4. Word and Image in Popular Science

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Gravitation, the graduate-level treatise by Charles Misner, Kip Thorne, and John Wheeler, is commonly referred to as 'the phone book' in reference to its impressive heft.[1] The 1,279-page tome, published in 1972, was billed as the comprehensive and authoritative textbook on Albert Einstein's general theory of relativity and the field that sprang from it. But, as David Kaiser recounts in his historical investigation of the text's reception, it blossomed into much more, becoming a surprise seller among members of the public, alongside its success with physics students. Kaiser credits a breezy prose style, the authors' tendency to wax poetic, and rich illustrations as factors that help account for this unanticipated popular success.[2]

It was not the first time an arcane scientific treatise had become a cult hit. A quarter-century earlier, Norbert Weiner's *Cybernetics*, a technical, philosophically motivated treatise on feedback mechanisms in technology and nature, became a must-read among the American intelligentsia.[3] And since the 1930s, publishers had successfully marketed pulp-science titles written by leading scientists to a wide market.[4] But the outlier success *Gravitation* enjoyed better reflects an emerging late twentieth-century context in which the publishing industry could count on an appetite among general audiences that sprang, at least in part, from a different well. Consuming or displaying these works might have functioned as a marker of intellectual sophistication, as in the case of *Cybernetics*, and it might also have served a didactic purpose, as in the case of pulp science titles. But more than that, it spoke to a desire for science to provide meaning in a secularising world.[5] This helps explain the broad appetite for works – at least in certain subjects – that exceeded much of the readership's technical

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[1] Misner, Thorne and Wheeler, *Gravitation*.

[2] Kaiser, 'Tale of Two Textbooks'.

[3] Weiner, *Cybernetics*; Kline, *Cybernetic Moment*.

[4] Gormley, 'Pulp Science'.

[5] Evans, 'Faith in Science'.

competence. The relationship between word and image would be crucial for exploiting that potential.

The discussion that follows is designed to do explanatory work. I have often wondered about a remarkable asymmetry in the history of twentieth-century physics. Certain subfields, such as cosmology and high energy physics, which investigate the farthest reaches of the universe and the smallest components of matter and energy, respectively, tugged much more sharply at the popular imagination than others, such as solid state and condensed matter physics, which describe the properties of the sort of complex matter we encounter on a terrestrial scale, and which makes up our technologies. The asymmetry is curious in light of the remoteness of the former from quotidian human affairs and the manifest relevance of the latter to the technological artefacts that transformed twentieth-century life.

My previous efforts to explain this asymmetry focused on two factors: the proximity between condensed matter physics and technology, which diverts attention from physicists' intellectual accomplishments, and the purloined-letter effect, a tendency to devalue accomplishments that appear to be obvious and thereby undercut widespread faith in human ingenuity in an era when science is called upon as a secular source of meaning.[6] I have been remiss, however, in neglecting the visual. Here, I address that omission by showing how word and image combined to perpetuate popular prestige asymmetries in late twentieth-century American physics. Images, and the language that surrounded them, worked in two parallel ways within scientific media to promote the popularity of certain types of physics over others: by instilling awe and by appealing to whimsy.

The Subtle Machinery of Awe

Gravitation was 'as attractive to *Scientific American* subscribers for its "mystique" as to doctoral students struggling to enter the field,' per Kaiser.[7] Not all scientific works that enjoyed popular success bristled with formidable equations, like *Gravitation*, but many did share another of its features – a distinctive combination of words and images calibrated to convey a combined sense of understanding and awe, as in an early spread that depicts Albert Einstein grinning while riding a bicycle, next to quotes attributed to him, such as 'What really interests me is whether God had any choice in the creation of the world.'[8]

[6] Martin, 'Prestige Asymmetry in American Physics'.

[7] Kaiser, 'Tale of Two Textbooks', 133.

[8] Misner, Thorne and Wheeler, *Gravitation*, 43.

Misner, Thorne and Wheeler did their part to link understanding and awe, and the combination proved potent. The awe belonged to the reader – or viewer – but the understanding did not have to. It was enough that *someone* understood. Many popular expositions are woefully insufficient to communicate anything a physicist would regard as genuine understanding. They instead communicate a subtler message – *this is understood.* Moreover, they insist that both understanding and those in possession of it are worthy of reverence. Text and image were frequently coordinated in late twentieth-century works of popular science to advance those messages.[9]

Exemplary of the genre is Carl Sagan's *Cosmos*, released more or less concurrently as a book and a television programme in 1980.[10] The book was a sensation, spending more than seventy weeks on the *New York Times* bestseller list.[11] Sagan promised readers that he would reveal the cosmos as 'rich beyond measure … in the subtle machinery of awe.'[12] Much of that machinery was visual. The Hubble Space Telescope, which would make images of deep space commonplace as dorm-room posters and computer desktop images, would not launch for another decade. The 364-page book nevertheless contained nearly five hundred images and diagrams. It made liberal use of paintings, particularly those by Adolf Schaller, whose rendition of a quasar inside an elliptical galaxy graces the book's iconic cover.

The artistic renditions in *Cosmos* served two concretising functions. First, they gave readers visual access to astronomical data that would otherwise have been abstract. Objects like quasars and pulsars were central to astronomical practice by 1980, but they were studied through the radio signals they gave off. Visualising them required a leap of imagination. Second, artists' representations breathed life into more fanciful speculations, such as the possibility of organisms adapted to the atmospheres of gas giants, to which Sagan dedicated a two-page spread.

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[9] The questions of what counts as popularisation and who counts as a populariser are fraught, and recent scholarship has often sought to complicate the boundary between the practice of science and its dissemination to lay audiences. Here, I take a capacious view, and consider either works that either achieved a broad non-specialist audience or were crafted with the goal of securing widespread non-specialist interest. For a useful discussion, see Topham, 'Rethinking the History of Science Popularization'.

[10] Sagan, *Cosmos*; *Cosmos: A Personal Voyage*, dir. Adrian Malone.

[11] Lewenstein, 'Science Books'.

[12] Sagan, *Cosmos*, 4.

These images were calibrated to fire the imagination. Representations of far-off objects that astronomers had actually detected testified to the reach of human inquiry; speculative renditions asked readers to contemplate the frontiers it might yet open. Many of these readers would have known the original *Star Trek* television series (1965–9), which cast space as the final frontier. Although the series struggled during its late-1960s run, it gained a wide and devoted following through syndication in the 1970s, and *Star Trek: The Motion Picture* appeared in 1979. The Cold War–era science fiction of which *Star Trek* was representative commonly used space as a metaphor for human aspiration.[13] *Cosmos* pursued parallel goals, and spoke to an audience that had been sensitised by fiction to the idea of outer space as both accessible and brimming with potential.

The book established a pattern characteristic of popular science works from the late twentieth century. However fanciful the images, the captions are almost always dry and didactic. Sagan's caption for Schaller's representation of life on Jupiter, for instance, glosses over the unreality of 'imaginary but possible life forms in the atmosphere of a Jupiter-like planet,' and reminds readers that the rendition is in some sense rooted in fact: 'The cloud patterns are mainly those discovered by Voyager on Jupiter. Ice crystals in the high atmosphere are responsible for the halo around the Sun.'[14]

Sagan's body text, however, departs from this matter-of-fact tone. The page preceding the spread depicting gas-giant life forms celebrates the possibilities of the search for life beyond Earth, now that 'we have at last begun to listen for other voices in the cosmic fugue.'[15] Image, caption and body text perform a similar dance throughout the book. Images concretise the distant, abstract and fanciful. Sober captioning legitimises them as the products of deliberate scientific procedure. And soaring rhetoric invites readers to marvel at the possibilities those procedures bring within human grasp. Only the final caption in the book, attached to the iconic 'Earthrise' photo snapped by William Anders from the Moon (plate V), breaks this pattern and lapses into poesy, reflecting on the speed with which our planet is whizzing through the galaxy and concluding, 'We have always been space travelers.'[16]

A similar pattern can be discerned in other successful popular works with similar goals. Brian Greene's *The Elegant Universe* (1999) was not so lavishly illustrated as *Cosmos*,

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[13] Neufeld, *Spaceflight*.

[14] Sagan, *Cosmos*, 42.

[15] Ibid., 41.

[16] Ibid., 344.

but it did use illustrations in a similar way.[17] The book was designed as an accessible account of string theory, a research programme that sought a conceptual unification of the two main theoretical frameworks of modern physics—quantum mechanics and general relativity. Advocates of string theory billed it as the natural heir to the wildly successful programme of high energy physics research that had reformed scientific understanding of the building blocks of matter and energy through the mid-twentieth century.

But it was controversial. Critics countered that string theory lacked not only experimental traction but also any realistic prospect for it, and they questioned whether this post-empirical stance was helpful for the cultural standing of the sciences.[18] Sober, didactic captioning alongside images that gave readers conceptual purchase on abstract concepts, such as multiple additional dimensions rolled up within the four that we know from our macroscopic existence, was therefore a particularly useful tool for Greene. He sought to render the counterintuitive and contested propositions of string theory concrete – even while his prose echoed Sagan's high-minded rhetoric in suggesting that string theory contributed a 'rung on the human ladder reaching for the stars.'[19]

Anthropologist Sharon Traweek's ethnographic study of the Stanford Linear Accelerator (SLAC) described how many physicists, although often suspicious of organised religion, nonetheless viewed themselves as belonging to a kind of secular priesthood, dedicated to the 'revelation and custody of fundamental truth.'[20] Science in the second half of the twentieth century became a kind of secular religion for many popular audiences, and so its expositors were in the business not just of exposition, or outreach, but of meaning-making. This is the context in which we should interpret the image–caption–prose triangle that *Cosmos* exemplifies so well. The text-image relationship was calibrated to instruct, but also to instil a sense of wonder and to heighten the conviction that the subtle machinery of awe was sanctioned by the reliable machinery of scientific inquiry.

Weirdness and Whimsy

Appealing to a sense of wonder was not the only way the popularisers of physics sought to discharge their duty as custodians of fundamental knowledge. Physicists were also eager to

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[17] Greene, *Elegant Universe*.

[18] See Woit, *Not Even Wrong*.

[19] Greene, *Elegant Universe*.

[20] Traweek, *Beamtimes and Lifetimes*, 2.

show off their playful side. Though ostensibly at cross purposes to the serious business of instilling wonder, the two objectives found sympathy with each other in the late twentieth century.

How and why can be seen by examining the myth of Einstein, who was often understood to have stumbled upon the strange and counterintuitive insights of relativity because he was a childlike naïf, asking the simple-but-profound questions that stuffy, hidebound traditionalists would dismiss out of hand. This myth of Einstein was just that. His conceptual success was rather due to a combination of ability, rigour, perseverance and luck.[21] But the myth of the whimsical, playful Einstein – as embodied in the well-known image of him in his wild-haired later years flashing his tongue to a paparazzo – lived on nevertheless, and contributed to the intellectual image of a branch of physics that juggled particles with strange names and made counterintuitive claims about the fundamental nature of the physical world.

Richard Feynman's celebrity was cast in a similar mould. His 1985 book *'Surely You're Joking, Mr. Feynman!'* crafted his public identity as a 'curious character,' recounting stories of cracking safes at Los Alamos during the Manhattan Project and his affinity for the bongos.[22] Like the myth of the naïf, the archetype of the misfit iconoclast projected a character who, on account of his disregard for both entrenched dogmas and staid standards of behaviour,[23] could probe deeper into the crevices of nature than others.

Such qualities were commonplace in Feynman's field of theoretical high energy physics, which romanticised a certain intellectual cowboyism. Murray Gell-Mann famously pulled the name 'quark' for a new class of elementary particle from James Joyce's *Finnegans Wake*. Yoichiro Nambu's book *Quarks*, published in 1981 in Japanese before the English edition appeared in 1985, illustrated key ideas using beguiling cartoon characters, such as those representing the hierarchical organisation of matter in figure 12.[24]

<<Figure 12 near here>>

Workaday whimsy also crops up in the pedagogy of relativity, where the stock characters Alice and Bob began to be used in the late twentieth century to illustrate effects

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[21] Norton, 'How Einstein Did Not Discover'.

[22] Feynman, *'Surely You're Joking, Mr. Feynman!'*.

[23] I use the pronoun advisedly since this archetype played on a certain swashbuckling masculine ideal. See, e.g., Whitten, 'What Physics Is Fundamental Physics?', 10.

[24] Nambu, *Quarks*.

such as time dilation. The trope, which originated in cryptography, had spread into physics by the 1990s.[25] N. David Mermin, in a 2005 textbook, praised the characters for making 'some otherwise quite cumbersome narratives entirely colloquial and informational without sacrificing any precision,' and expressed the hope that he could 'pave the way for more appearances of Alice and Bob in the relativistic arena.'[26]

A whimsical attitude helped physics communicate the features of macroscopic and subatomic worlds that proved increasingly obstreperous with respect to classical physical intuitions. Playfulness helped to overcome a natural intuitive resistance to quantum and relativistic concepts. And images, as in the case of Nambu's cartoons and illustrations of Alice and Bob zooming through relativistic space, were one way physicists advanced that image, and linked the playful with the profound.

The evolution of bubble chamber images offers another clear example. The bubble chamber, developed by Donald Glaser in the early 1950s, became a workhorse instrument over the next decade. Filling a chamber with a superheated liquid and altering its pressure as charged particles passed through it would cause bubbles to form along the particles' tracks, leaving a clear visual record of their trajectory that could then be photographed. For Peter Galison, the bubble chamber was the apotheosis of the visual tradition in high energy physics, which sought to 'mimic nature through nature's own inscriptions.'[27] But these images had a life beyond offering apparently more direct access to natural processes than statistical analysis.[28]

In the 1980s, vividly colourised bubble chamber pictures moved into the mainstream. In 1980, CERN commissioned an in-house photographer, Patrice Loiez, to produce a series of decorative images based on bubble chamber data.[29] The results were striking enough that CERN made them the centrepieces of subsequent exhibits, including a stained-glass rendition (plate VI), which travelled around Europe as part of a laboratory charm offensive in the early 1980s. The image, rendered in primary colours, reflected the fundamental nature of CERN's

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[25] Rivest, Shamir and Adleman, 'Method for Obtaining Digital Signatures'.

[26] Mermin, *It's About Time*, xiii. Though far from the first use of the names in physics, even relativistic physics, this book did contribute to their later ubiquity.

[27] Galison, *Image and Logic*.

[28] Whether directness is in fact an observational virtue is controversial. See Franklin, 'Is Seeing Believing?'.

[29] Patrice Loiez, personal correspondence with the author, 7 October 2021.

work: an aqueous blue background on which were imposed sharp yellow particle tracks surrounded by rippling red haloes.[30] It was representative also of changes in the practice of physics at CERN. Colour displays had been introduced in the late 1970s, leading to internal discussions about what colours to use to best visualise particle data.[31]

Loiez's creation would have a remarkable career as an icon of physical inquiry. The stained-glass artwork was an early example of a genre that quickly gained popular traction. A snippet of a now-iconic image, enhanced and colourised, appeared on the cover of Prince's 1990 album *Graffiti Bridge*. A fuller version the image – which by the late 1990s was being sold as a postcard at the CERN gift shop[32] – featured as the album art for the US edition of The Strokes' *Is This It* (2001), after the UK cover was deemed too risqué for the American market. It graced the covers of numerous books, including the Canto reprint of Alastair Rae's *Quantum Physics: Illusion or Reality?* (1994), Gordon Kane's *The Particle Garden: Our Universe as Understood by Particle Physicists* (1996), Don Lincoln's *Understanding the Universe: From Quarks to the Cosmos* (2004), Freeman Dyson's *The Scientist as Rebel* (2006), and Peter Woit's *Not Even Wrong* (2006).[33]

Equally telling is what it was often supposed to reveal, according to the text around it. A 1998 note in the *Times Higher Education Supplement* reported on a collaboration between CERN and British artists, suggesting, in the caption to a version of a particle-track image, that such works would 'help the public grasp complex concepts of time and space.'[34] It is unclear, however, how such artistic representations could broaden public understanding. Captions for the image from press clippings in the 1990s and 2000s often point out that the tracks are the result of particles created after other particles collide, but they were rarely if ever used to elucidate how physicists used the images as evidence of physical processes. By the time these images became commonplace in the 1980s and 1990s, bubble chambers were being retired in favour of detectors that better supported statistical, rather than visual, data analysis.[35] These images instead stand as early representatives of the ethos animating the

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[30] 'People and Things'.

[31] O'Luanaigh, 'Seeing the Invisible'.

[32] Wenninger, 'In the Tracks of the Bubble Chamber'.

[33] Hossenfelder, 'Book Cover Physics'.

[34] Patel, 'Art Rises to Time's Challenge'.

[35] Galison, *Image and Logic*.

SciArt movement of the 1990s and 2000s, in which curiosity, in both senses of the word, became a 'key trope conventionally used to connect art and science.'[36]

Whereas for physicists, bubble chamber images were valuable because they offered an apparently direct visual record of otherwise invisible subnuclear processes, these souped-up versions presented a psychedelic version of the quantum world, attractive for their striking *un*reality as much as for the access they represented to fundamental reality. The words around them employed the language of understanding, but made little effort to confer it. The word-image relationship was rather an exercise in producing affect. Particle tracks represented physicists' ability to latch on to the elemental nature of the physical world, a fact the text alongside the images often reinforced, while psychedelic colouring emphasised the outré nature of that world, and recalled the colourful personae adopted by the people who explored it.

High energy physics and cosmology coordinated word and image as part of a myth-making process. The myth under construction presented physicists as secular priests, custodians of the natural world's deepest secrets. The myth was designed, in part, to maintain public support for areas of scientific inquiry that were growing increasingly expensive in the era of big physics. In the absence of direct military or economic benefits, large expenditures on telescopes and particle accelerators require justification in terms of a higher cultural good. The effort was in some measure successful. Although the hugely expensive Superconducting Super Collider lost its funding in the wake of the Cold War, large investments in both high energy physics and cosmology continued well beyond what might have been expected on the basis of their direct practical payoffs.[37] Visual culture played a key role. That effect was coveted, but not replicated, by other areas of physics.

The Physics of Materials: A Visual Deficit

The visual vocabulary of both high energy physics and cosmology found a good fit with the cultural context of the late twentieth and early twenty-first centuries. In a secularising Western world that looked to science as a source of meaning, images of far-away celestial objects and sub-microscopic particles, along with the language describing them, invoked awe towards the natural world and the capacity of the human mind to grasp it, as well as reverence towards the often-quirky individuals who pushed into those frontiers. What then, of

[36] Sleigh and Craske, 'Art and Science in the UK', 316.

[37] Riordan, Hoddeson and Kolb, *Tunnel Visions*.

the physics of complex matter? How did images feature in attempts to communicate to wider audiences, and does that usage help account for those fields' comparative lack of popular recognition?

Popularisation efforts focused on solids and other forms of complex matter were thinner on the ground than those focused on the cosmos or elementary particles. The reasons are many: solid state physics was well-supported by industry and so did not rely on stoking public interest to gain policy momentum for its projects. It was not so wedded to large machines that required political capital to build and maintain. Popularisation was not so attractive a career path for PhDs who could find well-paying jobs in industry. No solid state textbook enjoyed the breakthrough success of *Gravitation*, and no popular television series delved deeply into phonons or the band structure of solids. Solid state and condensed matter physics gained ongoing cultural sanction through their proximity to technology, however much some sought to break that association, and so saw less need for an aggressive public relations campaign.[38]

Nevertheless, the rare effort to reach broader audiences can be instructive. A representative example can be found in a 1967 article in *Scientific American* by Nevill Mott, the Cavendish Professor of Physics at Cambridge University. Mott was a decade away from being awarded the Nobel Prize in Physics along with his American counterparts Philip Anderson and John Van Vleck. Titled 'The Solid State', Mott's article sought to explain the basics of the field and the phenomena it addressed, with a focus on the difference between crystalline and amorphous solids.

The use of images in the article highlights the contrast between solid state physicists' approach to public communication and that of their colleagues in high energy physics and cosmology. Mott's images, and their captions, are almost exclusively – and, moreover, earnestly – didactic (see fig. 13). Throughout the article, and particularly in the diagrams accompanying it, Mott's central aim is to communicate key concepts in a straightforward and accessible way. He noted that solid state physics 'has ceased to be restricted to pure science and has become a working tool of technology,' but made no effort to stoke the sort of wonder or awe that was the hallmark of similar outreach by cosmologists and particle physicists.[39]

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[38] Martin, *Solid State Insurrection*, esp. ch. 7.

[39] Mott, 'Solid State'.

<<Figure 13 near here>>

But apart from these occasional efforts at explaining the field's key concepts, the popular imagery of solid state and condensed matter physics remains most notable for its absence. Unlike cosmology, which benefited from both rich artistic representations and, from 1990, the detailed images beamed to Earth from the Hubble Space Telescope, and high energy physics, which capitalised on seductive images of particle tracks, the physics of complex matter lacked a distinctive instrument that generated widely recognizable iconography. Even in the context of popularisation efforts, materials physicists did little to embellish the sorts of images created by x-ray crystallography or electron microscopy.

This is not, of course, a complete explanation for the different standing these fields occupied in the public consciousness. The sorts of images that get created in the first place are a function of the perceived appetite for them, and the way they are described depends on how their producers understand their objectives. But comparing the frequent affective function of word and image in high energy physics and cosmology with the thin, didactic, and occasional use evident in solid state and condensed matter physics does clarify how the former effectively leveraged the cultural context to its benefit.

Conclusion

An observer looking at physics from the middle of the twentieth century, with a premonition that the field was poised for wider recognition and acclaim, would have been forgiven for thinking that it would be the physics of materials, rather than high energy physics and cosmology, that would grab the public imagination – particularly in the practically minded United States. Materials are, after all, most closely connected to the developments that reshaped everyday life during the Cold War – the transistor, integrated circuits, televisions, MRI machines, Kevlar, plastics, polymers, alloys used in civil and military aviation, ceramics and non-stick coatings popping up in kitchens. The physics of elementary particles and space–time, by contrast, was distant, outré, effete.

As we know, however, the opposite transpired. Those areas of physics most remote from daily life parlayed that distance into a mystique that satisfied a growing appetite for scientific media offering a sense of meaning, rather than simply information about the world. The physics of materials would labour in the shadow of the technologies it helped create, struggling vainly to differentiate its intellectual achievements from its practical ones. Imagery, and the way it was discussed, offers one tool for making historical sense of this asymmetry.

Lillian Hoddeson and Adrienne W. Kolb have identified frontier rhetoric as a key element of the success high energy physics enjoyed in the late twentieth-century United States.[40] Physicists themselves spoke of pushing into the energy frontier and sought frontier instruments to discern what it contained. New frontiers implied new vistas, both in energy and in the final frontier of space. The ways those vistas were depicted, and those depictions discussed, helped to maintain the unusual cultural prestige of an abstract enterprise that was self-consciously distant from quotidian affairs.

The visual vocabulary of late twentieth-century popular science, corresponding as it did with the proliferation of colour television, the expansion of the Internet, and other shifts in visual media, therefore helped cement high energy physics and cosmology in the public imagination, convincing many that the deepest secrets of the world were within human grasp. Solid state and condensed matter physics, fields that did not craft a distinctive and recognisable visual identity, languished in popular obscurity. In this way, the visual, and the words with which the visual was framed, shaped the prestige politics of physics in the late twentieth and early twenty-first centuries.

[40] Hoddeson and Kolb, 'Superconducting Super Collider's Frontier Outpost'.