Between fact and fiction: demarcating science from non-science in popular physics books

Abstract

This paper looks at the ways in which popular science books, through their explicit insertion of science into the public domain, act to reinforce a distinct demarcation between scientists and their publics. It is argued that these books acquire a distributed media presence by acting as nodal points in an intertextual web. The intertextuality of popular science books causes images of science which are supportive of scientists' interests to continue to circulate in public discourse despite the alternative images thrown up by public scientific controversies reported in the news. The paper looks at examples of popular physics books which, like many other popularisations of physics, draw explicitly on science fiction. Since these texts do not respond to any specific controversy within or around science, they provide examples of 'routine' boundary work. It is argued that by working at multiple boundaries, texts such as these are able to claim potentially contradictory attributes for science at the same time as sustaining its place at the top of a hierarchy of ways of knowing.

KEYWORDS: popularisation of science, popular science books, boundary work, physics, science fiction, public understanding of science, religion

Dr Felicity Mellor
Humanities Programme
Imperial College
London SW7 2AZ
U.K.

e-mail: f.mellor@imperial.ac.uk
tel: +44 (0)20 7594 8746
fax: +44(0)20 7594 8763

Author copy. The final, definitive version of this paper has been published in *Social Studies of Science* 33:4 (August 2003) 509-538 by SAGE Publications Ltd. All rights reserved.

Introduction

The popularisation of science is an important part of the scientific process. All scientists engage in the production of texts addressed to groups other than the core group and, as Shinn and Whitley argue, all such texts may be thought of as popularisations (Shinn & Whitley, 1985; see also Lewenstein, 1995a). However, this generalised notion of popularisation also recognises different genres within it. The textbook, for instance, is a popularisation that takes a different form and addresses a different audience than does a review article, which is different again from a magazine feature. Hilgartner (1990) has characterised this range of genres as a spectrum reaching from 'upstream' texts close to the site of production of the science, to 'downstream' texts addressed to non-scientific audiences. Downstream texts provide a key forum in which the meaning of contemporary science is negotiated by non-specialist audiences. Through popular media such as television and newspapers, public images of science are constructed, legitimised and challenged.

Over the last fifteen years, scientists have engaged in popularising activities within a context of increasing concerns about the 'public understanding of science' (PUS). In the UK, the publication of a Royal Society report in 1985 inaugurated a period in which scientists were encouraged by their peers, government and the business community to present their results directly to the public. Among other recommendations, the report urged that: 'Scientists must learn to communicate to the public, be willing to do so, and indeed consider it their duty to do so' (Bodmer, 1985: 6). In the years that followed, calls were made for research funds to include some requirement for public outreach, scientist-popularisers were commended for their efforts, and most recently an 'independent' but 'pro-science' media centre has been established at the Royal Institution in London to act as a clearing house for news stories about science.¹

The rhetoric of the PUS movement has centred around an expressed desire to bring science to the public, to make it more publicly available and accessible. Yet in general, this task has been conceived as an educational challenge (the aim is to *explain* science) with a propagandist pay-off (successful popularising will lead to increased public support for science). This accords the audience, and even the media, a passive role in which it is scientists and their supporters – not journalists, consumers, activists or other non-scientists – who decide what it is that should count as science in the public sphere. Even whilst they seek to break down boundaries by bringing science to the public, PUS-oriented science popularisers erect boundaries by demarcating science from non-science and by assuming that it is scientists who have the most authority to mediate public science. In this way, the popularising activities of scientists and their proponents construct a public discourse about science which is supportive of scientists' interests.

Although scientists' interactions with news journalists have received some critical attention, there have been few studies of scientists own popularising efforts. In particular, there have been few studies of the role of popular science *books* in controlling public discourse about science.² Yet popular science books have enjoyed increasing prominence over the last fifteen years. In this paper, I look at how authors of

popular science books engage in a process of defining science, which affords scientists legitimacy in talking about science and delegitimises non-scientific voices. I argue that popular science books act as nodal points in an intertextual web of mediations of science and provide a non-controversial site for the normative construction of public science.

In what follows I examine the public positioning of popular science books and the ways in which they maintain the position of science through 'routine' boundary work. I will illustrate my argument by reference to a set of popular physics books, described in the next section, which explicitly address the boundaries around science by looking at the relation between science and science fiction. For convenience, in much of what follows I will use the term 'popularisation' in the narrow sense to mean popular science books. This is not meant to imply that other texts – from radio shows to grant applications – are not also forms of popularisation.

Popular science books

The growth in popular science publishing

There is a long tradition of prominent scientists writing books for public audiences – from the 'visible college' (Wersky, 1988) of scientist-popularisers in the first half of the twentieth century through to authors such as Carl Sagan and Stephen Jay Gould in the 1970s and 1980s. But over the last fifteen years or so popular science has emerged as a publishing category in its own right; a development which, in the UK, coincided with the emergence of the PUS movement. Calls for scientists to engage in popularising work encouraged scientists to see the writing of popular books as a legitimate activity and those in the PUS movement set out to reward such work. In 1988, for instance, the Committee for the Public Understanding of Science established the first science book prize, now described as 'one of the UK's most prestigious non-fiction literary prizes' and 'the scientific community's answer to the Booker prize'.³

Although the PUS movement helped legitimise scientists' popularising work, the growth in popular science publishing during the 1990s is most frequently attributed to the unparalleled success of *The Brief History of Time* by physicist Stephen Hawking (1988).⁴ *Brief History* spent 234 weeks in the UK top ten bestseller lists and sold over four million copies in hardback worldwide in its first three years of publication (White, 1998; Rodgers, 1992).⁵ Such sales are rarely achieved even by the most popular novels and although many other factors have contributed to the growth in popular science books, without doubt the Hawking 'phenomenon' helped bring their sales potential to the attention of publishers. Both publishers and bookshops now heavily promote popular science books, with many publishers having popular science lists and with booksellers setting aside areas of their shops for popular science.

As a result the genre has acquired a commercial reality with books being explicitly labelled as 'popular science'. As with any genre, this leads to both consumers and authors having a particular set of expectations about what such books will contain and about how author and reader will be positioned within the text. The context of scientists' concerns about the public understanding of science and their experience in popularising science within educational institutions means that many popularisations adopt a pedagogic tone and readers approach such texts with expectations that they will 'learn' something. Yet it is also important to recognise the diversity within the genre. Indeed, it is possible to identify three main modes of address: the narrational, the expository and the investigative.⁶

In the narrational mode, the structure of the book is dominated by narrative and the author adopts the role of storyteller, telling the story of an episode from the history of science or the life in science of one particular individual. Examples of such books include Dava Sobel's bestselling *Longitude* (1996) along with the many biographies of famous scientists. Like *Longitude*, most narrational popular science books are written by professional writers.

Expository books are structured around the exposition of a particular scientific discipline. This may include a narrative about the history of the discipline, but the emphasis is on a particular subject or theme and its logical consistency or empirical basis, rather than on a particular story. An expository text is more likely to be pedagogically orientated than books in the narrational mode. Hawking's *Brief History* is a classic expository text which sets out to explain current research in theoretical physics to non-specialist audiences. Expository books may be written by practising research scientists, other scientists in educational institutions, or professional science writers. However, in all cases the authors are presented within the texts as having some training or expertise in science, even if only through regularly writing on the subject. I will discuss the importance of the textual construction of the author in more detail below.

Finally, a small sub-set of popular science books present journalistic investigations into a topical and controversial subject of relevance to science. The most well-known example of an investigative popular science book is Rachel Carson's *Silent Spring* (Carson, 1963). Such books are usually written by journalists, activists or academics from disciplines other than the natural sciences. Because they often take an overt political stance, these books may not always be labelled as popular science even though they offer non-specialist accounts of scientific issues.

Needless to say, these categories are overlapping. For instance, the narrational mode overlaps with expository popular science at one end and with popular history books at the other. Indeed, nearly all popular science books contain some historical narrative and some exposition, so the distinction between the categories is one of emphasis only. However, the typology is useful because it helps separate out those popularisations – those in the expository mode – which are most closely identified with scientists themselves, and it is the expository mode with which this paper is concerned. It is expository books that are most unambiguously identified as popularisations of science by booksellers, publishers and the

authors themselves, but at the same time it is these books which most explicitly engage in the demarcation of science from non-science. By claiming merely to set out science in clear and understandable language, these books present science *as* science – implicitly (and sometimes, as we shall see, explicitly) identifying what counts as science and simultaneously identifying what does *not* count as science. This process is normative since the demarcation of science from other activities also involves a value judgement in which science is typically placed at the top of a hierarchy of ways of knowing.

Exemplar texts

In order to illustrate the ways in which expository popularisations demarcate science from other ways of knowing, I will focus on a set of popular physics books which all foreground the relation of science to science fiction.⁷ These books are particularly interesting because they deliberately present one way of knowing (science) by referring to another (narrative fiction). As a result, they explicitly work the boundary between science and fiction. In the course of so doing, they also address a number of other boundaries such as the boundaries of science with religion, magic and technology. The books are also significant because they embrace most thoroughly the science-fictional allusions which are found in a number of other popularisations of physics. I briefly describe the books here before looking at the prevalence of science-fictional references in other popular physics texts.

The Physics of Star Trek (Krauss, 1995) and *Beyond Star Trek* (Krauss, 1997) are two short books by US physicist Lawrence Krauss. At one level these books simply use science fiction as a clever marketing strategy by tying into the popular cult TV series. The first book was most successful in this regard being nominated as one of the *New York Times*' 'Notable Books of the Year' in 1996 (Editorial, 1996c) and as 'pop science book of the year' by the *Guardian* newspaper in the UK (Marks, 1996). Throughout both books, Krauss works hard to establish his identity as one of the family of theoretical physicists. These 'eminent' physicists and 'distinguished colleagues' 'confide' in him, answer his queries and reveal their Trekking passions (Krauss, 1995: 162; Krauss, 1997: 11, 169, 142, 130, 168). Stephen Hawking writes the forward to the first book. These are, then, presented very much as books *from* physics: the tribe speaking through one of their own. Claims made within the books are thus constructed as claims for physics. Although, like the other books studied here, Krauss's books do not respond to any particular debate or controversy, unlike the other authors he does engage with some current debates in passing. Thus he attacks religious fundamentalists, offers the 'objective reality' of the night sky as comfort against the editors of *Social Choice* (presumably he means *Social Text*), and notes that the U.S. Congress 'unfortunately' cancelled the construction of the Superconducting Super Collider particle accelerator (Krauss, 1997: 107, 46). Nonetheless, these are brief asides and do not constitute the focus of either of the two books.

The Cosmic Dancers is also by a US-based professor of physics, Amit Goswami (1983). Although co-authored 'with' his wife Maggie, the book is written in the first person singular throughout and thus in

content presents Amit Goswami as sole author. Published some twelve years before the first of Krauss's books, this is Goswami's first popular book although he had previously authored a well-known textbook on quantum mechanics.⁸ *The Cosmic Dancers* draws on a wide range of SF novels and short stories to offer examples of various physical processes. Despite the many passages reprinted from SF texts, this book, like many other expository popularisations, is pedagogical in tone.⁹ Unlike Krauss, Goswami refers to the limitations of some aspects of physics; mentioning, for instance, the 'often arbitrarily narrow boundaries sometimes imposed by scientists' and the 'dead ends' of modern physics (Goswami, 1983: 6, 58). Yet, always quick to note where ideas have come first from physicists, this is essentially a celebration of physics: 'Both physicists and science fiction writers truly are cosmic dancers, shaping and expressing our vision of reality' (Goswami, 1983: 9).

Michael White, author of *The Science of the X-files*, is a professional science journalist but he notes in his preface that he was 'a scientifically-minded, swotty fifteen-year-old' and the biographical note states that he was formerly a 'science lecturer' (White, 1996: viii, cover). Thus, whilst White does not write from within science, he claims a close relationship to it.¹⁰ Although commercially less successful than some of the other books studied here, the *Science of the X-Files* did reach the *New York Times* bestsellers list in 1996 (Editorial, 1996b). The book takes paranormal phenomena as its starting point, but despite the title, it makes few direct references to either *The X-files* or other SF texts. Along with short expositions on aspects of biology and psychology, *The Science of the X-Files* tells us about such things as the composition of the solar system, the curvature of space, the nature of quantum theory and the second law of thermodynamics. Presenting a mix of paranormal enthusiasm and scientific pedantry, White argues for an 'open-minded' attitude towards the paranormal (White, 1996: viii, 194). For him, this implies the need to search for a physical, biological or psychological explanation of such phenomena. Cultural or social explanations are largely invisible to White.

The Science of Discworld, on the other hand, presents a far more reflexive view of both science and literature (Pratchett et al., 1999). Co-authored by Terry Pratchett (author of the successful fantasy series of Discworld novels), mathematician-populariser Ian Stewart and biologist Jack Cohen, the book interweaves a specially-written Discworld story with a chronologically-structured account of the origin and evolution of the universe, the solar system and life on Earth. For these authors, the Discworld story – in which a group of magicians accidentally create a new universe, a 'roundworld' just like our own – is a 'thought experiment' affording an opportunity to 'look at science from the outside' (Pratchett et al., 1999: 11). The book was very successful in commercial terms: the hardback appeared in the UK top ten non-fiction bestseller lists for ten weeks and the paperback was in the top ten for six weeks.¹¹ Although two of the authors of this book are university-based scientists, the book does assume a critical stance with respect to some aspects of science. Reminding us that scientists do not always speak with one voice, *The Science of Discworld* draws attention to the limits of the reductionism of contemporary particle physics and genetics (Pratchett et al, 1999: 88, 266, 267).

Framing science through science fiction

These books form part of a recent trend of expository popular books entirely devoted to the science 'in' science fiction. As the above descriptions indicate, the set of books studied here deal mainly with the physical sciences, but a number of other books deal with biology and science fiction.¹² The physics books deal with science-fiction technologies which are the subject of thought experiments in theoretical physics but which are far removed from real technology. The biology books, by contrast, tend to discuss science-fiction technologies – such as cloning or the revival of extinct species – which have some proximity to actual technologies used in current biological research. As such, they need to be read in the light of the controversies surrounding these new technologies. Since I am here interested in the normative construction of science in *non*-controversial contexts, this study is restricted to the books focussed on physics.

Compared to the total number of popular physics books, the proportion structured entirely around science fiction is relatively small; but a great many other popular physics books invoke science-fiction tropes for some chapters only or make brief passing references to science fiction. For instance, despite being a standard exposition of modern physics and cosmology, *A Brief History of Time* contains several passing references to science fiction and a number of science fiction-like 'thought experiments' about space travellers (Hawking, 1988: 50, 98, 103, 139, 149, 166, 179). Other popular physics books are centred around one concept which has science-fiction overtones. For instance, a number of recent books about theoretical physics focus on 'time machines' (e.g., Davies, 2002; Gott, 2001; Nahin, 1993; Pickover, 1998) and other books take this approach for one or two chapters (e.g., Gribbin, 1993; Davies, 1995; Thorne, 1994).

The presentation of science through science fiction is also frequently adopted by professional science writers in newspapers and magazines. For instance, a recent news feature about asteroid collisions was illustrated with a picture from the SF film *Armageddon* and began by referring to a group of scientists as 'The X Files committee' (Rufford, 2000).¹³ Indeed, science-fictional allusions are so readily available that they become almost impossible to resist in news and feature stories about, say, antimatter or asteroid impacts. The same is also true within some of the sciences themselves. In theoretical physics, science-fictional concepts and language are used even in technical texts. For instance, researchers today frequently talk of 'time machines', 'teleportation' and 'warp drive'.¹⁴ This language inevitably brings with it a set of connotations derived from narrative fiction. Journalists reporting on these scientific developments cannot help but respond to this fictional context. For instance, features and news stories about quantum teleportation typically have headlines such as 'Beam me up my cup of coffee, Scotty' (Connor, 2000). Science fiction is not, therefore, some 'add-on' used simply to make science more digestible to the public. It plays a role in meaning-making both in the production of science and in the representation of science. And for scientists and non-scientists alike, the presence of science-fiction tropes

and narratives in texts about science becomes a part of the boundary work through which science is defined.

A science-fiction approach to science is also sometimes used in educational contexts. Some courses aimed at non-science majors or entrants into science from non-traditional backgrounds sometimes use the same 'science in science fiction' frame as the popularisations studied here.¹⁵ Indeed, Goswami's *Cosmic Dancers* has become a set text on some of these courses.¹⁶ As has already been noted, many popularisations are pedagogically orientated towards their audience and they are therefore read with educational expectations. Thus a newspaper reviewer said of the approach taken in *The Physics of Star Trek* that: 'it is a way of educating the general public about weird physics' (Lezard, 1997) and a *New Scientist* review, after finding the book to be a 'highly accessible analysis', suggested that: 'Perhaps there's a lesson here for writers of physics textbooks' (Editorial, 1996a). Authors, too, speak of the books in these terms. Lawrence Krauss, in an otherwise damning review of *The Science of the X-Files*, claims that: 'Anything that can motivate people to learn a little science while indulging in other pleasures is a good thing' (Krauss, 1996b).¹⁷

In these comments we see that the educational orientation of expository popularisations is enfolded in a rhetoric of 'accessibility'. Books tied to popular TV shows and novels go furthest in their attempt to appear accessible. Although such a manoeuvre is obviously tied to author or publisher desires to sell more books, their very potential in this regard inevitably construes these books as publicly accessible. Yet, the rhetoric of accessibility implies twofold boundary work. On the one hand, it assumes that a boundary exists between science and non-science which isolates science from non-scientific publics and which determines 'accessibility' as a problem to be addressed. On the other hand, it claims that these popularisations, by virtue of their accessibility, are able to dismantle or overcome the boundary between science and non-science. The rhetoric of accessibility is not confined to the popularisations studied here; accessibility is assumed to be an aim of all expository popularisations. Thus the success of Stephen Hawking's *Brief History* is perceived as a puzzle for the very reason that the book was *not* seen as being accessible.¹⁸ 'Genuine' science, then, is constructed as inaccessible to public audiences, whilst popularisations strive to be accessible and are judged on these grounds.

The rhetoric of accessibility is clearly related to the dominant view of popularisation as characterised by Hilgartner (1990). He found that by demarcating between 'appropriate simplification' and 'distortion', scientists construct a flexible boundary around science, which enables them to influence downstream audiences. Hilgartner focussed on how scientists, in a meta-discourse about the nature of popularised science, attempted to control downstream representations of science by journalists or policy-makers. Here, I am more interested in the representations of science written by scientists themselves or others who claim privileged access to science, and in the boundary work carried out *within* such texts. In particular, I am interested in how boundary work is enacted and publicly positioned in situations which lack the dichotomising tendencies of scientific controversies like that studied by Hilgartner. In the remainder of

this paper, I will discuss the public positioning of popular science books and will then examine the ways in which these books accomplish their non-controversial boundary work.

The public positioning of popular science books

Intertextual nodal points

Popular science books do not stand as isolated texts. They include references and allusions to other texts and, most significantly, they become catalysts for discussions about science across a range of media. Popularisers of science are invited to comment in a number of media fora from radio chat shows to TV documentaries; their books are reviewed in newspapers and occasionally even become the basis of news stories. Indeed, the publication of a new book can provide a news hook which facilitates the presentation of science in journalistic media. Even feature stories that are not driven by hard news require a clearly delimited recent event on which to hang the story. The publication of a book frequently provides this, enabling topics to be reported which would otherwise remain uncommented on. Similarly, the promotion of authors by their agents and publishers provides a ready supply of science commentators enabling debates, discussions and expositions to take place in other media.

The response in the UK media to Krauss's *The Physics of Star Trek* serves to illustrate this process. The book was reviewed in a range of newspapers and even became the subject of front page news stories,¹⁹ and for years after it was first published it continued to be mentioned in feature articles (Parsons, 1997; Highfield, 1998; Brooks, 1999). Krauss appeared on TV in his capacity as author of the book and there was also extensive coverage on the worldwide web.²⁰ Krauss's other popular science books (e.g., Krauss, 1989; 1994; 2001a; 2001b) and the reviews and comments they attract further extend and reinforce this intertextual presence. In this way, Krauss becomes constructed as a scientist-populariser through a whole web of texts referring to, and nucleated around, his writings. He acquires a textual prominence which identifies him as a public scientist and spokesperson for physics. Thus he appears on the high-profile documentary *Universe*,²¹ gives testimony on the future of space travel to the 'Vision 2001' hearing of the House Science Subcommittee on Space and Aeronautics, and is awarded the 1999-2000 Public Understanding of Science and Technology Award by the American Association for the Advancement of Science.

Other popular science books, including most of those studied here, also have a textual presence distributed across the media.²² This suggests that popular science books form nodal points in an intertextual web stretching across all the mass media. This intertextual web has a presence and permanence which few individual texts could alone acquire. Taken together, the texts become stabilised and self-replicating. Popular book writing leads to media appearances for the authors which in turn lead to higher sales, more media appearances and more book deals. Through such processes, a 'formula for

success' is established, which encourages other popular science writers to adopt similar approaches to their subject matter. Most notably, even the subject matter itself becomes stabilised. Despite their considerable differences in authorship and emphasis, the books studied here have remarkably similar scientific content. Focussing on theoretical physics and astrophysics, these books present the same set-piece expositions as can be found in countless other popularisations of physics – something that Pratchett and his co-authors ironically acknowledge:

We have, we are afraid, mentioned in the ensuing pages Schrödinger's Cat, the Twins Paradox, and that bit about shining a torch ahead of a spaceship travelling at the speed of light. This is because, under the rules of the Guild of Science Writers, they *have* to be included. We have, however, tried to keep them short. (Pratchett et al., 1999: 13)

Thus not only does the intertextual web lend popular science books a public presence beyond their individual sales, it also stabilises which aspects of science come to be popularised. In this way, particular constructions of science come to dominate across the media landscape. As a result, the intertextuality is itself constitutive of public images of science and forms a solid cultural backdrop through which scientists' images of science are maintained. This means that although some books may be considered noteworthy in terms of winning prizes, high sales or individual influence, other less successful books may nonetheless be significant in terms of their collective presence. The intertextual web is dynamic, with individual texts and authors continually changing. Yet the stability of the expository form in popular science writing and the routine boundary work such books undertake, affords a relatively unchanging conception of science despite the potential critiques of science which emerge from news coverage of controversial science.

My notion of an intertextual web is similar to the 'web of science communication' that Lewenstein (1995a) found associated with the 1989 announcement of the discovery of cold fusion. However, where Lewenstein looked at controversial science -- in news texts, technical texts and the readings and actions of scientists -- I focus on non-controversial popular texts and the readings available to public audiences. The context of communication is important in both cases, but I suggest that the intertextual web surrounding non-controversial texts addressed to public audiences *stabilises* the construction of science. By contrast, Lewenstein found that the inclusion of mass media in the web of science communication surrounding controversial science is associated with *instability*. My focus, then, is on the stability of public constructions of science rather than, as with Lewenstein's analysis, the communication practices within science and the information instability of scientific controversies.

Implied authors

Clearly, the intertextual web in which popular books are located is supported by a network of actors: the relatively small numbers of scientist-popularisers and professional writers who are regularly called on by

journalists and others working in public media. However, it is important to note that it is the texts and the intertextual web, not the actors or the network they constitute, which forms the interface with which public audiences directly interact. Authors are made present and relevant only through the reading of the texts. Audiences of mass media texts rarely have a chance to question scientists or authors themselves. Instead, the audience will construct an understanding of the author out of the clues within the text and the web of texts surrounding it. Thus, for the purposes of understanding the public construction of science, the author of a popular science book is significant as a textual presence, not as a living and breathing human being interacting with other living, breathing human beings. In other words, in so far as we discuss authors, we need to look at the 'implied author' of a book rather than the actual author.²³ One implication of this is that authors who are not practising research scientists can be constructed as 'scientists' within their texts or in other associated texts. For instance, Michael White is constructed within his books as having expertise in science by virtue of his regular science writing and his earlier experiences lecturing science, even though one might convincingly argue that the actual Michael White is not a scientist.

Another implication of the visibility of an implied author and the invisibility of the actual author, is that pursuing authorial motivations will not necessarily help to reveal the work these texts do in constructing public images of science. It is tempting to dismiss the recent growth in popular science as simply the result of scientists and publishers realising they can make some money by writing popular books. It is probably true that this did happen after the success of *Brief History*. Hawking's royalties were reputedly in the order of £2 per copy of the millions sold, and in the following years other scientists were able to command very large advances on popular books (White, 1998; Rodgers, 1992). But to say, as it is tempting to do, that popular science books are written because they present authors with a possible source of income is to say very little about the work they do as public mediations of science. Readers of books in a capitalist economy are aware that books earn money for authors and publishers, and are able to set such awareness aside as they look for other meanings within the book itself. To understand how popular science books act as a cultural resource of images about science we must, therefore, move away from questions about authorial intentions and look instead at the texts themselves and the contexts in which those texts are placed.²⁴ The books studied here are particularly market-savvy and were no doubt written because the publishers and authors felt they would sell well, but their commercial knowingness does not make these books innocent in other respects. Indeed, they are interesting precisely because of the active boundary work they do in protecting the position of science in a hierarchy of ways of knowing whilst appearing to be merely playing the popular market. What is more, they carry out this boundary work in a relatively uncontroversial context and thus go largely unchallenged.

Expository popularisations and 'routine' boundary work

As should be clear by now, I view popular texts as sites for the public construction of science. Traditional studies of popular science texts have tended to assume that science is an unproblematic body of facts and

have thus concentrated on issues of accuracy and content. More recently, a number of studies have adopted a constructivist perspective towards downstream texts. However, these studies tend to focus on the news media and on controversial episodes.²⁵ Indeed, news values such as conflict and negativity mean that science news does typically concern controversial, rather than non-controversial, science.²⁶ Hilgartner (1990), for instance, looked at news reports of the controversy over the link between cancer and diet. Other studies of controversial science also show scientists actively demarcating areas of expertise in public debates. For instance, Gieryn (1999), like Hilgartner, argues that this boundary work helps maintain the social authority and credibility of science. Gieryn discusses controversial episodes such as the cold-fusion announcement and decision-making processes such as whether to include social sciences in the NSF. Even where he considers boundary work which is an on-going engagement with the general milieu, Gieryn highlights elements of controversy, as in his discussion of the popularising work of the nineteenth-century physicist John Tyndall and the 'prayer gauge' debate.²⁷

Yet studies based entirely on controversial episodes give only a limited view of the ways in which public images of science are constructed through downstream texts. Firstly, even news stories about science are not always concerned with controversial issues; science news stories also often present science as uncontroversial and are used as upbeat light relief from the daily fare of bad news.²⁸ Secondly, the focus on news stories is in any case too narrow. Downstream texts take many forms in many media. Whilst news stories are clearly influential, it would be a mistake to assume that other texts have no influence on public conceptions of science. Thirdly, the focus on individual controversies means that the wider context of public mediations of science is rendered invisible. To be claimed in any one controversy, the authority of science must be a cultural resource already available in other texts about other issues. The active and publicly-visible boundary work which scientists and their supporters undertake in non-controversial situations helps provide a background of cultural assumptions and expectations of science against which controversies and other individual episodes in the public negotiation of science are played out. Many, but of course not all, expository popular physics books are examples of such non-controversial texts. They are presented, and are typically received, as expositions of generally agreed and accepted knowledge. Even when they reveal debate within the scientific community, they are not positioned as part of the debate. Similarly, even though they may be adopted as part of a public debate about the nature or role of science, the texts themselves directly address such debates only in passing, if that. In other words, such texts adopt a celebratory posture, rather than a defensive one.²⁹

Even so, the potential for such books to be recruited into controversies about the place of science in society means that these books are engaged in boundary work even if they are not directly engaged in controversies. This suggests that popularisations may be seen as a form of 'routine' boundary work – the ongoing day-to-day maintenance work that reinforces and sustains the social and epistemic status of science. This routine boundary work is significant because it maintains a cultural resource of normative images and understandings of science which acquire a wide public circulation and can be invoked whenever challenges are made to the position of science in society.

As the books studied here reveal, one of the features of routine boundary work is that they work several boundaries at once. In this, the situation is similar to the 'double boundary-work' which Gieryn identified in Tyndall's public science (Gieryn, 1999: 37-64). Gieryn argues that the necessity of working at two boundaries simultaneously magnifies the inconsistencies of the characteristics claimed for science. In the routine boundary work examined here, contradictory sets of characteristics again emerge. Yet in these examples, rather than magnify the inconsistencies that arise at any one boundary, the working of multiple boundaries can provide the means for negotiating inconsistencies. Although the contradictions remain, by engaging with several boundaries, the tensions that arise at any one boundary can be diffused.

Simply by virtue of their content and their labelling as popular 'science', popular science books tell us which ideas and activities count as science. But popularisations also go further, setting out the nature of the scientific endeavour as a unique and special way of knowing. I will examine the routine boundary work of popular physics by looking at the how the books foregrounding science fiction make particular claims for physics, define and demarcate other ways of knowing, and conduct their boundary work over time as well as across cultural space.

Staking claims for physics

The pervasive reference to science fiction in popularisations of physics immediately draws attention to the factual nature of 'real' science. Books with titles such as *The Physics of Star Trek* or *The Science of the X-Files* invite our surprise because of an assumed clear demarcation between science 'fact' and science 'fiction'. In this respect, the fictional simply acts as a foil against which the facticity of science shines all the brighter. Filling the pages of these books, then, is the message that physics tells the authentic story and science fiction mediates that story, losing authenticity (and hence accuracy and authority) along the way. This is similar to the rhetorical strategies of the scientists Hilgartner studied. However, in these books presenting science as fact *only* is not seen as sufficient to sustain its authority. Facticity alone leaves science a mere repository of the facts, with scientists as the caretakers. A caretaking role fails to carry with it the connotations of social and intellectual status that popularisations of physics such as these strive to accumulate. Facts, then, are an important *feature* of physics but they cannot be presented as its *essence*. Pratchett et al. state this most clearly: 'Science,' they say, 'is *not* about building a body of known "facts"' (Pratchett et al., 1999: 78, italics added).

The foregrounding of science fiction both raises the problem and resolves it. At the same time as drawing our attention to the assumed difference between science and fiction, these books elicit our surprise by positing a shared space between them. What science and fiction have in common, and what saves science from the oppression of facts, is their reliance on the imaginative. 'Ultimately', says Goswami, 'the most common bond between science fiction and physics, the one that makes them such good partners in the dance of reality, is imagination' (Goswami, 1983: 8). Thus by working the science fiction boundary,

popularisations are able to draw attention to the facticity of physics at the same time as they locate the essence of physics elsewhere. As Krauss suggests (with qualifications about the constraints of empirical investigation), a good slogan for modern science would be: 'We are limited only by our imaginations' (Krauss, 1997: 173).³⁰ Physics, then, is to be seen as an act of creative imagining, an intellectual endeavour. The juxtaposition of science and science fiction enables physicist-popularisers to stake their claims on the imaginative and to transform physics from mere fact-finding to an intellectual achievement: 'Our explorations of the universe represent some of the most remarkable discoveries of the human intellect' (Krauss, 1995: 174).

The claim on the imaginative also helps popularisers distance themselves from views of science as practical. Although, as we will see below, the practical innovations of technology are to be claimed as past successes of science, the everyday connotations of practicality are resisted. The mundane constraints of what is do-able are not for physics: 'as we physicists like to say', says Krauss, 'this is an engineering problem' (Krauss, 1997: 28). Indeed, technology can hinder science. White notes that 'many aspects of modern physics remain unprovable' because 'the equipment needed to demonstrate a range of effects is beyond our technological capacity' (White, 1996: 102). Science fiction again enables this tension to be negotiated. It is through fictionalised technology, unfettered by practical constraints, that physics can reach for the future:

Practicality is something we often dispense with when it comes to imagining the future. Part of the fun of physics, and science fiction, is recognizing that to make any progress in the world we can't limit ourselves to thinking about what we're capable of today. (Krauss, 1997: 35)

So the incorporation of SF-technology enables physics to be lifted out of the mundane practical world of the here-and-now that technology itself inhabits and represents. By working the science/fiction boundary as well as the science/technology boundary, the tensions that arise at the latter can be diffused.

If physics is imaginative and intellectual, rather than solely factual and practical, it can now be integrated into the wider culture where fictional narratives and the creative arts already circulate freely. Working at the boundary with fiction therefore allows popularisers to counter the perceived distance of physics from 'culture'. 'In spite of popular notions to the contrary', suggests Krauss, 'art and science will be forever intertwined' (Krauss, 1997: 133).³¹ However, this boundary work raises further inconsistencies, since being part of culture brings with it more dangerous connotations of the mundane or the everyday. In many popularisations of physics, these connotations are avoided by driving a deep wedge between common sense and the physics-reality that lies behind our crude perceptions. Thus in these books, as in many others, quantum theory becomes 'bizarre', relativity 'weird', negative energy 'exotic', and scientists are said to 'play with ideas so wild that often they seem to defy common sense' (White, 1996: 97, 2; Krauss, 1995: 49; Pratchett et al., 1999: 76).³² It is these wild ideas that enable physicists to explore 'the nature,

structure, and destiny of reality itself' (Goswami, 1983: 208, 9). By imagining the impossible then, physicists are able to reveal the reality behind the perceptions.³³

The uncovering of an underlying reality is a common theme in nearly all popularisations of physics and it has the effect of constructing physics as a quest for 'truth'.³⁴ Thus Krauss claims:

There is a common theme woven into much of our pop culture and mythology. It is this: that the world of our experience is a carefully concealed fiction, contrived to make us believe that things are what they're not. Underneath a mundane exterior, the protagonists of this world change their identity at will. . . .

The X-files? Men in Black? The Republican and Democratic Parties? No. I am referring to the Quantum Universe. This is the real final frontier, which must be explored if we are to one day comprehend the beginning and the end of time and the objective reality of the universe of our experience. (Krauss, 1997: 155-156)

The relation to 'truth' makes something special out of the imaginative within physics compared to science fiction, reinforcing the demarcation between the two. A *proximity* to science fiction enables the imaginative nature of physics to be highlighted, but the imaginative then couples to facticity to generate the truth-value which enables physics to stand *apart* from fiction. As these books keep telling us: 'Truth is stranger than fiction' (e.g., Hawking, 1995: xii). Imagining the impossible in narrative genres gives us fictions and myths. Imagining the impossible within physics brings the impossible within the realm of the possible.³⁵ Thus 'fiction' and 'myth' can be used as pejoratives even at the same time as physics is placed alongside the fictional (e.g., Krauss, 1997: 29; Goswami, 1983: 91; White, 1996: 159, 133; Pratchett et al., 1999: 252, 253).

The role of physics in uncovering reality encourages some popularisers, such as Amit Goswami, to turn to the science/religion boundary. For Goswami, the reality revealed by physics is connected to religious insights.³⁶ Finding commonality between physics and a generalised notion of spirituality, Goswami claims that:

. . . there seems to be a convergence of the thinking of mystics and physicists, and of psychologists and paranormal researchers, who all seem to assert as a result of their experience that there is an underlying reality that exists beyond the diversity of the material universe. (Goswami, 1983: 264)

Science fiction can play a role here too by offering a discourse on transcendence. Thus for Goswami, 'crossing the stargate is the science fiction metaphor for transcendence' (Goswami, 1983: 267), and the heroes of science fiction are the role-models for investigators of the transcendental domain of reality: 'Like the scientist-hero [in the SF novel] *Miracle Visitors*, the explorer . . . must extend his science from

the merely experimental to include the experiential as well' (Goswami, 1983: 275). Thus by working simultaneously at the science/fiction boundary and the science/religion boundary, authors like Goswami shift even further away from a focus on science-as-facts in order to claim transcendent phenomena for physics.

Goswami adopts what appears to be a conciliatory approach to religion, but in so doing he appropriates transcendent phenomena for physics. As will be seen below, other authors take a more hostile approach to religion, but they too claim for science some of the phenomena of religious and spiritual practice. Hence White suggests that 'physics plays a role' in the feats performed by fakirs and yogis which are explained by 'mental preparation, physical training and science' (White, 1996: 111-112), and Krauss claims that 'invisible forces are not merely the stuff of revelation; they are everywhere!' (Krauss, 1997: 88).

In a similar way, popularisers claim some of the features of magic for physics even whilst they see magic and science as clearly demarcated. Magic invokes the world of the 'mysterious' and the mysterious is one of the key attributes these books claim for physics. Krauss asks us to be 'thankful for the mysteries' since 'celebrating them is really what science and literature, and art – not to mention my own books – are all about' (Krauss, 1997: 175). And indeed, all these popularisations do celebrate the magical and the mysterious, with references to 'Einstein's magic', the 'technical wizardry' of *Star Trek*, the astronomer as 'a modern experimental wizard', and so on (Goswami, 1983: 111; Krauss, 1995: 112; Krauss, 1997: 109; Pratchett et al., 1999: 95). But science must also be distanced from magic just as it must be distanced from fiction. It is Pratchett et al., drawing as they do on a story based in a world of wizardry, who explore these tensions most thoroughly. To them, magic is aligned with common sense and *everyday* rationality, whilst science is not. Yet at the same time, magic is the category for that which we don't understand (Pratchett et al., 1999: 28-39). This, they argue, leads to a common perception that science *is* like magic: 'sufficiently advanced physics is indistinguishable from magic' (Pratchett et al., 1999: 23).

Again, we see here a distinction being drawn between physics and common sense. Through such a demarcation, popularisations of science present physics as a domain inaccessible to non-physicists. Even whilst claiming to integrate physics within the broader culture these popularisations therefore reinforce its otherness. Far from addressing concerns about the alienation of the public from science, books such as these reinforce a distinct demarcation between science and its publics.

So the boundary work of these popular physics books serves to define physics as imaginative, intellectual and transcendental. Physics is constructed as factual but not *just* a body of facts; as mysterious and magical but very different from magic itself; as part of everyday culture but defiant of common sense. Some of these features can be claimed by working the science/fiction boundary, but popular science books also turn to other boundaries, most commonly that with religion, to stake their claims. By working multiple boundaries a complex picture can emerge in which potentially inconsistent features are reconciled into a seemingly coherent view of science.

Defining the other

In the process of defining science, popular science books also inevitably define the 'other' with which science is to be compared. Demarcating science by reference to science fiction or religion therefore also involves the demarcation of these other ways of knowing. Furthermore, it also involves a valorisation which typically places science in a superior position.

Not surprisingly, the popularisations studied here do most work in the demarcation and valorisation of science fiction. For instance, Goswami goes so far as to offer a formal definition of science fiction as the source of positive challenges to science.³⁷ In this definition, the purpose and nature of science fiction is to be understood only in relation to science. Similarly, Krauss sets about defining science fiction by suggesting that the best science fiction is that which emulates the ways of physics:

While demands of realism are clearly less exigent for science fiction than for science, I think that at a deep level this spirit of imagination tempered by reality, or at least what might make a plausible reality, is what characterizes the very best science fiction as well.
(Krauss, 1997: 174)

The devices of science fiction are to be celebrated when physics can validate them or, better still, when they are initiated by physics. Thus for the authors studied here it is significant that 'long before the Star Trek writers conjured up warp fields, Einstein warped spacetime' or that a 'suggestion for a space drive is from a respected physicist' (Krauss, 1995: 31; Goswami, 1983: 41). Particularly worthy of praise are scientists such as Fred Hoyle who write science fiction themselves, for they can get their fiction 'correct':

Because Hoyle is a scientist, he has a delightful tendency to create a scenario in which scientists confer with each other using a language that is pretty close to being authentic.
(Goswami, 1983: 13)³⁸

But not all science fiction is so praiseworthy. When science-fiction writers get it 'wrong' or simply fail to attend to the authoritative voice of physics, they are indulging in 'scientific patter' and are departing the 'serious' territories of science for the realms of magic:

... some attempts of science fiction writers to overrule scientific laws are reminiscent of science fiction's rich heritage of sword and sorcery, and magic. ... When a writer waves an interesting idea at the reader but backs it up only with meaningless patter, he or she is using the idea as a magic wand. (Goswami, 1983: 6)

By highlighting the factual unreliability of some science fiction, these representations stress the facticity of science and contrast it to the factual-paucity of magic. Thus demarcating science through reference to science fiction, also involves the valorisation of science fiction and the demarcation of other ways of knowing, such as magic. Where science is credible, authoritative and full of meaning because it deals in facts, magic is *incredible*, easily dismissed and meaningless because it doesn't. Good science fiction will draw on the attributes of science to lend realism and authenticity to its stories; bad science fiction will wallow in the meaninglessness of magic.

Many popularisations of physics also work hard to define the 'other' of religion. Boundary work at the science/religion boundary either highlights the ways in which religion is different from (and, for these authors, inferior to) science, or it challenges the assumed separation between science and religion by finding common ground between the two territories. But in both approaches religion is redefined on scientists' terms.

For those who reinforce the separation between religion and science, religion is presented as irrational and opposed to science. Krauss, for instance, makes repeated digressions to highlight the anti-science leaning of the Christian Churches, with references to Galileo's trial, Bruno's burning, and the 'fanciful myths' of contemporary fundamentalists and Creationists against whom he offers 'ammunition' (Krauss, 1997: 11, 75). Similarly, Pratchett et al. dismiss the religious scholarship of the Middle Ages as: 'copying out bits of the Bible by hand in as laborious and colourful manner as possible' (Pratchett et al., 1999: 62). More aggressively, White claims that: '... the acceptance of immortal spirits, anthropocentric gods or concerned aliens is simply illogical and based entirely upon an exaggerated sense of self-importance' (White, 1996: 184).

On the one hand, for these authors the boundary drawn around religion shrinks as science advances. For instance, Krauss suggests that: 'once we understand the physiological basis of consciousness the theological realm of the soul will retreat, to avoid conflict with experiment' (Krauss, 1997: 137). But on the other hand, the boundary around religion is expanded to include all that is deemed irrational. Ufology, magic, mysticism, astrology, established religion – all are as one to these authors, all clumped together opposed to the ways of science. Condemning religion by association with the worst excesses of ufologists, White asserts that: 'the beliefs of some UFO enthusiasts differ little from the egocentric fallacies of any other organized religion' (White, 1996: 20). Similarly, Pratchett et al. compare religious opposition to science in the past with contemporary challenges:

Some of their [the priestly class's] descendants are still trying to stamp it out, even today . . . it's still not popular with postmodernists, creationists, tabloid astrologers and others who prefer the answers you can make up for yourself at home. (Pratchett et al., 1999: 31)

The exact identity of these modern-day threats varies from author to author, but taken together these books establish religion as coterminous with magic, astrology, New Ageism, postmodernism and pseudoscience: all are equally distant from science.

Although less dismissive of religion, those who take a more conciliatory approach to the science/religion boundary also seek to define religion on their own terms. By claiming transcendent phenomena for physics, popularisers with Goswami's sensibilities use the 'New Physics' to redefine God as depersonalised, non-interventionist and emasculated, and to strip religion of its social institutions, cultural symbolism and moral authority.³⁹ What at first sight seems to be a more conciliatory approach to the demarcation between science and religion, therefore has the same effect as the attempts to maintain the distance between them – the transcendent phenomena of religion are claimed for physics and both physics and religion are redefined in the process.

In both approaches to the science/religion boundary, the boundary work is further aided by calling on the past successes of science. Indeed, boundary work across a temporal dimension is an important part of the work popularisations do in establishing the authority of science. It is the weight of history that distinguishes science from religion and allows science to take on the attributes of the mystical without losing its claim on the rational. Thus Goswami supports his appropriation of the spiritual for science by an appeal to the triumph of Newtonianism over superstition:

Before Newton's laws of gravity, human beings were earthlings, separated from the cosmos by superstitious beliefs they themselves invented. After Newton's laws, the human spirit could fly with no bounds, knowing that the universe had to reckon with it. (Goswami, 1983: 31)

History here acts as an anchor. By anchoring science in its rational past, contemporary science can nurture the free-floating spirit. Without such an anchor, we're just left with the nonsense of superstition. Failure to attend to the weight of its history leads to a failure to recognise what is special about science. As White explains:

To be accepted, even the most unorthodox scientific hypotheses have to be supported by rigorous mathematics and must be consistent with a body of scientific knowledge stretching back to the seventeenth century. . . .

To the enthusiast of the paranormal, science at the limit can sometimes seem as esoteric and other-worldly as their own ideas. The difference lies in approach: science is based upon mathematical integrity and where possible, experimental verification – no theory is accepted until proven by experiment. (White, 1996: 102)

So the boundary that has successfully been constructed between science and religious 'superstition' through history is now deployed to demarcate the contemporary superstitions of pseudoscience from real science.

Technologising the future

The use of the past as a handle on the present is widespread in popular physics books. Nearly all expository popularisations include references to the past, offering roll calls of the 'great and the good' of physics as if they were ancestral lineages.⁴⁰ By revealing how modern physics is 'standing on the shoulders of giants',⁴¹ popularisations defend the social status of physics in the same way that members of an aristocratic family might defend their social status through a recitation of their ancestry. The telling of the history of the subject therefore plays a role in the routine boundary work enacted within popularisations.

In the books studied here, the past is also used to open the door on the future. Gliding down a temporal slide, these authors use the momentum of the past to project them into the future. 'I am convinced,' states Krauss, 'that the physics of today and tomorrow will as surely determine the character of our future as the physics of Newton and Galileo colors our present existence' (Krauss, 1995: 174). This slide from past to future is accomplished through the appropriation of technology. Implicitly assuming a technological-determinist position, these authors attribute 'such revolutionary achievements as nuclear energy, transistors, and computers' to physics – 'the womb from which this technological era sprang' (Goswami, 1983: 58).⁴² But if physics gives birth to technology, technology in turn helps support physics by making tangible its past successes and rendering unnecessary other ways of knowing:

... science became so overwhelmingly successful that, to many, the supernatural became almost superfluous. Nuclear physics, brain surgery and the advancement of space travel can be as exciting as hunting ghosts or trying to prove the existence of alien civilisations, and at the same time they are tangible with commercial and academic application. (White, 1996: viii)

The success of physics is thus confirmed when physics-then can be seen as technology-now. And likewise, the *future* success of physics is established if physics-now is presented as technology-tomorrow.

Technology-tomorrow is the fare of much science fiction and so once again science fiction offers the vehicle through which physics can stake its claims. Science fiction's technologising is able to make concrete the abstract concepts of physics. Just as science fiction gave solid cultural form to submarines and communication satellites before they achieved material solidity, so too wormholes, time machines or hyperspace are able to attain a reification that the abstractions of physics could, alone, never endow. By presenting wormholes as tunnels to other universes instead of (or rather, as well as) solutions to Einstein's

equations, the wormhole's geometric walls become as concrete as those of any other tunnel.⁴³ Even concepts such as anti-particles or neutron stars, already reified through a thorough embedding within theoretical texts and observational practices, benefit from this technologisation. Anti-particles cease to be mere resonances observed in publicly inaccessible particle colliders, but acquire a public life as the material for antimatter drives.

Even though these popularisers need science-fiction technologies to give form to their physics, they are careful not to place physics in a dependent position. Physics can maintain a higher status position because the science-fiction technology is itself shaped by the physics. Indeed, as we have seen, all these books devote much attention to instances where science-fiction writers draw on 'real' physics. Rather than a circle of mutual dependency, we have instead physics as both a beginning and an end point.

It is important in this that it is the physics, not the technology, that is 'real'. Real technology – the dirty nuts-and-bolts artefacts of the everyday world – is immersed in problems from which physics must be distanced. As Krauss notes: 'every new technology has bad as well as good sides' (Krauss, 1995: 101). The significance of technology is not, then, in its actual material manifestation. Rather, it is in its denotation of time-passing. The 'bad' side of technology can be negotiated if technology is valued not for the nature of the change it affects but for the change *per se*. For change is the indicator of the passage of time; change is evolution, progress. So, Krauss continues, technology, whether good or bad, will:

... force adjustments in our behaviour. ... I believe technology has on the whole made our lives better rather than worse. The challenge of adjusting to it is just one part of the challenge of being part of an evolving human society. (Krauss, 1995: 101)

The negative connotations of technology are therefore avoided if technology is denoted as a measure of time.

The future-sightedness of science fiction enables technology to form a continuous line stretching from past to future. The technology of the future, a *part* of the future, then becomes, through a synecdochal elision, the thing in itself: technology *is* the future. By claiming technology for physics, these books therefore also claim the future for physics. And in another synecdochal manoeuvre that works the other way, claiming *the* future for physics works to ensure that physics has *a* future.⁴⁴

From this it is clear that boundary work has a temporal dimension. The cartographic metaphors deployed by Gieryn (1999) to analyse examples of controversy-situated boundary work, useful as they are, have their limitations. Gieryn used map-making as an analytical metaphor for studying how scientists in a controversy dispute the boundaries of territories in cultural space. But cartographic metaphors fail to reveal if boundary work also makes claims across time. Whilst we can remember that geographical maps change over time, and that different people use different maps at different times, time is not explicitly

represented within such maps. Thus, in Gieryn's studies, the temporal *contingency* of the boundary work is apparent, but not its temporal *content*. In the routine boundary work examined here, the boundaries are drawn through time as well as around the cultural spaces of the moment. Popularisations reinforce the authority of physics by recounting origins stories of scientist-ancestors and they use both the past successes of physics and the cultural presence of futuristic technologies to claim a future for physics. This is certainly a form of boundary work, but it is more like drawing a family tree than drawing a geographical map. A family tree at once establishes the authenticity of the family and enfoldes the assumption that the tree will continue to spread out in the future as it has in the past. In other words, family trees consolidate family identity and authority by referring to both past and future. In the same way, the temporal dimension of routine boundary work in popular physics books consolidates the demarcation of physics from other ways of knowing, maintains its authority, and stakes a claim on the future.

Conclusion

Individual authors may have many reasons for wanting to write popular science. They may be research scientists with a genuine desire to explain their science to non-scientists, or they may have very little direct experience of science and be motivated solely by the need to make some money. But such issues are largely invisible to the readers of popular science. What public audiences are faced with are the books themselves (should they actually read them) and the web of other media texts nucleated around the books. It is therefore to the texts and their intertextuality that we must look to find the meaning of popularisations of science.

In terms of genre expectations, the form of popularisation most closely identified with both science and scientists is the expository book. Expository popular science books provide a non-controversial forum in which public images of science are constructed and maintained. Drawing on the pedagogic orientation of the PUS movement, such books appear to challenge the boundaries demarcating science from other cultural activities by giving their readers an opportunity to learn more about science. They claim to explain science in clear, 'accessible' terms whilst at the same time making it culturally relevant and widely available. Yet such a manoeuvre is predicated on the assumption that 'real' science – the unmediated science that popularisers claim to re-present – is isolated from, and inaccessible to, public audiences. The rhetoric of accessibility, and of the PUS movement more generally, serves to cover over the ways in which popular science texts promote the interests of scientists by reinforcing their epistemic authority.

The set of texts discussed in this article, like many other popularisations, explicitly concern the boundary between science and fiction. However, they also make repeated references to other ways of knowing. A

complex picture thus emerges of engagement at multiple boundaries. For instance, working at both the science/fiction and science/technology boundaries enables the past successes and cultural solidity of technology to be claimed for physics even whilst the negative connotations of modern technologies are rejected. Similarly, comparing 'bad' science fiction to 'meaningless' magic enables magic to be denigrated even as physics itself is claimed as magical. Through this multiple boundary work science is constructed as mysterious, imaginative and intellectual – a transcendental means to 'truth' – at the same time as it is presented as factual, practical and a part of everyday culture.

The routine nature of the boundary work further enables potential inconsistencies to be managed by avoiding the dichotomising tendencies of news-situated controversies of science. Rather than needing to fix a boundary and take up position on one side, popularisers engaged in routine boundary work can treat boundaries flexibly even within a single text. Thus boundaries can be breached even as they are reinforced. The exposition of science through science fiction breaches the science/fiction boundary and finds common ground in the role of the imagination; yet at the same time, the positioning of science beside science fiction highlights the factual paucity of the latter and so reinforces the boundary between the two. Similarly, popularisations which find common ground between science and religion appropriate features of religious thought for science and in so doing leave religion a diminished realm, just as do those popularisations which explicitly reinforce the science/religion boundary.

Although the popularisations studied here accomplish much of their boundary work through science fiction, their engagement at other boundaries means that they have much in common with other popularisations of physics. Woven among the expositions and explanations of most popularisations are references to other ways of knowing, especially religion, which define the 'other' against which science should be compared. When Stephen Hawking concludes *A Brief History of Time* by claiming that a unified theory of physics will lead us to 'know the mind of God', he appropriates God for physics and claims a universal and future role for science (Hawking, 1988: 193). The voice of the theologian or religious devotee is silenced as the voice of the physicist is promoted.

Claiming a future role for science is as much a part of the boundary work of popular physics books as is demarcating science from the other cultural spaces of the moment. Cartographic metaphors for boundary work are therefore limited and need to be complemented by alternative analytical metaphors. In this respect, popular science books are like family trees, tracing out the ancestors of the family of science in order to establish both its social status and its extended presence over time. Like the ever-increasing spread of the family tree, the temporal boundary work of popular physics books projects forwards into a future of continued growth, status and authority.

Expository popularisations of physics can be seen as examples of routine boundary work embedded in an intertextual web spanning the mass media. Rather than part of any debate about science, they are celebrations of science. The boundary work they produce is highly complex and by working a number of

boundaries in a non-controversial context, authors are able to claim for physics potentially contradictory features. A major accomplishment of this boundary work is to present physics as imaginative, future-oriented and integrated within the wider culture even whilst the public inaccessibility of physics is reinforced. In so doing, popular physics books maintain and augment the social status and epistemic authority of physics and claim for the subject both a past and a future of continued success.

Notes

An earlier version of this paper was presented at the *Demarcations Socialised Conference* in Cardiff, September 2000.

¹ Science Media Centre, <http://www.sciencemediacentre.org>.

² Among the few analyses which do include discussions of popular science books as popularisations are Gregory (1998), Nieman (2000), Turney (1999), Turney (2001), Yoxen (1985) and some of the contributions in McRae (1993).

³ Aventis Prizes for Science Books, http://www.aventissciencebookprizes.com/home_welcome.htm.

⁴ For a discussion of the book's role in initiating the popular science boom see Rodgers (1992), Turney (1999), and Gribbin (1998).

⁵ By 2002, the publishers reported nine million copies in print worldwide. Bantam Press, <http://www.randomhouse.com/bantamdell>.

⁶ Turney identifies four categories of popular science book: autobiography; how to/self-help/information books; dictionaries and primers for scientific literacy; and intellectual entertainment (Turney, 1999). I am limiting my discussion to Turney's categories of autobiography and intellectual entertainment. Turney's categories are based on a mix of audience-orientation (the last three categories) and authorial presence (the autobiographical category). My typology also enfold an element of audience-orientation in terms of the different implied reader responses of each mode. By this I mean that the narrativ mode constructs a preferred reader response of pleasure and entertainment (enjoying the story); the expository mode constructs a preferred reader response of learning and enlightenment; and the investigative mode constructs a preferred reader response of political action or concern. Needless to say, actual readers may respond in a wide variety of ways. A typology based solely on the structure of the text would probably consist of the narrativ and the expository modes only.

⁷ Most commentaries on science fiction begin with a note about how difficult it is to define. For the purposes of this paper, I take SF at its widest to include fantasy writing (such as the *Discworld* series by Terry Pratchett) and stories about the paranormal (such as *The X-files* TV series). However, although the popularisations studied here refer to texts such as these, they typically engage with the texts within the framework of the far more narrowly-defined sub-genre of 'hard SF'. For an overview of the genre, see Clute & Nicholls (1993) and Slusser & Rabkin (1986).

⁸ Since the publication of this book, Amit Goswami has gone on to write a number of other popular physics books connecting science, creativity and mysticism via quantum mechanics.

⁹ For instance, a discussion about how an arrow fired on a windy day will be blown sideways proceeds thus: 'To combine the velocity vector of the arrow with that of the wind, represent each vector by an arrow of proportionate length with the arrowhead pointed in the appropriate direction, drawing them foot to foot (Figure 2a). The resultant

vector, the sum of the two, is given by the long diagonal of the completed parallelogram as shown. The length of the diagonal gives the magnitude of the resultant velocity, and the angle it makes with any of the sides gives the direction' (Goswami, 1983: 15).

¹⁰ Physicist readers will be able to spot the tenuous nature of this close relationship by the several inaccuracies and confusions in his discussions of physical principles.

¹¹ *Daily Telegraph* bestseller lists, June to August 1999 and May to July 2000, compiled from data collected by Whittaker Booktrack and Bookwatch. The book also became the number two top science seller after *Longitude* for the first six months of 2000 (Editorial, 2000).

¹² Popular books focussed on biology and science fiction include: *To Seek Out New Life: the Biology of Star Trek* (Andreadis, 1998); *The Science of the X-files* (Cavelos, 1998); *The Science of Jurassic Park and the Lost World or, How to Build a Dinosaur* (DeSalle & Lindley, 1997); *Life Signs* (Jenkins & Jenkins, 1998); *Star Trek on the Brain* (Sekuler & Blake, 1998); and *The Real Science Behind the X-files* (Simon, 1999). Other books look at science and science fiction but are more marginal to the popular science genre. For instance, a series by the children's publisher Puffin claims to look at the 'truth' behind science fiction and includes two books by one of the authors studied here (White et al., 1999; White & Anderson, 1999). Similarly, a textbook by three US professors of physics, biology and English uses science fiction to present science to non-science majors (Dubeck et al., 1994).

¹³ The relationship between science and films like *Armageddon* has been discussed by Kirby (2003).

¹⁴ Recent examples of the use of science-fiction tropes in technical papers published in prestigious physics journals include: K.D. Olum, 'Ori-Soen Time Machine', *Phys. Rev. D*, Vol. 61 (2000) 124022; N. G. de Almeida, R. Napolitano and M. H. Y. Moussa, 'Accuracy of a teleported cavity-filed state', *Phys. Rev. A*, Vol. 62 (2000) 010101; D. Birmingham and S. Sen, 'Gott time machines, BTZ black hole formation and Choptuik scaling', *Phys. Rev. Lett.*, Vol. 84 (2000) 1074-1077.

¹⁵ In the UK there is even a whole undergraduate degree taking this approach: the BSc in 'Science and Science Fiction' at the University of Glamorgan.

¹⁶ For example, recent courses at the University of California Riverside, the University of Maryland, and Penn State University.

¹⁷ Similarly, in a newspaper interview Ian Stewart claims that *The Science of Discworld* has made science 'accessible to an audience with an awful lot of teenage kids in' (Midgley, 1999).

¹⁸ For instance, the prolific science populariser John Gribbin refers to *Brief History* as 'a notoriously difficult read for anyone without a degree in physics' (Gribbin, 1998). Michael White reports similar views on the 'puzzle' of Hawking's success (White, 1998).

¹⁹ Of the broadsheets, the *Daily Telegraph*, the *Sunday Telegraph* and the *Sunday Times* each carried one review and the *Guardian* carried separate reviews of both the hardback and paperback editions (Sandage, 1996; Berry, 1996; Edwards, 1996; Korn, 1996; Lezard, 1997). *New Scientist* also reviewed both the hardback and paperback editions (Editorial, 1996a; Editorial, 1997). When the book was first published in the US, the foreword by Stephen Hawking precipitated a flurry of news coverage even in UK newspapers. The story – about how Hawking now believed time travel was possible – first broke on the front page of the *Sunday Times* and three of the four UK daily broadsheets took up the story the following day (Leake & Syal, 1995; Wilkie, 1995; Baxter, 1995; Nutall, 1995; Highfield, 1995). When the book was finally published in the UK some months later, it became the focus of a long feature article in the *Independent* (Rodgers, 1996) and Krauss himself wrote a feature for the *Daily Telegraph* (Krauss, 1996a).

²⁰ TV appearances in the UK included *Science: the Final Frontier* (BBC2, 26 August 1996) and *The Sci-Files* (Channel 4, 30 May 1998). An example of web coverage was the online version of *New Scientist* which set up a

website devoted to the 'Physics of Star Trek' including an interview with Krauss and a forum for readers to ask questions direct to Krauss. 'Insight', *nsplus: New Scientist online*; now archived at <http://online.bc.cc.ca.us/sea/eng2>.

²¹ *Universe*, Channel 4, 15 November 1999.

²² *The Science of Discworld* is clearly positioned within a wider web, in this case drawing on the prolific and extremely popular fiction writings of Terry Pratchett as well as on Ian Stewart's numerous popular science books. Pratchett is reportedly the third bestselling author of all hardback fiction, and data from Whittaker Booktrack show that of the 44 books that remained in the top 5000 bestsellers every week over a 300 week period, 12 were by Terry Pratchett (Turner, 1999; MacArthur & Young, 2001). But as with *The Physics of Star Trek*, the publication of *The Science of Discworld* itself led to the publication of further texts including a commentary in *Nature* by Jack Cohen and Ian Stewart (2001). Likewise, Michael White's writings and media appearances, taken collectively, provide a wider textual context for *The Science of the X-Files*.

²³ For an introduction to the use of the term 'implied author' in literary theory, see Abbott (2002).

²⁴ This is not to imply that the popular success of such books is insignificant. Indeed, for the boundary work discussed here to have any meaning, it must succeed in addressing its audience. But it is the boundary work itself – the textual construction of science – rather than authorial motivations or the commercial success of these books, which is the focus of this paper.

²⁵ For an overview of studies of downstream texts, see Lewenstein (1995b). Lewenstein also notes the overlap with controversy studies.

²⁶ For a discussion of news values, see Keeble (1994). See also Dearing (1995).

²⁷ In an earlier paper by Gieryn (1983), most of his examples of demarcation 'routinely accomplished in practical, everyday settings' also focus on decision-making episodes, and his introduction to boundary-work analyses in the *Handbook of Science and Technology Studies* (Gieryn, 1995) is placed under the section on 'Science, Technology and Controversy'.

²⁸ In a content analysis of the coverage of science and technology in British newspapers, Bauer et al. (1995) found that only about a quarter of all articles dealt with controversies.

²⁹ For instance, the books studied here make, at most, only passing references to controversies and have not themselves become situated in any controversy. The closest they came to controversy was when one of the news reports following the US publication of *The Physics of Star Trek* claimed that 'Astronomers are concerned that the public is getting Star Trek-style science fiction dressed up as science fact' (Wilkie, 1995). However, other news reports did not adopt this angle and there was no wider debate about the merits or otherwise of using science fiction to popularise science. Although the distinction between debate-led episodes and less focussed public interventions is useful, I don't wish to imply that it is clear-cut. The difference is rather one of emphasis and explicitness.

³⁰ Likewise, Pratchett et al. claim that: 'Because a lot of science is really about this non-existent world of thought experiments, our understanding of science *must* concern itself with worlds of the imagination as well as with worlds of reality' (Pratchett et al., 1999: 12, italics in original).

³¹ Elsewhere, he is even more explicit: '... while it is an unfortunate modern misconception that science is somehow divorced from culture, it is, in fact, a vital part of what makes up our civilization. ... it is a pity that [scientific discoveries] are not shared among as broad an audience as enjoys the inspirations of great literature, or painting, or music' (Krauss, 1997: 174).

³² Technical papers also refer to negative energy states as 'exotic'. Pratchett et al. are here less comfortable with the wedge between common sense and science than many authors. For them: 'Science and common sense are related, but indirectly' since science is 'common sense *applied to evidence*' (Pratchett et al., 1999: 76, 77, italics in original). Yet

despite their more careful definition, for these as for other popularisers, the relationship of science to common sense is a key issue in defining what makes science special.

³³ Imagining the impossible is a recurring motif in these books. For example, Goswami refers to the Queen of Hearts imagining 'six impossible things before breakfast' (Goswami, 1983: 92).

³⁴ Jurdant has also argued that the defining feature of popular science is its truth claims (Jurdant, 1993).

³⁵ As Krauss notes: 'Modern science holds the key to knowing what is possible and what isn't' (Krauss, 1997: xii).

³⁶ Physicist-populariser Paul Davies (1983, 1992) also finds a spiritual meaning in the physics-reality.

³⁷ 'Science fiction is that class of fiction which contains the currents of change in science and society. It concerns itself with the critique, extension, revision and conspiracy of revolution, all directed against static scientific paradigms. Its goal is to prompt a paradigm shift to a new view that will be more responsive and true to nature' (Goswami, 1983: 2).

³⁸ See Gregory (1998) for a discussion of Fred Hoyle's writing as controversy-situated boundary work.

³⁹ See Hesse (1994) for a discussion of the ways in which physicists attempt to redefine the notion of God.

⁴⁰ Hawking's *Brief History* goes so far as to include appendices with brief biographies of Einstein, Galileo and Newton (Hawking, 1988: 195-200).

⁴¹ Newton's famous remark is often quoted in popular physics texts and was even used as the title of a recent book: *Giant's Shoulders* (Bragg, 1998). Robert K. Merton also used the phrase in a book title: *On the Shoulder's of Giants: A Shandian Postscript* (1965).

⁴² Pratchett et al. have less of a focus on technology than the other authors studied here, although they do use the SF technology of the space elevator as a metaphor throughout their book. They also use the black boxing of technology to argue for the common perception of science as magic and in so doing they conflate science and technology.

⁴³ It is worth noting that the traffic through this metaphorical tunnel travels both ways; wormholes as hyperspace tunnels are discussed within technical texts as well as popular texts and science fiction.

⁴⁴ Turney (2000) has argued that the histories told by scientists in the journal *Science* are also claims on the future.

References

- Abbott, H. Porter (2002) *The Cambridge Introduction to Narrative* (Cambridge: Cambridge University Press).
- Andreadis, Athena (1998) *To Seek Out New Life: the Biology of Star Trek* (New York: Crown Publications).
- Bauer, Martin, John Durant, Asdis Ragnarsdottir & Annadis Rudolfsdottir (1995) *Science and Technology in the British Press 1946-1990: Volume 1* (London: Science Museum).
- Baxter, Stephen (1995) 'To the Future at Warp Speed! Could Time Travel Come True?', *Independent* (2 October 1995): 17.
- Berry, Adrian (1996) 'Beam Me Up, Trekkies – It's Bad News', *Sunday Telegraph* (7 January 1996).
- Bodmer, Walter (1985) *The Public Understanding of Science* (London: Royal Society).
- Bragg, Melvyn (1998) *Giant's Shoulders* (London: Hodder and Stoughton, 1998).
- Brooks, Michael (1999) 'Farewell to the Universe', *Guardian* (18 March 1999) Online: 8-9.

- Carson, Rachel (1963) *Silent Spring* (London: Hamish Hamilton).
- Cavelos, Jeanne (1998) *The Science of the X-files* (New York: Berkeley Publishing Group).
- Clute, John & Peter Nicholls (1993) *The Encyclopaedia of Science Fiction* (London: Orbit).
- Cohen, Jack & Ian Stewart (2001) 'Where are the Dolphins?', *Nature* 409 (22 February 2001): 1119-1122.
- Connor, Steve (2000) 'Beam Me Up My Cup of Coffee, Scotty', *Independent* (20 April 2000): 7.
- Davies, Paul (1983) *God and the New Physics* (Harmondsworth: Penguin).
- Davies, Paul (1992) *The Mind of God* (Harmondsworth: Penguin).
- Davies, Paul (1995) *About Time: Einstein's Unfinished Revolution* (Harmondsworth: Penguin Books).
- Davies, Paul (2002) *How to Build a Time Machine* (Harmondsworth: Penguin).
- Dearing, James W. (1995) 'Newspaper Coverage of Maverick Science: Creating Controversy through Balancing', *Public Understanding of Science* 4: 341-361.
- DeSalle, Rob & David Lindley (1997) *The Science of Jurassic Park and the Lost World or, How to Build a Dinosaur* (London: HarperCollins).
- Dubeck, Leroy W., Suzanne E. Moshier & Judith E. Boss (1994) *Fantastic Voyages: Learning Science through Science Fiction Films* (New York: AIP Press).
- Editorial (1996a) 'Physics for Trekkies', *New Scientist*, 149 (10 February 1996): 41.
- Editorial (1996b) 'Bestsellers List', *New York Times* (16 June 1996) Section 7: 46.
- Editorial (1996c) 'Notable Books of the Year', *New York Times* (8 December 1996) Section 7: 76.
- Editorial (1997) 'Trekkie Heaven', *New Scientist* 154 (7 June 1997): 44.
- Editorial (2000) 'Top Five: Science', *Sunday Times* (2 July 2000) Culture: 35
- Edwards, Mark (1996) 'Nothing's Impossible', *Sunday Times* (26 May 1996) Books: 3.
- Gieryn, Thomas F. (1983) 'Boundary-work and the Demarcation of Science from Non-science: Strains and Interests in Professional Ideologies of Scientists', *American Sociological Review* 48: 781-795.
- Gieryn, Thomas F. (1995) 'Boundaries of Science', in S. Jasanoff, G. Markle, J. Petersen & T. Pinch (eds.) *Handbook of Science and Technology Studies* (London: Sage): 393-443.
- Gieryn, Thomas F. (1999) *Cultural Boundaries of Science: Credibility on the Line* (Chicago: University of Chicago Press).
- Goswami, Amit with Maggie Goswami (1983) *The Cosmic Dancers* (New York: Harper & Row).
- Gott, Richard (2001) *Time Travel in Einstein's Universe* (London: Wiedenfeld and Nicholson).
- Gregory, Jane (1998) *Fred Hoyle and the Popularisation of Cosmology*, PhD thesis, Imperial College, London.
- Gribbin, John (1993) *In Search of the Edge of Time* (London: Black Swan).
- Gribbin, John (1998) 'Time for the Earth', *Independent* (20 June 1998): 10-11.
- Hawking, Stephen (1988) *A Brief History of Time* (London: Bantam Press).
- Hawking, Stephen (1995) 'Foreword', in L. Krauss *The Physics of Star Trek* (New York: Basic Books): xi-xiii.
- Hesse, Mary B. (1994) 'Sources of Models for God', in J. Hilgevoord (ed.) *Physics and Our View of the World* (Cambridge: Cambridge University Press): 239-254.

- Highfield, Roger (1995) 'It's Time to Think Again: Professor Stephen Hawking has said he now Believes that Time Travel may be Possible', *Daily Telegraph* (2 October 1995).
- Highfield, Roger (1998) 'Santa Clauss: it Could be True', *Daily Telegraph* (7 November 1998): W1.
- Hilgartner, Stephen (1990) 'The Dominant View of Popularization: Conceptual Problems, Political Uses', *Social Studies of Science* 20: 519-539.
- Hilgevoord, Jan (ed.) (1994) *Physics and Our View of the World* (Cambridge: Cambridge University Press).
- Jasanoff, Sheila, Gerald E. Markle, James C. Petersen & Trevor Pinch (eds.) (1995) *Handbook of Science and Technology Studies* (London: Sage).
- Jenkins, Robert & Susan Jenkins (1998) *Life Signs* (London: HarperCollins).
- Jurdant, Bauduin (1993) 'Popularization of Science as the Autobiography of Science', *Public Understanding of Science* 2: 365-373.
- Keeble, Richard (1994) *The Newspaper Handbook* (London: Routledge).
- Kirby, David (2003) 'Science Consultants, Fictional Films and Scientific Practice' *Social Studies of Science* 33(2).
- Korn, Eric (1996) 'Boldly Going Wrong', *Guardian* (24 May 1996) Books: 9.
- Krauss, Lawrence M. (1989) *The Fifth Essence: The Search for Dark Matter* (New York: Basic Books).
- Krauss, Lawrence M. (1994) *Fear of Physics: A Guide for the Perplexed* (New York: Basic Books).
- Krauss, Lawrence M. (1995) *The Physics of Star Trek* (New York: Basic Books).
- Krauss, Lawrence (1996a) 'Will We Boldly go on the Same Treks?', *Daily Telegraph* (21 August 1996).
- Krauss, Lawrence (1996b) 'Confusing Fact with Fiction', *New Scientist*, 152 (16 November 1996): 52.
- Krauss, Lawrence M. (1997) *Beyond Star Trek* (New York: Basic Books).
- Krauss, Lawrence M. (2001a) *Quintessence* (New York: Basic Books)
- Krauss, Lawrence M. (2001b) *Atom* (Boston: Little Brown).
- Leake, Jonathan & Rajeev Syal (1995) 'Hawking: We'll be Able to Travel Back in Time', *Sunday Times* (1 October 1995): 1.
- Lewenstein, Bruce V. (1995a) 'From Fax to Facts: Communication in the Cold Fusion Saga', *Social Studies of Science* 25: 403-436.
- Lewenstein, Bruce V. (1995b) 'Science and the Media', in S. Jasanoff, G. Markle, J. Petersen & T. Pinch (eds.) *Handbook of Science and Technology Studies* (London: Sage): 343-360.
- Lezard, Nicholas (1997) 'Paperbacks: Pick of the Week', *Guardian* (3 April 1997) Books: 15
- MacArthur, Brian & Robin Young (2001) 'True Bestsellers Show They Ttand the Test of Time', *Times* (6 September 2001): 9.
- Marks, Paul (1996) 'That was 1996', *Guardian* (5 December 1996) Online: 18.
- McRae, Murdo William (ed.) (1993) *The Literature of Science: Perspectives on Popular Scientific Writing* (Athens: University of Georgia Press).
- Merton, Robert K. (1965) *On the Shoulders of Giants: a Shandian Postscript* (New York: Harcourt Brace).
- Midgley, Simon (1999) 'Parallel Worlds', *Guardian* (22 June 1999) Education: 2.

- Nahin, Paul J. (1993) *Time Machines: Time Travel in Physics, Metaphysics, and Science Fiction* (New York: Springer-Verlag).
- Nieman, Adam (2000) *The Popularisation of Physics: Boundaries of Authority and the Visual Culture of Science*, PhD thesis, University of the West of England.
- Nutall, Nick (1995) 'Time Travel Might be Real, says Hawking', *Times* (2 October 1995): 3.
- Parsons, Paul (1997) 'Wormholes for Warped Minds', *Guardian* (11 December 1997) Online: 12.
- Pickover, Clifford A. (1998) *Time: A Traveller's Guide* (Oxford: Oxford University Press).
- Pratchett, Terry, Ian Stewart & Jack Cohen (1999) *The Science of Discworld* (London: Ebury Press).
- Rodgers, Michael (1992) 'The Hawking Phenomenon', *Public Understanding of Science* 1: 231-234.
- Rodgers, Paul (1996) 'It's Illogical, Captain', *Independent* (12 May 1996): 45-45.
- Rufford, Nicholas (2000) 'Beware: The Next Giant Bsteroid Belt is Overdue', *Sunday Times* (23 July 2000): 10.
- Sandage, Tom (1996) 'Not as We Know It', *Daily Telegraph* (14 May 1996).
- Scanlon, Eileen, Elizabeth Whitelegg & Simeon Yates (eds.) (1999) *Communicating Science: Contexts and Channels* (London: Routledge).
- Sekuler, Robert & Randolph Blake (1998) *Star Trek on the Brain* (New York: W.H. Freeman).
- Shinn, Terry & Richard Whitley (eds.) (1985) *Expository Science: Forms and Functions of Popularisation* (Dordrecht: D. Reidel).
- Simon, Anne (1999) *The Real Science Behind the X-files* (New York: Simon and Schuster).
- Slusser, George E. & Eric S. Rabkin (1986) *Hard Science Fiction* (Carbondale: Southern Illinois University Press).
- Sobel, Dava (1996) *Longitude* (London: Fourth Estate).
- Thorne, Kip S. (1994) *Black Holes and Time Warps: Einstein's Outrageous Legacy* (London: Picador).
- Turner, Barry (1999) 'Counting the Big Book Events', *Times* (28 May 1999): 45.
- Turney, Jon (1999) 'The Word and the World: Engaging with Science in Print', in E. Scanlon, E. Whitelegg & S. Yates (eds.) *Communicating Science: Contexts and Channels* (London: Routledge): 120-133.
- Turney, Jon (2000) 'History as Told by Scientists in the Magazines they Read', paper presented at BSHS conference on *Science Communication, Education and the History of Science* (London, June 2000).
- Turney, Jon (2001) 'Telling the Facts of Life: Cosmology and the Epic of Evolution', *Science as Culture* 10: 225-247.
- Wersky, Gary (1988) *The Visible College* (London: Free Association Books).
- White, Michael (1996) *The Science of the X-files: the Truth* (London: Legend Books).
- White, Michael (1998) 'A Brief History of Triumph', *Daily Telegraph* (23 May 1998): A4.
- White, Michael & Jeff Anderson (1999) *Sci-Fi Explained: Mind and Matter* (London: Puffin).
- White, Michael, Jeff Anderson & Chris Moore (1999) *Sci-Fi Explained: Alien Life Forms* (London: Puffin).
- Wilkie, Tom (1995) 'Astronomers Say Time Travel is Just Science Fiction', *Independent* (2 October 1995): 2.

Yoxen, Edward (1985) 'Speaking Out About Competition: An Essay on 'The Double Helix' as Popularisation', in T. Shinn & R. Whitley (eds.) *Expository Science: Forms and Functions of Popularisation* (Dordrecht: D. Reidel): 163-181.

Felicity Mellor is a Lecturer in Science Communication at Imperial College London. Her research interests include the popularisation of physics, the representation of science in the media, and the role of narrative within science.

Address: Humanities Programme, Imperial College, London SW7 2AZ, U.K. Fax: +44 (0)20 7594 8763; e-mail: f.mellor@imperial.ac.uk