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Article

The Integral Nature of the Scientific Enterprise

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Abstract: Science seeks to explicate truths about our reality. But what is truth? How do we know things? Given our ignorance, and our fallibility, why should scientists be trusted? An account of knowledge that addresses these human questions is sketched, in conversation with recent advances in thermodynamics which underline the seminal importance of *unity* by demonstrating (i) a definite physical meaning of the idea of “unitary entity”, (ii) the commensurability of the *local* and the *non-local* (resolving the Loschmidt Paradox), and (iii) the applicability of this entropic physics to entities at all scales, whether small (“quantum mechanical”) or large (subject to “general relativity”). Similarly, integrity is indispensable to the scientific enterprise, whether at the level of the mathematico-physical, the practising scientist, the scientific community, or the public. As a human activity aimed at touching reality, it is fundamental that the scientific enterprise necessarily also has an irreducibly poetic component. Although in principle it cannot be completely specified, this enterprise is a cluster of procedures designed to increase our understanding of the natural world. Our apprehension of knowledge is irreducibly personal, depending both on our own individual integrity as well as on the integrity of the scientific community. Believing that “reality” exists and can be grasped (however incompletely), scientists look for coherence and value unified accounts. Strictly speaking, although reality can be known truly (if only in part) the idea of “objective” knowledge is an oxymoron, even if such an idea is often a useful approximation. Knowledge is necessarily personal.

Keywords: Anaximander; quantum gravity; prescientific thought; mereology; entanglement; atom

1. Introduction

Today there is a crisis of faith. Experts are not trusted. Climate change is denied. Conspiracy theories abound. How should the scientific community respond? What is it about the nature of the scientific enterprise that makes it trustworthy (and how can trustworthiness be promoted?)?

What *is* the scientific enterprise? Of course, from one point of view this question is trivial – everyone knows what it is: it’s what’s made the modern world! And of course, the scientific enterprise is generally celebrated for its unprecedented theoretical, empirical and technological achievements over the past few centuries and the concomitant benefits that have accrued to humanity.

The scientific enterprise is a communal activity designed to obtain reliable knowledge of the natural world. We depend on each other’s expertise (since most of what we know we cannot verify for ourselves): we also depend on the general good faith of the community since fraud is hard to detect reliably, even though it is quite rare. That is, the scientific enterprise depends heavily on the personal integrity of the scientists. And wider society must be broadly convinced of the integrity of the scientific community to believe that it is being told the truth.

But what *is* knowledge? How do we know things?

The *epistemic problem* (how we know things) has been intensively discussed by philosophers¹, and the emerging consensus is that it has no analytical solution: we limp inexorably from error to error. Nevertheless, our knowledge of the natural world has proved reliable, as witnessed by the ubiquitous artefacts on which we rely. The reason for this reliability is that, just as the scientific enterprise at the communal level is built on *integrity*, so at the personal level it is built on the search for *unity*.

Truth is *one*. For were it not, we could know nothing! Therefore we assert the integral nature of the scientific enterprise²: that *knowledge* is premised on an account of *unity*. For we may know truly even in the face of our limitations, since the truth the poets discern is the *same sort of thing* that the scientists discover – *truth is one*. Knowledge is personal³ and any philosophy of science must be properly metaphysical (and here by “*metaphysics*” we mean simply “*the metanarrative of physics*”)⁴.

¹ Carlo Rovelli has summarised the epistemic problem very acutely: “*we do not know how or why we think what we think ... When we seek a sure foundation on which to base decisions about our actions and thoughts we find that a sure foundation does not exist ... But this does not imply that we cannot or must not trust our own thinking. Recognising its limitations does not imply that it is not something to rely upon*” (Rovelli 2009, p.171f).

Rovelli’s thesis is that “*We must choose between hiding away in empty truths or accepting the radical uncertainty of our knowledge – remaining, like the Earth, suspended in a void ... This is the main characteristic of scientific thinking: what seems most obvious to us about the world can be false*” (*ibid.*, pp.177,180). In the face of our own uncertainties and our knowledge of our previous errors, how do we respond to crazy people spouting nonsense?

Robert Crease (2019, p.19) has written a book “*about how to get angry about science denial in the right way*” quoting the famous saying of Aristotle: “*Those who are not angry at the things they should be angry at are thought to be fools, and so are those who are not angry in the right way at the right time, or with the right persons*” (*Nicomachean Ethics*, Bk.4 Ch.5). It is necessary to get angry, and indeed we are angry; but as Crease points out in his discussion of Hannah Arendt’s contribution, “*There is no quick fix*” (*ibid.*, p.262). The issues are not simple – reality is elusive! Here we try to lay out these issues in an even-handed way.

² Clearly, the scientific enterprise involves *knowing stuff*; and consequently also knowing *how* we know it; and moreover *how we go about* getting to know things. That is, we shall consider *knowledge* itself, together with its *epistemology*, in the context of its *methodology*. These are massive issues on which the literature is truly enormous: we will of course be very selective in our conversation partners.

³ Michael Polanyi (1958) has insisted that **knowledge is personal** and Jerry Ravetz (1971, Introduction) has developed Polanyi’s case, calling for “*a new philosophy of science which, instead of asking ‘what sort of truth is embodied in perfected scientific knowledge’ proceeds by asking ‘by what activities and judgements, individual and social, can genuine scientific knowledge come to be?’*”.

⁴ Jaynes *et al.* (2023) have shown that any physical discussion must necessarily have a metaphysical context: since every narrative only makes any sense in some suitable metanarrative (and narratives in a natural language work as their own metanarratives).

This metaphysical context is normally tacit: indeed, so much so that it is usual for the physicists to be entirely unaware of it. The crux of the argument of Jaynes *et al.* (*ibid.*) is that poetic speech is invariably *prior* to prose speech, both logically and temporally: actually, Carlo Rovelli acknowledges this, “*seeing [in ritual] the grounding ... of the system of legitimacy at the basis of social life, and even for the reliability of human language itself*” (Rovelli 2009, p.167 citing Roy Rappaport’s classic 1999 work). It is the question of, and the justification for, the “**legitimacy of science**” that is our subject here. Why trust scientists? What is it about the scientific enterprise that makes it trustworthy?

“Metaphysical” is commonly used today pejoratively (Collins and Chambers dictionaries both list “fanciful” as one such synonym): philosophically it usually refers to “*ontology, or the science of being*”. This is, for example (approximately)

Note that when we say “*Knowledge is Personal*” we do not imply that knowledge is *individual*: we know things *together*, or not at all! “*No man is an island*” (John Donne, 1624). Since individually we can know rather little, knowledge must be a property of the community, and scientific knowledge a property of the scientific community.

Moreover, even though all practitioners will affirm that *intuition* is essential to scientists to enable them not only to articulate but also even to obtain their results (for example, see the penetrating discussion of Tom McLeish, 2019), it is not considered proper to mention this in formal presentations.⁵

The new account we propose here of the scientific enterprise (premisses on a new account of *unity*) has not been possible until rather recently. After all, “unity” is a metaphysical idea that historically played no direct part in physics (since the scientific revolution), and one can hardly claim that one’s account of the “scientific enterprise” is satisfactory unless one can also account for how the physics is known.

But it turns out that “unity” does have a physical embodiment just as “atoms” do. The reality of atoms has only been universally accepted for just over a century, and real “unitary entities” were

how Bas van Fraassen (2008) uses it: “*the step that leaves the entire game of metaphysics behind, and frees us forever from its illusionary charm and glamour*” (quoted in Flavia Padovani’s useful 2011 review). But here we use it in a way cognate to “metamathematics” or “metadata” etc: that is, we use “*metaphysics*” as simply the “*metanarrative of physics*” (see n.17 *passim* in Jeynes *et al.* 2023), noting that “physics” is used here in the wider sense Aristotle had in mind when he titled his *Physics*: “Φυσικὴ ἀκρόασις” [*physikē akroasis*] (literally “*listening to nature*”, meaning perhaps “*lectures on nature*”).

Note that Gödel (1931) explicitly uses “*metamathematics*” in his Incompleteness Theorem. Gödel had studied Immanuel Kant’s *The Metaphysical Foundations of Natural Science* (Kant 1786), in which Kant clearly has the same idea that David Hilbert also had: that a “complete” metaphysical grounding was available. Gödel showed this to be untenable.

So Kant says (for example): “... eine vollständige Zergliederung des Begriffs von einer Materie überhaupt zum Grunde gelegt werden müssen ...” [“... a complete analysis of the conception of a matter in general must be laid at its foundation ...”]. But, supported by Gödel’s seminal result, Jeynes *et al.* (2023) show that this search for “completeness” cannot be successful; since at the foundation of any knowledge is a *poetic appreciation* rather than an *analytical understanding*, such understanding itself being only a formal representation of the (prior) poetic appreciation. Terrence Deacon (2011) has insisted on the *incompleteness* of nature (and therefore also our *knowledge* of it).

- ⁵ An interesting recent exception (that goes to prove the rule) is explicit: “*Quantifying Intuition*” (Haddad *et al.*, 2024). The authors acknowledge that *intuition* as such is formally unmentionable (“*While recognised as an important guide during data analysis, being a heuristic parameter, it [the “happiness parameter”] has no firm basis in statistics and therefore cannot be quoted in publications*”) but go on to cast it in a formal Bayesian framework, which of course is publishable (Dunstan *et al.*, 2022).

Many authors, not only McLeish, have noted that scientists (and mathematicians) *know* what the result is before (often long before) they can *prove* it. Arthur Koestler has shown (1959) that this was also true of Kepler’s 1609 demonstration that the orbit of Mars was elliptical: Koestler reworks Kepler’s arithmetic, finding that he (Kepler) made *at least* two mistakes. Koestler is sure that Kepler got the right answer not by accident (fortuitously) but because he already knew what the answer was (serendipitously).

Another famous example is the heroic measurement of stellar parallax (of 61 Cygni: 286 micro-arc-seconds, a tiny quantity) by Friedrich Bessel in 1838. This was actually the first formal *proof* of the heliocentric hypothesis of Galileo, but in 1838 everyone *already* believed that the earth orbits the sun: this measurement was celebrated because of its extraordinary difficulty, not because it showed that Galileo was right all along! Indeed, Bessel only went to the trouble of making the measurements because he was already convinced of the heliocentric model. His empirical method was then of great interest since it was the observational evidence for the gigantic size of the Universe that had been thought unobtainable.

only established in 2022⁶. We will explain here how this and other advances in physics underpin a new account of the scientific enterprise that is holistic rather than reductionist, and allows us to speak both directly of technical *unity* and also (more indirectly) of moral *integrity*. This is a new sort of explanation that takes seriously both the physics and the metaphysics, both the analytics considered proper in scientific discourse and the poetics that are actually indispensable for any appreciation of the science.

2. Synopsis

This essay is structured to address the question of the nature of the scientific enterprise in a novel way that draws appropriate attention to the close philosophical relevance of recent developments in the physics of thermodynamics. The starting point (§3 below: “*Historical Perspective ...*”) is Carlo Rovelli’s proposal of his “Third Way”: midway between a dogmatic acceptance of the master’s infallible pronouncements, and the frequently-found default dogmatic position of many an intelligent and inquiring (yet opinionated) person that “*My view must be correct*”. We show here that Rovelli’s is a false resolution of this dichotomy, but that there does exist a valid way to understand the data; and moreover that this way underlines the unity (internal integrity) of philosophical thought, whether one is a poet or a physicist.

The obvious question (§4: “*Trusting Scientists*”) is “*Where does knowledge come from?*” together with the important sequel “*Who decides?*” We expect *experts* to know stuff and that we are supposed to *trust* them to know best – except that manifestly they sometimes don’t, even when it matters most. And yet we have to make do with the best knowledge we have. The scientists facing the public must make an honest use of rhetorical methods, not only to counter the falsehoods of the demagogues but also because science is a human activity in which metaphysical issues are unavoidable. It is no accident that professorships in the public understanding of science have emerged in recent decades, peopled by experts with known abilities in the rhetorical arts: today’s public poets of science.

It is after all *truth* that matters (§5: “*Realism ...*”), and if science is not the honest pursuit of truth then it doesn’t matter what else it is. Science is often presented as being a collection of “objective” hard-edged facts (§6: “*The Illusion of Objectivity*”) but this is not merely false but actually illusory. Rather, it is the search for a “unified” (coherent) view of the world (§7: “*On Unity*”). What is *fundamental* in this (§8: “*What is Fundamental?*”) It turns out that a very good physical case can be made for saying that “unitary entities” are *more* fundamental than “fundamental particles”. That is, the programme of *reductionism* that has ruled since “atoms” were again seriously posited in the 17th century has reached its natural limit: it turns out that physics is now developing a powerful way of speaking about *holistic* approaches (also implying cognates such as *wholeness* and *integrity*).

So how legitimate is the scientific enterprise (§9: “*Legitimacy ...*”), given that “mere facts” don’t actually *prove* anything at all, and we sometimes even get the “facts” themselves wrong? It turns out that the legitimacy of the scientific consensus must be established by *persuading* the public of its substantial truth. Legitimacy can be established only by persuasion. Science touches reality, so that the scientific truths we have grasped are also real however partial (or even fallible) they turn out to be. After all, the widgets continue to work!

⁶ The ${}^4\text{He}^{++}$ nucleus (in its ground state) was demonstrated a “unitary entity” by Parker *et al.* (2022), who correctly derived its consequent matter radius (see §7). The existence of “atoms” was long *assumed*, notably by Ludwig Boltzmann for his “statistical mechanics”. But it was not *proved* until in 1908 Jean Baptiste Perrin verified Albert Einstein’s 1905 treatment of the “Brownian motion” named for the 1827 observations of Robert Brown. And in 1913 Neils Bohr famously explained the structure of the hydrogen atom, relying on Ernest Rutherford’s 1911 analysis of Geiger & Marsden’s 1908 alpha scattering experiments.

It is interesting that in physics “unitary” is taken to refer to “unitary operators”, which are of central importance in quantum mechanics. A “unitary operator” is such that the product of the operator and its adjoint is the identity operator. But here, by “unitary entity” we mean “*that than which exists nothing simpler*”.

As an aside, this position of insisting on the one hand of the reality of the world, and on the other that “*knowledge is personal*” (Polanyi, 1958) is indistinguishable from the position the quantum physicists have taken on the philosophical crises highlighted by the paradoxes of their discipline (§10: “QBism”). QBism (Quantum Bayesianism) directs our attention to basic ideas on how we think of *probabilities*. It turns out that the Bayesian approach to probability applies in a scale-independent way: it is not limited in any way to quantum mechanics but also applies at the cosmic scale (for which general relativity is needed). In any case, it seems that probabilities are also physical quantities obeying physical laws (Parker et al. 2025b).

One way of summarising our argument here is to draw attention to the poetics of physics (§11: “Poetry ...”). A scientific argument can never be entirely self-contained (logically “complete”): it is always in some social or philosophical context whose importance may be (and sometimes will be) dominating. We then briefly discuss (§§12,13) various other issues (including some relevant aspects of Artificial Intelligence and its impact on the conduct of science) and conclude (§§14,15).

3. A Historical Perspective on Scientific Enquiry: Rovelli’s “Third Way”

Carlo Rovelli (2009, p.78) says, “Halfway between the absolute reverence of [the student for the master] and the rejection of those who hold different views, Anaximander [6th century BCE] discovered a third way ... he does not hesitate to say that Thales [of Miletus] is mistaken about this or that matter, or that it is possible to do better ... this narrow third way is the most extraordinary key for the development of knowledge.” Rovelli characterises the “religious” approach to knowledge by its “absolute reverence” which does not allow any modification of the master’s view, contrasting it with the “scientific” approach in which the follower is (sometimes) willing to say that the master was mistaken in this or that respect. Clearly, Rovelli’s representation of science is well-founded.

However, it seems to us that his representation of Christian attitudes is less so, even if he is correct to point to “*a classic thesis*” (by Geoffrey Lloyd, 2002) according to which “*a scientific revolution comparable to the one in the West did not take place in Chinese civilization – despite the fact that for centuries Chinese civilization was in many ways broadly superior to the West – precisely because the master in Chinese culture was never criticised or questioned*” (Rovelli *op. cit.* p.81). Rovelli contrasts the Pope’s view of infallibility⁷ with a scientific view which requires “*faith in human beings, their being reasonable, and their honesty in searching for the truth. This kind of faith in human beings is that of the luminous humanism of the Greek cities in the 6th century BCE at the root of the extraordinary intellectual and cultural flowering of the following centuries, which continues to bear fruit in the contemporary world. But this faith in humanity is not unchallenged. Many voices rise against it: “Cursed be the man that trusteth in man ...” (Jeremiah 17:5). The conflict between these two worldviews is ancient*” (*ibid.* p.141f). It seems clear to us that Rovelli does not grasp Jeremiah’s point (see below), and we should also note that Nicholas Spencer (2023)⁸ has carefully exploded the myth that the “scientific” and the “religious” worldviews are in “conflict”. The real position is much more nuanced than Rovelli says.

The very idea of “infallibility” is heavily contested in Christianity.⁹ Indeed, infallible propositions are simply not available, neither for theologians nor for scientists! Catherine Elgin (2017,

⁷ Rovelli says (*ibid.* p.140): “Pope Benedict XVI ... often says that to save ourselves from the relativistic drift, we have to defend the infallible Truth”.

⁸ Thanks to Sir Michael Berry for drawing our attention to Spencer’s book in March 2023

⁹ The (Roman Catholic) theologian Hans Küng (1970) explained that the Roman doctrine of “Infallibility” dates only from the 1st Vatican Council (1869-1870): this Council was abandoned as a consequence of the Franco-Prussian War, which Eric Hobsbawm (1975, ch.4 §1) insists was a cynical ploy by Bismarck to promote German reunification. We should always remember that our interdisciplinary boundaries are only there for our convenience: in reality everything is interconnected. Frank Hertog (2023, p.203) claims that the utility of Stephen Hawking’s new theory published posthumously (Hawking & Hertog 2018) “*lies in its capacity to unlock the interconnectedness of the universe.*” The theologians should listen to the historians, the historians to the physicists, and all of them to the philosophers. Basarab Nicolescu (2010) underlines the importance of “transdisciplinarity”.

p.33) has made a careful epistemological case for the proposition that “scientific understanding is non-factive” (that is, it is “true enough”). In fact, she contends, entirely convincingly, that “the capacity to make mistakes is an epistemic achievement ... far from being a concession to frailty, [fallibility] is a source of strength” (p.291).

The extract from Jeremiah that Rovelli quotes actually means the opposite of what Rovelli claims. Since Jeremiah of Jerusalem was a contemporary of Thales of Miletus, Rovelli’s reference to him in a book on Anaximander (Thales’ younger contemporary) is well-judged. But the Hebrew scholars are unusually unanimous in pointing out that the four verses (Jer.17:5-8) are a poetic unity. Cassandra Gorman (2021) has shown that the “metaphysical poets” in 17th century England were fascinated by the revelations of the new microscopes¹⁰, which made the commonplace seem outlandishly novel. She says that these poets “wrote poetry that meditated on the liberating power of atoms to dissolve and reaggregate into renewed and resurrected forms. This poetic history of the irreducible particle has not been written by historians of science” (ibid. p.22). The point is that these poets explicitly recognised poems as “atoms” (that is, indivisible: their integrity must remain inviolate – each word is indispensable). Jeremiah’s poem should also be recognised as indivisible, and we therefore give it as a whole. It can be translated (we follow the authoritative translation of William McKane, 1986):

Cursed is the man who trusts in men
 Who leans for support on material power
 Whose mind is alienated from Yahweh¹¹
 He is like one living destitute in the wilderness
 He is unaware when good comes
 He lives in parched places of the desert
 In an uninhabited salt waste
 Blessed is the man who trusts in Yahweh

Jeynes (2014) has commented on Küng: “The crux of the matter is, can any infallible propositions be identified? ... The Roman doctrine of papal infallibility ... [is] a juridical rather than a confessional issue ...”. The Christians will say (“confess”) that God does not deceive his church, and therefore Christians are safe if they rely on the leading of God (which of course is easier said than done). But Küng takes aim at “polemical Church definitions” (treated juridically by the Roman church), denying that it is useful to say that such definitions may be regarded as “infallible”: “A definition has a target; it is aimed at a specific error. But since there is no error without a kernel of truth, there is always a danger that a polemically aligned proposition will strike, not only the error, but also the truth contained in it. If a Protestant, for instance, states quite unpolemically that the just man lives by faith, the shadow of error that accompanies the proposition does not appear. But if he polemically makes the statement in reply to the error of a legalistic Catholic who exaggerates the importance of good works, there is a danger that the shadow of error may obscure the truth of his statement by the unexpressed implication that the just man lives by faith (without doing good works)” (Küng 1970 Ch.4 §10). Note that “The just shall live by faith” (“ὁ δίκαιος ἐκ πίστεως ζήσεται”, Apostoliki 1996) is a text of the Christian writers (Romans 1:17; Galatians 3:11; Hebrews 10:38), quoting Habbakuk 2:4 verbatim. This Greek translation of the Hebrew text (“עֲבֹדָה לִבְרָכָה”, Latinised as the “Septuagint” or the LXX) was made in Alexandria probably in the 3rd century BCE.

¹⁰ Thanks to Kevin Killeen for alerting us to Cassandra Gorman’s important monograph in 2022. As Jeynes *et al.* 2023 say (in their note #80): ‘It is hard to overestimate the importance of the advent of the microscope to natural philosophy. Suddenly things became much more complex and beautiful than anyone had imagined. This is excellently reviewed and described by Kevin Killeen (2017), who thus provides a corrective to our ideas of the emergence of “scientific modernity” which (as he puts it) “is often still viewed as a sad but necessary putting aside of the poetic.”’

¹¹ “Yahweh” [יהוה] is God’s personal name, usually rendered “LORD”; see the elliptical “explanation” at Exodus 3:14: “I am that I am” [אֶהְיֶה אֲשֶׁר אֶהְיֶה] (“ehyeh asher ehyeh”), or “ἐγώ εἰμι ὁ ὢν” in the LXX (Apostolikes 2012).

Who makes Yahweh his source of safety
 He is like a tree planted beside waters
 Stretching out its roots along a stream
 It has no fear when heat comes
 Its leaves remain green
 In a year of drought it has no anxiety
 And does not cease to bear fruit Jeremiah 17:5-8

The parallelism between the first and second halves of the poem is obvious even in translation: the Psalmist quotes the poem at length (Psalm 1) and Jesus alludes to it (see John 4:14, which actually quotes the related passages Jer.2:13;17:13). Jeremiah is deprecating reliance on external things (power in this case) and lauding internal honesty in just the way Rovelli would approve: in fact Jeremiah goes on to be explicit (in v.10), *"I the LORD search the heart and examine the mind"*, where Biblically the *mind* is located in the *heart*¹². Whether or not one believes in God, anyone of goodwill can approve Jeremiah's point, *mutatis mutandis*.

It seems clear that Rovelli's characterisation of religious rigidity – putting dogma before reason – is false, at least for Christianity, accepting of course that European history is littered with shocking horrors perpetrated by the powerful (who chose to call themselves Christian). Luther and Calvin specifically attacked the doctrine of the Pope in just the same way that Copernicus attacked the doctrine of Ptolemy (and just as respectfully¹³). Theology must change just as science must, and for the same reasons – both must be open to new understandings. But both are also subject to the same unwelcome rigidities of thought¹⁴, again for the same reasons: it is difficult to get people to change the way they think, and even more difficult to get people to *"keep their oath, even when it hurts"*, as the Psalmist demands (Ps.15:4). Even though it can lead to intellectual discomfort, the pursuit of truth (with Rovelli's admonition *"it is possible to do better"*¹⁵ in mind) has acted as the driver to the increase of knowledge.

Rovelli's position appears to be 'scientistic' (having an exaggerated trust in the methods of science as applied solely to a "narrative" set of observations) which in this case means that he ignores (or misrepresents) the metaphysical ("metanarrative") aspects we are drawing attention to.

4. Trusting Scientists

¹² *"thoughts of the heart"*, Genesis 6:5, is only the first of many examples. Of course, the Biblical writers were well aware that implying that the mind is "located" in the heart was a figure of speech, just as it was obvious that God having "hands" (*"the work of his hands"* Pss.8:6; 9:16 etc) was also a figure of speech. (Similarly for God's personal pronouns "he/his/him": clearly intended to be heard as gender-neutral.) The ancient poets did not have the nonsensical literal-mindedness that seems to be common today. The substantive point is that the "heart" is at the heart of things: we tend to think of it as a (rather important) pump, but the ancient poets did not know that, they thought of it (figuratively) as central to how we make decisions, especially moral ones.

It is surely worth pointing out that any body has *only one* heart. Psalm 16 has a play on "unity" and "duality": *"my kidneys instruct me in the night seasons"* (v.7 – there are *two* kidneys); *"my heart is glad and my liver rejoices"* (v.9 – one each of heart and liver). Similarly, Psalm 62:11 (*"One thing God has spoken, two things have I heard"*) contrasts *one* mouth and *two* ears.

¹³ Theologically, both Luther and Calvin were very restrained, although they were vigorous polemicists, as was customary in those days.

¹⁴ Max Planck's famous comment is often represented as *"Science advances one funeral at a time"* (see Planck 1950, pp.33,97)

¹⁵ *"It is possible to do better"*: of course Rovelli is not the first to say this sort of thing. Karl Popper (1945) famously said, *"I may be wrong and you may be right / and by an effort we may get nearer to the truth"*, commenting later that the saying was *"an attempt to summarise a very central part of my moral articles of faith ... [which] I called critical rationalism"* (Popper 1994).

People (including “experts”) are rather good at getting things wrong. Hanna Metzen (2024) discusses in detail the related idea of *trust* as it is used in the literature, pointing out that “*Epistemic trust in science has become an important issue in philosophy of science*” – and, one should add, also critically important today in the politics of both Europe and the Americas. Metzen does not discuss the mutual trust present in the scientific community itself that enables new results to be approved and absorbed: it is obvious that the peer review process (for example, and on which see Tennant & Ross-Hellauer, 2020, for a valuable recent assessment) depends on the *good faith* of all parties. In particular, articles in the physical sciences usually report and interpret the results of experiments, and it is essential to know *who* did the experiments¹⁶. By publishing, the authors assert that they are telling the truth about the reported observations. It is remarkably hard and usually unfeasible to detect bad faith. Generally, I have to *trust* you to tell *truth*. Not only Truth¹⁷, but also Trust is central in this enterprise. John Hardwig (1991) says, “*scientific knowledge rests on trust ... in the character of scientists*”. And this is the case even though bias is ubiquitous (recently extensively documented in its multiple forms by Jessica Nordell, 2021).

With the explosion of knowledge and the ubiquity today of multi-author papers¹⁸, we need effective collaboration more than ever (with the extra risk of error that implies). In collaborations the authors must all *trust* each other (as John Hardwig insists, 1985, 1991), even as they also must agree a common narrative¹⁹ (with the concomitant risk of groupthink). In fact, we need to “*rethink expertise*” (Collins & Evans, 2007). And when the wider public pick up the results, they need to be able to trust them too. How does this work?²⁰

¹⁶ The reason for this is that our knowledge is always ultimately founded on “personal testimony”, as Richard Bauckham (2006) has recently shown in an important and very far-reaching monograph. Bauckham engages in an extensive critical survey of trust (“*Testimony, then, of its very nature invites trust ... A fundamental attitude of trust is not gullibility but a necessary epistemic virtue*”), and he cites Paul Ricoeur’s (2000) “prudential rule”: “*first, trust the word of others, then doubt if there are good reasons for doing so.*” *ibid.* p.478f; Rosa Bologna *et al.* (2020) have recently applied Ricoeur’s “hermeneutic spiral” in an interesting way (to “unconscious influences on professional practices”). John Hardwig (1985) already explored the epistemic importance of *testimony*, as of course also did Michael Polanyi (1958).

¹⁷ John Ziman FRS gave a seminar in Bristol in 1973 extolling “Lord Truth”. Ziman “*broke fresh ground in his studies of science as a collective human enterprise*” (Berry & Nye 2006; see also Ziman 1978)

¹⁸ Derek de Solla Price (1962) long ago observed the trend to multi-author papers in scientific journals, and as an example of this John Hardwig (1985, 1991) discusses a paper with 99 co-authors (Abe *et al.* 1983) that determines a photoproduction cross-section of the charm particle.

¹⁹ C.S. Peirce (1877) long ago pointed out the importance of the *community* in establishing reasonable belief. (We thank an anonymous referee for reminding us of Peirce’s contribution.) John Hardwig (1985) acknowledges this contribution in his account of *epistemic authority*: he points out that instead of saying (for some proposition *p*) that “I know *p*” because some expert *A* knows *p* and I acknowledge *A*’s epistemic authority, we can say “**We** know *p*” since we (jointly) acknowledge *A*’s epistemic authority.

²⁰ Collins & Evans pick over these issues in detail, explaining how (as an example they do not use) a clerk of works on a building site who has perhaps served an apprenticeship as a bricklayer is expected (and is able) to judge whether the carpenters are doing a good job. Exactly the same applies in science, *mutatis mutandis*: just as peer reviewers have to be persuaded to trust the scientific authors, so the public have to be persuaded to trust the scientific community. In particular, Collins & Evans are interested in the important question, how can the public make use of science and technology *before* there is consensus in the scientific community? Of course, the question remains: is a consensus reliable even if it exists? How (and why) we disagree even in the face of consensus has been explored by Mike Hulme (2009) in some detail for the case of climate change.

Again, it seems that *good faith* is indispensable. I don't have the expertise (or the time) to check for myself everything *you* say. Even were it feasible (which it is not) it would not be practical: life isn't long enough. I can (and should) check that what you are doing is reasonable, that it conforms to your promises and also conforms to current standards (and so on), but it's not possible to check everything. This is part of what Carlo Rovelli means when he says (as we mentioned above) "*When we seek a sure foundation on which to base decisions about our actions and thoughts we find that a sure foundation does not exist*" (although he was thinking mainly of personal epistemics it is true at all levels, both of individual thought and of communal effort). It might be "reasonable to believe" this or that, but in the end we can never be entirely *sure* that we have got it right. Where then is the *truth*?

Rovelli is right – we simply have to live with the possibility of being wrong. This is admittedly rather frightening. But it also allows us to participate in the "*continuous critical revision of accepted knowledge ... [with] the ability to explore new images of the world*" (2009 p.181). This participation is in our own right, provided that we can make use of the expertise of the community that allows us to understand things that must have remained mysterious had we been alone.

Joseph Drew and others have directly addressed the issue of how to persuade the public to approve certain political actions. They draw attention to the effective practice of rhetorical methods, expanding on Aristotle's categories of *logos*, *ethos*, *pathos* and *kairos*²¹. The same sorts of things apply to the scientific community combatting antisocialism: it is simply not sufficient to make a *scientific* (logical) argument! Scientists must learn to handle rhetorical methods effectively, and this is not merely a political necessity: it is also an acknowledgement of the metaphysical context of all scientific activity.

We see that science (as pursued by the individual scientist) is dependent on the scientific community, which in turn is dependent on the wider community (as the public funder, lay cheer leader, and ultimate beneficiary of the outcomes of new scientific knowledge). Without the "expertise of the scientific community" scientists are on their own and understand rather little. But if they are willing to "stand on the shoulders of giants" then they can see further. Conversely, the scientific community trusts the individual - that's how peer review works.

This is also why "trust" is a political thing: the individual and social cannot be *disentangled*, and the public must be *persuaded* to continue to support the enterprise just as the scientific community must be *persuaded* to accept the results of the individual²². Clearly, this phenomenon of *entanglement* is observed not only quantitatively in quantum systems, but qualitatively in social ones too. And this entanglement "metaphor" is more realistic than one might have thought: new physics (Parker & Jaynes 2023a) has shown that the local and non-local are commensurate, as are also the reversible and the irreversible, and the causal and the acausal (see below §6).

5. Realism and the Metaphysical Existence of Truth

²¹ see Drew 2023, who also points out Aristotle's rhetorical tropes (the "major" ones are: *metaphor*, *metonymy*, *synecdoche* and *irony*), and in particular synecdoche (on which see Drew *et al.* 2018, who point out, following the "*Roman rhetor and inheritor of the Aristotelian tradition, Marcus Quintilianus*", that synecdoche is just as much *totum-pro-parte* as *pars-pro-toto*).

²² Brunet & Müller (2024) helpfully discuss the "feeling rules" of the peer review of major funding proposals. These concern the various rhetorical tactics that are recognised as either legitimate or illegitimate in this context (and similar considerations will apply in other scientific contexts too). This is a welcome recognition of the human nature of science.

And *persuasion* (particularly of the wider community) is of the essence: Entradas *et al.* (2023) open by saying: "*Public communication of science has become a key obligation of universities*", and go on to discuss *science communication* in very useful detail.

What is real? How do we know? The first question is ontic, the second is epistemic. We offer a different perspective to Carlo Rovelli's: his is scientific²³, ignoring (or misrepresenting) the metaphysical aspects; ours is scientific, acknowledging the metaphysics (the "metanarrative of physics"²⁴, where "physics" is intended in Aristotle's wider sense).

The point here is that Aristotle (and Plato before him) understood very well the metaphysical foundations of any physical knowledge they had. Indeed, they were explicit. Aristotle opens the *Physics* with a discussion of the method proper to obtaining knowledge in a scientific enquiry²⁵. Plato already spoke of "*the dialectical method*" as the only way to advance to first principles. For Aristotle the scientific method is necessarily metaphysical (since if the "first principles" are the *beginning* of physics, then the "dialectical path" to them must be a *metaphysical* one in precisely our sense – "*metaphysical*" is just "*the metanarrative of physics*"); this is a conclusion reached independently by Jeynes et al. (2023) on the grounds that the *meaning* of the terms used in a discussion cannot generally be established by the discussion itself.

The disconcerting fact is that physics today typically concerns a variety of phenomena that need intricate experimental apparatus to observe, and often mindbogglingly complex mathematical models to interpret. Is all this stuff even real? Physicists normally ignore philosophical questions, but they all believe that the world is really there and that (on a good day) they can touch reality²⁶: indeed, no less than two Nobel-prizewinning physicists have recently published their commitments to reality (Roger Penrose 2004, and Frank Wilczek 2021). We all want to know *how the world is*. It is striking that where standard empiricism glosses over the idealistic foundations of how we interpret observations, Nicholas Maxwell's "*aim-oriented empiricism*" approach is predicated on the metaphysical priority of unified theories (2020). We look for, and value greatly, an underlying unity in our physical theories, just as we like to hold coherent views on things in general. We will have more to say on *unity* (§7).

Rovelli (2007 p.177) claims that we must "*choose between hiding away in empty truths or accepting the radical uncertainty of our knowledge*". But why can we not courageously affirm the "truths" to which we are committed, while also accepting (as Rovelli correctly says) that we can – and do – get things

²³ Charles Lowney (2020) says, in a discussion of Polanyi's (1958) seminal work: "*the Enlightenment's ... critical rationalism brought a "scientism" that justifies only facts based on physics and considers meaning and human values to be illusory*", but we don't say that Rovelli goes that far!

²⁴ What precisely is meant by "*the metanarrative of physics*"? Is it an implicit philosophical framework? Or perhaps a poetic background to the logical structure of theories? Neither (or, perhaps, both). We mean, the way we talk about the issue (in a natural language) so as to convey its *meaning*. We should try to be precise, but in the end our understandings must be incomplete and we have to live with ambiguity. Nature is, but our grasp of it is necessarily limited (see Deacon, 2011).

²⁵ James Lennox (2015) has this account: Aristotle opens his *Physics* with a discussion of the method [μέθοδος, *methodos*] proper to obtaining scientific knowledge [ἐπιστήμη, *epistēmē*] in a scientific enquiry [φύσιν ιστορίᾱς, *physin istorias*]. The word "μέθοδος" is formed from the noun ὁδός (a *road*) and the prefix μετα- (in this context having the force of "*in quest of*"), thus meaning "*a path taken in pursuit of ...*" (in this case, knowledge). Plato already used μέθοδος in the *Republic* [Πολιτεία, *Politeia*] speaking of "*the dialectical method*" [ἡ διαλεκτική μέθοδος, *ē dialektikē methodos*] as the only way to advance to first principles. Consequently, Aristotle understood very well that the scientific method is necessarily metaphysical.

²⁶ We are "alethic realists" in Leon-Philip Schäfer's terms (2024), although Philip Pullman's (1995) beautiful idea of Lyra's "alethiometer" can hardly be thought to "touch reality". However, at least one eminent physicist has claimed to be a solipsist; see *The Solipsist's Plea*: "Oh Universe! / I assume that you exist. / Let me feel your far flung matter, / so that your illusion may persist" (Joan Vaccaro's personal website, https://joanv.me/solipsists_plea/index.php, accessed on 30 April 2022).

wrong?²⁷ Catherine Elgin (2017) in her book *“True Enough”* has explored the concept of *truth* from an epistemological point of view. She establishes the unsatisfactory nature of the “veritist” position, since it is fatally undermined by fallibilism (and Rovelli insists that our knowledge is necessarily “radically uncertain”: 2007, p.177). Elgin explains, *“Making mistakes is an epistemic achievement”* (2017, p.291). We may know, but we cannot know infallibly. Again, she explains, *“To accept a contention is to be willing and able to use it as a premise in cognitively serious assertoric reasoning”* (ibid. p.293). We may find out later that we were in fact wrong and then we would have to change our minds, although to do this we may have to be very brave as well as very honest. But it is a real achievement if we succeed in changing our minds!

Leon-Philip Schäfer (2024) explains that “realism ... is, in the final analysis, best characterised as an alethic view which restricts itself to an idea about the objectivity of truth, rather than an epistemic view which underwrites more extensive theses concerning the accessibility of this truth for human knowledge.”²⁸ Although Schäfer is making technical (and rather limited) points, it is worth making the more general point that we are “alethic realists” in his terms: we (together with Rovelli) also think that, as he says, “realism matters because it is a presupposition of fallibilism: if truth is ... determined by the facts of reality, then it is particularly difficult to access the truth and perhaps even impossible to achieve certainty in doing so”, and indeed not only would we affirm that it is hard to know reality

²⁷ Kevin Scharp (2021) has attacked the very idea of “truth”, claiming that *“the concept of truth is defective in the sense that its platitudes are inconsistent”* (although he also acknowledges that *“There is a meaningful English word, ‘true’, and there is a concept of truth expressed by that word”*). But Jamin Asay (2024) has attacked this thesis on the grounds that Scharp’s programme for repairing the (admittedly useful) concept is in fact empty. Asay does not show that the “concept of truth” is not defective, but he does assert that (the concept) TRUTH *“may well be irreplaceable”*. We think that to do science effectively it is necessary to believe both that the world is real and also that we can know it truly. Thus, to be a scientist we think that a commitment to truth is indispensable (and it is interesting that both Scharp and Asay use the word “commit” and its cognates repeatedly and without philosophical discussion – that is, as a philosophical primitive).

²⁸ Schäfer explains that the consensus philosophical view in both science and metaethics is currently that realists take the discourses of their fields at face value, and oppose approaches that do not allow clear “true/false” judgments (so that they do not allow truth judgments to be determined by mind states). However he argues that such a position is misleading (indeed, actively false) because scientific and moral issues are treated differently. Crudely, scientific realists holding this consensus position will *not* be (philosophically) neutral about the truth of general relativity (for example) where moral realists *will* be (philosophically) neutral about abortion rights (for example). But Schäfer points out that philosophers as such do not have the authority to make such judgments in scientific matters, just as it is widely recognised that they have no authority (as philosophers) to make such judgments in ethics.

Schäfer intends to argue against *“constructivist principles and relativist themes”* (ibid. n.21). He calls *“scientific realism ... much more epistemically deformed than moral realism ... because its (alethic) core idea about truth has been turned into an (epistemic) view about our cognitive access to the truth”*. Schäfer contrasts this with *“moral realism”* which *“remains neutral regarding normative-ethical judgments [because] it does not involve any anti-sceptical commitments [identifying] metaphysical, instead of epistemic views as its primary opponents”* (where by “metaphysical” here he means “ontological”). Schäfer concludes by arguing that the approaches of the scientific realists on the one hand and the ethical realists on the other could be unified if they both embraced *“a return to alethic realism”*, by which term he means *“a realist conception of truth”*, that is that *“the (objective) truth is deemed to be independent from (subjective) opinions”*. And by “objective” he means “observer-independent”. He points out that *“alethic realists are not actually indifferent towards sceptical worries, but merely strive to keep their conception of realism free from such epistemic commitments”*.

but also we would deny that it is possible to achieve certainty about it (since reality is elusive). But truth is out there, and we are looking for it.

6. The Illusion of “Objectivity”

Karen Barad²⁹ has asserted, *“The primary ontological unit is the phenomenon”* (2007, p.333). This conclusion is reached following a long discussion of the meaning of quantum mechanics and the entanglements that follow from it. Barad points out that these entanglements entail a revision of what we mean by “objective”: *“Knowing is not a matter of reflecting at a distance; rather, it is an active and specific practice of engagement. To know is to become entangled: objectivity requires that one takes responsibility for one’s entanglements”* (ibid., Ch.7, n.1).

The EPR Paradox proposed by Einstein, Podolsky & Rosen in 1935 pointed out that *entanglement* of two particles apparently could persist over very large distances, meaning that a measurement on one particle would determine the result of a comparable measurement on the other, in apparent violation of the prohibition on instantaneous transmission of information. This paradox was resolved by John Bell in 1964, who established what became known as the “Bell Inequality” as a test for the existence of hidden variables in a local theory. The issue is the interpretation of reality in quantum mechanics: is quantum uncertainty³⁰ ontic or merely epistemic (as most of us would like to think)? Is Schrödinger’s cat really both alive and dead at the same time (because the states “alive” and “dead” are entangled), or is it merely that our ignorance is profound? Is knowledge objective? Are the things that science describes and explains really there? Disconcertingly, it turns out that entanglement is really real, as many “Bell Inequality” experiments have shown.³¹

We will discuss what is “fundamental” below (§8) but the EPR paradox and the consequent interest in establishing violations of the Bell Inequality are at the heart of our current understanding

²⁹ We thank Rachel Holland for pointing us to Barad’s important work. Karen Barad identifies as non-binary, so we intend the reader to treat as gender-neutral any personal pronouns we use referring to “her”.

³⁰ The Uncertainty Principle simply asserts that conjugate operators do not commute, with a definite “canonical commutation relation” which is $[\hat{x}, \hat{p}] = i\hbar$. This means (crudely), if you know exactly where you are you have no idea how fast you are going, and conversely, if you know exactly how fast you are going you have no idea where you are. Did you hear the one about Heisenberg stopped for speeding? *Policeman*: well Sir, do you know how fast you were going? *Heisenberg*: no, but I know where I am ... (<https://www.ams.org/publicoutreach/feature-column/fcarc-uncertainty>, accessed 17th April 2024). This “Uncertainty Principle” is quite general: Parker & Jeynes (2021; see their Eq.18a *passim*) have shown that it is a consequence of Liouville’s Theorem and applies to entropic as well as energetic systems (*mutatis mutandis*).

³¹ For example, Proietti *et al.* (2019) report an elegant three-photon-pair implementation of a “Wigner’s friend experiment” demonstrating a violation of the associated Bell inequality, which was glossed online as the assertion “Objective Reality Doesn’t Exist, Quantum Experiment Shows” (<https://www.livescience.com/objective-reality-not-exist-quantum-physicists.html>, accessed 14 December 2022). The paper opens with the assertion, “*The scientific method relies on facts, established through repeated measurements and agreed upon universally, independently of who observed them.*” But reality is elusive. In this case the results observed are *not* “objective” (in the sense that they are not observer-independent). As Karen Barad explains in detail, this does not mean that reality itself is illusory, only that knowing it is not necessarily very straightforward:

“Traditional philosophy has accustomed us to regard language as something secondary, and reality as something primary. [Niels] Bohr considered this attitude toward the relation between language and reality inappropriate. When one said to him that it cannot be language that is fundamental, but that it must be reality that, so to speak, lies beneath language, and of which language is a picture, he would reply, ‘We are suspended in language in such a way that we cannot say what is up and what is down. The word ‘reality’ is also a word, a word we must learn to use correctly’” (Barad 2007 p.205; quoting Petersen 1985).

of reality and of our current approach to the “scientific method”. It turns out that for entangled systems we cannot use our standard notions of “objectivity” [observer independence], which are simply too crude: that very idea of “objectivity” is an approximation, and sometimes the approximation is just not good enough. The issue is locality versus non-locality, and causality versus acausality³² (and these apparently ‘simple’ dichotomies become seriously more complicated when time is complexified, see Parker & Jeynes 2023a discussed below §7). Entangled systems may have effects that are astonishingly non-local. And it may be that these are far more numerous and important than we have thought up to now. After all, we typically don’t see what we don’t expect (or what we don’t think exists)!

Barad makes the point (in the light of the quantum revolution) that our Newtonian view of the distinct knowability of *objects* as such (electrons, protons, etc.) is faulty. Strictly speaking, there is no such thing as “an electron” *per se*, since all electrons in the universe are more or less entangled together (being indistinguishable). The idea of a *single electron* is a convenient (and very successful) word game that enables us to set up effective models that allow us to correctly interpret certain sufficiently simple phenomena. But Barad insists: “No inherent ... subject/object distinction exists” (*ibid.* p.114).

Faye & Jaksland (2021)³³ concentrate on Barad’s proposal of “*agential realism*”, commenting that her account has been very influential in the humanities and implying that it has been ignored by

³² Thomas Hertog speaks of “*the orthodox way of reasoning in physics [which seeks] a fundamentally causal explanation for the universe’s biofriendliness*” (2023, p.198), going on to say: “*The first bottom-up attempt to untangle the riddle of design was to search for a profound mathematical truth at the kernel of existence ... But top-down cosmology turns the riddle of design upside down.*” Hertog and Stephen Hawking had concluded (with most other commentators today, including Rovelli) that those “*profound mathematical truths*” just did not exist, and another way of proceeding was needed.

David Bohm also commented on these (alleged) “*profound mathematical truths*”, also saying in effect that they did not exist, since “touching reality” is *guided* by mathematics, not *expressed* by it:

“... until the present [20th] century, the physical concepts were, for the most part, considered as primary, while mathematical equations were regarded as providing a more precise and detailed way of talking about [them] ... [but] during the 1920s Sir James Jeans said that God must be a mathematician, implying by this that the universe is constructed on a mathematical plan and that its essence is best grasped in terms of the mathematics itself. ... Heisenberg went much further along these lines and said very explicitly that the essential truth was in the mathematics. This view has become the common one among most of the modern theoretical physicists who now regard the equations as providing their most immediate contact with nature (the experiments only confirming or refuting the correctness of this contact). So without an equation there is really nothing to talk about. On the other hand, in the past we began talking about our concept of physical reality and used the equations to talk about them” (Bohm & Hiley, 1993. p.320).

Bohm is right: the formulation of our ideas in mathematical terms should be regarded simply as a systematic method of ensuring the integrity of complex logical arguments, with the mathematics ensuring the *validity* of the argument but saying nothing about its *truth*. That is, mathematics provides the disambiguated analytical narrative, whereas the (poetic) metanarrative is required to discern truth (see Jeynes *et al.* 2023). We must take Gödel’s metamathematical breakthrough seriously (Gödel, 1931; see §11).

³³ Karen Barad’s (2007) proposal of “*agential realism*” involves “*rethinking the relationship between materiality and signification*” (*ibid.* p.132). Faye & Jaksland (2021) comment on “*the widespread reception of Barad’s account of quantum mechanics ... in the social sciences and humanities*”, evaluate the relation of Barad’s proposal to Niels Bohr’s position, and assert that they are the first to assess “*Barad’s claim that agential realism, apart from its importance to social theorizing, is making a ‘specific scientific contribution to an active scientific research field (i.e., the foundations*

of quantum physics)’” (*ibid.*, quoting Barad 2007 p.36, and pointing out that Barad herself has not published on agential realism in the physics or philosophy of physics literature).

Faye & Jaksland assert that they refute “*Barad’s claim that agential realism captures the consequences of quantum mechanics for all domains of inquiry including social theorizing*” (*ibid.*). But what Barad says is not quite what they say she says: “*What is needed is an analysis that enables us to theorize the social and natural together ... To write matter and meaning into separate categories ... is to elide certain crucial aspects by design*” (*ibid.* p.25). (This is also closely related to Atmanspacher’s (2024) idea of “psychophysical neutrality”; see the discussion below, §7). The point of course is that one is unable to speak sensibly of “*matter*” without also being able to say what one *means*. We cannot say anything coherent about *matter* without also being able to say how we know such things, which involves speaking of the experiments one has to do (and interpret) and the measurements one must make. But measurement itself is much more anthropocentric than is commonly thought: metrologists themselves have drawn a careful philosophical distinction between *being a quantity* and *being measurable*. They point out that this distinction is an ontological one, and moreover, that “*measurement is primarily an epistemic process*” (Mari *et al.* 2013, 2021).

However, we believe that Faye & Jaksland’s conclusion (“*that neither Bohr nor quantum mechanics as a whole proves Barad’s agential realism to be true*”) is correct, if underwhelming. But they go on to point out, also correctly: “*Barad’s ideas are profound, interesting, and thought provoking, but like any other piece of social theorizing, agential realism must earn its merits, if any, by its utility and not by its quantum mechanical origin*” (where “utility” in this case – counter-intuitively – must be taken as idealistic rather than utilitarian). We are of the view that one does not have to swallow all of Barad’s position on “agential realism” to see the value of her position on the ontological priority of phenomena, a position that plays havoc with conventional views of “objectivity”.

Together with Faye & Jaksland we also look askance at the ideas of “quantum anthropologies” or “quantum geography” (for example), but we shouldn’t let the errors of youthful exuberance eclipse the deeper truth that we see as we are taught, most of the time, and it is a serious effort to see differently. And physics can help in upsetting the “common sense” views we are thoughtlessly wedded to so much of the time. We are convinced that our best scientific insights can indeed help to expose the substance of reality.

Faye & Jaksland claim that “*Barad’s summary ... is not entirely faithful to Bohr’s view ... [going] well beyond what Bohr seems to have had in mind when [Barad] promotes the phenomenon to an ontological unit*”: they insist that Bohr thought that “*This effect, i.e. the phenomenon, is the manifestation of a property that only exists in virtue of the interaction. It belongs neither to the object itself nor to the measuring instrument.*” This seems debatable to us (Bohr’s philosophy is notoriously impenetrable) – in any case Barad is not compelled to follow Bohr slavishly: and even if the former master’s view can be determined accurately, that does not mean that he wouldn’t take a different view today in the light of the further information available. Faye & Jaksland say, “*Barad misreads Bohr as if he was saying that, say, the position is a property of the phenomenon, whereas Bohr holds that the phenomenon is identical to the manifestation of a quantitative property that atomic objects can be attributed only because of its interaction with the measuring instrument. Thus, a phenomenon does not have an independent ontological status but depends on an interaction of the atomic object and the measuring instrument. Both of which, by the operational presumption of doing science, are presumed to be independently real.*”

Our judgment is that the last sentence is the crux: “*Both [the atomic object and the measuring instrument], by the operational presumption of doing science, are presumed to be independently real.*” We have already quoted Bohr himself: “*The word ‘reality’ is also a word, a word we must learn to use correctly*”. How are we assured of the “independent reality” of the “atomic object”? We regard Barad as being correct in pointing to the systematic entanglements of (supposed) “atomic objects” in a way that plays havoc with our naïve ideas of what “objects” are.

physicists (also critically unpicking Barad's treatment of Niels Bohr). They point out that Barad herself has not published on agential realism in the physics or philosophy of physics literature. They assert that "*agential realism [is] a theoretical framework that ... aims to inform social theorizing*".

But Barad is far more ambitious than that, she wants to rewrite ontology itself: "Existence is not an individual affair" (p.ix); "mattering is an integral part of the ontology of the world ... not even a moment exists on its own" (p.396). The world is really there, but only agents can know it. And the agents are themselves necessarily entangled in the world.

We are convinced that our best scientific insights can indeed help to expose the substance of reality. Therefore we regard it as axiomatic that, just as truth is one so reality must also be an integrated thing. Then our view as natural scientists of reality must be consistent with our view of it as concerned citizens (or poets). And consequently, we cannot treat insights into reality obtained from the natural sciences as "mere metaphors", the link is stronger than that. Iris Murdoch (1967³⁴) was very definite about this: "*Metaphors are not merely peripheral decoration or even useful models, they are fundamental forms of the awareness of our condition ... it seems to me impossible to discuss certain kinds of concepts without the resort to metaphor, since the concepts are themselves deeply metaphorical and cannot be analysed into non-metaphorical components without a loss of substance*".

Murdoch speaks of the unanalysable (non-analytic) nature of the use of language together with its rhetorical tropes (including *metaphor*), since she is deeply interested in the "*substance*" of reality, both as a philosopher and also as a novelist. The substance of reality as exposed by our best scientific insights, is not a different thing from the substance of reality as it impinges on our social lives, even if scientists tend to have a "Blind Spot"³⁵ when thinking about these wider issues.

George Berkeley long ago (1710) pointed out the centrality of perception to our ontological ideas (*esse est percipi*): it seems to us that Barad is only pushing this account towards a logical conclusion that appears to be consistent with the sophisticated observations of modern physics. The issue, precisely, is that our dominating intuition that integrity and unity must be of ontological significance appears to be incoherently articulated by our conventional (admittedly Newtonian) views of "objects". It seems that "cause-and-effect" is not as "simple" as we had naïvely thought, and this is underlined by the unexpected re-appearance of the idea of "non-locality" which had already disturbed Newton (he worried that gravity, "action at a distance", was not "properly" mechanistic: see Ducheyne 2011).

It is worth underlining this point. Barad correctly says that "*for Bohr, things do not have inherently determinate boundaries or properties, and words do not have inherently determinate meanings*" (2007, p.138). The practice of science is an intricately human activity. Even "doing experiments" is philosophically complicated. Barad quotes Ian Hacking (1983, p.230): "*most experiments don't work most of the time. To ignore this fact is to forget what experimentation is doing ... only when one has got the equipment running right is one in a position to make and record observations. That is a picnic*" (Barad, 2007, p.144f). How do we account, philosophically speaking, for the way the experimenter gets the experiment to work? It is important to realise that this typically takes a long time: even little experiments usually take days to set up, and big ones may take years for large teams.

Experimenters always want to *measure* something, and measurement necessarily requires a "*measurement model*", that is, according to the authoritative *International Vocabulary of Metrology* (JCGM 2008, §2.48), "*a mathematical relation among all quantities known to be involved in a measurement*". This is very demanding of the experimenters: for examples see Jeynes *et al.* 2012, and Jeynes *et al.* 2020.

³⁴ We thank Julia Jordan for alerting us to Murdoch's significant contribution

³⁵ Frank *et al.* (2024, p.viii) assert that "*Our scientific worldview ... ultimately runs aground on its own paradoxes of inner versus outer, and observer versus observed, that collectively turn on the conundrum of how to understand awareness and subjectivity in a universe that was supposed to be fully describable in objective scientific terms without reference to the mind.*" They call this conundrum the "**Blind Spot**" in analogy to the optical "blind spot"

Parker & Jeynes (2023a) give a more complete physics that is explicit in treating commensurately the local and the non-local, the causal and acausal, the reversible and the irreversible. They do this by systematically complexifying the entire formalism (with spacetime now utilising complex time, where the complex time plane has both “real” and “imaginary” axes³⁶) and then making full use of the mathematical power of complex analysis. The result (expressed in holographic natural units) is that the (Wick rotated) complex conjugate of the system Hamiltonian (representing the system *energy*) is shown to be the (complex) *entropy production* (which normally expresses the non-local restraints on the system).³⁷ Together, they are also found to be Hilbert transforms of each other, which (among other things) express a set of (continuum) cause-and-effect relationships across the 2-dimensional complex temporal plane. This result is seriously disturbing, since it mixes up categories that we thought we understood, as well as involving “complex time”. It also disallows the possibility of a unique cause-and-effect relationship for any particular set of phenomena. Complex time is an idea which seems very weird but which is becoming more familiar.

Essentially here we are asserting that the “subjective/objective” distinction is a category error if it is used to inform discussions of reality. Grammatical terms should not be used for ontological purposes. Rather the truth of any statement is to be found through the interplay of its syntactical (narrative and analytical) and semantic (metanarrative and poetical) components.

7. On Unity

(where the optic nerve exits the retina): *“At the heart of science lies something we do not see that makes science possible, just as the blind spot lies at the heart of our visual field and makes seeing possible”* (ibid., p.xi).

We are grateful to Robert Crease for introducing us to this important work.

³⁶ There is nothing intrinsically “imaginary” about imaginary numbers, just as “real” numbers aren’t intrinsically real. We only have this terminology because Descartes thought that the square root of -1 ($\sqrt{-1}$) was a fiction of the mathematicians. Roger Penrose explains: “... the seemingly mystical quantity $\sqrt{-1}$ [was] first encountered in the 16th century, but treated for hundreds of years with distrust ... until complex numbers became an indispensable, even magical, ingredient of our mathematical thinking ... these strange numbers also play an extraordinary and very basic role in the operation of the physical universe ...” (2004, §3.5, p.67). It is telling that Penrose uses the word “magical” (figuratively, of course): his chapter 4 is even titled “Magical Complex Numbers”. Note: a “complex number” is one that has both a “real” and an “imaginary” part.

³⁷ Apologies for the heavily technical language. All these arcane terms are “standard” and “well known” to mathematical physicists for proper explanation of which the reader is referred to the literature.

On the idea of “complex time”, *time* is “imaginary” in 4D Minkowski space-time. But this is a convention: Thomas Hertog (2023, p.240) has mused, in the context of a deep discussion of holographic cosmology: *“What if we conceive of AdS [anti-de-Sitter space] and its antipode in imaginary time?”*.

Whether time is imaginary and space is real (with the “signature” ‘- + + +’) or time is real and space imaginary (with the “signature” ‘+ - - -’) is largely a matter of convenience (see the discussion of ‘signatures’ in Penrose, 2004, §13.8, p.281). Note (again) that there is nothing particularly imaginary about “imaginary” numbers (involving $\sqrt{-1}$; these were called “imaginary” by Descartes because he didn’t believe they could be useful) just as there is nothing particularly real about “real” numbers.

But imaginary time also appears in “standard” quantum mechanics (see for example McGlynn & Simenel 2020), using the ‘Wick rotation’ (helpfully explained by O’Brien 1975). “Complex” time has been introduced by other contributors: most notably Ivo Dinov’s “spacekime” (for example Wang *et al.* 2022); but also Carl Frederick’s ideas of “granular space-time” (2022), and Philip K Dick’s “orthogonal time” (published posthumously, 2011). Exactly how these various ideas are related remains to be seen. (We are grateful to William Sarill, email 11th April 2024, for drawing our attention to these connections.)

Nicholas Maxwell (2020) insists, and we think he must be correct, that “*physics accepts only unified theories*”. This recalls Leszek Nowak’s conception of the *unity of science*, not mentioned by Maxwell but discussed in detail by Mateusz Wajzer (2024), who says (without mentioning Maxwell), “*Nowak concluded ... that scientific theories do not arise from the generalisation of empirical facts, and they are far from hypothetical-deductive systems ... idealisation, not abstraction, is at the core of the scientific method*”. Wajzer undoubtedly is correct to emphasise the centrality of *idealisation*³⁸.

Unity is an indispensable metaphysical idea without which (in our view) science would be impossible, and knowledge would be unattainable. Truth must be *one* to mean anything at all.³⁹ The rest mass of the electron is close to 9.10^{-31} kg (or 511 keV). This is true whoever or wherever you are. We can debate the uncertainties (which are very small for this parameter), and we can debate whether an individual “electron” can be thought even to exist *per se* (*pace* Barad 2007), and we can debate the difference between an interpretation we put onto an observed phenomenon and the posited entity being observed, and so on; but after all, we know the value we need to use for the rest mass of the thing we model as “an electron”.

It is disconcerting that even for the simplest possible example (the mass of a fundamental particle) such a periphrasis is required for adequate accuracy. Reality is elusive.

Do “unitary entities” exist? Gottfried Leibniz (1714) thought they did, and famously called them “monads”. But it was Henry More in the 17th century who coined the term “monad”, and it was the “metaphysical poets” who were deeply interested in the idea of “atoms”⁴⁰. We consider the archaic term “monad” to be essentially synonymous with the more modern “unitary entity” that we use here.

³⁸ This recalls Catherine Elgin’s (2017) assertion that idealisations are not *true* in the way epistemologists would like (instead, they are “*true enough*”!); she urges that “*belief, assertion and knowledge should be sidelined in favor of acceptance, profession and understanding*” (p.9). We thank an anonymous referee for alerting us to Elgin’s important book.

Mateusz Wajzer (2021) correctly says that “*reductionism ... can be considered as a standard cognitive procedure applied in science*”. But, as with all procedures, there are limits! We show (§8) that it is false to regard fundamental particles as invariably the most fundamental representation: in some circumstances there demonstrably exist unitary entities at least as “fundamental” as recognised “fundamental particles”. Wajzer’s comment (2021) that scientific models are usually “*counterfactually deformed and ontically poorer*” representations is fair: but scientific realists will recognise this ontic poverty and be open to richer representations.

³⁹ Ultimately, if truth is not one then nothing can be known. Of course, different actors have different assessments of what is true, and it may not always be possible to tell who is right. Reality is elusive. Monserrat Neto points out (email 11/4/2025) that in disciplines like sociology or psychology (for example), perceived “truth” may take more plural and context-dependent forms.

⁴⁰ Henry More explained the term in the glossary concluding his *Philosophicall Poems* (1642): “*Monad. Μονάς, is Unitas, the principle of all numbers, an embleme of the Deity: and the Pythagoreans call it Θεός, God. It is from μένειν because it is μόνιμος, stable and unmovable, a firm Cube of itself. One time one time one still remains one*” (he means, $1^3=1$: quoted in Cassandra Gorman 2021 p.50).

More, together with all his 17th century readers, would have heard in the word “Cube” echoes not only of the Pythagorean Cube (the source of the element of earth) but also of the Biblical “*Holy of Holies*” (a cube of dimension “20 cubits” – that is, about 9 metres, see *1Kings* 6:20, notionally a text from the 6th century BCE). See the Christian mirror of this in the “Holy City”, a cube of size 12000 stadia (2200 km; see *Revelation* 21:16, a text tentatively dated 68 CE by John Robinson, 1976).

On the term *monad* More explicitly cites Pythagoras, ignoring Giordano Bruno’s use of the term. Gorman explains that in his earlier work More used the term “*atom*”, only later preferring “*monad*” (or “*physical monad*”). Wilczek (2021, p.72, ch.3) cites Democritus (3rd century BCE) as author of “*the founding document of atomism*”. But this is historically incorrect since the 17th century scholars put effectively no weight on Democritus (see Gorman, 2021).

Using the new Quantitative Geometrical Thermodynamics (QGT: Parker & Jeynes 2019⁴¹) Parker et al. (2022) have recently demonstrated (without any quantum mechanics) that the alpha particle can be considered an *atom*, that is not strictly *indivisible* of course (since it consists of two protons and two neutrons) but *indiscernible*⁴² (since it strongly resists being *torn asunder* due to its very high binding energy). In QGT terms an “atom” is a “*unitary entity*” (that is: *than which exists nothing simpler*) which has the fewest possible degrees of freedom (when considered at the appropriate length scale).

Thus, in its lowest energy (“ground”) state the alpha (⁴He) is unitary⁴³. It turns out that the nuclear sizes of the helium isotopes ⁶He and ⁸He can also be obtained by QGT: but these isotopes are *not* unitary since they are unions of the (unitary) alpha and a (unitary) neutron halo: that is, ⁶He has a 2-neutron halo (the “dineutron”) and ⁸He has a 4-neutron halo (the “tetraneutron”). Even though the tetraneutron is on its own very unstable (disintegrating almost immediately into four separate neutrons), it is curious that Parker & Jeynes can also correctly calculate its lifetime by QGT by treating it as unitary (2023b).

It is also curious that the physicists love the image of “*Borromean rings*” (exemplified by the ⁶He and ¹²C nuclei⁴⁴): Constantino Tsallis (2024) calls the Borromean rings “*a beautiful metaphor for complex*

⁴¹ QGT can be mathematically described using the properties of holomorphic functions (complex differentiable – a very strong condition, see Penrose 2004 §8.2; “holomorphic” literally means “*the shape of wholeness*”): more than that, certain Maximum Entropy entities (the double-helix and the double logarithmic spiral, DLS) are found to be holomorphic in QGT. In fact, the double-helix is a special case of the DLS, and both are fundamental eigenvectors of the *entropic* Hamiltonian, and Parker & Jeynes (2021) have proved *entropy production* to be a conserved quantity.

Parker & Jeynes (2019) have used the holomorphic properties of the DLS to calculate observables of both DNA (including its chirality: the “right-handedness” of natural DNA was first shown to be a consequence of the Second Law of Thermodynamics by Parker & Walker 2010, in an information-theoretic context, and later more rigorously by Parker & Jeynes 2019, Appendix A); and also of the Milky Way (*ibid.*, Figures 1 & 2 *passim*).

Parker & Jeynes (2020) also analytically proved the stability of Buckminsterfullerene, a known result having been done constructively (using computational chemistry methods requiring significant super-computer time). However, such methods are much harder to understand as well as being far more expensive and not at all easy to generalise.

⁴² In the 17th century they were wary of claiming strict *indivisibility* (after all, could not the omnipotent God divide it if he wished?) so they used *indiscernible* (another of Henry More’s neologisms, now considered obsolete) instead. In the 21st century Parker *et al.* (2022) have found a real example of this indivisible/indiscernible distinction, since treating the alpha particle as a *unitary entity* enables them to calculate its size *ab initio* using QGT.

⁴³ Strictly, we should write ⁴He⁺⁺ since the helium nucleus is doubly charged (having two protons). A helium *atom* as commonly spoken of also has two bound electrons (that is, it is electrically neutral) and is enormous (radius 28 pm) compared to the ⁴He⁺⁺ nucleus (radius 1.7 fm; “pm” is picometers; “fm” is femtometers). But it is very easy to detach the electrons, so the (neutral) helium “*atom*” is misnamed (for historical reasons): that is, it is very far from being *indivisible*! We regard ⁴He⁺⁺ as truly being an *atom* in More’s sense (but indiscernible, not indivisible), or a *monad* in Leibniz’ sense. To avoid confusion we use “unitary entity”.

⁴⁴ For ⁶He, if the alpha (the ⁴He) or either of the halo neutrons is lost the resulting nucleus (the dineutron or ⁵He) is particle-unstable and disintegrates. If any of the constituent alphas is lost to the ¹²C nucleus, the resulting nucleus (⁸Be, an isotope of beryllium: this element has only one stable isotope ⁹Be) is particle-unstable and disintegrates (with a lifetime also obtainable by QGT: Parker & Jeynes 2023b).

Borromean rings are an ancient and widely distributed symbol of unity: there are well known examples in 6th century India (a temple in Thiruvannamalai, South Chennai: Lakshminarayan 2007) and in 7th century Norway (on the *Stora Hammars I* image stone). The Borromean rings were also well known in the Christian world as a metaphor for the unity of the Trinity: the earliest known image is in a c.1210 manuscript of Peter of Poitiers

systems". According to QGT (Parker et al. 2022) ^{12}C consists of a union of three alphas, as is also indicated experimentally: see the review by Freer & Fynbo (2014), who say that " ^{12}C is believed to possess a rather unusual structure, where the dominant degrees of freedom are those of α -particle clusters rather than nucleons".

The QGT treatment of ^{12}C is as a union of a unitary alpha and a unitary di-alpha, where the identity of the di-alpha is indeterminate (that is: of the three alphas in ^{12}C only two are involved, but which two is indeterminate; see Parker et al. 2022). This has a molecular parallel in the benzene molecule, which has three single bonds and three double bonds in the carbon ring, but specifically which carbon atoms have which bond is indeterminate⁴⁵.

Raphael Bousso (2002) has reviewed Gerard 't Hooft's idea of the "Holographic Principle" which asserts that the information⁴⁶ in a volume can be represented completely on the enclosing area. Parker & Jeynes (2021) have independently derived this "Principle" (represented by the Bekenstein-Hawking equation⁴⁷) from the *entropic* Liouville theorem, and applied it to unitary objects to obtain ab initio the size of the alpha particle (also related nuclei; Parker et al. 2022, who use the QGT formalism without any quantum mechanics). "Holographic" literally means "*writing the whole*" (that is, writing all the 3D information into 2D). It turns out, surprisingly, that the Bekenstein-Hawking equation applies not only to alpha particles (*ibid.*) but also to black holes (Parker & Jeynes 2023a). And both black holes and alpha particles may be treated (in QGT) as "atoms", that is, as *unitary entities* (than which exist no simpler) with quantitatively correct results. Note that while the alpha is only *indiscernible*, the black hole is actually *indivisible* (meaning, in 17th century terms, that not even God could divide it: that is, in modern terms, to speak of its division is to speak nonsense).

Berry & Dennis (2003) have looked for unity in their treatment of the case of classical crystal optics, which turns out to be much richer than expected. They say that "*the physics and the underlying mathematics can appear complicated, especially in the most general case of crystals that possess natural optical activity (chirality) and dichroism (absorption) in addition to biaxial birefringence*". But they find "*a geometrical approach*" which "*unifies and clarifies the many different phenomena that can occur*". What is interesting here is a) that their treatment is entirely classical, and b) that their "geometrical" methods treat abstractions of abstractions. Reality is elusive, and its elusiveness is intrinsic – quantum

(Pictaviensis, 1210). This is the *Scutum Fidei* ("shield of faith" – see Ephesians 6:16 in the Vulgate: "*in omnibus sumentes scutum fidei, in quo possitis omnia tela nequissimi ignea extinguere*"; Jerome, 405): this image is usually referred to in English as "*Shield of the Trinity*".

⁴⁵ Benzene is usually spoken of in terms of "*Kekulé resonances*" and "*delocalisation of the π electrons*". The details of the benzene ring continue to stimulate research (see Yirong Mo, 2009) and it seems likely that a QGT treatment of benzene like the one available for Buckminsterfullerene (Parker & Jeynes 2020) would be analytically satisfying.

⁴⁶ Information and thermodynamics have a very close relation since a communications system in thermodynamic equilibrium can transmit no actual information, as was proved by Parker & Walker (2014).

Thomas Hertog waxes lyrical about "holography" (2023, p.213 *passim*): "*The theoretical discovery of holography ranks among the most important and far-reaching discoveries in physics of the late twentieth century ... The development of a holographic cosmology ... is a journey deep into the cutting edge of theoretical physics, interlinking far-flung fields, from quantum information to black holes and cosmology ...*"

⁴⁷ Roger Penrose (2004, §27.10, p.715) explains: "*According to the famous Bekenstein-Hawking formula, a well-defined entropy can indeed be attributed to a black hole ... Note the appearance of Planck's constant, as well as the gravitational constant, indicating that this entropy is a "quantum-gravitational" effect. Indeed, this is the first place where we have encountered both the fundamental constant of quantum mechanics ... and that of general relativity ... appearing together in the same formula*" (emphasis original).

The Bekenstein-Hawking equation was originally devised by Jacob Bekenstein in 1972 to express the entropy of black holes. But although the BH equation expresses "black hole thermodynamics", Parker and others (2022, 2023a) have shown recently that it is applicable at all scales.

mechanics, general relativity and classical crystal optics are all independently mind-bogglingly intricate. QGT is also essentially (and abstractly) geometrical, and treats reversibility and irreversibility commensurately (Parker & Jeynes 2023a) just as Berry & Dennis can treat the general case (including dichroism which involves irreversibility). These issues are addressed at some length in the mini-Review of Jeynes (2023).

Harald Atmanspacher’s (2024) mereological review⁴⁸ of how *unity* is manifested in a disunited world, concentrates in particular on the distinction between “*the mental and the physical*”. He points out that there exists a “*domain of reality*” neither mental nor physical: in this domain there is a “*psychophysical neutrality*” between mind and matter. Physical science examples of psychophysically neutral positions are the “*mathematical Platonism*” of (for example) Roger Penrose (2007) and the “*implicate order*” of David Bohm (1980).

The ancient poet exclaimed (Psalm 133:1), “*Behold, how good and joyful a thing it is: brethren, to dwell together in unity*”⁴⁹, but the word “unity” is present neither in the Hebrew original nor in the ancient Greek translation (the Septuagint). It seems that “unity” (ένότητα) is a relatively modern

⁴⁸ Mereology (from the Greek μέρος, ‘part’) is the theory of parthood relations: of the relations of part to whole and the relations of part to part within a whole. (Stanford Encyclopedia of Philosophy)

Atmanspacher speaks of “mathematical Platonism” which he says is “a position in the philosophy of mathematics that has been promoted by many outstanding mathematicians from Gauss to Frege, Gödel, Penrose, Connes, and others ... Mathematicians prove theorems with their mental capacities, but the truth of a theorem is anchored in the psychophysically neutral domain.”

Atmanspacher gives wide-ranging examples of “psychophysical neutrality”, including (from physics) David Bohm’s idea of the “implicate order” (1980): Bohm points out that “*It is generally agreed that ... relativity [has not been] united with quantum theory in a fully consistent way ... the basic order implied in relativity theory and quantum theory are qualitatively in complete contradiction. Thus relativity requires strict continuity, strict causality and strict locality in the order of the movement of particles and fields ... in essence quantum mechanics implies the opposite.*” Bohm is looking for a “qualitatively new idea” and proposes that “*What they have in common is actually a quality of unbroken wholeness*” (Bohm & Hiley 1993, p.351f, his emphasis). Atmanspacher says of Bohm’s idea that it has “*much beauty and stringency*” (although Bohm’s treatment is “*hardly transparent*” to “*non-expert readers*”, involving detailed discussion of Clifford algebra, Hilbert space etc. – such things are beloved of mathematicians and theoretical physicists and there is a very large and interesting literature on them, unfortunately way beyond our scope here).

Interestingly for us, Atmanspacher regards “meaning” as an important example of substantiating some relationship with the physical aspect of reality: “*However seductive it may be to regard the concept of meaning ‘simply’ as an element of the mental domain, the view presented here considers this as ... the fallacy of a misplaced reification of a fundamentally relational concept – far too ‘simplistic’ ... to do justice to the subtle intricacies of the mind-matter problem*”. Reality is elusive: it is necessary to pay close attention to at least some “subtle intricacies”.

⁴⁹ Coverdale’s wording, taken from the Book of Common Prayer (originally authorised in 1558 by Elizabeth I’s Act of Uniformity).

Psalms are very hard to date, but Ps.133 may have been composed c.9th century BCE. The present Hebrew text (with vocalisation) is [הֵנָּה מְשֻׁבִּים וְיִמְהַלְּכִים יָשָׁבוּ אֲחֵיהֶם גַּם־יִחַד], translated as: “*How good and how pleasant it is that brothers dwell together*” (JPS 2000), or “*Look, how good and how pleasant is the dwelling of brothers together*” (Alter, 2007). The unvocalised text is usually taken as c.500BCE. The idea of “unity” can be thought to be implied in the text, but it is not explicit. Nor is it explicit in the Septuagint (the 3rd century BCE translation of the Hebrew into Greek): “*Ἰδοὺ δὴ τί καλὸν ἢ τί τερπνόν, ἀλλ’ ἢ τὸ κατοικεῖν ἀδελφούς ἐπὶ τὸ αὐτό*” (Apostoliki 1996).

idea, in Biblical texts first explicit⁵⁰ at Ephesians 4:3 (dated at 58 CE by John Robinson, 1976: “keep the unity of the Spirit in the bond of peace”)⁵¹, even though the idea of “one” (as a cardinal number) is very ancient (“Hear O Israel, the LORD your God, the LORD is one”: Deuteronomy 6:4)⁵². It is disconcerting that the idea of “unity” (the quality of one-ness) appears to have been current for barely 2 millennia. It seems that previously the idea was not so urgently needed.

Perhaps the very idea of “unity” is harder to grasp than one might think? Prior to St.Paul’s use of it in *Ephesians* it was used only very rarely: for example, Aristotle uses it in passing⁵³ (in a text acknowledged as “esoteric” – baffling students ever since) trying to speak coherently about *substance* (οὐσία), about what is fundamental, and about how change happens. “Unity” in such a context is clearly not a trivial idea! But Paul is speaking to everyone, not just the academics.

⁵⁰ “Unity” was not a neologism of Paul’s (appearing as “ἐνότης” in *Ephesians*) since Aristotle used it previously (as “ἐνότης” in the *Metaphysics* 1018a7). In just the same way, “atonement” (“at-one-ment”: an Englishing of the Latinate “reconciliation”) was not a neologism of William Tyndale, since the Oxford English Dictionary credits Thomas More with first usage a decade earlier. But just as Paul brought the idea of “unity” to a much wider public it was Tyndale (1526) who brought the word “atonement” (and its cognates) to a much wider public:

“Therefore yff eny mā be in Chrift/he is a newe creature. ... Nevertherleffe all thig^l are of god / which hath reconciled us unto hym felfe by Jesus Chrift/and hath geven unto us the office to preache the **atonement**. For god was T Chrift/ād made agreement bitwene the worlde and hym felfe / and imputed not their synnes unto them: and hath committed to us the preachynge of the **atonement**. ... So praye we you T Chriftes ftede/that ye be **atone** with God ...” (2Corinthians 5:17ff, Tyndale 1526) using the original spelling, including the long s (“f”) and the abbreviation for “n” (so that “ād” means “and”).

It was Tyndale’s influential translation of the Pentateuch (1530) that interpreted [יִּוִּם הַכִּפּוּרִים] (*yōwm hakkippurīm*), as “the Day of Atonement” (*Yom Kippur*, Leviticus 23:27 *passim*), an interpretation that has stuck in English, even though the primary meaning of [כָּפַר] is “cover” (see Genesis 6:14, “ἀσφαλτ” in the LXX).

⁵¹ “τηρεῖν τὴν ἐνότητα τοῦ πνεύματος ἐν τῷ συνδέσμῳ τῆς εἰρήνης” (Adelphothes 2000). Here “unity” ἐνότητα is explicit, and underlined in the next verse: “ἐν σῶμα καὶ ἐν πνεύμα...εἷς κύριος, μία πίστις, ἐν βάπτισμα”. Although this usage is commonplace today, the use of ἐνότητα here looks like a deliberate neologism explained in the following verse. Plainly, Paul had Ps.133 in mind: deliberately recasting the Hebrew texts to make them accessible to his pagan hearers.

⁵² Deuteronomy is usually dated c.8th century BCE, although it is traditionally claimed that an original version was composed by Moses, perhaps 17th century BCE. The (unvocalised) text we have is usually credited to Ezra the Scribe, c.500 BCE. The Hebrew text (with vocalisation) is: [שְׁמַע יִשְׂרָאֵל יְהוָה יְהוָה יְהוָה יְהוָה יְהוָה] which is translated (JPS 2000) as: “Hear, O Israel, the LORD is our God, the LORD alone”. Note that JPS interprets [יְהוָה] as “alone” rather than the cardinal number “one” (as in other places). The Septuagint Greek (3rd century BCE) is: “Ἀκουε, Ἰσραὴλ· Κύριος ὁ Θεὸς ἡμῶν Κύριος εἷς ἐστι” (Apostoliki 1996: using εἷς puts a slightly different gloss on the Hebrew). The ancient poets always want us to hear multiple meanings: they intend (and relish) ambiguity (see Ossa-Richardson, 2019).

⁵³ In the *Metaphysics* (Book Delta) as “unity of being” (ἐνότης τίς ἐστιν): καὶ τὰ μὲν οὕτως λέγεται ταῦτά, τὰ δὲ καθ’ αὐτὰ ὁσαυχῶσπερ καὶ τὸ ἐν· καὶ γὰρ ὧν ἡ ὕλη μία ἢ εἶδει ἢ ἀριθμῷ ταῦτά λέγεται καὶ ὧν ἡ οὐσία μία, ὥστε φανερόν ὅτι ἡ ταυτότης ἐνότης τίς ἐστιν ἢ πλειόνων τοῦ εἶναι ἢ ὅταν χρῆται ὡς πλείοσιν, οἷον ὅταν λέγῃ αὐτὸ αὐτῷ ταυτόν· ὡς δυοὶ γὰρ χρῆται αὐτῷ (Τῶν Μετὰ τὰ Φυσικὰ Δ 1018a4-9; Ross 1924, p.259f; thanks to Margaret Barker for this reference). This is translated (rather freely, by Lawson-Tancred, 1998) as: “There are as many cases of this as there are of per se [“καθ’ αὐτὰ”] unity. Those things are said to be the same whose matter is either formally or numerically one and also those things whose substance is one so that it is clear that identity is a kind of **unity of being** either for a plurality or for a single thing treated as a plurality, as is the case when we say that something is the same as itself and thereby treat it as two”.

Aristotle's physics is notoriously *teleological*, an aspect that physicists (and biologists) today are allergic to (for very good reason!). Today, the conventional wisdom is that the Universe is *ateleological* – it has no purpose. However, a unified account presupposes the variational Principles: David Hilbert famously regarded the *Principle of Least Action (PLA)* as fundamental to all physics, and the PLA has always seemed disturbingly teleological⁵⁴. Of course, the trouble is that *purpose* is obviously omnipresent in everything we do, and it appears that *purpose* is an essential characteristic of all living things. We have pointed out much scientific work that together seems to indicate the reality of purpose, and indeed Parker et al. (2025a) have now shown that *entropic purpose* may be formally defined as a valid quantity in physics. Also, Annie Crawford (2020) has carefully explained “that since teleological concepts cannot be abstracted away from biological explanations without loss of meaning and explanatory power, life is inherently teleological.”

8. What is Fundamental?

Jesus famously observed that the “*wyfe man bylth his houffe on a rocke*”⁵⁵ (Tyndale 1526). What is the *foundation* of our knowledge? We observe the sun rising in the East and setting in the West, but understand that this is an effect of the rotation of the Earth, not simply the sun riding his chariot across the sky (the obvious interpretation of the phenomenon). We observe the green leaf, and understand that the *greenness* comes from chlorophyll which catches the light energy, using it to fix carbon out of the air (giving us oxygen to breathe) in the wonderful process of photosynthesis, whose details are still being elucidated and which may rely on quantum mechanics (although Runeson et al. 2022 think not). What is fundamental? Frank Wilczek's book (2021) is actually called “*Fundamentals*”! Is quantum mechanics fundamental? Or gravity? Or integrity (which we might call “the wisdom of wholeness”)? Or?

Michael Parker and others have shown constructively that *unitary entities* (than which exist no simpler) can coherently be thought to exist. The size (matter radius) of the alpha particle in its ground state is calculated correctly from thermodynamics using no quantum mechanics at all on the basis that it is *unitary* (Parker et al. 2022). But everyone knows that the alpha (⁴He) is made of two protons and two neutrons (2+2=4). Which description is more “fundamental”? Is it the *unitary* quality of the alpha, or is it its “basic” constituents (protons and neutrons)? The way this last question is posed invites the standard reductionist answer that protons and neutrons are more “fundamental” than the unitary alpha, but Parker has shown that the observed phenomenon (the nuclear size) is correctly explained by modelling the entity as unitary (with the fewest possible degrees of freedom). If the alpha is broken into its constituent particles the total system is *not* “simpler”! This is a surprising result which confronts our prejudices. A “holistic” approach has, in this case, been demonstrated to be *more* “fundamental” than a reductionist approach⁵⁶ that requires ever larger amounts of energy to

⁵⁴ Michael Stöltzner (2003) explains in detail the commitment of Hilbert and Max Planck to the PLA, also discussing its teleological aspects at length. Sabine Hossenfelder (2022, p.159) says of the PLA, “*It was a revelation! Why hadn't anybody told me?*”, saying that they don't teach the PLA in schools because then everyone would get hooked on physics. She exaggerates of course, but she confirms our emphasis here on the importance of the PLA.

⁵⁵ ... ἀνδρὶ φρονίμῳ, ὅστις ᾠκοδόμησε τὴν οἰκίαν αὐτοῦ ἐπὶ τὴν πέτραν: Matthew 7:24ff (Adelphothes, 2000); see parallel passage at Luke 6:48ff. The English text is quoted *verbatim* with original spelling from the earliest modern English translation (Tyndale 1526). The “f” is the long “s” (which can still be seen in modern German orthography as a component of “ß”, the “*Eszett*” or “*scharfes S*”). Tyndale translated from the original Greek (using Erasmus' critical edition first published 1516 based on MSS no earlier than 10th century), and his Bible was printed (secretly) in Germany in a blackletter font. At that time Tyndale's Bible was *samizdat* literature regarded by the English political establishment as deeply subversive.

⁵⁶ contradicting Wilczek (2021), who is clear that the Second Law of Thermodynamics is **not** “fundamental” (see note on his p.93, ch.4), and who is also clear that “*It pays to analyse matter into the smallest units you can. After doing that correctly you can build back up, conceptually, and construct the physical world*” (p.62, ch.3). That is: the most

be concentrated into ever smaller scales in order to observe the “fundamental” phenomenon. We should emphasise that QGT has shown that “holistic” treatments are themselves fundamental: it is not necessary to show how they “emerge” from (supposedly) “fundamental” physics (on “emergence” see for example Gil Santos, 2020).

These new results in physics result in a *gestalt* switch in our ideas of what counts as “fundamental”. Previously we thought that “smaller” was equivalent to “more fundamental” – on the admittedly persuasive grounds that if a house is made of bricks then the bricks are “more fundamental” than the derivative house. Reductionism rules ok! ⁵⁷ The trouble in quantum physics is that neither protons nor neutrons are “fundamental particles” since they are both made of quarks (in the Standard Model). Anyway, who knows what quarks are? or if the Standard Model is correct? After all, quantum gravity is proving frustratingly elusive. There are far more questions than are comfortable, even for physicists.

But if “more fundamental” can include such holistic ideas as “unitary entities” then perhaps the whole way we approach the scientific enterprise needs some revision? This suggestion is underlined by Parker’s subsequent resolution of the Loschmidt Paradox⁵⁸, effected by a treatment which shows how the reversible and irreversible (and the causal and acausal, the local and non-local) are in fact commensurate (Parker & Jaynes 2023a). “Local” effects correspond to our standard “cause-and-effect” ideas. But “non-local” effects correspond to holistic behaviours of systems⁵⁹ (and it should be recognised that such behaviours are also central, implicitly, in the physics of those systems). The world will remain incomprehensible to us unless we appropriate this new holistic physics.

It is interesting that Potter & Mitchell (2022) list 8 properties of living organisms that allow us to think of them validly as *causative agents* (without any sort of dualism): the first is “*thermodynamic*

fundamental is the smallest. This conclusion seems to be mistaken on proper consideration of the work of Parker and others.

⁵⁷ Sabine Hossenfelder (2022, p.83) says, “*Fact is, we have never observed an object made of many particles whose behaviour falsified reductionism ... If you say ‘holism’, I hear ‘bullshit’*”; although she claims she is “*not a reductionist hardliner*”, so that she acknowledges that all possible experiments have not been done so that facts may eventually contradict her. We think they have already.

As examples, Thomas Hertog speaks of “*the end of the old reductionist dream ... even the most elementary law-like regularities are ultimately grounded in the complexity of the universe around us*” (2023, p.237f). Denis Noble (2012) is very clear that the reductionist approach is not appropriate for biological systems, insisting instead “*that downward causation is necessary*”.

⁵⁸ In 1876 and in response to Boltzmann’s “H Theorem”, Josef Loschmidt pointed out to Boltzmann that one shouldn’t be able to derive an irreversible process (the Second Law of Thermodynamics) from fundamentally reversible equations.

⁵⁹ Note that when we speak of a *system*, we always mean a composite comprised of a set of components; in which case a “system” can *never* be a “unitary entity”, which has no parts at the relevant scale.

Jaynes (2023) has reviewed the use of “Berry phase analysis” as a systematic physical approach to treating irreversible systems, and says: “*[This] approach (which is deeply geometrical) is connected to other more explicitly thermodynamic approaches (also deeply geometrical) [and] is of great importance as the geometry of a system embodies its nonlocal properties, which are usually expressed in terms of the variational principles (least action, maximum entropy, etc.). Reality is elusive precisely because it can be handled correctly only in a fully complexified theoretical framework in which eigenvalues are not real in the general case. Recent work [Parker & Jaynes, 2023a] has shown that for a more satisfactory and unified explanation, of many physical phenomena, even the description of time should be complexified*”. Real systems are invariably irreversible – this is an essential consequence of the Second Law of Thermodynamics. Geometrical thermodynamics emphasises the fundamentally *non-local* nature of physical systems (expressing their *holistic* character).

autonomy" (that is, the entity is in a stable low-entropy state), and the fourth is *"holistic integration"* (that is, pointing to the necessity of non-local effects). This account is consistent with ours.⁶⁰

Unity, non-locality, and irreversibility are all *fundamental* aspects of reality, but none are recognised as such by Rovelli (2009) or Wilczek (2021). Other eminent physicists are much less dogmatic: for example, Roger Penrose (2004, ch.27) has a long section on the Second Law emphasising the fundamental reality of irreversibility (never mind that the "fundamental" laws of physics are reversible as currently understood).

9. The Legitimacy of the Scientific Enterprise

What work may legitimately be regarded as "science"? The usual process is that one writes up one's results in a "paper" which is submitted to a scholarly journal for peer review; two or more accredited scientists then review the work and report to an editor, who may decide to publish after due consideration. Is the published work now "science"? No. The publication of work is no guarantee of acceptance by the scientific community. For example, the Reviewers may not notice mistakes in the work, and even egregious mistakes may be overlooked.⁶¹

As usual, and not unexpectedly, we depend on a consensus. Science is what the scientific community says it is (although there do exist some rather severe tests: what results can the scientists show?). In the end, the widgets that the scientific community makes available to the public are what convinces the public to continue to pay the scientists' salaries. And of course, there are also goods other than widgets: the inspiring pictures from the Hubble Telescope and its modern successors, and the wonderful TV programmes on the natural world are some examples.

What is the "scientific method"? John Randall (1940) has explored the development of the experimental scientific method in Padua in the centuries leading up to Galileo. He comments: *"the fact that the seventeenth century scientists, in revolt against the humanists' appeal to the authority of the past, preferred to put their trust in "natural reason" alone, and hence cared nothing for historical continuity, has sadly misled our judgment as to the fashion in which their thought was generated"* and concludes: *"But the return to experience is not for the sake of certain proof: for throughout the seventeenth century it is almost impossible to find any natural scientist maintaining that a mere fact can prove any certain truth"*. Because we

⁶⁰ Separately, Perunov *et al.* (2016) have explored the statistical physics of *"strongly driven systems that exhibit complex collective behavior ... for the first time establishing general relationships between far-from-equilibrium probability distributions over states and the thermodynamic fluxes that accompany their dynamical evolution"*, although they persist in imposing time-reversal symmetry. Nevertheless, these general relationships are clearly valuable for developing an appropriate "physics of living systems".

⁶¹ Of course, scientists are notoriously bad at detecting deliberate fraud as they generally assume that the work is done in good faith (and when Alan Sokal perpetrated his hoax in 1996 he was clearly not in good faith). For example, the Schön affair which led to a series of retractions of the work of Jan Hendrik Schön and co-authors in 2003. On fraud, Martin Gardner (2013, p.157f) says: *"Scientists untrained in the conjuring art of deception are the easiest people in the world to fool."* Thanks to Sir Michael Berry for drawing our attention to this book (2nd March 2023). John Hardwig (1991) quotes Arnold Relman (1983): *"fraudulent data may be rapidly identified in an area of great importance where research activity is intense, but that is probably not true in most fields"*.

Valentin Rodionov (2024) speaks of *"a torrent of problematic papers ... Despite the common belief that science self-corrects, most flawed papers evade retraction ... In fields such as chemistry and physics ... identifying problematic papers ... is challenging. And it is virtually impossible to get one retracted."* Moreover, much work in the scientific literature is rather low quality which ends up being ignored by the community: peer review filters out some of this stuff but by no means all. And some work may look important at first but turn out to be insignificant. After all, big results are far and few between. And even when big results are published they are often not immediately recognised.

see something does not mean that we *understand* it! In fact, many have noted that we typically only see what we understand!⁶² And conclusive “proof” of anything is fraught with difficulty.

On the “authority” of scientific experts, we should also point out here that as Robert Crease says (2019, p.252), “*Authority is a key feature of public space ... The success of totalitarianism is only possible with the erosion of authority.*” And he quotes Hannah Arendt’s “*Between Past and Future*” (1961): “*authority implies an obedience in which men retain their freedom.*” The scientific enterprise depends on the scientific community acknowledging the authority of the scientific consensus: this authority is not unchallengeable of course, but it remains our baseline. St. Paul urges us that “*we henceforth be no more children, tossed to and fro, and carried about with every wind of doctrine*”⁶³; we **ought** to need adequate persuasion to change our minds! Authority is not dispensable: it is inescapable that we are social beings which implies a submission to authority. This is not a bad thing, it just is. We are free to submit and we are free to dissent.

It is inescapable that the scientific enterprise rests on integrity: we have to trust each other to tell the truth about what we observe (even if, of course, we also do whatever checks are available). For we will repeat experiments only for the most important results – experiments are expensive and repeat experiments are not usually publishable. More than that: the scientific enterprise rests on the visceral desire of the scientists to *know* how the particular aspect of our wonderful world under investigation really works. Science is a passionate activity – scientists want to get things right! Moreover, the legitimacy of science cannot be communicated coldly to the public. Wholeness is the key. A scientific argument clearly must be considered dispassionately to confirm its validity. But a *valid* argument is not necessarily a *true* one. We want to know the truth about the world, and obtaining knowledge is a deeper activity than merely obtaining information. I can pile up heaps of information but understand none of it!

Another reason for scientists doing their best to report results in a dispassionate (or disinterested) way, is because they have the underlying conviction that what they perceive as the truth should be recognised as such by everyone. Another reason for scientists to aspire to dispassionate reporting is that they are (usually) very well aware of their own fallibility, including the natural propensity of having such fixed ideas about how things should be that the results are distorted.

Speaking now about the scientific practice itself, that is, the getting of the results not just the reporting of them, Philippe Stamenkovic (2024)⁶⁴ discusses the “Value-Free Ideal” (VFI): the idea

⁶² To randomly take one example of many, Jessica Nordell (2021, p.72f) comments on a class action before the US Supreme Court of sex discrimination against 1.6 million female Walmart employees. The court ultimately “*disqualified the lawsuit, ruling that female employees didn’t have enough in common to be a “class” for a class-action lawsuit*”. In 2011 Antonin Scalia wrote the majority opinion, maintaining “*that it would be impossible for a company to reach the kind of disparities seen at Walmart without a coordinated master plan of prejudice*” (*ibid.*; q.v. for full references).

Goethe wrote “*Was man weiß, sieht man erst*” in an Introduction to an issue of the art magazine *Propyläen* (c.1800), and also “*Man erblickt nur, was man schon weiß und versteht*” in a letter to his friend F. von Müller (24th April 1819). And of course, Jesus famously referred to those who were supposed to understand as “*blind guides*” (ὁδῆγοι τυφλοὶ; Matthew 23:16), and again, to those who claimed to understand, “*if you were blind you would have no guilt, but now you say you see, your guilt remains*” (Εἰ τυφλοὶ ἦτε, οὐκ ἂν εἴχετε ἁμαρτίαν· νῦν δὲ λέγετε ὅτι βλέπομεν· ἡ ἁμαρτία ὑμῶν μένει; John 9:41).

⁶³ ἵνα μηκέτι ὦμεν νήπιοι, κλυδωνιζόμενοι καὶ περιφερόμενοι παντὶ ἀνέμῳ τῆς διδασκαλίας (*Ephesians* 4:14; Adelphothes, 2000). John Robinson (1976) dates *Ephesians* 58 CE.

⁶⁴ Philippe Stamenkovic (2024) argues against claims “*that extra-scientific values are inevitable in scientific practice (on the descriptive level) [and] that they should influence all aspects of the scientific enterprise (on the normative level)*” on the basis that such practice “*does not clearly distinguish between scientifically established facts and scientifically informed claims taken as a basis for policy-making*”. Stamenkovic calls this the “Value-Laden Turn” and

that science is (or should be) “value-free” (or “objective”). Of course, the original arguments for the VFI included the need to protect “*public trust in science*”, an issue central to our concerns here. But, as a human activity, the scientific enterprise cannot be “value-free”! Stamenkovic urges that “*scientific claims*” should be clearly distinguished from “*scientifically informed decisions*” – the former can be reasonably “value-free”, but the latter cannot be in principle since decisions are always made on the basis of their value (as assessed by the decision-maker).

Unfortunately, Stamenkovic has too optimistic a view of “scientific claims”: he asserts that “A science based on facts (further generalised in the form of laws and principles) represents the ideal of scientific inquiry”. The trouble is that interesting facts don’t exist – since if it is a “fact” then it is *per se* uninteresting (since everyone agrees). Nobody now worries about whether it is the Earth orbiting the Sun or vice versa, but this was only formally established as a “fact” by Bessel’s observation of stellar parallax in 1838, an observational tour de force that was only interesting as such, but not as establishing Galileo’s opinion (which had by then already long been the consensus). Thomas Kuhn’s (1962) description of the discovery of oxygen by Lavoisier (and Priestley) is an object lesson in how the very expression of “facts” is plastic and must be negotiated, and Paul Feyerabend (1975) powerfully makes comparable arguments. Surely any useful philosophical discussion should capture the fact that we only do science at all, as Robin Ince (2021) has pointed out, because we are interested.

It is true that scientists wish to establish facts (hence Stamenkovic’s insistence on “*ensuring the truth of scientific knowledge*”), but what eventually becomes recognised as a “fact” is still only a “good idea” while it is being established. And, as we have seen, the truth of the proposition may well be accepted before (or even long before) the “fact” itself is properly established as such. Truth is always interesting (but “facts” never are *per se* – until of course they start to be called into question (at which point they are no longer “facts” at all: reality is elusive).

But a “fact” (in the sense of the considered consensus view of the scientific community) is necessarily “already a social thing” since “it concerns events and circumstances in which many are involved; it is established by witnesses and depends upon testimony” (Crease, 2019 p.262; quoting Arendt, 1961). And it is this “very social character” of “facts” that can be used by science deniers “to discount them” (ibid.). We have already mentioned Richard Bauckham’s monograph on personal

contrasts it with the “Value-Free Ideal” (VFI), specifically in the context of what he calls “*phase 2*” (the “acceptance/rejection” or A/R phase), that is, “*what to conclude from the investigation*”. He “*argues for the need to minimise as much as possible (although not exclude) the influence of values in the A/R phase where claims are accepted or rejected.*” All these “high-level” (philosophical) discussions approximate what really goes on, of course. Scientists want results, they don’t want “no result”. So “rejection” is not usually in view (unless it can be glossed positively as some sort of “acceptance”. Scientists are much more interested in what results do mean (positively) than in what they don’t mean (negatively). And this always colours how results are presented.

Stamenkovic acknowledges the “*simplifying idealisations*” he uses: because *reality is elusive* it is not always possible to be sure of the scope of, and adequately assess, such approximations. But he illustrates his argument with definite examples, which is good practice as a constructive approach to expressing meaning adequately. He specifically argues that “*science-informed claims for policy-making should naturally be influenced by extra-scientific values*”.

Stamenkovic has a long section on “uncertainties” which he insists (correctly) “*must be stated clearly*”. The trouble with this is that one can conform precisely to the “*Guide for the Expression of Uncertainty in Measurement*” (JCGM 1995), but whether one’s consequent statement of uncertainty is “clear” is a very strong function of its auditor. Moreover, the very idea of “measurement” is much more anthropocentric than is commonly thought, with metrologists themselves affirming that “*measurement is primarily an epistemic process*” (Mari *et al.* 2013, 2021). In the end the scientist must act with *integrity* (as Stamenkovic acknowledges repeatedly), and integrity is primarily a human (“extra-scientific”) value. This means that in principle “science” cannot be done coldly; that is, avoiding the introduction of values (which are necessarily “extra-scientific”).

“eyewitness” testimony (2006) which he shows is fundamental to all knowledge. Frank et al.’s whole “Blind Spot” thesis (2024) says the same thing from an entirely different point of view. And John Hardwig was long ago insisting on a principle of testimony (1991) to establish “epistemic authority” (1985). He says, “Cooperation, not intellectual self-reliance, is the key virtue in any scientific community. But epistemic cooperation is possible only on the basis of reliance on the testimony of others” (ibid.). After all, science is a human activity, and knowledge is personal (Polanyi 1958).

For our purposes Stamenkovic’s approach appears to be insufficiently fundamental, since he seems to think that “scientific truth” is well defined (and attainable): he says, “... *without [truth] there is no science.*” Of course, at a practical level we can be sufficiently sure of things that we can be confident of success in proposed actions (which is his particular interest). But at a philosophical level, what sense does it make to say (for example) that Newton’s physics was “true”, in view of the non-Newtonian advances in physics starting with Maxwell’s electrodynamics? On the other hand, it is also clearly perverse to say Newtonian physics was “false”! Catherine Elgin (2019, p.1) is right to say that a “*veritist*” approach is not “*plausible*”: she insists that what she calls “*felicitous falsehoods*” are “*epistemically valuable*”.

Stamenkovic acknowledges this when he says that the scientific corpus (“*the total body of scientific knowledge*”) is “[*representative of*] our best available, most reliable (although always revisable) knowledge”. “Revisability” is the critical idea here. It turns out that “facts” may be revisable. What is considered a “fact” today” may be considered as an erroneous idea tomorrow, although the body of phenomena that had been considered to establish that “fact” remains in the record. So *something* must have been true about it, even if that thing was not expressed correctly. Karen Barad (2007, p.333) is surely correct to insist that it is the *phenomenon* that is the “*primary ontological unit*”.

Michael Lissack (2017) points to the “*hidden assumptions*” that “*allow ambiguity⁶⁵ to be bracketed away at the expense of transparency*” imposed as “*enabling constraints*” (in the form of *ceteris paribus* – “other things being equal”), acknowledging Jürgen Habermas (1996) who points out that “*scientific activity ... fragments into a number of competing viewpoints that are shot through with values*”. The investigation of such enabling constraints (in the form of “*uncritically examined presuppositions*”) reveals “*hidden assumptions ... which can get in the way of the acceptance of a scientific claim*”. Scientists acknowledging their *hidden assumptions* more transparently, as Lissack proposes, should result in the more willing acceptance by the public of scientific claims.

Stamenkovic points out that “*there is a fundamental requirement to distinguish between facts and values*”. Science is a human activity, done because we want to know how the world really is. This activity is “*shot through with values*” (as Habermas correctly says), and yet we wish to achieve a consensus view on this or that aspect of the world. This is what “facts” are. But we vigorously deny that all this is just a “matter of opinion”, since the phenomenological underpinning of an accepted “fact” (together with its formal interpretation) is a matter of public record! The “facts” may change (often in rather subtle ways) but the public record persists. Trust in scientists and the work they produce must surely require the public interplay of facts and their associated values, allowing the integrity of the work to be openly displayed. The aim is to persuade the public that reality really is being described truthfully.

10. QBism

Since we are realists who insist that “knowledge is personal” (Polanyi 1958)⁶⁶, are we not also QBists (“quantum Bayesians”)? QBism is regarded by many as a “philosophically rigorous approach

⁶⁵ We are grateful to Julia Jordan for alerting us in 2022 to Anthony Ossa-Richardson’s important monograph on “ambiguity” (2019). Jeynes *et al.* (2023) interpret ambiguity as the characteristic property of the *metanarrative* of science (the “*poetics of physics*”), saying that scientists properly strive to avoid (or at least reduce) ambiguity, where poets revel in it.

⁶⁶ We use Polanyi’s formula: “*personal knowledge*”. But both Polanyi and we are acutely aware of the *social* context of knowledge. We know rather little individually! Monserrat Neto (email 11/4/2025) points out that it

to quantum mechanics” which “cuts no epistemic or ontological corners”⁶⁷. David Mermin (2012) has summarised QBism helpfully, explaining that it elegantly disposes of the “shifty split” that John Bell deplored (the discontinuity between the microscopic and macroscopic involved in making the “observation” that “collapses the wavefunction”⁶⁸), and points out that the real issue is how we think of probability. Are we “frequentist” or “Bayesian”⁶⁹? Michael Levine (2019) points out that “in many problems ... there is no true model”, and we point out (again, see above) that “measurement is primarily an epistemic process” (Mari et al. 2013) and that the “Guide to the Expression of Uncertainty in Measurement” (JCGM 1995) explicitly avoids the concept of a “true value” of a measurand on the grounds that such a value is unknowable in principle, and any estimate of it must be expressed together with a “measurement uncertainty”. Although it is truth we seek we also admit our limitations (to say nothing of ontic uncertainty). It should be added that determining probabilities is not only a philosophical minefield but a technical one too: Steven Goodman (speaking to the medics, 2008) has helpfully listed various ways that people can (and do) misuse statistics to pretend to the scientific method. Howson & Urbach (1989) examine the way scientists actually appeal to probability arguments, directly addressing the charge against Bayesianism that it is “too subjective”.

Leifer (2014) has provided a deeply interesting and informative review of issues associated with QBism, specifically seeking to expose the implications of choosing an ontic rather than an epistemic interpretation of the wavefunction Ψ (which is the basic entity in quantum mechanics). Leifer correctly denies that this issue is “metaphysical” (in the conventional sense of “the science of being”), insisting that it is strictly a technical (“scientific”) issue of physics, backing up this assertion with a careful mathematical exposition, and saying that “what Bell’s Theorem really shows us is that the foundations of quantum theory is a bona fide field of physics, in which questions are to be resolved by rigorous argument and experiment, rather than remaining the subject of open-ended debate.” It seems that these questions are not all resolved, however: the Pusey–Barrett–Rudolph Theorem (Pusey 2012) proved that (under certain conditions) Ψ is ontic (that is, a state of reality and not merely a state of knowledge). The consequences of this are both subtle and far-reaching, with the details beyond our scope here. However, we should recall that Karen Barad (2007) has made a persuasive case that the categories “ontic” and “epistemic” are themselves mixed, and that we should therefore speak of the “onto-epistemic”: “there is good reason to question the traditional Western philosophical belief that ontology and epistemology are distinct concerns” (ibid. p.43)⁷⁰.

might be better to speak of “*interpersonal knowledge*”. Of course, this is correct, but although knowledge is necessarily interpersonal it must also be grounded in the personal integrity of the individual. After due consideration it is *I myself* that must (or must not) approve what *you* say. Therefore it is correct to speak of *personal knowledge*.

⁶⁷ Robert Crease, private communication 13th March 2024

⁶⁸ It is this “shifty split” that Thomas Hertog (2023, p.37) also has in mind, that casts “*a cloud that still hovers over the frontier of physics today: the problem of how the macro and the micro worlds fit together*”, although the context is the “*radically different directions*” taken by the “*two full-scale revolutions*” at the beginning of the 20th centuries: “*relativity and quantum mechanics*”

⁶⁹ “*Most physicists have a frequentist view of probability: Probabilities describe objective properties of ensembles of “identically prepared” systems. [Contrast the] Bayesian view: An agent assigns a probability p to a single event as a measure of her belief that the event will take place.*” (Mermin, 2012)

⁷⁰ In her Conclusion to ch.4 (“*Agential Realism*”), Barad goes further, saying: “*The separation of epistemology from ontology is a reverberation of a metaphysics that assumes an inherent difference between the human and non-human, subject and object, mind and body, matter and discourse. Onto-epistem-ology – the study of practices of knowing in being – is probably a better way to think about the kind of understandings that we need to come to terms with how specific interactions matter. Or, for that matter, what we need is something like an ethico-onto-epistem-ology ... because the becoming of the world is a deeply ethical matter*” (ibid., p.185; emphasis original).

Bayesian methods try to specify prior information where “frequentist” methods aim to be strictly “objective”. That is, the frequentists pretend to “objectivity” where the Bayesians admit to their beliefs on the grounds that no-one decides anything without believing something. Bradley Efron (2005) points out that “*Bayesian statistics has seen a strong movement away from subjectivity and toward objective uninformative priors in the past 20 years*”, but comments that “*in practice, it isn’t easy to specify an uninformative prior*”.

In the important case of a “Bertrand Paradox”⁷¹, Parker & Jeynes (2023c) have shown how to introduce the required uninformative prior in the form of an additional natural constraint: *scale invariance*. This also automatically eliminates the “shifty split” problem that has bedevilled the quantum physicists (where exactly lies the boundary between the microscopic and macroscopic worlds?). Entropy is blind to scale, and the scale-blindness of Parker’s new “quantitative geometrical thermodynamics” (QGT; Parker & Jeynes 2019) is explicitly a feature of its hyperbolic spacetime. Therefore QGT is expected to be (and is!) valid both for quantum mechanical entities (like alpha particles: Parker et al. 2022) and also for entities of general relativity (like black holes: Parker & Jeynes 2023a). This involves a length scale range of at least 35 orders of magnitude for which QGT is demonstrably valid.

David Bohm argued for an “Undivided Universe” (Bohm & Hiley 1993): in QGT Parker has shown us a uniform (undivided) treatment of both QM and GR entities. Taken with the nonlocal nature of thermodynamics and the holomorphic nature of actio-entropy (Parker & Jeynes 2023a⁷²), it is clear that QGT offers an ontological description that accords well with the Bohmian conception of wholeness (Bohm 1980). Speaking of probabilities (to the wider physics community), Mermin (2012) also says, “*you had better reexamine what you wrongly may have thought you understood perfectly well about the nature of probability.*” QBism revises the usual way of thinking about *probability*, and Parker et al. (2025b) have shown (separately) that we can “*treat probability as a physical quantity grounded in hyperbolic Minkowski spacetime, and obeying all the appropriate physical laws*” – that is: *probability is physical*.

⁷¹ Parker & Jeynes (2023c) have given an example of exactly this difficulty of specifying the uninformative prior in their resolution of a longstanding “Bertrand Paradox” that appears to undermine a cornerstone of logical inference. The Principle of Indifference (the simplest non-informative prior in Bayesian probability) has been shown to lead to paradox for non-discrete problems. But if the Principle of Indifference is faulty then our ability to think straight is also called into question! This Paradox is therefore important since if unresolved it would undermine the whole legitimacy of our standard methods of logic (including Bayesian ones): if they don’t work properly in the continuous case then they are hardly to be relied upon ontically! Indeed, Leifer’s (2014) review of issues associated with QBism is undertaken using a formalism (a “rigorous measure theoretic probability theory”) explicitly designed to work for “continuous spaces”, since, as he says, “*the wavefunction involves continuous parameters ... It would be odd to attempt to prove the reality of the wavefunction within a framework that does not admit a model in which the wavefunction is real in the first place.*”

But it turns out that the Bertrand Paradoxes can be resolved provided that the correct uninformative prior is used, and to properly express the Principle of Indifference requires one to introduce a scale invariance prior (that is, a relativity of scale) which results in a non-uniform (but still Maximum Entropy) probability distribution (contrary to expectation). The “scale invariance” requirement has been described in some detail, if rather inconclusively, by Peter Milne (1983; he admits that “we find obscurity at the heart of the scale invariance argument”, an obscurity enlightened by Parker & Jeynes’ treatment, 2023c).

We thank Nicholas Shackel for alerting us to Milne’s paper (private communication 13th March 2024). On the Principle of Indifference see also Shackel (2024).

⁷² “actio-entropy” is an idea first introduced by Velazquez *et al.* (2022). “Action” is an important physical quantity (defined by an appropriate line integral of the Lagrangian): “entropy” is shown by Parker & Jeynes (2019) to be a precisely isomorphic quantity (defined by an appropriate line integral of the *entropic* Lagrangian).

A new understanding of the physics of probability and its Bayesian explication via a relativity of scale is now also offering important new insights into the very nature of reality itself.

11. The Poetry of Physics

It is now widely accepted that every act of understanding requires a leap of the imagination. *Knowing* is imaginative. To establish the terms they use for new concepts, scientists must “negotiate their meaning” (using Martin Edwardes’ phrase, 2019), which is always a metaphysical step requiring a use of language that can only be called poetic (see Jeynes et al. 2023). An imaginative leap (or an “intuitive leap”) is just the same thing as the “leap of faith” (properly the “leap by faith”⁷³) proposed by Søren Kierkegaard explicitly in his “Unscientific Postscript” (1846) and implicitly in his discussion of Abraham’s faith in “Fear and Trembling” (1843). The essential fact is that there is no disembodied or impersonal knowing. *Knowledge is personal* (Polanyi 1958) just as much as *information is physical* (Landauer 1991, 1999)⁷⁴.

No human enterprise may be formally *defined*. It may be *described*, or (better) *exemplified*, but no properly human activity may be entirely specified. And although the knowledge of reality may be approached variously, yet truth is one. That is, poets and scientists may variously seek knowledge of the one reality, all using their own appropriate methods, but ultimately it is still the same reality they all describe, however differently. Because reality is elusive it is hard to grasp, and we need many varieties of approach to lay hold of it.

We have said that “science is what scientists do”⁷⁵, intending not to give a tautological and useless “definition” but to indicate the humanity of the activity. Many attempts have been made to define the “scientific method” but there remains no consensus. This is because humans want and do surprising (and undefinable) things⁷⁶. One needs to be a poet to speak adequately of “aspiration” or “inspiration”, or even “wonder” or “delight” – all ubiquitous in those captivated by science (the scientists). Those not so captivated demand to know the “use” of the (very expensive) activity, and it turns out that knowing true things about reality indeed has many material benefits, but scientists typically do not labour diligently for this knowledge because of its “usefulness” (or to get rich) but because they are moved by the poetry of the thing.

It is becoming fashionable to bracket “science” together with “poetry”. Carlo Rovelli is regularly called “the poet of science”⁷⁷, and the astrophysicists have delighted the world with their wonderful pictures of the cosmos. There are many examples. These things should be taken seriously also by philosophers: they are not merely media froth. Reality is slippery and very hard to grasp (as Robin Ince also points out: “even the most solid and sure things you can set your watch by become malleable and slippery. This includes time itself”: Ince 2021 p.89): our methods for learning about it depend essentially on inspiration – a poetic quality *par excellence*. The renowned philosopher Ernst Cassirer “liked to tell the following story: once he met the great mathematician [David] Hilbert, the ‘Euclid of our time’, and asked

⁷³ The “leap of faith” referred originally to leaping over Gotthold Lessing’s “ugly broad ditch” – “*der garstige breite Graben*” (1777); see Yasukata (2003).

⁷⁴ This juxtaposition may be thought inappropriate since “Shannon information” (which is what Landauer was speaking of) is explicitly (and deliberately) *impersonal*, where “knowledge” is definitely (and necessarily) *personal*!

⁷⁵ Thomas Hertog (2023, p.247) also says this: “Science is what scientists do. We advance by exchanging ideas ...”

⁷⁶ We can avoid a discussion of “free-will” here. Sabine Hossenfelder (2022, p.128) is definite, saying (several times): “the future is fixed, except for occasional quantum events that we cannot influence”, which seems to rule out free-will. But her discussion of this is quite long and complex, with the conclusion that she doesn’t deny the reality of imagination. The future (in her view) is fixed, but it is still unpredictable. What we mean by “free-will” turns out to be hard (and contentious) to define.

⁷⁷ One could also point out here the assessment of Thomas Hertog (2023, p.61) that Lemaître’s 1931 letter to *Nature* (Lemaître 1931) was “cosmopoetic”: “Lemaître’s cosmopoetic letter is one of the most audacious scientific texts of the twentieth century. It counts no more than 457 words but can be regarded as the charter of big bang cosmology.”

him about one of the latter's disciples. Hilbert answered: 'He is all right. You know, for a mathematician he did not have enough imagination. But he has become a poet and now he is doing fine.' Cassirer always heartily laughed, when he told this story ..." (Gawronsky, 1949)⁷⁸.

The positivist attempt of the 20th century to try to tie down the "scientific method" has failed, crippled by reality itself which refuses to be tied down. In his foundational work Kurt Gödel (1931) showed it was a logical tautology that any real system cannot be known completely, proving constructively that any logical system at least as rich as arithmetic contains theorems⁷⁹ which are certainly true but nevertheless undecidable in that system. Even arithmetic, which we usually consider child's play, is logically incomplete! It is interesting that Gödel's Incompleteness Theorem made the first formal use of metamathematical methods, although this use was foreshadowed by Anselm's treatment of his "Ontological Argument" in the *Proslogion* (1078); see the discussion by Jeynes et al. (2023) of Anselm's poetic metanarrative, systematically overlooked by modern philosophers.

A modern view of the scientific enterprise avoiding the myth of "completeness" that Kant popularised (1786) was Charles Peirce's view that the methodology of science starts with "**abduction**". A scientific investigation involves induction from data and deduction of consequences, but the original activity of forming explanatory hypotheses (crucial to the inductive/deductive steps) is a creative (not strictly a logical) one. "*The abductive suggestion comes to us like a flash. It is an act of insight, although of extremely fallible insight*" (Peirce 1903, emphasis original). Peirce's idea of abduction has been widely discussed, for example by Lucia Santaella (Braga, 2019) and Timothy Shanahan (1986). Ernan McMullin (1992) discusses *abduction*, but prefers *retroduction* (also used by Peirce): "*central to retroduction ... is the imaginative modification of existing concepts, or the creation of new ones quite remote from the universals or forms that might be abstracted from perceptual experience*". McMullin's work is widely regarded as seminal, for example by Bas van Fraassen (2013), who says that he "*takes us on a fabulous journey through the history of philosophy of science*", concluding "*When McMullin states ... that the success of retroductive inference is a contingent matter, he ... does not go far enough. That the contingent conditions for the success of retroduction actually obtain could only be inferred by retroductive inference: an insight that sweeps the rug from under any assurance of epistemic safety to be found there.*"

12. Machine Intelligence

We have glanced at issues of public trust in science above. However, a very modern concern is, 'Can Artificial Intelligence (AI) be "trustworthy"?' since one might have expected such a question to be related to the enquiry about "the integral nature of the scientific enterprise". After all, AI is a "scientific" activity, isn't it? "Bing" (the AI bot now supplied by Microsoft as standard) actually answers this question quite well: "*Artificial intelligence is not human, so we should avoid terms like "trustworthy AI" that not only humanize AI but also imply a level of dependability that simply does not exist. However, broad adoption of AI systems will require humans to trust their output. Many AI systems to date have been black boxes, where data is fed in and results come out. Trust is a priority, but many organizations haven't taken enough steps to ensure AI is trustworthy. Many current efforts are aimed to measure system trustworthiness, through measurements of Accuracy, Reliability, and Explainability, among other system characteristics.*"

A supplementary question to Bing about the "metanarrative" of its answer also elicited a sensible response under six headings: (i) *Context & Background*; (ii) *The Nature of AI* (not human, therefore lacking human characteristics); (iii) *The Dual Nature of AI* (good and bad aspects); (iv) *Trust and Trustworthiness*; (v) *Challenges and Responsibilities*; (vi) *Operationalizing Trustworthiness* (mentioning that "practical philosophy" can "guide the development of AI"). This response is revealing from our point of view here: it appears sensible and competent (and useful), but really it

⁷⁸ Thanks to Sir Michael Berry for drawing our attention to this story (private communication, 29th March 2024)

⁷⁹ Strictly these are only "well-formed formulae" (not "theorems" which must have proofs): they are formally proved "not meaningless", but they also demonstrably have no proof in the system.

hasn't grasped what we have tried to explain here as "metanarrative" (that is, the context that enables our *understanding* of the narrative in question). Rather, it is, again, simply a set of facts. Could I ever compose poetry of bullet points?

In terms of the discussion here, a scientific narrative is designed to iron out ambiguities in the handling and interpretation of the observations, but such a narrative *per se* cannot engender *understanding* either in the practitioner or in the student (or any interested citizen). For an explanation of the *meaning* of the observations (to "get to the truth of things") one must resort to the (metaphysical) metanarrative. We have seen how Joseph Drew (2023) has drawn attention to the real benefit available from a proper attention to Aristotle's methods of rhetoric to persuade people to trust scientists, and James Lennox (2015) has shown how explicitly Aristotle grounded his *Physics* in a prior metaphysics.

We also have seen how, on the face of it, AI is capable of competent (and useful) summaries of the conventional wisdom. But clearly the boundaries of its competence are ill defined (and probably undefinable). How unknowable these boundaries are is central to the issue of its trustworthiness, and has stimulated much work helpfully reviewed recently by Karoline Reinhardt (2023), and including notably the "*Ethics Guidelines for Trustworthy AI*" (EU 2019) developed by the "High level working group" (the "AI-HLWG") of over 50 experts. The AI-HLWG have proposed a pilot "Trustworthy AI Assessment List" (*ibid.* pp.26-31) which has 7 headings: (i) *Human Agency and Oversight*; (ii) *Technical Robustness and Safety*; (iii) *Privacy and Data Governance*; (iv) *Transparency*; (v) *Diversity, Non-Discrimination and Fairness*; (vi) *Societal and Environmental Well-Being*; (vii) *Accountability*. The AI-HLWG gives "Key Guidance" for developers, suppliers and users: namely to "adopt a Trustworthy AI Assessment List", adapting it to the "specific use of the system" and insisting: "*Ensuring Trustworthy AI is not about ticking boxes, but about continuously identifying requirements, evaluating solutions and ensuring improved outcomes ...*". These instructions are very human and addressed to the responsible humans, deliberately using value-laden terms ("identifying", "evaluating", "ensuring"). This implicitly acknowledges the *metanarrative* that this present work is explicitly articulating. As is frequently the case with AI based on a large language model, the output is good at providing a useful narrative but it does not creatively infer the underlying metanarrative.

Fodor & Pylyshyn (1988) asserted that artificial neural networks (ANNs) cannot do "*systematic compositional generalizability*" in principle, and it's worth pointing out Abigail Tulenko's (2024) view that this generalising principle can be traced to the 11th century Persian philosopher Ibn Sina (influential in Europe where he was known as "Avicenna"). Avicenna thought that the mark distinguishing humans from animals was that humans can reason from generalized rules whereas animals can only think about particulars. And it is this human capacity for universals that AI has found remarkably hard to match, although Lake & Baroni (2023) have shown that, using "common neural networks without added symbolic machinery", if the training is guided by the "meta-learning for compositionality" (MLC) approach the ANNs can match human performance. The critical condition for this is (as for all ANN training) to do with the training programme. Clearly training programmes using MLC can be very general, yielding remarkable results. Nevertheless, from a philosophical point of view, the fact that we can get ANNs to convincingly mimic certain human behaviours does not erase the underlying dependence of the AI system on our own intelligence and indeed the active involvement of an overarching human intervention. It remains the case that AI systems are amoral: they have *behaviour* but not *judgment*. They have no *understanding* of the metanarrative.

More generally, Karoline Reinhardt (2023) makes the points well that a) *trust* and *trustworthiness* are two different things (people can trust the untrustworthy and distrust the trustworthy), and also that b) trust is an ambivalent thing (we can after all "*trust that the world is going to end*"). She argues that "*What is needed is an approach to trust that is also informed with a normative foundation and elements emphasized in the research on trust in other fields, for instance, in social sciences and the humanities, especially in the field of practical philosophy.*" We draw attention to her requirement for a "normative foundation", which we would align with our discussion of the *metanarrative*. She asserts that "*taking the self-determination and autonomy of people seriously involves accepting that trusting is a game with an open end. It is their choice to trust, or not to trust.*" That is (reprising our arguments above), unfortunately it

remains necessary to *persuade* people to trust even those things that are trustworthy (leaving it as a possibility that malign actors will also seek to persuade people to trust the untrustworthy). And she concludes: *“it might turn out that in the end what we need is not more trust in AI but rather institutionalized forms of distrust.”* It is interesting that the development of AI and its recent substantial successes are stimulating us to re-visit what the scientific endeavour really is.

13. Discussion

In this work we have presented some of the integral aspects found in the highly successful adventure that is the modern scientific enterprise. In doing so, we have also underlined the contribution of new physics (including Parker and others) illuminating key aspects of the unitary nature of the enterprise, and which has also culminated in the resolution of the Loschmidt Paradox using complexified time (Parker & Jeynes 2023a). Here we briefly discuss both some further aspects of complex time and also some further aspects of knowledge being *personal*, including the importance of *storytelling*.

It is noteworthy that complex time as an emerging and increasingly powerful scientific paradigm has also been used systematically by Ivo Dinov's group in “Big Data” data science applications (Dinov & Velez 2022). Undoubtedly their use of complex time (which they call “kime”) enables them to *“interrogate large, multiplex, and heterogeneous datasets ... using spacekime analytics”* relying on a *“commonly used mathematical trick of lifting the space of a problem to identify solution paths that are not clearly visible in lower dimensional spaces”*. By using complex time (“kime”) they transform 4D spacetime into a 5D “spacekime”. It is interesting that two completely independent groups have used complexified time for quite different applications, but for the same underlying mathematical reason: namely that complex analysis has extraordinary mathematical power.

In this regard we should also mention the major recent advance in quantum chromodynamics (QCD) of Deur, Brodsky & Roberts (2024: explained by Brodsky et al., 2024). These workers have also used complexification (using a 5D spacetime) and a holographic approach to calculate the strong force at “large” distances. How these various and still nominally independent applications of complex time can enable a new metaphysical⁸⁰ interpretation underpinning our understanding of reality still remains an exciting future prospect.

How does “complex time” help in our quest for unity and integrity? It is a part of the structure of reality that is only now being clarified, although time was always known to be a slippery philosophical idea: it was Augustine of Hippo in *“Confessions”* (XI:14; c.400 CE) who famously said, *“I know very well what time is, until someone asks me!”*⁸¹

Treating science as *story* underlines the essential truth that *knowledge is personal*, as Michael Polanyi (1958) observed long ago. Paul Grobstein (2005) has urged us to develop a *“story of science as story telling and story revising”* which *“may provide a foundation for a less wrong view of science ... the ultimate test of [which is] what new stories develop because of it”* (emphasis original). Robert Crease has pointed out that *“Stories make things appear that you cannot see or think about otherwise”* (2019, p.263). Frank et al. (2024, p.ix) go further: they consider that stories *“constitute a modern form of mythos ... [orienting us and structuring] our understanding of the world”*.

Thomas Dillern (2019) seems to be an isolated modern proponent of Polanyi's view of *personal knowledge*, although Jerry Ravetz's (1971) school was active previously in creatively developing Polanyi's view on *craftsmanship*. Dillern says that *“the things that are most interesting to gain knowledge about are things that ... provide something meaningful to humanity, which is something the modern mechanical science view fails to accomplish on its own”* and pointing out Polanyi's insight that *“tacit knowledge is the basis of all explicit knowledge ... tacit powers are the ultimate faculty through which humans acquire and hold all knowledge”*. We have here represented this viewpoint by insisting on the indispensable

⁸⁰ “metaphysical” meaning “the metanarrative of physics” where “physics” is interpreted in the wider Aristotelian sense.

⁸¹ “What is time? I know well enough what it is, provided nobody asks me” [*“quid est ergo tempus? si nemo ex me quaerat, scio”*].

metaphysical context of our physical explanations (following Jeynes et al. 2023). ‘Polanyi’s Paradox’⁸² (David Autor, 2014) is a central and necessary idea for mediating our conception of “knowledge”. All knowledge is formally incomplete, and the idea that “scientific knowledge” is somehow different is simply mistaken. But all human knowledge (and we know no other) is metaphysical: the metanarrative is invariably indispensable (even when it is tacit), and even physical knowledge cannot be *understood* without its metaphysical contexts. “Grasping truth” is essentially metaphysical.

It is worth pointing out explicitly that “*tacit knowledge*” (described in some detail by Polanyi, 1958) is a fine cover for unrecognised assumptions being smuggled in to the interpretations of the data, so that understanding how the metanarratives work has become essential.

14. Summary

The scientific enterprise has developed out of recognition over the last four hundred years, from marvelling at microscopic wonders and exalting in the simplicity of celestial mechanics to having the power to destroy the world; from the conceit of the clockwork universe to the bafflement of quantum uncertainty; from the triumph of reason to the conundrums of reality. But it has turned out that reality is far more baffling than we had ever expected. Newton thought he could specify the scientific method, but with every advance in knowledge it seems that our account becomes less complete.

Here we point to the overriding idea of *unity*: you want to know how the world is? then seek a coherent account! And do it with as much diligence and honesty as you can muster. For reality is elusive, and a casual approach will find only dead ends. Moreover only a single-minded quest in good faith has any chance of finding out new things.

For it turns out that unity remains a powerful idea: even in physics “*unitary entities*” have been shown to successfully model things that – looked at another way – seem to be composites of other “fundamental” particles.

15. Conclusions

The scientific enterprise seeks to gain knowledge of the natural world, where the very *possibility* of knowledge is premised on an appreciation of *unity*. Unity is a metaphysical concept, but it is physically embodied in the alpha particle and the black hole, both of which are *unitary entities* (“than which exist nothing simpler”). Radically new physics now articulates these ideas.

New physics enables and informs new philosophy. The recognition that there are real examples of unitary entities which we can specify and discuss, has allowed a much more definite idea of what is *fundamental* (also fatally undermining a reductionist view). Unity always was a powerful idea. Now that it is underpinned by physical reality it is more powerful still.

The idea of *unity* is fundamental to our idea of reality itself, essential not only to the basic physics but also to the *integrity* with which we (both personally and socially) engage in, report, and receive the scientific enterprise. That is, it is essential at all levels: the mathematico-physical, the experimental, the scientific community, and the public for whom in the end the science is done.

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