaxed human sacrifice video is merely referred to as a "strange ritual" and is described as "a work of fiction showing a contrived scene. CERN does not condone this kind of action, which breaches CERN's professional guidelines. Those involved were identified and appropriate [sic] measures taken" (CERN Press Office, n.d.). Note that the language is carefully selected to defuse and downplay the potentially sensational nature of the story by focusing on the facts. That the FAQ page rose to the top of related Google search results suggests that meeting sensational screaming headlines on social media with a more deliberate and sedate approach should be the wave of the future (Mandelbaum, 2016).

As Euclides Montes reflected in 2009 in the face of the anxieties surrounding the start-up of the LHC, "Fear has always been a travel companion of scientific progress.... This deep-rooted fear of what lies just beyond us – both physically and intellectually – has characterised humanity's thirst for knowledge as well as its reaction to the advancements the quest has brought with it." In the Internet Age, these fears are also frequently stoked by "absurdities spread with the speed of light" (Sessions, 2008). Art has always reflected life through an imperfect mirror, while scientists have too often isolated themselves from the greater society in which they reside. Scientists and artists both view the natural world with awe. In working together, they not only have the potential to more effectively inform and entertain, but garner the support of the general public they both ultimately serve.

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