"Always open any curiosity door we find": The Saganesque Substructure of *Stranger Things*

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Science and Disenchantment

"I believe that the extraordinary should certainly be pursued. But extraordinary claims require extraordinary evidence."
(Sagan, Broca's Brain *62)*

The Duffer Brothers' original pitch book for a miniseries named *Montauk* what became *Stranger Things* (2016-2025) proudly proclaims its horror to be "rooted in science. Dark matter, black holes, worm holes, alternate universes… we want to use the mathematics of theoretical physics to ground our horror in reality" (Duffer & Duffer, *Montauk* 11). In the intervening years, the Duffers have repeatedly confirmed the centrality of science to the series, including the Season Five reveal of the Upside Down as a wormhole (e.g., Grow; Romano). *Stranger Things* is not a science documentary, and no one can expect the science to always be 'correct.' Nor can all the various uses of science in the series be described in a single paper.

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However, as with other explorations of *Stranger Things'* portrayal of the 1980s, one can ask how faithful The Duffer Brothers are to what was known about particular aspects of science in that decade for example, wormholes versus how such concepts are described in the popular science of the time.

Such an analysis must accept that *Stranger Things* is, in general, a "simulacrum" of the 1980s, taking pieces from both history and the popular films of the times to create something that "resides in an in-between not 1980s, not 2016, but both" (Griffith 13; Mackay 69). In addition, as a work of science fiction, by definition it "incorporates supernatural, estranged, or nonempirical elements" not found in reality; however, it "naturalizes" such elements by grounding them in a scientific methodology that appears (reasonably) self-consistent within the Secondary World (Malmgren 11). As J.R.R. Tolkien explains, the author creates a "Secondary World which your mind can enter. Inside it, what he relates is 'true': it accords with the laws of that world. You therefore believe it, while you are, as it were, inside" (Tolkien 52). While the additional elements might be truly "supernatural" religious, magical, or occult elements existing completely outside the laws of nature (even within the Secondary World) and hence incapable of ever being explained by science they can also be "paranormal" or perhaps "super-natural": beyond the laws of nature as currently understood, yet entirely natural (in terms of the Secondary World, and perhaps even within our own) (Hill).

The history of science is likewise filled with examples of phenomena that have shifted from super-natural to natural through the use of the empirical scientific method, ranging from the biological (e.g. the functions of the human body) to the cosmological (e.g. planetary motion and the origin of the universe) and all manner of topics in between. The ability to use

scientific principles to understand what was once considered unexplainable is typically viewed as part of the excitement of doing science, even when the ultimate explanation is not what one expected (or perhaps even hoped for). For example, astronomer Carl Sagan, arguably the most well-known American scientist of the 1980s, opined

> Science invites us to let the facts in, even when they don't conform to our preconceptions. It counsels us to carry alternative hypotheses in our heads and see which best fit the facts. It urges on us a delicate balance between no-holds-barred openness to new ideas, however heretical, and the most rigorous skeptical scrutiny of everything. (Sagan, *The Demon-Haunted World* [*Demon*] 27)

However, others have viewed the process of modern (post-Scientific Revolution) science as "disenchanting," narrowly viewing it as a closeminded servitude to the laws of nature (Reeves 65). Josh A. Reeves views the scientific methodology utilized by the central group of children in *Stranger Things* known as the Party and their older allies as "another way of imagining science, one that can be both fully enchanted and scientific at the same time," which he defines as promoting "individual experience over naturalistic understanding, which makes it more open to realities that lie beyond what we can understand" (Reeves 66). Although for much of the paper Reeves seems to argue for what scientists might call experimental versus theoretical science,[1] by the end he veers into theology and, by definition, the truly supernatural that which can never be explained by science. Much of his argument (based on the first four seasons of the show) that there are important aspects of the *Stranger Things* Secondary World that

defy scientific understanding even within the rules of the Secondary World itself was effectively countered in Season Five, through a number of important revelations (including the nature of the Upside Down and the source of Eleven's powers). While Reeves might now argue that in the end the Duffers simply sold out to disenchantment, I argue that both the role of science, and the process by which scientific inquiry is conducted in the series, reflect a highly enchanted and enchanting scientific mindset that was popular in the 1980s due to the efforts of Carl Sagan.

Called "the Mister Rogers of complex scientific concepts" and "America's most effective salesman of science," Sagan burst into the public consciousness in the 1970s with numerous guest appearances on *The Tonight Show with Johnny Carson* and his Pulitzer Prize winning book *The Dragons of Eden*, culminating in his record-breaking public television series *Cosmos* (1980) (Perry; Golden 69). His public influence persisted until his death in 1996, as reflected in his 1985 Congressional testimony on climate change, revised versions of the *Cosmos* series (including one aired in 1986, during the heart of the *Stranger Things* timeline), and numerous additional best-sellers. Unlike many of his contemporaries, Sagan balanced speculation with skepticism and embraced curiosity. Sagan, like Hawkins Middle School science teacher Scott Clarke, sought to educate both inside and outside the classroom, to help others understand the universe and find joy in the discovery process. This paper offers a close reading of not only direct references to Sagan within the series, but also the deeper Saganesque approach to science adopted by the series' heroes.

Depictions of Scientists in Popular Culture

"Many hypotheses proposed by scientists as well as by nonscientists turn out to be wrong. But science is a self-correcting enterprise." (Sagan, Cosmos *91)*

Science teacher Scott Clarke (Randy Havens) is one of many fictional scientists featured within the series. While Clarke is clearly a heroic figure, the same cannot be said of the majority of the others. Roslyn Haynes describes seven stereotypes of scientists in popular media, including two flavors of what is colloquially termed the *mad scientist*: the "evil alchemist" engaged in secretive, illegal/immoral experiments, and the "mad, bad, dangerous scientist," the megalomaniac with the potential to destroy the world (Haynes 245, 251). Scientists depicted in the Whedonverse (which has its parallels to the world of *Stranger Things*) provide handy examples of some of these stereotypes; for example, the former stereotype is reflected in Topher Brink of *Dollhouse* (2009-2010)[2], and the latter (although in satire) by Doctor Horrible and his eponymous *Sing-Along Blog* (2008). Drawing specifically from *Buffy the Vampire Slayer* (1997-2003), while Season Four's Maggie Walsh is a particularly clear example of a mad scientist, "morally bad scientists" abound throughout the series (Porter 59; Nylin par. 26). In *Stranger Things*, Dr. Martin Brenner (Matthew Modine) embodies aspects of both of these tropes; his decades of secret government-sponsored experiences on adults (including pregnant women) and children not only results in the birth of Eleven (Millie Bobby Brown) and the honing of her powers, but countless deaths and ultimately to Vecna's (Jamie Campbell Bower) ability to threaten the entire world.

The 1980s setting of the series allows the Duffers to effectively draw upon real-world Cold War scientific projects (and the conspiratory mindset that surrounded many of them) for inspiration and reference (Griffith 8-9; Relidzyńska 235). This includes both secretive (e.g. MKULTRA) and openly

publicized programs (e.g. Reagan's Space Defense Initiative (1983), nicknamed Star Wars). For example, the fictional Hawkins National Laboratory, operated by the Department of Energy (DOE) with secret connections to the military, is presumed by local residents to be working on "space weapons…. like, Reagan's Star Wars" ("Chapter Three: Holly, Jolly" 1.3, 11:42-53) and "weapons... to fight the Russians" ("Chapter Seven: The Bathtub"1.7, 11:20-28). The series (and especially its prequel play, *Stranger Things: The First Shadow*) also draw upon persistent conspiracy theories concerning supposed secret government science experiments with teleportation, especially the so-called Philadelphia Experiment/Project Rainbow (Moore; "Philadelphia Experiment").

After Brenner's death in Season Four, the mantle of main mad scientist is borne by military scientist Dr. Kay (Linda Hamilton), through her gruesome experimentation on creatures from the Abyss and single-minded obsession with recreating Eleven's powers (via decidedly unethical experiments on pregnant women and their fetuses) for the sake of creating bioweapons. By the series finale, her own subordinates openly describe her as having a "God complex" ("Chapter Eight: The Rightside Up" 5.8, 02:40-43). The Soviet scientists introduced in Season Three apparently lack the megalomania of Brenner but do engage in a variety of ill-fated experiments both to create gateways to the Upside Down and biowarfare-directed experiments on Demogorgons and other creatures from the Upside Down in Kamchatka. This codes them as a combination of Haynes' evil alchemist trope and that of the "helpless scientist" who falsely believes they can control their experiments and both their intended and unintended consequences (Haynes 247-8). In the Whedonverse an obvious

example is the technicians of the Facility in *The Cabin in the Woods* (Larsen 10-1).

In contrast, Dr. Sam Owens (Paul Reiser) envisions himself as the "noble scientist" (a heroic figure who works toward the benefit of society or to save the world) who admits to Nancy (Natalie Dyer) and Jon (Charlie Heaton) that he is trying to fix both the ethical and scientific mistakes of Brenner ("Chapter Four: Will the Wise" 2.4). However, by the end of Season Two he ends up as another example of the "helpless scientist," unable to control the gate to the Upside Down opened within the lower levels of Hawkins National Lab or prevent the spread of the Abyss's influence throughout the fields and other fauna of Hawkins (Haynes 245-6, 252-3). L.E. Carmichael describes Owens' fault as not "the same kind of arrogance as Brenner's…. Owens' comes from a lack of imagination… he can't imagine a world where science might actually fail a world where the unknown defies our attempts to define it, predict it, and ultimately put it in a safe little box where it can't hurt us" (Carmichael, "Part II").

As will be shown, science teacher Scott Clarke clearly represents a true "noble scientist," through his "open sharing of information… team research… [and] knowledge wholly directed to the benefit of society" (Haynes 246). However, he reflects more than this narrow trope, as his character owes much of his personal ethics and scientific ethos to real-world scientist/science educator/science popularizer Carl Sagan.

Carl Sagan and Scott Clarke: Curiosity in Action

"Science confers power on anyone who takes the trouble to learn it." (Sagan, Demon *38)*

Born in 1934, Carl Edward Sagan was raised in a working-class Jewish New York neighborhood of New York. He earned his

bachelor's, master's, and doctorate degrees (in Physics and Astronomy) from the University of Chicago. Following postdoc work in biology at University of California, Berkeley and Stanford University, he was hired into the astronomy faculty of Harvard. After being denied tenure, he joined the faculty of Cornell University in 1968 as the David Duncan Professor of Astronomy and Director of the Laboratory for Planetary Studies, posts he held until his death in 1996 from pneumonia (a complication of his two-year battle against myelodysplasia) (Morrison). Sagan was a trailblazer in two interdisciplinary fields: exobiology (the scientific study of the origin and nature of possible life beyond earth) and planetary sciences. He openly rejected traditional disciplinary siloes and drew upon his interests in astronomy, biology, chemistry, and other fields while stressing critical thinking and creativity over "disciplinary expertise" (Morrison; Marsh 470-1, 478). Sagan's personal approach to science embodied the innate enchantment of the scientific endeavor; as he explained, "Curiosity and the urge to solve problems are the emotional hallmarks of our species" (Sagan, *Dragons* 81).

Sagan's interdisciplinary background served him well as a member of the scientific teams behind most of the major interplanetary missions of the 1970s and 1980s, including flyby and lander missions to Venus, Mars, Jupiter, and Saturn. He computed the first model for the atmosphere of Venus that included a significant greenhouse effect, correctly predicting it to have the highest planetary surface temperatures in the solar system. His co-authored explanation that seasonable variations in the appearance of certain surface features on Mars was due to wind-blown dust was proven correct by the Mariner 9 and Viking missions, while other work explored the complex atmospheric chemistry of Jupiter and the largest moon of

Saturn (Morrison). During the height of his fame in the early-to-mid-1980s, Sagan used his scientific knowledge and public fame to bring attention to a number of political issues, testifying before Congress about the greenhouse effect and climate change, openly opposing Reagan's Star Wars program, and leading the charge to investigate the possible climatological impact of a large-scale nuclear war (the nuclear winter scenario) (Morrison).

A popular teacher and successful writer of popular-level science books, Sagan became America's most well-known ambassador for science after first appearing on *The Tonight Show with Johnny Carson* in November 1973. More than two dozen additional appearances followed (Morrison). Audiences were drawn to this attractive, well-spoken, good-humored and enthusiastic scientist who defied stereotypes of his field; his unique ability to bring the headiest concepts down to earth and equally distinctive speaking voice made him "sexy in a sense that transcends mere sexuality" (Davidson 263-4). For his part, Sagan understood the importance of his repeated opportunities to speak to Carson's national audience, what he termed "the biggest classroom in history," not only in raising public interest in (and understanding of) science but importantly support for funding of scientific research and exploration (Morrison).

Sagan is perhaps best-known today for *Cosmos: A Personal Voyage*, the 13-episode documentary series first broadcast on the Public Broadcasting Service in September 1980. Co-written with Ann Druyan (whom he later married) and Steven Soter, *Cosmos* won the Peabody Award, was rebroadcast in several different editions in the US and around the world, and was eventually viewed by an estimated 400 million people. One such special edition was broadcast in the fall of 1986 (between the in-world events of *Stranger Things* Seasons Four and Five). The

companion book, written by Sagan, spent more than a year on the *New York Times* best seller list and remained the best-selling science book in English until Stephen Hawking's *A Brief History of Time* (1988) (Morrison; Shermer 490). In his role of narrator and cosmic tour guide, Sagan began the series' premier episode, "The Shores of the Cosmic Ocean," by inviting the audience on a voyage of scientific exploration, to reclaim their birthright and know the universe for themselves. As he explained,

> We wish to pursue the truth, no matter where it leads. But to find the truth, we need imagination and skepticism both. We will not be afraid to speculate; but we will be careful to distinguish speculation from fact…. [T]he cosmos is also within us we're made of star stuff. We are a way for the cosmos to know itself…. We're going to explore the cosmos in a ship of the imagination unfettered by ordinary limits on speed and size…. Come with me. (1.1, 5:21-6:54)

The impact of *Cosmos* cannot be measured in viewing numbers or awards, but in the real-life impact it had on generations of scientists, including this author. Computer Systems Engineer Amy Elaine Jones recalls that her first viewing of the series in 1983 "gave this little girl an invitation to think and permission to wonder responsibly…. Sagan taught a generation that to understand reality is not to banish mystery but to meet it honestly" (Jones).

While his circle of influence is decidedly far more limited than that of Sagan (although one could argue he plays a larger role in saving the world in the series), *Stranger Things* earth science and biology teacher Scott Clarke clearly embodies the

best of Sagan's enchanted scientific method (while also sharing the same although reversed initials[3]). The Duffers began to draw direct connections between Clarke and Sagan from the pilot script of *Montauk*. A classroom scene has Clarke taking a decidedly Saganesque tactic with his students, inviting them to "start thinking of this class as an investigation into the greatest *mysteries* known to man. You'll need to learn to think beyond your own senses. This means using your imagination" (Duffer & Duffer, *Montauk Pilot* 32). After most of his class affirms that they had, indeed, watched *Cosmos* as assigned, Clarke continues "You may remember something Carl Sagan said: 'Imagination will often carry us to worlds that never were, but without it… we go nowhere'" (Sagan, *Cosmos* 4, qtd. in Duffer Brothers, *Montauk Pilot* 33).

In the series, Clarke channels Sagan in other ways. While he clearly engages in nerdy activities, such as playing *Dungeons & Dragons*, listening to Weird Al Jankovic, and quoting Tolkien, like Sagan he is depicted as much more than a one-dimensional stereotype. He is shown in two different romantic relationships over the series, and alpha male Jim Hopper (David Harbour) is openly jealous of Joyce Byers' (Winona Ryder) enthusiasm for Clarke's impromptu private lesson on magnetism ("Chapter Two: The Mall Rats" 3.2). But it is in his role as trusted interpreter of science for the residents of Hawkins (and his unabashed enthusiasm for this role) that Clarke most closely mirrors Sagan. In "Chapter Seven: The Bathtub" (1.7), Dustin (Gaten Matarazzo) immediately knows to call his teacher for help in constructing a sensory deprivation tank for Eleven, even late on a Saturday night. Unknown to Dustin, his teacher is currently relaxing with his current love interest. While Clarke initially tries to deflect Dustin's admittedly curious request to Monday morning, Dustin's

reminder of Clarke's personal mantra to "never stop being curious. To always open any curiosity door we find" is all that is needed to refocus the teacher's attention from his date to his student ("Chapter Seven: The Bathtub" 1.7, 26:02-18).[4] Fast-forward four years in-world, and Erica (Priah Ferguson), now one of his students, knows where to go for help in building a telemetry tracker to locate Dustin in the Upside Down. Again, while Clarke is initially taken aback by the 5 AM in-person wake-up call (taking him out of bed and away from a different lover), he is quick to spring to the aid of his former student ("Chapter Six: Escape from Camazotz" 5.6).

L.E. Carmichael declares Clarke to be the "real hero of *Stranger Things*. He doesn't have El's superpowers, it's true, but he empowers everyone he encounters. He empowers them with knowledge and compassion" ("Part IV"). But in contrast to the other scientists in the series, it is a power that is "both genuine and humble he loves science for science, not for what it might give him" (Carmichael, 'Part IV"). Stephanie Garrison also extols Clarke's heroism, noting "Knowledge has its own kind of power," including "the sex appeal of intelligence" (Garrison). It is in his multiple roles as teacher/mentor/role model/expert/collaborator that Clarke aids the Party and allies in saving the world. Along the journey, the viewer learns much about 1980s science, science fiction, and science popularization.

Into the Abyss: Wormholes in 1980s Science and Science Fiction

"I don't know whether the tunnel is stable against small perturbations…. I'm not yet sure of any of this. But at least if the tunnels can be Einstein-Rosen bridges, we can give some answer when they tell us we were hallucinating."
(Sagan, Contact *406)*

The single direct reference to Sagan by name in the series as televised appears in Season One's "Chapter Five: The Flea and the Acrobat" (1.5). After Will's (Noah Schnapp) sham funeral, Mike (Finn Wolfhard) secretively pumps Clarke for information about the Upside Down by seemingly innocently asking "you know how in *Cosmos*, Carl Sagan talks about other dimensions?" (1.5, 19:03-15). Clarke feeds the boys' interest in traveling to other dimensions with his usual respect and enthusiasm, despite the fact that others might deem such a seemingly frivolous conversation curious for the funeral of Mike's best friend. Using a paper plate and the engaging analogy of a flea who is free to travel in a spatial dimensional (the underside of the rope) that the acrobat is unable to explore, the teacher holds an impromptu lecture on extra-spatial dimensions. He concludes that, while their existence is allowed by the laws of physics, actually traveling to another dimension represents an engineering problem of mammoth proportions (even theoretically): "You'd have to create a massive amount of energy. More than humans are currently capable of creating, mind you, to open up some kind of tear in time and space, and then [as he folds the plate and pushes the pen through both sides] you create a doorway" (1.5, 20:32-57). Clarke's claim that such a doorway would disrupt both gravitational and magnetic fields, and evoking of the common trope in science fiction of a small localized black hole possibly destroying the world, are not completely faithful to the science; however, within the Secondary World of the series the side effects of the Upside Down are consistently portrayed as such, allowing them to be used as in-world signifiers, especially the supposed effect on magnetic fields (1.5).

The terms *another dimension* and *another universe* are tossed around quite loosely, and used interchangeably, in

popular media to refer to several distinct physical situations; for example, our universe could contain additional spatial dimensions both large and, as in the case of the flea, microscopic that are imperceivable in our everyday lives, or separate realities (other universes) may exist. However, in "Chapter Six: Escape from Camazotz" (5.6) the big reveal is that the Upside Down itself is not a parallel universe, as the characters had previously assumed, but actually a wormhole accidentally created by Eleven in 1983 when directed by Dr. Brenner to make psychic contact with a Demogorgon, connecting our universe to another that Dustin dubs the Abyss (in *D&D* lingo). The Abyss is the true home of all members of the so-called hive mind, including the Mind Flayer, Vecna (after having been banished there by Eleven in 1979), the Demogorgons, and other shadowy creatures. The Duffer Brothers' use of wormholes can be situated within the decade of the show's timeline, based not only on what was known about these theoretical objects in the mid-1980s, but how they were reflected in the popular media of the time, including the works of Carl Sagan.

While echoes of wormhole physics appeared in the scientific literature starting not long after Einstein's 1915 publication of his General Theory of Relativity, the first recognizable wormhole then called a "bridge" in space-time appeared in a 1935 paper by Einstein and Nathan Rosen; it became known as the Einstein-Rosen bridge (Einstein & Rosen 73). The first diagram of a wormhole (as a "tunnel" with two "mouths") appeared in John Archibald Wheeler's 1955 paper, with the term "wormhole" first appearing in his 1957 paper with Charles Misner (Wheeler 534-5; Misner & Wheeler 533). A further model was published by Kruskal in 1960, and the discovery of a solution for Einstein's field equations describing

a rotating black hole by Kerr in 1963 allowed for speculation that someone might be able to pass through such a black hole (creating a tunnel in space-time) (Visser, *Lorentzian Wormholes* 75). These last two models led to speculation that what appeared as a black hole at one mouth could be an anti-black hole at the other mouth, spitting out material at a furious rate as what became known as a white hole. However, by 1974 it had been suggested that any white hole that could be formed would quickly be turned into a black hole (Parker 40).[5]

By the early-1970s, the standard party line in physics was that wormholes are theoretical objects allowed by the laws of physics that could hypothetically connect two regions of space-time in our universe or, perhaps, two universes. Many of the wormhole solutions to the equations of general relativity were essentially clever manipulations of black hole solutions, which meant that they were not traversable (could not be exited by someone who somehow survived the initial trip inside). If a tunnel *could* be created, it would soon pinch off, preventing matter from passing through. Other problems were the extreme tidal forces near the mouth of a wormhole that could tear apart matter attempting to enter (similar to the infamous *spaghettification* known for black holes) and extreme radiation that would prove lethal for any would-be traveler (Morris & Thorne 395-9).

Despite the known problems with black holes and wormholes that precluded using them as interdimensional transit systems, they frequently appear as such in 1970s film and television, including *The Giant Spider Invasion* (1975), *Space: 1999* (1975), *Star Trek: The Motion Picture* (1979), *Phantasm* (1979), and perhaps most infamously in Disney's *The Black Hole* (1979). In popular media the term *Einstein-Rosen bridge* is frequently used to describe any type of wormhole, when in fact it is only

correct for the original Einstein & Rosen model, an oversight that made its way into physics textbooks as well as popular culture including Mr. Clarke's post-funeral lecture (Guendelman et al. 2).

Popularizations of science vary widely in their treatment of these objects in the 1970s and 1980s, depending on the author's personal taste (and intention). For example, in what has been termed "one of the most worthless of all books about black holes," mathematical physicist John Taylor highlights the dangers posed by such objects (Gardner 18). These include not only the "horrors of the black hole interior" and the possible "death of intrepid explorers" but that a black hole represents "the ultimate doomsday weapon" (Taylor 10, 190). Science writer Adrian Berry's 1977 *The Iron Sun* speculates so wildly about black holes and white holes that a reviewer claims he "should have known better than to write this book" (Znajek 867). On the other hand, mathematician Eric Rucker's *The Fourth Dimension* (1984) uses everyday experiences to highlight less speculative characteristics of wormholes, for example comparing the appearance of another universe seen through a wormhole's mouth to an image seen in "a glass Christmas tree ornament" (Rucker 118). Astronomer Harry Shipman expresses great skepticism in *Black Holes, Quasars, and the Universe* (1980), relegating wormholes to "theoretical speculation on the fringes of black hole research…. I find it extremely unlikely they will be discovered in the real world" (130).

In typical Sagan style, *Cosmos* balances the speculative with the factual in dealing with the possibility of wormholes. Sagan notes that wormholes "have been seriously suggested, although they have by no means been proved to exist. Might gravity tunnels provide a kind of interstellar or intergalactic subway, permitting us to travel to inaccessible places much

more rapidly than we could in the ordinary way?" (Sagan, *Cosmos* 242). Later in the book (and series) Sagan returns to wormholes as a potential way to explore other universes (if they exist), as correctly referenced by Mike after Will's sham funeral. After discussing the possible existence of higher spatial dimensions (a bit differently than Clarke's flea and acrobat analogy), Sagan discusses possibly traveling through a "hypothetical tunnel or wormhole through the next higher dimension…. Can we find such a wormhole? Could we survive the trip? We might emerge in some other place and time. Perhaps in another universe" ("The Edge of Forever" 1.10, 34:20-41).

Clarke discusses Einstein-Rosen bridges/wormholes by name in "Chapter Three: The Turnbow Trap" (5.3), in a classroom lesson attended by Erica Sinclair. Clarke draws and describes the wormhole with "an hour-glasslike shape," and describes them as "entirely theoretical." Erica enthusiastically responds to his prompt that wormholes have "captured the fascination of scientists and science fiction writers alike" as being because they could "allow matter to travel between galaxies or dimensions without crossing the space between." Clarke highlights the scientific difficulties with wormhole travel, noting that "If wormholes did exist, they would be extraordinarily unstable. Their enormous gravitational force would rip them apart at the very moment they formed" ("Chapter Three: The Turnbow Trap" 5.3, 25:54-26:49). To The Duffer Brothers' credit, Clarke's discussions about parallel dimensions and wormholes have been praised by scientists for their relative fidelity to the science (e.g. Ahart; Bagchi; Siegrist).

Staying in-world for the sake of consistent analysis, where might Clarke have learned about wormholes, in greater detail than in the fleeting references in *Cosmos*? As previously noted,

there were numerous popularizations that discussed black holes and wormholes varying greatly in quality during the years prior to and during the main timeline of the series (1983-1987). One of the most important appeared in September 1985, between the events of Seasons Three and Four: the publication of Carl Sagan's novel *Contact*, a work which Clarke would have certainly read. In the final draft of the novel, Sagan had a group of scientists travel many light-years toward the center of the galaxy using black holes. He had the forethought to send the draft to his friend, Kip Thorne, an expert in gravitational physics, for his opinion. Thorne knew that both black holes and the then well-known wormhole models would not work (for the reasons already explained); but Thorne wondered if the laws of physics *could* allow for a truly traversable wormhole (for example, one that would not quickly pinch off). Several pages of calculations convinced him that it was *theoretically* possible, but only if the throat or tunnel of the wormhole was threaded with material that has a very high tension (to hold the throat open). Such material would surprisingly have an average negative energy density (Thorne 486-8). Sagan incorporated Thorne's suggestions into the final version of the novel, and that might have been the end of the story.

However, Thorne became interested in further studying the conditions under which the laws of nature might allow such wormholes.[6] The result was a seminal 1988 paper with former student Michael Morris that includes several models of hypothetically traversable wormholes. They term material with an average negative energy density, needed to hold open the wormhole's throat, "exotic" matter (Morris & Thorne 405). This paper opened the 'curiosity door' for other researchers, leading to what Matt Visser later termed a "major Renaissance in wormhole physics" (Visser, "Traversable" 203). Among the

questions Morris and Thorne tackle is finding additional models of traversable wormholes and understanding the conditions under which nature would allow for the creation of exotic matter. For while the existence of negative energy densities associated with the quantum fluctuations of the electromagnetic field between two highly conductive (metal) plates had been predicted by Hendrik Casimir in 1948 (and preliminary evidence of its reality was seen as early as 1958), the laws of nature appear to put severe restrictions on the amount of exotic material one can create, a significant restriction on the engineering of a traversable wormhole (James et al. 486). With this background in mind, we can briefly analyze The Duffer Brothers' use of wormholes for self-consistency with 1980s science.

Since the Upside Down (UD) is frozen in time at the moment Eleven made contact with the Abyss (November 6, 1983), Brenner's journals found in the UD version of Hawkins National Lab should contain scientific knowledge dating to that time and not more recently. And since the military builds a base in the UD after the events of Season Four (i.e., in 1986) separate from the lab already there, their scientists apparently have confidence that the wormhole is sufficiently stable; however, for safety reasons, it appears they do not wish to collocate it with the "swirling ball of exotic matter" seen above the Hawkins National Lab in Season Five (a depiction of exotic matter that the Duffers admit allows scientists to "poke plenty of holes" in their science) (Romano). In the spirit of science fiction world-building, as noted in the introduction, it is reasonable to give the show a pass here, and chalk up the series' version of exotic matter generation as somehow related to a science fiction version of the Casimir effect (vaguely invoking electromagnetic fields), although Eleven's connection to this is nebulous at best.

This aligns with the series' claim that the existence of local doorways (so-called gates) to the UD has an immense effect on magnets, including compass needles, as well as the Soviet scientists' use of high-powered lasers (beams of electromagnetic radiation) to attempt to open their own gates. The need to generate large amounts of exotic matter to stabilize a wormhole is conflated with extreme drawdowns from the electrical grid to power their lasers.[7] Accepting these caveats, individual notations in Brenner's notebooks (as seen in "Chapter Five: Shock Jock" 5.5) align with the in-world science of the series:

> EM fields might contribute by providing the necessary negative energy density and tension.
> Electromagnetic fields interact with the fabric of space-time. This could create repulsive gravitational effect stabilization.
> Theoretically, traversable wormholes need "exotic" m[atter] with negative energy density to counteract the gravitational forces that would thus [?] make [?] … wormhole to collapse. This exotic matter could … repulsive gravitational effect, necessary to keep wormhole stabilized and open.[8]

Dustin combines his formal and informal lessons from Clarke, readings/viewings of *Cosmos* (and perhaps other books/documentaries), and Brenner's notebooks to develop his explanation of the Upside Down and its connection to the Abyss, a central scene of exposition in "Chapter Seven: The Bridge" (5.7). As he explains, the UD is a wormhole, an

> [Dustin]: … interdimensional bridge that rips through spacetime. It is wildly unstable, but held together by exotic matter, which we found dead center right above the lab. In theoretical physics, they call this type of bridge a
> [Erica and Clarke interject]: Wormhole.
> [Dustin]: And this wormhole connects Hawkins to here, another world that I've coined the Abyss…. (5.7, 27:10-34)[9]

The careful reader might believe that Brenner's knowledge about traversable wormholes is yet another anachronistic error, among a number noted by viewers (Shelton), as the major work on traversable wormholes described above dates to *after* November 6, 1983. However, a 1973 paper by Homer G. Ellis was the *first* publication of one of Morris and Thorne's traversable wormhole models (which he terms a "drainhole"), and independently notes that it requires matter with "negative energy" to hold it open (Ellis 116). In addition, the use of the term "exotic" to describe material with a negative energy density dates to at least 1985, close enough to the 1983 usage in-world in *Stranger Things* to give the Duffers points for effort (Balbinot 77). The in-world use of wormholes can be consistently extended back to the timeline of the prequel play (the hypothetical Philadelphia Experiment in 1943) again within the established scientific laws of the Secondary World if one accepts the Duffers' assertion that the Philadelphia Experiment is a real event that involves secret research into traversable wormholes after the publication of the Einstein and Rosen paper. At the risk of fueling potential conspiracy theories, like much of physics, real world wormhole research has been funded by the government; for example, Misner's 1960

paper "Wormhole Initial Conditions" was supported by the Office of Naval Research (Misner 1110).

In including all of this scientific realism, the Duffers remain true to their promise to root their fiction in physics, and spark conversation about wormholes among the series' fans; they also invite scientists to channel their inner Sagan by communicating with the general public about the series' depiction of wormholes through their social media and other internet posts (e.g. Riddle 2025; WashU Arts & Sciences 2026). In so doing, they extend the reach of the series' Saganesque enchanted view of science beyond the show's audience and model not only what an enchanted view of science entails, but the inherent excitement fostered by such a scientific method.

The *Stranger Things* Scientific Method

"[on the discovery of the planet 51 Pegasi b] My wonder button got pushed hard when that discovery was announced. And it happens regularly. It certainly happens in my own research…. My wonder button is being pushed all the time." (Sagan, qtd. in "A Slayer of Dragons" 33)

As previously noted, Scott Clarke exhorts his students to be naturally curious and to think of science as a journey of exploration into the unknown rather than a tedious march toward an easily predictable right answer on a standardized test. It is a testament that Clarke's students and former students embrace and remember his lessons in scientific methodology, even years later. When admonished by the librarian that he has already reached his limit of five checked-out books, Dustin will not be denied the resources he needs to determine the identity of the pollywog-like creature he names Dart: "I am on a curiosity voyage, and I need my paddles to travel. These books... These books are my paddles" ("Chapter Three: The Pollywog" 2.3, 08:33-50). While Dustin is perhaps the most extreme example, the members of the Party and their allies are generally

curious as a group, and willing to seek out information from whatever source is necessary. The parallel with the Scooby Gang of *Buffy the Vampire Slayer* is fairly clear: as William Wandless observes, "folks dig research" (Wandless, par. 1). The Clarke of the Scoobies is obviously Giles, "responsible for infecting the group with his contagious appetite for knowledge" (Wandless par. 7). Similarly, Lisa Cheby calls Giles' "ability to engage students in inquiry and his modeling of the research process as a life-long learning practice" his "teacher superpower" (6). Like Clarke, Giles "channels and focuses natural curiosity and desire to help into research and learning" (Cheby 15).

As noted, an important clue to the connection between the UD and the various gates that connect to it is the effect they have on magnets. For example, in "Chapter Five: The Flea and the Acrobat" (1.5) Dustin observes that all their compasses are pointing in the wrong direction, recalling Clarke's class lessons in magnetism as well as his prediction in the earlier flea and acrobat discussion that such a tear in space-time would disrupt local magnetic fields. This observation is referred to throughout the series, allowing a variety of characters to locate the existence of numerous hidden gates. Joyce seeks out Clarke for an explanation for the demagnetized refrigerator magnets she has twice observed, and uses the knowledge gained through Clarke's impromptu science lesson (complete with the construction of an electromagnet) to locate a secret Soviet lab on the outskirts of town ("Chapter Three: The Case of the Missing Lifeguard" 3.3). Another example is Mike's recollection of Clarke's fifth grade lesson that mixing chemicals can result in the creation of a different substance, an important realization to discovering the growth of a physical Mind Flayer proxy through the incorporation of biological material plus chemicals

("Chapter Five: The Flayed" 3.5). Likewise, in "Chapter Eight: The Mind Flayer" the Party combines Clarke's discussions of selected insect behavior as a hive mind with the description of the Mind Flayer in their *D&D* manual to make sense of what they are observing. Hopper dismisses this as merely "a kids' game," but Dustin defends it as an "analogy for understanding whatever the hell this is" (2.8, 00:27:03-19).

Matt Duffer explains that the Party is "theorizing based on their knowledge from fantasy gaming and their science teacher, Mr. Clarke," encouraging them to put the pieces of the puzzle together in a way that allows them to make sense of events that can't be found in a standard science textbook (Berkshire). Similarly, the Party and their allies draw upon other popular media with which they are familiar, such as *The Lord of the Rings*, and in the case of Holly Wheeler, *A Wrinkle in Time*, to make sense of the super-natural events they encounter "instead of automatically reacting in fear and disbelief" (McCarthy 673). However, the Party's reliance on *D&D* is nearly their downfall in Season Five, in terms of relegating the existence of the UD to what they have been considering the supernatural "dark magic" of Vecna. Instead, Dustin comes to realize that "It isn't dark magic. Vecna didn't make it. Science did" ("Chapter Six: Escape from Camazotz" 5.6. 02:45-03:00). But in true noble scientist fashion, Dustin accepts and learns from his mistake, leading to his final model of the UD and its connection to the Abyss.[10] Once again, as Sagan notes, "science is a self-correcting enterprise" (*Cosmos* 91).

Conclusion

"Not explaining science seems to me perverse. When you're in love, you want to tell the world." (Sagan, Demon *25)*

Jamie McDaniel notices a pattern in the first two seasons of the series, a "*communitas*" in which "everyone makes a unique contribution to helping with the Upside Down and that no one character should become the center of attention for inspiration" (216). It is the Party — the extended family — rather than the lone superhero or solo mad scientist who triumphs in the end. For example, while Dustin presents the final model of the UD to the group, the ultimate plan to stop Vecna is based on myriad additional pieces of information added by his friends. As a collective, they draw upon the skills they have learned from Scott Clarke, and data gathered during their open-minded investigation of the events of the past four years. In the end, it is Steve (Joe Keery), previously one of the least scientifically fluent members of the extended Party, who devises the plan to climb the radio tower to access the Abyss and thwart Vecna's plan to merge their worlds ("Chapter Seven: The Bridge" 5.7). When asked by Erica how he feels about "helping to save the world and all that," Clarke allows himself a moment of pride (including an uncharacteristic swear word): "It feels pretty swell. Pretty goddamn swell" ("Chapter Eight: The Rightside Up" 5.8, 05:26-33). The audience knows that Clarke has certainly earned this moment in the spotlight.

Stephanie Garrison opines that Clarke invokes in viewers "nostalgia for either the teacher we wished we had or the one we were fortunate enough to have; that one teacher who broke through the monotony of mundane academia and opened our eyes and imagination to something beyond the school's four walls and graphite-filled Scantron bubbles." Like Sagan, Clarke's ultimate lesson is the realization that "the Curiosity Door will always be unlocked — if we would only choose to open it" (Garrison 2016). But given the centrality of a Saganesque scientific method to the series, it would be natural to ask

whether *Stranger Things* is, intentionally or not, "actually a show about making science cool?" (Bagchi). Again, numerous scientists have lauded *Stranger Things's* relative fidelity to the science involved, including the potential existence of other dimensions/universes and wormholes. But this was not limited to the Season Five revelation of the nature of the UD. In light of Season One's commercial success, Paul Lester of the Department of Energy's Office of Public Affairs crafted a July 2016 official blog post humorously explaining "We don't mess with monsters, but the Energy Department is in the business of detecting invisible dangers. Energy Department scientists throughout the country create new technologies that help prevent terrorists from getting their hands on nuclear materials" (Lester).

Science educators have also used the series' science, including other dimensions and wormholes, to interest their own students in these topics (e.g., Riddle; Woolcock). Students including potential science communicators of *this* generation have also become involved. Olivia Richter, in 2017 a senior in the School of Communication and College of Arts and Sciences of American University, shares in her school newspaper that

> one of the show's biggest draws for me is how successful it is in making science and curiosity seem so cool.... In a society where, particularly in middle school, the kind of scientific curiosity and thirst for knowledge these boys display is often seen as uncool, Dustin and his friends are excellent role models to anyone watching who loves to learn. (Richter)

Similarly, Harini Kannan, in 2016 a junior in the College of Arts and Sciences at Cornell, reflects in the *Cornell Sun* that

> The most important aspect of this show is that it champions the idea of human curiosity. It is rather riveting and novel to have a show so deeply rooted in the positivity of human curiosity, especially when it seems like we live in a society which often fails to question what is and what could be. (Kannan)

There are cautionary tales from Sagan's own life that must be recalled, however. In a 1980 *Time* magazine cover article, Frederic Golden opines that "Most scientists, increasingly sensitive to the need for public support and understanding of research, appreciate what Sagan has become: America's most effective salesman of science. His pitch in *Cosmos* and indeed in all his popularizing is classic Sagan…. What scientist could disagree?" (Golden 69). The problem is that by that time Sagan's career had already suffered from a backlash that biographers argue contributed significantly to his failure to achieve tenure at Harvard: "Students loved him, but some colleagues bristled at what they perceived as self-aggrandizement and pandering to the public" (Morrison). Many of Sagan's students became important research scientists in their own right; another, Bill Nye, became famous for his own science popularization. Many scientists not fortunate to have had him as a professor including Neil deGrasse Tyson openly name him as an inspiration; yet the stigma remains (Cull). In 1991 Sagan was blackballed in the first round of voting for membership in the National Academy of Sciences and ultimately received far less than the two-thirds positive votes required for membership (Morrison). Sagan became the victim of what is now termed the

"Sagan Effect," in which a scientist's "popularity and celebrity with the general public was thought to be inversely proportional to the quantity and quality of real science being done, despite the fact that throughout his career Sagan published, on average, an impressive one peer-reviewed scientific paper per month" (in addition to his popular-level works) (Shermer 490, 493).

While as a middle school science teacher Scott Clarke would be immune to the "Sagan Effect," real world professors and scientists are not. The result is a US science establishment that is ill-equipped to fight back against political interference and the siren's call of attractive conspiracy theories. As Arthur Caplan warns, "US science itself is to blame. It has disparaged its public communication as unnecessary and looked down on those few who tried to educate broader audiences about the wonders, benefits, methods and advancements of science. The belittling of the astronomer and planetary scientist Carl Sagan is a prime example" (4395).

But hope remains. In recalling Sagan's role in sparking his own research into traversable wormholes, Kip Thorne shares that

> I began to recognize the power of the kind of research that Carl Sagan's phone call had triggered…. We physicists, I believe, have tended to avoid such questions because they are so close to science fiction. While many of us may enjoy reading science fiction or may even write some, we fear ridicule from our colleagues for working on research close to the science fiction fringe. (Thorne 492-3)

The current embracing of *Stranger Things* as a vehicle for interesting students and the general public in what are

sometimes considered rather esoteric branches of science, such as particle physics and general relativity, might be the spark that inspires a new generation of scientists. Like the members of the Party, they may keep open the curiosity door and welcome in the mysteries of their universe, seeking answers to what Thorne terms "Sagan-type questions" (193).

Near the end of his life, Carl Sagan argued that

> A proclivity for science is embedded deeply within us, in all times, places and cultures. It has been the means for our survival. It is our birthright. When, through indifference, inattention, incompetence, or fear of skepticism, we discourage children from science, we are disenfranchising them, taking from them the tools needed to manage their future. (Sagan, *Demon* 317)

As Dustin would contend, we are taking away their paddles. Through the actions of their characters, The Duffer Brothers have opened the curiosity door for a new generation, demonstrating how an embracing of enchanted Saganesque science can save a fictional world. In the face of climate change, natural resource limitations, and the rise of pseudoscience and science denial, perhaps such a lesson could also play a not insignificant role in saving our own. Carl Sagan certainly would approve and so would Scott Clarke.

Notes

[1] Experimental science explores the natural world through hands-on experimentation/observation. The natural laws underpinning what is observed may or may not be known at that time. Theoretical science explores natural laws through mathematics and computer modelling; what is discovered to be theoretically possible (i.e., what does not violate natural law) may or may not have been observed in the real world at that time. For example, black holes were theorized decades before any observational evidence for their existence was found. On the other hand, the first white dwarf stars (dense stellar corpses the mass of the sun but the diameter of the earth) were observed (and their extreme properties measured) several decades before the development of the theory of quantum mechanics, and hence before we could understand why they can exist.
[2] Depending on one's interpretation, Topher might also embody aspects of Haynes' detached "inhuman researcher," especially in early episodes (249). See Porter (61-69) for a detailed discussion of his evolution as a character. Whedon's use of mad scientists throughout his various works is explored in detail in Porter as well as Nylin.
[3] An anonymous reviewer suggested that perhaps Scott Clarke owes his name to two science fiction writers, Orson Scott Card and Arthur C. Clarke.
[4] Similarly, in the Season Four opener of *Buffy the Vampire Slayer*, Buffy is surprised to find Giles in a romantic situation when she shows up on his doorstep seeking guidance concerning the mysterious disappearance of college classmate ("The Freshman").
[5] For a detailed review of the history of the concept of wormholes, see Visser, *Lorentzian Wormholes*.
[6] For more information, see Thorne, Chapter 14.
[7] It is a bit unclear as to whether the Soviets are trying to create a gate into the UD, or whether they want to make their own wormhole connected directly to the Abyss. The Duffers' use of multiple entryways to the wormhole all of the various gates and rifts, large and small, that seemingly open and close without impacting the integrity of the wormhole itself is more science fiction than science.
[8] Transcribed by the author from screenshots of Brenner's notebooks found at https://www.reddit.com/r/StrangerThings/comments/1pw9nzr/did_anyone_compile_or_screenshot_dr_brenners/.
[9] Note that the visual image of the wall of the wormhole as shaped like an hourglass (as seen in various drawings in the series, described in Clarke's lesson, and the long-distance view from the Void outside the UD) is a common error found in science fiction. In reality, this shape is associated with the *embedding diagram*, a two-dimensional representation of a three-dimensional object; in most wormhole models, the mouths and the wormhole itself are actually

spherical in shape. For a contemporaneous discussion of embedding diagrams, see Kaufmann (140-1).

[10] Dustin's first helpless scientist moment (to use Haynes' classification) occurs in Season 3 when believing he can control Dart and hide him from the Party and Mr. Clarke (2.3).

Works Cited

Ahart, Jenna. "Are We Living in a Parallel Universe? The Strange Physics of *Stranger Things*." *Nature News*, 19 December 2025, https://www.nature.com/articles/d41586-025-04088-z.

Bagchi, Shrabonti. "The Science of *Stranger Things*." *Mint Longue*, 27 May 2022, https://lifestyle.livemint.com/smart-living/innovation/the-science-of-stranger-things-111653652875716.html.

Balbinot, R. "Crossing the Einstein-Rosen Bridge." *Lettere al Nuovo Cimento*, vol. 43, no. 2, 1985, pp. 76-80.

Berkshire, Geoff. "'Stranger Things' Finale: Duffer Brothers Talk Cliffhangers, Death and Season 2." *Variety*, 18 July 2016, https://variety.com/2016/tv/news/stranger-things-finale-duffer-brothers-interview-season-2-1201816664/.

Caplan, Arthur. "How Stupid Has Science Been?" *EMBO Reports*, vol. 26, 2025, pp. 4395-4396, https://link.springer.com/article/10.1038/s44319-025-00562-x.

Carmichael, L.E. "Mad Scientists of *Stranger Things*: Part IV Mr. Clarke." 18 November 2019, https://www.lecarmichael.ca/2019/11/mad-scientists-of-stranger-things-part-iv-mr-clarke/.

---. "Mad Scientists of Stranger Things: Part II Sam Owens." 24 September 2019, https://www.lecarmichael.ca/2019/09/mad-scientists-of-stranger-things-part-ii-sam-owens/.

"Chapter Eight: The Mind Flayer." *Stranger Things*, Season 2, Episode 8, Monkey Massacre Productions and 21 Laps Entertainment, 2017, written by The Duffer Brothers, directed by The Duffer Brothers, Netflix, 2017 (Streaming Netflix).

"Chapter Eight: The Rightside Up." *Stranger Things*, Season 5, Episode 8, Monkey Massacre Productions and 21 Laps Entertainment, 2025, written by The Duffer Brothers, directed by The Duffer Brothers, Netflix, 2025 (Streaming Netflix).

"Chapter Five: Shock Jock." *Stranger Things*, Season 5, Episode 5, Monkey Massacre Productions and 21 Laps Entertainment, 2025, written by Curtis Gwinn and Caitlin Schneiderhan, directed by Frank Darabont, Netflix, 2026 (Streaming Netflix).

"Chapter Five: The Flayed." *Stranger Things*, Season 3, Episode 5, Monkey Massacre Productions and 21 Laps Entertainment, 2019, written by

Paul Dichter, directed by Uta Briesewitz, Netflix, 2019 (Streaming Netflix).

"Chapter Five: The Flea and the Acrobat." *Stranger Things,* Season 1, Episode 5, Monkey Massacre Productions and 21 Laps Entertainment, 2016, written by Alison Tatlock, directed by The Duffer Brothers, Netflix, 2016 (Streaming Netflix).

"Chapter Four: Will the Wise." *Stranger Things*, Season 2, Episode 4, Monkey Massacre Productions and 21 Laps Entertainment, 2017, written by Paul Dichter, Jessie Nickson-Lopex, and Kate Tefry, directed by Shawn Levy, Netflix, 2017 (Streaming Netflix).

"Chapter Seven: The Bathtub." *Stranger Things*, Season 1, Episode 7, Monkey Massacre Productions and 21 Laps Entertainment, 2016, written by Justin Doble, directed by Shawn Levy, Netflix, 2016 (Streaming Netflix).

"Chapter Seven: The Bridge." *Stranger Things*, Season 5, Episode 7, Monkey Massacre Productions and 21 Laps Entertainment, 2025, written by The Duffer Brothers, directed by The Duffer Brothers and Shawn Levy, Netflix, 2025 (Streaming Netflix).

"Chapter Six: Escape from Camazotz." *Stranger Things*, Season 5, Episode 6, Monkey Massacre Productions and 21 Laps Entertainment, 2025, written by Kate Trefry, directed by Shawn Levy, Netflix, 2025 (Streaming Netflix).

"Chapter Three: Holly, Jolly." *Stranger Things,* Season 1, Episode 3, Monkey Massacre Productions and 21 Laps Entertainment, 2016, written by Jessica Mecklenburg, directed by Shawn Levy, Netflix, 2016 (Streaming Netflix).

"Chapter Three: The Case of the Missing Lifeguard." *Stranger Things*, Season 3, Episode 3, Monkey Massacre Productions and 21 Laps Entertainment, 2019, written by William Bridges, directed by Shawn Levy, Netflix, 2026 (Streaming Netflix).

"Chapter Three: The Pollywog." *Stranger Things*, Season 2, Episode 3, Monkey Massacre Productions and 21 Laps Entertainment, 2017, written by Justin Doble, directed by Shawn Levy, Netflix, 2026 (Streaming Netflix).

"Chapter Three: The Turnbow Trap." *Stranger Things*, Season 5, Episode 3, Monkey Massacre Productions and 21 Laps Entertainment, 2025,

written by Caitlin Schneiderhan, directed by Frank Darabont, Netflix, 2025 (Streaming Netflix).

"Chapter Two: The Mall Rats." *Stranger Things*, Season 3, Episode 2, Monkey Massacre Productions and 21 Laps Entertainment, 2019, written by The Duffer Brothers, directed by The Duffer Brothers, Netflix, 2019 (Streaming Netflix).

Cheby, Lisa. "'Well, We Start, Not Surprisingly, with Research.': Depictions of Guided Inquiry and Critical Information Literacy Instruction in *Buffy the Vampire Slayer*." *Slayage*, vol. 23, no. 2, 2025, pp. 1-52., https://buffystudies.org/wp-content/uploads/2026/02/cheby_library.guided_inquiry.pdf.

Cull, Monica. "The Man Who Brought Us the Universe: 4 Things We Have Thanks to Carl Sagan." *Discover*, 20 December 2021, https://www.discovermagazine.com/the-man-who-brought-us-the-universe-4-things-we-have-thanks-to-carl-sagan-43142.

Davidson, Keay. *Carl Sagan: A Life.* Wiley, 1999.

Duffer Brothers. *Montauk Pilot*. N.d. https://www.sellingyourscreenplay.com/wp-content/uploads/screenplay/scripts/Stranger-Things.pdf.

Duffer, Matt, and Ross Duffer. *Montauk*. 2019, https://screencraft.org/wp-content/uploads/2019/07/StrangerThings_Bible.pdf.

"The Edge of Forever." *Cosmos*, Episode 10, KCET, 1980, written by Carl Sagan, Ann Druyan, and Steven Soter, directed by Adrian Malone. https://archive.org/details/CosmosAPersonalVoyage/1980+Cosmos+(A+Personal+Voyage)+-+Ep+10+The+Edge+of+Forever.mp4.

Einstein, Albert, and Nathan Rosen. "The Particle Problem in the General Theory of Relativity." *Physical Review,* vol. 48, 1935, pp. 73-77.

Ellis, Homer G. "Ether Flow Through a Drainhole: A Particle Model in General Relativity." *Journal of Mathematical Physics*, vol. 14, no. 1, 1973, pp. 104-118.

"The Freshman." *Buffy the Vampire Slayer*, Season 4, Episode 1, Mutant Enemy, 1999, written by Joss Whedon, Douglas Petrie, and Tracey Forbes, directed by Joss Whedon, *Daily Motion*, 2022, https://www.dailymotion.com/video/x8dbdc8.

Gardner, Martin (1988) "The Ultimate Turtle." *The New York Review of Books*, 16 June 1988, pp. 17-20.

Garrison, Stephanie. "Mr. Clarke, the Real Hero of Stranger Things." *The Rumpus*, 10 November 2016, https://therumpus.net/2016/11/10/mr-clarke-the-real-hero-of-stranger-things/.

Golden, Frederic. "The Cosmic Explainer." *Time*, 20 October 1980, pp. 62-69.

Griffith, Zachary. "Stranger Things, Nostalgia, and Aesthetics." *Journal of Film and Video*, vol. 74, no. 1-2, 2022, pp. 3-18.

Grow, Kory. "'Stranger Things': How Two Brothers Created Summer's Biggest TV Hit." *Rolling Stone*, 3 August 2016, https://www.rollingstone.com/tv-movies/tv-movie-features/stranger-things-how-two-brothers-created-summers-biggest-tv-hit-105527/.

Guendelman, Eduardo, et al. "Kruskal-Penrose Formalism for Lightlike Thin-Shell Wormholes." *arXiv*, 22 October 2016, https://arxiv.org/abs/1512.08029.

Haynes, Roslyn. "From Alchemy to Artificial Intelligence: Stereotypes of the Scientist in Western Literature." *Public Understanding of Science*, vol. 12, 2003, pp. 234-253.

Hill, Sharon. "Natural to Supernatural and Every Para-thing In Between." *Skeptoid Blog*, 24 October 2011, https://skeptoid.com/blog/2011/10/24/natural-to-supernatural-and-every-para-thing-in-between/.

James, Oliver et al. "Visualizing *Interstellar*'s Wormhole." *American Journal of Physics*, vol. 83, 2015, pp. 486-499.

Jones, Amy Elaine "Carl Sagan and the Forgotten Generation: How Cosmos Turned Wonder into Science." *Medium*, 13 October 2025, https://medium.com/@amyj5640/carl-sagan-and-the-forgotten-generation-how-cosmos-turned-wonder-into-science-5d39f88c468a.

Kannan, Harini. "*Stranger Things* Puts the Science (And Much More) Back in Science Fiction." *The Cornell Daily Sun*, 24 August 2016, https://www.cornellsun.com/article/2016/08/stranger-things-puts-the-science-and-much-more-back-in-science-fiction.

Kaufmann, III, William J. *The Cosmic Frontiers of General Relativity.* Little, Brown and Company, 1977.

Larsen, Kristine. "'They're Something Nightmares are From': *The Notion Club Papers* and *The Cabin in the Woods*." *Journal of Tolkien Research*,

vol. 10, issue 1, 2020, article 5, https://scholar.valpo.edu/journaloftolkienresearch/vol10/iss1/5/.

Lester, Paul. "What 'Stranger Things' Didn't Get Quite-so-right About the Energy Department." *Department of Energy*, 5 August 2016, https://www.energy.gov/articles/what-stranger-things-didnt-get-quite-so-right-about-energy-department.

Mackay, Antonia. "*Stranger Things* in strange times: Nostalgia, surveillance and temporality." *Screening American Nostalgia: Essays on Pop Culture Constructions of Past Times*, edited by Susan Flynn and Antonia Mackay, McFarland, 2021, pp. 66-79.

Malmgren, Carl D. *Worlds Apart: Narratology in Science Fiction*. Indiana University Press, 1991.

Marsh, Owen. "Life Cycle of a Star: Carl Sagan and the Circulation of Reputation." *British Journal for the History of Science*, vol. 52, no. 3, 2019, pp. 4674-4686.

McCarthy, Kayla. "Remember Things: Consumerism, Nostalgia, and Geek Culture in *Stranger Things*." *Journal of Popular Culture*, vol. 52, no. 3, 2019, pp. 663-677.

McDaniel, Jamie. "Growing Up in the Upside Down: Youth Horror and Diversity in *Stranger Things*." *The Palgrave Handbook of Children's Film and Television*, edited by Casie Hermansson and Janet Zepernick, Palgrave Macmillan, 2019, pp. 205-22.

Misner, Charles W. "Wormhole Initial Conditions." *Physical Review*, vol. 118, no. 4, 1960, pp. 1110-1111.

Misner, Charles W., and John A. Wheeler (1957) "Classical Physics as Geometry." *Annals of Physics* 2: 525-603.

Moore, Kasey. "Three Major Revelations from 'Stranger Things: The First Shadow.'" *What's on Netflix*, 17 January 2024, https://www.whats-on-netflix.com/news/three-major-revelations-from-stranger-things-the-first-shadow/.

Morris, Michael S., and Kip S. Thorne. "Wormholes in Spacetime and Their Use for Interstellar Travel: A Tool for Teaching General Relativity." *American Journal of Physics*, vol. 56, no. 5, 1988, pp. 395-412.

Morrison, David. "Carl Sagan's Life and Legacy as Scientist, Teacher, and Skeptic." *Skeptical Inquirer*, January/February 2007, https://web.archive.org/web/20160201115954/http://www.csicop.or

g/si/show/carl_sagans_life_and_legacy_as_scientist_teacher_and_skeptic.

Nylin, Sören, "Mad, Bad Scientists and Cute, Curious Magicians: The Quest for Knowledge in *Buffy* and the Whedonverse." *Slayage*, vol. 7, no. 4, 2009, n. pag., pars. 1-56, https://buffystudies.org/wp-content/uploads/2026/02/nylin_slayage_7.4.pdf.

Parker, Barry. "Black & White Holes: Minis, Maxis &… Worms!" *Star & Sky*, vol. 1, no. 12, 1970, pp. 32-40.

Perry, Tod. "46 Years Ago, Carl Sagan Beautifully Explained the Fourth Dimension with Just an Apple." *Upworthy*, 9 February 2026, https://www.upworthy.com/carl-sagan-beautifully-explained-the-fourth-dimension-using-a-sliced-apple-ex1/.

"Philadelphia Experiment." *Naval History and Heritage Command*, 20 November 2017, https://www.history.navy.mil/research/library/online-reading-room/title-list-alphabetically/p/philadelphia-experiment.html.

Porter, Heather M. "'We're Also Misunderstood, Which Great Humanitarians Often Are': Examining the Intelligence and Wisdom of the Mad Scientist Topher Brink." *Re-Entering the* Dollhouse: *Essays on the Joss Whedon Series*, edited by Heather M. Porter and Michael Starr, McFarland & Company, 2022, pp. 56-71.

Reeves, Josh A. "Enchanted Science? The Supernatural Imagination of *Stranger Things*." *Religion, Theology, and* Stranger Things, edited by Andrew J. Byers and Adam J. Powell, Lexington Books, 2025, pp. 63-74.

Relidzyńska, Alicja. "Anthropocene Nostalgia for the 1980s in Netflix's *Stranger Things*." *European Journal of American Culture*, vol. 40, no. 3, 2021, pp. 233-247.

Richter, Olivia. "How 'Stranger Things' is Making Scientific Curiosity Cool." *The Eagle Online*, 4 December 2017, https://www.theeagleonline.com/article/2017/12/how-stranger-things-is-making-scientific-curiosity-cool.

Riddle, Katia. "What *Stranger Things* Gets Right About Wormholes." *NPR*, 31 December 2025, https://www.npr.org/2025/12/31/nx-s1-5662703/stranger-things-upside-down-wormhole-explained.

Romano, Nick. "What is the Upside Down? *Stranger Things* 5 Finally Answers Series-long Mystery." *Entertainment Weekly*, 25 December

2025, https://ew.com/what-is-the-upside-down-stranger-things-5-finally-answers-series-long-mystery-11874655.

Rucker, Rudy. *The Fourth Dimension*. Houghton Mifflin, 1984.

Sagan, Carl. *Broca's Brain*. Random House, 1979.

---. *Cosmos*. Random House, 1980.

---. *Contact*. Simon and Schuster, 1985.

---. *The Demon-Haunted World*. Random House, 1996.

---. *The Dragons of Eden*. Ballantine Books, 2012.

Shelton, Jacob. "Every Inaccuracy in the 'Stranger Things' Version of the '80s. *Ranker*, 15 September 2025, https://www.ranker.com/list/how-accurate-is-stranger-things-to-the-80s/jacob-shelton.

Shermer, Michael B. "This View of Science: Stephen Jay Gould as Historian of Science and Scientific Historian, Popular Scientist and Scientific Popularizer." *Social Studies of Science*, vol. 32, no. 4, 2002, pp. 489-525.

"The Shores of the Cosmic Ocean." *Cosmos*, Episode 1, KCET, 1980, written by Carl Sagan, Ann Druyan, and Steven Soter, directed by Adrian Malone. https://archive.org/details/CosmosAPersonalVoyage/1980+Cosmos+(A+Personal+Voyage)+-+Ep+01+The+Shores+of+the+Cosmic+Ocean.mp4.

Shipman, Harry L. *Black Holes, Quasars, and the Universe*. 2nd ed., Houghton Mifflin, 1980.

Siegrist, James. "Searching for the Upside Down." *Department of Energy*, 28 October 2017, https://www.energy.gov/articles/searching-upside-down.

"A Slayer of Dragons." *Psychology Today*, January 1996, pp. 30-3, 62, 65, 66.

Taylor, John G. *Black Holes: The End of the Universe?* Avon Books, 1973.

Thorne, Kip S. *Black Holes and Time Warps*. W.W. Norton and Company, 1994.

Tolkien, J.R.R. *Tolkien on Fairy-stories*. Edited by Verlyn Flieger and Douglas A. Anderson. HarperCollins, 2008.

Visser, Matt. *Lorentzian Wormholes: From Einstein to Hawking*. Springer-Verlag, 1996.

---. "Traversable Wormholes from Surgically Modified Schwarzschild Spacetimes." *Nuclear Physics B*, vol. 328, no.1, 1989, pp. 203-212.

Wandless, William. "Undead Letters: Searches and Researches in *Buffy the Vampire Slayer*." *Slayage*, vol. 1, no. 1, 2001, n. pag., pars. 1-26, https://buffystudies.org/wp-content/uploads/2026/02/wwandless_-_slayage_1.1.pdf.

WashU Arts & Sciences. "Physics Professor Breaks Down the Science of *Stranger Things* Season 5." @washuartsci, 16 February 2026, https://www.youtube.com/shorts/Y-xuCkY_OHc.

Wheeler, John A. "Geons." *Physical Review*, vol. 97, no. 2, 1955, pp. 511-536.

---. "On the Nature of Quantum Geometrodynamics." *Annals of Physics*, vol. 2, 1957, pp. 604-614.

Woolcock, Nicola. "How *Stranger Things* Could Inspire a New Generation of Physicists." *The Times*, 11 January 2026, https://www.thetimes.com/uk/education/article/stranger-things-physics-schools-students-kmg37fmrs.

Znajek, Roman. "Jumping into Black Holes." *Nature,* vol. 267, 1977, p. 867.