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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? A theory 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

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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?)?

Although 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, Carlo Rovelli summarises the current situation 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 has written a book "about how to get angry about science denial in the right way" (2019, p.19) 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" (2019, p.262). The issues are not simple – reality is elusive! Here we try to lay out these issues in an even-handed way.

Rovelli has a chapter titled "*Prescientific Thought*" in which he contrasts a proper scientific attitude with a "religious" one, using a well informed and subtle argument that very clearly deprecates the religious attitude even though he acknowledges that most people today "*believe that a true understanding of the world must include gods or God*" (2009, p.154): he thinks that most people are, in fact, mistaken in this.

In contrast, Jeynes *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: here by "metaphysics" we mean simply "the metanarrative of physics": see below, §4). 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 Jeynes *et al*. (*ibid*.) is that poetic speech is invariably prior to prose speech, both logically and temporally: actually, Rovelli himself acknowledges this, citing Roy Rappaport's classic work (1999) as "*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). 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?

Rovelli 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 wrong? 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).

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 experiments[1]. By publishing, the author asserts that he or she is 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 Truth[2], but also Trust is central in this enterprise.

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

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[1] 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

[2] 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)

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presentations. 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).

This paper 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 (§2) 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 (§3) 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[3].

It is after all *truth* that matters (§4), 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 (§5) but this is not merely false but actually illusory. Rather, it is the search for a "unified" (coherent) view of the world (§6). What is *fundamental* in this (§7)? 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[4] 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 (§8), 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!

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 (§9).

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3 Entradas *et al*. open by saying: "*Public communication of science has become a key obligation of universities*" (2023), and go on to discuss *science communication* in very useful detail.

4 Wilczek (2021) cites Democritus (3rd century BCE) as author of "*the founding document of atomism*" (p.72, ch.3). But this is historically incorrect since the 17th century scholars put effectively no weight on Democritus (see Gorman, 2021).

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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.

One way of summarising the argument is to draw attention to the poetics of physics (§10). 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 discuss (§11) various other issues (including some relevant aspects of AI and its impact on the conduct of science) and conclude (§12).

2. 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 discovered a third way … he does not hesitate to say that Thales 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 infallibility[5] 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)[6] 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. 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[7] so that 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".

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

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5 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*".

6 Thanks to Sir Michael Berry for drawing our attention to Spencer's book in March 2023

7 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.*"

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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[8], 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). Infallible propositions are simply not available, neither for theologians nor for scientists!

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)[9] has shown that the "metaphysical poets" in 17th century England were fascinated by the revelations of the new microscopes[10], 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 recongregate 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). 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 Yahweh[11]
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
  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

8 "*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 ("Εβδομήκοντα", Latinised as the "Septuagint" or the LXX) of the Hebrew text was made in Alexandria probably in the third century BCE.

9 Thanks to Kevin Killeen for alerting us to this monograph in 2022

10 As Jeynes *et al*. 2023 say (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" is God's personal name, usually rendered "LORD" (see the elliptical "explanation" at Exodus 3:14)

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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 respectfully). 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 thought[13], 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*" 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.

3. Trusting Experts

People (including "experts") are rather good at getting things wrong. There is now a detailed literature on the multiple ways we make mistakes (notably the classics by Reason, 1990; and Dekker, 2006). Moreover, bias is ubiquitous, and has recently been extensively documented in its multiple forms by Jessica Nordell (2021).

With the explosion of knowledge and the ubiquity today of multi-author papers, we need effective collaboration more than ever (with the extra risk of error that implies). In collaborations the authors must all trust each other, even as they also must agree a common narrative (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? 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

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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.

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

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*" (*op.cit*. 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* (Drew, 2023), and also Aristotle's rhetorical tropes (the "major" ones are: *metaphor*, *metonymy*, *synecdoche* and *irony*), and in particular synecdoche (on which see Drew *et al*. 2018[14]). The same sorts of things apply to the scientific community combatting antiscientism: 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 individual[15]. It turns out that this phenomenon of *entanglement* is observed not only scientifically in quantum systems, but qualitatively in social ones too. And this entanglement "metaphor" is more realistic than one might have thought: new physics (Parker & Jeynes 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 §5).

4. Realism and the Metaphysical Existence of Truth

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 scientistic[16], ignoring (or misrepresenting) the metaphysical aspects; ours is scientific, acknowledging the metaphysics. "Metaphysical" is commonly used today pejoratively (Collins and Chambers dictionaries both list "fanciful" as one

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14 They 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*

15 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.

16 "*the Enlightenment's … critical rationalism brought a "scientism" that justifies only facts based on physics and considers meaning and human values to be illusory*" (Lowney, 2020).

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such synonym): philosophically it usually refers to "*ontology, or the science of being*". Here we use it in a way cognate to "metamathematics" or "metadata" etc[17]: that is, we use "*metaphysics*" here (following Jeynes *et al*. 2023) as simply the "*metanarrative of physics*", noting that we may also use "physics" in the wider sense Aristotle had in mind when he titled his *Physics*: "Φυσικὴ ἀκρόασις" [*physikē akroasis*] (meaning "*listening to nature*", or perhaps "*lectures on nature*").

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* (here we follow James Lennox's account, 2015) with a discussion of the method [meqodoς, *methodos*] proper to obtaining scientific knowledge [ἐπιστήμη, *epistēmē*] in a scientific enquiry [φύσῐν ἱστορῐ́ᾱς, *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*" [ἥ διαλεκτική μέθοδος, *ē dialektikē methodos*] as the only way to advance to first principles. Consequently (and note that if the "first principles" are the *beginning* of physics, then the "dialectical path" to them must be a *metaphysical* one in precisely our sense), Aristotle understood very well that the scientific method is necessarily metaphysical, a conclusion reached independently by Jeynes *et al*. (2023) since 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 reality: 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*[18]. 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* (§6).

We need to consider the view of Leon-Philip Schäfer (2024) who claims that "realism … is, in the final analysis, best characterised as an alethic[19] 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." 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.

On "authority", we should also point out here, parenthetically, 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*

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17 see discussion at Jeynes *et al*. (2023 n.17 *passim*); and note that Gödel (1931) explicitly uses "*metamathematics*"

18 although 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).

19 although Philip Pullman's (1995) beautiful idea of Lyra's "alethiometer" can hardly be thought to "touch reality"

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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. Paul urges us that "*we henceforth be no more children, tossed to and fro, and carried about with every wind of doctrine*"[20] (Ephesians 4:14): we ought to need adequate persuasion to change our minds! Authority is not dispensible: 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.

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".

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 we would not only affirm that it is hard to know reality but also 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.

5. The Illusion of "Objectivity"

Karen Barad[21] 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 uncertainty[22] ontic or

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20 ἵνα μηκέτι ὦμεν νήπιοι, κλυδωνιζόμενοι καὶ περιφερόμενοι παντὶ ἀνέμῳ τῆς διδασκαλίας (Adelphothes, 2000)

21 We thank Rachel Holland for pointing us to Barad's important work.

22 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,

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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?

It turns out that entanglement is really real, as many "Bell Inequality" experiments have shown. 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*"[23]. 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). But, 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).

We will discuss what is "fundamental" below (§7) but the EPR paradox and the consequent interest in establishing violations of the Bell Inequality are at the heart of our current understanding 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 acausality[24] (and these apparently 'simple' dichotomies become seriously more complicated when time is complexified, see Parker & Jeynes 2023a discussed below). 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 think exists (or don't expect)!

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. There is no such thing as "an electron" *per se*, since all electrons in the universe are more or less entangled together (being strictly 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).

Commentators on Barad have concentrated on her[25] proposal of "***agential realism***", which 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*

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*).

23 https://www.livescience.com/objective-reality-not-exist-quantum-physicists.html (accessed 14 December 2022).

24 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)

25 Barad identifies as non-binary, so we intend the reader to treat personal pronouns here as gender-neutral.

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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" (Barad ibid. p.25)[26]. 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".

We regard it as axiomatic that, just as truth is one so must reality also be an integrated thing, and then our view of it (reality) as natural scientists must be consistent with our view of it as concerned citizens (or poets). On this view we cannot treat insights into reality obtained from the natural sciences merely as "mere metaphors", the link is stronger than that. Iris Murdoch[27] 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*" (1967). 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. 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. But we agree with Bohm & Hiley (1993) on the question of how we touch reality: "*… 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*" (*ibid.* p.320). We think that Bohm is right to take the older view that touching reality is *guided* by mathematics, not *expressed* by it; in other words, the formulating of our ideas in mathematical terms should be regarded simply as a systematic method of ensuring the integrity of complex logical arguments. The mathematics ensures the *validity* of the argument but says nothing about its *truth*. This could be restated as: "mathematics provides the disambiguated

[26] This is also closely related to Atmanspacher's (2024) idea of "psychophysical neutrality", see the discussion below (§6)

[27] We thank Julia Jordan for alerting us to Murdoch's significant contribution

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analytical narrative, whereas the (poetic) metanarrative is required to discern truth". We must take Gödel's metamathematical breakthrough seriously (Gödel, 1931; see §10).

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. 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)[28]. 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.

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" (where the optic nerve exits the

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

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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)[29].

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" axes[30]) and then making full use of the mathematical power of complex analysis. The result (expressed in natural units) is that the system Hamiltonian (representing the system *energy*) is shown to be the complex conjugate of the (Wick rotated) *entropy production* (which normally expresses the non-local restraints on the system). 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. Of course, *time* is "imaginary" in 4D Minkowski space-time[31] – or at least, the time dimension is "imaginary" relative to the 3 space dimensions, where the "signature" ('+−−−' or '−+++') may be chosen for convenience (see the discussion of 'signatures' in Penrose, 2004, §13.8, p.281). 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[32]: Ivo Dinov and other's "spacekime" (for example Wang *et al*. 2022), and Carl Frederick's ideas of "granular space-time" (2022). Also, Philip K Dick's "orthogonal time" (published posthumously, 2011) seems to be related to these "complex time" ideas. But exactly how these various ideas are related remains to be seen.

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.

6. On Unity

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).

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. 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

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29 We are grateful to Robert Crease for alerting us to this important work

30 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 (√-1) was a fiction of the mathematicians. Roger Penrose explains: "*… the seemingly mystical quantity √-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.

31 Thomas Hertog (2023, p.240) has also said, 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*"

32 We are grateful to William Sarill (email 11th April 2024) for drawing our attention to these connections.

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 thought they did, and famously called them "monads" (1714). But Henry More much earlier explained them 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*" (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*" (see *1Kings* 6:20 and *Revelation* 21:16). 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*"). We consider the archaic term "monad" to be essentially synonymous with the more modern "unitary entity" that we use here.

Parker *et al*. (2022) have recently demonstrated 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 *indiscerpible* (since it strongly resists being *torn asunder* due to its very high binding energy). 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 *indiscerpible* (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/indiscerpible distinction, since treating the alpha particle as a *unitary entity* enables them to calculate its size *ab initio* using the new Quantitative Geometrical Thermodynamics (**QGT**: Parker & Jeynes 2019) without any quantum mechanics. In QGT terms a unitary entity (*than which exists nothing simpler*) has the fewest possible degrees of freedom (when considered at the appropriate length scale). Thus, in its lowest energy state the alpha (^4He) is unitary[33]. 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 ^{12}C nuclei): Constantino Tsallis (2024) calls the Borromean rings "*a beautiful metaphor for complex systems*". 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. According to QGT (Parker *et al*. 2022) ^{12}C consists of a union of three alphas, as is also indicated experimentally: see 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 a-particle clusters rather than nucleons*". If any of the constituent alphas is

33 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 indiscerpible, not indivisible), or a *monad* in Leibniz' sense. To avoid confusion we use "unitary entity".

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lost to the ^{12}C nucleus, the resulting nucleus[34] (^8Be) 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 Thiruvanmayur, 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[35] is in a c.1210 manuscript of Peter of Poitiers (Pictaviensis, 1210).

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). 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 indeterminate: this 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.

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 DNA[36] and of the Milky Way (*ibid.*, Figures 1 & 2 *passim*), and also to analytically prove the stability of Buckminsterfullerene (Parker & Jeynes 2020)[37].

Raphael Bousso (2002) has reviewed the "Holographic Principle"[38] which asserts that the information[39] in a volume can be represented completely on the enclosing area. Parker & Jeynes (2021) have independently derived this "Principle" (represented by the Bekenstein-Hawking equation[40]) from the *entropic* Liouville theorem, and applied it to unitary objects to obtain *ab initio* the

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34 "^8Be" is an isotope of beryllium: this element has only one stable isotope ^9Be.

35 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*"

36 The chirality ("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).

37 This has been done constructively using computational chemistry methods (which require significant super-computer time), but such methods are much harder to understand as well as being far more expensive and not at all easy to generalise.

38 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 …*"

39 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).

40 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*

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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)[41]. 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 *indiscerpible*, 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 mechanics, general relativity and classical crystal optics are all independently mind-boggling. 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).

Mereology has been discussed in detail by Harald Atmanspacher (2024) in the form of "dual-aspect monism", by which he means a "*psychophysical neutrality*" (his emphasis) between mind and matter: that is, there exists a "*domain of reality*" that does not distinguish between "*the mental and the physical*". 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) 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".

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where we have encountered both the fundamental constant of quantum mechanics … and that of general relativity … appearing together in the same formula" (emphasis original).

[41] This is admittedly a rather peculiar way of putting it, considering that 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.

The ancient poet exclaimed (Psalm 133:1), "*Behold, how good and joyful a thing it is: brethren, to dwell together in unity*"[42], but the word "unity" is present neither in the Hebrew original nor in the ancient Greek translation (the Septuagint)[43]. It seems that "unity" (ἑνότητα) is a relatively modern idea, in Biblical texts first explicit[44] at Ephesians 4:3 (dated at 58 CE by John Robinson, 1976: "*keep the unity of the Spirit in the bond of peace*")[45], even though the idea of "one" (as a cardinal number) is very ancient ("*Hear O Israel, the* L*ORD your God, the* L*ORD is one*": Deuteronomy 6:4)[46]. 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 more difficult and hard to grasp than one might think? Prior to Paul it was used only rarely and in esoteric contexts. For example, Aristotle uses it in passing (as "*unity of being*", ἑνότης τίς ἐστιν): καὶ τὰ μὲν οὕτως λέγεται ταὐτά, τὰ δὲ καθ᾽ αὑτὰ ὁσαχῶσπερ καὶ τὸ ἕν· καὶ γὰρ ὧν ἡ ὕλη μία ἢ εἴδει ἢ ἀριθμῷ ταὐτὰ λέγεται καὶ ὧν ἡ οὐσία μία, ὥστε φανερὸν

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

43 Psalms are very hard to date, but this one may have been composed c.9th century BCE. The present Hebrew text (with vocalisation) is [הִנֵּה מַה־טּוֹב וּמַה־נָּעִים שֶׁבֶת אַחִים גַּם־יָחַד], 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 ἀδελφοὺς ἐπὶ τὸ αὐτό" (Apostoliki 1996).

44 "Unity" was not a neologism of Paul's (appearing as "ἑνότητα" in *Ephesians*) since Aristotle used it previously (as "ἑνότης" in the *Metaphysics* 1018a7). In just the same way, "*atonement*" was not a neologism of William Tyndale, since the Oxford English Dictionary credits Thomas More with first usage a decade earlier. But 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. … Nevertherleſſe all thigꝭ are of god / which hath reconciled us unto hym ſelfe by Jesus Chriſt/and hath geven unto us the office to preache the atonement. For god was ī Chriſt/ād made agreement bitwene the worlde and hym ſelfe / and imputed not their ſynnes unto them: and hath committed to us the preachynge of the atonment. … So praye we you ī Chriſtes ſtede/that ye be atone with God …*" (2Corinthians 5:17ff, Tyndale 1526) using the original spelling, including the long s ("ſ") and the abbreviation for "n" (so that "ād" means "and"). It was Tyndale's influential translation of the Pentateuch (1530) that interpreted [יֹ֥ום הַכִּפֻּרִ֛ים] (*yōwm hakkippurîm*), as "the Day of Atonement" (*Yom Kippur*, Leviticus 23:27 *passim*), an interpretation that has stuck in English, even though the primary meaning of [כפר] is "cover" (see Genesis 6:14, "ἀσφαλτ" in the LXX). Note that "atonement" is, properly, "at-one-ment": that is, an Englishing of the Latinate "reconciliation".

45 "τηρεῖν τὴν ἑνότητα τοῦ πνεύματος ἐν τῷ συνδέσμῳ τῆς εἰρήνης" (Adelphothes 2000). Here "unity" ἑνότητα) is explicit, and underlined in the next verse: "ἓν σῶμα καὶ ἓν πνεῦμα…εἷς κύριος, μία πίστις, ἓν βάπτισμα". Although this usage is commonplace today, the use of ἑνότητα here looks like a neologism deliberately explained in the following verse (but see n.45 above). It seems plain that the writer (Paul) had Ps.133 in mind: he is deliberately recasting the Hebrew texts to make them accessible to his pagan hearers.

46 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 text we have is usually credited to Ezra the Scribe, c.500 BCE. The Hebrew text (with vocalisation) is: [שְׁמַע יִשְׂרָאֵל יְהוָה אֱלֹהֵינוּ יְהוָה אֶחָד] which is translated (JPS 2000) as: "*Hear, O Israel, the* L*ORD is our God, the* L*ORD alone*". Note that JPS interprets [אֶחָד] as "alone" rather than the cardinal number "one" (as in other places). The Septuagint Greek (3rd century BCE) is: "Ἄκουε, Ἰσραήλ· 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.

ὅτι ἡ ταυτότης **ἑνότης τίς ἐστιν** ἢ πλειόνων τοῦ εἶναι ἢ ὅταν χρῆται ὡς πλείοσιν, οἷον ὅταν λέγῃ αὐτὸ αὑτῷ ταὐτόν· ὡς δυσὶ γὰρ χρῆται αὐτῷ (Τῶν Μετὰ τὰ Φυσικὰ Δ 1018a4-9[47]; Ross 1924, p.259f). This is translated (rather freely, by Lawson-Tancred, 1998) as: "*There are as many cases of this as there are of* per se ["καθ᾽ αὑτὰ"] *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 is trying (in a text which has baffled students ever since) 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 (Aristotle's text is acknowledged as "esoteric").

7. What is Fundamental?

Jesus famously observed of the "*wyſe man*" that he "*byltt his houſſe on a rocke*"[48] (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?

Mike 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 (^{4}He) 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 approach[49] that requires ever larger amounts of energy to be concentrated into ever smaller scales in order to observe the "fundamental" phenomenon. We should emphasise that QGT has shown that "holistic"

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[47] That is, *Metaphysics* (Book Delta). We thank Margaret Barker for drawing our attention to this reference.

[48] … 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 "ſ" is the long "s" (which can still be seen in modern German orthography as a component of "ß", the "*Eszett*" or "*scharfes S*"). At that time Tyndale's Bible (translated from the original Greek and printed in Germany in a blackletter font) was *samizdat* literature regarded by the English political establishment as deeply subversive.

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

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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! [50] 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). And what are quarks? And is the Standard Model correct anyway? 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 Paradox[51], 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 & Jeynes 2023a). "Local" effects correspond to our standard "cause-and-effect" ideas. But "non-local" effects correspond to holistic behaviours of systems (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.

Jeynes (2023) has reviewed the use of "Berry phase analysis" as a systematic physical approach to treating irreversible systems[52], and real systems are invariably irreversible – this is an essential consequence of the Second Law of Thermodynamics. 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 & Jeynes, 2023a] has shown that for a more satisfactory and unified explanation of many physical phenomena, even the description of time should be complexified*" (*ibid.*). Geometrical thermodynamics emphasises the fundamentally *non-local* nature of physical systems (expressing their *holistic* character).

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).

8. 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. Of course, scientists are

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[50] Thomas Hertog also 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).

[51] 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.

[52] 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.

notoriously bad at detecting deliberate fraud[53] (for example, the Schön affair which led to a series of retractions of the work of Jan Hendrik Schön and co-authors in 2003) 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). 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.

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 *see* something does not mean that we *understand* it! In fact, many have noted that we typically only see what we understand![54,55] And conclusive "proof" of anything is fraught with difficulty.

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, and its legitimacy 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!

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53 Martin Gardner (2013, p.157f) says on this: "*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).

54 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).

55 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*" (ὁδηγοὶ 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).

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Speaking now about the scientific practice itself, that is, the getting of the results not just the reporting of them, we should consider in some detail the position of Philippe Stamenkovic (2024) who 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 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.

He points out that the original arguments for the VFI included the need to protect "*public trust in science*", an issue central to our concerns here. Interestingly, he acknowledges the "*simplifying idealisations*" he uses: we take the view that *reality is elusive* and that it is not always possible to be sure of the scope of, and adequately assess, the approximations we use. But he illustrates his argument with definite examples, which in our view is good practice as a constructive approach to expressing meaning adequately. Encouragingly, he specifically argues that "*science-informed claims for policy-making should naturally be influenced by extra-scientific values*", but he warns that "*scientific claims*" should be clearly distinguished from "*scientifically informed decisions*".

However, the trouble with his claim that "A science based on facts (further generalised in the form of laws and principles) represents the ideal of scientific inquiry" is that interesting facts don't exist – since if it is a "fact" then it is per se uninteresting. 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[56], 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. The point (which any useful philosophical discussion should surely capture) is that we only do science at all, as Robin Ince (2021) has pointed out, because we are interested (and "facts" aren't interesting!). Nevertheless, Stamenkovic's insistence on "ensuring the truth of scientific knowledge" is valuable.

It is true that scientists wish to establish facts, 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

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[56] And of course, for the establishment of a credible value for the parallax of 61 Cygni. The modern value is 286 micro-arc-seconds; a tiny quantity, very hard to measure, so that Bessel's empirical method was then of enormous interest. And of course, his value for 61 Cygni's stellar parallax, which implied that its distance from us was 10.4 light years (quite close to the modern value of 11.4 light years), was also interesting in itself since it was the observational evidence for the enormous size of the Universe that had been thought unobtainable. Indeed, Bessel only went to the (enormous) trouble of making the measurements because he was already convinced of the heliocentric model.

"to discount them" (ibid.). We have already noted Richard Bauckham's monograph on personal "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. Science is a human activity, and knowledge is personal (Polanyi 1958).

Stamenkovic takes "truth and objectivity to be the most important, defining aims of science … without which there is no science." The very idea of "objectivity" is questionable, as we have discussed above, but we can gloss it here as "being dispassionate". However, for our purposes Stamenkovic's approach appears to be insufficiently fundamental, since he seems to think that "scientific truth" is well defined (and attainable). 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"! Stamenkovic acknowledges this when he says that the scientific corpus ("*the total body of scientific knowledge*") is "*[representive 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.

Science is a passionate activity – scientists are always interested in getting things right. Even if they do their best to report results in a dispassionate (or disinterested) way, this is because they have the underlying conviction that what they perceive as the truth should be recognised as such by everyone. Moreover, scientists are 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: this is another reason for aspiring to dispassionate reporting.

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 ("extra-scientific") values.

On the "value-free ideal", Stamenkovic could (but does not) cite Jürgen Habermas (1996) who points out that "*scientific activity … fragments into a number of competing viewpoints that are shot through with values*". Michael Lissack (2017), who cites Habermas, is concerned to recognise *ambiguity* as an essential (if implicit) component of the scientific enterprise. He says that ambiguity in science is "*regarded as a 'problem' … The aim of current-day 'science' ... is truth … This aim is at odds with the notion that ambiguity can be built into scientific methods*". Lissack does not claim that scientific methods *should* be ambiguous, on the contrary: he points to the "*hidden assumptions*" that "*allow ambiguity to be bracketed away at the expense of transparency*" imposed as "*enabling constraints*" (in the form of *ceteris paribus* – "other things being equal"). The investigation of such enabling constraints (in the form of "*uncritically examined presuppositions*"), is called "*second order science*" revealing "*hidden assumptions … which can get in the way of the acceptance of a scientific claim*". Anthony Ossa-Richardson's important monograph on "ambiguity" (2019)[57] appeared too late for Lissack, but 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. But we regard Lissack's proposals, concerning the more willing *acceptance* by the public of scientific claims if the scientists acknowledge their *hidden assumptions* more transparently, as well-judged and helpful.

[57] Thanks to Julia Jordan for alerting us to this monograph in 2022

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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 is being described truthfully.

9. QBism

Since we are realists who insist that "knowledge is personal" (Polanyi 1958), are we not also QBists ("quantum Bayesians")? QBism is regarded by many as a "*philosophically rigorous approach to quantum mechanics*" which "*cuts no epistemic or ontological corners*"[58]. 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"[59]), and points out that the real issue is how we think of *probability*. Are we "frequentist" or "Bayesian"[60]? 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 GUM (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 Y (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) Y 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

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58 Robert Crease, private communication 13th March 2024

59 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*"

60 "*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)

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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)[61].

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*".

Parker & Jeynes (2023c) have given an example of exactly this (the 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[62] (1983; he admits that "*we find obscurity at the heart of the scale invariance argument*", an obscurity enlightened by Parker & Jeynes' treatment, 2023c).

Moreover, since the necessary "extra" information (in the form of an additional natural constraint) is precisely that of *scale invariance*, the "shifty split" problem that has bedevilled the quantum physicists (where exactly lies the boundary between the microscopic and macroscopic worlds?) is also automatically eliminated. 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

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[61] 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).

[62] 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).

nature of thermodynamics and the holomorphic nature of actio-entropy (Parker & Jeynes 2023a[63]), 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 & Jeynes (2023d) 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*.

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.

10. 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"[64]) 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).

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" [65], 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) things. 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" [66], 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

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[63] "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).

[64] The "leap of faith" referred originally to leaping over Gotthold Lessing's "*ugly broad ditch*" – "*der garstige breite Graben*" (1777); see Yasukata (2003).

[65] Thomas Hertog also says this: "*Science is what scientists do. We advance by exchanging ideas* ..." (2023, p.247)

[66] 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.*"

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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 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)[67].

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 theorems[68] 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.

11. Discussion

In this work we have discussed some of the integral aspects found in the highly successful adventure that is science. In doing so, we have also underlined the contribution of new physics (Parker and others: 2019, 2020, 2021, 2022, 2023a, 2023b, 2023c, 2023d) into the scientific edifice, that illuminates 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). 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 & Velev 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 metaphysical interpretation underpinning our understanding of reality still remains an exciting future prospect.

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). Treating science as story underlines the essential truth that knowledge is personal, as Michael Polanyi (1958) observed long ago. 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".

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

68 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.

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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 metaphysical context of our physical explanations (following Jeynes *et al*. 2023). 'Polanyi's Paradox'[69] (David Autor, 2014) is a central and necessary idea for mediating our conception of "knowledge". No knowledge is formally complete, and ideas that "scientific knowledge" is somehow different are simply mistaken. But all human knowledge (and we know no other) is metaphysical: even the physical parts cannot be *understood* without the metaphysical contexts. "Grasping truth" is essentially metaphysical.

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 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. Can poetry ever be composed 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

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[69] summarised as "*we can know more than we can tell*". This is related to the classical "*Meno Paradox*", referring to Plato's Socratic dialogue: "*a man cannot enquire either about that which he knows, or about that which he does not know; for if he knows, he has no need to enquire; and if not, he cannot; for he does not know the very subject about which he is to enquire*."

"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.

12. Conclusions

We may know truly even in the face of our limitations. But persuading the public requires a proper use of rhetoric – that is using not only logic (*logos*) but also the other qualities listed by Aristotle: *ethos*, *pathos*, *kairos* (Drew 2023).

Michael Polanyi (1958) has insisted that knowledge is personal and Jerry Ravetz 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?'" (1971, Introduction). Such a philosophy must be properly metaphysical (Jeynes et al. 2023), since the truth the poets discern is the same sort of thing that the scientists discover – truth is one.

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