



Mythopoeic Society

mythLORE

A Journal of J.R.R. Tolkien, C.S. Lewis,  
Charles Williams, and Mythopoeic Literature

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Volume 21  
Number 2

Article 48

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Winter 10-15-1996

## A Physics of Middle-earth

Jenny Coombs

Marc Read

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### Recommended Citation

Coombs, Jenny and Read, Marc (1996) "A Physics of Middle-earth," *Mythlore: A Journal of J.R.R. Tolkien, C.S. Lewis, Charles Williams, and Mythopoeic Literature*: Vol. 21: No. 2, Article 48.

Available at: <https://dc.swosu.edu/mythlore/vol21/iss2/48>

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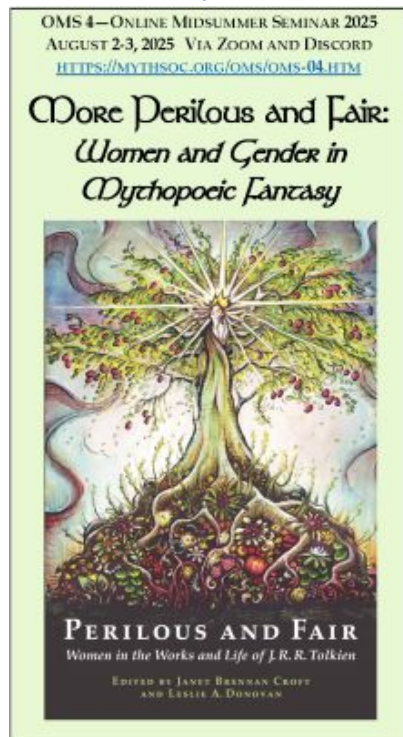
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## A Physics of Middle-earth

### Abstract

This paper takes a light-hearted look at how far one can go in applying primary world science to Middle-earth. Tolkien purists and physics purists may wish to pass over this!

### Additional Keywords

foresight; genetics; palantíri; physics; sight; swords; technology

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# A Physics of Middle-earth

Jenny Coombs and Marc Read (delivered by Marc Read)

**Abstract:** This paper takes a light-hearted look at how far one can go in applying primary world science to Middle-earth. Tolkien purists and physics purists may wish to pass over this!

**Keywords:** foresight, genetics, palantíri, physics, sight, swords, technology

Tolkien wrote in Letter 210 that “I dislike . . . any pull towards ‘scientification’ . . . No analysis in any laboratory would discover chemical properties of *lembas* that made it superior to other cakes of wheat-meal.” However, he also wrote, in Letter 131, that his works should “leave scope for other minds and hands, wielding paint and music and drama.” Yes; and why not science?

There seem to be at least two ways of going about a scientific analysis of the various features that make Middle-earth different from the world that we inhabit today. We can attempt to explain away magic by showing how the seemingly magical effects could, in fact, be produced by the operation of the physical laws that we all know and love. This is the approach which is favoured by my co-author. The other way is merely to provide new scientific laws to govern Middle-earth: and if these clash with the ones that we use, well, so much for the idea that Middle-earth and our world are one and the same. Perhaps there is a middle way, and this is the one that I prefer. Under this approach we can explain those things which fit neatly with our science, and plead lack of information instead of explaining the others – lack of information either about physics, or about Middle-earth. It is into this mould that this paper most easily falls. We shall discuss the worth of this whole scheme later in the paper.

We can put some of these principles into operation by looking more closely at the information that we are given about the various races of Middle-earth, and this is what we intend to do to in this paper. Elves, dwarves, hobbits and men each have their own peculiarities. Here we shall be looking at some quirks of biology, science and technology in Middle-earth. It is true that our title claims to examine physics, but titles of papers often prove deceptive. Anyway, “Science is either physics or stamp-collecting,” in the words of Rutherford, and neither of us indulges in philately.

Elves are strange. Even the most cursory reading of the works will lead anyone to that conclusion, especially if we think about the Elves of *The Hobbit* (which I suspect that we would rather not do). They can intermarry with men and produce fertile offspring, and thus they are the same species, by definition. I rather fancy that any man attempting to inform Elves about this matter of definition would reduce his life-expectancy dramatically. However, they have physical differences from us, the most obvious being that they do not die. However strange this may at first appear, it is much

more confusing why other races *do* age and die than why the First-born do not. Our cells gradually stop renewing themselves: the Elves’ just stay as good as new. More surprising is the total immunity of the elves to disease. It seems that one or the other of these factors can be inherited in those of mixed blood, who are longer-lived than their purely human contemporaries. It is a debatable point whether this longevity is due to a resistance to disease or an extension of the time until cell renewal begins to break down, or both. The tolerance of various races to disease is highly questionable, since we don’t seem to have any records of individuals’ (as opposed to entire populations’) falling prey to natural illnesses. But back to Elves.

Elven eyesight is known to be very good. Legolas can spot an orc-host at twelve leagues, and give fairly detailed descriptions of Éomer’s éored at a distance of five leagues. This is remarkable, and highly embarrassing for Aragorn, though Gimli refuses to be impressed. Resolving power depends on the width of the aperture and the wavelength of the light observed. A back-of-the-envelope calculation (always the best sort) established that if Legolas used only visible light, he would have been a bug-eyed monster, to the extent of having eyes on stalks in order to fit in a human-shaped face. Rather than force all known Tolkien illustrators to redraw their life’s work, we concluded that Elves have more of the high-frequency spectrum available to them. Assuming resolution of half a metre at fifteen miles, and a roughly human-sized pupil, we find that their visible spectrum extends to about 170nm, or 2000 THz – impossibly high energy. Maybe the tale grew in the telling, but this does not affect our main point: that Elves could see well at least into the ultra-violet – and this is not really so improbable. Many insects can see UV; as indeed could humans if only their lenses were removed (our receptors respond to high frequencies but they are blocked by our lenses). All that is required therefore is for Elven lenses to transmit high energy electromagnetic waves. Increased resolution also requires higher-density retinal receptors – but this is a purely physiological point and therefore not significant.

Something else is remarkable about Legolas’s sighting of the riders. He can see that there are 105 men galloping across the plains (possibly including Éomer). It is possible that he was merely counting very quickly (and even this would be a considerable feat), but a more attractive explanation would

be that he has just seen that there are this many, as I might see directly that there are two or three objects in front of me without having to count them. I find personally that I can only see twos, threes and possibly fours in this manner – larger groups are broken up into these and then summed. I don't know if this is typical of humans generally; but it seems inconceivable that 105 could be grasped “just like that” by any normal man. Feats such as these can be performed by some autistic people, which indicates that they are not entirely alien to the human brain, though. Elves would probably be the annoying types who know their Log tables by heart and could do any sort of mental arithmetic. Pure Maths seems to be the sort of field attractive to folk who have at best a tenuous connection with everyday affairs, and we can imagine Fermat's Last Theorem's having no terrors for the Eldar.

We know a further difference between Elves and Men, and this is related to their metabolism. During the pursuit of the orc-hoards across Rohan, we are told of Legolas that “in the waybread of the Elves he found all the sustenance that he needed.” Now we shall perform the banned chemical analysis of lembas. It certainly could not have contained much (if any) Vitamin C, for that chemical decomposes rapidly. It is highly unlikely that Elves did not require this vitamin, and so we may conclude that they synthesised their own, like all primary-world animals save guinea-pigs, monkeys and men. The others, certainly, are worn down more quickly on the chase, and we attribute a certain part of this to malnutrition; lack of vitamin C, as well as leading eventually to scurvy, also causes anæmia, since it is required for the absorption of iron into the body.

We notice that the gene for beardlessness is transmitted from Elves to Half-Elves, and is to be found in those with even the slightest blood relation to the eldar. Círdan is a bearded mutant. A highly debatable theory is that he was sporting a false beard in homage to the Istari, or as a sign of solidarity with the dwarves of the Ered Luin. My co-author is tempted to hazard that Njal, as in the *Saga of Burnt*, has elven blood: at least he displays the typically Elven characteristics, of wisdom, prescience and beardlessness. Possibly there were Númenórean descendents among the Norsemen; this would account for their skill in sea-faring and also their predilection for killing anyone who disagreed with them. Talk of beards naturally leads to talk of the Khazâd. In *The Hobbit*, they are resplendent in beards of white, yellow and (surprisingly) blue. This is however, a possible result of small amounts of black pigment – we do not need to assume that Dwalin was making a fashion statement.

We move on to a consideration of the Dwarves. Mike Percival wrote a good article in *Mallorn* a few years ago about the draining of Moria (1988, pp. 30-32), and it seems reasonable to suppose that they had access to geothermal technology at the height of their civilization. I hope that I do not offend either engineers or Dwarves by saying that the Dwarves were the engineers of Middle-earth. On a related theme, it was encouraging to see in *The Treason of Isengard* that Tolkien toyed with the idea of Saruman's holding a

Dwarven ring: certainly the wizard's technological aspirations fit in with the dwarves' racial characteristics. In their heyday, the Dwarves supplied armour and weaponry to the Elves. In return the Elves heaped abuse on their valiant but short comrades, whom they charmingly nick-named ‘Naugrim’, or ‘Stunted Ones’. But this is not the place to pursue the pro-Dwarven sentiments of Taruithorn. The dwarves also appear to have been less isolationist than the First-born, freely trading their technology with, say, the hobbits.

The technology of the Edain didn't regain the heights of the Númenóreans until well after the end of the Third Age. One fragment in *The Lost Road* even refers to flying ships in the years immediately following the Akallabêth. This leads us into the murky waters of reliability of sources, which we shall return to before too long. It is tempting to think flying ships a legend that sprang up because of the incredible achievements of the Dúnedain, much as in later years the Palantíri were transformed into legends of bird-like spirits bringing messages to the King. We must be careful, though, in deciding which technologies to discard in this matter. Flying ships we can discount, as being removed from all later versions of the story.

It has often been asked why the technological level of the survivors of the Downfall was so low, and why what technology they did have had so many seeming lacunæ. As one example, there seems to be no reference to printing. However, this is quite a straightforward technology, certainly within the grasp of those who made steel bows, and is one of those inventions which is relatively simple to develop once someone has had the initial idea. There are, we suggest, two reasons for this phenomenon. The first is that the technology of Númenor was artificially accelerated by a certain Annatar, Lord of Gifts. And what possible gift other than knowledge could he give, given his situation? It would then hardly be strange to find the considerable resources of the race being concentrated on weapons research. But even so, this would not explain such obvious gaps.

To do this, we must consider the position of the Faithful. They were opposed to everything that Sauron stood for, and would, we suggest, have seen any advanced technologies as being the works of the devil. It was unfortunate from a technological point of view that Middle-earth was colonised by intolerably proud Luddites, technophobes who would use not Númenórean technology but the sword and the bow. The surviving artefacts, such as the Palantíri, were Elven made. The fear of a second Akallabêth obviously scared the Faithful and their descendants away from developing anything much of their own accord. Even at the end of the Third Age, we still have the office of King's Scribe in Gondor.

Nevertheless, the Faithful brought with them some truly powerful items: the Palantíri. We have here the benefit of a remarkably full description of their powers and operation, in the chapter “The Palantíri” in *Unfinished Tales*. The trouble is that they do not seem to operate by any known physical laws. However, it is indisputable that they do operate according to some sort of strict laws. The lesser stones, at

any rate, must be oriented correctly in order for them to be used; and using the stones, a “surveyor” could see things many miles away, unless the location he was scrying was dark. Telepathic conversations could be held between the operators of two stones; and the Osgiliath stone could eavesdrop on any of these conversations. Just to complicate the matter still further, the stone at Eryn Beraid looked only Westward to the stone at Avallónë and was not connected to the other stones in any way. Indeed, the mention of a Stone in the Far West is surprising: presumably communication could have been set up between the Faithful (who had control of the stones) and Valinor. This could explain a lot, including the Faithful’s knowledge of the plan of Ar-Pharazôn and their preparations for fleeing the Downfall.

So how could these things operate? Given that they can see through mountains, one might imagine that they “saw” by means of some sort of radiation that isn’t blocked easily, like neutrinos, but in that case why should they reflect off the target? And why can’t the stones see into dark places? That suggests some sort of visible electromagnetic radiation, unless “dark” is being used metaphorically. This, though, seems unlikely, and light isn’t noted for its tendency to go through mountains. Possibly the light is bounced off something; but what? A satellite? It seems unlikely that Eärendil is sitting there with a mirror, even though he may be described as the Flammifer of Westernesse. It’s at this stage that we could mutter sagely, “Hmm. Insufficient data.” Even Terry Pratchett’s standard cop-out, “it’s quantum, innit?”, doesn’t help us here.

If we wish to press on in this matter, we must invoke a scientific principle which has long been the domain of authors wishing to lend an air of spurious verisimilitude to an otherwise bald and unconvincing narrative. Yes, folks, it’s time for Hyperspace. Some of you may have read an article by a certain Marc Read in *Amon Hen* (1989, pp. 17-18) many years ago, attempting to explain the globing of the world and the removal of the Valar as a change from a Euclidean topology of space to a Minkowski topology of space-time. Perhaps extra physical dimensions are the single most useful tool in today’s science for the Pseudo-Scientist. When we read about superstring theory requiring a number of physical dimensions which runs well into double figures, perhaps we feel that our explanations aren’t so silly after all. But the counter-intuitive nature of modern science, fascinating though it is, is only a digression. Let us return to our hyperspatial Palantíri.

The way in which the vision of the Stone is not blocked, and yet is restricted to the light illuminating the actual scene being observed, goes to suggest that the scene is not being transmitted to the Stone by any radiation. Rather, it would seem that the scene is directly observed by the Surveyor. It is as if the Surveyor were actually there. Or, to put it another way, it is as if the light from the scene travelled directly to the Palantír. What better way for this to happen than for the light to travel down a “wormhole”, a hyperspatial tunnel, it need only be a tiny size. Any light entering this volume would then travel directly to the stone. The various ways of controlling the palantír then translate to various ways of

controlling the motion of this camera-space. The light takes a short-cut through another physical dimension. The standard analogy formed by removing one dimension may come in handy here – instead of looking around the surface of a sphere, we look from one point on the surface to another through the space in the middle. Of course, this is perfectly ridiculous. Although it is a nice picture, it would end up with, in effect, faster-than-light travel. Admittedly, the only thing travelling faster than light would be light itself, which mercifully rules out the possibility of Elven, Palantír-powered, jump-driven starships, but this is still enough to make causality a headache for anyone. Although this is a drawback from the scientific point of view, it might well be seen as a bonus from the textual point of view; after all, Palantíri can also see backwards and forwards in time, and that really could result in causality migraines.

Even this pseudo-explanation doesn’t tie in with all the facts that we are given about the Stones. How could Osgiliath eavesdrop? A repeater station located in hyperspace? Surely such a thing is beyond the realm of possibility, unless one is E.E. ‘Doc’ Smith. And how are thoughts transmitted between two Palantíri in the same network? As Jenny sums up the whole matter of hyperspatial communications, “Aaaaaaaaargh!”

The whole question of foreseeing the future is a vexed one. The Mirror of Galadriel shows possible futures, including things that may not come to pass. Such an intrusion of probability reminds us instantly of the field of Quantum Mechanics. A fascinating *Horizon* programme on television about a month ago (1992) revealed that theoretical physicists are coming to accept the so-called Many Worlds interpretation, and some other serious and possibly sober theoreticians are starting to suggest that time travel, of a sort, is a possibility. The “of a sort” is very important here and I shall discuss it now. The main objection to time travel is that it would seem to be open to the Grandfather paradox – what would happen if I killed my grandfather before my father was born?

The solution to this lies in the Many Worlds theory. This is an interpretation of quantum mechanics which suggests that every possible quantum event actually occurs. If (as is usually the case) two or more events are contradictory – the wave function collapses into one state or another – then the Universe splits. In one branch event “A” happens, in another it does not. In the classic thought-experiment, we may say that in one branch, Berúthiel’s cat is killed, and in the other it remains alive. For many years this was seen to be the most flagrant breach of Occam’s Razor imaginable: we’re inventing untold universes just to avoid letting probability in. Jenny points out that it is impossible to breach a razor, but let that pass. Now I have been reliably informed that cosmologists, being depressed about dealing with only one universe, think that the other Many worlds have at least as much claim to existence as ours. Weird.

The most interesting thought that comes with this ontological nightmare is that perhaps some sort of communication between the parallel worlds (for want of a better term) is possible. Thus, it has been argued, we could

have the equivalent of time travel so long as we stepped “sideways” in time, and across to a parallel world, so keeping all time-lines unmuddled. Any science fiction author who tried to get away with this would probably be laughed at, but it’s just another example of Haldane’s law in action: “The Universe is not only queerer than we suppose, it is queerer than we can suppose.”

Anyhow, it now seems that we could explain Galadriel’s Mirror as being a way of looking into the various parallel worlds. The time difference could be explained away by having worlds which developed at slightly different rates. After all, there is going to be a vast number of worlds out there. Indeed, J. Danforth Quayle’s famous quantity comes in handy here – “nearly infinite”. This explanation seems vaguely unsatisfactory but I am horribly afraid that it could be backed up by science. Any theoretical physicists out there are invited to do the maths, and let us know the results; perhaps by the Bicentenary conference. The question is basically, would such a device violate any physical laws? As Gell-Mann said, “Whatever is not forbidden is compulsory.” Suffice to say that this is an area of real interest in modern research, especially for science fiction fans and rationalising pseudo-scientists.

We can now look at some of the powers of the Rings. I think that it is fair to say that they can be seen as the products of the various effects mentioned here and in our earlier paper (Coombs & Read, 1991). The ability to locate the other wearers and, perhaps, know their thoughts seems closely related to the functions of the Palantír. Amon Hen seems to act as a natural amplifier for the power of vision; it is terrifying to think what might happen to a ring wearer on Amon Lhaw. The problems of invisibility we have implicitly handled in our earlier paper, “Valaquanta”. They also seem to amplify the wielder’s natural ability – another idea closely tied in with our earlier work.

My co-author has turned her attention to two different examples of “magic” in Arda, and treated each in a different way. First, the Silmarils. These are bright, but not blinding to look at; it is unlikely that their luminosity exceeds that of a 100W light-bulb. Yet we are told that a silmaril became the morning-star. The obvious explanation, if explanation we seek, is that this is mythology, a story told by an ancient people; in reality, of course, Eärendil is Venus, the poisonous, sulphurous second planet. It is entertaining, however, to imagine for a moment that we are in a universe where the morning-star is a Silmaril, a few miles above the earth. The problem then arises of how the silmaril is still visible, and so bright; similar problems occur with the story of the Sun and Moon. In *The Book of Lost Tales* (Tolkien, 1983, p. 201), the Sun increases in heat and brilliance after its launching, so that, as Christopher Tolkien comments “the reflection rises less readily than if the Sun that brilliantly illumines the whole Earth was but one fruit of Laurelin then Valinor must have been painfully bright and hot in the days of the Trees”! But in Tolkien’s later writing there is no mention of any such increase in luminosity. So why do the heavenly bodies still look bright? Or rather, why do we feel that they *ought* to look dimmer?

Well, that may be because we all have an instinctive feeling for the inverse-square law, which governs how distant objects appear to dim. So, we could either question the assumption that the Morning-Star is just a silmaril, without maintaining that it is a planet, or we could see what would happen if the inverse-square law did not hold. Let’s consider the second case first.

The inverse-square law is simply derived for the case of an isotropic light-source emitting at constant power,  $P$ . The brightness as seen by an observer at a distance,  $r$ , away from the source depends on the power density at the location of the observer, which is  $P/4\pi r^2$  since the light spreads out equally over the surface of a sphere. Hence the brightness falls off at  $1/r^2$  – the inverse-square law.

We shall now consider the two-dimensional case. Consider a light-source on a plane, which emits a “light-circle” instead of a light-sphere. The brightness presumably depends on power per unit length, instead of power per unit area. The brightness to an observer at a distance  $r$  from the source would therefore be  $P/2\pi r$ . But this formula could be readily be changed if the light, instead of travelling in a plane, were to travel on some more complicated two-dimensional curve. Imagine, for instance, that the light-source, the observer and the light are all constrained to move on the surface of a sphere of radius  $a$ . Then elementary geometry shows that the brightness falls off not as  $1/r$ , but as the reciprocal of  $a \cdot \sin(r/a)$ . If Arda were the three-dimensional surface of a suitable four-dimensional object, the desired function of brightness against distance could be obtained; that is to say, one in which light sources appear much brighter when they are further away. The problem is that of finding such a strange object. Jenny has devoted much thought to this, but, despite constructing many three-dimensional diagrams out of paper and mutilated satsumas, has had to give up. Is there an  $n$ -dimensional topologist in the house?

There are other possibilities concerning Eärendil. What was Vingilot made of? After all, we can see certain artificial satellites from reflected light. But what light could it reflect? This raises the whole problem of the Sun, as mentioned earlier. Perhaps some layer of the atmosphere acted as a natural photomultiplier, solving all our problems at a single stroke. I am attached to this explanation but can think of no justification for it whatsoever. Still, when has that ever got in the way of a good theory? Anyway, we shall now turn to the other area which Jenny has been investigating.

As we stated at the start of this paper, there is another way of going about things, which is to maintain that Middle-earth is *our* earth, and that therefore all its physical laws must be compatible with ours. Let us pursue this line of thought for a while. Our principle weapon will be source criticism. The various histories and legends of Arda exist as many different documents, in a great variety of styles, and are often flatly contradictory. Consider the difference, for example, in style as well as plot, between the playful “Tale of Tinúviel” in *Lost Tales* (Tolkien, 1984, pp. 3–48), and the sombre “Lay of Leithian” (Tolkien, 1985, pp. 150–308). Clearly these can be regarded as Tolkien’s successive reworks and adaptations of the myths.



It is more rewarding, however, to consider them as equally valid in the secondary world, but as representing different traditions, from different ages and cultures, of the same facts or legends. And, just as with primary-world historical sources, one must consider not only the material but its author: when he lived, what his culture was, how close he was to the events he describes, how he gathered his information. Many of the documents we have are songs or lays; has the poet adapted his material for dramatic effect, or for some other reason? To understand *The Aeneid* one must consider Maecenas, who commissioned the work, as well as Virgil who wrote it. When discussing the portrayal of Orcs, one must remember that history is written by the victors. The racist, misanthropic tone of *The Silmarillion* betrays its Elven origin; and the constant reference to the great height of the heroes of the War of the Ring makes sense when we remember that the Red Book was written by hobbits.

So what is the relevance of this to a discussion of science? It is that one need not take every statement at face-value, as we have already shown. Exaggeration, confusion, and misunderstanding all play their part in the description of technological artefacts, especially when such artefacts belong to a civilization other than the narrator's, and to a technology he does not understand. An example is the Elven swords, Orcrist, Glamdring, and Sting, which magically glow in the dark to indicate the proximity of Orcs.

Whereas Jenny can accept the Palantiri as products of some far-advanced science, she balks at luminous ironmongery. This seems to be "magic" pure and simple. She prefers to say that the reports that the swords glow when Orcs approached are untrue: they are based on rumour, exaggeration, and superstitious belief in the omnipotence of the ancient Elven science that produced them. Rather than being actually self-luminous, the swords were in fact only highly reflective. In dark surroundings, they reflected what available light there was, and so still seemed bright, just as white clothing shows up more at night. Over time this was distorted into the legend that the swords emitted their own light, and eventually that they glowed to indicate the presence of enemies.

Elven swords are in fact repeatedly referred to as "bright"; though how far this is merely a rhetorical adjective is hard to say. The ancient Elven swords are also prized for their strength. Both of these could be explained if the Noldor at the height of their civilisation were capable of manufacturing large single crystals of metal. This is a technology which we are just beginning to master. Normal metal consists of many small grains, or crystals, of metal atoms bonded in grain structures. Fracture occurs at grain boundaries; the size of the grains affects the strength of the metal; techniques such as tempering and work-hardening depend on this. If a sword consisted of monocrystalline iron, it would be very resistant to many forms of stress. It would also, due to its uniform surface, be highly reflective.

Now, I would be quite happy to accept monocrystalline swords, and of course the general point about source analysis. In this case, though, I think that reports of glowing swords are not greatly exaggerated. The sources that we have

are relatively reliable; presumably the translated version of the Red Book was the annotated copy of Findegil, only two copies removed from the original. Bilbo could well be forgiven for making up some of the excesses of *There and Back Again*, but the Red Book was destined to be read by the great and the wise. The whole question is simply one of where to draw the lines between magic, legend and science.

This is much harder than it may sound. Clarke's Law is often cited in this context: that "any sufficiently advanced technology would be indistinguishable from magic." I suppose that most people would accept this; the disagreements start when someone tries to argue, fallaciously, from this to the idea that anything that is indistinguishable from magic must be advanced technology. Logically, this is the fallacy of affirming the consequent; to make the latter claim is to say far more than is stated by Clarke's Law, which is unobjectionable in itself.

It will be useful for the purpose of this discussion to set up two hypothetical Tolkien fans, the Scientist and the Magician. I hasten to add that both of these are caricatures; we are leaving the final decision to you. None of you will be surprised to hear that we're on the side of the Scientist in this argument. Perhaps the difference between Jenny and myself is that she is a little constant in her views while I waver with the natural indecision of the philosophy student.

The Magician really can't see the point of a paper like this. Almost certainly, he's not interested in science much in the primary world. Even if he is, he doesn't see why any of it should apply to Middle-earth. The Scientist makes him feel vaguely angry, and he feels a great temptation to jump up and down shouting, "He that breaks a thing to find out what it is has left the path of wisdom." He feels cheated if Magic is explained away: something precious has been lost, in his estimation. Perhaps the reason that he likes Tolkien so much is that he can find in Middle-earth the mysteries which are so elusive in today's over-scientific age.

The Scientist thinks that if man didn't break things from time to time we'd still be sitting in caves. He's probably got at least some scientific training. He really cannot understand the irrational technophobia of the Magician. He probably likes Middle-earth because of its inner consistency and logic. For him, the whole logic of that world breaks down if it cannot be codified and regulated somehow.

The Magician cannot help but admire the passage in Keats:

There was an awful rainbow once in heaven:  
We know her woof, her texture; she is given  
In the dull catalogue of common things.  
Philosophy will clip an angel's wings.

The touch of science is for him the kiss of death. He draws support from Tolkien's seemingly anti-technological views.

But the Scientist is at a loss as to what to say in reply. Surely, he thinks, a rainbow is all the more beautiful for knowing the laws that govern it, not less! The simplest object is, to the Scientist, a source of limitless wonder. His ear strains ever after the music of the spheres. What though Tolkien seems to disapprove of his pursuits? Tolkien seems to have disliked every subject apart from his own field at one stage or another in his career.

It is because they have so little in common that their disagreements arise. If the Magician could only realise that the Scientist is not attempting to destroy the mystery, but to push it back even deeper to the mysteries that perplex modern science, then he might be more respectful. Similarly, the Scientist should not dismiss the Magician out of hand. For heaven's sake, this is meant as an enjoyable pastime, not a war. And here we reach the nub of the matter. For the Scientist, such analyses are fun. Jenny and I enjoyed writing this paper immensely, and we hope that you're finding it interesting and, perhaps, amusing.

I'm sure that the argument as to whether or not it is in the spirit of Middle-earth to analyse things from the scientific point of view is one that will go on for a long time. I'm aware that this paper is rapidly beginning to sound serious, and so I must do something – people who know me often suspect things are deeply wrong when my Tolkienian writing turns serious. So I shall close this section with a presentation of my own view, which might offend some “purists”. If so, I'm sorry; but it's the only view I know well enough to explain. Then I shall present a few last mad ideas for future scientific enquiries into Middle-earth. We'd be thrilled if any of these were to stimulate any of you into writing something similar.

So, why do I enjoy this pseudo-scientific approach to the writings of J.R.R. Tolkien? Well, for me, giving a full scientific account of a seemingly magical phenomenon gives rise to the same sort of intellectual satisfaction as finishing the *Times* crossword. The analogy is good, in that at my present state of knowledge I have precious little chance of doing either satisfactorily. It's a challenging intellectual pursuit which draws together most of the things that I'm really interested in. Above all, it's a great game to treat the writings of Tolkien as if they were historical records, and see what sense we can make of them. It's a game which I think all Tolkien fans enjoy. In the back of my mind the whole time is the nagging thought that “after all, they are only works of fiction.” But this doubt is pushed aside when discussing such themes as are dealt with in this paper. It is quite ironic, then, that we take the opposite approach “one level down”, as it were, and introduce the obvious doubts about bias of the author only when we analyse the corpus as being secondary-world history. No wonder critics of Tolkien get confused!

“But it's only fantasy!” Well, yes, it is fantastic; but Middle-earth is the result of a genuinely sub-creative process. It's my belief that any conceivable world which isn't going to break apart under the stress of internal contradictions will have to have certain properties found in the primary world: for example, it must have causality of a sort. There is at least a good case for saying that the most fundamental laws of physics must hold as well. But this is

leading us into the murky waters of modal logic and counterfactuals. Maybe this is a subject for another paper, one indulging my philosophical whims instead of my scientific ones. But on that note I shall leave this serious theme. Jenny's answer to this whole problem is slightly different from mine: but I just wanted to show that at least we've thought about what we're doing.

And now I turn with relief to a few ideas which the pseudo-scientific approach to Middle-earth could yield. As I mentioned earlier these are some areas we think could be developed much further.

- i. An economic analysis of Middle-earth. This project has already been started by Mark Poles of Taruithorn in his excellent and amusing “Exchange Rates in Middle-earth”.
- ii. An investigation of the neuropsychology of Elves. Just how could they perform all those extraordinary mental feats?
- iii. The whole matter of telepathy. This would be very problematic but could take comfort from the wonderfully pseudo-scientific and ramshackle way parapsychology has proceeded in the primary world.
- iv. A genetic approach to beards. Why were dwarven females bearded? What was the genetic difference between the branches of hobbits? How often would Boromir have needed to shave?
- v. What about mithril? Presumably a natural alloy, but of what? It seems to be just about the perfect material for most purposes. I suppose that it was a pity that the Dwarves seem to have mined it all well before our age began.
- vi. Then there's the problem of how one could start with Elves and end up with Orcs, quite apart from the whole matter of Orcish immortality or otherwise. Is this straightforward genetic engineering? Or perhaps a programme of what has happily been called “dysgenics”?
- vii. Exactly what technologies were developed by the end of the Third Age? It would be very useful if someone could undertake the tedious task of indexing all mentions of artefacts in the books. Especially welcome would be a listing of the incredibly patchy technology of the Shire. Need we take seriously hobbit umbrellas? And surely only an advanced civilisation could be decent enough to produce waistcoats. Next we'll be hearing of hobbits in bow-ties. Whatever is Middle-earth coming to?

And on that happy note we shall draw this short paper to a close. We both hope that some of you will have understood what we've been saying, and, more importantly, the reasons why we say it.

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